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Miesenberger

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Editorial

This is it: The very first digital edition of the ICCHP open access compendium "Future Perspectives of AT, eAccessibility and eInclusion". It took 17 ICCHP editions and more than 30 years to go this last step towards an additional publication to reach a 360° view on AT, Accessibility, ICT with and for people with disabilities and older adults.

The idea to collect these hidden gems and precious contributions that typically get forgotten in mere theoretically based conference proceedings was in our heads for more than 10 years now – to put together these practically oriented gems within all this theory and compile a hands on, user driven, open access and accessible compendium out of it that makes our proceedings "whole" again. AT, eAccessibility and eInclusion are user, practice and service driven domains. Progress and success are very much based on the interaction with, contribution by and participation of all stakeholder groups (e.g. users, end user organizations, service providers, policy, administration, industry, NGOs). Every voice counts in the exchange on the impact of R&D on practice and in domains in need of creative and innovative R&D and co-operation.

And this is what happened now in order to strengthen exchange and co-operation between practice and R&D as a key asset for technical and social innovation. ICCHP invited interested authors coming from diverse domains to submit outlines of concept papers, models, reports, ideas, and position papers on topics related to digital inclusion.

In this compendium, you find these "gems" out of all handed in contributions, 29 papers that were accepted as contributions that will be / are / were also part of the ICCHP presentation program 2020 and will help / helps / helped us support a creative and innovative program facilitating cross-sector interaction. Over 180 pages of knowledge, application and experience to foster innovation and enable a glimpse into user experiences and what happened to all the findings we made in these decades since the very first ICCHP. The papers are aligned to follow the structure of the 2020 ICCHP proceedings and give you a complete overview on what was presented during ICCHP 2020 – Come and get involved, lean back and enjoy the full view for this very first time!

Of course this is also an opportunity to thank: To all the people strengthening us and supporting us in this endeavor, to all authors that went this important step with us, to all colleagues from JKU Linz and Masaryk University Brno that supported us with designing, collecting and tweaking the accessibility of this format – and to ICCHPs founder Roland Wagner, who is not able to celebrate with us this new ICCHP "baby", but would be more than happy to see it grow and succeed.

Andrea Petz   Klaus Miesenberger

Association ICCHP, August 2020, Linz, AT

Contents

Artificial Intelligence, Accessible and Assistive Technologies

Conversion Method of Braille Music Based on MusicXML

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Abstract

When visually impaired musicians play and learn staves, they are faced with the problems of resource scarcity of Braille music and low conversion efficiency of music score to Braille. The reform and development of information technology has provided many solutions to these problems. In this paper, we mainly give an automatic conversion method of Chinese Braille music from stave or JianPu (numbered musical notation). Through the research the relationship between Braille music and MusicXML, a MusicXML based conversion method is designed. In the process of conversion, the first step is obtaining the node information of the MusicXML document, and secondly, the node information is converted into a corresponding blind spot according to the Chinese Braille music standard, and finally the translation result is compiled. Verification of our algorithm by 7 scores, the average accuracy of the experimental results is 96.50%.

Keywords: stave, MusicXML, the visually impaired, Braille music

Introduction

The commonly used electronic music formats are MIDI, MusicXML, Sib, etc. MusicXML (Music extensible markup language) is a standard open format for exchanging digital sheet music [1]. It is designed for sharing sheet music files between applications, and for archiving sheet music files for use in the future. MusicXML is intended to be easy for automated tools to parse and manipulate. Compared with MIDI, MusicXML has expression marks and basic rhythm of the piece, which can express the notes and marks of staves in more detail.

In computers, Braille ASCII Code is used to represent Braille. Braille ASCII encoding is a subset of the ASCII character set, using 64 ASCII characters (32-95) to represent 64 six-point Braille characters. Braille music is a Braille code that allows music to be notated using Braille cells so music can be read by visually impaired musicians. Braille music uses the same six-position Braille cells as literary braille. However, Braille music assigns a separate meaning to each braille symbol or group of symbols different from literary braille and has its own syntax and abbreviations. The is an international standard for Braille music. "China Braille musical signs GB/T 16431-2008" developed by China Braille Press and other units used in China.

The number of visually impaired people in China is about 17 million. With more and more visually impaired people engaged in music work, the demand for Braille music is increasing. The work described in the paper is part of The Braille Online Platform of China (BOC, www.braille.org.cn). The BOC, which provides Braille translation and Braille digital resource services, is the first comprehensive platform for the 17 million visually impaired in China. By using BOC platform, users can conversion Chinese, English, mathematical and chemical formulas, music scores, physical circuit diagrams to Braille, and the translation results have high accuracy.

This section describes the background of Braille music translation and gives an introduction of MusicXML and Braille music; the second section will introduce research on Braille translation; the third

section explains the translation method of Braille music; the fourth section is the experiment and result analysis; The fifth section is the full text summary.

State of the Art

In recent years, the development of computers has produced some research on Braille translation. The paper [3-5] realize the conversion of Chinese characters to Braille. Papers [6-8] has basically solved the scientific problem of conversion between mathematical formula and Braille. Up to now, there are few researches on the automatic conversion of Braille music. In paper [9], a DSP-based notation recognition and Braille music conversion algorithm is proposed. Papers [10-11] adopted a method of parallel voice division from MusicXML format to Braille music, but its system took a long time to get results due to factors such as data transmission and the accuracy of translation was not given in the paper. The paper [12] proposes a MIDI-based conversion method.

In this paper, we show a method of Braille music conversion based on MusicXML. We use this method to build a website that users can visit this website for free anytime and anywhere. During the translation process, the program can make its own judgment based on the content of the translation. The conversion is based on China Braille musical signs, supplemented by the New International Manual of Braille Music Notation. We try to adapt the conversion results to the style of Chinese folk instruments. We improve experience of visually impaired and the accuracy by judging the occurrence of simplified rules.

Conversion Method of Braille Music

The design and implementation of a new method which can convert MusicXML to Braille are described in this section. Furthermore, this section also introduces some complex and important algorithms and their implementation.

Converting Method Description

This section describes the formal description of the method. By analyzing the correspondence between the MusicXML format and the Braille music, the conversion program is implemented.

A musical elements map refers to the set of Braille required to form a certain section of Braille music with specific meaning. A measure(M) can be expressed as formula (1).

$$M = M_{attributes} \cup M_{direction} \cup M_{note} \cup M_{others} \qquad (1)$$

In formula (1), M contains all the elements of MusicXML. Among them: $M_{attributes}$ represents the set of music score attributes, where $M_{attributes}$ = {staves, time signatures, key signatures, clefs, othermusical data and transpositions}; $M_{direction}$ means the set of music score expressions, where $M_{direction}$ = {words, dynamics, wedge, segno, coda, rehearsal , dashes, pedal, metronome, and octave-shift}; M_{note} indicates the set of music score notes, where other elements M_{note} = in {pitch, duration, ties, cords, lyrics}; M_{others} represents the set of other elements in the music score, where M_{others} = {backup, barline, ...}.

$$B = B_{notes} \cup B_{others} \cup B_{control} \qquad (2)$$

In formula (2), B means the set of Braille ASCII code, B_{notes} indicates the set of Braille music notes, and B_{others} represents the set of other elements in the Braille music, and $B_{control}$ is the set blank blocks and newlines.

B_{notes} = {Y, Z, &, =, (, !,), M, N, O, P, Q, R, S, T, U, ?, :, $,], , [, W, V, D, E, F, G, H, I, J}
B_{others} = {", #, %, ', *, -;,<, +,,,-,>,@;,A, B, C, K, L, X, 0,1,2,3,4,5,6,7,8,9}
$B_{control}$ = {blank, newlines}

Rule function R refers to the conversion form MusicXML to Braille ASCII code. Ot can be expressed by formula (3).

$$M \xrightarrow{R} B \qquad (3)$$

$$R = R_{trans} \cup R_{simp} \quad (4)$$

In formula (4), R_{trans} and R_{simp} respectively represent rules of sequential conversion of Braille music and simplified rules of Braille musical symbols.

We conduct analysis the structure of MusicXML and the composition of Braille music. The rules have the following forms: the formula (5) is a sequential structure, the formula (6) is a simplified rule for "grouped", the formula (7) indicates that the left and right hands of the piano are displayed in separate lines, the formula (8) is the structure of the octave marks. In these formulas, P is the set of parent node in the MusicXML file, and here only indicates that m_i has a different parent node. The angle brackets indicate parent-child relationship, and the same angle brackets indicate sibling nodes. $b_i \in B$, $b'_i \in B$, $m_i \in M$, $p_i \in P$ (i = 1,2,3, …).

The corresponding models of the formulas are shown in (a), (b), (c), (d) of Figure 1.

$$R_{trans}(\langle p_1, \langle m_1, m_2 \rangle \rangle) = \langle b_1, b_2 \rangle \quad (5)$$

$$R_{trans}(\langle p_1 \langle m_1 \rangle \rangle, \langle p_2 \langle m_1 \rangle \rangle, \langle p_3 \langle m_1 \rangle \rangle, \langle p_4 \langle m_1 \rangle \rangle) = \langle b_1, b_2, b_3, b_4 \rangle \quad (6)$$
$$R_{simp}(\langle b_1, b_2, b_3, b_4 \rangle) = (\langle b_1, b'_2, b'_3, b'_4 \rangle)$$

$$R_{trans}(\langle p_1 \langle m_1 \rangle \rangle, \langle p_2 \langle m_1 \rangle \rangle, \langle p_3 \langle m_2 \rangle \rangle, \langle p_3 \langle m_2 \rangle \rangle) = \langle b_1, b_2, b_3, b_4 \rangle \quad (7)$$
$$R_{simp}(\langle b_1, b_2, b_3, b_4 \rangle) = (\langle b_1, b_2 \rangle, \langle b_3, b_4 \rangle)$$

$$R_{trans}(\langle p_1 \langle m_1, m_2 \rangle \rangle, \langle p_2 \langle m_3, m_2 \rangle \rangle) = \langle b_2, b_1, b_2, b_3 \rangle \quad (8)$$
$$R_{simp}(\langle b_2, b_1, b_2, b_3 \rangle) = \langle b_2, b_1, b_3 \rangle$$
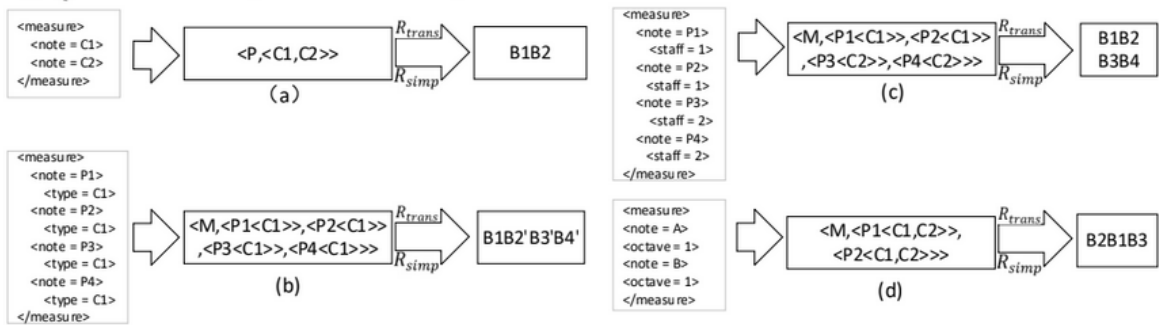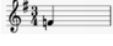
Fig. 1. Modes from MusicXML to Braille music

According to formula (5), we give a sheet music fragment and translate it into Braille music in order. As shown in Figure 2.

Fig. 2. translate of sequential structure

We take the score ![score] as an example, and its corresponding DOM tree of MusicXML is shown in Figure 3, The character comparison table is shown in Table 1.
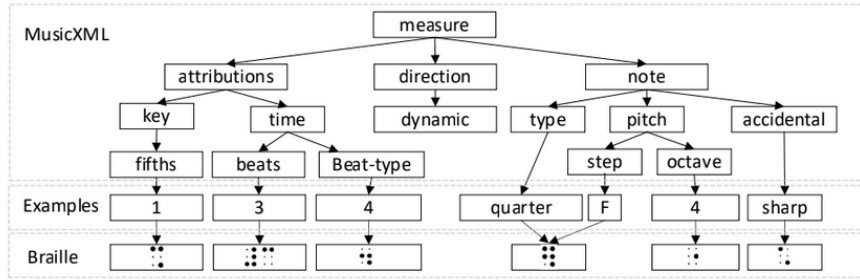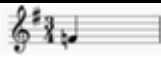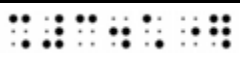
Fig. 3. MusicXML DOM tree

Table 1. character comparison table

Name	Value				
![score]					
Composition of words					
MusicXML label	<Key>	<Time>	<accidental>	<octave>	<step><type>
ASCII code	%	#C4	*	"	]
ASCII code vaule	37	35 67 52	42	34	93

System Implementation

After understanding the logic of the method, this section introduces the implementation of the method, including the specific steps of the method and the complex and important algorithm.

This method mainly has 5 steps. 1) Upload the MusicXML document and the system parses the DOM tree. 2) Get the title information and translate the song title asynchronously. 3) Adopt the idea of loop traversal, and generate Braille with reference to MusicXML and Braille ASCII code comparison table. 4) Simplify the Braille music according to the algorithm. 5) Sort out the output format according to user needs. As show in Figure 4.
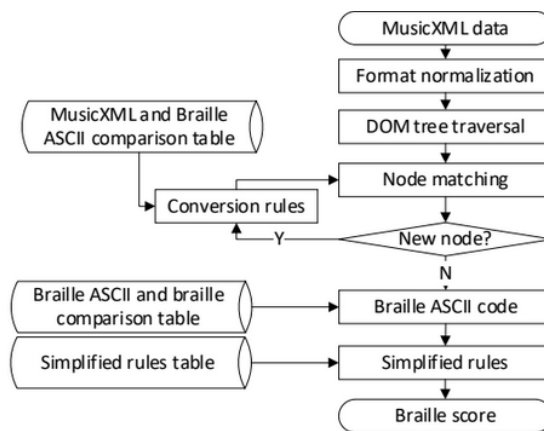
Fig. 4. The flowchart of this method

While looping and traversing, we need to solve the problem of converting the MusicXML tree structure to the Braille linear structure. In MusicXML format, we know the outermost label should be <part> label. Within the <part> tag is the <measure> tag, which is the section in the score. Each <measure>

tag contains multiple <note> tags, that is, notes. These three tags form the structure foundation of MusicXML file. Thus, the principle of convention traversal is: the outer label traverses first, the inner nested label traverses later.

In the conversion of MusicXML to Braille, one of the most important and difficult ones is simplification of the Braille music. For example, in chords in which the notes are of equal value, one note only is written. The others are indicated by their intervals from that note. In chords which belong to the upper series of notes, the upper note is written and the lower notes are expressed by descending intervals. But in the lower series, the lowest note is written and the others are expressed by ascending intervals.

We use ▤ as an example, there are three quarter notes in this example, which are represented in Braille notation as ⠿⠿⠿, The first Blindspot are notes, and the remaining two Blindspot are intervals. Figure 5 is an example of processing chords.

Fig. 5. The example of processing chords

Another important and difficult part is the shorthand for notes or music marks in Braille. For example, three or more 16ths or smaller-value notes may be "grouped" in braille. The members of the group will all be in the same beat or portion of a beat and have the same value. When "grouped", only the first note of the braille group contains dots 3 and/or 6 as necessary. The other notes in that group are written as if they are 8th notes. The example is shown in Figure 6.

Fig. 6. The example of "grouped"

Experiment and Result Analysis

Table 2. test cases and scores correspondence table

Test cases	Music score
A	Xiao Bu Wu Qu
B	Kang Ding Qing Ge
C	Flower Dance
D	Round Dance
E	Summer
F	Sonatina in G
G	ALISTIRMA 48

We select some test cases, as shown in Table 2. We use Sibelius, musiccore3 and other software to convert pdf format musical files to MusicXML format, but errors inevitably occur during the conversion process. The experimental results were provided by relevant staff of China Braille Press. The calculation formula of conversion accuracy is shown in formula (9). Translation time is the average of five translations.
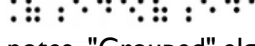
$$\text{Conversion accuracy} = \frac{\text{Correctly converted blind spots}}{\text{Total conversion}} \qquad (9)$$

Table 3. number of elements in the score

Music	Total conversion blind spots	MusicXML errors	Wrong number of blind spots converted	Translation time (s)	Conversion accuracy (%)
A	699	0	15	0.181	97.85
B	575	2	6	0.187	98.60
C	4408	1	98	0.221	97.78
D	338	4	6	0.187	98.22
E	2475	13	176	0.199	92.36
F	326	0	17	0.169	94.78
G	2178	15	89	0.201	95.91
Average	1571	5	55	0.195	96.50

The experimental results we obtained are compared with the paper [11], and the conversion time is much faster. We made a comparison and got the mean of the result data after five times per method. In the developer tools of Google Chrome, we use the value of the load parameter under the Network option as the conversion time. The results showed that that using A as a test case our methods were 2.26 seconds faster than theirs, and other test cases were also faster. we did not compare the conversion accuracy because of the paper [11] does not give the accuracy of their translation and the Braille score standards based on translation are not exactly the same. This method is based on the "China Braille musical signs GB/T 16431-2008" standard, and the experimental results are based on this standard.

We found that the obtained MusicXML file had errors on some of the rest signs while the music software had errors in processing other format scores. For example, in stave B, ≡ should be a wholes rest but it was translated as a half rest in MusicXML.

Errors were also found in the experimental results. Let's use the stave C as an example, our experimental translated ♫♫♫♫ into ⠼⠃ ⠂⠄⠙⠪⠊⠆ ⠂⠄⠂⠄ but the correct result should be ⠼⠃ ⠂⠄⠙⠪⠆ ⠂⠄⠂⠄. Because the program had used the "grouped" algorithm when processing the notes. "Grouped" algorithm does not got grouping information for notes, which led to the error of the last note in the note grouping and caused more translation errors in the C and E staves. We will continue to optimize the algorithm to reduce errors during translation.

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In the conversion accuracy, Kang Ding Qing Ge had the highest accuracy rate of 98.60%. Summer' s accuracy rate was low, 92.36%, mainly due to the summer chords. We will continue to improve in the later period. The average time for the 7 pieces of music is 0.195s, and the average accuracy is 96.50%.

Conclusion

In this paper, a conversion method from music score to Braille music based on MusicXML format is proposed, which can automatic conversion from staff to Braille. First, we get MusicXML files through software such as Sibelius, musiccore3, etc. Next, we get Braille music from MusicXML file use the

method proposed in this paper. But conversion errors will occur during the conversion process. After experiments, the average accuracy rate is 96.50%. The program code of this method is placed on The Braille Online Platform of China (http://www.braille.org.cn/music/). This method improving the translation speed from staff score or short score to Braille music, and bringing great convenience to musicians with visual impairment. But this is not enough, we will further improve its accuracy and apply the score recognition to it.

Acknowledgements

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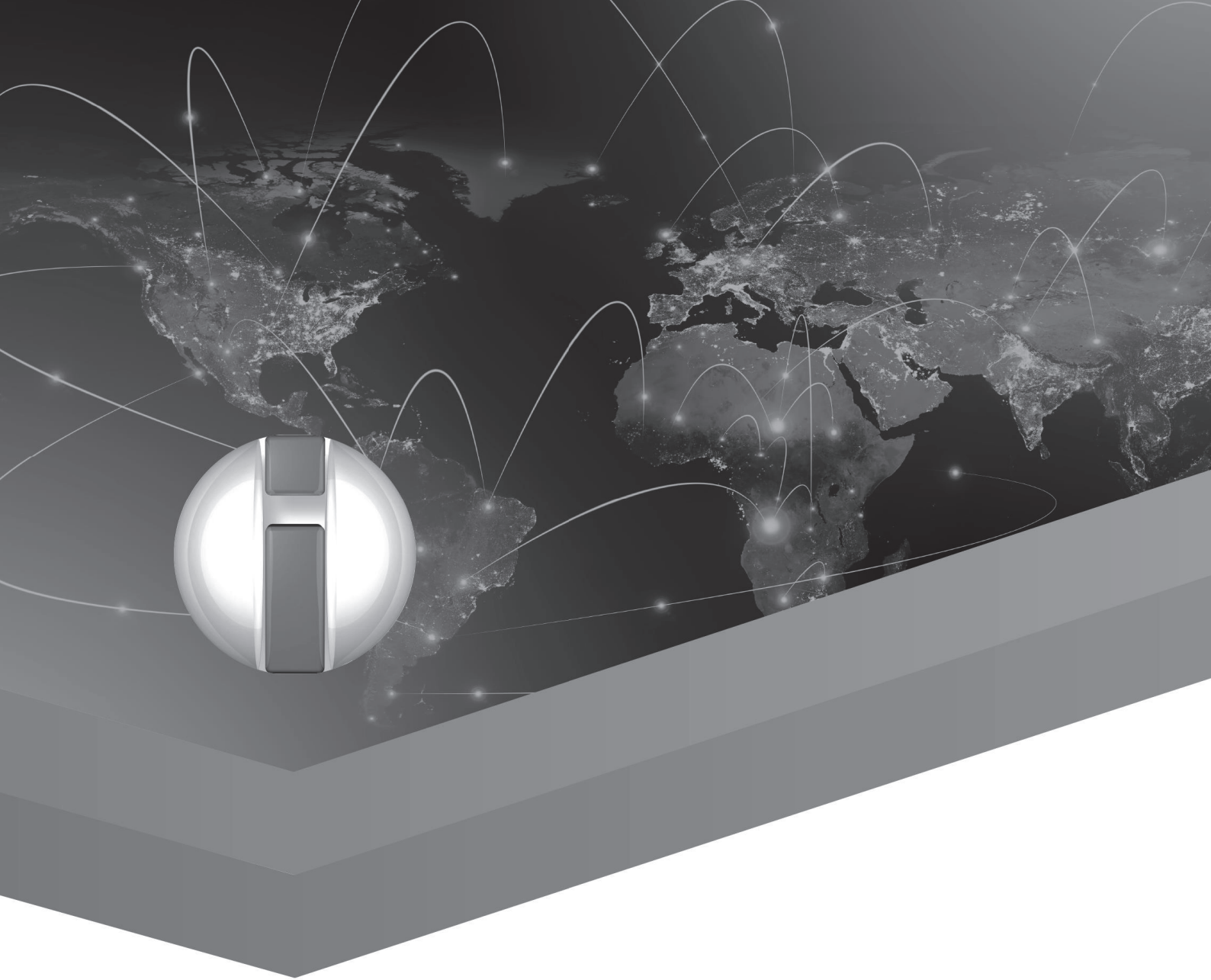
XR Accessibility

Learning from the past, addressing real user needs and the technical architecture for inclusive immersive environments

Design of a Modular System Exoskeleton and Mobile Application for Hand Rehabilitation after Trauma Injuries

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Abstract

Hand injuries are common but if left untreated, they may result in loss of function. Rehabilitation helps the patient to regain the hand's full functionality. Hand therapy is generally necessary following surgery in order to ensure successful rehabilitation. This usually takes place at home under the direction of a therapist and can last for up to 6 months. To assist the rehabilitation process, several devices have been designed that help a patient perform the therapy by themselves. Because people usually interested in trying new technologies, this hand exoskeleton was designed to help the patients do their exercises at home in a fun way. The objective was to design a portable, lightweight exoskeleton with a fast adjustment assemble the system. The device is able to support fingers and to reproduce a flexing action while isolated second injuries.

Keywords: Hand Rehabilitation, Exoskeleton, Modular system.

Introduction

This paper presents the development of an exoskeleton able to provide rehabilitation exercises to treat patient's injuries and restore the function of the hand. It was observed that mechatronic devices are effective, but the problem is that they are not adjustable and are not able to be readily fitted on different hand sizes. Furthermore, the user has to allocate specific time for rehabilitation exercises [1-3]. State of the art in this field is represented by the exoskeleton Gloreha Hand Rehabilitation Glove and AMADEO [10-12]. The actuation system of this kind of devices, however, is enormous and heavy to be practical for use in home therapy [13, 14]. A smaller version, which the patient can use at home, is available but it still is very bulky. Another problem of the existing mechanical system is that is mandatory the assistance of a second person that helps the patient to set up the therapy [15, 16]. If the intention is to have a device that a patient can use at home it needs to be both lightweight and easy to put on without assistance [4, 5]. Most of the structures that exploits wires have a problem in common: actuators are placed outside the device, on a fixed structure that can barely follow the movement of the patient. In this way, the user is constrained in a position during all the training session. It may naturally result in a degradation to the patient approach to the therapy and a bad execution of the exercises. The aim of rehabilitation is the improvement of range movement, straightening of muscles and acceleration of callus formation. It is also very important to restore proprioception in a region of trauma. The modular system exoskeleton provides a means of both passive and active macro region rehabilitation. In the passive rehabilitation the movement of the finger is facilitated by the exoskeleton structure. Active rehabilitation occurs by activating the device using muscle excitation [6]. The patient is able to change the modular structure of the exoskeleton depending on the type of injury. Through the combination of rigid (PLA) and flexible (TPU) materials the device is able to fit on different hand size. At the same time, it is possible to apply different levels of the exercise to suit different circumstances. The automatic control system allows patients to carry out their daily work in parallel with the rehabilitation exercises. It saves time and enables fast-moving back to practical life. In addition,

the exoskeleton enables to use of a mobile application which can further improve rehabilitation efficiency and can be used by the therapist directly to monitor patient status.

Mechanical Configuration

The goal of the exoskeleton in a modular adjustment system is to assist with the restoration of normal function to an injured finger. Its mechanical design was specifically intended to facilitate passive and active rehabilitation [7]. Three primary sub-system were made for this purpose (actuator, transmission and support structure). In this system a Paralax servo motor is an actuator. The transmission system comprises of copper sticks and a gear system. The support structure is a combination of flexible and rigid modular assembling parts.

Flexible Structure Analysis

Several shapes have been evaluated as can be seen in figure 1. The most convenient shape is number 6. It consists of 14 trapezoidal features. In the space in between them, there is a V-shaped 3 axis bridges to guarantee the structural integrity of the shape without compromising the flexibility and thus allowing the free open-close movement of the hand and allows finger to be moved in the axial direction. It is fundamental, as the center of rotation of each phalanx is not placed in the same position as the support. Thus it will need to deform in the axial position to follow the movement of the finger.
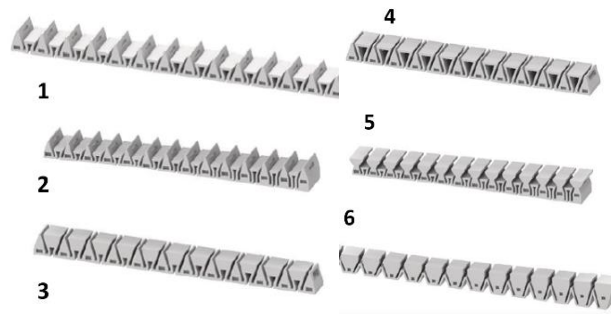
Fig. 1. Exoskeleton flexible structures.

Transmission System

The transmission system is organized by sending Force from Servo motor/ Linear actuator to the flexible finger structure. To realize this action, a flexible stick was used. To choose the right material some tests have been performed. The main requirements for this analysis were flexibility and stress tolerance. An additional goal of the test was to understand which type of material can keep the load up to 30 N. Thus, the flexibility becomes the primary functional criterion.
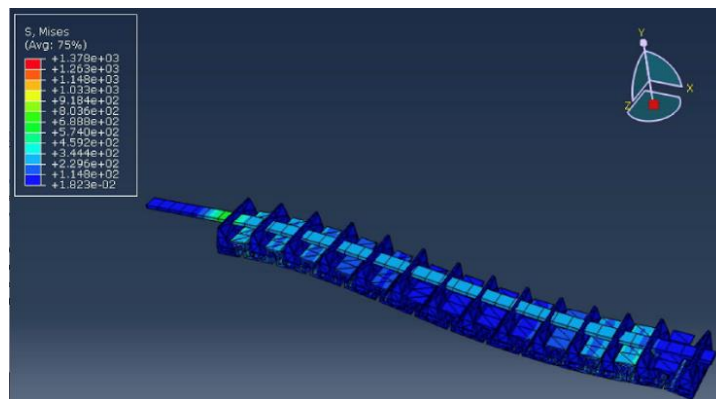
Fig. 2. FEM analysis

3D Printing

It was decided to create the physical components by using 3D printing technology with Thermoplastic Polyurethane (TPU) thus allowing the necessary elasticity to adapt to the hand movement. Figure 3 shows the flexible component which is mounted on the upper part of the patient hand through some connection mechanism placed between the fingers and on the palm, the objective is to create an easy-to-use mount. That is because, while the flexibility of the material may enhance the comfort, on the other hand, it may bring to some serious problem when the patient is wearing it. TPU is the only commercial material that both can be used as 3D printer material and is flexible, thus in the market are available different typologies from different resellers.
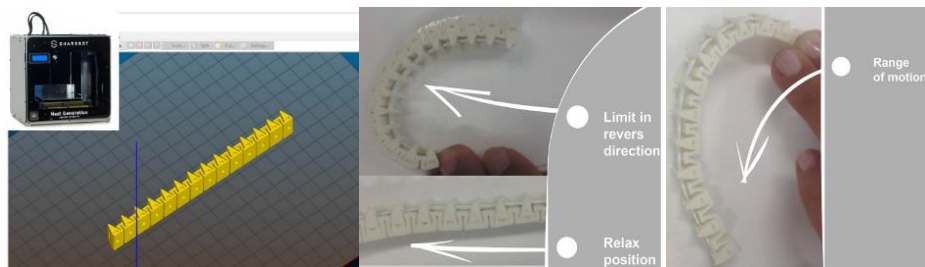
Fig. 4. Flexible structure limits Fig. 3. Slic3r software and the Sharebot Next Generation 3D Printer.

Modularity

The exoskeleton is a light and portable device. It has individual approach to each customer and in the same time at is cheap. Before we figure out that all our patients need an individual approach, depending on the diseases or trauma injures. At the same time, we have patients with only one injured finger and patients who have problems with all the upper limbs. Our patients have problems on right and on the left hand, there are different gender, different age and different hand sizes. The exoskeleton proposed in this paper is the best solution for them. It has a different assembly configuration as can be seen from Figure 5. Depending on the temporary disability our costumer with a therapist can choose device configuration.
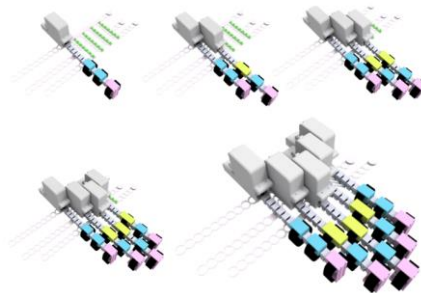
Fig. 5. Modular exoskeleton structure.
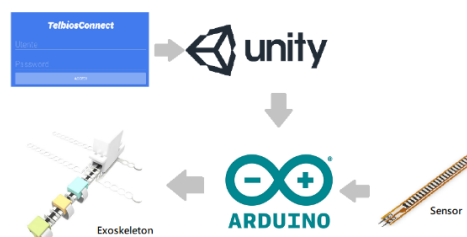
Fig. 6. System Architecture

Control System and Software

The exoskeleton uses the Arduino IDE software for control [8]. Arduino can be activated in two different modes.The passive mode which is selected by click- ing the switch on the bottom of the Unity software control unit and the active mode. This is automatically selected by reading the data from the flexible sensor located between the exoskeleton and the patients finger. The tele-rehabilitation architecture of the system makes it possible for a therapist to track patients status remotely by TelbiosConnect [9]. The large amount of data that this generates can be integrated with mobile applications allowing optimization of treatment procedures and the analysis of the patients response. Fig. 6 shows the system architecture.

Results

The modular exoskeleton was tested on healthy people to verify the limitations of the system and how it can be improved. In the test participated 11 peoples between 20 and 47 who were required to complete a questionnaire regarding their experience with the system. The questions were based on a five-point Likert scale (1-5 with 1 being strongly disagree to 5 being strongly agree). During the test were performed:

- Description of the device that is going to be tested, what is its purpose and how it is expected to perform
- Frequency of use
- Easy to use
- Function of the system
- Learning time for using device
- Compactness of the device
- Interaction design of the device
- Description of the exercises that are going to be executed
- Assemble adjustment modular system on the hand
- Calibration

Figure 7 shows the exoskeleton mounted on the user's hand.

Position 1   *Position 2*
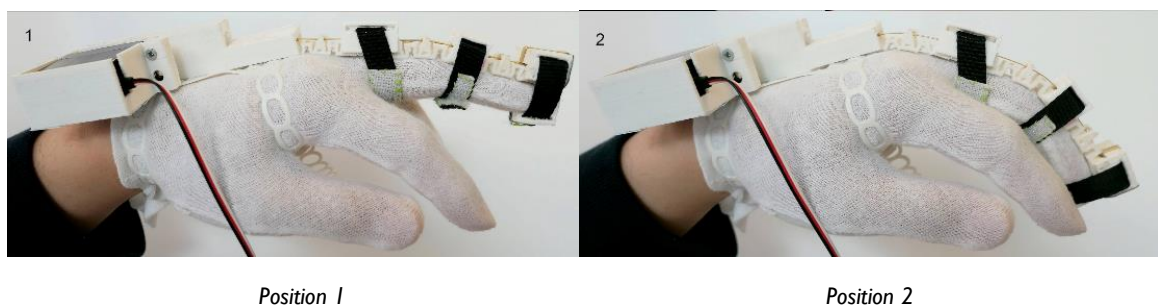
Fig. 7. User wearing the exoskeleton

Mobile Application

In this section, we present an application for upper limb rehabilitation that con- trols the exoskeleton, sets the parameters and shares them with the therapist. There are few factors that create a demand for providing the phone application: modern user expectations, controlling exoskeleton, saving data, setting possibility, share data with the therapist. First of all, the application allows to control Exoskeleton and set repetition as can be seen from figure 8. Moreover, during rehabilitation progress, settings have to be change, the application ensures de- vice control for the repetition process, as well as, speed control. The application merges data and shared it with therapist.

Fig. 8. Mobile application

Test Results

The modular exoskeleton was tested on 2 groups of people:people without hand injuries (healthy people) and patients from Villa Beretta rehabilitation center. The aim of the tests was to identify any limitations of the system and how it can be improved. After each test subjects were required to answer the survey questions. The first test was conducted using 11 healthy subjects (7 male, 4 female) aged between 20 and 47 who were required to complete a questionnaire regarding their experience with the system. The questions were based on a five- point Likert scale (1-5 with 1 being strongly disagree to 5 being strongly agree) During the test were performed: Description of the device that is going to be tested, what is its purpose and how it is expected to perform, function of the system, description of the exercises, assemble adjustment modular system on the hand. Fig. 9 shows questionnaires results.

The second test was performed using 4 patients (2 male, 2 female) aged between 40-79 from Villa Beretta rehabilitation center who were required to complete a System Usability Scale (SUS) regarding their experience with the system.
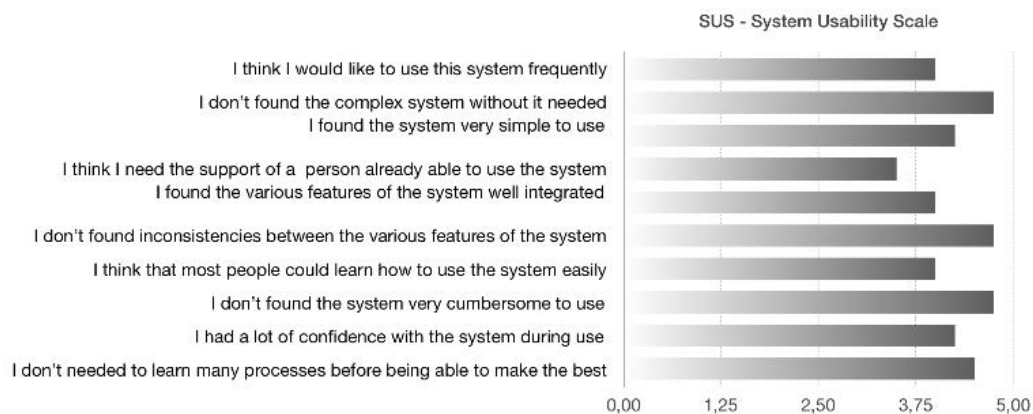
Fig. 9. Healthy people test result

Fig. 10 shows the SUS results of the case study with the score of 81.25 indicating an above average result. The results showed that healthy subjects were more satisfied with the operation and control of the system and less satisfied with understanding how to assemble the modular exoskeleton on the hand. This area needs some improvement in order to simplify process.

20
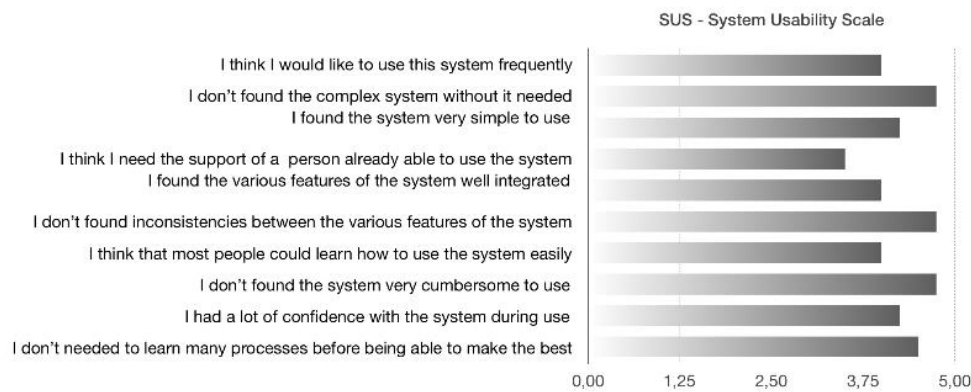
Fig. 10. Patient SUS results

Conclusion

The modular exoskeleton was tested on both injured and healthy subjects. The result shows that it is easy to understand how to assemble and use the device. It is able to accommodate different finger lengths and the rigid cap, which is located precisely over each knuckle, acts as a protector for each phalanx bone. It also en- ables the contact force to be restricted to the damaged finger reducing the possi- bility of secondary injuries. Because of the materials used in its construction, the exoskeleton is both lightweight and portable and integration with TelbiosCon- nect App enables the patient to carry out rehabilitation at home. Future work, will focus on simplifying the assembly system to make it more user-friendly; im- proving the transmission system to increase the range of rehabilitation practices and building a VR application to further improve the rehabilitation efficiency.

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Large-Scale Web Accessibility Observatories

Improving Web Browsing Experience Using a Screen Reader for Visually Impaired Persons

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Abstract

The purpose of this study is to develop a browser's extension to present modified web pages to eliminate problems specific to the browsing environment for visually impaired users of screen readers. Our extension modified websites to eliminate unnecessary headings, links, and other elements that may adversely affect viewing with a predefined screen reader. Then, we experimentally evaluate whether the changes occur in the web browsing experience on visually impaired persons. The result indicated that the developed extension leads to a shortening of the elapsed time for browsing a website, and in particular, it may lead to a shortening of the listening time of the screen reader between keystrokes.

Introduction

Many visually impaired people use a screen reader to browse websites on a daily basis. These Web sites used to be composed of only text and images, but currently, they have become more diverse and complex with the introduction of interactive elements such as maps in addition to audio and video contents. As a result, visually impaired people who use screen readers are forced to switch other compatible screen readers and browsers in order to properly navigate such web environments. Therefore, visually impaired people have to face the complexity of learning the unique operation method for each website compared to those without visual impairments. In recent years, the purpose of using web technology has been diversified, and some visually impaired users require the transmission of information through SNS and the operation of web applications. Therefore, the variety of operations required for the visually impaired is increasing by the day, even with the improvement and progress in web accessibility.

On the other hand, to improve web accessibility for visually impaired people, numerous studies have been conducted. Particularly, these studies include the contents guidelines such as W3C WAI guidelines [1-3], and usability improvements of screen readers [4-7]. In this context, the evaluation of the structure and elements of the web site is also being conducted. Specifically, Shimura et al. reported that structuring a website was useful for improving accessibility [8]. Shoji et al. mentioned the usefulness and challenges of guidelines by the evaluation using pseudo input forms [9]. However, many of these studies were conducted using simulated sites. Not many measures are taken to deal with elements such as advertisements that visitors do not need, such as real sites.

Therefore, in this study, we aim to develop a system to present a well-formed web site in order to eliminate problems specific to the browsing environment for visually impaired users of screen readers. First, we create a Google Chrome extension that shapes websites to make it easier for screen reader users to view it. Then, we experimentally evaluate whether the changes occur in the web browsing experience on visually impaired persons.

Table 1: Formatting examples of CSS/HTML elements in developed extensions

Sites	Items	CSS Selectors	HTML elements	Formatting
Google	Search results from Twitter and news.	#rso > dic:nth-child(3)	g-section-with-header	Move items to the end of the search results (#brs)
Yahoo	Search results for news, summary, Q&A, etc.	#WS2m > div.cmm		Move at the top of related search items (#Si2)
Lifehacker	Pickup articles displayed at the top of the new article		div.lh-headerTop h3	Deleting a Heading Element
	Category / feature list displayed at the top of the new articles		nav.lh-globalNav-pattern.lh-globalNav-pattern--category, nav.lh-globalNav-pattern.lh-globalNav-pattern--feature, nav.lh-globalNav-pattern.lh-globalNav-pattern--regular h3	Deleting a Heading Element

Picture 1: Appearance of the web pages modified by the developed extension. Left and right figures represent the original page and the modified page, respectively.

Our Extention

As a system for shaping web pages, we created an extension that runs on Google Chrome and Mozilla Firefox. We created it because there was no need to introduce any special software at the time of development and evaluation. We developed this extension by using JavaScript as the programming language and jQuery for efficient web page formatting.

This extension works when a screen reader user accesses a specific website by Google Chrome. First, we analyze the HTML elements of the site and search for unnecessary headings, links, and other elements that may adversely affect viewing with a predefined screen reader. In this case, it searches not only the HTML tag itself but also the CSS selector side. The formatting examples of CSS / HTML elements in developed extensions are shown in Table 1. Finally, the retrieved elements are changed, moved, and deleted, and the shaping results are presented on the screen. The left and right figures of Picture 1 show an example of screens of the search result page in Google before and after formatted by our extension. While the left figure displays advertisements and news, the right figure removed the advertisements and only views the search results.

Evaluation

Six total blind people in their twenties participated in this evaluation. They included five males and one female and all of them usually used screen readers. They were asked to perform a task of finding and

opening a specific page. The websites used for the evaluation were Google, Yahoo (search site), and Life Hacker (WordPress type site).

Prior to the evaluation experiment, the participants were asked to fill out a questionnaire about their disability conditions and their use of the screen reader and the website. In the experiment, participants were first asked to wear headphones and adjust their usual screen reader and volume to their preferred settings. Their comments indicated that they had usually used PC Talker and NVDA as screen readers. Next, they were asked to perform experimental tasks to comprehend the structure of the website before and after being modified by our extension. After that, we asked them to perform the tasks of searching for a specific keyword to find a link and opening a specific article on the site before and after the modification. In this case, we recorded the speech of the participants and recorded the operation screen, the time when the key was pressed, and the keys pressed as a log of the operation. Finally, to investigate the subjective evaluations of each site, we asked the participants to input the answer to the items of NASA-TLX and also answer the problems and their impressions about the original and modified sites. Data analysis was performed in the elapsed time and number of keystrokes after elimination of the outliers (10% from the larger one).

Results and Discussion

An analysis of variance on the time required by screen reader, site, and shaping status revealed significant main effects for site and shaping status ($p < .05$, ART ANOVA [10]). The elapsed time was shorter after the modification, as shown in Picture 2. However, in the total number of keystrokes, only a significant main effect of site type was observed in the well-formed condition, while no significant main effect was observed in the well-formed condition. Therefore, the result indicated that the developed extension leads to a shortening of the elapsed time for browsing a website, and in particular, it may lead to a shortening of the listening time of the screen reader between keystrokes. In particular, there were many feedbacks where the effect of modifications was confirmed on Google. The reason for this may be that advertisements, news and Twitter comments marked up with headlines are no longer displayed, so the participants could move quickly to the search results.
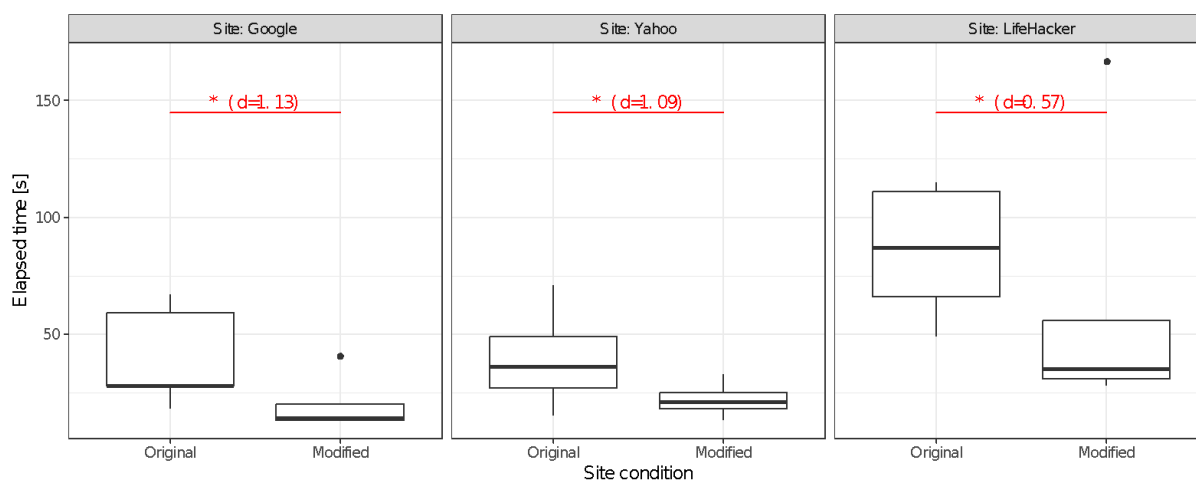
Picture 2: Appearance of the web pages modified by the developed extension. Left and right figures represent the original page and the modified page, respectively.

Table 2: Feedback from the participants

Participants	Google	Yahoo	LifeHacker (Wordpress-like site)
1	I didn´t feel any changes at the modified site.	I operated easier after the modified sites.	I felt it easier to browse the modified site because there were fewer readings of "dummy."
2	I didn´t feel any changes at the modified site.		I could feel the difference between the original and modified sites, but I could not say which was better.
3	I operated easier after the modified sites.	I didn´t feel any change from the plastic surgery. I looked for the search results with a combination of cursor movements and heading jumping.	I could feel the difference between the original and modified sites, but I could not say which was better.
4	I felt it easier to find the search results after the modification because of the omission of Twitter timeline.		Though I felt it a little easier to navigate the modified site, the change in Google was greater.
5		I felt more burden to check the original site because I did not know the layout of the site.	
6	When I want to get information for a purpose, I felt it better to use the modified site. But when I want to get information at random, it is better to use the original site.	I got along better at the modified site.	At both sites, I felt that it took a lot of time because of a lot of unneccesary information.

Conclusions

We developed an extension for Google Chrome to present modified web pages to eliminate problems specific to the browsing environment for visually impaired users of screen readers. Our extension modified websites to eliminate unnecessary headings, links, and other elements that may adversely affect viewing with a predefined screen reader. We evaluated the effects of such modifications to the usability based on the web browsing experience on visually impaired persons. The result indicated that our extension contributed to shorten the browsing time to look for the target information, and particularly decrease their listening time of the screen readings between keystrokes.

In the future, we plan to implement additional functions in the extension to make the web browsing experience using screen readers available to various sites.

Acknowledgements

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Pilot Studies for Evaluating a Web Accessibility Observatory

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Abstract

As with most software development projects, the WADcher observatory to monitor web accessibility must cater to the needs of the eventual users, be they web commissioners, developers or expert reviewers. However, these three different groups show quite different requirements with regard to their tasks and their proficiency when using monitoring tools and also understanding of technologies and web accessibility in general. Therefore, a common observatory needs to consider all of these requirements and as best as possible fulfil them. The realization of this claim then can only be tested through extensive user testing with representatives of all groups.

Another important aspect regarding web accessibility are the different legal frameworks that have been set up in European countries as well as the different tools and rulesets that can and should be used. To verify whether all national requirements are actually met, the tests also need to extend beyond a single country and must include a widespread test group.

Introduction

The EU Web Accessibility Directive (WAD) [2] establishes accessibility requirements for the websites and mobile applications of public sector bodies across the EU. The WAD's accessibility requirements describe what must be achieved for the user to be able to perceive, operate, interpret and understand a website, a mobile application and related content. However, it does not specify what technology should be selected for each website, online information or mobile application.

For this purpose, the EU funded the research project WADcher (www.wadcher.eu) is developing an integrated platform to verify the compliance and reporting of websites and mobile applications bodies with the accessibility requirements set out in the WAD, and subsequent Commission implementing decisions on monitoring methodologies and model Accessibility Statements.

Web accessibility as a concept is supposed to provide everyone with access to all websites whether they have an impairment or not. Therefore the W3C has put forward the Web Content Accessibility Guidelines (WCAG), now in the version 2.1 [1], which represent a baseline for the requirements for a website to be deemed accessible. As there are many different kinds of impairment and some functionalities are more basic than others, there are also different levels of compliance to these guidelines. Although the WCAG are the internationally accepted standards for web accessibility assessment, and the Web Accessibility Directive (WAD)[2] as well as the harmonized standard on ICT products and services by the EU is referring to it [3], there have been several countries and organizations that have issued different or adapted guidelines themselves. Some of these are also recognized by national legislation as the de facto standards for the respective country to evaluate web accessibility. This is for example true in Germany, where the BITV guidelines are used for assessment. As a result, the WADcher web accessibility observatory has to provide access to tools that can evaluate websites based on different rulesets and thus has to be able to relate the results of different tools together. To support this interoperability the W3C has issued the Evaluation and Report Language (EARL)[4].

User centered design is a commonly used framework for software development. Thus, there has already been extensive scientific research on including users in the development process [5, 6]. Especially in the field of design for all and universal design the inclusion of users with special requirements has been promoted as one of the main approaches to gather requirements and fulfil them already in a design phase. This generally leads to more accessible designs and also helps reduce costs of reworking or redesigning products and services [7].

With respect to the evaluation of software, there is also a lot of literature [8, 9]. Going through the different stages of software development and deployment one might differentiate between alpha, beta and final testing with the proposed pilot studies on the web observatory being located between an alpha and beta test as there are still features to be added, while the visuals and GUI are generally in the final stages.

Our Work

Targeted Usergroups

There are basically four different main user groups for a web accessibility observatory. Firstly there are the web commissioners who are responsible for certain websites or domains. They are the main user group for the observatory, as they are required to monitor the accessibility of their websites under WAD and are the focal point to enact all other activities. Two more central user groups are web developers and expert reviewers. While the former are mainly tasked with improving the accessibility of the monitored websites, once a web commissioner issues a contract. The expert reviewers on the other hand support the web commissioners in assessing the accessibility as the automatic tools are often unable to distinguish whether an error is actually one or not. In addition, national monitoring bodies constitute a separate user group, as they are tasked with reporting on the national level of accessibility and they have to coordinate the national assessment efforts and these workflows need to be included in the final observatory. With regards to the amount of testers, it is foreseen that for the first iteration of user testing 5 users of all groups except for the national monitoring body where obviously only 1 user can test, are sufficient.

Use Cases to be Evaluated

As with any software tests, the actual processes and steps the users have to take in order to evaluate all or most of the functions need to be clearly defined. In the case of a web accessibility observatory there are a number of specific processes that the users have to conduct. For the respective development project, the defined use cases were as follows.

- Allow the user to log in
- Create a new accessibility monitoring project
- Evaluate the accessibility of a given project (create an assessment)
- Access the details on an assessment
- Create and assess an Accessibility Statement for the site

In addition to these cases that are directly related to successfully conducting a continuous web accessibility monitoring there is also the creation of an accessibility statement that is an important function for persons responsible for websites as under WAD they are generally required to provide such a statement on each of their websites.

Selection of Trial Sites

Regarding the sites that should be checked for the pilot studies, there are also some important factors that need to be considered. With respect to the general workflow of the observatory, any website might be checked as this generally does not differ for different websites. However since WAD is

currently only applicable to public sector bodies and therefore public authorities have the highest pain in getting their websites assessed, it is reasonable to first target this group. As different countries have set out different rules and requirements for the actual implementation of the WAD it is necessary to also include a broad sample of different nationalities in these pilot test to see, whether these legislations can be met. Therefore, for the pilot site testing a broad mix of websites from different countries was chosen. These range from communal websites, websites of regions, to websites of federal ministries and also include websites of agencies. In addition, the content presented on the websites was pre-screened to allow for a maximum variety of different media forms to be tested. The latter should ensure that all relevant success criteria of different web accessibility assessment standards could be evaluated.

Questionnaires Used to Collect User Feedback

To collect the user responses and further the development of the observatory a couple of questionnaires were developed that could track the completion of the use cases as well as indicating the difficulty in their usage for the users. In total there were three different instruments used with 2 quantitative and one qualitative questionnaire. The first survey applied to the users was a general use case tracker that questioned the users on whether the proposed tasks could be completed and also how difficult the task completion was for them on a scale from 1 to 5. Furthermore, the users could indicate whether there were functional problems or they had some comments on improvement. The second questionnaire applied was a shortened "System Usability Score"-survey [10] that tracked the ease of use based on 10 questions on the impression of the user on a scale from 1 to 5. Lastly the users were provided with a qualitative post study interview where they could give free answers on the use of the observatory as well as further indicate the main positive and negative aspects on the current implementation of the observatory.

Current Results

Based on the already conducted user testing it can be shown that the current implementation of the observatory is already highly functional and can be used by most users. Almost all tasks set before the users in the use cases could be completed in the current implementation with only minor problems arising mostly due to incompatibilities of different web browsers.

Table 1: Task execution difficulty reported by pilot sites

Task / Average Difficulty[1]	Site 1	Site 2	Site 3	Site 4	Overall Averages
Login into the Observatory & manage User	2.0	2.0	1.2	2.3	1.9
Create a project with simplified test & all standard values	3.3	3.8	1.2	2.3	2.7
Create an Audit for the new project.	1.3	1.0	1.0	1.7	1.3
Wait for the "Audit Completed" notification	3.0	1.4	2.2	2.3	2.2
See the Evaluation Results by selecting the project (or anther if its not yet finished) & select its latest Audit	4.3	1.0	2.0	2.8	2.5
Create & Preview a draft Accessibility Statement.	3.7	1.2	1.8	1.0	1.9
Cumulative Averages	2.9	1.7	1.6	2.1	2.1

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[1]The meaning of values:
1 Irrelevant, the problem does not need to be solved, but it could be improved.
2 Low: the problem causes uncertainties, but it does not prevent the task completion.
3 Medium: the problem can slow down the task execution, but does not prevent task completion.
4 High: the problem causes frustration and prevents the task completion.
5 Very High: the problem stops use of service.

Also, the usability scores for the current implementation are already above 50% of the possible scores showing that already a sufficient level could be reached in the early stages.

Table 2: Aggregated System Usability Scores for the pilot implementation

Question	# of Users	Average Score
1. I think that I would like to use this tool frequently.	24	3,38
2. I found this tool unnecessarily complex.	24	2,54
3. I thought this tool was easy to use.	24	3,25
4. I think that I would need assistance to be able to use this tool.	24	3,00
5. I found the various functions in this tool were well integrated.	24	3,42
6. I thought there was too much inconsistency in this tool.	24	2,38
7. I would imagine that most people would learn to use this tool very quickly	24	3,21
8. I found this tool very cumbersome/awkward to use.	24	2,17
9. I felt very confident using this tool.	24	3,25
10. I needed to learn a lot of things before I could get going with this tool.	24	3,04
Overall SUS Rating		2,96

From those evaluations and the qualitative feedback given by the pilot site testers, a list of potential improvements for the Web Accessibility Evaluation Platform WADcher could be derived. The key points shall be presented here.

Conclusions and Possible Next Steps

At the current stage, the pilot tests need to generate more data to be able to statistically provide valuable insights into the functionality and usability of the developed web accessibility monitoring observatory. However even with the current data it can be shown that the tools developed to evaluate such an observatory yield valid and useful information and the overall process is able to provide the development team with helpful input on where to focus for the further development of the client.

In order to reach the proposed results and the impact, there will be a second round of pilot studies performed that will reach out to an even larger group of countries and participants. The tests will not only focus on the usability and general functioning of the observatory but will extend the current test settings towards more real life examples and a workflow that is close to what can be expected once WAD monitoring is fully enacted.

Based on the questionnaire results and the qualitative feedback by the pilot site users, also a number of recommendations could be derived to further improve the platform but also to derive, which parts of the evaluation where working and which parts needed improvement. These points are presented in the following:

- The one-to-one "think out loud" evaluation methodology worked very well, especially online with screen-sharing, and generated a wealth of detailed user feedback and suggested improvements. It can therefore be assumed, that this method should be employed more often to evaluate software in it's development stage, however it has to be stated that this method is also very time consuming and intensive for both the interviewer and the interviewee. If conducted correctly though it is also highly accessible to persons with disabilities.
- The interaction with the participants of the pilot revealed a significant interest of the public bodies in WAD and the upcoming compliance milestone of September 2020.
- The final WADcher service will need to provide more support information on the WAD requirements, possibly by linking to resources, tutorials and training from the WAI-Guide project. Also, the reporting requirements of WAD Monitoring Bodies will need to be

addressed. However, the trials have disseminated awareness of both WADcher and the WAD, especially amongst the public bodies that were involved.

- Overall, users found the WADcher system straight forward to use and functional, and liked the graphical illustration of assessment results.
- The WAD-compliant Accessibility Statement template and its partial auto-completion was much appreciated. However, the system will need to provide more support to reduce the burden on users to address the long list of "NonCompliant" issues that require extensive user inputs and support.
- WADcher should incorporate more and better organized help and walkthrough resources on the mission and practical use of each of the components with which the user must interact. The system needs clear simpler explanations using less jargon with more contextual help, especially in interpreting the accessibility evaluation and in filling the Accessibility Statement.
- The system's compatibility with the various web browsers needs to be refined, to avoid errors that users found, and to fully support various functionalities.
- The final WADcher system should accommodate more Accessibility Assessment Tools by different vendors, to give the users a better choice of the tool that they prefer or are already using.

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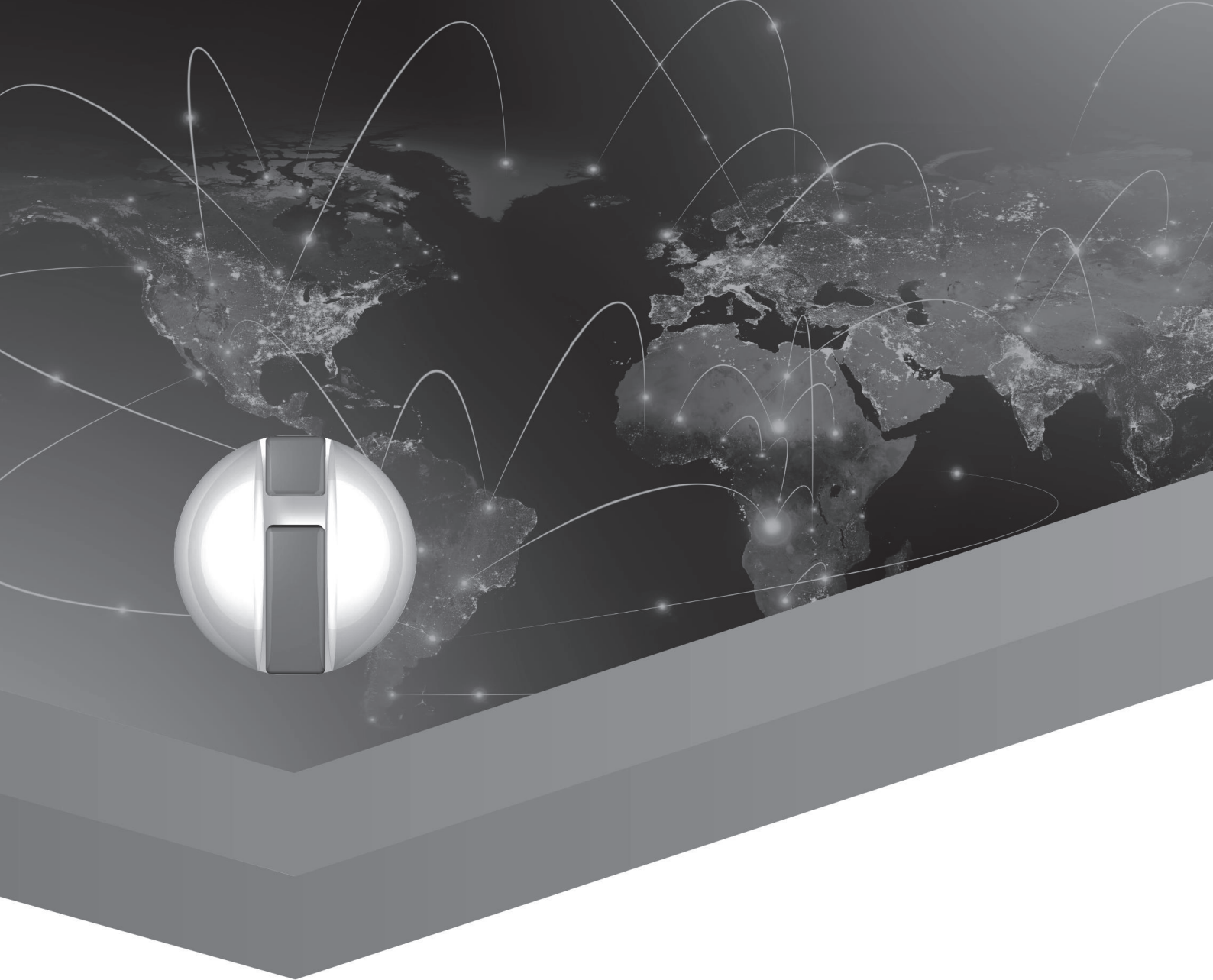
AT and Accessibility for Blind and Low Vision Users

Towards Accessible Complete Plain Text to General Public Reader

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Abstract

In this article, we analyze the difficulties to access spatial information and propose some solutions. Our objective is two-fold: to create any type of document easily, and to make it accessible and intelligible for all audiences, blind and sighted people. Digital document accessibility, which in addition to readability also includes understanding and appropriation, should be improved. We propose some solutions to enhance the efficiency of screen readers for difficult 2D objects such as graphics and tables. Linear reading can be facilitated by inserting additional tags and attributes proposed by HTML5 or WAI-ARIA. Thanks to a simple language with lightweight tags, we offer the possibility to automatically generate more accessible documents without specialized knowledge of these functionalities. From the plain text document, HTML and SVG codes are generated. To complete the formatted document, a description file is produced in parallel to accompany the understanding of complex documents - UML diagrams or tables - and also to present the structure of the complete document.

Introduction

This article presents some solutions of accessible document writing for people with visual impairments in order to communicate with sighted audiences [1,2]. It innovates by the fact that it does not place the visually impaired person (VIP) as a reader but as an author of documents. We also wanted to make this project attractive to other audiences: students learning to design schemes, diagrams and Web developers sometimes bewildered by the difficulty of making their work accessible.

We propose to enhance the level of accessibility for digital documents [3,4]. We suggest with our approach, not to increase the number of constraints proposed by the WCAG [5], but to decrease the quantity of rules that an editor must have in mind.

Our approach has the particularity to be developed for a blind teacher which expresses the wish to be able to communicate with well-sighted students. Our project, which is progressing according to an iterative method, differs by taking into account a proactive participation of the readers [6].

If you are a sighted person, you have about a 36% chance of not having a VIP among your 200 readers. But, if you are a VIP, the probability to have at least 199 sighted readers is close to 100%. This example uses the probabilities of a binomial law with a prevalence of 0.5% and it is based on statistics provided by the WHO [7]. Each generated document must be accessible but also must bring to students added value for their understanding.

In the first section, we present how a simple text could be written by blinds. This text requires additional information for a complete perception. Indeed, the visual rendering is not always identical to what is heard from the automatic reading by a screen reader.

The inclusive text editor for tabular structure and diagram description has been already implemented. Table representation will be presented in the second section.

Finally, we shortly speak about diagram conception, needed enhancement, and we conclude with perspectives of development.

Linear Composition

Digital documents are made accessible mainly through the constant improvement of screen readers [8]. As with listening, the vocal restitution of any document is linear [9]. So, it is important to understand any complex structure [10,11].

We create the documents using a generic basic tool: a text editor. We follow the principle KISS: keep it simple and intuitive. If a basic literary text is relatively simple to understand, it is quite different for a more complex structure. We have drawn inspiration from languages such as Markdown and PlantUML [12,13] to extend the functionalities of the basic text editor in order to facilitate the creation of documents and allow their universal use. We want to maintain, as much as possible, the principle of least surprise, therefore a lightweight markup language with simple, non-obtrusive tags is used.

Our "tag text editor" is designed to be easy to write and, for the source text, also easy to understand through TTS (Text-To-Speech); indeed, a special care has been taken to ensure that the tags are easily identified by screen readers. Without knowledge of dedicated languages (such as HTML and SVG), the final output (generated file) meets the requirements of readability and visibility for all audiences. These languages are widespread for the diffusion of information and permit to include many possibilities to make accessible documents [2, 3].

We have developed our software, called Latitude, using design patterns from literature [14] and in particular: Factory, Builder, and Chain of Responsibility. Latitude (abbreviated to Lttd in the following diagram) is the short name for Light and Accessible Text Including Tags and Using Universal Design.
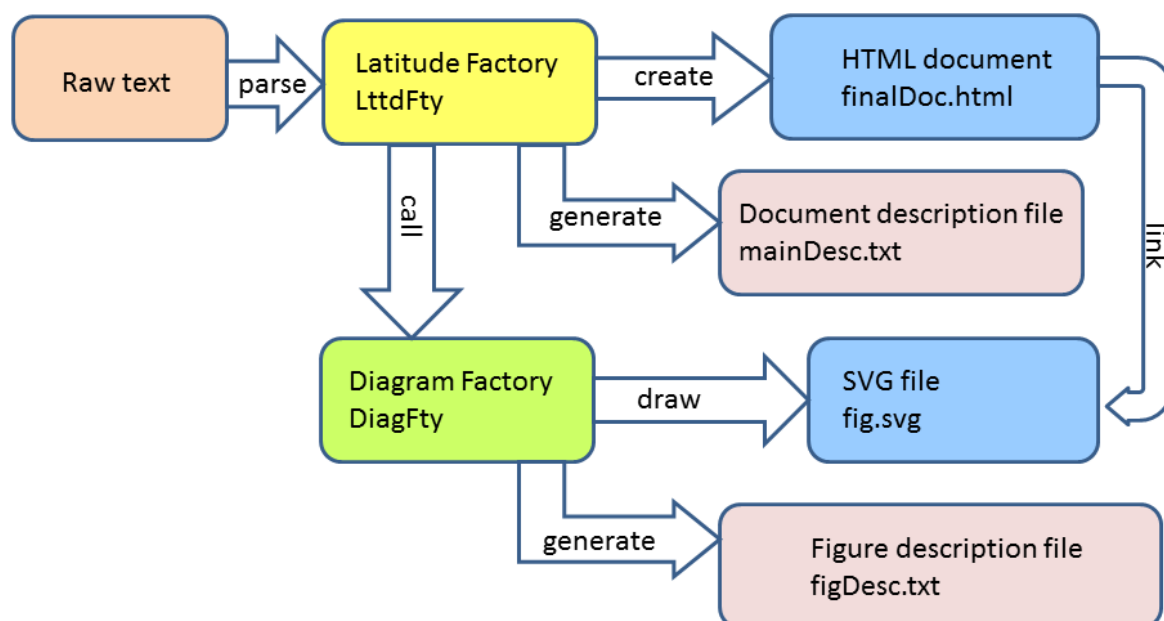
Fig. 1 Text document creation process

The user creates a simple text file, a plain text enriched with lightweight tags. This raw text is processed in the Latitude factory (Lttd Fty). From this point of entry, the structured and accessible HTML document is generated as well as a document description file. In addition, for diagrams, the definition elements are sent to a second factory (Diagram Fty). This second factory generates an SVG file for the schemas as well as a description document allowing a textual description.

According the target audience, blinds and students, the description texts are very useful. This is why we would like to draw your attention to these complementary documents. They contain statistical

elements (size, complexity), warnings such as typographical elements (paragraphs or sentences that are too long) and suggestions for improvement.

For texts or tables, it will give indications such as size and reading complexity (Flesch score [15]), point out titles, items or paragraphs that are too long, make suggestions on structuring into sections and subsections. For a class diagram, it can give indications on the structure, its complexity, vocalize as a reader would the various component elements and indicate overlaps or problematic positioning.

The description file therefore helps blind people, who do not have a global perception of the document, but also students who want to benefit from an indicative feedback.

Such approach is disruptive with classic approaches to the accessibility: it takes it the other way round. Our extended editor enables VIP writers to produce a document that meets the expectations of both, VIP and (well-) sighted readers; it is an inclusive text editor.

The proposed approach may be attractive for other audiences: students learning to design inclusive text with graphics, web designers who must design accessible sites, etc. [2] The proposed approach gives insight in ways to make data presentations more ergonomic and easy to understand; moreover, it gives the opportunity to discover new ways to data and knowledge acquisition, and new ways for learning (inclusive) strategies.

Text Composition

A document of a relatively large size is made up of sections that are themselves divided into subsections. Each section is identified by a title. In many languages, these titles are indicated by specific tags. These are not well identified by a screen reader. For example, we encounter brackets, exclamations points, dashes, etc. This is why we are introducing a symbol that stands out from the usual. We propose the equal sign (=), and we reverse the usage that the number of symbols increases with the depth of the nested sections. As we respect the typographical advice, we only offer four levels of nesting (division). The first level, equivalent to the most important title "h1" of HTML will be represented by five equal signs. The last level (the least important) will be composed with only two equals.

The advantage of this choice is double: the equal sign is well identified by vocal synthesis and the user can easily navigate with respect to the levels with the search function. The text created is enriched by light markup. The latter makes it possible to provide informative elements on the formatting such as the presence of a title, a word placed in italics, etc. The presence of the tags must guarantee that the legibility of the original text is maintained.

Each section is composed of a title, paragraphs and possibly, subsections. We automatically study if these sections are well balanced inside the document and indicate to the author what are the shortest or the longest ones. We suggest, if necessary, to add sections and subdivisions [6]. The paragraphs are decomposed in sentences, each of them in words and syllables. This process permits to apply the Flesch score and to measure the readability of the document [15,16].

The balance between sections and the determination of readability are very useful guidelines for blind authors. They are also useful for novice writers [17].

The perception of a good distribution of sections is not arithmetic but geometric. Therefore, we calculate the number of sections and subsections desired according to the overall size of the document. We indicate the imbalances found between sections.

To calculate the Flesch score, we need to be able to extract not only the words but also the syllables from a sentence [18]. We can thus indicate the readability of the text, but we can also point out the complexity of a paragraph, the inappropriate length of a title or an item in a list.

Creation of Tables

We present how to create a table and its visual and accessible restitution. A table consists of cells, each cell being situated at the junction of a column and a row [19].

In HTML, a table consists of four important notions: cells and among them, headings, rows, and caption.

With the progressive evolution of HTML, the WAI initiative [20], and the efficiency of screen readers, the tables are relatively accessible. But this accessibility is relative. It is limited, at the base, to the vocalization by the screen reader of the contents and the indication of the positioning of the cell: the number of its line and that of its column. The headings of the columns are indicated if they are correctly filled in [19]. If the table is a bit complex, i.e. if there are: several header lines with column groupings, cell merges, row headers, then the voice description is impossible without the introduction of specific tags and attributes proposed by the WAI-ARIA [20]. An example of a complex table with merged headings is given in table 1.

Table 1 An example of complex table

Country	Main Cities		Residents (millions)
	Capital	Metropole	
Algeria	Algier		34
Australia	Canberra	Sydney	42
Belgium	Bruxelles		12
Brazil	Brasilia	Sao Paulo	110

Current languages such as Wikitext for example, only allow these indications by writing these attributes in the tables created. However, they are very difficult to implement and, moreover, they are not known to the general public [21]. This public is precisely the one that proposes the tables. It is for this reason that we have developed a code analyzer that automatically inserts all the tags necessary to make any type of table accessible.

Our parser scans the lines defining a table and automatically detects the separator. This frees the user from a limited choice. We allow the use of three commonly used cell separators: pipe, tabulation, and semicolon. The pipe has our preference for its perfect vocalization in the plain text by the screen reader. Nevertheless, we allow tabulation for its common use by certain languages and writers. The semicolon is useful whenever interaction is possible with a CSV-formatted document.

With our proposed solution, it is no longer useful for the writer to provide tags to allow a complete description of a cell with its row or column headings. If cells are merged, if a header gathers several columns or if headers are placed at the beginning of a row, a table not using the ARIA recommendations will not allow voice output. However, the voice output is part of the information of the contents and structure of the table. We automatically process the data so that this information can be entered. When browsing the table, we create an object model to detect the headers that inform each cell. We

then place the ARIA tags correctly so that the screen reader reads all the information that will help to navigate through the table.

Latitude creates an object-oriented image of a table, composed of typed cells: header and body. The groups of cells (fusion) define automatically references (id) in attributes. This id is added to the reference, headers, encapsulated into the td html tag. Different other attributes like role and scope are systematically included permitting accessibility [22].

For the user, it is no longer necessary to explicitly specify the headers: just leave a blank line to avoid placing a header. In the same way, the first cell of each row is the row header; a blank cell allows not specifying it. Finally, you must specify several separators in a row to merge cells. To create complex headers on several lines, a separator, following many dashes, visually and audibly separates head and body. According to our syntax, the table title is situated just after the dedicated __table tag. This possibility, indicated in the description file in case of omission, will be transformed as information elements of the html caption.

As to draw bar charts or pie charts the data is sometimes grouped in a table, we used the same format to make these diagrams. The first line of the table allows you to define the labels while we allow up to three lines of data that will allow this information to be presented on the same bar chart or with one pie chart per line, sized to be placed side by side in the same figure. In both cases, a calculation is automatically performed to correctly dimension the information. For the bars, it is necessary to estimate the height differences, in order to balance as well as possible and to allow the best visibility. A scale is determined automatically. For the choice of colors, a library is proposed by default, which allows distinguishing the contiguous zones by following the recommendations of accessibility in particular, those of contrast and color blindness.

Simple and complex tables are formatted to be accessible with the tags proposed by W3C. Their design remains, for the creator, as simple as possible. It is not required to know the attributes or behaviors of screen readers [4].

Accessible Diagrams for All

Our product allows easy integration of diagrams and graphics that we know can be made accessible with SVG [23], vector graphics structured by XML. We are inspired by PlantUML [13]. We add some complementary aims: readable code, accessible SVG use of ARIA attributes addition of a document given a textual description of the properties of the diagram.

Our first need was the easiness to ensure readability of the source code by a screen reader. The syntax must be understood by blinds throughout the vocalization [24]. Second, the description proposes a good rendering for visualization. Any sighted person must see what he does. Third, to facilitate the learning of the elements of the code, we have ensured consistency among the various proposed UML diagrams: class, object, sequence and activity. In Figure 2, an excerpt from the object model used by Latitude, is given: *There are three inheritance trees, designing the structure of the builder pattern used by Latitude. Each Block is either the main document or a section. The Principal and Article classes inherit from Block. Each Block can itself be composed of Articles. Within each Block we find individuals and, optionally, other Blocks. The instances of Individual correspond to different kinds of HTML elements: Paragraph, Table, Figure… These subclasses inherit from Individual and structure the code. The class Scheme is linked to another external class called Graphics. The instances of a subclass of Graphics, translate different UML diagrams and generate the SVG accessible code.*
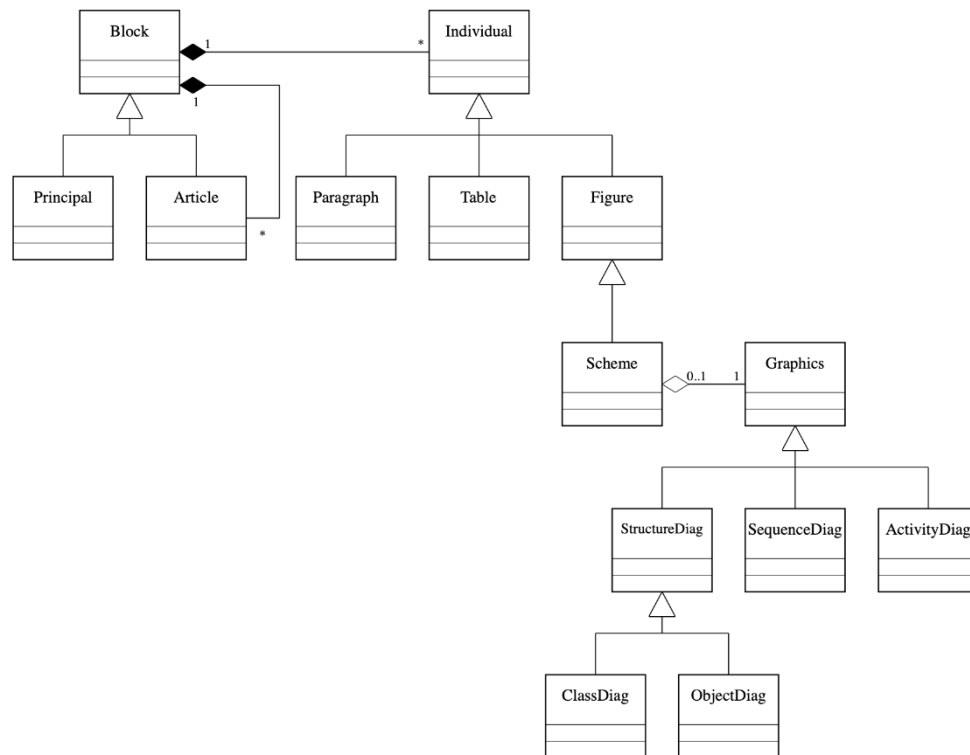
Fig. 2 An example of the object model coded in SVG, generated by Latitude (in depth description in text above).

Each individual is a part of a division. A scheme represents a diagram; it is a particular individual, coded in SVG. There are many other classes in our model, but this diagram gives a glimpse of our achievement. We can generate these diagrams either directly by calling a specific class or by inserting the code into a document containing, for example, text. Our original characteristics are the automatic generation of a SVG graphic including description tags for linear browsing, and including this diagram in a captioned figure in the global document. To enable this accessibility, we have used all the possibilities offered by the ARIA attributes.

Finally, in parallel with the generation of the diagram, our software creates a description document. This document analysis offers an alternative description, given information about the structure like: number of various elements, sentence explaining links (associations, messages), size and positions… All this information is given in the form of sentences that are clearly stated by the screen reader. If this annex is an invaluable aid for the blind, this document proves to be interesting for learning.

Conclusions and Perspectives

Our project is incremental. With each request, we add the expected functionalities. The primary target audience is the blind, who must be able to communicate with a normal audience, integrating appreciated and necessary visual elements [25]. On the other hand, we make a tool that is also useful to students because they have to formalize their diagrams and get the phrased description of their realization. Finally, we show that it is possible to enrich web page design tools by making them accessible without having to deal with an impressive number of constraints. This can be an alternative solution to allow everyone to access websites. We need to improve automatic text analysis. To do this, we need to get closer to typographers, authors and educational experts.

For tables, we are in the process of adding the ability to merge cells vertically, and to allow content formatting: centered or aligned, automatically detecting whether columns or rows contain numbers

for example. But the multiplicity of situations requires extreme caution in this area. Also, we aim to introduce a score, equivalent to the Flesch one, to indicate the complexity of a table. The proposed library of diagrams must be enhanced offering various functionalities. We add them as and when requested. Students are the best evaluators: they need to take ownership of the opportunities. At the frontier between tables and graphs, we plan to introduce curves drawn from data. Already, we can read a table and draw a bar chart or pie chart on demand. This is not trivial, it is necessary to be able to make a judicious choice of colors according to accessibility constraints and, also, to define an appropriate scale for the best possible visibility.

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Visual Assistant - TV for the Visually Impaired

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Abstract

The Visual Assistant image-enhancement system is built around the idea that the presentation of the outside world should be tailored to the working parts of the visual system of the visually impaired user by enhancing the image to make the most of the residual vision they have. It enables people suffering from vision loss to modify every aspect of a TV image to alleviate their specific eye condition and enables them to see images more clearly.

By magnifying subtle visual information around the contours of objects we are able to uncover unseen clues about shapes and expose hidden edges, enriching the image and making it easier to be understood by the visually impaired user. A medical diagnosis of a person's visual impairment is used to design a degradation model able to answer a simple question: what is wrong with the image, and what can we do about it. As images on the screen are degraded by a well-understood process it can usually be reconstructed by reverse-engineering the degradation model. A reconstructive compensation strategy is modelled to counter the deterioration in a resolution of details, contrast or saturation. Based on the model a reconstructive adaptation strategy is created to counter the impairment of the eye lens and retina.

Introduction

Understanding the world visually begins with object boundaries. By enhancing the edges of an object we aid the viewer's cognitive process. Humans make sense of the world visually by understanding where one object ends and another begins – object edges are the most important feature for viewers attempting to make out small details. Enhancing at least some of the visual cues helps the human vision system to create a more accurate primal sketch.

The estimated number of people visually impaired in the world is 440 million [1] 216 million had moderate to severe visual, 188 million had mild visual impairment and 36 million are blind. Functional presbyopia affected an estimated 1094 million with 666 million being aged 50 years or older. Globally, the principal causes of visual impairment are uncorrected refractive errors and cataracts, 43% and 33 % respectively. Other causes are glaucoma, 2%, age related macular degeneration, diabetic retinopathy, trachoma and corneal opacities, all about 1%.

Our eyes exhibit age-related changes in performance as we age — particularly as we reach our 60's and beyond. Lens muscles that control our pupils lose some strength. Cells in the retina that are responsible for normal colour vision decline in sensitivity as we age, causing colours to become less bright and the contrast between different colours to be less noticeable. 8 out of 10 people over the age of 65 suffer from some form of sight loss. A 2018 survey commissioned by the American Foundation for the Blind in partnership with Comcast shows us that visually impaired people watch four or more hours per day — almost as much as the general public. 53% of those surveyed reported that they experienced difficulty in following along with key visual elements. We concluded from this survey and our own subsequent user testing that the majority of visually impaired people are digitally excluded from the full enjoyment of what the TV represents in the 21st century - a central information and entertainment hub.

Partial sight, ageing and congenital deficits all produce changes in perception that reduce the ability to distinguish shape-related clues. These changes influence accurate object recognition resulting in a decreased understanding of the environment. Experiments have shown that visually impaired people are more likely to recognise objects and structures in the environment if the boundary between objects of interest and the background around the edges of objects are clearly marked.

Picture 1: Different conditions that can be mitigated with Visual Assistant technology

Our Work

Media regulators have in recent years demanded that broadcasters and other providers make their content accessible through assistive technologies such as video description, text-to-speech and voice control for navigating on-screen TV programme guides. Visual Assistant technology takes accessibility to another level – the provision of moving images tailored to the specific eye condition of the TV viewer.

Enhancement of subtle changes in the displayed image adds back a sense of reality and brings an improved sense of the physical to the visually impaired. By enriching natural visual cues with artificial elements users can heighten their contrast sensitivity and visual acuity greatly. A better understanding of the fundamental perception components of salient objects in the world ultimately leads to a visually impaired user's ability to decipher the shapes of objects, enabling easier comprehension of dispersed and non-continuous visual information see see [2] We have discovered that even a minimal enhancement of image visual cues has a profound impact on our ability to decipher the content. Much research in this field has been focused on methods for superimposing high contrast edges over the existing image to increase 'readability' or 'viewability' by heightening the contrast between objects and background almost to the extreme. Augmented vision models have been proposed utilising visual multiplexing techniques such as the wideband enhancement algorithm that superimposed modified image edges over the original image, enhancing the high spatial frequency components [3-6]. These methods all suffer from the paradox that they increase visibility by enhancing the contrast of high frequency, that is edge areas, but in doing so they decrease the quality and resolution of the image as a whole. The effect is further amplified by the visual cortex induced enhancement of edge bands beyond their true natural appearance. The result of these known techniques are unrealistic images.

Creating an inclusive digital TV experience for all has been at the heart of our R&D at Visual Assistant and the outcome of our work is a prototype Visual Assistant TV that enables people suffering from vision loss to modify every aspect of a TV image to alleviate their specific eye condition enabling them to see the images more clearly.

The Visual Assistant image-enhancement system is built around the idea that the presentation of the outside world should be tailored to the working parts of the visual system of the visually impaired user by enhancing the image to make the most of the residual vision they have. It enables people suffering from vision loss to modify every aspect of a TV image to alleviate their specific eye condition and enables them to see images more clearly. The human visual system makes decisions based on the presence of spatial distribution and intensity of depth and focus cues. The degraded image produces changes in perception that reduce the ability to distinguish details cues and greatly influence our ability to

focus resulting in a seemingly blurred image. By changing the appearance of visual cues we can help our visual system to better process each image.

By magnifying subtle visual information around the contours of objects we are able to uncover unseen clues about shapes and expose hidden edges, enriching the image and making it easier to be understood by the visually impaired user. A medical diagnosis of a person's visual impairment is used to design a degradation model able to answer a simple question: what is wrong with the image, and what can we do about it. As images on the screen are degraded by a well-understood process it can usually be reconstructed by reverse-engineering the degradation model. A reconstructive compensation strategy is modelled to counter the deterioration in a resolution of details, contrast or saturation. Based on the model a reconstructive adaptation strategy is created to counter the impairment of the eye lens and retina.

The adaptation strategy based on a degradation model enables better 'readability' by enhancing and augmenting the most important visual cues. This produces graphic images that have enhanced colours, contrast, brightness and sharpness of details - changed according to the user's low vision or visual impairment functional needs. The aim is to emphasise the details of a scene so as to make them more visible to the viewer while changing the original image minimally.

Simulated visual cues can be perceived as unnatural when changes in intensity, contrast or pattern appear to be in stark contrast to adjacent areas. We discovered that together with changing the contrast in the depth cues, the spatial density of artificial depth cues needs to be influenced as well - this because our human visual system perceives any changes as unnatural. When spatial density is lowered to a suitable level and fused with the original image the viewer gets a realistic representation of depth cues that help trigger the correct accommodation as well as regenerating the natural feel of depth cues.

Using an alternative presentation for sharp edges by rendering them as sparse pixels allows us to represent a wider range of edges from the visually dominant to very discrete edges with minimal variations in the area. The most important part of the enhancement strategy is rendering the enhanced areas using a sparse pixel cloud method so that changes are accepted by the human visual system as natural shadow like structures. Densities of tiny halftone dots influence how the retinal image will be created gaining the influence of some reflex actions of the human visual system. Using an alternative representation for edges, by rendering them as sparse pixels, provides an opportunity to represent a wider range of visual cues from the visually dominant to very discrete ones even with minimal variability in pixel intensity values of the edge area. A non-deterministic process simulates natural light dissipation by an exponential degradation function that creates an increasingly random scattering of pixels to spread residual brightness information to the neighbouring pixels.

Although Visual Assistant offers out of the box prescriptions for most common vision impairments we know that every eye is unique. Every prescription can be further tailored and perfected to fit your eye condition. The prescription is a series of image modifications that restores the deteriorated areas of the retinal image by adding missing visual cues. The restored image is projected to the retina and perceived by the remaining vision with the best possible contrast, sharpness of details and vibrancy of colours.

Visual Acuity Loss

Visual acuity commonly refers to the clarity of vision and loss of visual acuity in portions of an image with fine detail (known as high spatial frequency loss). To resolve the loss of fine detail the eye's optical system has to project a focused image on the fovea, a region inside the macula having the highest density of cone photoreceptor cells, thus providing the highest resolution and best colour vision.

Picture 2: Right image shows a simulation of what the patient will see after we enhance acutance of image

An adaptation command chain strategy is based on augmentation of high frequency areas, contrast in these portions of the image with fine details are increased to highlight the differences in the detail by selectively brightening and darkening the edges of the detail in the image. People with refractive errors are not candidates for this kind of technology.

Contrast Sensitivity Loss

Sight is a contrast dependent sense and the real world is made of subtle changes in contrast. Loss of contrast sensitivity refers to an inability to distinguish between gradations of brightness or between shades that are similar in colour. Loss of contrast is often a good predictor of how extensive functional vision loss is. With some patients' loss of contrast further darkens the dark parts of an image while others feel that loss of contrast causes images to become greyer overall, to the point that edges can become lost.

Picture 3: Right image shows a simulation of what the patient will see after we enhance contrasts of details

Picture 4: Right image shows a simulation of what the patient will see after we enhance both acutance, contrast and colours of image

One of several strategies how Visual Assistant overcomes contrast sensitivity loss is based on tonal remapping followed by a contrast remapping in dark, mid-tone and highlight areas. Linear tonal remapping improves the brightness mapping, spreading it uniformly across the dynamic range of the image, whereas nonlinear contrast remapping improves the brightness differences of the shadow and mid-tone, the darker regions, and/or highlight the brighter regions at the expense of the brightness differences in other regions.

Central Field Loss

Macular degeneration (Hole) is the leading cause of vision loss among older people. Macular degeneration affects the part of the eye responsible for sharp, detailed central vision. In practice, the eye naturally focuses on the centre of its vision. This makes it very difficult to look at things outside of the grey area. It can cause blurring or darkness in the centre of the visual field, and can also affect the ability to determine details and contrast.

Picture 5: Right image shows a simulation how patient with central field loss can modify image based on position and magnitude of the scotoma

A Visual Assistant overcomes blind spots first by determining their position and magnitude. Information on the position of the blind spot (scotoma) is remapped onto the relatively intact areas of the retina, parts not affected by the blind spot, by selective magnification and remapping of key areas of the image and shrinking the peripheral areas. The retinal area to which a specific element of the image is projected is increased, which increases the probability that more intact photoreceptors will be covered.

Peripheral Field Loss

Individuals with peripheral vision loss, so called tunnel vision, retain clear central vision. In some cases, small patches of retinal activity on the periphery are preserved, making it possible to detect movement and objects that assist with one's orientation. Visual Assistant overcomes tunnel vision by pushing some

information from the edges of the visual field towards the centre of the retina where the visual acuity of Glaucoma, Retinitis pigmentosa, Detached retina, Optic Neuritis and Papilloedema patients is still working.

Picture 6: Right image shows a simulation how patient with peripheral vision loss can modify image based on the magnitude of the tunnel

Our Work

Visual Assistant TV was designed by Visual Assistant Ltd in collaboration with the Computer Graphics Laboratory team at the University of Ljubljana. Visual Assistant has been presented and well received at Optometry forums in Rome, Athens and Klagenfurt. Our approach to the Royal National Institute of Blind People resulted in their asking for user testing that we conducted using an RNIB protocol. The Slovenian Association for the Blind and Visually Impaired agreed to help organise nationwide testing of our prototype that subsequently took place in 10 different locations. Invitations went out to potential candidates and 93 people offered to take part. Of the 53 **visually impaired** participants 43 (**78%**) participants performed the tasks better with the Visual Assistant TV and only 1 (2%) performed better without. A further 5 (9%) performed the same with or without the Visual Assistant [7].

Visual Assistant is the first personalised video correction technology allowing you to create a TV experience aligned with your vision needs. Our system helps almost all visually impaired people with severe impairments or mild refractive errors to see images in more detail and contrast while also sitting further away from the screen. Every imaginable aspect of the image, from colour vibrancy, contrast of visual cues, sharpness of detail, brilliance of light (to mention just a few!) can be enhanced to create the best possible viewing experience.

Possible Next Steps

Low vision people would welcome a TV program to have higher acutance, enhanced contrast and more natural looking colours. The image quality issues inherent with streaming video persist and the demand to improve the quality of streaming video can only increase in the future. Visual Assistant is perfectly adopted to be embedded into new digital set top boxes to give them contrasting and sharpening abilities for the benefit of visually impaired. Broadcasters and streaming video providers such as Amazon, Netflix and YouTube will be able to complement their services with this technology to make video content on home entertainment systems more accessible.

Public service broadcasters are mandated to support content that caters to minorities and a primary broadcasting mission that speaks to and engages with its citizens whether sighted or visually impaired. They are natural partners for Visual Assistant technology. With an estimated customer base of 440m people worldwide we see Visual Assistant technology evolving from a dedicated set-top-box to an embedded chip within TV receivers.

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Comparison of two Teleconferencing Systems with respect to Accessibility and Usability for Blind Persons: Zoom and BigBlueButton

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Introduction

In this memo, two teleconferencing systems, Zoom and BigBlueButton, are compared with respect to their accessibility/usability with a screen reader software for blind users. Here is the list of products, with the precise version numbers, which are covered in the report. It is understood as work in progress, meaning that, over time, I plan to include more screen readers and web browsers, perhaps even more teleconferencing systems, in the comparison.

Operating system:

Microsoft Windows 10 Version 1909 [1]

Teleconferencing systems:

- Zoom Version 5.0.2 [1]
- BigBlueButton Clientversion 862 [3]

Web browsers:

- Mozilla Firefox Version 76.0.1 (64-Bit) [3]
- Google Chrome Version 81.0.4044.129 (64-Bit) [5]
- Microsoft Edge original version 44.18 [6]
- Microsoft Edge Chromium Version 81.0.416.68 (64-Bit) [7]
- Microsoft Internet Explorer Version 11.778 - Updateversionen 11.0.185 (development discontinued) [8]
- Opera Version 68.0.3618.63 [9]

Screen Readers:

- Freedom Scientific Jaws Version 2020.2004.66 [9]
- NVDA Version 2020.1 [11]

Zoom

General Impression

Zoom can be used both as a Windows program and as a web application. Since web applications tend to behave differently with different combinations of web browser and screen reader, a blind user will probably prefer the Windows program variant, which will furnish a clear advantage for Zoom. As for the Windows program variant, from the screen reader user's point of view, the user interface appears to be a very primitive one – just a series of buttons focusable with the Tab and Shift-Tab keys. However, hot keys for the buttons are present, so the buttons can be easily used with the keyboard. This makes the Windows client quite well and easily usable for conference participation.

As for the web interface, it is quite well accessible and not too overloaded. Its appearance resembles that of the Windows program interface; however, hot keys for the various buttons are not present

in the web interface. So, when using Zoom, a screen reader user will probably prefer the Windows program interface over the web interface.

Details

Granting access to the computer's audio output and microphone
This has to be done once when you first use Zoom on a new machine. In Google Chrome, Microsoft Edge Chromium, and Opera, a dialog box containing the necessary controls is automatically focused and therefore easily accessible. In Firefox, that alert is not focused automatically – you must actively navigate to it by a series of F6 presses. Also, bear in mind that audio support for Zoom under Firefox does not work for Firefox versions smaller than 76.0.

Hot keys in the Windows program interface
Whereas these keys are not automatically verbalized or brailled out by the screen reader when a button is focused, the keys are listed on the web, at this address: https://support.zoom.us/hc/en-us/articles/205683899-Hot-Keys-and-Keyboard-for-Zoom

As an alternative, you may get the list of available hot keys from a tab in Zoom's Settings menu, which is an item of the Zoom systray menu. Should you run Zoom with an account, you may also access the Settings menu from a button within the main Zoom window.

Web browsers
- Firefox: Works well, but bear in mind that, in order to use full audio support, you need to have Firefox 76.0 or greater
- Google Chrome: Works well
- Microsoft Edge original version: Not recommended: Similar problem with access to audio as with older Firefox versions – screen reader support of this browser not yet fully developed
- Microsoft Edge Chromium: Works well – with regard to accessibility, behaves just like Google Chrome
- Microsoft Internet Explorer: Not recommended - Similar problem with access to audio as with older versions of Firefox – this browser is old and insecure
- Opera: Works well, but bear in mind that, when you use Opera with the Jaws screen reader, the Jaws search function – Strg + f – does not work

BigBlueButton

General Impression

BigBlueButton appears to be available only as a web application, having the advantage that the user need not install any software other than a standard web browser. On the other hand, web applications tend to impose difficulties on a screen reader user. In the concrete case, these difficulties mainly are connected to the keyboard combinations built into the system. It seems that not all of them will always work. In addition, when the Jaws screen reader and the Firefox web browser are used, some of the combinations are in conflict with keystrokes used by Jaws; if you want to use them in the web application, you must prefix them with a special „pass-through" command in Jaws, which makes their use unpleasant. Fortunately, users who, for such reasons, do not want to use the shortcuts need not, because all the functions envoked by these keyboard combinations can also be reached by buttons on the web page which are easily accessible. The general structure of the web page is a simple one – it is not overloaded, and the essential structural elements, which are quite a few, can be accessed through headings. This will make the system well usable for most screen reader users after quite a short time of practice.

Details

Granting access to the computer's audio output and microphone
This has to be done once when you first use BigBlueButton on a new machine. In Firefox you get an alert, which can be focused by several presses of the F6 key. In Google Chrome, Microsoft Edge

Chromium, and Opera, however, the alert is automatically focused and may therefore be easily accessed.

Hot keys in the web interface

As pointed out, I observed that they do not always work reliably, an observation which I generally made when dealing with hot keys on web pages. In any case, they are listed in the Options menu of BigBlueButton. Observe that the modifiers used for the shortcuts are different between the various web browsers: While in Firefox the keys have to be pressed together with the Alt and the Shift key, in Google Chrome, Microsoft Edge Chromium, and Opera the Alt key alone is used. Fortunately, BigBlueButton knows with which browser you access it, and it adapts the list of keys to these conditions. Strangely, that mechanism fails when using Opera, where the list under the Options menu states that there are no keys available. But don't worry – you do have all the keys which you would have with other browsers, prefixed with the Alt key. An exception is Alt + p, which will open the Preferences Dialog in Opera, such that it cannot be used as a hot key for any web application, thus also not as a hot key for BigBlueButton. As said also, when you are working with the Firefox/Jaws combination of web browser and screen reader, some of the keys will conflict with keys used by Jaws. Should you want to use such a key for BigBlueButton, you must prefix it with a special „pass-through key", which is the Jaws Key plus the number 3 – not on the number pad – in Jaws. To have an example: If you want to use Alt + Shift + m to mute the audio, you must first press Jaws Key plus the number 3, then Alt + Shift + m. Would you press Alt + Shift + m without the prefix, you would envoke a Jaws function instead.

Fortunately, there are only very few BigBlueButton hot keys which are in such a conflict. At the time of writing, with the version numbers given above in effect, only two key combinations, namely Alt + Shift + m and Alt + Shift + l, belong to that category – all other key combinations offered by BigBlueButton can be used as listed. However, over time Jaws and/or BigBlueButton may change their keyboard assignments, such that you should have a method at hand to safely know that a particular combination does not conflict with one defined in Jaws. Such a method is available, as follows:

In order to check whether a certain keyboard combination in BigBlueButton conflicts with a Jaws keyboard command, follow these steps:

1. Start Jaws
2. Start a teleconference in BigBlueButton, and bring it to the foreground of your Windows system
3. Press Jaws Key plus the number 1 – not on the number pad -, to envoke the Jaws keyboard help mode. In this mode, whenever you press a key or key combination, its meaning within Jaws is verbalized rather than executing the key
4. Press the key combination in question. Should it be reserved by Jaws, Jaws, being in Keyboard Help mode, will announce the function assigned to the key by it. Should the key combination be free, Jaws will just echo back the name of the combination.
5. Press Jaws Key plus number 1 again to terminate the Keyboard Help Mode

To have an example, take the Alt + Shift + m combination: When you start Jaws, enter a BigBlueButton conference, bring it to the foreground, press Jaws Key plus the number 1 to envoke Keyboard Help Mode, and then press Alt + Shift + m. Jaws will tell you „Alt + Shift + m switches to the menu mode of your Braille display". You do not need to understand the meaning of this message, but now you know that this is a Jaws key combination, which, should you want to use it in BigBlueButton, has to be prefixed by Jaws Key plus number 3. If, however, you do this very procedure with the Alt + Shift + o combination, Jaws will just echo back „Alt + Shift + o", from which behavior you may safely infer that Alt + Shift + o is currently a key combination not touched by Jaws.

Web browsers

- Firefox: Works well - caution when using it with screen reader Jaws because of some BigblueButton hot keys – see details above

- Google Chrome: Works well
- Microsoft Edge original version: Does not work – BigBlueButton issues a message that this browser is not fully supported
- Microsoft Edge Chromium: Works well – with regard to accessibility, behaves just like Google Chrome
- Microsoft Internet Explorer: Does not work - BigBlueButton issues a message that this browser is not fully supported – old and insecure
- Opera: Works well. Bear in mind that, should you open BigBlueButton's Options menu to get informed about the built-in hot keys, then you get the erroneous message that no keys are available. However, all the keys which would be available with other browsers will work with Opera also, the only exception being Alt + p which will open the Preferences Dialog in Opera. Also, bear in mind that, when using Opera with screen reader Jaws, the Strg + f key combination to search for a string in Jaws does not work – but this is a problem between Jaws and Opera and has nothing to do with BigBlueButton.

Conclusion

Both teleconferencing systems, Zoom and BigBlueButton, may be used well with a screen reader for a blind person. When working with Zoom, you will probably prefer the Windows program interface because it offers hot keys which are missing in the Zoom web interface. When using BigBlueButton, you do have a simply and clearly structured web interface, containing hot keys, to use. When working with various web browsers, some special aspects need to be taken into account, which are detailed in the sections above. As a general tip, I recommend using a current web browser such as Chrome, Firefox, Microsoft Edge Chromium, Or Opera.

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Survey on Use of Smart Speakers and Smart Home Devices by Visually Impaired People in Japan

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Abstract

In recent years, smart speakers, which are devices with voice assistants, are quite popular. These are incredibly significant devices especially for visually impaired people, who often make up for lack of visual information with audio information. We conducted a questionnaire survey on 113 visually impaired persons regarding smart speakers and smart home devices. Our aim is to elucidate what is important and difficult for the visually impaired persons and to help increase their convenience.

Keywords: Smart speakers · Smart home devices · Visually impaired people.

Introduction

VUI (Voice User Interface) is becoming popular [10]. Smart speakers are based on VUI. It is an easy-to-use interface especially for visually impaired people, as it is possible to give instructions by voice and obtain the result by voice. Although there are not only smart speakers without a screen but also those with a screen, any smart speakers are "voice-first" and are easy to use for visually impaired people. Therefore, we can work towards developing additional functions for smart speakers, such as an application for the visually impaired. This type of application is called "skills".

To develop applications for smart speakers, we are required to understand the needs of the users. Furthermore, it is important to design the dialogue model well because the smart speaker obtains the information properly from the dialogue. Since visually impaired people use voice to make up for the lack of visual information, there is a possibility that they can play an active role both in giving ideas for applications and in designing dialogue models. In many cases, the application is developed by programming. Even if the degree of visual impairment is severe, visually impaired people can do the programming by using screen readers. From these points, visually impaired people have more advantages in developing smart speaker skills.

We have tried to build a programming education related to VUI for visually impaired people [1], [7], [11], [15, 16]. A student with severe visual impairment developed a smart speaker application and received the Alexa Skill Award 2018 Finalist Award[2]. He was also featured on Amazon's website [3], [9]. In addition, from the end of 2018 to the beginning of 2019, visually impaired students developed smart speaker skills as a team [6] and presented the results [5]. Furthermore, two teams of visually impaired students participated in Alexa Skill Award 2019 Hackathon Tokyo vol.2 took the 4th and 6th place [12, 13]. These are proofs that visually impaired people can play an active role in this field.

In addition, at Sight World 2018, which was held from November 1st to 3rd, 2018 for visually impaired people, we gave demonstrations of smart speakers and explained the development environment of smart speakers' applications. Many visually impaired people have visited our demonstration and are interested in smart speakers. Therefore, we are certain that they have a great interest in smart speakers and related technologies [16]. Our research project on education for visually impaired students won both the Grand Prize and the Joyo Bank Award at the Ibaraki Tech Plan Grand Prix [14].

This research is a basic research on visually impaired people, who could play an active role in the field of voice interface, as it is indispensable to investigate the use of smart speakers and related smart home devices by visually impaired people. The purpose of this research is to accurately understand the usage situation, usefulness, and concerns regarding smart speakers and related smart home devices for visually impaired persons. It is considered to have great social significance because this research will enable the development of new functions that will help the visually impaired people. For this purpose, we conducted a questionnaire survey on visually impaired people by email and web form and at the Sight World 2019, an event for visually impaired people. We obtained the results from 113 people.

Survey on the Use of Smart Speakers for Visually Impaired People

Overview of the Questionnaire for the Visually Impaired

A questionnaire survey was conducted on visually impaired persons aged 20 or above using three methods. The first method was survey sent via email, we used multiple mailing lists registered by the visually impaired. The implementation period was one week from August 18, 2019 to August 24, 2019. The second method is to use SurveyMonkey, an online survey tool. The survey period for SurveyMonkey was about three weeks from August 19, 2019 to September 10, 2019. The third method is face-to-face interviews that were conducted on November 3, 2019. Through these multiple methods, we decided to investigate a wide age group in various situations. The content of the questionnaire survey was the same for each method, and the total number of questions was 23.

The number of valid respondents was 113. The breakdown is 27 e-mail responses, 67 responses from SurveyMonkey, and 19 face-to-face interviews. The respondents were 75 men and 38 women. By age, there were 15 in their 20's, 19 in their 30's, 24 in their 40's, 31 in their 50's, and 24 in their 60's and over. When the participants were asked about their level of visual impairment, 90 people chose "It is difficult to read displayed characters on electronic devices". The remaining 23 respondents answered, "Although I have visual impairment, displayed characters can be distinguished without using the text-to-speech function when using electronic devices (PCs and smartphones)". In this paper, the former is regarded as a "screen reader user (U-SR)" and the latter as a "screen reader non-user (NU-SR)".

Interest in smart speakers by visually impaired people

People's interest regarding smart speakers is shown in Table 1. (Regarding the tables in this paper, the number in parentheses indicates the number of people.) There are many people who are interested in smart speakers but have never used them. 20% of people who were "interested and using" were in their 20's, and 73% people were "interested but not used" and they were also in their 20's. People in 20's are found to have lower usage rates of smart speakers than the other age groups. The highest percentage, 67%, of people who were "interested and using" was in their 40's.

Table 1. Relation between ages and interest level concerning smart speakers

Age	interested and use	interested but do not use	not interested
20's (15)	20% (3)	73% (11)	7% (1)
30's (19)	47% (9)	42% (8)	11% (2)
40's (24)	67% (16)	21% (5)	13% (3)
50's (31)	58% (18)	42% (13)	0% (0)
60's or up (24)	38% (9)	58% (14)	4% (1)
All ages (113)	48% (55)	45% (51)	6% (7)

As shown in Table 2, for screen reader non-users (NU-SR's), the percentage of people who are "interested in and use smart speakers" is lower than screen reader users. It seems that NU-SR's are

more interested but have not yet used smart speakers. This may be related to the need for smart speakers.

Table 2. Relation between screen reader usage and the interest level to smart speakers

screen reader user or not	interested and use	interested but do not use	not interested
NU-SR (23)	30% (7)	65% (15)	4% (1)
U-SR (90)	53% (48)	40% (36)	7% (6)

Interest in Smart Home Devices by Visually Impaired People

As shown in Table 3, many people were interested in smart home devices. The percentage of interested people is about the same as for smart speakers. Compared to smart speakers, there were more number of "interested but not used" people than "interested and using" people. Lesser people use Smart home devices than smart speakers Smart home devices seem to be more unusable than smart speakers even if they are interested. As shown in Table 3, the ratio of those who are "interested in and use smart home devices" was lowest in 20's.

Table 3. Relation between ages and interest level concerning smart home devices

Age	interested and use	interested but do not use	not interested
20's (15)	7% (1)	80% (12)	13% (2)
30's (19)	26% (5)	68% (13)	5% (1)
40's (24)	33% (8)	63% (15)	4% (1)
50's (31)	16% (5)	80% (25)	3% (1)
60's or up (24)	17% (4)	79% (19)	4% (1)
All ages (113)	20% (23)	74% (84)	5% (6)

As shown in Table 4, there were many screen reader users and non-users who were interested but did not use smart home devices.

Table 4. Relation between screen reader usage and interest level concerning smart home devices

screen reader user or not	interested and use	interested but do not use	not interested
NU-SR (23)	4% (1)	87% (20)	9% (2)
U-SR (90)	24% (22)	71% (64)	4% (4)

Usage of Smart Speakers by Visually Impaired People

From Table 5, there are many "people who use it almost every day" and "people who do not use it at all". This could mean that there are barriers to getting started, but once visually impaired people start using them, the devices will be more frequently used due to the increased convenience. By age group, 80% of people in 20's did not use smart speakers at all. Many people in 40's and 50's use the devices almost every day.

From Table 6, screen reader users (U-SR's) clearly use smart speakers more frequently than non-screen reader users (NU-SR's).

Table 5. Relation between age and smart speaker usage frequency

Age	every day	2-3 times a week	once a week	once a month	rare	not used
20's (15)	20% (3)	0% (0)	0% (0)	0% (0)	0% (0)	80% (12)
30's (19)	32% (6)	11% (2)	5% (1)	0% (0)	5% (1)	47% (9)
40's (24)	54% (13)	8% (2)	4% (1)	4% (1)	0% (0)	29% (7)
50's (31)	58% (18)	3% (1)	0% (0)	0% (0)	0% (0)	39% (12)
60's or up (24)	33% (8)	4% (1)	0% (0)	0% (0)	0% (0)	63% (15)
All ages (113)	42% (48)	5% (6)	2% (2)	1% (1)	1% (1)	49% (55)

Table 6. Relation between screen reader usage and smart speaker usage

Age	every day	2-3 times a week	once a week	once a month	rare	not used
NU-SR (23)	17% (4)	9% (2)	0% (0)	4% (1)	0% (0)	70% (16)
U-SR (90)	49% (44)	4% (4)	2% (2)	0% (0)	1% (1)	43% (39)

Regarding the functions that become convenient with smart speakers, many respondents answered "clock / timer / alarm function" (54 people), "weather forecast" (52 people), and "play music" (44 people). A general user often used for "listening to music" [4], but the visually impaired may place more emphasis on "devices that can be operated by voice" than "speakers listening to music". The answers to the questions about difficulties with smart speakers were as follows. "The setting method itself is difficult (even without visual impairment)", said 28 people. 47 people answered that it is difficult to set up due to visual impairment. 21 people answered "It is difficult to understand how to use" and 47 people answered "It is difficult to dealing with trouble". 25 respondents answered, "I do not feel any difficulty". The difficulty due to the visual impairment and the difficulty of dealing with the trouble are great. There was still a free statement saying that "the use of a smart speaker alone is OK, but it is difficult to set it to smart home devices."

Of the 55 respondents who did not use smart speakers at all, 48 (87 %) answered that they were "interested but not using". In addition, the reasons why these 48 people feel uneasy when introducing smart speakers are "It is difficult to find how to respond when trouble occurs" (25 people), or "It is difficult because of visual impairment" (24 people). Many people feel that the barrier due to the visual impairment is still high and it is difficult to deal with troubles, so many people hesitate to introduce it.

Usage of Smart Home Devices by Visually Impaired People

The usage status of smart home devices for the visually impaired are shown in Tables 7 and 8. Smart home devices are not used by most visually impaired people. From the tables 3 and 4, there are many people who are "interested but not used". Thus, it can be inferred that if the introduction barrier can be reduced, it is likely that many visually impaired people will use them.

Table 7. Relation between age and smart home devices usage frequency

Age	every day	2-3 times a week	once a week	once a month	rare	not used
20's (15)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	100% (15)
30's (19)	26% (5)	0% (0)	0% (0)	0% (0)	0% (0)	74% (14)
40's (24)	25% (6)	0% (0)	0% (0)	0% (0)	4% (1)	71% (17)
50's (31)	6% (2)	6% (2)	0% (0)	0% (0)	0% (0)	87% (27)
60's or up (24)	17% (4)	0% (0)	0% (0)	0% (0)	0% (0)	83% (20)
All ages (113)	15% (4)	2% (2)	0% (0)	0% (0)	1% (1)	82% (93)

Table 8. Relation between screen reader usage and smart home device usage

Age	every day	2-3 times a week	once a week	once a month	rare	not used
NU-SR (23)	0% (0)	0% (0)	0% (0)	0% (0)	4% (1)	96% (22)
U-SR (90)	19% (17)	2% (2)	0% (0)	0% (0)	0% (0)	79% (71)

The answers to the difficulties in using smart speakers were as follows. 55 people answered "It is difficult to dealing with trouble". 53 people answered "Difficult to set because of visual impairment", and 34 people answered "The setting method itself is difficult (even if there is no visual impairment)", 28 people answered "It is difficult to understand how to use" and 21 respondents did not feel it to be difficult.

The difficulty is felt more strongly than the smart speaker. Some commented that they were worried about security, the procedures for setting were inadequate, smart home devices are expensive, and they wanted to learn how to use it.

Conclusion

A questionnaire survey revealed the usage status of smart speakers and smart home devices. It was found that visually impaired people, unlike sighted people, find value in "devices that can be operated by voice" rather than "speakers listening to music". Although they are interested in smart speakers and smart home devices and felt that these devices may be useful, they feel its difficult to introduce it due to concerns about security issues and difficult set up process. In particular, the barriers to smart home devices still high.

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Art Karshmer
Lectures in Access to Mathematics, Science and Engineering

SpeechMatE:
A Speech-driven Maths Editor for Motor-Impaired People

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Introduction

All over the world, millions of people have severe motor disabilities (e.g., diplegia, tetraplegia), temporary or permanent motor impairments (e.g., tendinitis, arthritis, musculoskeletal diseases), and motor disorders (e.g., developmental coordination, stereotyped movements), which hamper many of their everyday activities [17]. In particular, people with upper limb disabilities, amputations or hand disorders run into difficulty when required to write either with a pen on paper or with text-entry through keyboard, use a pointing device or operate a touchscreen.

So far a number of solutions have been developed to facilitate text-entry through techniques which do not require finger coordination, dexterity or fine motor skills (e.g. eye-tracking, speech recognition, adaptable onscreen keyboards, switches). [21, 22]. These solutions are effective when entering and editing text (i.e. characters, words and sentences), but they are not designed for typing and editing maths. Even though some of these assistive tools can actually be used for typing maths, they require a considerable amount both of cognitive load and physical effort [5]. For instance, a person with tetraplegia can use a head-mounted pointing device or an eye-tracking input system to select and enter maths symbols in an off-the-shelf editor, but the time and cognitive load required to perform these tasks are extremely high in comparison to average speed and effort for typing maths by pen on paper or through mouse and keyboard. As a consequence, concentration is drawn away from mathematical concepts and simplification rules towards the typing technique [16, 6, 5]. Recent development of speech-to-text (STT) technologies has paved the way for the design and development of new speech-based interaction paradigms which are to introduce motor-impaired people (MIP) to hands-free typing and editing of maths.

This work presents *SpeechMatE*, a prototype application designed to type and edit maths through speech input in the Italian language. To the best of our knowledge, it is the first tool that enables input of mathematics in Italian. At this stage of development, *SpeechMatE* can be used to type arithmetic and elementary algebra taught in the first year of Italian secondary schools.

Related Work

Research on techniques to support people with motor impairments in typing has investigated a number of different solutions. This section, at first introduces text-entry systems not specifically designed to type maths expressions, but which can be used also to enter math notation in conjunction with a mainstream maths editor. Afterwards, it examines systems designed to type mathematics via speech input.

Text-Entry Systems for People with Motor Impairments

Text-entry techniques for MIP can be classified in five categories: direct selection, scanning, pointing, gestures and speech-to-text [21].

Through direct selection MIP can select one out of a limited set of keys. This technique is used in chording [11], ambiguous [12] and encoding [19] keyboards. Through scanning, items in a list (e.g., characters, words) are automatically highlighted sequentially until one is selected [14, 13]. Text-entry based on pointing is performed by selecting characters through a pointing device controlled by a body part such as head [10], eyes [15], nose [20], foot [18] etc. Typing based on gestures is achieved through the recognition of a set of gestures (e.g., through a camera or a touchscreen), representing characters or words[2] [26].

These solutions present three main limitations: low typing speed, error proneness and a steep learning curve [21, 22], [9]. By contrast, thanks to recent development of speech recognition techniques, STT enables fast and effective dictation of entire sentences at a time. *SpeechMatE* adopts STT to facilitate maths typing.

Speech-to-Text Systems for Writing Mathematics

This section introduces the systems which have been developed to write mathematics through speech input. TalkMaths [24, 25] is a prototype application which translates arithmetic, elementary algebra and trigonometry from spoken English into LaTeX or MathML. It adopts Dragon Naturally Speaking[3] (DNS) as speech recognition system. The translation rules are defined only for English and they are based on pauses, which slow down the dictation process [8].

Mathifier [1] is an open source software module which converts maths expressions from English into LaTeX. It combines a dictionary, a language model and an acoustic model to recognize mathematical English utterances. It uses Sphinx-4 [23] to recognize speech. This system has been designed for recognizing maths only in English, and as yet no reliable Italian speech recognition has been enabled.

CamMath [8] is designed to prove the advantages of continuous speech over discrete utterance of mathematical expressions in English. It works as a front-end for Scientific Notebook[4], a commercial maths editing system. It uses Microsoft speech recognition platform which supports recognition of the Italian language only through Microsoft development tools.

Bernareggi et al. [3] investigate speech input of mathematics in the Italian language for the LAMBDA editor [2], a commercial maths editor for visually impaired people. Speech is recognized through DNS. A dictionary of symbols and commands which are valid for the LAMBDA editor is defined. Hence, the dictation process is limited to the LAMBDA editor and it is far from dictation in natural language. Metroplex MathTalk[5] is a commercial application that provides speech input of arithmetic, algebra, calculus and statistics in English. Recognition is based on DNS and it implements a dictation model based on pauses, which slow down the dictation process.

EquatIO[6] enables dictation of simple maths expressions in English in MS Word and in GSuite applications.

SpeechMatE, similarly to CamMath and Mathifier, adopts continuous speaking interaction and it includes software components which can be used for free. Unlike all the previous solutions, it is designed for the Italian language.

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[2] https://www.click4all.com/it/
[3] https://www.nuance.com/index.html
[4] http://www.mackichan.com/
[5] https://www.metroplexvoice.com/
[6] https://www.texthelp.com/en-us/products/equatio/

SpeechMatE

System Description

SpeechMatE consists of five main functional components: a speech recognizer, a parser, a LaTeX editor, a LaTeX compiler, and a PDF viewer supporting hot reload when open files change. The user interacts with the system through speech commands, or the dictation of text or maths expressions. Speech flow is processed by the speech recognizer which generates the corresponding text in the Italian language. This text is parsed by the parser that converts mathematical expressions into LaTeX and links speech commands to a corresponding script in the editor. Afterwards, the result of the parser is sent to the editor which updates the PDF document or executes the script.

Two videos[7] show how *SpeechMatE* works.

Fig. 1: A high level representation of the components of SpeechMatE

Design Challenges

The design process has gone through three main challenges: (i) the design of a speech interaction model which defines how to dictate text and maths in the Italian language so that they can be parsed and properly input and edited in a document; (ii) the selection of a maths editor which can enable the editing and displaying of maths in real time while writing; (iii) the identification of an automatic speech recognition service that is reliable for the Italian language and which can be used for free.

The Speech Interaction Model

SpeechMatE enables full speech interaction, which means that all the operations available in *SpeechMatE* must be enabled by speech. To this purpose, three environments are defined: the text environment, wherein speech flow is recognized as text according to the rules of the Italian language, the maths environment, wherein only mathematics can be dictated and the commands environment for entering all the editor commands (e.g. editing, open, save). Three reserved words (i.e. testo, matematica, comandi) are used to activate the desired environment. So far, this work has defined the maths environment for arithmetic and elementary algebra. There is not a reference book for spoken mathematics in Italian, so the rules to read maths expressions in Italian are defined by localizing the rules for English introduced in the Handbook for spoken mathematics [4]. Mathematical expressions that can be dictated are defined as sequences of:

Atomic symbols including for example Latin letters, Greek letters, numbers, parentheses

Operators that are applied to one or more mathematical expressions that can be separated by reserved words and ended by the stop word fine.

Here are some examples of expressions (in Italian) which can be dictated with *SpeechMatE*: *"aperta quadra 12 più aperta tonda 13 meno 4 chiusa tonda diviso 3 chiusa quadra diviso 4"* "open square bracket 12 plus open round bracket 13 minus 4 close round bracket divided by 3 close square bracket divided by 4"

$$[12 + (13 - 4) \div 3] \div 4 \qquad \textit{Expression 1}$$

"frazione numeratore 2 più 4 denominatore 5 fine meno 6" "fraction numerator 2 plus 4 denominator 5 end minus 6"

$$\frac{2+4}{5} - 6$$

<div align="center">Expression 2</div>

"frazione numeratore x alla 4 fine meno 1 denominatore frazione numeratore x più 1 denominatore x meno 1 fine meno 3 fine" "fraction numerator x to the power of 4 end minus 1 denominator fraction numerator x plus 1 denominator x minus 1 end minus 3 end"

$$\frac{x^4 - 1}{\frac{x+1}{x-1} - 3}$$

<div align="center">Expression 3</div>

The Maths Editor

The functional role of the maths editor is to enable entering text and mathematics as well as the editing and the displaying of mathematical expressions in visual notation while typing. Initially, the features of the editor were defined while typing. Initially, the features of the editor were defined, then a number of editors were compared in order to choose the most adequate one. First, since LaTeX is the most complete system to compose scientific documents, in view of future extensions, the editor must include tools to assist the writing LaTeX documents (e.g., syntax highlighting). Second, in order to automate operations through speech commands, the editor must include a scripting language. Third, for the expressions to be displayed in visual notation in real time, the editor must be interfaced with an external LaTeX compiler, which in turn is interfaced with a PDF viewer with hot reload capabilities.

A number of LaTeX editors were compared to select the most adequate one, including, in particular Glimpsee [7], Overleaf[8] and TeXStudio[9]. In the end, TeXStudio was chosen for its being an open source, cross-platform and fully-featured LaTeX editor. Potentially, it can be extended through QTScript[10], a JavaScript-like scripting language and it can be interfaced with a LaTeX compiler (e.g. latexmk on Mac OS or LaTeXdaemon for Windows), which is in turn interfaced with a PDF viewer (e.g. Skim for Mac OS or SumatraPDF for Windows). Every time the document is saved, the PDF document is updated and viewed.

Automatic Speech Recognition for Italian

Many different speech recognition systems were evaluated with respect to the ability of recognizing the Italian language. They can be divided in two groups: online and offline recognizers. For what concerns offline recognizers, Sphinx, Kaldi and DeepSpeech were analysed and it emerged that, at the present stage of development, they are not accurate enough for recognizing Italian language.

Among online recognizers, Google Cloud Service[11], Microsoft Bing[12], Houndify[13] and IBM Watson[14] are commercial solutions that recognize Italian very precisely. Nonetheless, the pricing scheme based on the number of requests or on the number of processed minutes leads quickly to high costs when applied to continuous speech recognition.

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[8] www.overleaf.com
[9] www.texstudio.org
[10] doc.qt.io/archives/qsa-1.1.2/language.html
[11] cloud.google.com/speech-to-text/
[12] azure.microsoft.com/en-us/pricing/details/cognitive-services/speech-services/
[13] www.houndify.com
[14] www.ibm.com

In the end, Google Cloud Service was chosen, which is available for free with some restrictions through Google Chrome browser.

Implementation

A JavaScript application listens to the continuous speech input that is sent to the recognizer via Web Speech API[15]. The recognizer transforms speech into text based on grammar rules specified in JSpeech Grammar Format[16] (JSGF). These rules force the recognizer to properly recognize Latin letters, Greek letters and numbers. The text generated is sent to a multi-thread parser that transforms the maths expressions into LaTeX in real time. The output of the parser is sent to the document in TeXStudio. If a command is sent, TeXStudio will run a script. If text or LaTeX is sent, TeXStudio will save the document and the LaTeX compiler will generate the PDF document to be displayed by the PDF viewer.

Conclusions and Future Work

This work has introduced *SpeechMatE*, a prototype system which can be used by MIP to type maths through speech input in the Italian language. This prototype is the starting point for future development along four main directions: (i) adoption of an open source speech recognizer which properly recognizes the Italian language; (ii) extension to further mathematical notations including in particular trigonometry, calculus and set theory; (iii) design and development of speech- driven navigation and editing of maths expressions; (iv) usability evaluation with MIP.

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Automatic Tagging of Formulae in PDF Documents and Assistive Technologies for Visually Impaired People:
The LaTeX Package `axessibility` 3.0

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Introduction

Assistive technologies for visually impaired people (e.g., screen readers, Braille displays, magnifiers) work well with digital documents containing structured text. On the other hand, when digital documents contain mathematical formulae, there are still many issues concerning the accessibility that should be addressed. In the recent years, many improvements have been achieved, but a comprehensive solution is still far to be obtained.

For instance, different multimodal systems to write and read scientific documents through nonvisual tools have been developed. One of the most used tools is the LAMBDA editor [2], that allows blind people to write and process text and mathematical formulae through Braille display and speech output. However, LAMBDA is not a mainstream tool to produce accessible scientific content by sighted people. Another way for allowing the reading of digital scientific documents by visually impaired people involves the use of MathML in web pages, also through MathJax (see, e.g, [5]). Indeed, MathML, being a markup language intended to the writing of formulae, can be interpreted by most common screen readers to generate a verbal description of the formula [3, 16]. Moreover, MathPlayer, a web browser plug-in for rendering MathML on the screen, through speech output and on Braille devices, enables hierarchical navigation of mathematical formulae, including bi-dimensional notations used, e.g., for matrices [14]. MathJax can be embedded in web pages to enable adaptable accessibility features for representing and navigating formulae (e.g., LaTeX, ASCIIMath or CSS representation; [6, 7]). However, MathML is not used for authoring documents but only for displaying.

The LaTeX language can overcome the above issues, because it is widely used by the academic community for writing scientific documents and producing PDF documents. Several works [8-10], [13], [15], [18] exploit LaTeX in different ways for improving the accessibility of scientific documents, both for the writing and the reading. Unfortunately, since these tools are produced for a small community, due to the rapid evolution of technology, they often incur in maintenance and compliance issues. Therefore, in general, the PDF documents obtained from LaTeX were not accessible, because a tagged structure is missing and the formulae are not readable at all by screen readers. It may be possible to add accessibility features to mathematical content as alternate text and to tag manually the structure of the obtained PDF documents. It can be specified manually using, for example, a proprietary editor such as Adobe Acrobat. Guidelines have been produced to create accessible PDF according to this procedure [17] with a focus on mathematical content [11, 12], [4]. However, this approach requires the availability of a suitable editor, and it entails additional labor from the document author. Furthermore, alternate text most often does not carry the same semantic value as the original mathematical content.

In a previous work [1], we presented a preliminary version of a new LaTeX package that allows to produce accessible formulae in the PDF documents by automatically adding a textual replacement corresponding to the LaTeX commands that generate the formulae. This prototype provided just a

first, partial solution to the problems illustrated above: only some environments for inserting formulae were managed there, and no tagged structure was generated. Moreover, the solution leveraged undocumented proprietary features of PDF readers in order to work. In this paper, we present the last updated version of this package, now named `axessibility.sty`, available on the CTAN repository and also present in the current TeXLive distributions. The formulae are now marked and described using both the `/Alt` and `/ActualText` attributes in the PDF document, and many more environments are considered. In particular, also multiline structures are now managed. Furthermore, we are also able to produce some tagged structures in the PDF document, and developing additional functionalities, to be implemented in subsequent versions.

The LaTeX package `axessibility` 3.0

In the first version of the package, our approach required the `accsupp.sty` package, which was used in order to inject PDF `/ActualText` commands for (inline and displayed) formulae into the output file. A subsequent version expanded this functionality to multiline displayed formulae environments. In this most recent update we added the option of using instead the `tagpdf.sty` package, through which each inline or displayed formula in the source LaTeX document is wrapped into a marked content sequence. In addition, the original formula is added to this marked content sequence as `/ActualText` and `/AltText`. These properties are read by screen readers and braille displays instead of the ASCII representation of the formula, which is often incorrect. Additionally, the package adds a tagged PDF structure. This includes, at the moment, the top level document structure element, to mark the beginning and the end of the document, and the P (paragraph) tag for each formula.

To create an accessible PDF document for visually impaired people, the authors just need to include the `axessibility.sty` package into the preamble of their LaTeX project. The supported mathematical environments will then automatically produce the `/ActualText` and `/AltText` contents and include them in the produced PDF file. Formulae will also be automatically tagged, as well as the document environment. The tagging of other text tokens (paragraphs, sections, etc.), at the moment, has to be inserted manually, under the guidelines of the `tagpdf.sty` package.

The environments for writing formulae which are presently supported are `\(`, `\[`, equation*, equation, and all the environments present in the `amsmath.sty` package for multiline formulae. Hence, any formula inserted using one of these environments is accessible and tagged in the corresponding PDF document. The click-copy of the formula LaTeX code from the PDF reader, to be pasted elsewhere, works if the screen reader is active. In Figure 1, we report the use of the `axessibility.sty` package in a simple LaTeX document, together with the corresponding source code of the PDF output.

Additional Tools and Features

In addition to the `axessibility.sty` package, we developed additional software to address two use cases: preprocessing scripts to support the application of the package on existing documents, and screen reader dictionaries for natural language reading of formulae made accessible with `axessibility.sty`. Inline and displayed mathematical modes activated by the old syntaxes `$...$` and `$$...$$` are not supported by the `axessibility.sty` package (as in the previous versions). An additional issue lies in the usage of userdefined macros in the LaTeX code. While this is a common practice to avoid code repetitions and simplify document authoring, it can limit the accessibility of formulae with `axessibility.sty`. Indeed, `axessibility.sty` is transparent to commands used in math environments, which means that it will include standard LaTeX as well as custom macros within the replacement text.

```latex
\documentclass[a4paper,11pt]{article}

\usepackage{axessibility}

\title{The golden mean}
\author{}
\date{}

\begin{document}

\maketitle

\tagstructbegin{tag=P}\tagmcbegin{tag=P}
The golden mean is the number
\tagmcend\tagstructend

\[\frac{1 + \sqrt{5}}{2},\]

\tagstructbegin{tag=P}\tagmcbegin{tag=P}
that is, the root larger in modulus of
\tagmcend\tagstructend \auxiliaryspace
\( x^2 - x - 1. \)

\end{document}
```

The golden mean

The golden mean is the number

$$\frac{1 + \sqrt{5}}{2},$$

that is, the root larger in modulus of $x^2 - x - 1$.

```
%PDF-1.5
%ÐÔÅØ
11 0 obj
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/Length 2504
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Td [(golden)]TJ/F52 1 Tf( )Tj/F27 17.2154 Tf 51.215 0 Td [(mean)]TJ
ET
/P <</MCID 0 >> BDC
BT
/F26 10.9091 Tf/F52 1 Tf( )Tj/F26 10.9091 Tf 134.765 588.53 Td [(The)]TJ/F52 1 Tf( )Tj/F26 10.9091 Tf 22.296 0
Td [(golden)]TJ/F52 1 Tf( )Tj/F26 10.9091 Tf 34.352 0 Td
[(mean)]TJ/F52 1 Tf( )Tj/F26 10.9091 Tf 28.925 0 Td [(is)]TJ/F52 1 Tf( )Tj/F26 10.9091 Tf 10.911 0 Td
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/Alt <FEFF0020005C00660072006100630020007B00310020002B0020005C0073007100720074002000 7B0035007D007D0032007D002C>
/ActualText <FEFF0020005C0066007200610063002000 7B00310020002B0020005C0073007100720074002000 7B0035007D007D0032007D002C>
>> BDC
BT
/F15 10.9091 Tf/F52 1 Tf( )Tj/F15 10.9091 Tf 278.974 564.088 Td [(1)-222(+)]TJ/F48 10.9091 Tf/F52 1 Tf( )Tj/F48 10.9091
Tf 18.788 9.024 Td [(p)]TJ
ET
```

Fig.1: A short LaTeX document, employing the package `axessibility`; below, the source of the typeset PDF document, where it is highlighted the hexadecimal code corresponding to the LaTeX command `\frac{1 + \sqrt{5}}{2}`, automatically generated by the package.

However, custom commands used by an author may bear no meaning for other readers. To (partially) overcome these issues, we developed *Axesscleaner*, an external script written in Python and Perl, through which it is possible to substitute unsupported environments with suitable replacements. It also replaces user defined macros with their content, in order to only contain standard LaTeX code within the replacement text. An alternative approach requires the typesetting with LuaLaTeX (see the package documentation).

Mathematical formulae included as replacement text using `axessibility.sty` are easy to read by LaTeX proficient users, using either a screen reader or a braille display. However, for novice users, the LaTeX code read by a screen reader may be difficult to comprehend. To address this problem, we also provide dictionaries for NVDA and JAWS screen readers, which convert LaTeX commands contained within the replacement text created by `axessibility.sty` into their natural language counterparts (e.g., '\frac{1}{2}' becomes "one half").

All the above tools, including `axessibility.sty`, are available at our github repository `https://github.com/integr-abile`

Finally, we highlight that our package can be used for uploading accessible papers on arXiv. In particular, it is sufficient to add our package, selecting the `accsupp` option, and the auxiliary file 00README.XX just containing the text `nostamp` (this allows to avoid errors in the production of the corresponding PDF file).

Future Work

We are currently working on a new update of the package, in order to

1. provide the automatic tagging of all paragraphs, section headers, etc.
2. convert the LaTeX code into MathML and embed it in the PDF document
3. automatically manage the environments that are not currently supported

Moreover, we are currently developing additional scripts for NVDA, using sophisticated natural language processing techniques, to personalize formula reading considering their complexity and context. In addition, these scripts will enable an interactive navigation of formulae, allowing to move between elements of the formula with hotkeys. The scripts will be developed for the NVDA based on Python 2.X, and will be updated for the NVDA version based on Python 3.X, when the latter will be more stable.

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Tactile Graphics and Models for Blind People and Recognition of Shapes by Touch

Platform for Math Learning with Audio-Tactile Graphics for Visually Impaired Students

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Abstract

Effective teaching and understanding of Mathematics are essential for achieving success in an academic or professional career, especially in a technical area. In the case of blind or visually impaired people, the limited access to math educational materials is an additional cognitive obstacle that influences various parts of life. Therefore, within the authors' research, a platform that shares graphic math content (charts, geometric figures, etc.) in the audio-tactile form to blind students was developed. The paper intends to present the developed solution and the initial results of teaching math based on the audio-tactile form of presenting the graph math content. The platform developed within the research is not only designed to share the visual information used in mathematics, but it allows the users for independent learning in a step by step way and then evaluation of student's progress made by a teacher or a psychologist. To measure the effectiveness of the proposed platform and learning method, the authors proposed quantitative measures: improvement of learning results, users' feelings (sentiment analysis), assessment of cognitive aspects of test participants. Initial research on the test group indicates better assimilation of math knowledge and improved participants' positive sentiment and their cognitive abilities.

Introduction

Effective teaching and understanding of Mathematics are essential for achieving success in an academic or professional career, especially in a technical area. In the case of blind or visually impaired people, the limited access to math educational materials is an additional cognitive obstacle that influences various parts of life. It should be pointed out that the presentation in Mathematics is mainly based on visual and spatial techniques. Therefore, acquiring the materials by people with visual disorders seems to be quite problematic. These limitations make that blind people encounter more problems with learning than sighted people. Moreover, one of the biggest challenges for blind and visually impaired people is understanding and proper interpretation of the information presented in the graphic form. Such information can be passed using alternative techniques, where the main focus is on hearing and touch. The conducted theoretical analysis points out many difficulties with passing graphic information to students with visual disabilities. In many cases, the commonly used braille notation is ineffective for presenting math content. A large number of extra contents may overload the cognitive center. Hence the process of receiving such information takes more time and is more complex. Some facilitation in information access in text and graphic form is the development of information-communication technologies and assistive ones, such as screen readers, voice synthesizers and zooming programs.

In the case of platforms for learning math dedicated to blind students that do not use tactile graphic details, the main assistive elements are audio messages reading out math formulae and clues that indicate possible ways of solving the problem [1-5]. However, literature sources indicate that for blind people learning math is more effective when it is assisted by platforms and equipment providing audio and tactile information [6-11]. Passing a piece of additional information via the sense of touch improves the process of math learning. Paper [12] discussed the use of tablets, including tactile graphics and audio description, for presenting math content. The other solution is the SVGPlott system [13], which

was developed to be user-oriented. Thanks to this attitude, both blind and sighted users can prepare function charts and automatically generate text descriptions. The authors [14] checked the possibility of learning such math areas as geometry, measurements, data analysis, statistics, and probability using audio-tactile tablets. The received results clearly show that using touch elements while learning math improves the cognitive abilities of blind students.

Based on the literature review, it can be stated that in some cases (the high complexity of graphics), the presentation of graphics only in tactile form is insufficient for correct understanding the figure by a blind student [15].

Therefore, within the authors' research, a platform that shares graphic math content (charts, geometric figures, etc.) in the audio-tactile form to blind students was developed. The paper will present the developed solution and the initial results of teaching math based on the audio-tactile form of presenting the graph maths content.

Our Work

The platform was developed based on the guidelines [16, 17], and the authors' set of rules for the interactive sounding of tactile graphics [18]. The authors applied previous experience in extending the Daisy standard to include voiced mathematical formulas [19]. These rules help to present more contextually additional sound information regarding the meaning and description in touching parts of a tactile picture, including the amount and way of passing the sound information.

The platform developed within the research is not only designed to share the visual information used in mathematics, but it allows the users for independent learning in a step by step way and then evaluation of student's progress made by a teacher or a psychologist. It should be noticed that the presented solution is characterized to be universal and easily distributed compared to other expensive ones.

The test bench consists of a 13" touch tablet with an Android system and developed software for interactive audio-tactile presentation. During the exercise solving, previously prepared educational materials, including tactile elements (charts, schemas, etc.) printed on the specialist tactile paper, are put onto the tablet screen. The application prepared on the tablet aims to detect the touch and gestures made by a blind person, and depending on the element being touched, supplying additional sound information of it. The proposed solution is very economical, and it does not require buying additional devices for audio graphics. Fig. 1 presents an example of a geometry exercise on the developed platform.
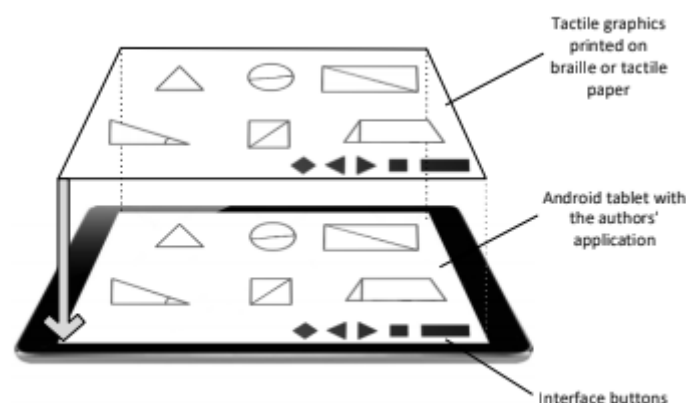
Fig. 1: Presentation of graphic content in the developed solution in the form of audio-tactile on the example of an exercise from geometry.

The traditional (simple) method, where the descriptions of elements are shared in Braille, requires the user to move back a hand from a component he is touching to read its description. Undoubtedly, it makes the process of math learning highly difficult. The proposed solution helps to avoid this problem and allows us to adjust the content of sound alerts after the element has been touched, depending on the solving phase. Each element being touched can have several alternative descriptions (simple, compound, etc.), which can be read depending on whether the element has been taped on once, twice, or more. This feature distinguishes the presented solution compared to others.

The proposed solution is available to expand the product offer on the market by adding the ability to perform exercises interactively on the tablet. The user has the option of learning mathematics step by step while accessing the sounded graphics on the screen of the device. The user receives current information and tips on the correctness of solving the exercise through continuous feedback from the application - a review of the literature showed that this is a very significant problem.

As part of the platform, at the current stage, a set of 15 sound-based mathematics exercises dedicated to the high school level has been prepared, containing graphic elements. These are graphs of linear, quadratic and trigonometric functions as well as geometric figures. Each picture was made in vector graphics and saved in SVG format, and each element from this file was delivered with one or more text descriptions referring to individual stages of the exercise solving. Such a picture is displayed on the tablet while the exercise is being solved. At the same time, its printed tactile version is placed on it (Fig. 1). As the consequence of using the Text-to-Speech library in Android after touching a tactile element on a piece of paper, this touch is recognized on the tablet (there is no problem to detect touch through the paper), and the appropriate description is read out by voice. For each picture, a set of exercises were also prepared in the form of interactive tests, and a suitable interface with five keys was proposed, by which a blind person can solve the exercise in a tactile manner (Fig. 2).

Fig. 2: Application interface for step-by-step exercise solving navigated through the test.

Developed platform (the web teacher application) allows also preparing digital audio-tactile pictures with multichoice testes. A teacher can send prepared educational materials to the students' tablets. Next, after solving the exercises by the students, the filling tests are sent back to the teacher web application. The web application allows the teacher to browse and analyse the student's answers. The teacher can also send feedback information to the student about the test result with additional comments and tips. The teacher applications also allow monitoring the student learning progress and display the statistics and identification of difficulties while solving exercises. The developed platform improves math education of visually impaired student.

Experiments

The selected research group consisted of 10 blind students. The group consisted of 2 women and 8 men, aged 15–18. Psychological consultation allowed the authors to adopt the following inclusion criteria:

- the group includes persons whose degree of visual impairment or blindness was significant (more than 90% of blindness),
- the vision disability was acquired during their lives,
- the group was consistent with the duration of disability,
- people in the group did not have any other disabilities.

The tests that allowed to assess the effectiveness of the proposed solution were divided into 2 stages:

Stage 1
The participants solved math exercises containing graphic content available in the tactile form (without sound descriptions) – the first experiment (E1).

Stage 2
The participants solved math exercises containing graphic content available in the audio-tactile form (with the use of the authors' platform). The sound descriptions changed along with the stages of solving the exercise – the second experiment (E2).

During each stage, the students solved 15 exercises. However, tasks in stages 1 and 2 differed but were from the same division of mathematics, and their level of difficulty, according to the opinion of mathematicians, was very similar.

Quantitative measures were used to assess the effectiveness of the proposed approach:

1. Evaluation effectiveness of the method used to solve the exercise (percentage of correct partial answers when solving the exercise concerning the number of all stages of the exercises - expressed as a percentage).
2. Users' feelings – sentiment analysis based on counting the elements (words) of positive and negative emotion after processing the speech into the form of bag-of-words [23] based on the user's free expression.
3. Assessment of cognitive aspects based on the survey developed for the needs of other studies in three subcategories.

Cognitive aspects assessment may help to understand the logical functions and other features, including memory, judgment, attention, decision-making and problem-solving, evaluation, etc. , A questionnaire was developed based on the discussed issues and the analysis of the literature on the subject (Table 1).

Table 1: A research questionnaire of cognitive aspect.

Question number	Question	Cognitive subcategory
Q1	I think about different ways to solve a given problem.	Knowledge operationalization
Q2	I try to combine new things I learn with the things that I've met before	Knowledge operationalization
Q3	I try to make sure that what I do is correct	Ability of self-correction during the learning process
Q4	I try to understand my mistake in case I do something wrong	Ability of self-correction during the learning process
Q5	When I study, I consider only those problems that I have previously done	Ability of self-correction during the learning process
Q6	When work is difficult, I only solve the easier part	Strategy for solving exercises based on gradation
Q7	I only do the necessary minimum	Strategy for solving exercises based on gradation

Answers for all questions were possible in nominate scale with grades from 1 to 5 with step size equals one. Then the sum of points obtained by a particular participant was divided by the maximum number of points possible to obtain and expressed in percent scale. Psychologists proposed the evaluation of three cognitive subcategories:

1. **Knowledge operationalization:** can be understood as a process of selecting information that corresponds with the definitions of specific phenomena adopted in the course of conceptualization.
2. **The ability of self-correction during the learning process:** it can be described as the ability to use the acquired knowledge and given clues to make necessary corrections in solved exercise.
3. **Strategy for solving exercises based on gradation:** using the acquired knowledge to solve a given more complex exercise.

The Research Results

A summary of the obtained results regarding the effectiveness of the method used for exercise solving presents Table 2. It shows the normalized (to % scale) an average number of points scored by each test participant after solving 15 exercises during experiments 1 and 2. Participants' sentiment and assessment of cognitive aspects have been presented in the bar charts (Fig. 3 a and b).

Table 2: A summary of the results obtained by the participants' in terms of the effectiveness of the method used for solving the exercises during stages 1 and 2.

	Average participants' results after solving 15 exercises (%)									
Participant no.	1	2	3	4	5	6	7	8	9	10
Stage 1	59	60	71	64	61	41	36	74	44	63
Stage 2	80	75	75	75	73	51	45	96	59	65
Progress	+21	+15	+4	+11	+12	+10	+9	+22	+15	+2

Conclusions and Possible Next Steps

The presented audio-tactile method of sharing the graphic content in mathematical exercises, combined with the change of descriptions depending on the phase of solving the exercise, improved both the skills of the blind in solving mathematical exercises with graphic elements (Table 2) and the emotional attitude (Fig. 3a). According to the literature, a negative attitude is one of the main barriers to learn mathematics by the blind. Referring to the obtained results of cognitive aspects (Fig. 3b), improvement was achieved in all three subcategories. The most significant increase was noted in the category of concept acquisition and selection of information, which translated into improving the skills of self-development of mathematical skills and problem-solving.

To sum up, the developed method can be helpful for both a teacher for more effective math lessons and a blind student to self-study. In the future, it is planned to commercialize the developed method by developing a more significant number of exercises, extending tests to a larger number of students, managing the order of solving exercises and extending the evaluation of cognitive aspects towards developing guidelines for a specific student. We plan also to improve functionality of the developed platform and language localization. The platform helps in student education both in the classroom and remote via Internet. This solution can be also applied in science education such as: biology, physics, chemistry etc.
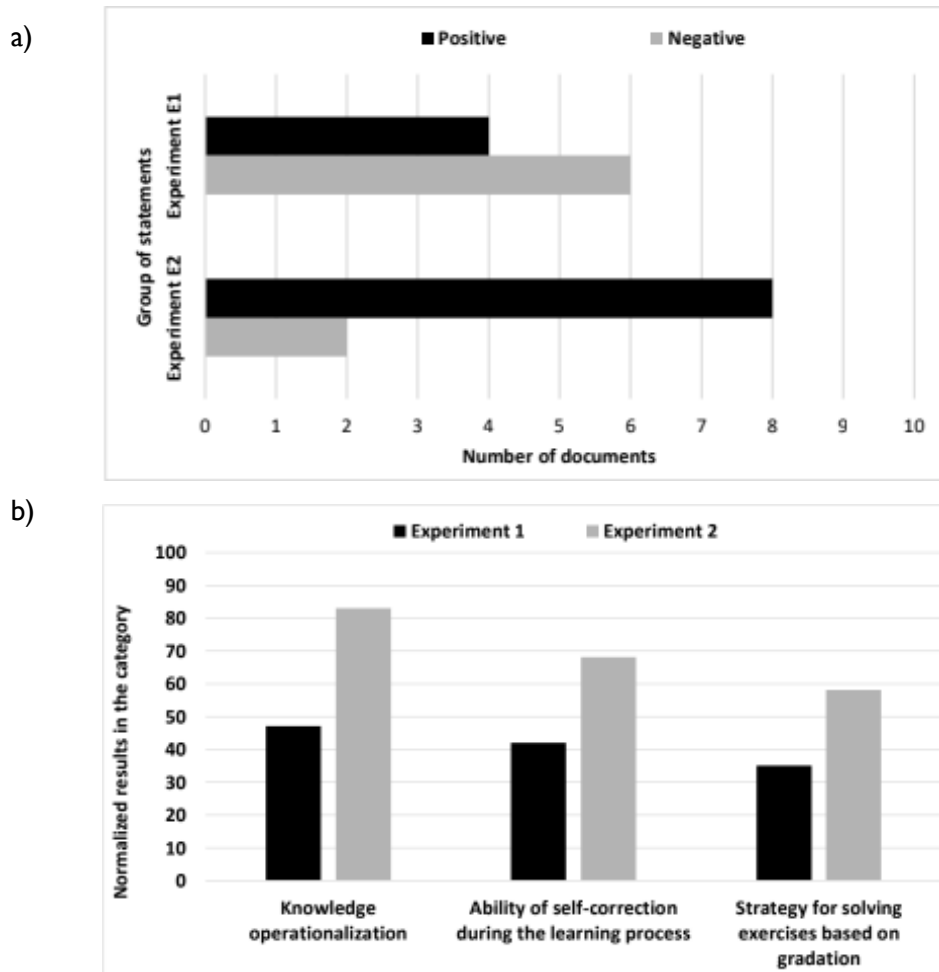
Fig. 3: a) Summary of the sentiment analysis obtained during the research, b) Summary of assessment of cognitive aspects obtained during the research.

Acknowledgements

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Utilizing Machine Learning Models for Developing a Comprehensive Accessibility System for Visually Impaired People

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Abstract

Equal access to text and graphics is important while reading online documents. Existing technologies for visually impaired people can provide accessible text but not full access to graphics. We introduce a comprehensive accessibility framework that is capable of generating accessible text and tactile graphics for a variety of graphics types in an HTML document. The architecture of the framework also offers extensibility and device independence. The framework uses image classification techniques to classify various kinds of graphics and applies simplification methods specific to the graphics category. This paper describes the components of the framework and illustrates the process of tactile graphics generation for the tree diagram category.

Introduction

Information access, especially from online resources, has become an inevitable part of our day-to-day life. However, communities with disabilities especially visually impaired people have only limited access to online content. Software solutions like screen readers give a fair amount of access to the text. Yet, the access available to online graphics (like diagrams, photographs, illustrations, graphs etc.) is extremely limited, posing a major hindrance for visually impaired to their involvement in the workforce, education and general reading.

The challenge of creating accessible tactile graphics has been an important topic of multiple studies over the past few decades. Previous research [2], [19] suggests that multimodal presentation of graphics aids better comprehension since it facilitates two-hand exploration on a haptic display and audio feedback for navigation and text. Even though a multimodal presentation is effective compared to sole audio or tactile presentation, in the real-world blind people rely on screen readers even for graphics. For educational purposes, embossed tactile graphics and traditional braille books are common ways of providing accessible graphics, although they are expensive. These facts raise the question of why blind people are not using multimodal systems for graphics access in their daily lives?

There is a huge gap between research developments in the area of graphics accessibility and real-world solutions available for visually impaired people. Multimodal solutions are faced with numerous challenges. Most of the multimodal systems [3], [5], [14], [16] are designed to work with one of the tactile devices like pin-matrix display, embossers or haptic force feedback devices that are expensive; making those systems highly device-dependent and unaffordable. Generic systems [5], [12, 13], [16] that handle a variety of graphic categories do not generate effective tactile graphics for all categories. Systems [3], [7], [18] that handle specific graphic categories can generate highly comprehensible graphics; however, their commercial prospects are limited compared to generic ones since they are too specific. Many of the promising low-cost multimodal systems like DiGVis [17] and GraVVITAS [8, 9] incorporate new navigation and interaction techniques that require hours of training for the user to get familiar with the system. Also, there is no provision for a blind user to opt for an interaction or navigation technique that is familiar to them since the system doesn't provide an alternative approach.

Even though there are many successful tactile representations[17] for generating tactile versions of charts, directed graphs, flowcharts etc., without their inclusion in a generic system, these representations can become obsolete.

To bridge the gap between the literature of accessible graphics and solutions available in the real world, we suggest a device-independent, extensible and comprehensive accessibility system. The system is a software framework that can automatically generate tactile graphics for a wide variety of diagrams based on its type. The system is also capable of incorporating numerous tactile representations including ones from past projects. Our system uses image classification techniques to categorize graphics into selected categories like trees, graphs, flowcharts, bar charts, scatterplots, pie charts, etc. Each category is handled separately by applying specific rendering rules based on the category and choice of tactile display. The system also separates semantics from the presentation of graphics and creates an intermediate file that includes semantics and structure. This approach gives the flexibility of generating different tactile outputs for each category. Previously Gonu [6] and Fredj [4] have used the semantic based approach for generating accessible diagrams. Any effective tactile representation from literature can be incorporated in our system by defining underlying rendering rules and linking them to specific diagram categories. The system can be extended to handle new graphic categories by including them into the image classification algorithm and adding appropriate rendering rules.

In this paper, we discuss the overview of the comprehensive system and image classification technique implemented. We also illustrate how tactile representation like Tabular Form Diagram (TFD) [15] from literature can be incorporated in our system to handle graphics that belong to the tree diagram category.

Overview of the System

The system consists of four modules – filtering, classification, transformation and audio modules and two libraries to provide speech rule templates and braille text (see Figure 1). In the current scope, the framework accepts simple HTML web pages that primarily contain just graphics in SVG (Scalable Vector Graphics) format or a combination of text and graphics (SVG). We use SVG format for graphics as per the accessibility guidelines [11] provided by World Wide Web Consortium (W3C).

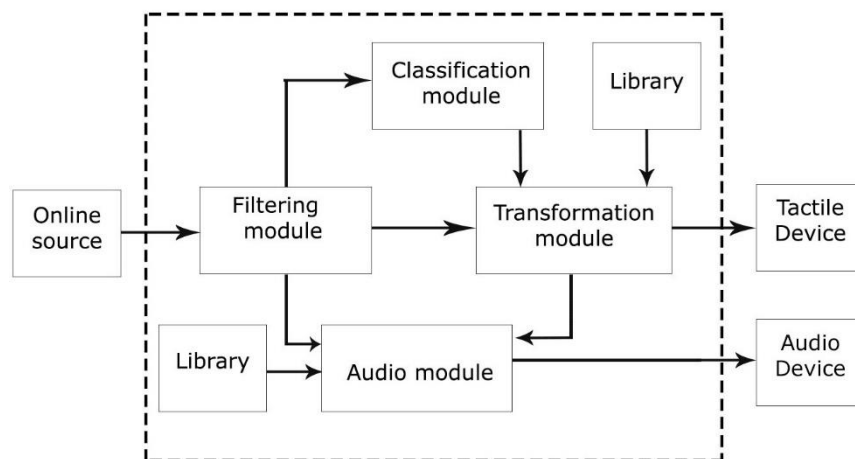*Fig. 3 Block diagram showing the components of the framework*

The filtering module processes the head and body section of the web page. The module extracts metadata information from the head section. From the body section, text and graphics are extracted

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[17] A tactile representation is the simplified version of graphics specific to its graphics category that can be rendered into tactile graphics

and stored separately. All the processed information including text, graphics and metadata are stored in XML format. The XML file created by the filtering module provides required input for other modules like the transformation module and the audio module. The audio module can access metadata and text from the filtered data for further processing. The graphics content in raster graphic format – png or jpg is fed to classification module and graphic content in SVG format is forwarded to transformation module for further processing. The key purpose of the filtering module is to perform primary level processing and segmentation of input HTML content.

The audio module is responsible for creating overview information of the webpage and converts the text in the HTML page to speech. The overview of the web page is mainly extracted from the metadata received from the filtering module. Overview information gives an outline of the contents of the webpage. It helps the user to get the context before accessing the text. The audio module creates an XML document containing the text and overview of the web page that can be used by speech synthesizers to deliver audio output.

The classification module accepts raster graphics and categorizes them into categories. The module uses numerous computer vision techniques for feature extraction and utilizes machine-learning models, like Support Vector Machines, for implementing image classification (details below). The category of the input graphics is forwarded to the transformation module to aid further processing and simplification of graphics. The majority of graphics available over the Internet is in raster graphics formats. To get ample data points for classification purposes we used raster graphics instead of vector graphics.

The transformation module obtains two inputs - graphics (in SVG format) from the filtering module and the category information from the classification module. The SVG file is processed based on the category of graphics; and semantics and structure are extracted from the graphics. An intermediate file in XML format is created that contains three sections – overview, structure and semantics of the graphics. The intermediate XML file is then processed to generate a tactile format suitable for the category of graphics. The tactile format is later rendered into tactile graphics that can be displayed on a tactile device. The framework gives the user the flexibility to choose audio and tactile devices of their preference. Embossers, matrix-pin display and haptic displays like haptic gloves, phantom robots or any custom devices can be used as tactile displays. In order to use the tactile device of one's preference, the tactile representation compatible with the device and associated rendering rules must be added to the framework. Preliminary work related to the framework can be found in [1].

Image Classification

The framework is a generic system that aims at automatic generation of tactile graphics for a variety of graphics including various types of diagrams and pictures. However, in a generic system, applying the same rendering rules for all graphic types will not always yield comprehensible tactile outputs. Therefore, to generate effective and comprehensible tactile output for every graphic type, we have incorporated a multiclass image classification model. This classification model enables our framework to include design considerations and rendering rules specific to each graphic type while handling multiple graphic types. Image processing and image classification was used previously in other projects like TGA [12], TeDub [14] and Tactiled [10]. TGA used machine learning and image processing techniques to identify text and separate text from images, while TeDub used these techniques to classify and extract information from technical drawings. Tactiled on the other hand used machine learning for identifying quality images that are fit for conversion to tactile graphics.

To include a variety of graphics we used a systematic categorization of graphics. Initially, we created two broad categories – pictures and diagrams based on the presentation format; where pictures are real world representations and diagrams are abstract ones. As an initial step towards implementing multiclass classification, we built a model for classifying graphics into pictures and diagrams. This project

was beneficial in determining features for graphics and machine learning models for implementing image classification. Since our focus is generating tactile graphics for diagrams, in the next step, we expanded categories under the diagram. At first, four categories – trees, graphs, flowcharts and digital circuits, were included under diagrams. Currently, the classification model handles seven categories: bar chart, pie chart and scatterplot along with the first four.

Description of Dataset

The current dataset contains 130 to 150 images under each diagram category. There are around 50 unique images under each category. These images are scaled, rotated and inverted to obtain the full image set. These images are obtained from Google Images based on search results. Specific keywords related to each category like a tree diagram, directed graph, node-link diagram, bar graph, histogram etc. were used to attain proper results. The images were labelled, resized and organized into folders with category names to get the full image set.

Feature Extraction

Computer vision and image processing techniques are required to extract features from images. We used MATLAB computer vision toolbox to apply appropriate feature extraction techniques. Speeded Up Robust Features (SURF), Colour Histogram and Histogram of Oriented Gradients (HOG) were the features initially considered for modelling.

SURF can be used to extract salient features and descriptors from images. SURF descriptors specify an image feature by defining the pixel intensity distribution within the local neighbourhood of the interest-point. In our project, we used a grid size of 8 X 8 to extract SURF feature points from the image. By retaining only 80% of the strongest features and using K means clustering for creating the bag-of-visual-words, we obtained a feature vector of size 1 by 800 for each image. Each column value of the feature vector is a number between 0 and 1.

A colour histogram is an important feature that can be useful in differentiating diagrams. In a colour histogram, the number of pixels with a specified RGB (Red Green Blue) value is counted for every RGB value in an image and is plotted in a histogram. In images containing diagrams, the most frequent colour occupies more than 10% of the total pixel count. So we calculated the percentage of pixels occupied by the most frequent colour in an image from the colour histogram and added this value to the SURF feature vector after normalizing.

HOG features are used for object detection in an image. The HOG descriptor defines an image feature by counting the occurrence of gradient orientation in local neighbourhoods in an image. In our project, we used a cell size of 8 X 8 initially and later modified it to 16 X 16 for faster computation. A HOG feature vector of size of 1 by 6758 was computed for each image when the cell size was set to 16 X 16.

Discussion

The goal of our work was to try out different models and choose the best performing model for multi-class classification involving 7 diagram categories. Dataset was split into two sets where 80% of the dataset was used for training and 20% was kept as test data. Due to the smaller size of the dataset, we used 5-fold cross-validation rather than reserving a portion of the dataset as a validation set. SVM (Support Vector Machine), Decision Trees, and KNN (K Nearest Neighbor) models are learned and the confusion matrix was calculated for these models. MATLAB was used to implement all machine learning models. All models were trained first with one feature and then a combination of two features and then all three features were included.

All the models were evaluated based on overall accuracy, false-negative rates and total misclassifications. SVM models outperformed decision trees and KNNs. Further analysis of SVM models

showed that with Linear, Quadratic, Cubic and optimized Gaussian SVM overall accuracy was above 80% (see Figure 2). All these models showed better accuracy and false-negative rates when SURF features alone or a combination of the colour histogram and SURF features were used. SVM with Gaussian kernel gave an overall accuracy of 91.5 (with SURF feature alone) and 91.8 (with SURF and colour histogram features) when a Bayesian optimizer was used. The misclassification cost was also minimum with optimized Gaussian SVM.
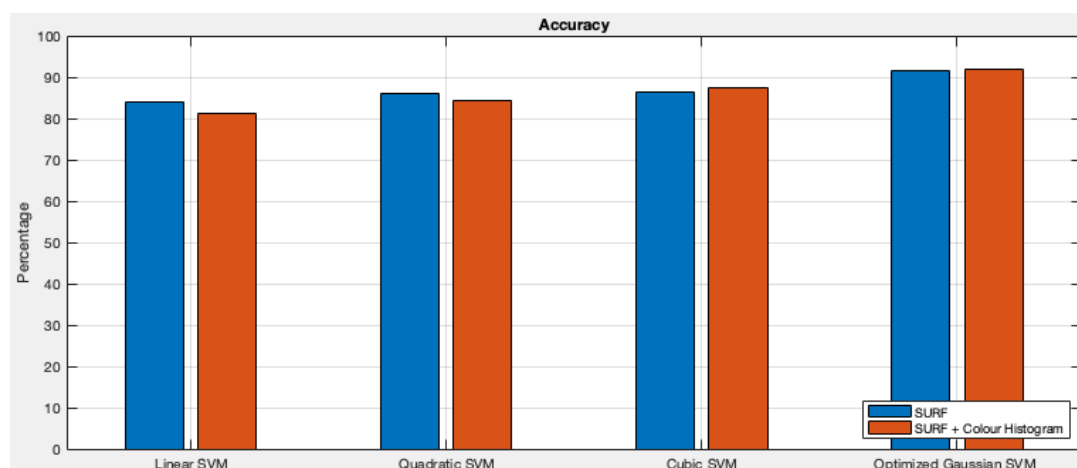
Fig. 4 Bar graph showing accuracy of various SVM models

The results of the analysis demonstrated that optimized Gaussian SVM and SVM in general is an appropriate model for our classification purpose. We did not consider neural networks and deep learning even though a lot of popular image classification problems use these learning methods since our dataset is small and the probability of overfitting will be high with neural networks and deep learning methods.

Tactile Graphics Generation

The transformation module is the component that is responsible for producing the tactile representation that can be displayed on a tactile device. The transformation module receives two inputs – SVG from the filtering module and the graphics category from the classification module. Based on the category, the SVG is processed and an intermediate XML (IXML) file is generated. A tactile representation is selected depending on the user's choice of a display device and the category of the graphics. The intermediate XML is processed by applying simplification rules which will produce a specific output. Using this output the tactile representation can be rendered on the tactile device. We are adopting the tactile representation –TFD for generating a tactile version of tree diagrams. TFD works well with our current choice of the display – pin-matrix display and embossed papers.

Workflow of the Transformation Module

The transformation module is a very complex module that performs a substantial amount of information processing in terms of processing graphics and processing XML data. Transforming the graphics into a tactile representation occurs in 3 stages (see Figure 3).
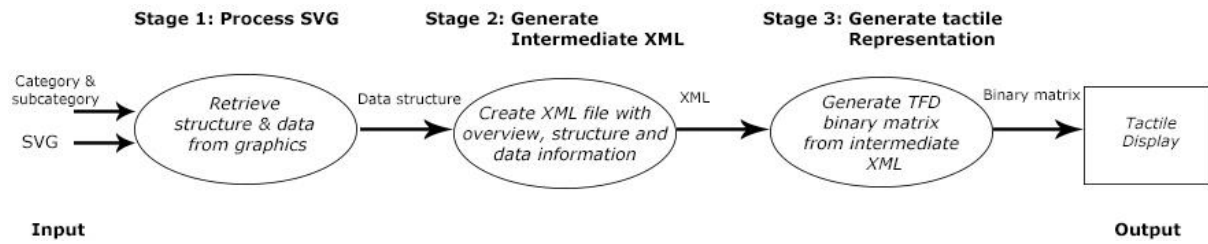
Fig. 5 Diagram showing the workflow of Transformation Module. Stage 1, 2 and 3 of the tactile graphics generation process is shown.

Stage 1- Process SVG: In this stage, the transformation module accepts category information and SVG source. Based on the category, all the elements in the SVG source are processed using specialized algorithms to retrieve structure and semantics from the graphics. The structure of the graphics mainly constitutes various shapes used in the graphics, strokes and fill used for those shapes, and any relevant presentation or visual details. The semantics or data obtained from the graphics usually contains the details of the elements in the graphics, the relationship between elements and any other information conveyed by the graphics. For example, in the case of trees, graphs or node-link diagrams, the structure contains information like shape used to represent node, stroke and fill used for the node, the shape used to show the relationship between nodes etc. The semantics or data part contains information presented by the graphics like the name of the node, weight associated with edges, the relation between various nodes etc.

Stage 2 - Create intermediate XML: During this stage, the transformation module processes data structures passed on from the previous stage. The main goal at this stage is to generate an intermediate XML file. For each category of graphics, templates of intermediate files are already created and available to use. The contents of the data structures are processed so that appropriate values can be added to the template file. The template file ensures a certain level of validation for the values added.

The intermediate XML file has 3 parts – overview, structure and data (contains semantics). The information required to fill structure and data sections is mostly directly available from the data structures from Stage 1. However, some details like the relationship between nodes (in case of tree diagrams and similar categories) necessary for the data section are not directly available. Special algorithms are used to retrieve such information from the data structures. The bounding box method is one of the techniques we use in those algorithms.

Information required for the overview section is also not available directly. Based on the category of graphics, multiple algorithms are used to retrieve those values from available data. In case of tree diagram, algorithms that perform Bread First Search (BFS), find the root node and the leaf node of a given node and find the depth of the tree are used to retrieve those values. The overview information is delivered in audio modality. The overview section contains information like category and subcategory of graphics, description and summary of the graphics. Some tactile representations like TFD transform the graphics completely to achieve the tactile version. In such cases, structural information is not required and only data and overview sections are populated with values.

Stage 3 - Create tactile representation: This is the last stage of information processing. Graphics need to be simplified to generate tactile graphics to be perceived on a tactile device. In this stage, the data section from the IXML file is processed and transformed into a form suitable to encode all information needed for the tactile representation. The tactile representation is then displayed on the tactile device.
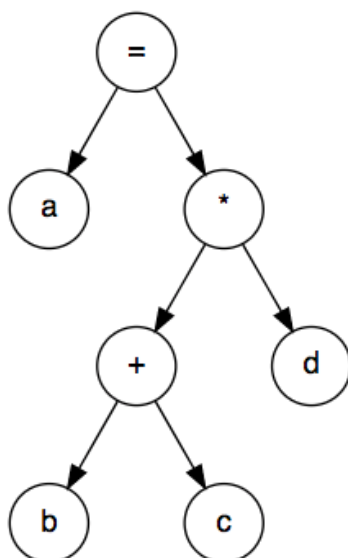
Fig. 6 Tree diagram showing an expression tree

An Example

An expression tree (see figure 4) in SVG format available over the internet (https://uva-cs.github.io/pdr/slides/graphs/exp-tree-1.svg.) is used to demonstrate the tactile graphics generation process. The expression tree is created using standard SVG elements and semantic information like class attribute is added to the node and edge elements. At first, the node and edge elements are processed to retrieve structure and semantics. To determine the relation, algorithm applying the bounding box technique is run with coordinates of the nodes and edges that return nodes connected to each edge. Once the node, edge and relation information is retrieved, IXML is generated using the template file. Category, subcategory and description retrieved from the classification and filtering modules respectively are added to the overview section along with depth information obtained from the algorithm to find the depth of the tree. Values needed for the data section are obtained directly from node, edge and relation information retrieved previously. The algorithm – find-child-node returns child nodes corresponding to each node. This information and order parameter set using the Breadth-First Search (BFS) approach is added to each node in the data section. The order parameter can be also set using Depth First Search (DFS) approach to generate a tree diagram similar to the visual version. The IXML file generated by processing the SVG code of a tree diagram shown in figure 4 is given below. Two nodes and one edge are added to give an idea of the IXML file.

```
<?xml version="1.0" encoding="utf-8"?>
<info>
<structure></structure>
<overview><category>diagram</category><subcategory>tree diagram</subcategory>
<description>This diagram shows relation between parent and its elements</description>
<graphicdetails><depth>4</depth> <totalnodes>7</totalnodes> <totaledges>6</totaledges>
<root roottotal="1"><name>=</name></root><leafs leaftotal="4"></graphicdetails></overview>
<data>
<nodes node-total="7">
<node isroot="True" isleaf="False"><name>=</name> <order>0</order>
<children><child>a</child><child>*</child></children></node>
<node isroot="False" isleaf="True"><name>a</name><order>1</order><children /></node>
</nodes>
<edges edge-total="6">
<edge><name>edge1</name><startnode>=</startnode><endnode>a</endnode></edge></edges>
</data></info>
```

According to the conversion rule for rendering tree diagrams using TFD, semantic information from IXML is encoded into a two-dimensional array referred to as the transformation matrix or T-matrix. T-matrix is a binary matrix of the size M X N where M = (total nodes * 4) + 4] where 4 is the value of the number of dots per row. And N = (total nodes * 5) where 5 is the value of the number of dots per column. The position of each node in the TFD and which pins need to be raised to display the graphics is determined based on the order parameter associated with each node. The tactile output is supplemented with the audio output.
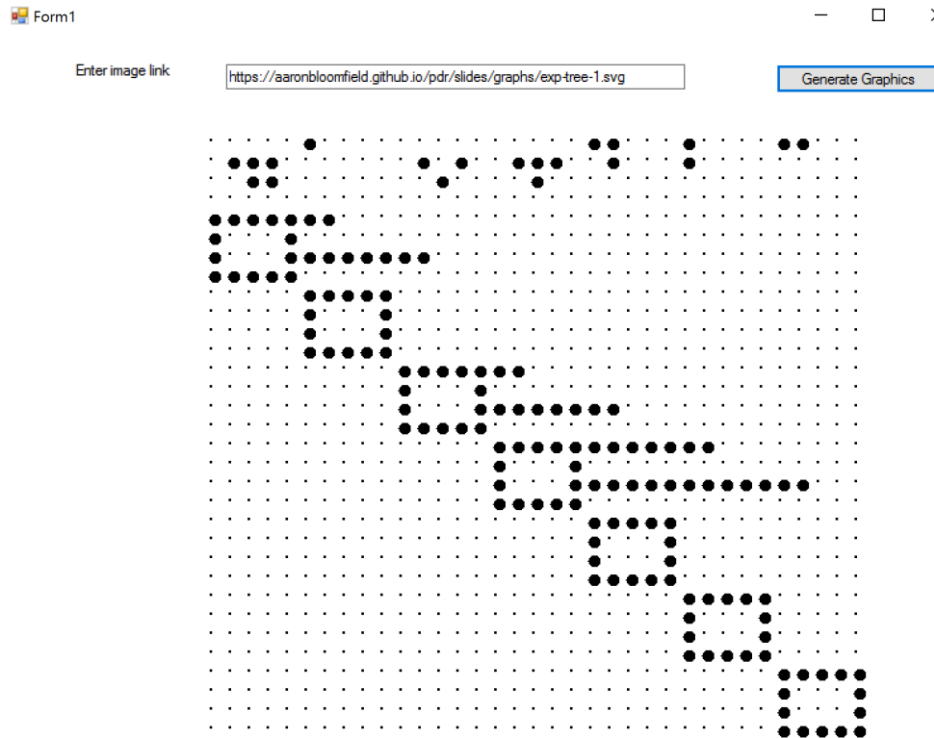
Fig. 7 Tactile graphics of tree diagram shown in figure 4 generated in TFD Format

Tabular Form Diagram (TFD) was developed as part of the project Talking Diagrams [15] based on the feedback from an experienced computer user with severe vision impairment. TFD creates a tabular arrangement of components of the diagram preserving the relative positions in the original diagram. To construct a TFD for an n node diagram, a table with (n+1) X n rows and columns is created. The top row of the table is allocated for node labels. A block positioned diagonally downward in the table represents a node. To represent an edge, a horizontal line is drawn from the start node to the column of the end node. It is easy to represent directed graphs since the direction is taken as pointing from the start block. Figure 5 shows tactile version of the expression tree (Figure 4) in the TFD format.

Each type of graphics has specific tactile representation that will display the graphics in the best possible way based on the choice of display devices. For example, TFD is an appropriate tactile representation to present graphs and node-link diagrams on a pin-matrix display and embossed paper [15]. For that reason, we have chosen TFD for the tree diagram category. Likewise, for every category, a specific tactile representation will be assigned so that all categories of graphics can be presented well with our system. Depending on the tactile representation, the encoded information is available in a file or table or even in a matrix. In the case of TFD, the intermediate XML file is processed to generate a binary matrix that stores all information required to render TFD. The transformation module is implemented using .Net Framework 4.7.

Conclusions and Outlook

In this paper, we presented a multimodal comprehensive accessibility system that is device-independent and extensible. The system is a software framework capable of generating tactile graphics for a variety of diagrams. Even though the framework is generic (handling a variety of graphics), by utilizing machine learning models for the classification of graphics into categories, we are able to apply rendering rules specific to the category. At present, our optimized SVM model can classify graphics into 7 different diagram categories. The evaluation of various machine-learning models and feature extraction techniques are discussed in the paper. We also explained the components of the framework and illustrated the process of tactile graphics generation for tree diagram category when the display preference is pin-matrix display or embossed paper.

In the future, more tactile outputs need to be generated for the tree diagram category that will work for other haptic devices. Also, rendering rules must be added for 6 other diagram categories to utilize the benefits of the framework. At present, the graphical user interface is in a preliminary stage. The GUI must be modified to include various diagram categories and its tactile outputs and also input fields must be added so that users can select their device preference. The potential and efficacy of the framework cannot be evaluated without the involvement of the intended user group. We plan to conduct a user study to evaluate the GUI and tactile outputs generated by the framework in the near future.

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Exploring Maps with Touch: An Inclusive Haptic Device

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Abstract

This paper presents a preliminary case study for the accessibility of maps for Visually Impaired People (VIP) using a novel haptic interface called F2T (Force Feedback Tablet). This device allows VIP to actively explore and feel graphical content and receive feedback on the explored image properties through a combination of dynamically generated force-feedback effects. Simplified room layouts were displayed to VIP, each including an entrance, an exit, and walls with a variety of angle shapes between them. The obtained results indicate that the F2T allows VIP to recognize different types of room layouts with good accuracy (with a mean absolute error of less than 10° when identifying angles between walls), and also shows the usefulness of the "guided" exploration mode to hasten the discovery of an unknown layout.

Introduction

In our current digital society, graphical data is becoming increasingly ubiquitous. Most information sources have been digitized, and the advent of smartphones, social media platforms and wearable smart devices have powered an ever-growing exchange of video and image content over the web. Thus, culture and education are getting increasingly reliant on pictures, schematics, videos or maps, and accessing such information is difficult for Visually Impaired People (VIP). Traditional screen readers and braille devices are not adapted to tap into this flow of information, limiting VIP's inclusion in society and lowering their quality of life.

For VIP, accessing maps and graphical content often requires specifically designed documents in relief, such as maps with magnets, thermoformed surfaces or 3D representations of objects. However, such representations are often expensive to print, represent a static set of elements with a fixed scale and level of details, and require well-thought simplifications to be intuitively understood.

During the last decades, many efforts have been made to develop interfaces allowing to dynamically display / convey graphical contents to VIP [1, 2], using various types of interfaces such as taxel matrices [3], electro-tactile surfaces [4] or plain vibrators [5]. However, despite their advantages in being able to display different types of contents and dynamic information, very few haptic devices are actively used by VIP [6]. One of the reasons for this lack of adoption is the difficulty to recognize and differentiate objects displayed through those devices. Indeed, most touch-feedback technologies either provide edge or texture-based perception, thus presenting an incomplete representation. This greatly limits their use for the comprehension of graphical information

The F2T (Force-Feedback Tablet) [7] was developed to provide a new way for VIP to explore and intuitively interpret graphical content such as maps and images. It allows VIP to explore and feel graphical content through an interactive interface that generates haptic effects based on the underlying content of the image. Those haptic effects encode specific spatial properties of the image (such as edges or textures) depending on where the user is directing the focus of its exploration.

This paper explores the usability of the F2T for assisting the discovery of 2D indoor plans. Indeed, previous research has shown that haptic displays can effectively support interpreting map-based information [8, 9], but these haptic dynamic representation of maps are often difficult to interpret and memorize. To allow for an intuitive exploration, such devices should provide information to both

localize and distinguish the various elements (i.e. objects or areas) of the image. Combining the various force-feedback effects of the F2T with the users' movements, should allow them to perceive both the edges of objects and to give an identity to those objects by linking them to different haptic "textures", thus helping VIP gain a more accurate mental images of the explored contents [10, 11].

The next section summarizes the main principles of the F2T and the following one presents preliminary results obtained using the F2T to explore simplified geographic maps.

F2T or An Inclusive Haptic Device

The F2T allows VIP to explore and feel maps (and other graphical contents) by moving a small mobile platform held by motorized axes over a virtual image (cf. Fig. 1). They guide the platform by pushing a joystick placed on it and receive dynamically generated haptic feedback based on the content of the currently explored region of the image (which is defined by where the platform is over the virtual image). The user can both freely explore the image or be guided through it by the device itself. It uses various force-feedback effects to provide information about relevant properties of the explored image, such as the nature of the currently explored section (e.g. corridor, room, wall, …), the presence of a path or of points-of-interests (PoI), etc.

Fig. 1 Model of the F2T (left) and its current prototype (right): a flat thumbstick (center of the tablet) acquires user's intended movements; the actuated support moves the thumbstick to generate a large variety of haptic effects from images displayed on a screen to which the F2T is attached.

The F2T's control system allows a wide range of interactive haptic effects to represent the content of an image. Those effects vary by the amount of "control" exerted over the movement of the mobile support by the device itself.

On one end of the continuum, *passive effects* will slightly alter the final movement of the support, compared to the user's intended movement. Those effects usually apply a speed or direction correction to the intended movement. For example, a specific room could be distinguished from the neighboring area by having a high "friction" coefficient, requiring more efforts to cross (by moving the joystick through it). This resistance can be constant on the whole room, or could increase in a stepwise manner, to indicate stairs. Similarly, walls could be indicated by a "vertical step" that needs to be overcome by pushing the joystick with a certain threshold of force to be able to "move over" the wall, akin to climbing a cliff-face. Finally, those effects can be combined to create more complex ones, such as "canyons" that aim to keep the support within a specific "rivulet" by dragging it back towards its center when the user tries to move away from it, akin to trying to escape gravity well. This effect can be used to encode preferred paths, from which you can divert but to which you will always be brought back, unless you find another of those paths to "fall" into.

On the other extreme of this continuum, you have active effects, which are different types of guidance modes, where the device guides the user along a predefined path. Depending on the type of guidance, the user is either fully locked onto that path, or can slightly deviate from it, but cannot escape from it or stop its progress, akin to swimming laterally into rapids.

The following experiments explore how to combine those effects in order to convey cartographic data into haptic stimulations, allowing VIP to efficiently explore and mentally represent the spatial organization of simple indoor plans.

Test Protocols and Results

Previous preliminary evaluations showed that the F2T can be used to convey basic geometric shapes and movements [11]. To further extend those results to more complex shapes and tasks, we designed two simple experiments: identifying the angle between two walls and recognizing the layout of a room (composed of several walls with different types of angles between them). Twelve blindfolded sighted participants were enrolled for both studies, with 9 participants between the ages of 20 and 30, and 3 between 30 and 50 years old.

Angle Perception

To verify that the F2T allows blindfolded participants to perceive and identify various angles, we prepared six different haptic images representing acute, right and obtuse angles (c.f. Fig. 2). The angles were presented in a randomized order, and no other information on the types of angles to expect was given to the participants. Each haptic image covered the exploitable surface of the F2T (20 x 20 cm). The green areas represent virtual walls and cannot be crossed.

For each trial, the participant could freely explore the image and was given the guideline of following the edges of the virtual wall to identify the angle between the two walls as fast as possible and give its approximate value orally. Participants could express angles greater than 180° by giving the complementary angle if they felt more fluent with salient angles. The exploration time needed to give an answer was also recorded.
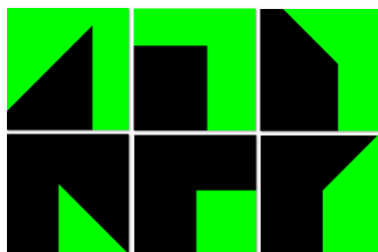
Fig. 2 Angles of 45°-90°-135° (top row) and 315°-270°-225° (bottom row) presented in a random order during the test.

Fig. 3 shows the average exploration times (in seconds) and the Mean Absolute Error (MAE, in degrees) when identifying the angle for each angle value. The average exploration time was 58.5 seconds with a standard deviation of 12.8 seconds. The exploration times were longer for the angles greater than 180°. Such results are probably due to larger surface (black) which had to be explored, and the increased facility of "loosing" the edge when sliding against it. Indeed, it was observed that the user's finger moving too fast could lose the edge of angles greater than 180°, making participants loose time during their exploration.
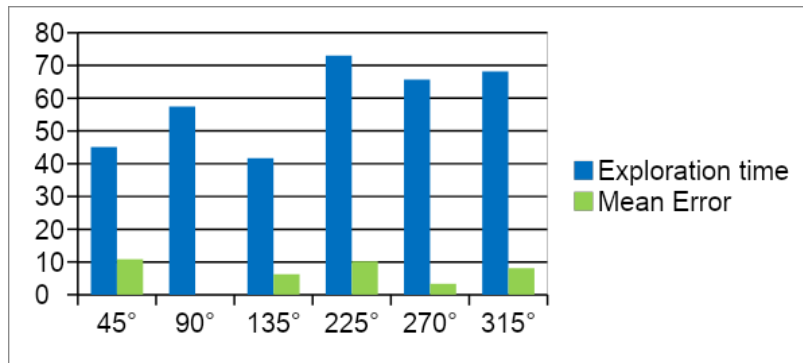
Fig. 3 Average Exploration Times (in seconds) and Mean Absolute Error (in degrees) for the six angles

The highest MAE (of 9.5°) was observed for 45° and 315° angles, while the MAE is around 8.2° for 135° and 225° angles. Right angles (90° and 270°) were the most easily recognized ones, with a MAE of 0° and 3.33° respectively.

Layout Perception

The following experiment consisted of haptic images combining several walls (impossible to cross) at different angles, into four basic room layouts (c.f. fig 4), each with an entrance and an exit, indicated by a specific passive friction effect. Each layout was presented with the entrance facing the user, at the bottom of the layout, to give the participant the feeling of entering the room.

The same 12 participants were asked to explore and memorize each layout and then draw it, including the position of the exit door. Participants were divided in two groups: half of the participants explored the layout freely until they felt comfortable enough to draw it, while the other half was first guided around the virtual room through a path showing the exit door, before being allowed to freely explore the room until they felt confident in drawing its shape. Each of the 4 virtual rooms was presented in ascending order of topological complexity. They were told that those 4 rooms were part of an apartment, each room connected to the next by its exit.

P1   P2   P3   P4

Fig. 4 Each of the 4 virtual rooms, in order of complexity.

Fig. 5 shows two sets of the collected drawings for each of the 4 layouts. Each participant was able to easily find the location of the exit door and to correctly reproduce the layout. The 2 rooms with diagonal walls (P3 and P4) were generally more confusing, with some participants pointing out the difficulty to remember the position and angles of all walls.
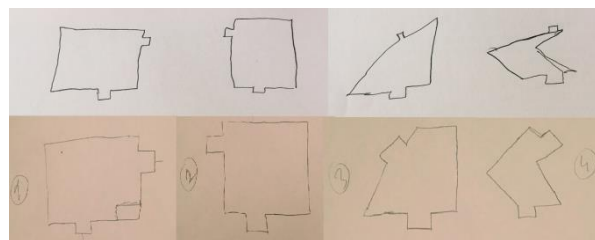
Fig. 5 Two sets (upper and lower lines) of drawings of the 4 virtual rooms.

The average exploration times are shown in Fig. 6. The free exploration time in the non-guided condition were longer (μ = 95.4s) than in the guided one (μ = 53s). This means that the guided exploration allows users to understand (and mentally represent) the structure of the layout while they are guided, thus reducing the time they need to freely explore it before being comfortable drawing it.
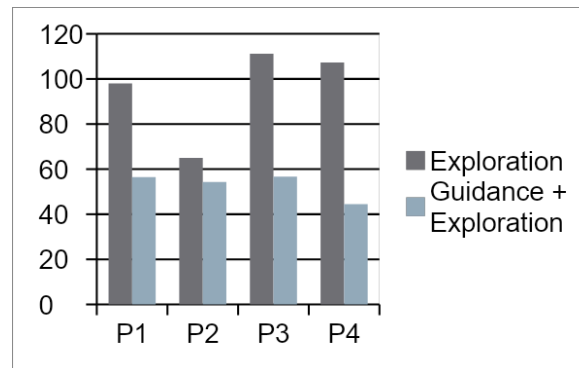
Fig. 6 Average exploration time of the rooms.

Interestingly, the last 2 layouts generally required longer explorations times in the non-guided condition (due to the non-straight walls and angles), but this difference wasn't observed in the guided condition. The greater difficulty in mentally representing the last 2 layouts could be partially explained by the thumbstick producing non-smooth and sometimes slightly curved diagonal movements due to the current prototype's imperfections.

Similarly, participants took more time exploring the first room due to the novelty of the task, but only in the non-guided condition. The participants found that the guidance was very useful to better and faster apprehend the explored layout and confirmed that a free exploration phase was required afterwards to consolidate their understanding of the room's layout. Some participants also reported that the used guiding speed was sometimes too high;

These preliminary results show the F2T's potential to allow the comprehension of haptic images of spatial data such as maps. And despite a lack of quantitative results to validate its usefulness, participants highlighted the usefulness of the guided exploration to rapidly give them an overview of the whole layout, allowing them to explore it more efficiently after.

Mental Representation of the Whole Apartment:

The final task the participants were given was to draw the whole apartment by linking the four interconnected rooms they previously explored. This task required them to mentally rotate some of the rooms in order to connect the exit of a room with the entrance of the next in a coherent manner. Fig. 7 presents the expected result and two examples of the collected drawings for this task, which was correctly accomplished by all the participants.
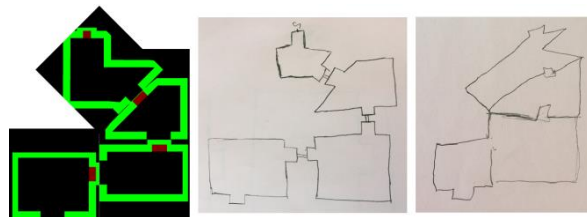
Fig. 7 Four interconnecting virtual rooms and two examples of drawings of the mental representation of the connecting rooms.

Conclusions

This communication introduces a potential use case for the Force-Feedback Tablet, a novel haptic interface allowing VIP to intuitively explore and interpret images such as cartographic data through a combination of haptic effects. Simple experiments were designed to evaluate the spatial cognition of blindfolded participants (such as the mental rotation of layouts) using the device to explore cartographic data. The results obtained are encouraging but will need to be confirmed with more robust protocols to more reliably test specific hypothesis on the relative importance of specific haptic effects for representing relevant elements of cartographic data (such as points of interests, elevators…). The possibility of adding localized audio cues to identify "noisy" elements of the map (such as fountains, coffee shops…) is also being studied.

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Cognitive Disabilities and Accessibility

Pushing the Boundaries of Inclusion using Digital Technologies and Accessible eLearning Environments

The MekoS Project

Sonja Abend

Abstract

The project "People with intellectual disabilities in empirical social research" (MekoS), funded by Aktion Mensch, was carried out at the Institute for Empirical Sociology (IfeS) in Nuremberg from March to July 2017. The MekoS project pursued two main goals: The acquisition and expansion of the participating scientists' competencies in communicating with people with (intellectual) disabilities and the empowerment of people with intellectual disabilities in research. Participants of the project were scientists from IfeS and employees of the Workshop for Disabled People Noris Inklusion (WfbM), the latter being people with intellectual disabilities. In order to get to know each other and to exchange information at eye-level, the participants visited each other at their workplaces. Several trainings on the topics of disability, communication, Easy-to-read language, and care rights were carried out. During these, the participants had the opportunity to cultivate self-awareness and reflection. They could practice their newly acquired soft skills with the help of a theoretical input from lectures given by expert speakers. Some training modules were inclusive, i.e. people with and without intellectual disabilities took part. As a central and sustainable project result, a two-part brochure was produced cooperatively. It includes a standard language section aimed at academics, which conveys various aspects of participatory research and thus provides support for inclusive research projects. In a second part, it informs people with intellectual disabilities in Easy-to-read about empirical social research. Easy-to-read was also used to create papers such as the consent form, all developed by both scientists and WfbM employees. The brochure can be downloaded free of charge.

Introduction

People with intellectual disabilities are the focus of many research projects. An overview of all planned, ongoing and completed projects in Germany can be found on the REHADAT homepage.[2] Participatory approaches of research no longer regard the people whose circumstances they investigate as objects to be explored, but include them in the research process. They are regarded as actively involved co-researchers with their own point of view. The joint research of scientists together with people with intellectual disabilities [7] requires that the participants know their research partners' living and working spaces as a foundation for cooperative work. The ability to communicate successfully with each other also plays a very prominent role. The first major project goal of MekoS was to establish and train the communication ability of scientists. As part of the MekoS project, scientists were trained in Easy-to-read before first contact with the employees of WfbM. The focus lay on practicing dialogues. (The joint seminars for the scientists and the employees of the Workshop for Disabled People are presented in more detail in the section *Our Work*.) The MekoS project aimed to give young scientists the opportunity to gain experience in contact and communication with people with (intellectual) disabilities. This is relevant because for the success of surveys about people with intellectual disabilities, it is not so much their cognitive abilities that make an impact, but primarily the communicative competence of the interviewers [10]. The project and the brochure produced within serve as a basis for further participatory and inclusive research projects.

The second major project goal was to inform people with intellectual disabilities about research. It pursued approaches of empowerment and was achieved specifically for the project itself through the exchange and mutual acquaintance of the workplaces and the creation of the brochure. MekoS aimed to enable people with intellectual disabilities to make self-determined decisions about participation in subdivided stages of a research process. The brochure consists of a part in Easy-to-read, which is addressed to people with intellectual disabilities, and a part in standard language, which is addressed to

researchers. The booklet is reversibly bound. An enclosed glossary explains terms that have been identified as relevant by the employees of the Workshop for Disabled People. In the part of the booklet that is addressed to researchers, text templates as well as information on communication with people with disabilities can be found. The text templates were developed by the participating researchers and employees of the Workshop for Disabled People according to the rules for Easy-to-read of *Inclusion Europe*.[9]

Our Work

At the beginning of the project, the scientists were coached for the interaction with people with disabilities through training units. In the first seminar they received general information about different types of disabilities and the respective communication specifics. The topics were hearing and deafness, visual impairment and blindness as well as physical disability with wheelchair use.

After the theoretical introduction, the participants could take part in an excursion to upskill self-awareness: Mundane tasks were to be completed in groups of two. One person was simulated to be blind or in a wheelchair, the second person was an accompanying. The roles were swapped after the completion of the assignment.

In a blindness simulation, participants had to withdraw money from an ATM. The first problem already occurred when they tried to find the headphone plug-in, which is necessary to enable the voice output of the machine. The still visually impaired participants were also challenged to buy a tram ticket. The groups that were travelling in wheelchairs were tasked to buy a coffee to go.

Most important was the subsequent reflection. The scientists were impressed and touched by their experiences and insights into the daily challenges of people with disabilities.

The second seminar focused on Easy-to-read language and intellectual disability. In this seminar, the legal framework for Easy-to-read, its history and the guidelines of *Inclusion Europe* were presented. The researchers were educated in Easy-to-read by developing a text which helped them introduce themselves during their first visit to the Workshop for Disabled People.

Next, the scientists visited the Workshop for Disabled People Noris Inklusion (WfbM). The MekoS project was presented to a group of employees there. These employees had been briefed by a member of the workshop's social services department about the purpose of the project and could decide voluntarily for or against participation. The workshop council was involved in the decision making process from the very beginning. After getting to know each other and introducing themselves, the workshop employees showed the scientists their workplace - a printing shop with various printing machines and everything needed to produce print media. The brochure that would be created over the course of the next few weeks would be printed using the machines of the workshop as part of the cooperation.

Due to the fact that both groups were well prepared for the other group, everyone was quickly in exchange and dialogue. Four employees of the workshop decided to continue working on the project. They were accompanied at all further appointments by a member of the social services department. This was important so that the workshop employees always had someone close at hand who they could trust in new situations and unfamiliar surroundings.

At the next meeting, the employees of the workshop for disabled people visited the Institute for Empirical Sociology. They were given a tour of all the offices, the library, the copy room and the servers, and each member of the institute's staff shortly explained their own projects. A common break had been prepared by the student assistants of the institute. Based on the assumption that breaks play an important role at congresses, the breaks and the provision of snacks were already taken into account in the project planning. It was impressive to see the commitment of the student assistants. Eating habits

and food intolerances were discussed – in non-complex language. One student assistant, for example, began to address the question of whether it was possible for people with intellectual disabilities to choose a special diet such as veganism for themselves, and how employees of a Workshop for Disabled People could implement it.

All further meetings took place in the rooms of the Institute for Empirical Sociology. That was, above all else, the wish of the WfbM employees. The common breaks after the meetings were soon attended by all the present employees of the Institute, even those not involved in the project. In this way, scientists from other areas were also able to gain experience in dealing with people with intellectual disabilities.

The German law on guardianship has many levels and is much discussed in all its complexity. Self-help for the disabled, politics or research are just some of the addressed areas. In MekoS, a lawyer, who also serves as a guardian for people with disabilities, hosted a two-part seminar on care law. The seminar was inclusive and all employees of the institute had the opportunity to participate, the information being presented with the help of case studies. Care and guardianship are part of the everyday life of the employees of the Workshop for Disabled People; thus, they were able to enrich the abstract topic with their personal contributions.

An especially controversial question came up: Should people in care be allowed to decide for themselves whether they want to participate in a research project or should the consent of the guardian be required? A legal assessment of the issue clarified that people in care should decide for themselves whether they participate in a research project as respondents or not. The lawyer present backed this by referring to the constitutionally guaranteed right to freedom of expression.

Textvorlagen

Projektbeschreibung

Ziel einer Projektbeschreibung ist es, über alle relevanten Dinge eines Projektes zu informieren. Wichtig ist dabei, dies kurz, prägnant und verständlich zu tun.

Folgende Tabelle dient der Orientierung, welche Inhalte in einer Projektbeschreibung enthalten sein sollten.

Inhalt	Erläuterung
Wer	Name der Forschungseinrichtung Name der Mitarbeiter/innen
Barrierefrei	Nutzung/Gebrauch ohne fremde Hilfe möglich
Welches Projekt	Name des Projekts
Was	Darstellung des Forschungsvorhabens (in einem Satz)
Forschungsdesign	Vorgehen bei der Projektumsetzung, inkl. zeitlicher Umfang
Freiwilligkeit	...der Teilnahme
Anonymität	Wahrung der Anonymität
Projektansprechpartner	Name, Telefonnummer und Mailadresse
Projektpartner	Name des/r Ansprechpartners/in

Figure 1: The matrix for the project description

Another part of the project was to decide which explanations should be written in Easy-to-read language. The workshop employees were taught about the ideal typical sequence of a research process

[11]. They were already familiar with individual steps from earlier in the MekoS project, from the tour of the institute and from the stories of the researchers in the personal conversations, which always took place in between seminars or during the breaks.

In the end, they asked for three text templates in Easy-to-read: a project description, a declaration of consent for participation and a declaration of consent for the use of photos, film and sound recordings.

All parties involved felt that the declaration of consent, which respondents have to sign before interviews, should be written in Easy-to-read. The employees of the Workshop for Disabled People repeatedly pointed out that it also would be best to keep it short. An additional explanatory document was rejected. However, it was very important to the employees that the declaration of consent could be discussed in depth with the researchers or interviewers before or during the completion of the document. This should serve to create the opportunity for the employees to ask questions because personal interaction seemed more important to them than written explanations.

Einverständniserklärung

Nachname	Vorname

Ich bin über das Ziel der Studie _____ informiert.

Ich bin über den Ablauf der Studie X_____ informiert.

Ich bin damit einverstanden, dass alles, was ich bei der Befragung
- sage oder
- aufschreibe

von _____ wissenschaftlich bearbeitet werden darf.

Alle Daten über mich werden anonymisiert.

Und das, was ich gesagt oder aufgeschrieben habe auch.

Anonymisiert heißt, man kann nicht mehr erkennen, welche Person was gesagt hat.

Ich nehme freiwillig an der Studie teil. Ich weiß, dass alle Angaben nur für die Wissenschaft verwendet werden. Die Ergebnisse der Studie werden anonymisiert veröffentlicht.

Ich weiß, dass diese Erklärung bei _____ aufbewahrt wird. Ich weiß auch, dass diese Erklärung vernichtet wird, wenn die Studie fertig ist.

Datum, Unterschrift

Figure 2: The declaration of consent

The document on the use of photos, film and sound recordings was designed after the special request of the WfbM employees. Declarations of consent for the use of photographs are becoming increasingly important with the ongoing debate about data protection. One participant was able to share his experiences on an event where he had signed such an especially tailored declaration. This document is designed in a way that it can serve as a template for events.

Textvorlagen

Nutzung von Foto-, Film- und Tonaufnahmen

Nachname	Vorname	Geburtsdatum

Ich bin damit einverstanden, dass _____ Foto-, Film- und Tonaufnahmen für seine Öffentlichkeits-Arbeit nutzen darf.

Die Aufnahmen dürfen gedruckt werden.
Sie dürfen auch im Internet veröffentlicht werden.

Ich verzichte darauf, dass mein Name genannt wird.
Ich bin jedoch damit einverstanden, wenn mein Name genannt wird.

Diese Einverständnis-Erklärung gilt ohne Beschränkung auf die
  - **inhaltliche**
  - **zeitliche und**
  - **räumliche Nutzung.**
Sie gilt also „für alles, immer und überall".

Ich kann diese Einverständnis-Erklärung schriftlich widerrufen.
Das kann ich immer machen.
Ich muss das schriftlich machen.
Ich kann mir dabei helfen lassen.

Datum, Unterschrift

Figure 3: The document of consent for the use of photo, film and sound recordings

In the discussion about where in the brochure the developed documents should be included, it was important to the WfbM employees that the templates were placed in the standard language part which is addressed to the researchers because they are the ones who first work with the documents. Another reason for this placement was the concern that if the templates were included in the Easy-to-read section, they might be overlooked by scientists.

Some of the project funds went into the graphic design of the brochure. Responsible for that was a social work student who had experience in graphic design and in Easy-to-read language. She participated in all the meetings. From the beginning, there was a consensus that photos were not suitable. Drawings, as they are used in many Easy-to-read publications, were rejected by the employees of the Workshop for Disabled People because they evoked the association of picture books for children. Pictograms, on the other hand, were considered appropriate. It was especially important to the WfbM employees though to avoid an abundance of pictorial elements. Again and again they highlighted that the booklet was not a picture book for children, but a brochure for adults.

The WfbM graphic designer attended the last meet-up in order to create the final design. The workshop staff (supported by the social service employee) explained the brochure and the desired procedure to follow. Based on that overview, the graphic designer could develop her own layout design. Her suggestion was to dispense with any form of symbols and pictures and instead work with colorful highlights that would help the clarity of structure. This proposal was accepted and the colors were determined together. The employees of the workshop wanted to avoid too many colors in order to keep up a design that was aimed at adults. The color blue was agreed upon very quickly because it

is part of the *Inclusion Europe* logo. The second color, based on the wish of one male WmbF employee, was supposed to look "solid". Everyone agreed with grey.

When eventually the graphic designer presented the new design, it became apparent that the color-guided layout was much more popular among the workshop employees than the design that used pictograms.
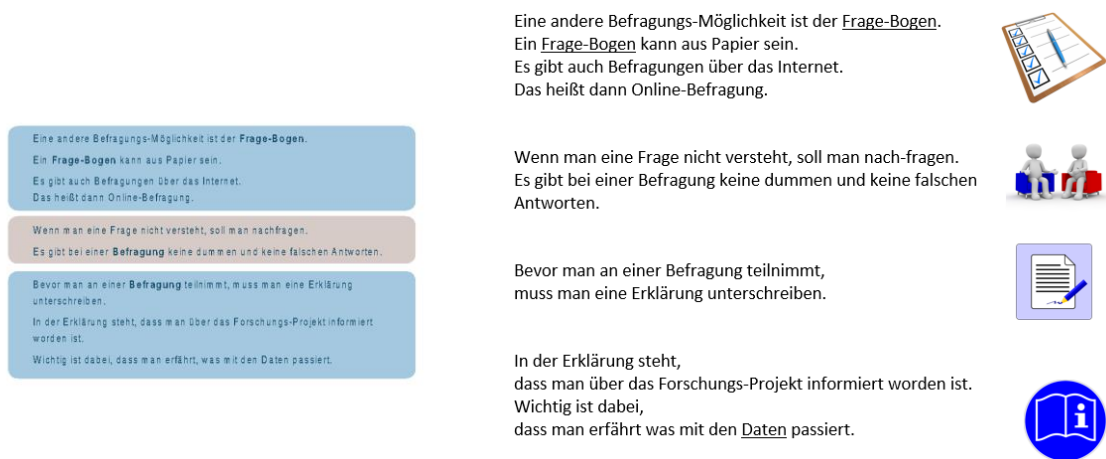
Figure 4: On the left: One page of the MekoS brochure with color highlights. On the right: The same page of the MekoS brochure with pictograms (previous design).

In a poll, all the employees of the Workshop for Disabled People voted for the layout with color highlighting and without pictograms.

Conclusions and Possible Next Steps

Research by Bock has shown that texts that include pictures are better accepted by people with functional illiteracy as well as people with intellectual disabilities. However, in Bock's study, participants initially opted for texts without images. Subsequent surveys showed that by doing without pictures, the participants wanted to express their self-image as competent readers [5].

To date, there are no empirical studies that have taken layout into account by using color highlighting. This desideratum should be closed. The question to be further explored is whether color-guided structures have a positive influence on the textual understanding of people with intellectual disabilities and at the same time maintain the self-image of the competent reader.

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Implementing New Technological Devices in Social Services: Introducing the miTAS Project

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Abstract

People with disabilities belong to a vulnerable target group and are affected by inequalities in many regards, including digital participation. New technologies, such as applications on mobile devices, can improve vocational skills, and increase the chances of participation in working life. However, many of these applications are not used in the long term, for example because of decreasing motivation, barriers in implementation or lack of knowledge. The miTAS application, which provides step-by-step instructions for working tasks, is examined as an example to show, (1) which pedagogical and didactic methods can be used to introduce new technologies in facilities for people with disabilities, and (2) how the acceptance of new technologies can be improved. 18 semi-structured interviews with employees of facilities for people with intellectual disabilities were conducted to shed light on these two aspects. The results indicate the importance of framing (e.g., time frame for familiarization, infrastructural frame), of perceiving an added value by using the new application, of support in case of problems, as well as engagement and commitment to use and try the application. Based on these results, supplementary material such as videos, presentations or checklists were created, as well as templates for different tasks, and best-practice examples. Our approach and adjustments are presented in this paper.

Introduction

In early 2020 the COVID-19 pandemic changed daily life. Due to legal measures (i.e., curfew, contact bans) digitalization processes became more dynamic. Face-to-face meetings were changed into virtual meetings, people have started working in home offices, and sports courses have been increasingly streamed online. The willingness in society to try new technical and digital possibilities is higher than ever. But "[t]he digital revolution" [1] had already begun before the COVID-19 pandemic started. A recent study of January 2020 indicated that more than 4.5 billion people worldwide use the Internet frequently, which corresponds to a share of almost 60% of all people worldwide [2]. Digitalization enables us to stay connected, to keep on working, shopping, and administrating. This revolution is not over yet. Massive developments are being promoted (e.g., autonomous systems, Internet of things, and artificial intelligence [see 1, 3, 4], and "it can be assumed that their importance will increase significantly in the near future" [1]. Despite progressing digitalization and arising opportunities, not everyone has the same chances to be part of this development. "The differing use of digital media often results in different participation opportunities within important and scarce social resources. Wealth, education, (social) security, and health, as well as individual autonomy, can be assigned to these resources" [5]. Social inequalities, for example resulting from inadequacies of access to the Internet, affect the social participation of each individual.

In Germany, 14% of society do not use the Internet [6]. Elderly people, prisoners, unemployed people, people with disabilities, and especially people with intellectual disabilities are more likely to be digitally disadvantaged. Among many others, people with intellectual disabilities are often lacking access to the Internet and digital devices [7], to (digital) education and opportunities for media literacy acquisition [8]. Also, disadvantages are identified in the area of employment. According to the National

Longitudinal Transition Survey-2, only 51.8% of people with intellectual disabilities are gainfully employed [9]. Increasing employment by enhancing skills and media literacy would increase the independence of people with intellectual disabilities [9], since employment and living situations are "merely two post-school variables by which to judge quality-of-life outcomes" [9]. Using technology as "instructional support for teaching chained tasks in the areas of life skills and vocational/employment skills" [9] can provide valuable ways to promote self-management, self-instruction and enhance self-determination of these people.

Initial research focusing on mobile technologies figured out that these technologies are well suited to support people with disabilities at work [10, 11]. Despite processing opportunities, various barriers (e.g., infrastructure, religious and traditional understanding of welfare) exist in social services, which arise as barriers for using new technologies [12]. However, the potential of new technology (i.e., smartphone or tablet applications) is still a new research field in this area. So far, only a few projects [13] have focused on people with intellectual disabilities and the improvement of their employment. Andreassen et al. (2020) developed an intervention for patients with cognitive impairment in three rehabilitation clinics in Sweden [14]. Here, "an Interactive Digital Calendar with Mobile Phone Reminders (RemindMe)" was developed to enable the clients "to take the initiative and to plan, structure, and organize everyday life as well as to remember to carry out planned activities" and to increase autonomy. Besides, other studies focused on tablets to improve the social and personal skills of elderly people or people with disabilities [15], for example by using social media (e.g., Facebook) [16] or using an individualized multi-sensorial smartphone app to enhance independence when traveling and for orientation [17].

Also, several intervention studies survey the use of different technologies to promote activities in specific areas of life (e.g. [9], [18, 19]). However, those intervention studies often do not propose an overall concept for the utilization of the technology, although the use and efficacy of the respective technology is examined. We strongly suggest that mobile devices enable people with intellectual disabilities to learn more independently and increase their motivation to manage their working tasks. For this purpose, both, the technology and an educational concept is necessary for the use of technology in the respective setting. Taking into account recent literature and research, we assume that caregivers (i.e., employees, staff members, parents) play an important part in teaching media literacy and providing access to new technologies for people with intellectual disabilities [7], [20, 21]. Therefore, the miTAS project focuses not only on the development of the miTAS application, but also on an educational concept to motivate end-users, caregivers, and staff to use the miTAS application in their daily work. We hypothesize that the first steps in getting to know the miTAS application already have a great influence on employees' acceptance. This paper aims to present results from the first evaluation phase of the miTAS project, which shows experiences in using the miTAS application, and from which further strategies for technology implementation can be derived.

Introducing the miTAS Project

miTAS (*multimedia individual training and working assistance system)* is a project supported by the Federal Ministry of Education and Research (duration October 2019 - September 2021), in which the miTAS application is developed, implemented and evaluated. This application concerns the processes of job training and working, and combines it with a pedagogical and didactic approach for this purpose [17]. The miTAS application supports practical and everyday tasks in different professional contexts and facilities by creating individually tailored profiles for each person of the target group depending on his or her needs. Working tasks (e.g., cleaning desks, sorting laundry or assembling a desk chair) can be provided with self-provided pictures, videos, descriptions, and audio tracks in the form of checklists or step-by-step instructions to address different sensory channels. The miTAS application offers the opportunity to enlarge the interface and to use a read-aloud function. In this way, an attempt is made to design the application as accessible as possible by implementing both the WCAG 2.1 [22] and the

Universal Design for Learning [23] to increase users' participative opportunities. People with intellectual disabilities, as well as caregivers, can create and co-design different tasks. Also, published tasks generated by other facilities, people with intellectual disabilities or employees can be downloaded and assigned to individuals' profiles. Further information (e.g., emergency contacts, employers, and addresses) complete the individual profile. The app is defined by its multimedia usage. Due to its functionality on different devices (smartphone, tablet, laptop) and browser application, miTAS can be used in various contexts and situations. Thus, the application can not only be used to perform logistics tasks in a warehouse or for outdoor gardening tasks, but also on the way to work or for learning.

In addition to the application, the "miTAS media box" offers learning materials (e.g., checklists, videos, descriptions) and, in future, tutorials and exercises. The media box is designed as a website, on which different materials and aids based on pedagogical concepts of station learning [24] are available for all interested parties to familiarize themselves with the miTAS application and its functions. The combination of the miTAS application and the media box enables a blended learning concept [25], which makes it easier to get to know the application and virtually supplements on-site use. Both can be used according to individual needs, level of knowledge, interest, and competencies.

Four partners from the context of vocational training of young adults with intellectual disabilities, and autism spectrum disorder enable the use and research of the miTAS utilization in their facilities in Germany.

Three evaluation phases are planned in the project. The first evaluation took place in November and December 2019. It focused on the pedagogical and didactical approach to implement the miTAS application in the facilities. The first evaluation aimed to find out how the application was introduced by the project staff in the facilities and how they tried to motivate their colleagues to deal with the new application. Therefore, the research questions of this paper are:

1. Which pedagogical and didactic methods have been used by the project staff to introduce the miTAS application in the facilities?
2. How can the employees' acceptance of using new technologies be achieved in the long term?

To answer the research questions, semi-structured interviews were conducted with employees of the facilities. A total number of 18 employees took part in the interviews which lasted between 20 and 40 minutes. All employees were informed about the project and the data protection regulations in advance. The clarification letter and the consent were reviewed and approved by an ethics committee of TU Dortmund University. All interviews were recorded, transcribed [26], and anonymized [27]. The software Atlas.ti 8 was used for the evaluation of all interviews.

The interviews consisted of four topics. The first topic served as an introduction to the interview. Questions were asked about the institution and the working context. The second topic aimed to find out about the employees' attitudes towards the use of digital media and asked for an assessment of their own media literacy. Afterward (third topic), questions about the miTAS application were asked. Here, the focus was on the motivation of the employees to use the miTAS application and the analysis of pedagogical and didactic familiarization. The fourth topic offers an outlook, in which the employees could express their wishes regarding further use and work with the application.

Results from the First Evaluation Phase

Following the process of inductive content analysis [28], categories were derived from the transcripts in an open coding process [29]. After finishing the content analysis, 15 categories were identified. This paper presents four out of these 15 categories, which contribute to answering the research questions.

Monitoring the First Steps – Getting to Know the Application

The employees were taught by miTAS team members in several phases. In the first phase, short personal discussions took place between the project staff and the employees. These were mostly spontaneous discussions in which the employees were briefly informed about a new project in their facility by the miTAS team members. They also talked briefly about the miTAS application without getting too specific. In the second phase, information events were organized by the project partners to inform the employees about the miTAS project in their facilities and to give a brief demonstration of the usage of the miTAS application. The event aimed to arouse the interest of the employees, who were asked to test the application together with their clients, i.e., people with intellectual disabilities. After the information event, some employees volunteered to try out and test the application. For those employees, a workshop was held by the project staff (phase three). Here, employees first gained experience with the miTAS application and tried different functions. Afterwards, the employees were instructed to try out and test the miTAS application together with their clients. In this phase, the employees were on their own for the first time. While the employees continued learning by themselves, they had to develop a concept to introduce the clients to the miTAS application.

Improving the Didactic Approach - Evaluations by the Employees

In the interviews, the employees were asked about their familiarization with the miTAS application. 17 of the 18 employees rated the familiarization in the various phases as very good. Improvements were mentioned concerning the time intervals between the various phases: "There was an information event. That was good! But the time between the information event and the workshop was too long" (employee 16).

In addition to hints for further pedagogical and didactic arrangements of the workshops, it could also be noted that in the last phase, i.e. the phase in which the employees should continue to work independently with the application, problems arose. The interview quotes showed that working with the miTAS application stagnated from this phase onwards. The employees stated that their last application usage was a long time ago. Having not enough time for familiarization, difficulties in operating the application and missing benefits are cited reasons for this stagnation: "Working with the app is very stressful at the beginning. So, I think the cases where miTAS improves our work are not that frequent. It is quite an effort to get to know this app" (employee 1). However, the employees also mentioned many ideas and suggestions for improvement to counteract the unfavorable framework conditions and the low perceived benefits.

Raising Acceptance among Employees when Using the miTAS Application

Suggestions to improve acceptance among employees include first and foremost task templates that can easily be adapted and edited. With the application, it is possible to create well-elaborated tasks, copy them and adapt them to one's own needs. For example, a well-elaborated cake recipe can be taken as a basis and adapted to one's own wishes (e.g., new ingredients). Such a template saves a lot of time for employees and clients.

Furthermore, the employees would like to see best-practice examples of the application and videos to illustrate how to use it. Such best-practice proposals should show how people with intellectual disabilities work and deal with the application. In these examples, the respondents expressed wishes for quotes from short interviews with the clients as a way of highlighting added value for the use of the application.

To sum up, the employees evaluated a phased familiarization with the miTAS application as very positive. Suggestions for improvement were made regarding the duration of the workshops (phase three) and the intervals between the offers in the phases. The fourth phase, in which employees have

to work independently with the application, is problematic. Time problems in combination with a high complexity of the miTAS application and a perceived low benefit lead to a low motivation to continue working with the application on their own. As a result, the miTAS application is rarely used anymore. This is an important insight to further adapt the pedagogical concept and to take up the suggestions of the employees from the interviews as hints for further improvements. However, hints for a successful implementation of new technologies could be derived from the interviews.

Discussion and Implications

The results show that the employees` acceptance is not always high enough to ensure long-term use of the miTAS application. But if the employees are supported in using the app by colleagues or facility management (e.g., providing time, giving space), they would be willing to use the miTAS application. As soon as the employees are asked to deal with the miTAS application on their own, the acceptance is not high enough. The results of the first evaluation phase showed various reasons for this. First, the miTAS application was perceived as too complicated to use. Moreover, the employees criticized that there was not enough time to get to know the app and its functioning due to time concerns for familiarization. Furthermore, they could not see any added value in using the application, hence their motivation to invest time and effort in that app was low.

In the first industrial revolution, technical progress already led to protests [30]. So, the acceptance of technology is not a new or innovative topic. Acceptance means that an individual has a positive attitude towards an object. Acceptance cannot be forced and is shaped by individuality [30]. A positive attitude usually develops over different acceptance phases, which include an attitude phase, action phase, and usage phase [30].

In order to understand the employees' attitude towards the miTAS application, it is necessary to take a closer look at these acceptance phases:

1. attitude phase: The employees are confronted with a new technology. The advantages and disadvantages are weighed against each other and a preliminary evaluation is made.
2. action phase: Based on the provided information, the innovation is dealt with more intensity.
3. usage phase: The new technology is used and reassessed.

Research on technology acceptance indicated various factors (perceived usefulness, ease of use, job relevance, enjoyment of use) that influence acceptance [31, 32]. In regards to the above-mentioned intervention studies, similar results could be identified in the implementation of new technologies in various settings.

Ismaili & Ibrahimi (2017) examined the potential of assistive technologies using the example of smartphones and tablets to support students with special needs [33]. They found that a motivational environment plays an important part in the formation of a positive attitude towards a technology: "a supportive family, a competent instructor and an affordable technology would have a positive impact on special needs students" [34]. Lee & Shin (2017) investigated technical aspects of smartphones as an example of smart products and found that the specific characteristics of a technology (i.e., adaptability, multi functionality, ability to cooperate) significantly influence the perceived usefulness of a technology, and therefore are crucial for its acceptance [34]. Maiorana-Basas et al. (2014) were also able to show the importance of perceived usefulness of a technology for adults with hearing impairments [35]. Finally, Ahmed (2017) was able to prove that, in addition to the technical characteristics of technologies, the skills of the users also play an important part in the acceptance of these technologies [36]. If, for example, a user feels insecure or "too stupid" for usage, the attitude towards the object can easily become negative. The insights gained from these studies as well as the theories of technology acceptance research can provide clues as to why acceptance of the miTAS application was still very low among the employees surveyed.

Referring to the evaluation mentioned above, further discussion approaches and implications can be worked out. In the first evaluation phase, short personal discussions were held with employees. As these were described as spontaneous discussions, it can be concluded that they were not prepared in terms of content. In this case, it would have made sense if the employees had received information about the miTAS application in advance. For example, informative flyers or advertising material, which could have been sent by email, would be conceivable. In this way, the employees would have been prepared for a new technology being tested in their facility. To improve this phase, the project team has started to create informative (advertising) material. For example, an image film about miTAS was created and a flyer was designed to provide initial information. These materials are available in the media box.

In the second phase, an information event was organized. Each project partner organized this event independently and compiled the material for it. This phase was perceived as very helpful by the employees. The organization of an event like this is therefore a good way of providing information and arousing interest. In order to improve this phase, the project team has developed a standardized presentation for all project partners. This presentation includes a short demonstration video about the miTAS application, which addresses the added value of this application in different contexts and situations, and shows the suitability of miTAS to perform different tasks. It was illustrated, for example, by quotes from interviews of participants with learning difficulties.

The information event was followed by a workshop phase, in which the employees could try out the miTAS application and learn about its functions. In order to improve this phase and to promote the independent further development of the application, a workshop guide was developed, which leads through the workshop with tasks, guidelines and exercises, and finally releases the participants with very concrete tasks for further work. For example, one task for employees and clients is to reflect cooperatively on which skills they want to learn or improve through the application, which tasks they have difficulties with and how these can be improved by using the miTAS application. The materials for this reflection can also be found in the media box. Furthermore, the workshop guide points out the method of coffee lectures, which can be held in the facilities at regular intervals and which encourage to continue working with the miTAS application.

From the experience gained in this project and the results of current research, some of the aspects mentioned here can be generalized and summarized. Particular aspects manifesting as prerequisites for implementing new technological devices are presented in a short summary as follows. These can likewise serve as a guideline for implementing new technologies in different contexts. In general, different framework conditions have to be considered, as well as prepared, discussed, and, if necessary, adapted.

Framework:

- *time frame* (e.g., when and to which extent per day can the new technology be used? How long does the whole implementation process take? How can long-term planning and a contingency plan look like?)
- *physical frame* (e.g., how can a secure and appealing environment without distractions and pressure be created?)
- *personnel frame* (e.g., who is involved in the implementation process? Which members of the facility? Who will be a contact person or an emergency contact?)
- *technological / infrastructural frame* (e.g., how many hardware and software devices are needed and available? To which extent is wireless network needed and to which extent can it be used?)

Establishing these frameworks creates the prerequisites for successful implementation and a gainful common project. Besides these basic requirements, different aspects contribute to this aim, too.

- *support* (e.g., who can help to deal with problems? Does the facility management and employees support the implementation process, too?)
- *engagement, commitment & involvement* (e.g., how can the new technology be implemented together with, for and by everyone? Are the participating individuals interested? How can a positive attitude towards new technology be maintained?)
- *motivation* (e.g., how can the participating individuals be motivated (short- and long-term)? What is the added value when using the new technology and how can it be illustrated and apparent? How can modest success experiences be created?)

For a long-term implementation of new technological devices, for example applications, decisions have to be made, and working processes have to be adapted, which means a lot of effort and arrangement. Only if the framework is provided, well structured, organized, and adaptable for individual needs, as well as if internal motivational aspects are addressed, the implementation process can be successful.

Conclusion, Planned Activities and Outlook

The miTAS project is currently on its half-way stage. Two further evaluations are planned, either in digital form or in the actual field. The project team will take up the evaluation results and further develop the didactic concept. At the same time, materials are created which address the deficits mentioned above (time, personnel resources). The second evaluation phase will have these further developments evaluated by the employees. Further research questions deal with how the acceptance of the employees in social services can be improved and which framework conditions are needed.

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Can the Use of Augmented Reality Help People with Learning Difficulties Succeed at Vocational Training in Home Economics?

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Abstract

This paper deals with digital learning assistance in vocational education of people with learning difficulties. Digital media are used as core elements to examine augmented reality (AR) based vocational learning for people with learning difficulties in the field of home economics. The article describes the opportunities and challenges of digital learning approaches for these people and takes a look at the didactical as well as the technological level. The presented concept and implementation is part of the ongoing R&D-project LernBAR (Learning based on Augmented Reality).

Introduction

Digital media can support vocational tasks in daily life. People with learning difficulties benefit greatly from visual content and learning opportunities that are close to the actual workplace and -situations. Furthermore, digital instructions can be used individually and have great potential for heterogeneous learner groups since it allows differentiation between the learners. One innovative digital learning method is learning based on Augmented Reality. When using AR additional information (videos, audios, texts, pictures etc.) is presented with the help of a mobile device (glasses or tablet) in the real environment complementing the view of reality. Objects or markers can be recognized by the system to call up environment related digital artefacts as additional information directly at the workplace. Learners are guided and supported individually through the learning process, providing motivation, allowing repetitions, adjusting of learning speed, etc. AR specifically relates the learning experience to the actual workplace in reality. [4]

Home economic services are important in the working fields of gastronomy, hotel industry, social services as well as health care and care for the elderly. Although training figures in this field have reduced over the years, home economic services are gaining increasing importance due to demographic and social development in society. [3] Since the increasing digitization continually causes changes in work- and everyday life, the vocational training in home economic services should not be an exception. A modernization of the training concept using innovative digital learning methods like Augmented Reality could increase the appeal and future sustainability of the vocational training. [4]

Home economic services represent a big part of vocational training for people with learning difficulties. Therefore, three institutions that offer vocational training in this field are supporting the project as partners (Josefsheim Bigge gGmbH, Hannoversche Werkstätten gGmbH, Lebenshilfe Erfurt gGmbH).

The project examines how Augmented Reality content can be developed for people with learning difficulties on a technological and didactical level. Therefore, the aim is to realize AR-based learning at the workplace, as well as establishing further learning opportunities via an e-learning platform. Furthermore, a new adjusted curriculum for vocational training in housekeeping will be developed and tested during the project. The new innovative training concept aims to help trainees to gain a qualification for the regular labour market and benefits people with and without disabilities alike.

Learning Based on Augmented Reality

Learning with Augmented Reality especially supports learning at the workplace: Compact learning content can be called up at learning stations via visibly placed markers (similar to QR codes) using gestures or voice commands. In cooperation with the practice partners contents that are most difficult for the learners in the vocational training were identified. On the basis of these analyses, the AR learning stations were set up at the workplace taking the needs of the target group into account. The learners are supported through compact action-guiding information tailored to the work process. When using AR glasses the hands are free to implement the instructions, which are displayed as images, video or text. The real working environment is thus enhanced by virtual information. The retrieval of AR content is also implemented for tablets. In contrast to AR glasses, tablets are used more intuitively, since many learners already know how to use a smartphone. Furthermore, tablets are less expensive, so the partners can purchase more and thus equip more learners with it.

Fig. 8: Use of tablet and AR glasses in practice

In addition to the compact AR learning stations (for glasses and tablets), a learning platform on which learners can prepare for their exams, is also being realized. The learning platform provides learning videos, work assignments, exercises and exchange opportunities. The learning platform can be called up with different devices. LernBAR thus focuses on holistic learning scenarios that combine learning at the workplace on the one hand and work process-oriented learning on the other.
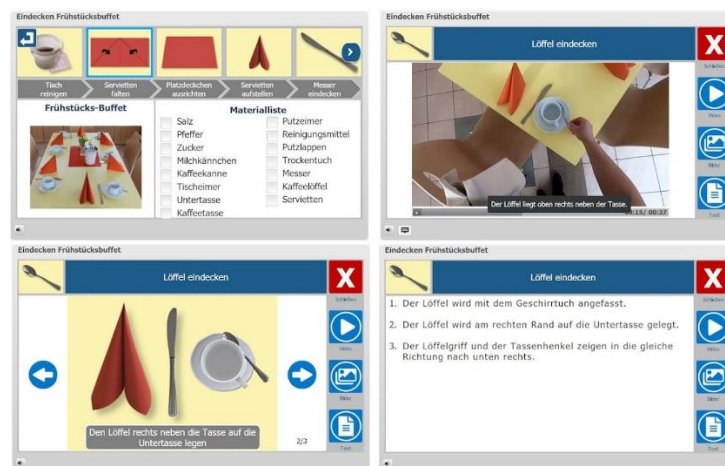

Fig. 2: Impressions e-learning platform. From left to right: Overview of the learning scenario, video content, picture-gallery, text.

Method Used

Methodologically, the project is divided into 6 phases. In Phase 1, the Curriculum-Development, an adjusted curriculum for all partners is designed. Therefore, an analyses of literature and interviews with the partners are carried out in the first step. Then a document analyses of existing curricula from the practice partners is used to develop the adjusted curriculum. The curricula are merged to one unified curriculum which also includes digital learning. [6] Furthermore, issues in the learning process reported by the partners during the interviews are guiding the selection and design of the learning cases.

In Phase 2, the Work-process Analyses, researchers from TU Dortmund University are visiting the partners on site to develop the learning cases for the AR and the e-learning course. The work-process analyses include observations, control videos, expert interviews and interviews with trainees. [8]

The development of the learning content, as well as the technical preparation and implementation are included in Phase 3 of the project. The material gathered in the work-process analyses is used to create learning content for the AR learning scenarios and the e-learning platform. On the technical side an application for displaying the learning content on glasses and tablets is developed and the e-learning platform is adapted to the needs of the project.

Phase 4 is the Testing-Phase, during which the AR learning stations and the e-learning scenarios are tested with the target group using observations and surveys on acceptance and usability. The results from the testing allow target group specific adjustments on the contents and technology which are realized in Phase 5, the Re-Design.

The last Phase to achieve in the project is Phase 6: Implementation. Therefore training courses and guides/manuals are developed. Furthermore future-workshops and network meetings are provided, as well as participation in congresses and publishing the results.

The project strives for results in practice as well as in research. The desired results in practice include 30 AR learning stations at the workplace, that work hybrid on AR glasses and tablets. The AR learning stations are placed in different home economic settings and present information in a particularly compact and practical way so they can be used in the work process. On the other hand, the 30 learning stations are embedded in thematically corresponding learning scenarios on an e-learning platform.

The e-learning is offered to support studying at home, deepening knowledge and preparing for exams. In addition to the learning content quizzes and exercises are offered so the learners can test their level of knowledge. The learning scenarios can be accessed anytime, from anywhere and with all mobile devices.

Goals in research are amongst others to gain practical research data on learning and teaching with digital media, especially AR and insights on acceptance and usability for people with disabilities. The findings of the project can also be used as preparation for a scientific transfer that includes further areas of life, as well as further target groups.

Project Challenges

So far there has been little research on how AR-based learning can be designed in an inclusion-oriented way, therefore this is a central task of the project. The challenge is to make the application as low-barrier as possible to make it accessible to a heterogeneous user group. However, new technologies and the associated requirements can also lead to new barriers. Especially in the case of content for people with learning difficulties the dimensions of understanding must not be ignored [2]. Since this target group may not be able to abstract content sufficiently, alternatives to e.g. auditory and visual content must always be offered to address different channels of perception. [1, 9] The development of digital learning approaches must therefore be realized in a practical way and with the systematic

involvement of the target group. So far, it is clear that AR glasses are only suitable for short work sequences, as they cannot be worn over a longer period due to their weight [5]. Furthermore, when designing the learning scenarios, a balance must be found between self-controlled learning and guidance in order to avoid causing excessive demands on the learners. Also the intended usability of the AR application is central in the project. In addition to accessibility via tablets, training and teaching staff will be able to create AR learning content themselves using a content management system.

Transfer and Further Development

The marker-based AR application makes it possible to offer learning content beyond the project duration at different working locations, since markers can be printed and attached as required. The project therefore not only promotes vocational capacity to act during the vocational training, but also considers the transfer to other locations (e.g. other companies). Since the AR technology is being constantly developed and improved it is expected to have great impact on future work- and everyday life [7]. Overall, digital learning approaches like this have great potential to support people with learning difficulties in the learning process. This potential can unfold if learning applications are prepared in a user-centred manner and information is shown by means of descriptive, multimedia information along a work process. From a pedagogical perspective, it is advisable not to make full use of technological possibilities, but to prefer low-threshold AR solutions that are easier to understand for people with learning disabilities.

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Personalised AR Instructions to Tailor Cognitive Support During Assembly Work

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Abstract

This study addresses Augmented Reality (AR) by means of a top-mounted video-projector, as a tool to provide cognitive support during assembly tasks in a special needs context. The study's first objective is to compare the effect of three experimental conditions (AR instructions with different levels of detail) on several outcome variables. These are assembly time, error-making, perceived complexity, necessary assistance and variables related to well-being. Next to AR, also paper instructions are included, in view of the study's second objective, which is to compare this novel (AR) approach with the traditional (paper) approach.

With these aims in mind, a data collection is set up in which 100 participants execute five different realistic assembly tasks with different levels of instructional detail. Participants of the study are students from secondary education special needs schools and have weak cognitive skills, some also have a physical impairment.

This study fits within a larger project of which the ultimate goal is to provide instructions that are adjusted to an individual's needs, at any moment of the learning curve. As such, we pursue an adaptive AR system that positively affects the outcome variables as compared to a system that does not enable such personalized support.

The Ultimate Application Idea and the Motivation of this Study

The ultimate application idea concerns rendering augmented reality (AR) instructions of which the level of detail is adjusted to an individual's needs, at any moment of the learning curve. In that way, subjects with lower ability levels could for example be given more elaborate instructions than subjects with a higher ability. In doing so, we aim to provide tailored cognitive support to students with weaker cognitive skills in particular, enabling them to perform better than would have been possible without this personalized AR support. More specifically, we pursue beneficial effects in terms of several other outcome variables as well, such as assembly time, error-making, perceived complexity, necessary assistance and variables related to well-being.

However, before designing personalized instructions, we need to know what the effect is of AR instructions with different levels of detail on the outcome variables. In that perspective, we set up a data collection in which 100 participants execute five different realistic assembly tasks with different levels of instructional detail, which are randomly assigned across all participants and tasks.

In what follows, the theoretical underpinning of our study is described. Afterwards, the state of the art in this area is briefly elucidated. This is followed by the methodology of our study and a description of our future work. Final results are not yet available but we will try to share some preliminary results during the conference presentation.

Theoretical Underpinning

Two main theoretical principles can explain why personalised AR instructions can positively affect learning. The first principle applies to AR and states that people can learn more deeply from a combination of words and graphics than from words only [5]. The second principle applies to the personalised aspect of the instructions and implies that the learning process can be fostered when learners are given just the right amount of support when carrying out tasks that they are not yet able to handle independently. This second principle draws upon the idea of scaffolding [6], [11] notion of the zone of proximal development. These two principles on how to optimally support learners are now elaborated in some more detail.

The first theoretical principle is referred to as the multimedia principles. These principles rely on empirical evidence and are based on how humans process information. Their aim is to optimally guide cognitive processes during learning. The multimedia principles seem to work particularly well for learners with little prior knowledge and few self-regulation [5], which makes them especially suitable for learners with weaker cognitive skills.

There are different multimedia principles that apply to AR and that explain why AR can positively affect learning. A first principle is that AR instructions not only consist of words, but also of graphics, which helps people to process information better. A second principle concerns the spatial and temporal contiguity that limits extraneous load, as instructions are only shown when and where they are needed. AR realizes this by spatially overlaying digital instructions with a physical object. Third, by only showing the relevant information and foreseeing an instructional design that reduces extraneous material, essential and generative information processing can be promoted. This is beneficial, as the human working memory capacity is limited.

The second principle involves personalising instructions (adaptivity) and relies on the idea of scaffolding, in which the level of instructional detail is faded out as a subject starts to master a task. This approach is also in line with Vygotsky's [11] notion of the zone of proximal development. This notion concerns tasks of which the difficulty is situated between what learners could accomplish alone and what they could accomplish (and master) with assistance (described as "scaffolds" by Reiser [6]). This helps to foster learning, by stepwise mentally organising coherent structures and integrating it with pre-built structures from previous assembly attempts (long term memory). When supporting and guiding self-regulated knowledge construction, scaffolds are increasingly important for those learners with weaker self-regulating skills [10]. AR is one of many possible tools that can be used to operationalise personalised instructions.

State of the Art in this Area (Other Projects, Publications, ...)

There exist quite some empirical studies on the use of AR during assembly work. However, these studies typically do not take place in a special needs context. Broadly speaking, when comparing AR to the traditional instructional approach, AR tends to result in mixed findings as regards completion times, and in predominantly positive findings as regards error-making and cognitive load [9].

There also exists quite some empirical studies on using AR in a special needs context, but usually for other applications than for assembly work. In education for instance, AR can yield interesting advantages. A meta-analysis of sixteen single-subject design studies revealed that AR is most beneficial in promoting a subject's learning skills, followed by social, physical and living skills [1]. Another interesting application of AR for special needs subjects is for example the combination of speech recognition with augmented reality technology, resulting in real-time subtitles to assist hearing impaired people (e.g. [3]).

However, studies that investigate the effect of AR instructions during assembly work in a special needs context are very scarce. Nonetheless, there is a study of Korn, Schmidt and Hörz [4] with impaired persons that addresses AR during assembly. In this study, no overall beneficial effects of AR (in-situ projections) as compared to a traditional approach were found. Nonetheless, the study's results suggested that AR was only beneficial for higher performing operators, in that they could assemble tasks faster and made fewer errors. However, cognitively weaker subjects took much less advantage of the AR instructions. Chang, Kang & Huang [2] trained three persons with cognitive impairments for a specific vocational skill: short-order food preparation. Although this is not a real industrial assembly task, it also consists of a pick-and-place routine. In the baseline phase of the study, a system of least prompts (SLP) was used, in which subjects gradually received more intrusive prompts (respectively verbal, gesture, model and physical prompts). The intervention phase made use of simplified QR-codes to provide subjects with AR-based prompting, in which visual cues that represented the required food items were shown on an LCD screen. The results showed that subjects selected and positioned the food in a much more accurate way when using the AR prompts in the intervention phase, as compared to using the least prompts of the baseline phase. What is more, however, is that subjects maintained their acquired skill level as established during the intervention phase in a follow-up test four weeks later, when no AR prompts were used anymore. Seemingly, the AR intervention improved the subjects' skill level.

As regards personalized AR instructions during assembly work, research is scarce as well. There is an empirical study by Westerfield, Mitrovic and Billinghurst [12] of which the results indicate that for novice learners, an AR system providing adaptive guidance can be beneficial.

These promising yet scarce findings demonstrate the relevance of investigating the effect of personalised AR instructions amongst subjects with weaker cognitive abilities during assembly work.

Research Questions

This study pursues the following objectives:

- Investigating the effects of three different levels of instructional detail of AR instructions on several outcome variables. These are assembly time, error-making, perceived complexity and variables related to well-being. For each outcome variable, an interaction terms that consists of the instructional medium and the attempt number is included in the analysis to investigate if and how learning effects differ across the conditions.
- Comparing this novel (AR) approach with the traditional (paper) approach. To this end, next to AR instructions, also paper instructions are included in the study.

This study fits within a larger project of which the ultimate goal is to provide instructions that are adjusted to an individual's needs, at any moment of the learning curve. As such, we pursue an adaptive AR system that adjusts the level of detail of the instructions to the learner in real-time. In doing so, such system attempts to positively affect the outcome variables as compared to a system that does not enable such personalized support.

Methodology

Participants

We plan to collect data for 100 participants, executing five different assembly tasks. The participants are students from secondary education special needs schools (average age around 18 years). Most of the participants have weak cognitive skills, some also have a physical impairment. For now, we have already collected data for 23 participants across four tasks. From September onwards, the data collection is planned to restart.

Tasks and Instructions

The different instructional media are randomly assigned to tasks and to participants, while making sure that each level of detail in AR occurs just as frequently. Given that we are also interested in the learning curves, participants will execute some of the tasks multiple times (up to three times, sometimes more).

Participants are confronted with five tasks (see Figure 2) that are realistic for an assembly context:

- Assembling a wooden bird house;
- Assembling a small car using parts from a mechanical STEM kit;
- Making a thee box, by folding a carton box and filling it with different kinds of thee;
- Composing a set of colour samples that represent different furniture designs;
- Putting together a first aid kit by filling it with different components.

Figure 1: A participant putting together a first aid kit using AR instructions (left picture) and assembling the wooden bird house using a traditional paper manual (right picture).

During each task, a participant is supported by one of the following four instructional media (see Figure 2 for an example applied to the first aid kit task):

- A traditional instruction that is commonly used in daily practice (paper manual);
- An AR instruction, only providing a low level of detail (a limited amount of simple instructions);
- An AR instruction, providing a medium level of detail;
- An AR instruction, providing a high level of detail (many detailed instructions, including pictures, arrows, text, …).
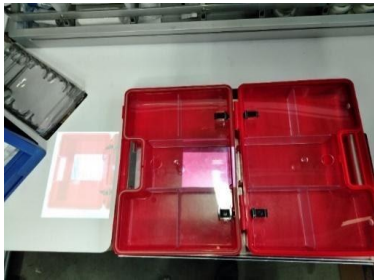
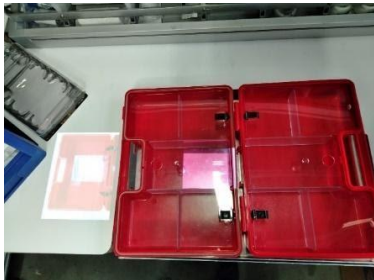| LEVEL OF INSTRUCTIONAL DETAIL	PICKING	POSITIONING / ASSEMBLY
"Low detail" instruction: Does not show pictures nor text nor arrows; highlights which and how many parts should be picked (but does not indicate from which shelf); highlights where the part is to be put/assembled		
"Medium detail" instruction: Shows picture(s) and arrows; Does not show detailed text; highlights important details; highlights which and how many parts should be picked (but does not indicate from which shelf); highlights where the part is to be put/assembled		
"High detail" instruction: Shows picture(s), text and arrows; highlights important details; highlights which and how many parts should be picked from which shelf; highlights where the part is to be put/assembled		

Figure 2: The way in which the different levels of instructional detail are implemented in AR for the example of the first aid kit task. For picking and for assembly, less instructions are given as the level of detail decreases.

The paper instructions include the same steps with the same graphics and text as the AR instructions with a high level of detail, to allow a one to one comparison.

Apparatus

Our study operationalises AR by means of a projective display. This technology yields several interesting advantages over head-worn (AR glasses) and hand-held (e.g. tablet-based) solutions, thanks to its hands-free operation, proven and relatively simple technology, relatively short time required to prepare instructions, and comfortable and safe use [8].

The AR set-up (see Figure 1) consists of a short-throw video projector that displays instructions on a table at which an operator is sitting. Next to this, the projector also highlights the box where parts need to be picked from. Finally, a camera allows to detect movements of hands, which enables feedback loops, for example to indicate when faulty pickings happen.
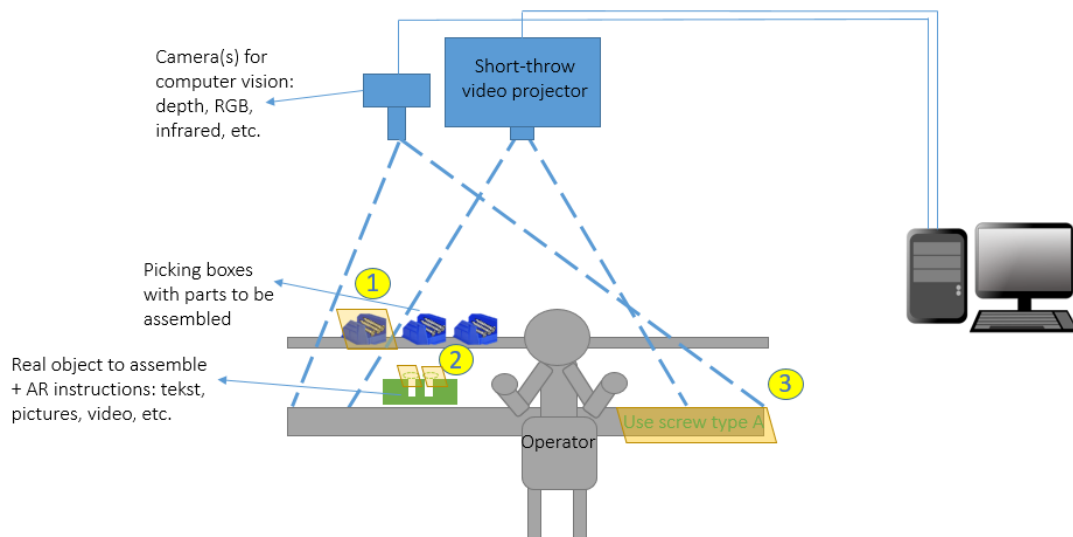
Figure 3: AR set-up consisting of a short-throw video projector that displays instructions on a table at which an operator is sitting. Next to this, the box where parts need to be picked from is highlighted. Finally, a camera allows to detect movements of hands, enabling feedback loops.

Experimental Design and Procedure

First, each participant performs an accustomisation task, to become more familiar with the AR system (e.g. using touch buttons to go to the next step, finding out at which place instructions appear and how they should be understood). Afterwards, the participant consecutively performs the five tasks, of which the order is counterbalanced. In a random way, three of the five tasks are to be executed multiple (at least three) times.

The Predictor and Outcome Variables

These are the different predictor variables and how they are operationalized:

- The spatial intelligence: participants have 5 minutes time to complete a paper questionnaire based on the Revised Minnesota Paper Form Board Test [7]. For reasons of time limitations, the original questionnaire consisting of 64 questions is reduced to 20 questions that span different levels of difficulty. Along with the strict time limit, this prevents the occurrence of a so-called ceiling effect. As the test is a multiple choice one, a correction for guessing is applied.
- The experience with the task at hand, or a similar task: rated on a 4 point Likert scale
- The experience with the AR technology: rated on a 4 point Likert scale

The different outcome variables are operationalized in the following way:

- Assembly time: the total time required to complete an assembly task (in seconds), logged by the AR authoring tool.
- Error-making: the total amount of errors that is visible when manually inspecting the final assembly part.
- Necessary assistance: the number of times that a supervisor needed to help the participant in order for him or her to be able to finish the task (either by explaining something, or by helping to assemble a certain step).
- The perceived complexity, stress, physical effort and competence frustration: these variables are rated on a 4-point Likert scale by means of a questionnaire that partly consists of questions from the NASA Task Load Index (Hart & Staveland, 1988) inquiring physical effort and competence frustration. The questionnaire is further complemented with questions inquiring the perceived complexity and stress. Finally, the questionnaire is also adapted to the target group by reducing

the number of choices from a 20-point to a 4-point Likert scale and by using smileys, which makes it easier for participants to interpret the different responses.

Data Analysis

By systematically varying characteristics of the task and the context (including the amount and kind of support), we can study their effects on the outcome variables of interest (such as performance and well-being). To answer both research questions, time series data from all participants will be analyzed by means of multilevel (or mixed-effects) models that account for the likely situation that the baseline level, the learning curve, and the effects of interventions depend on the participant. By including characteristics of the participants in the model, we will get a better insight in this variation over participants (for instance, the effect of a specific kind of support may be effective for specific kinds of persons, but useless for other kinds of persons). Order effects are accounted for by including the order of a task in the analysis as a covariate.

Future Work

We will continue the data collection from September onwards. After analyzing the data, we will have an idea of the effect of the different AR instructions on all outcomes, and how these effects relate to the traditional approach (paper-based instructions). This information can help us to improve the cognitive support, and to take the next step towards personalized instructions.

We believe that using the AR system will help students to prepare for their future job context, by getting more familiar with digital technologies. In addition, we hope that the system itself will be useful on the job as well, in that it reassures operators, supports them to work more independently, helps them to deal with more complex tasks and reduces error-making.

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ICT to Support Inclusive Education

Universal Learning Design

Accessibility Evaluation of Video Conferencing Tools to Support Disabled People in Distance Teaching, Meetings and other Activities

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Abstract

The current covid-19 pandemic has transferred educational, work and other activities on-line and made it essential to be able to use videoconferencing tools. This raises many issues for disabled people, including the accessibility and usability of these tools. However, studies evaluating accessibility and usability of these tools seem to be lacking and this paper contributes to filling this gap. It has three main contributions: (i) the presentation of criteria to be used in this valuation; (ii) a preliminary study of the experiences of the two disabled authors; (iii) preliminary recommendations for tool developers.

Keywords: video conferencing tools; distance teaching; distance meeting; disabled people; accessibility

Introduction

A wide range of technology has been in use for a number of years to support learning and teaching. Phone and video conferencing were already being used for meetings to a limited extent, both for convenience and in response to global climate change. Some conferences offered distance presentation options. However, the mandatory physical distancing introduced by the COVID-19 pandemic forced the majority of activities to move on-line, at least on a temporary basis.

Learning and teaching, work, meetings, social and leisure activities all moved on-line, often at minimal, if any, notice, giving little or no time to prepare. In the case of education the focus was generally on using technology to present classes and lectures using videoconferencing technologies, often lacking the time to consider the underlying pedagogical issues and the full potential of the technology. Previously Skype was probably the best known and most commonly used tool, whereas now many other tools are being used, including Zoom, MS Teams, Jit.si and Google Meet.

This raises a number of issues for disabled people. These include their access to all necessary hardware, including any relevant assistive technologies, at home, the ability to download any necessary software, access to any required assistance and the accessibility and usability of the tools and all their functions. Where free versions do not provide the full functionality and workplace, or other organisational subscriptions are not available, there is also the issue of being able to afford account/subscription costs. This paper will focus on the accessibility and usability of video conferencing tools. To the best knowledge of the authors, there are no full studies of the accessibility and usability of these tools for disabled people.

The paper contributes to filling this gap. It has three main contributions: (i) the presentation of tools which can be used to evaluate the accessibility and usability of online presentation and video conferencing tools for disabled (and non-disabled) people; (ii) a preliminary small scale study of user experiences with these tools; and (iii) preliminary recommendations for tool developers. It has a particular focus on the educational context since in this area tools and experiences are more generally relevant.

The paper is organized into 6 sections. Section 2 briefly overviews the relevant literature and section 3 presents the methodology. Section 4 presents the criteria and section 5 the results. The concluding section, 6, discusses the results, provides preliminary recommendations and suggestions for future work.

Related Work

There is a wide range of tools to support on-line learning, including video and video-streaming, screen and resource sharing, quizzes, polling, video chat, survey, to favour students engagement, as well as videoconferencing tools, which themselves have a number of features. Research suggests that student satisfaction increases with an increased level of interaction in on-line conferencing systems [1]

The following discussion considers the literature on the accessibility of videoconferencing tools, videos, video chats, screen sharing, and video streaming sessions. In the last few years, videos have been increasingly used as an educational tool, in science, schools, work, and personal study. However, people with single or dual vision or hearing impairments or processing impairments experience barriers to accessing audiovisual materials. In addition, while many autistic people appreciate audiovisual materials, some of them find the dual-channel impossible to deal with.

Both blind and deaf people can use subtitles but the frequently poor quality education of hearing-impaired people, as well as the fact that for deaf signers the subtitles are in a foreign language, may mean they experience difficulties in understanding long or low-frequency words. Deaf singers prefer a sign language version. However, the use of edited versions of subtitles is controversial [2]. An Accessibility Adaptor that translates video subtitles of videos to SignWriting has been tested by the Worldwide Web Web Accessibility Initiative [3]. However, Signwriting, which is a written graphical representation of sign language, is used by a few Deaf people, so not very useful. Audio descriptions of the video can be used by blind people, but are rarely available.

Learning Management Systems, such as Moodle, provides a number of options to access online learning resources and engage in activities, such as quizzes. Studies of their accessibility include [4]. There are also early studies of making e-learning courses accessible to disabled students and teachers with disabilities [5].

An investigation of the usability and accessibility of six popular video call Android applications including Skype, WeChat, Hangouts, Tango, Line and Viber found that none of them was fully accessible for blind people [6]. The accessibility of the Web conferencing tool Adobe Acrobat Connect system has been investigated [6] and the results show that a fair degree of keyboard accessibility is not sufficient for an effective interaction by keyboard and screen reader users.

The International Foundation for Electoral Systems (IFES) has suggested guidelines and good practices for employers for conducting accessible virtual meetings. This includes providing all materials in accessible formats in advance, participants identifying themselves before speaking and speaking clearly and slowly and using live transcription or captioning. A comparative evaluation of Skype (v.8 and Business), MS Teams, Zoom and GoToMeeting based on 10 criteria found that none of them met all the criteria [8].

Methodology

In an educational context, considerably more attention has generally been given to the accessibility and other needs of disabled learners than disabled teachers. This makes it particularly important to consider teachers' accessibility requirements. When teaching through videoconferencing, the teacher has the role of meeting host, as well as participant and therefore needs to be able to carry out all the additional activities required of the meeting host as well as to participate in the meeting. Some tools require

hosts, but not participants to log in and to set up an account if not using an organizational one, whereas other tools, particularly Skype, require everyone to set up an account and log in.

The criteria to be considered in evaluating the accessibility and usability of the different tools have been obtained through a functional analysis involving consideration of the various activities required to both participate in and host a meeting. These key functions were used to draw up an initial list of criteria, which will be developed and expanded in subsequent work.

A preliminary study of a number of different videoconferencing tools was carried out by the two disabled authors. This is based on an analysis of the tools they have already used both for teaching and in meetings, including Google Meet, Jit.si, Microsoft Teams, Skype, Skype for business and Zoom. Most of these tools offer different versions, including web based, apps for PCs and and mobile app-based versions (for Android and IOS operating systems) and in some cases there is the option of phone dial in, but without many of the functions.

The current evaluation is of the web and PC app versions of the tools with phone dialin. The authors plan to carry out an indepth study of web, PC and mobile applications and involving a number of disabled teachers.

Criteria

This section presents the criteria used in the accessibility evaluation. They have been defined on the basis of the main tool functions offered to the user.

Tool Features

Video conference tools such as Skype, Meet and Zoom provide functions for two main roles: (a) host, who creates and manages the video conference (e.g., teacher or group leader); (b) participant, who takes part in a distance lesson or a remote meeting (e.g. student, research partner, group member). Therefore, the following tool functions should be accessible: (I) Joining and participating in a meeting, (II) Hosting (organising) a meeting, (III) Chairing or facilitating a meeting, (IV) Participating, including turning on and off audio and Video; (V) Support for assistance and communication with assistants; (VI) Advanced options; (VII) Setting up and managing an account (if required).

Evaluation Criteria

These functions can be used as the basis of the accessibility evaluation criteria. Many of the functions are required by all meeting participants, whereas some are only used by meeting hosts. The preliminary evaluation is based on a subset of the above functions since there are a considerable number of them. The results are based on the experiences of the two disabled authors of this paper in using these videoconferencing tools from home in teaching and work related and other meetings during the Covid-19 lockdown period. One of them accessed the tools with the Jaws screen reader and the other used phone dial in.

Table 1: List of features offered by the video conferencing tools

I	Joining and participating in a meeting
	Participating without requiring an account Signing in, if necessary Connecting to the meeting Option of audio-only or audiovisual when you use the link Using meeting tools to indicate you want to speak Hearing other participants Speaking and being heard by other participants Using chat
II	Using audio and Video
	Using system tools to mute and unmute your microphone Using system tools to adjust microphone volume Quality of sound Turning video on and off Zooming video in and out Quality of video
III	Hosting a meeting
	Logging in Setting up a meeting Setting up a meeting with cohost(s) Inviting participants to join Admitting participants
IV	Chairing a meeting
	Awareness of participant indications they want to speak using meeting tools Awareness of participant indications they want to speak using the chat Awareness of phone participant indications they want to speak Inviting participants to speak Controlling whether or not the meeting is recorded.
V	Support for assistance and communication with assistants
	Host liaison with cohost e.g. about admitting participants showing powerpoint or other videos for a participant using audio only Support for interaction with another participant Support for captioning Support for sign language interpretation
VI	Advanced options
	Using meeting tools to set up small group discussion in 'breakout' rooms Participating in small group discussions Reporting back to the main meeting
VII	Managing an account
	Other

Results

Due to space limitations the following discussion summarises the authors' overall experiences with the different tools based on the criteria rather than provide details of performance for each of the criteria. The authors are only aware of a phone dial in option being available for Jit.si, MS Teams and Zoom. To

retain a degree of anonymity while separating out the different experiences the authors will be referred to as SR (screen reader user), ASO (author needing to avoid sensory overstimulation) and ND (non-disabled). SR uses a JAWS screen reader and ASO generally uses the internet with colours and graphics turned off.

Google Meet

SR found Google Meet relatively easy to use via Jaws screen reader, but was unable to access the shared content. However, they were disappointed at the lack of a 'Raise hand' function to indicate you want to speak and enable the chair to see the order in which people raised their hands. They noted the host does not have the option of muting all speakers. They appreciated the shortcuts for microphone and videocamera, but considered that some additional shortcuts were required to enhance the interaction.

Jit.si

ASO has both used successfully it and been unable to dial in. They originally thought that the problem was lack of the correct meeting ID, but now think that the meeting may not have been set up to allow phone dial in. This was probably due to inexperienced meeting hosts not knowing how to set up meetings for phone dial in and implies that clearer information is required on the site. Call quality was good on the one occasion they managed to dial in, but they were unable to use the meeting functions from a phone. SR was able to use this tool, but experienced difficulties with the button labels, as they did not provide feedback on their status (e.g. microphone muted or unmuted). They also found that many functions were inaccessible.

MS Teams

SR found interaction with MS Teams quite complex and experienced difficulties in orientation within the user interface. However they found the file sharing option very useful for giving them access to slide content in powerpoint format. The terms shortcuts were more useful in theory than practice, as difficult to remember. ASO has used MS Teams quite frequently to participate in meetings. They have used the phone dial in option successfully, though sometimes difficulties were experienced in entering the meeting ID or password, including through insufficient time being allowed. They have found call quality very variable. In particular, sometimes the sound from other participants has broken up or been lost briefly. Further problems including participants being exited from the meeting for no reason and having to dial or link in again. ASO is unable to access the chat and is unaware of phone options for accessing meeting tools other than un/muting. They have been unable to unmute when the meeting host has muting everyone and this is apparently a well-known problem with MS Teams.

Skype

Both SR and ASO have found that inaccessibility has increased with version 8 and above and regret that older versions cannot be used. SR is able to make and answer audio and video calls, but finds the process difficult and lengthy, as it requires a lot of steps using Tab. ASO used to be able to use Skype and was able to turn the video input off and adjust microphone volume, but did not find it particularly accessible and was unable to use the chat. They also noted that calls involving multiple people could take a long time to set up. They now avoid it. ND has noted that an older friend experienced considerable difficulties in learning to log in to Skype, set up a call and add people to it. ASO has noticed that people of all ages can experience difficulties in adding people to Skype calls.

Skype for Business

This has now been replaced by MS Teams and is not missed. SR has found many of the hosting features are inaccessible. No dial in option is available. ASO was able to use the link and to hear participants

but could not join in the discussion, as no tools were visible (presumably due to being indicated purely graphically) and the default option was microphone muting.

Zoom

ASO has used Zoom both for teaching and for meetings. The site presents too much visual disturbance to enable them to log in and act as a host. They, therefore, use the phone dial in and have successfully used the mute/unmute phone tool. Their negative experiences with Zoom and Skype for Business links have discouraged them from using other links. They have become aware of phone options for indicating they want to speak and meeting host functions, but have not tried them. They have experienced difficulties when waiting for a host to admit them to a meeting due to musak, though muting the speaker and wearing ear defenders reduces the problem. They have asked for black and white powerpoint slides to be sent in advance to enable them to print them out since they do not have access. When lecturing a teaching assistant has set up the meeting and shown the powerpoint slides. SR has used zoom both as participant and meeting coordinator. They consider many of the tool features accessible, but have experienced great difficulties with content sharing of other people's presentations, but not with sharing their own presentation. The large number of buttons on the user interface means numerous keyboard steps are required unless shortcuts. ND has observed that hovering the mouse to show the menu was not intuitive for older inexperienced users.

Conclusions

The paper has discussed the evaluation of the web-based versions of a number of different videoconferencing tools. This included the development of a number of evaluation criteria. A preliminary evaluation was carried out by the two disabled authors, with support from the non-disabled author in checking and testing the tools. The results showed that none of the tools was fully accessible to screen reader users or users with graphics and colours turned off or using phone dial in. A particular problem for screen reader users was found to be content sharing, as video content was only available in graphical form which is inaccessible via screen readers. However, MS Teams provides file-sharing options which support screen reader access, as long as the file itself is screen-reader accessible and, for instance, provides alt descriptions of graphics. File sharing options would also enable files to be printed out.

As far as the authors are aware only Jit.si, MS Teams and Zoom provide phone access. This is required for accessibility for some disabled people However, not all meetings using these tools provide phone dial in, probably due to inexperienced hosts not being aware of the option or need. None of these tools provides phone access to the chat or all tool functions. Documents need to be shared in advance (which can be advantageous to some disabled people) or with the assistance of a support person. Several of the tools provide options to turn off or not receive video input. However, the tools are designed to use video and consequently disabled people who use audio only are likely to have a poorer experience. The ability to set up and host meetings and show presentations during them is important for teaching and other workplace activities. All the tools performed poorly in this area.

The authors are planning to develop and extend the criteria and apply them in a large scale study of experiences disabled people with diverse impairments and other characteristics of using videoconferencing tools. The study will cover web based and PC and mobile app versions of the tools to allow comparisons. The evaluation will have both quantitative and qualitative elements and the results will be used to develop more details recommendations for tool developers and users.

Preliminary recommendations include: (i) the provision of file-sharing or other options to provide access to screen shared content for screen reader users; (ii) phone dial in access with options for accessing the system tools; (iii) the tool home and other pages should meet web accessibility guidelines, including text versions of all links and following user specifications for colour, graphics etc.

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Exploiting Synergies between Digitalization and Inclusion to Raise an Organization's Inclusive Capacity on the Example of Vocational Education and Training

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Abstract

The paper reports on the results of a 2-year ERASMUS+ funded project (project acronym: EICON) that explored opportunities to increase an organization's overall capacity with regard to inclusion by using Information and Communication Technology (ICT). The application domain in which the results were developed and implemented was Vocational Education and Training (VET). The scientific approach has been reported in an earlier publication [1], this publication is addressing the practitioners' level.

Introduction

At present, inclusion and digitalization are independent drivers of the strategic advancement of Vocational Education and Training (VET) organizations. Although independent, inclusion and digitalization have also intersecting areas with mutual impact (see Figure 1). For example, much research looked at the use of digital media in classrooms, and how it may render teaching and learning in the classroom more inclusive. In the application domain of vocational education and training, however, a focus on the classroom alone might be too narrow. To become truly inclusive, a wider view on the whole organization is required to be able to exploit the full potential of digital media and Information and Communication Technology (ICT) for building up and maintaining a VET organization's inclusive capacity.
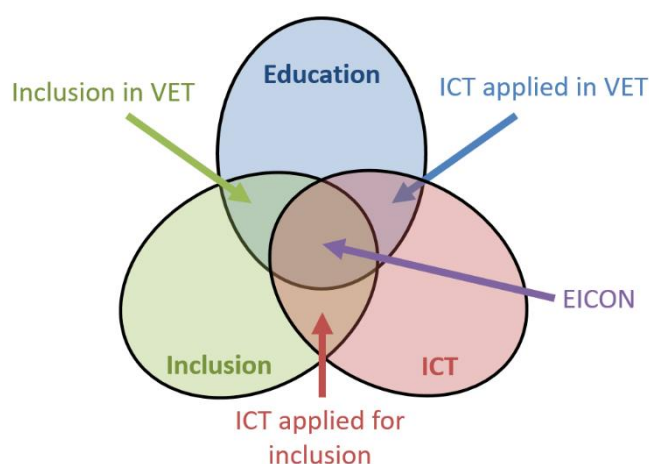

Figure 1 The EICON project explored the synergies between Vocational Education and Training (VET), Information and Communication Technology (ICT) and Inclusion

Research Context

It has been observed that there is a lack of thorough analyses or systematic approaches on how to gear organizational digitalization strategies and activities at both classroom- and organization-level towards the same aim, in this case towards the increase of a VET organization's inclusive capacity. Hence, in the previous ICCHP conference in 2018 it was suggested to (i) analyze VET organizations as a complex system to understand the relationships among all system elements and to recognize the role of each element to raise the system's inclusive capacity (systems approach), and then (ii) to scrutinize each of those elements that are identified as strong levers in organizational change to which extent they could benefit from the use of digital media and / or ICT [1].

While the analysis of educational organizations was already performed as an international project run by the European Agency for Special Needs and Inclusive Education [2] in 26 countries, the systematic examination of these strong levers was on the agenda in 2018. Since then, an ERASMUS+ Key Action 2 Strategic Partnership in Vocational Education and Training project, called EICON - Enhancing inclusion capacity of educational organizations / institutions providing VET with ICT, performed this activity with a focus on particularly strong levers (i.e. factors that highly impact on the whole system). The project commenced just after the previous ICCHP conference in 2018 and will be finished in October 2020.

Project Approach

The composition of the project consortium made it clear from the outset that the results had to take into account the diversity of contexts in which VET is implemented in the participating countries. Furthermore, it is the aim of such projects to be applicable in other EU member states. At the same time, it was clear to all participants that such a project cannot replace an organizational development measure that is tailored precisely to an organization and its stakeholders, and that initiates and directly accompanies a change process. Under these premises, therefore, what can be the added value of a project which, moreover, was financially only endowed with travel funds for meetings of the partner organizations?

- The project focuses on the early phases of organizational development, in particular the pre-development and start-up phase. This is where key decisions are made that significantly influence the direction of an organizational development. It is therefore essential to anchor the topic of inclusion centrally so as not to run the risk of the measure becoming a technology-driven project.
- Due to the international composition of the project partners with different VET and inclusion traditions, the diversity in Europe is appropriately taken into account. In addition, the project also involves other stakeholders outside the consortium in the development of the project results in order to make the relevance and usability as broad as possible.
- Since no best practices are known in the subject area of the project, the result cannot draw on and use their experience and approaches. Nevertheless, the project can provide impulses that arise from the diversity of perspectives within the consortium and motivate innovation without aligning the users of the results with previously defined goals.
- Even if there were examples of best practice, they usually show only one way. This quickly leads to a loss of focus on other, as yet unused implementation paths. Therefore, the project takes up the findings of a research project [2] and examines the key factors identified there for implementing inclusive VET as broadly as possible.

Against this background the following project approach was implemented. The EICON project consisted of a series of seven meetings (approx. 3-monthly), each focusing on a central thematic area: (1) pedagogy & teaching / learning approaches, (2) technology & infrastructure, (3) establishing & maintaining links to employment / labor market, (4) stakeholder involvement, collaboration &

partnerships, (5) leadership, (6) transition & target scenarios for VET organizations, and (7) continuous improvement process. Thematic areas (1) to (5) refer to specific success factors in inclusive VET, derived from research, while the thematic areas (6) and (7) deal with the basic orientation of organizational development and its sustainability. Participants of these meetings were experts from the six partner organizations who had joined forces to elaborate practice-oriented recommendations, plus additional National experts that were invited by the respective meeting hosts to provide further insights.

Five of these meetings were focusing on VET specific topics and produced a specific draft outcome (here: checklist, see next section) that was then published for a certain time on a consultation platform to collect further ideas, comments or suggested changes from a wider audience in Europe. Finally, the feedback from externals had been discussed and used for the finalization of the results. These finalized results, a series of five checklists, have been published on the project's website [3] (see Figure 2).
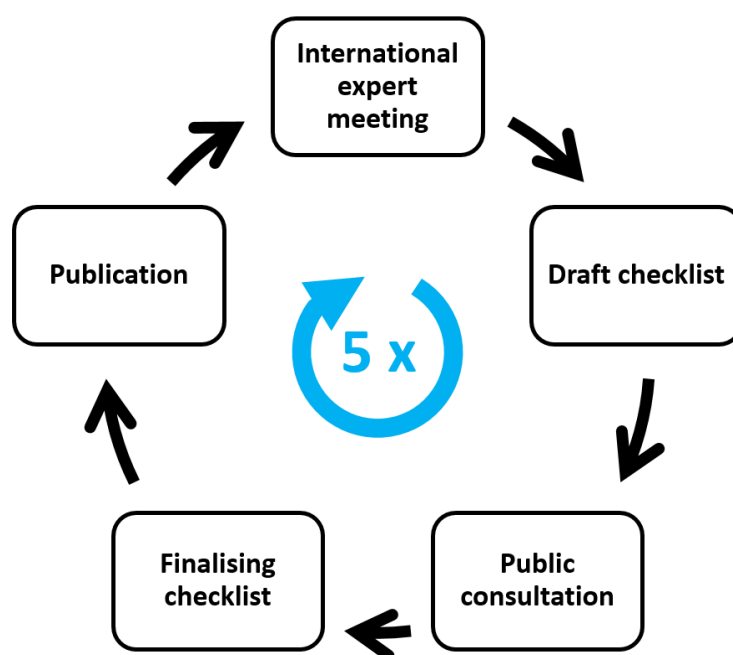

Figure 2 Five cycles, consisting of international expert meetings to draft checklists and subsequent consultation phases to finalize checklists and to publish the results

Results

The project participants have jointly agreed to produce project results in the form of checklists and to make them available to VET organizations as they set out to improve their inclusion capacity. However, these are not checklists, which are used, for example, to implement all necessary activities and then confirm them on the checklist. Rather, these checklists are intended to help all those involved to take a look at key areas of the organization and to discuss together the potential of ICT for improving inclusion.

This type of checklist can be used especially in the pre-development phase of organizational development to assess where the organization stands in relation to the use of ICTs to support inclusion. This is particularly relevant at early stages of organizational development, as knowing where an organization stands is the prerequisite for defining appropriate steps forward. Hence, the use of these checklists could be part of a data gathering phase in an organization before any change processes are initiated or even decided. However, the checklists need to be complemented with other tools that, e.g., evaluate the organization's level of inclusive pedagogy or the stakeholders' readiness for change (e.g. inclusive mindsets, ICT biographies, openness for change).

From the moment organizational development begins, however, the checklists can also serve as a pool of ideas. Numerous ideas and examples from practice have been incorporated into their development, which can be particularly helpful at the beginning of a change process, allowing innovative ideas to flow in and ambitiously formulate the objectives.

Five thematic checklists are now available at the end of the project. Although all thematic areas are also linked, the project partners have decided to leave this thematic subdivision as otherwise the result might be too complex and therefore difficult to apply in practice. It is recommended to work through each checklist point by point in a team, e.g. a steering committee consisting of the main stakeholders in the VET domain, and to discuss how the current setup of the organization is and what stimulus each entry generates.

However, the use of checklists should not imply that an organization can only implement inclusive VET if all checklist items have been processed positively. There is neither scientific nor empirical evidence for this. However, each checklist entry addresses a different facet of inclusion, and each positively answered entry indicates a higher degree of inclusion capacity.

On the other hand, the checklists can also be used in the context of a planned procurement of ICT to check whether and what contribution the planned technology can make to inclusion (see example below). If it turns out that no checklist item can be answered positively, it can be assumed that the technology cannot make a positive contribution to increasing inclusion capacity.

Project partners who are VET organizations themselves have trialed the checklists internally to assess their applicability and usefulness. The partners are convinced that these checklists provide effective guidance on areas where the use of digital media would not just increase an organization's efficiency but also contribute to an overarching leitmotif for the whole organization, in this case: inclusion. They emphasized that the checklist items should be reviewed both at classroom level as well as at organization level, because an increase of an organization's inclusive capacity requires that impact is not limited to the classroom level. On the other hand, a VET organization / institution cannot be inclusive without having inclusion implemented at classroom level, i.e. both levels are essential.

Example: Excerpt from the checklist on "Pedagogy and teaching / learning approaches"

Does the respective ICT / digital media / digitalization strategy ...

- facilitate innovative teaching methods or to adapt pedagogical methods and techniques that support learner-centered approaches?
- support the implementation of individualized and flexible curricula?
- contribute to optimize the teacher / learner and support staff / learner ratio (e.g. by in-creasing efficiency)?
- increase the organization's flexibility in VET opportunities and courses to allow progress from one level to another?
- support new or better options to prevent or reduce dropout?
- support to maintain an atmosphere of commitment, caring and belonging?
- help to maintain a good balance between theoretical subjects and practical training?
- contributes to a focus on practical learning approaches that also includes theoretical/academic subjects?
- help to manage multi-disciplinary teams?
- allow learner assessment prior to the start of courses in order to tailor a VET programme to the individual?
- support to change the structure and duration of the VET programmes if required?

So far, testing has been limited to only a few organizations. However, two project partners will use the results on a large scale in the coming months. The first is a national agency in Sweden, whose task is

to advise and support education providers in implementing inclusion. Here, the checklists will be used in counselling interviews and worked through together with the respective stakeholders. The consultants of this National Agency see themselves as the process facilitators. On the other hand, the Greek Ministry of Education with its Directorate for Special Education is also involved. Here, too, the checklists are to be used throughout the VET area.

Acknowledgements

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Information Technology in the Development of Musical Abilities in Children with Disabilities

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Annotation

The problem of the development of musical abilities in children is still not yet well developed both in musical psychology and in musical pedagogy. Even less developed is the problem of the development of musical abilities in children with disabilities. The authors mainly investigate the inclusion of such children in musical activity with the goal of enhancing their social skills, developing communicative and speech skills, and familiarizing themselves with life phenomena. The search for means and methods of developing their special musical abilities, unfortunately, is not today an urgent scientific topic for authors dealing with the development of children with disabilities. However, in the few studies available, the authors nevertheless consider the possibility of the musical development of the child, in particular, the development of his musical abilities: melodic hearing, rhythmic feeling through new information technologies. The aim of this work is to reveal the possibilities of using such information technologies in games, sounding books, in the independent work of the child at home when using Skype, as well as video lessons that the child received at school, for the development of musical memory, melodic hearing, and purity of intonation. The effectiveness of such a complex of methods was confirmed by the results of tests for the development of musical memory in children with disabilities, on the formation of skills: to perceive a musical work, simultaneously singing and playing melodies, to reflect the musical genre in motion.

Keywords. Information technology, children with disabilities, musical abilities, musical development.

Introduction

The analysis of the literature on the use of information technology in working with children with disabilities showed that their main idea concerns the formation of social skills in children [1]. Meanwhile, such children with different educational opportunities, different types of health problems can be just like perfectly healthy children engaged in musical and artistic creativity. At the same time, the goal of such creativity, as in healthy children, will be not only socialization, but also the development of certain special - musical or artistic abilities. In literature and in practice, there are many examples of how children with disabilities, having varying degrees of mental retardation, problems in the development of the musculoskeletal system, and vision loss, have successfully demonstrated developed musical or artistic abilities. In this regard, the question arises of the possibility of teaching music to them or some other kind of artistic creation, during which the development of these special abilities occurs. Currently, in various educational institutions and, above all, in children's music schools, in children's art schools, teachers have become interested in working with such children. This is due to the fact that parents of children with disabilities began to bring children with disabilities to classes in such schools, striving to ensure that their children, like healthy children, receive full musical and artistic development. Teachers of schools, seeing an interest in the musical and artistic education of children and parents, began to strive to diversify their working methods, primarily through the use of information technology. Practice shows that often such technologies include only audio material, or a specific video series, consisting of cartoons and fragments of children's films. Less commonly used are

games or educational computer programs, which significantly impoverish the possibility of developing special musical abilities in children with disabilities.

Literature Analyses on the Inclusion of Information Technology in the Development of Musical and Artistic Abilities of Children with Disabilities

The solution to the problem of including a child with disabilities in the process of musical creativity is considered by the authors from different positions. So, they believe that musical activity can act as a means of socializing children, because inclusion in collective forms of work contributes to their cohesion and interaction. Such musical activity will contribute to the formation of social skills even in preschool children with health problems [2]. Some teachers and researchers consider musical activity as a means of developing special musical abilities of children with disabilities. However, even when diagnosed, these musical abilities are considered in unity with other abilities: communicative, verbal, etc. [3]. The authors draw attention to the development of musical abilities of children with ASD. They explored the possibility of developing performing abilities - playing the piano in children with autism and children who don`t have health problems. During the experiment it was found that both of them, performing plays in pairs, can show the same good results [4]. The authors of this work emphasize the importance of such training in that children began to develop more dynamically and in a communicative way. Communication and musical creativity of a child with disabilities is a topic that is considered by a number of authors from various angles. So, for example, M.V. Pereverzeva believes that folklore can be such musical creativity. The involvement of children in folklore contributes to the establishment of trusting relationships between participants in a folklore ensemble [5]. Folklore, included in the process of children's creativity, can act as a specific environment in which music, speech, dance represent a unified space for children. And if in all spheres of folklore activity the musical development of the child will take place, together with its general development, and then corrective work with such children will be much more effective. The need for such a comprehensive work, which will involve all types of daily activities of children with hearing problems, is indicated by L. Grammatico [6].

A special place in work with children with health problems began to take the work of authors, which indicate a positive role in their education information technology [7, 8, 9, 10]. The authors, relying on the results of experimental work, prove that the introduction of computer technology can significantly affect the formation of a child's emotional responsiveness to music, which is the main musical ability, and to obtain certain knowledge about music [9]. The importance of information technology in teaching music to teenagers with autism spectrum disorder is indicated by A. Hillier, G. Greher, A.Queenan, S. Marshall, J. Kopec. The authors proved that a touch screen can be successfully used in teaching music to children with autism [8]. An interesting experience in teaching autistic music is presented by M.C. Buzzi, M. Buzzi, G. Paolini, M.T. Paratore, C. Senette, who investigated the possibility of the Suoniamo app to visually structure music for children with autism. First, the training was conducted on the virtual keyboard of the piano, then on a real piano. With such training, children began to clearly understand the meaning of rhythm, notes, and also pause in musical writing [7].

Experiment on the Introduction of Information Technology for the Development of Musical Abilities of Children with Disabilities

A generalization of the authors' works on the problem of the development of musical abilities made it possible to develop a complex of information technologies that was tested at the Yekaterinburg Children's Art School No. 4 "ArtSozvezdie" (Yekaterinburg, Russia). This school is known for working with children with disabilities for many years. All work with such children at school is aimed at actively activating its socialization by including the child in art, including it in joint activities with other children, teaching them to understand art, and creating certain artistic products. The school has a special program for children with problems in mental development, in the development of hearing and vision,

and the musculoskeletal system. This program is "Free Creative Development", which organically includes a set of lessons such as painting, music, the basics of theatrical play, eurhythmy, arts and crafts, conversations about art, the psychology of communication and creativity. A feature of this program is that in many of these classes, school teachers use information technology to successfully achieve the goal of socializing the child through art. A special place in this program is given to musical creativity. The huge opportunities of information technologies allow children to listen to music in excellent performance by famous musicians, which forms an emotionally positive tone in children's mood, musical creativity using a computer allows you to build musical instrument playing skills, and the use of music video films helps to develop interest in both music and and to a specific plot of such films. Information technology allows educators who teach children with disabilities to develop their musical abilities. Having such abilities, a child can successfully realize himself in creativity, find application for his abilities in performances at concerts before peers and parents, and can help other children learn to play the instrument. All this speaks of social demand, which is of no small importance for the further optimistic development of a child with disabilities.

To conduct an experiment, the authors of this article developed a set of information technologies for the development of various musical abilities. These technologies were proposed to be used by teachers during musical classes with children, as well as in the implementation of assistance in performing home musical classes. The complex of information technologies used in classes with children with limited health abilities was: games, using information technologies, books with information support, a homework system using Skype, video lessons.

So, for the development of musical memory and ear for music, the game was used, its name is "TOM", which is understandable even to those children who have an average degree of mental retardation in development. Despite the fact that the goal of this game is to form care and responsibility for the hero of the game, it is used to develop such musical ability as musical memory and ear for music. The method of such development is repetition. The child plays a musical phrase or a small piece of music, and Tom repeats, that is, plays a recording of the child's performance of music. In this game, not only performing skills are formed, but also, as indicated, musical memory.

The development of musical ear was made in the process of another game - "What is being done in the house?" This game, the content of which is well known to all those educators who conduct music classes with preschool children. In the computer version, it is slightly changed, musical fragments appear in it sequentially and with a gradual complication of the musical material, in addition, it has a visual series: animation, which significantly increases the child's interest in both its content and its musical material. In addition to the development of musical hearing, this game also contributes to the development of such qualities as the ability to carefully perceive music. Another important skill that develops in the process of using this game is the ability of a child with disabilities to reflect in movement: with fingers, hands, head, the metro-rhythmic beginning of a particular musical genre - a song, dance or march. Scientists have found that the musical abilities of a child develop in the process of his active perception, when motor activity is included in this process.

Musical hearing was also developed with the help of the well-known application for a cell phone - "Real piano", when the child played the melody of the song and performed it with his voice, which developed the purity of intonation and hearing of the child. The game "Who is better?" used in a duet: child teacher. In the event of a mistake, often deliberate, the child stopped and corrected a note incorrectly sung or lost by the teacher.

Gaming technologies include the use of the Magic Pencil series of books. Drawings in a book can be voiced with a magic pencil when a child clicks on one or another picture, while both noise and musical sounds are heard. The sound obtained with such a pencil can form the ability of a child with disabilities to listen to sounds, to distinguish musical sounds and sounds - noises. In addition to the formation of

musical abilities, such books also develop the knowledge of the child, as he gets acquainted with life phenomena, with the heroes of fairy tales, with animals, plants, birds. A series of books "Magic Pencil" is aimed at introducing children to visually impaired, totally blind and, in connection with their features, because they do not have reading skills. In addition, using such a book, a child can get acquainted with musical instruments and their sounds, with musical genres and children's songs, which are sound next to certain fairy tales printed in such books.

The child's independent work with parents on musical education when using information technologies consists in consolidating those musical abilities that develop in music lessons, as well as in the formation of skills that were also formed in such classes. Children and their parents are provided with a video of the lesson, which is produced with the permission of the parents or legal representatives of the child. This record is a methodological tool for both the parent and the child himself. Studying at home, the child and the parent use it with the aim of recalling the musical work, as well as the technical tasks that were formulated by the teacher and the ways that made it possible to solve these problems. Parents who were interested in the formation of such technical skills in the child, such videos from the lessons were sent to e-mail.

According to the program "Free creative development" in line with the preparation of the child for playing a musical piece on the piano, Skype lessons were offered at home. So, the content of such classes with children with disabilities in health included finger games, breathing exercises, and speech exercises. Using a computer program, the teacher on the computer screen displayed pictures that were shown to the child on Skype, they showed the child the quality of the assignment. When the task was completed correctly, a color picture arose, and when it was incorrect, a black and white picture arose.

Key Findings

A check of the effectiveness of the information technologies used, which was mentioned above, was carried out at the end of the second quarter of the 2019-2020 school year. Special tests for musical memory (test for the child "Repeat the melody" on the keyboard), for the ability to perceive a musical composition (test "Listen carefully to the music"), for the simultaneous performance and singing of a simple melodic line using the "Real piano" program (test "Play and sing notes"), on the ability to reflect the musical genre in motion (the" Dance to Music "test) showed that musical memory, perception of music, and intonation skills developed in every child with disabilities in a positive way. A comparison of the results at the beginning of the school year and at the end of the second quarter made it possible to identify positive dynamics, which made it possible to formulate further research prospects: the search for the possibilities of using information technologies for teaching children to play the piano, in particular, identifying the most acceptable Synthesia modes for children with disabilities mental capabilities, the effectiveness of the piano simulator for the Windows platform. The prospects of the study may be the identification and practical testing of computer games and exercises for the development of such musical abilities in children with disabilities as a sense of rhythm, intonation hearing, emotional responsiveness to a particular piece of music.

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Including Students with Disabilities in Distance Education

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Abstract

The aim of the project InSIDE is to develop accessible distance education (DE) programmes for individuals with disabilities (visual, hearing, or mobility / physical impairments). The overall objectives of the project are to: a) develop new and innovative, accessible and inclusive DE programmes improving the quality of Higher Education (HE) for individuals with disabilities and offering flexible learning and virtual mobility, b) build capacity and professional development in administrative and teaching staff in developing and carrying out accessible and inclusive DE programmes, and operating the accessibility offices, and c) involve individuals with disabilities in a user-center design so that accessibility and usability are achieved in conjunction, and the links between education and society are strengthened.

Keywords: Disability, tertiary education, distance education, eLearning,

Motivation

It has been reported that Individuals with Impairments (IwI) are unwilling towards their transition to university, face serious challenges during their university attendance or quit their studies without developing the necessary skills to cover future working requirements.

In Africa, more specifically, on one hand, HE education has failed modernization, and on the other, IwI are numerous and have limited access to appropriately designed university programmes. Thus:

1. In Africa, 3.3% people aged from 15 to 59 years old suffer from a severe disability, while 19.1% experience a moderate or a severe disability (WHO, 2011). In Morocco, Algeria and Tunisia there more than 1MM persons (per country) with sensory disabilities, mobility impairments from musculoskeletal diseases and unintentional and intentional injuries (WHO, 2009).
2. Though in Africa there are more than 1600 Higher Education Institutions (HEIs), tertiary education has not been prioritized for decades and the lack of development actions has led to the shortage of skilful human resources and the absence of connection between studies and labour market demands (UNESCO, 2017). Access to HE for the general population is at about just one-fifth of the global average (GPE, 2015). Equally discouraging is the scant participation of IwI in HE. The data collected from the participant institutions indicate a percentage of 0.02-0.03% (disabled persons in the general student population based on the number of enrolments every academic year) for Algeria and Tunisia, and 0.01-0.08% for Morocco. From those few enrolled, only the 50%, approximately, graduates.

Therefore, we suggested the development of inclusive and accessible DE programmes as a solution to education and unemployment dead ends for IwI in Partner Countries (Morocco, Algeria and Tunisia). Though there may arise short-term costs (adapting the educational material, training the staff, acquiring equipment), the long-term benefits (i.e. economically active citizens) outweigh them. (GSDRC-Helpdesk Research Report, 2012) Hence, a wide horizon of education and training opportunities for

continuity and success in academic course, new and/or job-specific skills acquisition, emerges as a key element towards modernization of HE in Morocco, Algeria and Tunisia.

InSIDE: Including Students with Impairments in Distance Education (https://www.inside-project.org) is a multi-axis project and, consequently, it addresses multiple thematic national priorities and an amalgam of regional priorities resulting in diversification within the region in terms of the objectives. The specific ones are outlined below:

- Extended literature review for precedent trials in DE for individuals with disabilities.
- Development of the most suitable educational material for individuals with disabilities in terms of accessibility, usability and educational efficacy through the study of end-user requirements.
- Adaptation of a course delivery system that best serves the needs of individuals with disabilities in DE.
- Foundation of accessibility services in HE so that students with disabilities would be supported during their attendance in HE.
- Training of advisors in the services of the accessibility offices, and the training of the trainers (advisors and representatives) so that they will be able to train the end-users (teaching staff and students with disabilities).
- Examination of the regular co-operation of all the above to deliver inclusive DE courses effectively when learning and skill enhancement are concerned, considering end-users feedback too.

Methodology

InSIDE is structured in five main execution stages from the study of the state of the art to the implementation of Pilot courses output of the designed DE programs.

State of the Art Research

Included a detailed examination of the current literature on:

- Distance Education training programmes for individuals with disabilities.
- Adapted educational material for students with disabilities.
- DE delivery systems (software) focussing on the accessibility aspect.

Development and Assessment of Adapted Educational Material

Based on the literacy review, educational material in a preliminary version was developed to meet the needs of students with disabilities. The team produced representative samples of all the different types of information output both in printed and in digital form. In addition, the team prepared a presentation of: a) the adaptations to the different types of information output, and when was not possible b) the alternatives for presenting information satisfying minimum requirements for education. The different types of information with the respective adaptations and alternatives per impairment was catalogued in detail.

The adapted and the alternative materials were assessed with reference to their accessibility and usability adequacy as well as to the end-users' satisfaction. The assessment process will be completed in two stages, a) through a pilot study – with the participation of 5 persons from each impairment category (visual, hearing, mobility/physical) – the accessibility and usability adequacy will be examined in detail, and b) 90 persons from each impairment category will be asked to refer their requirements as end-users of the material under examination.

Firstly, special education material is approached holistically and is assessed by so great a number of individuals with disabilities. That, among others, permits us to reach valid and objective results. Then,

adaptations can be applied on the material to improve it. The result would be fully accessible, usable and effective material that can be proposed as a template for the educational material that in the future. Finally, guidelines for the development of fully accessible, usable and effective educational material are analytically described.

Due to the corona-crisis, the assessment of the educational material is not completed.

Assessment of the Most Widespread LMSs and Adaptations

Based on the results from "State of the Art", the most widespread LMSs were critically examined in reference to their accessibility and usability aspects, targeting to propose possible improvements in order to increase their usage by individuals with disabilities. Hence, LMS developers or providers could apply the proposed alterations. It is possible to find more information about the evaluation and selection of LMS in the next contribution of this compendium (*Valentin Salinas Lopez: How to Select an Accessible Learning Management System for Distance Education*).

Training of the Accessibility Advisors, Trainers, and End-Users

Due to corona-crisis, this part had to be postpone. However, the aim is each participant university form Partner Countries establish an accessibility office. For doing so, a training session will take place so that two persons from each university will be trained on the operation of the office and act in the future as accessibility advisors in their university. A second training session will take place in each participated university of Partner Countries. It will focus on the guidance upon the acquisition of assistive technology, management issues, and functionality directions.

In the next stage, two accessibility advisors and four trainers-representatives of each university of the Partner Countries will attend a training programme in DE for students with disabilities. They will be instructed on the development and the use of the adapted educational material, the use of the LMS, and the delivery of DE programmes for students with and without impairments. The participants will also receive training on how to train the rest teaching staff in their universities.

Finally, the training in DE will be completed at the universities of the Partner Countries - at their place in their own premises using their own equipment. Lastly, end-users will be trained, teaching staff, and, next, individuals with disabilities. The content of the training will pertain to the development of adapted educational material, the delivery of DE courses with the use of the adapted LMS, and the operation and the services of the accessibility office.

In the training of end-users (individuals with impairments), the six local trainers of each university will train individuals with disabilities and representatives of the respective local associations. The duration of the training of each group will be 7 days, and both trainings of teaching staff and of individuals with impairments –will be assessed to define their results.

Implementation and Assessment of Pilot Courses

Each one of the participant universities of the Partner Countries will carry out DE pilot courses-2 programmes per university. The pilot courses will engage a) the accessibility advisors of the university, b) teaching staff that have been trained in the Trainings stage c) students with disabilities, and d) students without impairments. The aim will be 3-4 instructors to educate about 6-8 individuals with impairments and 6-8 individuals without the targeted disabilities. These instructors will prepare the necessary educational material with the support of the accessibility advisors. The subjects of the programmes will be chosen with the providence of being different between each other in order to examine how different specialties could be delivered through a model of DE for individuals with impairments.

The results of the educational process will be examined through an assessment tool resembling the tests conducting at the end of a semester in the context of a university program. Moreover, the participants' satisfaction will be examined through specific-designed questionnaires to all the different parts teachers and students.

Conclusion

Not only on European level but worldwide there is no DE programme for individuals with visual or hearing or mobility/physical impairments fully completed in terms of accessibility, usability and educational effectiveness in all fundamental components – educational material and pedagogical approaches, DE delivery system, and accessibility services. Thus, it is undisputable that the InSIDE proposal is innovative throughout its core design. More specifically, the project's innovative aspects lie in:

- The holistic approach of the educational material. Hence, the team will develop complete educational material in all the possible types of information output in printed and in digital form: a) text (simple text, table, mathematical representation), c) audio, d) graphics (image, diagram, digital design), e) multimedia (presentation, video, 3D graphics/video), f) tactile (model). The material will be delivered in adapted format to meet the needs of students with disabilities and/or in alternative forms wherever the initial format is not efficiently adaptable. These modifications will be managed under the prism of each impairment – visual, hearing, mobility/physical.
- The user-center design – i.e. for the first time the material will be examined by a great number of end-users (individuals with disabilities) with the purpose of further improvements in the consequent stage of the project.
- The multi-aspect adaptation of the DE delivery system – i.e. adaptations pertaining to accessibility, usability and educational effectiveness.
- The overall assessment through complete DE programmes and the participation of end-users that will end up in feedback and possible suggestions.

To sum up, the project is equipped with two main innovation axes: a) the holistic approach of developing DE programmes for individuals with visual, hearing, mobility / physical impairments that will culminate in a ready-to-use tool, and b) the user-center design that engage end-users in various development stages fostering social integration and enhancing intercultural understanding.

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How to Select an Accessible Learning Management System for Distance Education

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Abstract

The fast development of Distance Education (DE) and Blended Learning generates a wide, diverse, and fast-changing offer of Learning Management Systems (LMS). Selecting the right LMS for setting up distance education programs gets more challenging, in particular when specific requirements of teachers and learners with disabilities have to be taken into account. This was the challenge that the InSIDE project faced at the beginning of its execution. This project aims to implement DE programs accessible for visual, hearing, and motion disabled people in 11 universities of the Maghreb region. This paper presents the methodology, results, and lessons learned from the selection of the LMS to base the delivery of the DE on.

Keywords: Digital Accessibility · Tertiary education · Distance education · eLearning · Learning management systems.

Motivation

This desk research is part of the project InSIDE: Including Students with Impairments in Distance Education (https://www.inside-project.org/) which aims to implement accessible Distance Education (DE) programs in 11 universities in North African countries (Algeria, Morocco, and Tunisia) to support the inclusion of students with visual, hearing and motor disabilities. Consequently, at a certain point, a decision had to be made on which Learning Management Systems (LMS) to use as a foundation for the provision of DE.

The answer to what LMS best suits an educational project is not trivial. Three factors contribute to the complexity of this question. Firstly, the ecosystem of software implementations for DE delivery changes quickly pushed by the constant evolution of DE and innovations in educational institutions. Secondly, the features of LMSs are quite diverse and difficult to match when comparing. This fact may be explained due to the different teaching methodologies used to ground implementation and disparity in targeted learner profiles. Thirdly, each educational project has its own priorities and requirements. The establishment of appropriate criteria and to weight the desired features for the selection of the LMS is of paramount importance and one of the key points for the success of a distance educational project.

For the specific case of the InSIDE project, the selected LMS had to fulfill the following requirements, which are ordered by importance:

- suitable for the provision of distance higher education,
- accessible for visual, hearing and motor disabled people,
- customizable,
- independent from third parties, which means it could be self-hosted and modified freely.

Methodology

Due to the complexity of the task, it is divided into a 5-steps procedure to ensure valuable, reliable, and precise results. Those steps comprise market research, system requirement elicitation, available options filtering, comparison of the most interesting alternatives, and the final selection.

A Search of Most Widely Used LMS

In order to provide a first approximation to the problem of finding the right LMS, this first step consists of an extensive search of the most widely used software solutions. For this purpose, a list of all found available options is created. The only restriction applied is that the outcomes of the solutions listed should seem as much as possible as the ones of a learning management system.

LMS Basic Requirement Elicitation

In this step, the desirable features of the chosen system are prioritized and set. Thus, this step comprises all the necessary actions to obtain the system's functional requirements. This step is of paramount importance, due to the resulting requirements that are the basement of the following steps and greatly influence the final decision. Therefore, actions taken here should enable an educated selection of the LMS in the end.

Candidate Screening

At this stage, the listed LMSs are filtered using the output from the previous step. This reduction in the searching set allows for better further comparative analysis.

Comparative Analysis of Selected LMSs

The comparative analysis attempts to highlight the differences between the selected alternatives. Additionally, the comparative should focus not only on showing differences in general features but also on those features that are key for the project. Those key features can be extracted from the project requirements set in the 2nd step.

It begins by gathering detailed information of each LMS compared. Due to the large amount and variation of features, it is necessary to do this previous step. Then, it is possible to proceed with the match of features testing each compared alternative when possible or searching in the available documentation. Finally, each feature can be evaluated and graded.

Final Decision

At this final stage, not only the output of the comparative analysis but also the project requirements for the system and the detailed information of compared systems are available. There is no "best one fits it all solution," so the goal here is to make the best possible choice, the educated, good one. It is advised to take a holistic approach when deciding using those resources and the context in which the projects are being developed.

InSIDE Development and Results

Here are the results of the application of this methodology for the selection of a LMS for the InSIDE project.

A search of Most Widely Used LMSs

Below are listed all LMS and companies that provide DE found during the third quarter of 2019.

- aTutor
- Blackboard Learn
- Canvas
- Claroline
- Cornerstone OnDemand
- Desire2Learn or Brightspace
- DoceboLMS
- eCollege
- Edmodo
- EduNxt
- eFront
- Engrade
- EthosCE
- GlobalScholar
- Glow (Scottish Schools National Intranet)
- Google
- Grovo
- Growth Engineering
- Halogen Software
- HotChalk
- ILIAS (Integriertes Lern-, Informations- und Arbeitskooperations-System)
- Inquisiq
- itslearning
- Kannu
- LAMS
- LearningCart
- LON-CAPA (Learning Online Network with Computer-Assisted Personalized Approach)
- Moodle
- Open edX
- OpenOLAT
- Sakai
- Schoology
- Skillsoft
- Spongelab
- SuccessFactors
- SumTotal Systems
- SWAD (Shared Workspace At a Distance)
- Taleo
- Totara Learn
- Udutu
- Uzity
- WeBWorK
- WizIQ

LMS Basic Requirement Elicitation

As the complexity of the inside project is high because InSIDE involves many different actors, it was decided to conduct a survey focused on DE and inclusion. This was the starting point for the requirements acquisition procedure.

The developed questionnaire consists of 10 questions formulated with the aim of providing grounded information of participating universities on actual needs and specific local requirements, social inclusion and background, experience, and competence in DE. At the end of this section, in Table 1, we display the questions and the summary of the answers given by participating universities.

Answers show that the selected system should have the following features:

- Multilanguage support.
- Accessible for visual (VI), hearing (HE), and motor disable (MO) people.
- Lessons with rich multimedia content, audio and video.
- Advanced means of communication, like forum and chat.
- Free of charge for students and universities.

Finally, it is worth to mention that Moodle stood out as the most popular LMSs through the project's participants.

Candidate Screening

In this step is reduced the alternatives to enable a further sensible comparison. The criteria used to keep only the most interesting LMSs were:

1. The system should be accessible to VI, HE, MO disabled people. Alternatively, it must allow modifications in order to achieve the desired level of accessibility.
2. It must be able to deliver full distance higher education programs. That implies the system should be able to handle rich media content, grading management, and advanced communication features like chat and forum.
3. It should be licensed as Free and Open Source Software (FOSS), which implies no cost for students and no cost of acquisition or use to universities. This assures freedom of system customization and modification. Thus, it is possible to implement specific local requirements and fix accessibility issues without the permission of third parties.
4. Moodle must be included due to its popularity among participants. The strong expertise that participants have in this system was of noticeable benefit for the project if this alternative was selected in the end.

Finally, we kept the following 7 LMSs on our list:

- Moodle [1]
- aTutor [2]
- Open edX [3]
- Canvas [4]
- Chamilo [5]
- Totara Learn [6]
- Edmodo [7]

Table 1. Questions and results of answers from the 10 completed questionnaires.

Question	Answer (when apply order is by frequency and descendant)
What is the official language in your institution?	French, Arabic, English, Greek, German
Is DE available at all in your institution?	Yes, 9, No, 1
At what level does your institution provide DE?	Internal purposes, continuing education, bachelor and master programs
Estimate the ratio of courses at your institution that is provided as DE.	< 20% of the total educational offer, 8 20% of the total educational offer, 2
In what languages does your institution provide DE courses?	Arabic, French, English, Greek, German
Which software are you using for providing DE services now?	Moodle, 10 Big Blue Button, 2 Google Classroom, 2 edX, 1 WizIQ, 1
What features are crucial for a successful DE platform?	File repository Lessons with video, audio Grading feature Courses and student management Advanced communication features like chat and forum Free cost for students and provider
Is your institution part of any DE network, pool, or initiative?	No, 10
Does your institution have services for students with disabilities?	Yes, 8, No, 2
Are students with disabilities studying in your institution?	Physical disabled Blind or visually impaired Deaf or hard of hearing

Comparative Analysis of Selected LMSs

This comparison aims to ease the decision-making focusing on differences of general features and accessibility. Each of the filtered alternatives has to be studied in more detail to assess each feature regarding the project context and goals. Table 2 summarizes the results.

Table 2. Comparison of LMS by features

LMS features	Moodle	Open edX	aTutor	Chamilo	Totara Learn	Canvas	Edmodo
Usability	+	++	+	++	+	++	+
Authoring tool	++	+	O	+	++	+	++
Interoperability	+	++	O	++	+	+	+
File repository	++	+	O	++	O	+	++
Video	++	++	+	++	++	++	++
Audio	++	+	+	+	+	+	+
Forum	+	+	+	+	O	O	+
Chat	+	+	+	+	+	+	++
Task and marks	+	++	+	++	++	+	+
Reports	++	+	O	+	++	+	+
Analytics	++	++	-	+	++	+	+
Student mgmt.	++	++	+	++	++	+	++
Open learning	+	+	+	+	+	+	+
Private learning	+	+	+	+	+	+	+
Internationalization	++	+	+	++	+	+	+
Accessibility compliance	++	+	++	O	+	++	+
Keyboard-only	+	+	++	O	O	++	++
Screen reader	++	+	++	O	O	++	++
Subtitles	+	+	+	O	O	++	O
Maintenance	O	++	+	++	O	++	+
Documentation	++	+	O	++	++	++	+
Community	++	+	-	++	+	+	++
Own-hosted	+	+	+	+	O	O	O
SaaS	Third-party	+	Third-party	+	+	+	+
License	GPLv3	AGPLv3	GPL	GPLv3	GPLv3	AGPLv3	GNU/ GPL

Final Decision

In the end, taking into account all information gathered and the comparison made, it was agreed that Moodle[1] was the most recommendable system to be used in the InSide project. It meets all requirements in terms of accessibility, functionality, usability, customization and license. However, what influenced the final decision most was that most of the project participants had some expertise in working with it.

Moodle, despite its advantages, specifically in digital accessibility, has a number of limitations. The biggest one is regards to its complexity and usability. It is not easy to manage in the beginning and lacks simple-to-obtain support – if it is not used as a service hosted by an external provider. In the frame of InSIDE, this downside is mitigated thanks to the experience of participants. Other alternatives were considered seriously as aTutor [2], Open edX [3], and Canvas [4], but in the end, they did not provide extra advantages.

Conclusion and Follow-up

To sum up, the current offering of LMS could easily overwhelm and confuse those who try to make a decision on which LMS to use to implement accessible DE. The combination of aggressive selling found the myriad of teaching methods, and specific requirements make this task a hard endeavor. The presented procedure addressed these issues with the aim of a specific DE implementation. The presented approach offers some methodological help in DE implementations, providing not only a limited set of good options to start with but also a procedure to tackle the search with their own requirements.

Recent developments of distance work/education due to COVID-19 encourage a review of the methodology and an update of results with the post-pandemic offer of LMSs.

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ENTELIS+: Accessibility skills for a technology enhanced learning in an inclusive society

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Abstract

ENTELIS+ attempts to create and apply innovative approaches and methods to empower inclusive education. Additionally, this project encourages common values as well as empower digitally excluded groups with digital skills such as people with disability. In precise terms, this project aims to eliminate the digital divide by collaborating organizations to build policies and strategies for people with disabilities. This will be further accomplished by developing digital skills of old age and persons with disabilities and raising awareness about accessibility.

Keywords: Inclusive education, Accessibility programs, Digital skills

Introduction

The digital revolution has altered the way we live, learn, stay connected, and work in society. ICT education is a necessity for all to participate in different areas of life. Therefore, digital literacy skills will have to develop by all sections of society. However, there is digital exclusion with people with disabilities and old age people due to numerous reasons as mention in the state of the art (see chapter 2). Consequently, this digital excluded section is lacking self-management abilities and not able to add sufficient contribution to society. This project aims to remove this digital divide and foster inclusive education in society.

State of the Art

Inclusive education is the fundamental right of a human. People with disabilities have an equal right to learn in an inclusive environment [1-4]. They should have high-quality services to help them in daily living. They should have better opportunities to take jobs in the labor market. Accordingly, they can play an important role in society. It further helps them to live a life with self-determination and to become a proud citizen of their country. The European Commission has adopted a new agenda [5] to ensure the right skills, right training, and the right support available to all people in the European Union. Additionally, they are also working with various projects to improve ICT skills in the labor market.

There are around thousands unfilled vacancies for ICT specialists in the EU. Consequently, this is a huge opportunity for people with disabilities to take these jobs in the area of ICT. Likewise, there is a tremendous improvement in the area of accessibility and assistive technology, which further improve the chances of people with disabilities to take jobs in the area of ICT.

The older people are facing digital exclusion too, because they have poor digital skills. Accordingly, there is a need to develop technology with natural interaction techniques, improved user experiences for adults. Additionally, this further helps old people to have more independence and improve their self-management abilities.

As per societal consensus, assistive technology and accessibility are not only beneficial for people with disabilities but also for the whole society. Therefore, accessibility has been on the action plan over four decades. However, it is not properly integrated with the education of educators, administrators, managers, caregivers, and policy makers of people with disabilities. Accordingly, accessibility should

integrate into mainstream education and this curriculum shift should be high in the action plan for people with disabilities.

There are various support services introduced in the last decades to fulfill the requirement of people with disabilities and substantial expertise is developed around these services. Although, the CRPD (Committee on the Rights of Persons with Disabilities) Committee [8] observes that these support services should be structured to meet all life-spectrum needs in a wider way. Therefore, there is a need for innovation to expand the support provision and to improve the existing support systems so they can fully meet with the standard of the human rights convention.

Design and Method

The ENTELIS+ project aims to achieve the call objective building based on previous achievements and creative methodologies, such as the EIPonAHA group [6] and the ENTELIS network [7], in order to incorporate demonstrated progress in the area of digital communication skills for old age and person with disabilities. Additionally, this further helps in:

- Fostering accessibility also as a common European value. Accessibility is a key driver for active citizenship, employability, and overall inclusion.
- Going to build on the findings of the ENTELIS project as a co-operation and networking actively involving combinations of specific (private/public) stakeholders throughout various sectors. Additionally, it is based on the approach of working at the local level of the European Innovation Partnership on Active and Health Ageing (EIPonAHA) project, where network members work in collaboration to achieve a common target.
- Attempting to generate impact at the system level and partner organisations. This project is following the ENTELIS blueprint. Therefore, the work package (WP) consolidation is proposed to have a meaningful impact in the region and to improve the vertical and/or horizontal level.

WP1. Building the case: In this WP, framework knowledge is produced. This framework helps to build the case about the value of delivering digital skills for old age and persons with disabilities to promote inclusive education, more citizens participate in the society, better job opportunities, and employability.

WP2. Knowledge Brokerage & Training: In this work package, the conceptual framework is specified. Additionally, the methodological approach is commonly accepted and core training material for the various pilots is established. A common glossary and vocabulary will be created with description of concepts like accessibility, digital skills, digital divide, inclusive education etc.

WP3: Localisation of Training and pilot plans: Using the design-thinking methodology and following the training material built in WP2, unique local plans will be prepared for every pilot. The training material will be prepared in the different languages of pilot countries, then the local partner who is concerned for piloting must ensure that there is an appropriate quorum in the scheduled timeframe to plan out the pilot and it will pick the participants. The training will be structured taking into account all aspects of the venue's accessibility, training materials and any information submitted must meet accessibility requirements.

WP4: Dissemination and Exploitation: This work package contains the various strategies to disseminate the project materials and update the findings and project materials through participating countries and their respective regions. Additionally, there are strategies to leverage project results-will be connected to the previously created dissemination plan.

WP5: Evaluation & Quality Assurance: This work package covers advisory board management and project assessment.

WP6: Project Management: This work package contains different aspects of project coordination.

Conclusion

ENTELIS+ project helps to raise awareness about the value of accessibility. Accordingly, accessibility facilitates inclusive education in society. Additionally, this project assists older people and people with disabilities in digital skill development. Furthermore, it builds the capacity of those key actors (service providers and public authorities) in charge of designing and implementing facilitating frameworks.

Consequently, this project decreases the digital divide by improving the organization to work together in the formulation of guidelines and policies for the advancement of digital skills for the digital excluded section in the society.

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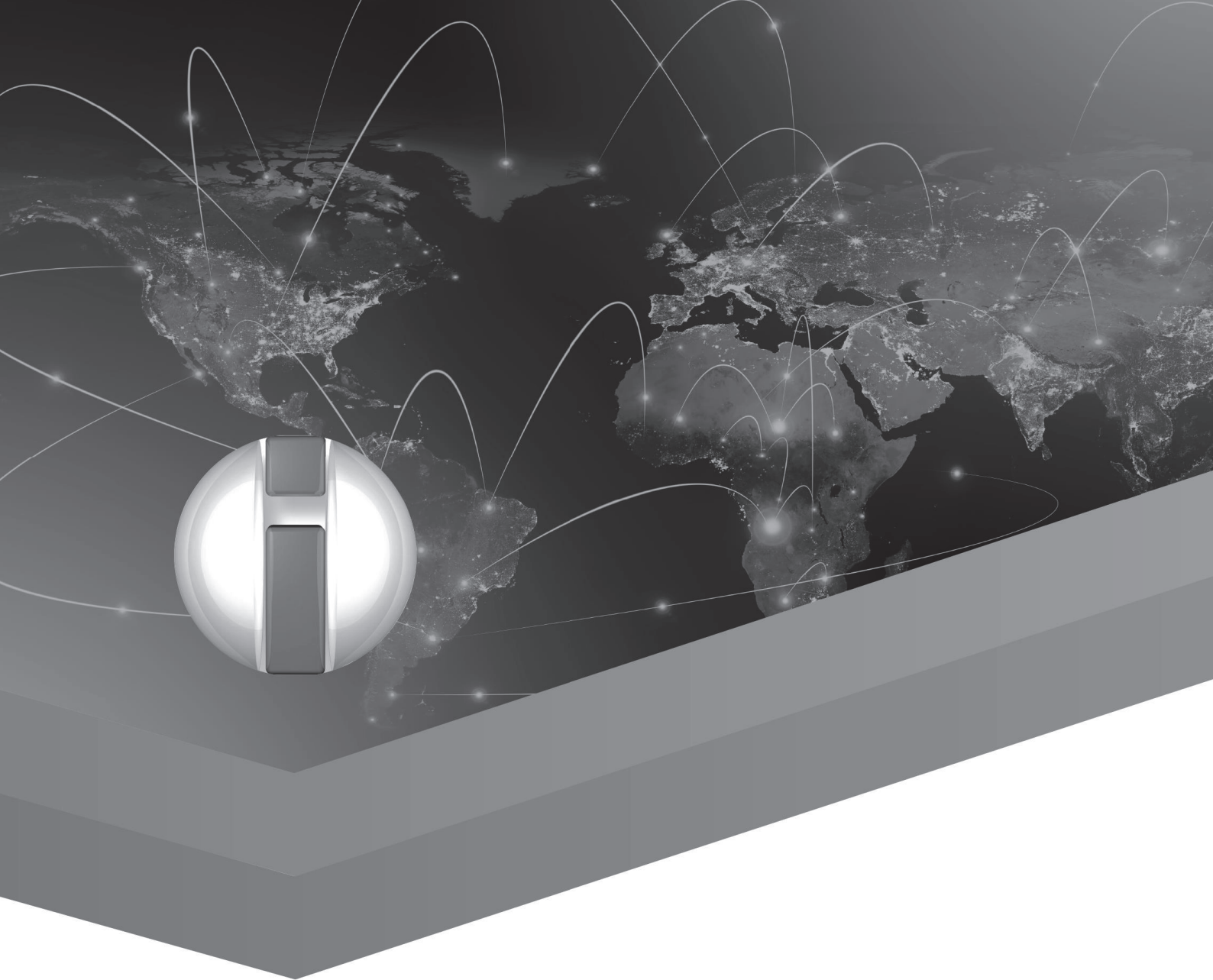
Hearing Systems and Accessories for People with Hearing Loss

Online Communication Assistant System for Deafblind Person

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Abstract

Due to the spread of COVID-19, distance communication system is required in order to do jobs. In this case, there is not the sufficient solution to real timely exchange conversations with deafblind person. In this study, we propose online communication assistant system which established real-time duplex channel with all participants including both hearing persons and visually impaired individuals. This system works as standard web application with voice recognition system on multi-platform computer devices including mobile smart phones. Our propose system gives really useful to establish a communication network for doing job tasks.

Introduction

Deafblindness is a dual sensory impairment which has the combination of vision and hearing impairments[5]. This leads to significant barriers to communication, accessing information. According to the reference[3], deafblind people can be categorized into four groups.

1. A person who is deaf and blind from birth.
2. A person who is born deaf or hard of hearing and later their vision starts to deteriorate.
3. A person who is born blind or vision impaired and later their hearing starts to deteriorate.
4. A person who has become deafblind due to old age, accidents or illness.

Deafblind people use several different communication methods, including speech and tactile approaches [2, 3]. The most commonly used methods of communication for the deafblind are tactile sign language and Braille. Braille is a tactile system of reading and writing for use by people who are blind and visually impaired all over the world. Currently, Braille is also being used by a minority of deafblind people. Letters and numbers are represented by raised dots arranged in six-dot Braille cells. It is read by moving a finger over a line of Braille cells [1], [3].

On the other hand, due to the explosive spread of COVID-19, there is an urgent need to establish distance communication in various places. In particular, the communication is very important for doing jobs. Also, the communication flow may happen in a variety of settings, one-to-one, many-to-one, one-to-many, many-to-many, and situations, in presence or remote face-to-face, live, or delayed broadcasting, etc. In order to perform these various forms of communication remotely, it is necessary to develop a method of distance communication that can be used by everybody.

A survey of systems that support distance communication for the deafblind has already proposed various methods. For instance, Ludovico Orlando Russo et al. developed a novel Cloud Robotics architecture empowered by hand tracking technology and 3D-printed bio-inspired robotic arms to enable remote on-line communication for deafblind people in tactile sign language, the communication system most natural to them [4]. In this method, multiple tentacle sign language conversations can be conducted through the web interface. However, in order to effectively utilize this system, deafblind people must be able to have good Tactile Sign Language skills as well as a good grasp of technical

knowledge which can become a barrier to those Deafblind people who do not have those sets of skills and background knowledge.

Rohit et al. utilize wearable technology to propose a communication tool among blind, deaf, and dumb people[5]. This system establishes conversations between individuals using communication lines. However, this is not suitable for communication with a large number of people. Moreover, in order to use this system, each client needs a mobile telephone line, which generates communication costs depending on time.

Although there are various methods as described above, there are various problems in establishing communication in an inclusive environment.

In this study, we would like to propose a system for casual and remote communication between a large number of people which is inclusive of deafblind people as well as hearing people. This system was developed for the use of a Deafblind student who is currently studying in our university. So, we wanted to create a system that would enable Deafblind students to be able to access information in real time, allowing them to study and gain information at the same speed and time together with other students. We believe that our system will allow them to do so as efficiently as possible.

Outline of Our Developed System

All client PCs are connected to the virtual network hub by using Softether application.
It means all devices are on the same network segment and they can communicate each other without any limitation by sockets.

The internet

Hearing person

Client PC based on Windows 10
Web chat system developed by authors

Web browser and Message monitor which shows which message deafblind user is now reading.

Client PC based on Windows 10 with any screen reader software. Web chat system developed by authors is installed.

Visually impaired person

VPN Gateway

OS : Windows 10 Pro 64bit
Installed software :
 Softether VPN Server (virtual hub)
 Screen reader NVDA
 Original developed Software
  Chat and Message relay server
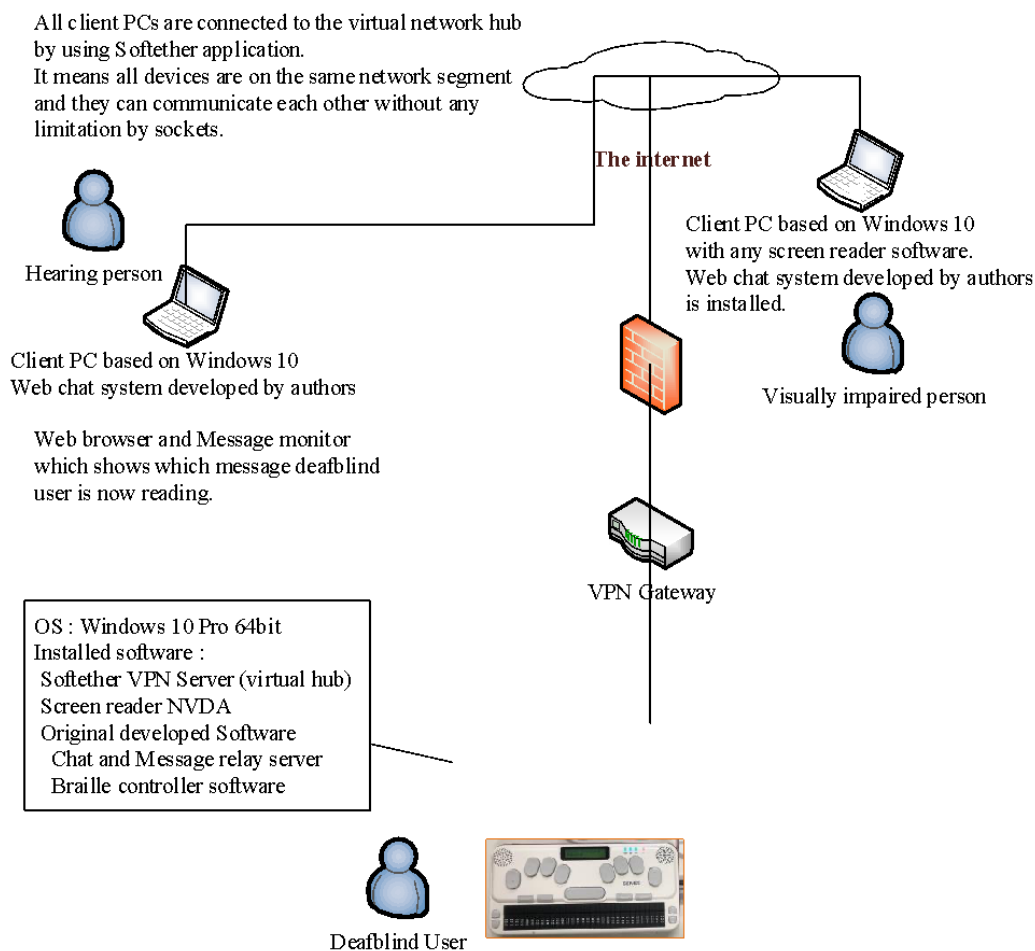 Braille controller software

Deafblind User

Fig. 1: System configuration which shows connections between clients and deafblind user's client. The small stick pc is a server works as a controller to distribute messages and show a braille form message.

The proposed system consists of three components: a Web-based chat support application that supports conversation input, a system that outputs conversation information to the deafblind user in Braille, and a server system that relays all these important information.

The base hardware is implemented by one ultra-small stick PC, and communication is achieved by a star-type network based on this PC. Each client was connected to the same network segment as the stick-type PC via VPN, and the address used for communication was the local link address. Fig. 1 shows the overall system configuration.

In the proposed system, based on the communication environment by Web socket, the conversation is established by utilizing the mechanism of conversation transmission by the character information with many people. On the Web interface, conversation input corresponds to voice input, and conversation output can be read out by voice as well as confirmation on the screen. This component is used by the hearing-impaired and the deafblind user can utilize the functional part that speaks. You can check what you say on the connected braille display. Fig. 2 shows the screen when voice input is performed on the mobile interface. This system consists of extra hardware components such as Braille sense U2 and Intel's Compute Stick. NVDA was used to generate the data displayed on the braille display. The developed control software has a function to display Braille when the deafblind person needs it and a function to transmit the displayed Braille information to the relay server. The relay server communicates between the web chat and the Braille control client software and relays from the Braille control client to the monitor client software.
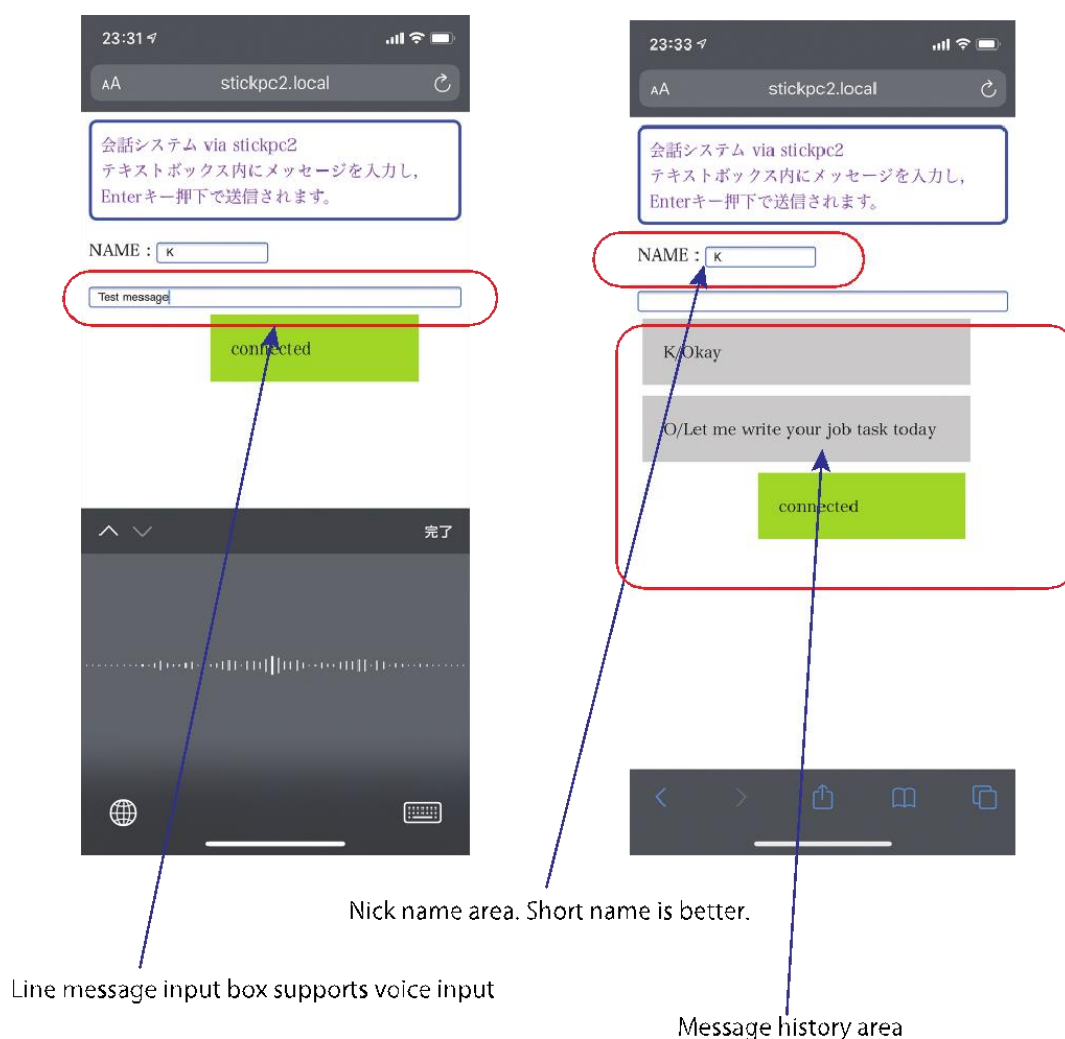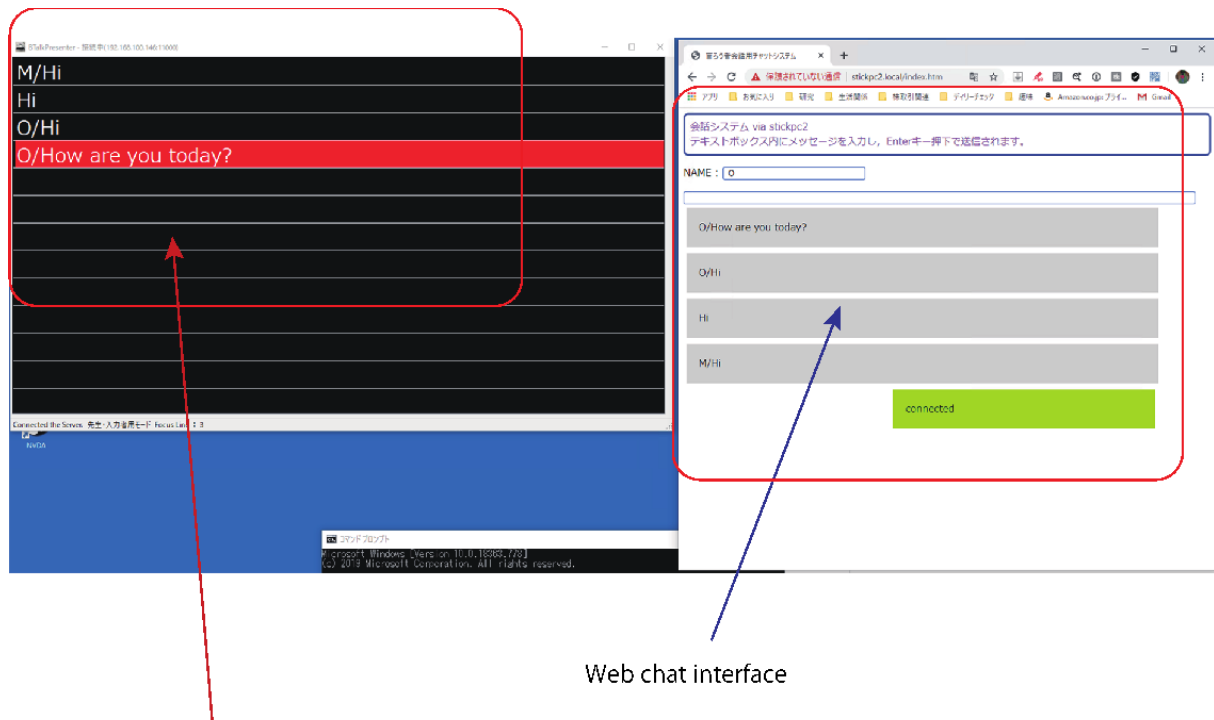

Fig. 2: Mobile voice chat interface based on iOS system.

Web chat interface

Monitoring software which shows the blind student is currently focused on the line he is reading.
Red line means current line he is reading by braille display device.

Figure 3 Desktop chat interface and the monitor client software which displays current message that deafblind person is reading. This interface is for hearing or visually impaired persons.

The hardware which makes up our system consists of a standard PC which runs on the Windows 10 operating system, including an installed copy of the Non-Visual Desktop Access screen reader, otherwise known as NVDA. NVDA supports many Braille displays, including the Braille Memo that is produced in Japan, thus allowing for Braille output to be provided once a Braille Memo or Braille display is hooked up to the Windows 10 pc

On the voice input screen, after setting the name to identify who is speaking, the speaker can send their messages by voice or keyboard input. The utterance or written message is then displayed to other participants as shown in Fig. 3 (using a connection from a Web browser on a desktop PC). At this time, the situation is as shown in Fig. 4 with the Braille output control client software. The content spoken by the speaker is automatically added as an index based on the speaker's name, and it is possible for a deaf-blind student to confirm who spoke the content. In addition, since the message read by deafblind persons can be confirmed in real time, it is inevitable that various considerations such as devising the utterance content and consideration of the timing of utterance are inevitable to make it easier for all deafblind students to understand. Hence, with this interface, anyone can speak in chronological order and avoid conflicts arising because of people talking at the same time.

Use Cases with Deafblind Student

Let me show an example of using this system. Currently, the department to which the author belongs includes students who are Deafblind and are educated in the same environment as other visually

impaired students with normal hearing. This student is a Deafblind, and the outline of the vision and hearing impaired is as follows.

- Sight: Light perception.
- Hearing: Hearing loss 60 dB (recognized as sound, but extremely difficult to understand as words)

Since this student is a Deafblind, uses Braille or finger Braille is the main ordinary communication. In addition, his vision was gradually deteriorated, and he retained his vision until the fourth grade of elementary school, but since he became blind, he has a spatial cognition. Hearing ability became more difficult from the first grade of junior high school, and now is recognized as severe hearing loss, also almost difficult to hear in the classroom environment such as lectures. Therefore, unable to hear screen reader in the class etc. So, the way of communicating this student is use braille or finger braille.

Using this system, we tried to communicate with this student through the Internet based chat.First, Shown in Figure 1 which is Utilize Softether VPN application on Windows StickPC that is automatically connect to the Virtual HUB installed in the university. And connect the PC used by Normal hearing person to the same Virtual HUB through the Softether VPN application as well. Then, start up the Web browser on the PC of the Normal hearing person, and use the link local address to connect to the chat server running on StickPC. Also, startup braille display monitoring software to grasp the line information that the deafblind person is reading in Braille in real time. Under the above environment, we attempted a conversation for about an hour between a deafblind student and a Normal hearing person.

As a result, there is an influence of utterance due to character input, and some gaps occurred. But smooth communication implemented using a mechanism for grasping the conversation lines read by the deafblind person in real time. At the end of the conversation, we confirmed the usability of this system with deafblind student. The user's opinion was extremely comfortable conversation was established with grasp information in the real time. From the above, possibility has confirmed to establish an online conversation by this system.

On the other hand, system configuration has problem sometimes, and there is a restriction that all terminals must be connected to the same segment by VPN, so preparation for conversation becomes complicated. To overcome this drawback, it is necessary to make improvements such as using Web sockets based communication for general-purpose. Furthermore, creating an addon package for NVDA which uses NVDA's built in braille output control part would be usability improvement for Deafblind students.

Discussion and Future Work

In this paper, we prototyped distance communication assist software between hearing persons and a deafblind person. The interface of the speaker is designed so that all participants can confirm the conversation contents in real time by using WebSocket communication so that information can be shared without barriers even if the hearing participants are not familiar with tactile Sign Language and other specific skills used by deafblind people. By using this system, it is not necessary to have a dedicated person who is in charge of conveying the different messages to the Deafblind participants as has been done in the past, and all participants can speak while paying attention to various considerations so that they can be easily understood in chronological order.

Speech to text technology has greatly improved. However, transcribing every word into text is time consuming and inefficient, taking into consideration the situation of the student who is Deafblind. We use a lot of unnecessary words while speaking such as um, err, etc., which creates difficulties for the student when reading the information in Braille. Currently, the situation is that 1 or more students usually type out what the teacher is saying in real time in order to assist the Deafblind student. It is possible to pick out only the necessary parts of what the Japanese teacher is saying. Therefore, we

would like to use AI technology to improve this process in order to assist the Deafblind student to access information more efficiently and effectively. In the future, we will evaluate the prototype system using remote communication, identify the necessary issues, and aim to establish more natural and real-time communication.
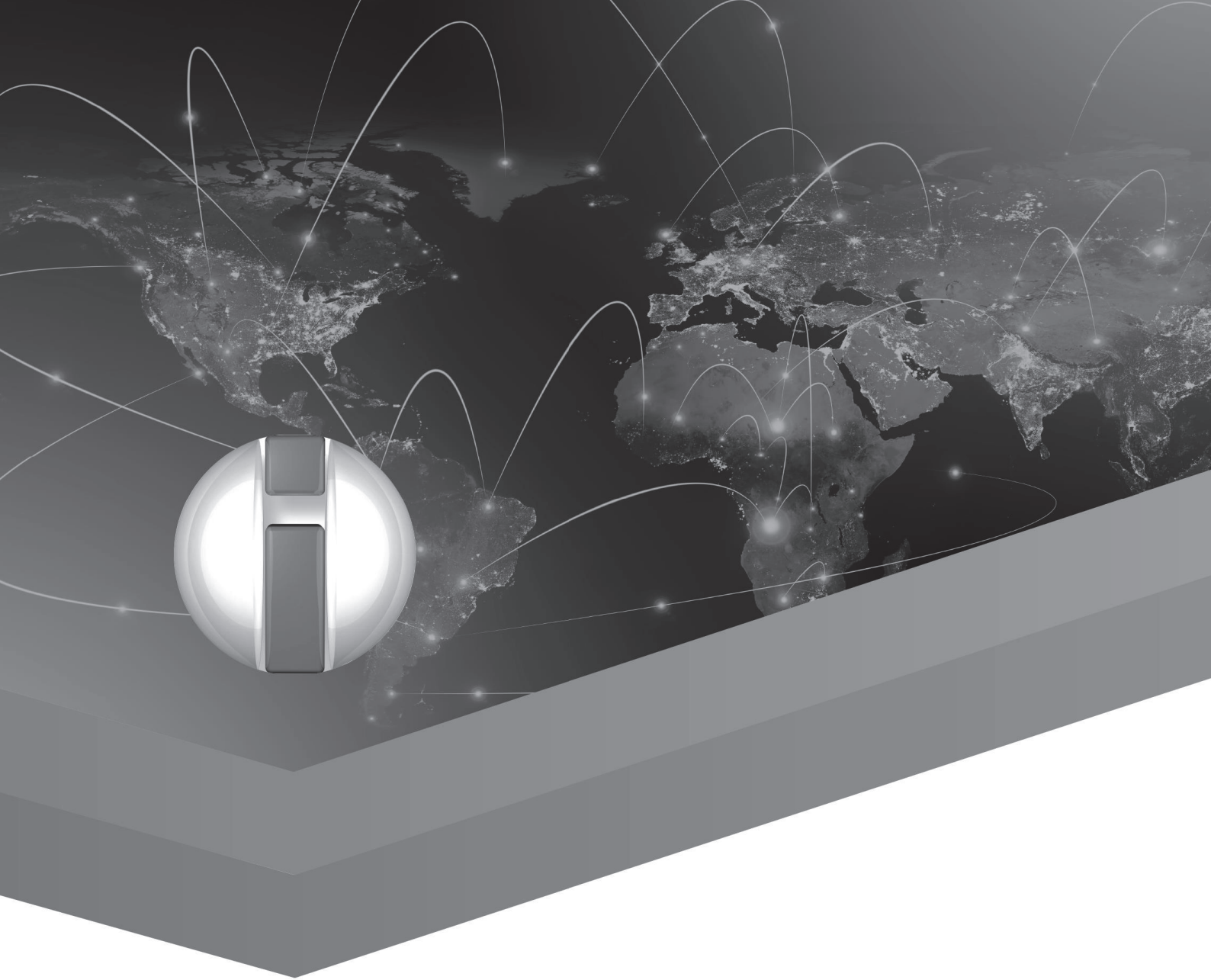

Figure 4 Braille display shows red line messages show in left image. Braille user can read each message on the chat where he wants to access anytime. Also, others can detect these situations.

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Innovation and Implementation in the area of independent mobility through digital technologies

Co-Production of Knowledge for Designing Inclusive Digital Mobility Solutions – The Methodological Approach and Process of the TRIPS Project

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Abstract

We are still far from achieving the ambitions of ensuring independent living and providing equal opportunities to enjoy seamless, accessible, and independent travel for persons with special access needs. The goal of the project TRIPS (*TRansport Innovation for vulnerable-to-exclusion People needs Satisfaction*) is to empower people with different access needs to play a central role in the design of inclusive future mobility solutions. For this reason, a participatory approach is developed and applied to co-product knowledge on existing barriers, co-create solutions and co-evaluate the resulting prototypes and services. The project thereby engages seven European cities in the open innovation process. The paper introduces the first phase of the project, the user requirements analysis by illuminating the methodological approach and reflecting on first results of the co-production of knowledge. Special emphasis is placed on the building of the local working groups and their involvement in the research. The paper further demonstrates how participatory research in the context of inclusive mobility is enabled despite the current COVID-19 pandemic situation.

Introduction

According to the European Health and Social Integration Survey (EHSIS), in 2012 there were 42 million people aged 15–64 years who are considered having a disability. The definition of disability refers to people having a longstanding health problem and/or a basic activity difficulty that act as a barrier to participate in any of 10 life areas [1]. Meanwhile, today's transport systems remain inaccessible in considerable parts for people with disabilities, compromising their equal access to important services, job opportunities, education travel, overall lifestyle choices and capacity for independent living. By ratifying EU Treaties and the UN Convention on the Rights of Persons with Disabilities, EU member states have committed to respecting the rights of people with disabilities for independent living and to providing equal opportunities to enjoy seamless, accessible, and independent travel. This, however, has yet to materialize for people with access needs in the whole EU. As transport currently undergoes rapid transformation with new mobility models (e.g. vehicle sharing schemes) and transport-related digital solutions (e.g. Augmented Reality) coming into play all over the world, it is an opportune moment to design future mobility systems to be more inclusive from the very beginning. Participatory approaches are a promising way to engage users with access needs to become active participants in open innovation since they are experts of their own mobility and access needs. Engaging citizens through participation allows researchers to investigate user needs in complex systems, such as transportation [2]. Participatory approaches like *Action Research* [3], *Participatory Design* [4] and *Research through Design* [5] have been established in research and development, yet, there are only few attempts to adopt participatory and co-production to create inclusive mobility solutions [6-9]. To the best of our knowledge, there have not been participatory projects addressing transport systems in a comprehensive way, but only elements of it. The new European research project TRIPS aims for

adopting this comprehensive approach by addressing different access needs, various mobility systems in several European countries.
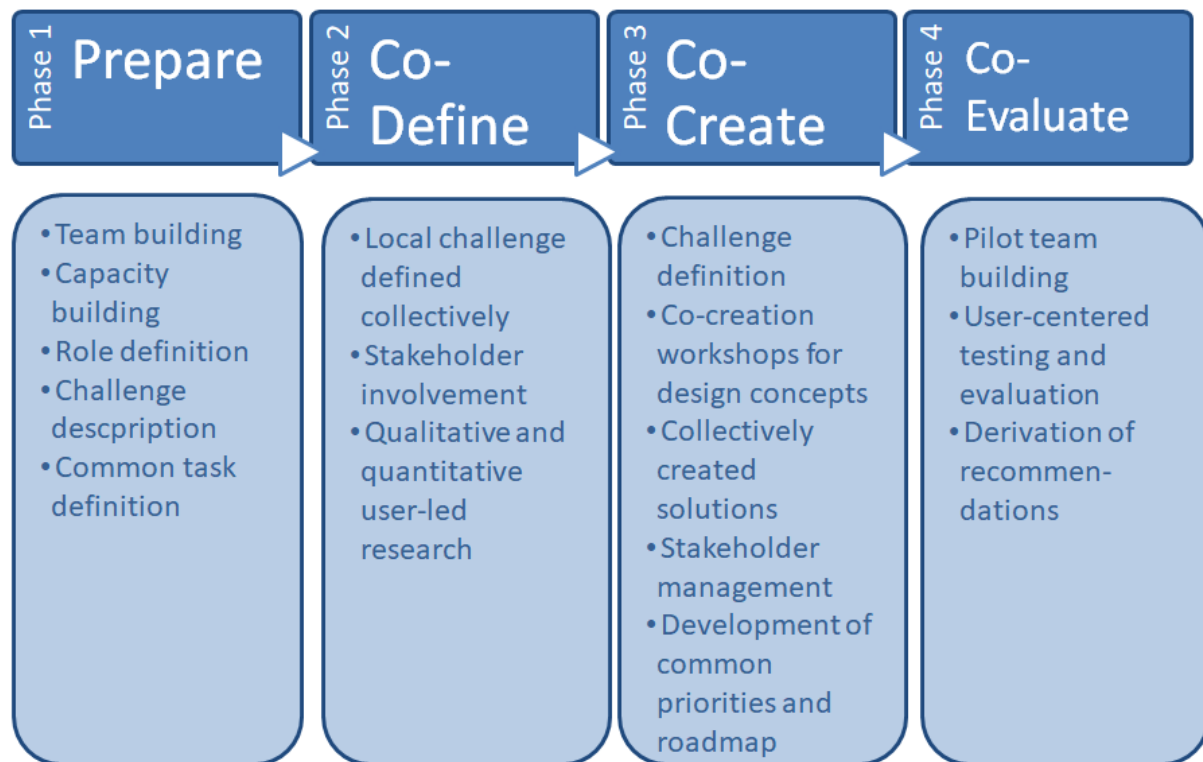
The TRIPS Approach

The goal of the *Horizon 2020* project TRIPS (*TRansport Innovation for vulnerable-to-exclusion People needs Satisfaction*, https://trips-project.eu/) is to design, describe and demonstrate in practice how to empower people with disabilities to play a central role in designing the inclusive digital mobility solutions. It puts forward a co-design approach that underpins Mandate 473: *Design for All* to eliminate discrimination and improve Access-for-All to mobility services [10]. This project seeks to understand important and often overlooked aspects of user impact and user's ability and readiness to take advantage of new mobility opportunities by undertaking in depth qualitative and extensive quantitative user research and targeted user involvement in the co-design of urban mobility solutions during the pilot studies.

The TRIPS consortium brings together pan-European networks of users with access needs, transport organisations, assistive technology experts and municipalities to engage in open innovation on mobility. Supported by design methodology experts, systems integration experts and privacy experts, the TRIPS project will deploy a *Co-design-for-All methodology* in seven European pilot cities – Bologna, Brussels, Cagliari, Lisbon, Sofia, Stockholm and Zagreb – to develop selected inclusive digital mobility solutions and their respective business cases to support their subsequent adoption. During the upcoming three years, TRIPS will conduct the research on user needs and attitudes towards future mobility solutions, review the state-of-the-art on accessibility, mobility and related digital and assistive technologies and policies and devise an index to measure mobility. The project will also bring users and transport experts together to discuss institutional barriers to adoption, agree innovation priorities and policy changes, co-develop an innovation roadmap and agree research priorities. In doing so, the project reaffirms the role of disabled users as drivers for change and active citizens alongside with regional authorities and businesses in designing digital transport solutions, and policy-makers in designing appropriate regulatory frameworks and social and educational strategies.

The co-production process in TRIPS is divided over four phases based on an iterative approach. In the *Prepare* phase, the working groups were formed that empower citizens of the seven mentioned cities to participate in the project. In the subsequent *Co-produce* phase, the barriers that were identified and the end-user perspective was examined based on the findings of social media content analysis and qualitative interviews as described below. The aim of the third phase - *Co-create*, is to together with the users to find possible solutions of the Technology Readiness Levels 3+ for the previously identified barriers and challenges. These solutions will help municipalities on their journey to accessible inclusive digital mobility. The methodology is described in the section concerning the planned activities. As the last step of the co-production process the created solutions are implemented and evaluated in the *Co-evaluate* phase. The created products will be tested by the users in a pilot study in the seven cities. Furthermore, the project aims for developing the *Mobility Divide Index* (MDI) as a set of comparable indicators for evaluating transport systems and creating new, user-centric standards for researchers, policy makers, transport and urban planners.

This paper aims to describe the methodological approach used in the first two phases in more detail – see *Prepare* and *Co-define* (see figure 1 below). In the following sections, the co-production of knowledge is introduced and the performed activities are presented: 1) forming of working groups, 2) implementing social media content analysis and 3) conducting qualitative peer-interviews. Furthermore,

the planned activities, especially the quantitative survey and the co-creation, are presented.

Phase 1 **Prepare**	Phase 2 **Co-Define**	Phase 3 **Co-Create**	Phase 4 **Co-Evaluate**
• Team building • Capacity building • Role definition • Challenge descpription • Common task definition	• Local challenge defined collectively • Stakeholder involvement • Qualitative and quantitative user-led research	• Challenge definition • Co-creation workshops for design concepts • Collectively created solutions • Stakeholder management • Development of common priorities and roadmap	• Pilot team building • User-centered testing and evaluation • Derivation of recommen-dations

Picture 1: Four phases of the co-production process of the TRIPS project

Co-Production of Knowledge

The TRIPS methodology promotes close collaboration between transport users and stakeholders through Participatory Research and Design processes [11, 12]. Adopting the lens of participatory change, the project aims to facilitate interactions between different stakeholders to develop mutual understanding and alignment of interests. The participatory character is also emphasized in co-production that aims for improving public involvement in research as active collaborators [13]. The project thereby builds on participatory design approaches in the context of transportation like the living lab approach of the project *Reallabor Schorndorf* [14]. TRIPS aims to adopt Wright et al. [15] notions of participatory design that postulates that 'knowing the users" in their lives, requires both an understanding what it feels like to be that person (empathy) and what their situation is like from their own perspective (perspective sharing). Thus, the goal of the user research and needs identification in TRIPS is to understand disabled citizens' divergent needs and attitudes towards future mobility as a means for designing inclusive mobility solutions for all. A mixed methodical approach [16], combining qualitative and quantitative methods, is applied to study the user needs.

Originally, the consortium planned to engage disabled users through face-to-face interviews and conduct a shadowing study to observe users taking public transport during their trips in the various partner cities, to understand the challenges they face during their end-to-end journeys and explore the criteria affecting their transport-related decisions. The current COVID-19 pandemic situation, however, demanded a rethinking of the original plan. Instead, a social media content analysis was performed to identify barriers of public transport use in the cities under consideration. Furthermore, the face-to-face interviews were replaced by phone/online interviews. During the qualitative research, the data was analyzed to create user profiles and inform the development of questionnaire for validation with the wider disability community and other vulnerable-to-exclusion groups. For this part,

the project will develop an accessible online questionnaire and engage members of the European Network on Independent Living (ENIL) in various European cities as respondents. The online survey will remain open until the end of the project, by when we aim to reach a minimum of 500 disabled and other vulnerable-to-exclusion citizens (such as senior citizens, immigrants) across EU member states to allow for cross country comparisons.

Forming of Local Working Groups

Co-production is a new way of working which empowers all the actors in the process to participate fully on the basis of shared knowledge and equal partnership [18]. As the first step of the co-production process, working groups were established in each of the seven cities. The working groups consist of about 10-15 people, including persons with different access needs (wheelchair users, visually impaired individuals, hearing impaired individuals, persons of short stature, etc.), transport providers, representatives of city municipality and specialist of assistive technologies.

The most important elements of the co-production process can be summarized in two points: 1) the working group must work in the co-productive way from the very beginning to enable users to exert influence decisions at an early stage of the project, by defining the list of strategic priorities and key challenges worth considering for execution; 2) partners (transport partners, city officials, and users) agree on a common goal or outcome they want to achieve from the beginning. To ensure all actors across the cities have the same understanding of co-production, the TRIPS consortium made a concrete summary document on how to put co-production into practice. This document highlighted the essential principles of successful co-production, such as sharing of knowledge and power, finding time and space to develop and discover skills, providing guidance around the time and work commitment and compensation for the members of the group.

To stimulate equal partnership and a change of power dynamic towards user-centricity, we ensured that disabled users take the coordinating role in the working groups. For this reason, ENIL members and other activists, experienced in working with people with disabilities, were recruited for the roles of the Local User Lead. Starting from March 2020, the Local User Leads were introduced to the representatives from the city and the local transport providers. An essential step towards the joint work in the project was the definition of roles of the working groups and to establish communication channels for continuous exchange. The working groups leaders and at least one more member of the CUT were trained as co-design facilitators in order to plan and guide the co-design sessions with transport providers, representatives of city municipality and specialist of assistive technologies. This resembles the high rung of partnership on Arnstein's ladder of citizen participation [19], which describes different levels of participation similar to a ladder.

One of the first tasks for the Local User Lead was to bring people with disabilities in the city together around the topic of accessible transport and so form a User Group of people with different access needs as part of the working group. This will be done by first defining the barriers to accessibility at the start of the project with the goal to develop pilot solutions to remove (some of the) barriers at the end. Due to the COVID-19 situation the start of the (physical) meetings of the working groups have been postponed. Instead of this, the Local User Lead will start connecting disabled people in the city to TRIPS through the sharing of recourses for the media content analysis and by asking them which transport barriers they face by implementing the qualitative interview. This will ensure the groups can start from a strong position and have the first physical meeting of the working group towards the end of August, 2020. Later on, they will work on the quantitative survey.

Social Media Content Analysis

Social media content analysis uses user-generated social media data that serve as a barometer for monitoring changing attitudes toward newsworthy or controversial issues [20]. Media content analysis has been used for studying public opinion on a topic like concerns and challenges related to the introduction of a e-scooter system [23]. In TRIPS project, this method of data collection was used to

identify barriers that people with access needs face before, during and after their travelling with public transport (by bus, metro, subway, taxi, ridesharing, bikesharing, micro-mobility etc.). The social media content analysis provides insights into the topics people discuss about at platforms, in social media channels and as comments to online newspaper articles. The entries were analyzed thematically according to the following research questions:

1. Which topics do the different web entries focus on?
2. Which barriers of public transport and its related features (access/booking) are addressed?
3. What similarities and differences in content exist between the different cities?

At least 30 media entries concerning accessibility of public transport, barriers, assistance services etc. were researched in each of the project cities. For the analysis, social media platforms, such as Twitter, Facebook and Instagram were scanned based on appropriate search terms like *Disabled/mobility-impaired / wheelchair /visually impaired / blind / deaf, hearing impairment / Public transport / bus /metro/ subway / transit / mobility / taxi.* In contrast to other approaches like reported by Gössling [23], only social media entries by private persons were selected for analysis but no official journalistic reports or articles. Both, selection and analysis has been conducted by working groups who are familiar with the specific characteristics of the local transport systems and the media channels. Entries and related information were collected in a table that comprises information concerning the nature of the disability referred to, the described barrier and possible solutions named. Content was analyzed in detail regarding their informative and affective reactions to public transport-related issues and systematically coded and clustered with the software MAXQDA based on grounded theory [21,22].

Our primary results of social media content analysis highlighted the relevance of existing barriers, especially the recurrent complaint about missing or broken ramps which is the most frequent topic addressed in social media related to accessibility of public transport. The social media analysis revealed that some groups of public transport users with special access needs, like persons with sensory impairments and mental impairments are rather underrepresented in online discussions about existing barriers while others, especially wheelchair users, use this medium more frequently. The results of the social media content analysis also revealed several solutions proposed by the social media users that are mostly related to the provision of real-time information. One of the analysed Facebook entries suggested more regular checks: "W*hat we want is to demand rigor and transparency. Perhaps considering regular visits by NGOs-PDO, who can have access, without pre-schedule, to garages, who can request fault reports, request the total number of complaints in the last three years, be aware of the number of stops that do not allow people to pull over and use the ramp...*" (Content on Facebook from Lisbon). Another social media entry summarized the underlying demand that the TRIPS project is aiming to serve with its open innovation approach, "*It is best to construct public transport in such a way that it works for everyone from the beginning*" (Content on Facebook from Stockholm).

Interviews

Interviews with people with access needs were conducted to acquire in-depth information and insights concerning the knowledge and opinions of the interviewees. Interview guidelines were prepared in advance but were regarded as a loose framework based on open semi-structured questions. The questions were clustered to four topics: 1) choice behavior (e.g. "Are there any transport means that you do not use or avoid? For what reason?"), 2) barriers (e.g. "Which are the main barriers you face when using public transport?"), 3) assistance (e.g. "What technology do you use and would like to use to help at each stage of your journey with different means of transport, both for booking and traveling?") and 4) participation (e.g. "Are there other possibilities to get involved in transport design in the city? Do you feel they are meaningful?"). The interviews were conducted via phone or video chat by the local users leads. Each local user lead interviewed 7 persons with access needs in each of the seven cities.

The primary results of the interviews revealed that the public transport systems in the cities under consideration are far from being accessible for everyone. It was expressed by the interviewees that there are solutions that would make transportation more accessible but they are not implemented, not used in the right way. A lot of accessibility equipment are broken, such as elevators, escalators or audio announcements in busses. The interviews contributed to the findings of the social media content analysis by enriching the results and providing more insights into the thoughts, attitudes and intentions of persons with sensory impairments that were rather underrepresented in the social media analysis. The interviews revealed that persons with visual impairments often face barriers like inaccessible ticket machines or missing audio announcements in busses.

Planned Activities

The qualitative studies represent a cornerstone for the proceeding survey study. The accessible online questionnaire aims for minimum 500 respondents from various European cities. Members of disability organizations (such as *European Disability Forum*) and members of other organizations representing other vulnerable-to-exclusion citizens, such as senior citizens (*AGE Platform Europe*), migrants (*European Movement International*), people of lower economic status (*The European Anti-Poverty Network*) will be invited to participate in the survey study starting in autumn 2020.

Cross-country comparison of the results will provide further insights into commonalities and differences in the requirements of disabled individuals concerning their mobility needs and inform prioritization of research and investment agendas to maximize the impact of transport accessibility efforts. These mobility needs and requirements will be further accounted for making strategic decisions on the challenges to focus on in the co-design process that starts from the notion that all participants are equal partners with equal power of decision making [18].

The co-design-for-all methodology of phase 3 (*Co-create*, see Figure 1) will engage citizens of the project cities for creating accessible solutions. The working groups will help to prioritize ideas and define the focus of the co-design workshops. They will be peer trained in the method and take part in the co-creation workshops together with representatives of the municipality and transport operators to develop prototypes. These prototypes and demonstrators will be further tested and evaluated for usability and user acceptance by different users in the pilot phase in the seven project cities (phase co-evaluate, Figure 1).

Expected Impacts and Conclusions

The research contributes to enable safer and more comfortable travel to all passengers with and without access needs. As a first result, the project will provide a review of the accessibility of current and future mobility systems, assistive systems and ICT technologies related to transport to identify gaps. Based on the analysis of existing barriers, the Co-design-for-All methodology of TRIPS project will create the conditions for the equal participation of all citizens in open innovation and for the development of inclusive mobility designs from their inception. Thus, the identification of barriers while using the public transport is just the first step that will be followed by a comprehensive *Co-creation* phase to identify, discuss and test accessibility solutions for the specific conditions in the seven cities.

An expected impact of the project is to help policy-makers design appropriate regulatory frameworks by creating a comprehensive roadmap that distils the project's findings into recommendations for policy-makers, transport authorities, regional authorities and operators. The TRIPS consortium thereby engages users with access needs and institutional actors in the development of policy recommendations, an industry roadmap and research priorities. Furthermore, the development of the *Mobility Divide Index* (MDI) based on the findings, will contribute to form a set of comparable indicators and proposing a new, user-centric standard available for researchers, policy makers, transport and

urban planners, operators and stakeholders' representatives. To conclude, the project will empower people with disabilities to play a central role in the design of inclusive digital mobility solutions.
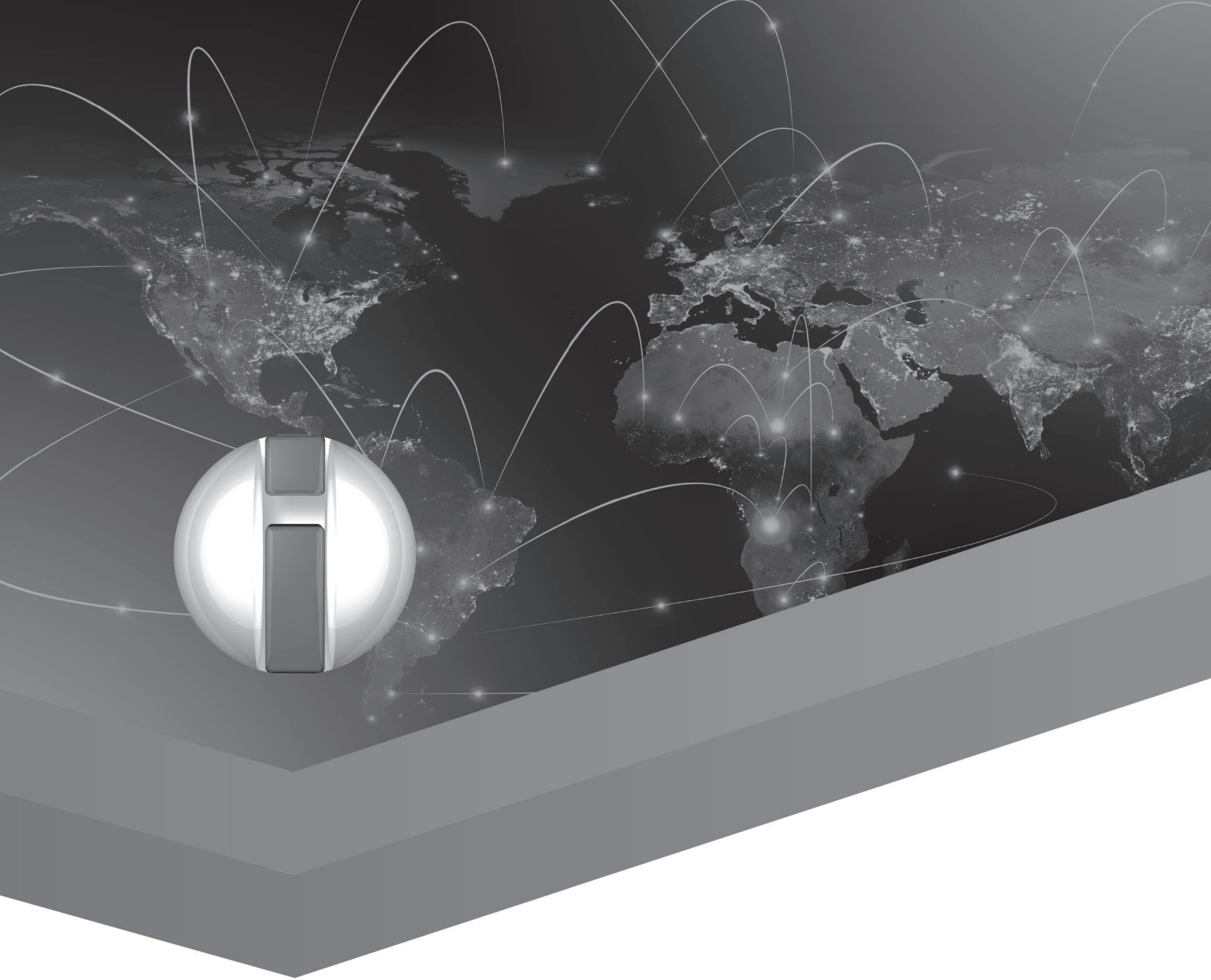
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Service and Care Provision in Assistive Environments

Project RADAR: Vocational Guidance and Employability for Blind and Partially Sighted People

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Abstract

RADAR attempts to resolve the complex problems relevant to the blind and the VIP (visually impaired people) unemployment level in the European Union. Additionally, this project aims at overcoming the shortage of information on different possibilities offered by the labor market for them, in particular related to the fast changes on the labor market due to the ongoing digitization in all domains of work. Traditional jobs no longer exist, new domains ask for accessibility, training and education and new approaches in services for vocational inclusion. This demands for new approaches for enhancing knowledge of existing training opportunities linked to accessibility programs in use and new areas of employment. Examples of viable practice should be exchanged and adapted to the local situation. The concept of getting more information regarding employment is important for blind and VIP to make their personal path of career growth and professional development.

Keywords: Blind and partially sighted people, employment, labor market, accessibility programs

Introduction

There are different issues regarding employment of blind and VIP in EU countries, as the ongoing research on the state of the art performed in the RADAR project underlines (see chapter 2). These job seeker's traditional professions such as a telephone operator are slowly disappearing in the EU because of technological advancement and rapid socio-economic changes. Therefore, a greater / wider knowledge of the opportunities offered by the most recent ICTs is needed. Generally, blind and VIP faced difficulties in access to resources and support in self-employment when compared with their employed colleagues, especially with regard to personal assistance as well as other kind of support. This project aims to solve this complex problem regarding employability of blind and VIP.

State of the Art

The unemployment rates of blind and visually impaired people in the European Union are currently [2] high. However, there is relevant progress made in recent years by the EU legislative systems [1] for inclusion of blind and VIP impacting on the situation in the different countries. Additionally, there are new professional opportunities available for this group due to advanced assistive ICTs.

This high unemployment rate may be due to following reasons:

- There are different definitions of "blindness" and "visual impairment" in the different countries of European Union [3].
- There are various kinds of employment, legislative/administrative systems [4] and economic situations, as well as different level of social security programs in the EU countries. These points make hard for a worker with disability [5] to compete easily in the EU labor market.
- Blind and VIP workers are registered for a significantly longer time in employment exchange services lists as compared to other workers.
- Employment related information is not equally widespread among EU [4] countries. Additionally, there is less information available on latest profession or training resources for blind and VIP

[6]. The development of education and training programs for new and developing job domains is lagging considerably behind.

Design and Method of the RADAR Project

This project acts directly on Employers and Operators who are responsible for employment and job-application services for blind and VIP (e.g. mentors, career guidance professionals, etc.), both in public or private offices for VET (Vocational Education and Training) inclusion policies and work.

This project appears to offer standard actions and intellectual outputs. These outputs aimed to:

- Raise employer's awareness and understanding of VIP employability problems, explain job tasks and professional positions that could be performed by them, and provide information on the standards/technological criteria required to improve their working conditions.
- Improve the quality of work-placement & VET guidance services for partially sighted and blind job seekers, and improve the sectoral skills of their associated operators. Due to the ongoing digitization in all domains and continuous development / diffusion of ICTs for accessibility and support, they will acquire more in-depth information about new learning opportunities and developing careers coverable by VIP too.
- Enhance the skills of tutors, teachers, support teachers, trainers, and educators to manage VIP's specific training & working needs.
- Focus on a package of the peculiar skills for educators, trainers, labor service operators, employers, guidance professionals and employers that could be a reference to prepare them to deal effectively with the needs of the blind and VIP.

RADAR's main Outputs are:

- *Training-Employability-Accessibility Framework*: This guideline covers the demanded technical profiles (or skills) covered by VI job-seekers and blind by assistive ICTs. Moreover, VET services through a comprehensive analysis of the peculiar needs of employers and labor services operators. Additionally, a general comparative system of VIP job placement and social inclusion procedures, explaining for each country concerned – accessibility shortcomings, strength and development procedures.
- *Special Guidelines For Employers*: Guidelines on new job positions and job activities that could be potentially coverable by blind and VIP, using latest assistive ICTs, to encourage the culture of work-place accessibility, including description on duties and recruiting benefits;
- *Operative Guidelines For VET and Career Guidance Operators*: Highly efficient guidelines for jobs and job-application service operators to be informed of the most suitable approaches for addressing/managing the specific requirements of VI job-seekers, understanding the latest training opportunities (e.g. internships, training courses etc.) and creative elements for their successful work placement.

Conclusion

This project will provide useful information, guidance and materials for blind and VIP, employers, trainers, VET, career guidance operators, trainers, support teachers, and teachers. Moreover, this is also helpful for the informal support sector (families, friends) of blind and VIPs as the have a key role in supporting inclusion throughout their personal and professional life. The outputs will be available on an accessible website, which guarantees its wide circulation among different organization, all kinds of employment actors and social institutions working on VIP and blind inclusion policies and actions.

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Improving the Accessibility of Touristic Destinations with an Assistive Technology For Hiking – Applying Universal Design Principles Through Service Design

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Abstract

Accessible Tourism focus on the logistical attributes being accessible to all and on the process to develop accessible products and services with all stakeholders of the touristic destination. Assistive technologies can be used to improve the accessibility of touristic destination and attraction. Some assistive technologies are designed for hiking. However, their integration on the customer journey has to be designed as a service. To this end, universal design principles and guidelines can be used to design products and services accessible to all. Universal design and accessible tourism are both rooted in the social model of disability, which states that it is the society who is disabling. The potential and the conceptualization of applying universal design principles for tourism has been widely discussed. However, little has been done to operationalize this idea. In this article, we demonstrate how to co-create with users an accessible touristic service based on an assistive technology who enables hiking for people using wheelchairs. Our main findings illustrate the pros and the cons of using and assistive technologies and the importance of considering the whole customer journey to improve the accessibility of touristic destinations.

Keywords: Accessible Tourism, Assistive Technology, Universal Design, Service Design, User-Centered Design

Introduction

The article 30 of the Convention on the Rights of Persons with Disabilities (CRPD) aims that equal participation in tourism is a right. Rooted in the social model of disability, accessible tourism is based on the principle that the socially constructed environment excludes people with disabilities from participating in tourism activities [1]. Accessible tourism is broader than just the issue of accessibility. It is a complex relationship between an individual, the environment in which he or she lives and the tourism industry. Therefore, it is the responsibility of touristic destinations to understand the needs of people with disabilities and to design inclusive tourism services.

People with disabilities, particularly those with reduced mobility, represent an important growing market for touristic destinations due to the ageing population. To attract these customers, it is necessary to improve the overall accessibility of destinations and of attractions. Natural environments are particularly interesting. Even if improvements are possible, such as the construction of trails, these will often not be enough to ensure accessibility. In this case, assistive technology can be used. However, the integration of assistive technology into the service chain requires service design work with all the stakeholders.

In this context, the concept of Universal Design is interesting because it aims to create products and environments that can be used by people of all ages, sizes and abilities [1]. To create accessible touristic services, the individual, the environment and all stakeholders had to work together. Therefore, universal design and its seven principles are of first importance. Universal design incorporates: *"… the design of products and environments to be usable by all people, to the greatest extend possible, without the*

need for adaptation or specialised design…" [2]. As Michopoulou et al. stated [3], competitiveness of touristic destination should be enhanced by universal design principles.

In this article, a brief literature review is done on accessible tourism, assistive technology and universal design. Then, the service design methodology is presented. The case-study and its findings are illustrated. Finally, a conclusion is done.

Literature Review

Accessible Tourism

The research field of accessible tourism focuses on the themes of inclusion, people with disabilities and the ageing of the population and their implications for tourism supply and demand. Based on the assumption that disability is a social construct, the concept of accessible tourism varies according to the cultural and historical contexts. The demands of tourists with disabilities as well as the understanding of other stakeholders in tourism environments are evolving. Rooted on the social model of disability, accessible tourism assumes that the socially constructed environment excludes people with disabilities from participating in tourism activities [1].

Accessible tourism is a niche market. Most of the research papers in the field focus on one dimension of disability, access and mainly mobility. The proposed market segmentation is based on the level of assistance that people need [1]. However, this market tends to grow. Indeed, the world's population is ageing, particularly in Western countries. This phenomenon goes hand in hand with an increase in the number of people with disabilities. Indeed, there is a significant relationship between age and disability [4].

Accessibility is based on different geographical levels, micro, meso and macro. Physical access, access to information and social activities as well as services can be distinguished at each level. On the other hand, access can be divided into three dimensions: physical access, sensory access and access to communications. Barriers to accessible tourism are also grouped into three categories of constraints: physical, attitudinal and lack of information. Access to information along the customer journey is paramount, particularly in the tourism industry where several independent providers interact to provide the experience. Natural and wilderness environments, as well as heritage sites, are often difficult to access or to improve accessibility due to legal constraints. However, their accessibility is a right [5].

An important work of accessible tourism is to understand what barriers are socially constructed and how to transform them to create accessible environments. Here, the contribution of theory on leisure constraints is important. This theory focuses on barriers, non-participation in entertainment activities and lack of leisure opportunities [1]. Constraints can be classified into three categories: intrapersonal (related to the person, his/her psychological, physical or cognitive state), interpersonal (related to social interactions or relationships in social contexts) and structural, the latter including, for example, financial issues, lack of time, laws, etc. [6]. Even if these barriers and constraints are well documented, little research has been conducted on how to design a barrier-free touristic service.

Assistive Technology in Tourism

To enable people with disability to perform some tasks, assistive technology (AT) devices are designed [7]. AT can be low-tech, as crutches or adapted cutlery, mid-tech like rollator or wheelchair and high-tech like speech-to-text engine

For touristic experiences, AT are useful along the customer journey. During the information phase, tourists can use AT to control their computer [8] or web accessibility tools like webpage readers.

During the journey, all the means of transport should be accessible. Then, at the hotel, people with disability would enjoy adapted accommodation and bathroom.

Specific AT can be used for leisure activity. Such AT exist for skiing, ice-skating and hockey or horse riding. Furthermore, a lot of sport activities are accessible for people with disabilities. The para-Olympic games are the flagship event for these activities. Besides, other AT enable people to do hiking (e.g. Freedom Trax, Ziesel, JST Multidrive and RIPCHAIR 3.0).

Universal Design

Ron Mace states that "universal design means the design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" [9]. The goal of Universal Design is to simplified life for everyone by designing goods, services or buildings accessible and usable by all people [10].

Universal design is based on seven principles: 1) Equitable Use, 2) Flexibility in Use, 3) Simple and Intuitive Use, 4) Perceptible Information, 5) Tolerance for Error, 6) Low Physical Effort and 7) Size and Space for Approach and Use. These principles are expanded in a set of guidelines. "The purpose of the Principles of Universal Design and their associated guidelines was to articulate the concept of universal design in a comprehensive way" [11].

From a service perspective, Universal Design is useful to address the complexity and diversity of disability considering the different disabilities, the level of support that individual needs and the methods of communication [12]. However, to be accessible, a service must be designed in respect to these seven principles. It means that the designer has to incorporate them in his work. In the tourism sector, Darcy et al. [10] recommend some strategies that a tourism operator could apply to conform to the principles of universal design. These strategies are defined as principles like "Acquiring knowledge of the appropriate laws and internationally recognised accessibility standards" or "Including people with disabilities as planning team members" (p. 244). Furthermore, the concept of "accessible tourism value chain" [13] can be linked to the customer journey techniques used in user-centered design methodologies like service design.

Service Design Methodology

The Service Design methodology developed by the HES-SO Valais-Wallis in Switzerland (www.hevs.ch/servicedesign) is used to design an inclusive and accessible touristic experience. It consists of four phases: 1) Field Research, 2) Script, 3) Staging and 4) Production. This is a user-centred design methodology. Indeed, in each of the four phases, users are strongly involved in the co-creation process.

The field research phase, based on proven qualitative research methodologies such as ethnomethodology, ethology, or phenomenology, allows the descriptive and analytical study of the context, service and problem [14]. Based on the data collected, the script phase uses service marketing tools such as customer journey, service blueprints [15], scenario and user stories to design the service. Then, the service can be prototyped and staged using theatre-based re-enactment [16]. During this third phase, experiments (pre and/or quasi) are organised as at-scale test. It enables to measures the quality of the service through feedback from users and assesses its price and willingness to pay [17]. Finally, the service can be launched on the market (phase 4, production).

For this research, we conducted a netnography [18] as phase 1, field research. Then, using a service blueprint, we designed the accessible touristic service using an assistive technology for hicking. Finally, we conducted a pre-experiment in a touristic destination to generate new knowledges about this accessible hiking service. It will help the touristic destination to launch the service on the market.

Findings

Our case-study takes place in Valais, a major touristic region in Switzerland. The attractiveness of Valais lies, among other things, in its landscape, its mountains and its wilderness. Its assets are sometimes an obstacle, particularly in terms of accessibility, especially for people with reduced mobility, whether permanent, temporary (e.g. a skiing accident) or due to age. Switzerland ratified the Convention on the Rights of Persons with Disabilities (CRPD) in April 2014. Accessibility of public places as well as information about them are rights. The Swiss federal act on the elimination of inequalities affecting people with disabilities (LHand) considers inequality as difficult or impossible access for reasons of architecture or vehicle design. In this context, assistive technologies for hiking could be used to improve the accessibility of touristic destinations and attractions, especially for natural and wilderness environments. This case-study demonstrates how to co-create with users an accessible touristic service based on an assistive technology who enables hiking for people using wheelchairs. Especially, the case of Freedom Trax, a caterpillar on which a chair is installed, illustrates the service design work to be done in order to make hiking trails accessible through an assistive technology.

During phase 1 – Field Research, we first conduct a netnography. On the web, we found three similar devices: Ziesel, JST Multidrive and RIPCHAIR 3.0 and Internet forums with discussions on the thematic accessible hiking through assistive technology. The comments submitted by Internet users have been analysed. The main findings of our field research are: 1) In order to allow people to walk in complete safety, the destination has to determine the practicable trails and to provide an informative leaflet listing the trails and indicating their level of difficulty. 2) The positive aspect of this type of device is that it allows accessibility to tourist attractions. As, an Internet user wrote *"it would be a great pleasure to get this type of vehicle and not stay on the beach and watch the people living, the same for the mountains"*. 3) It allows people to live an adventure, to have action and to find the pleasures of an old life that are missing. "*Also, I sometimes miss the action from my old life*". 4) These devices allow inclusion *"but a good autonomy and 20 kilometers per hour to go for a ride with friends who are on bikes"*. 5) The problems noted are the price *"a small fortune for me, too bad it's a great machine!"*, 6) the transfer on the device *"I don't know how I could transfer to the device"* and 7) the size of the device *"on the other hand it's not versatile at all, it's only made for large spaces"*. 8) It is also interesting to note that advices given by the people sharing an experience is very much appreciated by the other users.

For the second phase – Script, we draw a blueprint of the service. We base our work on the following customer journey steps: 1) Inspiration, 2) Information, 3) Preparation, 4) Travel & Parking, 5) Discovery an handling of the assistive technology, 6) Transfer, 7) Hiking, 8) Return of the assistive technology, 9) Travel back home and 10) Sharing of experience. This blueprint helps us to organise the next phase of our service design work, the pre-experiment. Indeed, all the stakeholders and their actions are described in this document.

During the third phase – Staging, we conducted a pre-experiment in order to test some hypotheses and to generate knew knowledges. During fall 2019, a first pre-experiment was conducted in Crans-Montana, a touristic destination in Switzerland. This enabled to test the entire customer journey, including getting into the cabin with the Freedom Trax, transferring a person from a wheelchair to the Freedom Trax and a trail and hiking. Unfortunately, after a few minutes the Freedom Trax was damaged. Nevertheless, this pre-experiment generates knew knowledges: 1) An emergency chain must be set up in case of breakdown, 2) It is imperative that the routes be tested, marked and secured and 3) Transfers must be controlled by the personnel providing the assistive technology. Theses knowledges are of first importance for the fourth phase – Production.

Figure 1: Test of the Freedom Trax in Crans-Montana, Switzerland

The seven universal design principles enable to audit the service. Both the assistive technology and the hiking experience were analysed. Regarding the assistive technology, in this case the Freedom Trax, an important issue concerns the maximum degree of slope the device is capable of traversing. Indeed, the Freedom Trax did not prevent the error (principle 5) of the user with a visual and auditive signal. Another issue concerned the information (principle 4) that the Freedom Trax give regarding a breakdown. Indeed, it was impossible for the user as well as the accompanying persons to understand the problem and to solve it. Regarding the hiking experience, this first pre-experiment cannot confirm that the service is conform to the universal design principles, especially for diverse abilities. Indeed, it should be tested with more people.

Conclusion

Accessible tourism is particularly interested in accessibility issues. Rooted on the social model of disability, accessible tourism is based on the principle that the socially constructed environment excludes people with disabilities from participating in tourism activities [1]. Tourism destinations must therefore understand the needs of people with disabilities and design inclusive tourism experiences. Indeed, people with disabilities, particularly those with reduced mobility, represent an important and growing market for tourist destinations due to ageing society.

As tourist attractions, natural environments are interesting. Although there is room for development, such as trail construction, these will often not be enough to ensure accessibility. In this case, assistive technology can be used. However, its integration into the service chain requires service design work with all stakeholders involved. Indeed, the entire customer journey must be designed in an accessible manner. To illustrate this effort, a service design work is conducted with users to improve the accessibility of a touristic destination with an assistive technology for hiking.

Several knowledges have been generated during this research: 1) The entire customer journey must be accessible, including services such as parking, toilets, restaurants, and cable-car. 2) Transfers must be supervised by the staff providing the assistive technology. 3) It is imperative that the trails are tested, marked, and secured. 4) An emergency chain must be set up in case of breakdown or accident. 5) The price of such a system is high. Some people will not be able to afford it for occasional use. It would seem more sensible that touristic operators hire it. 7) Sharing experience between people seems to be a good way to reassure future users. 8) Specific training courses could be organised for tourism service providers to train their employees in the use of the assistive technology and, more generally, to raise their awareness of special needs.

These knowledges can be applied to other assistive technologies used to make a touristic attractions and destination accessible. The main finding is that the hiking experience is just one step of the accessible tourism value chain. So, the whole customer journey must be designed in accordance to the universal design principles. Furthermore, universal design principles are not enough to ensure the accessibility of touristic destination. Experiments must be conducted in order to generate knowledges

and to minimize risks before the market launch of such accessible touristic services based on an assistive technology.

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Using Event-Based Communication and IoT Standards to Improve Interoperability in an AAL Scenario

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Abstract

INTRODUCTION: One of the most significant challenges in the development of applications and AAL (Ambient Assisted Living) platforms is the interoperability between the various systems that compose the AAL platform. However, one solution would be to use the Internet of Things (IoT) technologies and standards to address requirements that, such as interoperability, are common to both domains. OBJECTIVES: To propose a model of sensor data representation and an IoT-based architecture in an AAL context, which reduces the impact of interoperability without overwhelming the overall system performance.

METHODS: We have developed an AAL platform using pub/sub communication. A Raspberry Pi acts as a gateway among sensors, the RabbitMQ platform, and the AAL applications. We have developed a data representation model, based on existing AAL models, and a Protocol Buffers communication strategy that considers platform independence and spatial decoupling to address interoperability. RESULTS: We implemented and evaluated our model with the integration of two AAL applications installed in a Living Lab, which uses distinct devices, data formats, and programming languages. Then, we simulated a daily situation and analyzed the results regarding the overall performance. Results showed our solution presents a faster average response time than without its adoption. Also, our solution performed more stable behaviour.

Introduction

Recent studies indicate that the proportion of the older people in 2050 will be approximately 20-25% of the people worldwide [6,9], surpassing the younger population for the first time [8]. Then, studying solutions to increase the independence and self-care of older adults become more relevant. Nowadays, one among the paradigms in vogue is the Ambient Assisted-Living (AAL). AAL Active and Assisted Living Programme - (http://www.aal-europe.eu) - defines AAL as "the use of information and communication technologies (ICT) in a person's daily living and working environment to enable them to stay active longer, remain socially connected and live independently into old age" [8].

One of the most significant challenges in the development of AAL systems is the interoperability between the various subsystems that compose them: physical sensors, actuators, Activities of Daily Living (ADL) systems, caregivers' mobile applications, etc. Many of the problems of interoperability in the AAL domain are due to the lack of technology standardisation, the diversity of device manufacturers, and the scarce adoption of AAL reference architectures. The issue of interoperability isn't new. Heterogeneity of protocols, APIs, and platforms, as well as the need to establish communication among them, exists since the rise of distributed computing [2]. IEEE defines interoperability as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [1]. Several types of platforms and protocols have been proposed and developed over the years to solve this issue. Nevertheless, the evolution of

computational systems and the advent of new paradigms from distributed computing, such as the Internet of Things (IoT), continues to create a scenario of extreme heterogeneity.

Nonetheless, many requirements for the development of AAL systems also exist in the Internet of Things (IoT) domain. Thus, IoT standards, or most adopted solutions, are great candidates to meet most of the requirements of an AAL platform. The use of event-based communication, brokers, unified data format, the adoption of IoT reference architectures, and the use of IoT communication standards can reduce issues arising from the arduous integration between AAL subsystems built by several manufacturers. But even with the use of IoT standards, solutions for interoperability in AAL need also to consider other requirements focused on the care and needs of older individuals (e.g., privacy, reliability, bi-directional communication, mitigation of false negatives).

We found in the scientific literature works that attempt to combine IoT and AAL for the problem of interoperability. However, few solutions use established IoT standards such as RabbitMQ or MQTT brokers [3]. In this context, we propose a model of sensor data representation and an IoT-based architecture to an AAL scenario, which reduces the impact of interoperability without overwhelming the overall system performance. For that, we considered platform independence and spatial decoupling as first-class requirements to address interoperability.

With our study, we aim to answer the following research question (R.Q.):

Can a data representation model and event-based architecture meet the requirements for interoperability in an AAL scenario without compromising the system performance?

We have developed iAAL, an AAL platform using publish/subscribe communication. It acts as a middleware between sensors/actuators/multimodal subsystems. It uses IoT concepts and technologies to meet common AAL and IoT requirements. iAAL uses a data model conceived to represent information sent by sensors, actuators, and multimodal subsystems that compose an AAL system. Those subsystems could be implemented in distinct languages and use different types of communications patterns. This data model also supports the representation of qualitative sensor data (e.g., frequency range, energy, timestamp). We implemented and evaluated the model with the integration of two AAL applications. Results showed our solution presented a faster average response time than without its adoption.

Methodology

Once we have established the state of the art for interoperability solutions in the AAL domain [3][4], we started to design our solution having a Living Lab as the motivating scenario.

Évry Living Lab

Picture 1 presents the map of our Living Lab located in the laboratory EVIDENT in Évry, France. The Living Lab simulates a functional apartment of an older adult. The apartment has one corridor, one bedroom, one bathroom, one living room, one dining room, and one kitchen. Currently, this Living Lab has several sensors, actuators and AAL systems, used for research purposes.
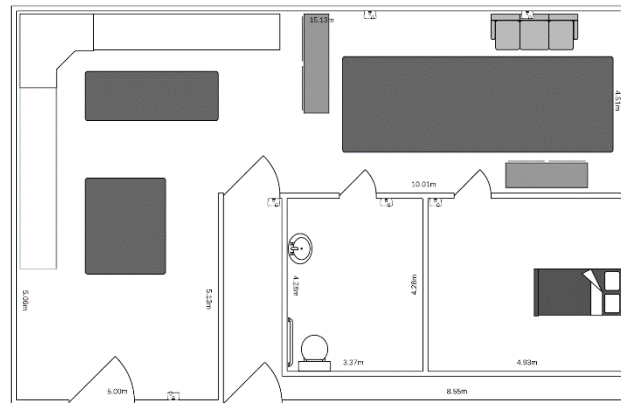
Picture 1: Évry Living Lab

Picture 2-A shows one of the six infrared presence sensors distribute throughout the Living Lab rooms. Those sensors send a signal to a computer, which has a Java system controlling each time the sensors detect a movement. Picture 2-B and 2-C shows a smart lamp in the lab and the KNX server - which programmatic controls the entire Living Lab lighting system. The lamp control system was developed in Python. Besides, the Living Lab has three smart carpets, marked in dark grey in Picture 1, with pressure presence sensors implanted. They detect the presence of an individual by detecting their steps and send the data to a gateway encapsulated in a Raspberry Pi. In this gateway, a C system evaluates the state, speed, and trajectory of the individuals based on the trace sent by the sensors. The Raspberry Pi also runs a fall detection system, implemented on MATLAB, based on data arising from multiple sensors.

Picture 2: Sensors in Living Lab

iAAL

Each of the subsystems present in the Living Lab uses devices from distinct manufacturers. They employ a variety of communication protocols and programming languages, becoming an example in a short scale of the interoperability problem in AAL domain. Using this motivating scenario as a case study, we propose iAAL (interoperableAAL), an extensible and adaptive middleware. iAAL focuses on the integration between AAL subsystems and applications. Its objective is to provide data acquisition from the AAL subsystems to AAL application developers transparently. For nomenclature purposes, we will refer to sensors, actuators, and other types of AAL subsystems as "Entities". A set of design principles guided us during the conception of the middleware architecture. They were defined based on the

analysis of the state of the art of AAL platforms. Challenges detected in our motivating scenario also contributed to those design principles. The iAAL design principles are:

- **DP1) Low coupling:** the entities should be weakly coupled to the platform, facilitating the maintenance of the system and replacement of sensors and actuators. For that, we made use of wrappers;
- **DP2) Agnostic data representation model:** the data representation model should follow a platform-independent pattern, such as JSON or Protocol Buffers. In this way, the data flows from the wrappers to the platform in a standardized format;
- **DP3) Separation between acquisition logic and data management logic:** the separation into two distinct intercommunicating layers allows the isolation of certain requirements (e.g. interoperability and the older adults needs);
- **DP4) Use of IoT protocols and technologies:** IoT and AAL platforms have many requirements in common, especially regarding data acquisition and device communication. A layered architecture facilitates the use of established IoT protocols and technologies;
- **DP5) Gateway-based architecture:** the entity diversity present in an AAL-oriented smart home scenario demands a server that functions as a hub for all data. The use of a gateway in a Raspberry Pi solves this issue, providing mobility and enabling future expansions; and;
- **DP6) Gateway-Cloud Communication:** the possibility of sending data from the gateway to a server in the Cloud, or to Fog, either for processing or monitoring purposes [7], [11].

Architecture Overview

Picture 3 shows an overview of the iAAL middleware. Our approach is an extensible and adaptive AAL platform focused on integration between AAL entities and applications. Its proposal is to use standards of IoT and Fog Computing domains to meet the common requirements between IoT and AAL (e.g., interoperability, context-awareness). For instance, iAAL supports publish-subscribe, intermediating communication between entities and connected AAL applications. The architecture separates features focused on device interaction (encapsulated in the Entity Management Layer) from the features that meet the target audience requirements (encapsulated in the Data Management Layer).
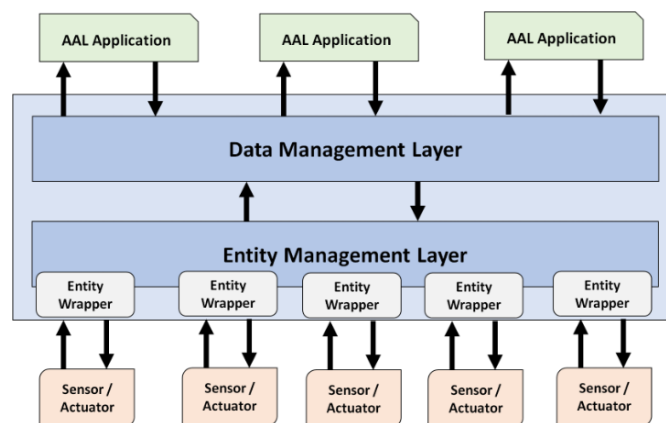
Picture 3: iAAL overview

Entity Management Layer provides interoperability between the AAL entities. Its objective is to centralize communication between the platform and all the Entities present in the system in an agnostic and weakly coupled form. In addition to interoperability concerns, we designed the Entity Management Layer and Entity-platform communication considering the issue of performance and information quality. Thus, the response time to a data request must be in an acceptable parameter compared to the same request being made directly to the entity. For that, Entities could send timestamp and QoC metadata to the platform with their raw data. Entity Management Layer executes in a RabbitMQ broker, which

receives the data from all AAL entities and disseminate it using publish-subscribe notifications. In our case scenario, we deployed the Entity Management Layer - as well as wrappers and handlers - in a Raspberry Pi. This approach acts as a gateway between the various AAL entities and applications.

Data Model Representation

We propose a data model to be used in the communication between AAL entities. Our model is based on the solutions of Palumbo et al (2014) [9] and Hossain et al (2016) [5]. It's implemented in Protocol Buffer abling a device-independent data format. Picture 4 presents the initial version of our data model, with the essential data (entity identifier, timestamp, and raw data) and optional quality data (location). We intend to add more QoC data to the model.

```
message Data {
        int32 Entity_Id;
        string Timestamp;
        string RawData;
        string Location;
}
```

Picture 4: Data model template

Living Lab Simulation

We evaluated the communication between Living Lab entities (i.e., infrared sensors in Java; lamp actuators in Python, and smart carpet sensors in C) and the RabbitMQ broker. Each Entity sends data following its format in its programming language, but all data must reach the broker using the same format. The use of two intermediate steps, entity-handler and handler-wrapper, enables the data transformation. Some sensors have processing or power limitations forbidding them to communicate directly with iAAL, since their only function is to acquire data continuously. In those cases, Handlers encapsulate the sensor. They add, if necessary, timestamp and, when is possible, QoC data. The main objective of a Handler is to act as intermediary providing quality information when the sensor is not enabled to provide.

For the iAAL, a Handler works as an extension of the Entity. Its secondary function is to allow iAAL to manage the life cycle of the Entities (e.g., start and stop data acquisition). A Wrapper receives the data from the Entities (or their handlers), transforming it into our standard model and sent it to the broker. Each Entity has its wrapper, written in the same programming language. As a consequence, the wrappers act decoupling the gateway and the Entities.

In our Living Lab scenario, we evaluated iAAL response-time and stability. We developed wrappers for the infrared presence sensors (in Java) and a system that simulated the use of the smart carpet, as well as its wrapper, in Python. Wrappers receive both data, converted into our model (represented in Protocol Buffers), and sent to the Entity Management Layer. An application hosted on a web server received data from the iAAL and presented the location of an individual on the Living Lab map, according to the activated sensors. This Web app acts as an external entity illustrating the advantages of data integration in the broker.

Performance Evaluation

We carried out a performance evaluation using two setups. One setup uses iAAL aiming to measure the response time between the sensors and the Web app - which shows user's location in the Living Lab - when they use the iAAL as their data broker. In the second setup, sensors are connected to the Web app directly. For the evaluation, we planned a walking trajectory inside the Living Lab, in which a user visits all the rooms. During this visit, he activates all the sensors distributed in the environment.

The sensor names identify their location and device type. Entrance, LivingRoom-1, LivingRoom-2, Bedroom, Bathroom, and Kitchen are the infrared sensors. The carpet sensors are LivingRoom-TP, Kitchen-TP, and Dinner-TP. During the trajectory, the user passed by the bedroom and the living room twice. Picture 5 shows an example of the data received by the wrappers and the data sent to RabbitMQ following our model in the iAAL setup.

```
1579546621.639632
Sending position to client: {'Location': 'room1', 'Entity_Id': 92630, 'Timestamp': '648.5118508338928'}
127.0.0.1 - - [20/Jan/2020 15:57:01] "GET /socket.io/?EIO=3&transport=polling&t=M_4KB9o&sid=ada49c05d4ee4f63b9c3aee66036266a HTTP/1.1" 200 -
192.168.0.167 - - [20/Jan/2020 15:57:01] "GET /socket.io/?EIO=3&transport=polling&t=M_4KAtm&sid=8e3358523823437dbee7a7cc90bd3ca3 HTTP/1.1" 200 -
Message received: b'\x08\xd6\xd3\x05\x12\x11653.6779298782349*\x05room1'
1579546626.8075955
Sending position to client: {'Location': 'room1', 'Entity_Id': 92630, 'Timestamp': '653.6779298782349'}
127.0.0.1 - - [20/Jan/2020 15:57:06] "GET /socket.io/?EIO=3&transport=polling&t=M_4KBR_&sid=ada49c05d4ee4f63b9c3aee66036266a HTTP/1.1" 200 -
192.168.0.167 - - [20/Jan/2020 15:57:06] "GET /socket.io/?EIO=3&transport=polling&t=M_4KB9o&sid=8e3358523823437dbee7a7cc90bd3ca3 HTTP/1.1" 200 -
Message received: b'\x08\xc6\xd3\x05\x12\x11655.7966821193695*\x07kitchen'
1579546628.9527798
Sending position to client: {'Location': 'kitchen', 'Entity_Id': 92614, 'Timestamp': '655.7966821193695'}
127.0.0.1 - - [20/Jan/2020 15:57:08] "GET /socket.io/?EIO=3&transport=polling&t=M_4KCim&sid=ada49c05d4ee4f63b9c3aee66036266a HTTP/1.1" 200 -
192.168.0.167 - - [20/Jan/2020 15:57:08] "GET /socket.io/?EIO=3&transport=polling&t=M_4KCO2&sid=8e3358523823437dbee7a7cc90bd3ca3 HTTP/1.1" 200 -
127.0.0.1 - - [20/Jan/2020 15:57:10] "POST /socket.io/?EIO=3&transport=polling&t=M_4KDgb&sid=ada49c05d4ee4f63b9c3aee66036266a HTTP/1.1" 200 -
127.0.0.1 - - [20/Jan/2020 15:57:10] "GET /socket.io/?EIO=3&transport=polling&t=M_4KDEC&sid=ada49c05d4ee4f63b9c3aee66036266a HTTP/1.1" 200 -
Message received: b'\x08{\x12\x11660.4849998950958*\nkitchen_tp'
1579546633.6271327
```

Picture 5: An excerpt from the Wrappers log during Experiment 1

Since some sensors don't send timestamp information, this metadata is inserted when data arrives in the wrapper. Therefore, we conducted the two setups using the wrapper timestamps to evaluate the impact of adding the Entity Management Layer between the sensor and the final application. We evaluated each setup 10 times repeating the user visit trajectory. Then, we calculated the average response time of each sensor-Web app communication. As a baseline response time, we used the average network ping from 700 samples between the wrapper and the Web server (0.011s).

Results

Picture 6-A shows a comparison of the average response time between each wrapper and the Web app in both setups. Picture 6-B shows a comparison of box plots distribution of all response times obtained in the 10 times of both experiments.
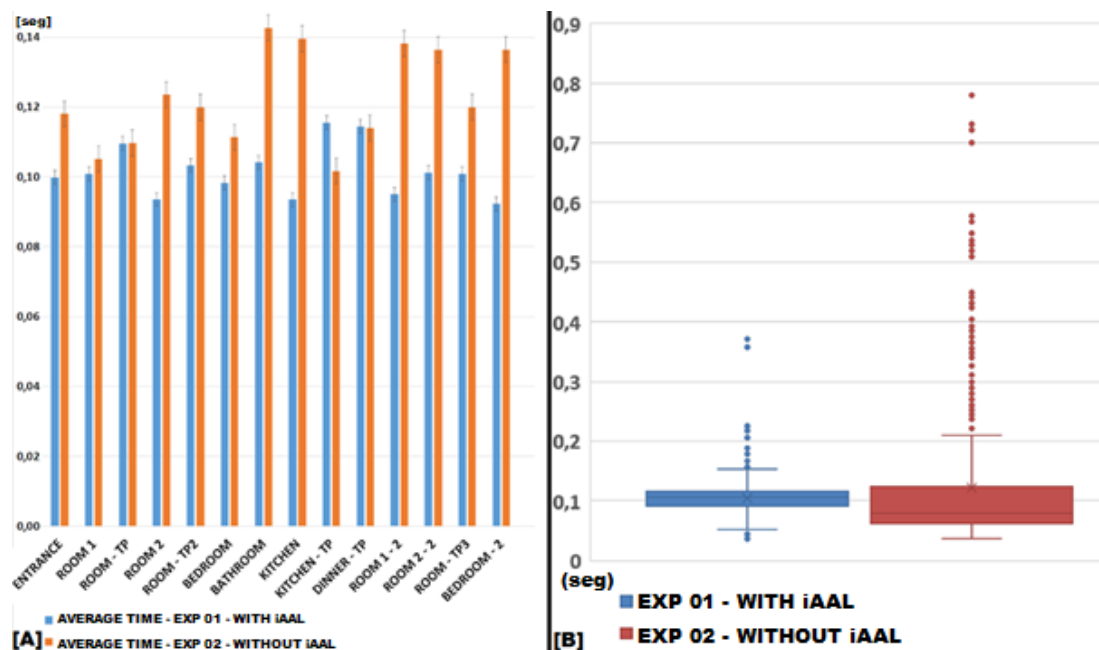
Picture 6: [A] A vertical bar graph comparing the average response times of each wrapper for the two experiments. [B] A boxplot chart comparing all the response times for both experiments.

The median of response time of Experiment 2 (0.0788 s) were faster than those of Experiment 1 (0.1042 s). Nevertheless, Experiment 2 had many more outliers. The standard deviation of Experiment 1 was 0.0332, while the standard deviation of Experiment 2 was 0.1039. We conclude that Experiment 1 presented a faster average response time than Experiment 2, and more stable results.

The inclusion of one more layer between entities communication entails an increase in the processing time of the data exchanged. However, except for the Kitchen-TP sensor, the results of Experiment 1 were, on average, consistently faster than those of Experiment 2 and with lower confidence intervals. The addition of the Entity Management Layer in the communication process between the sensor and the Web app allowed interoperable communication without a performance decline. Picture 6-B shows the decrease in time caused by the addition of the layer was not significant.

We hypothesize that the use of Protocol Buffer and RabbitMQ reduce data size and allow fast data dissemination. Also, we observed in Experiment 2 more outliers increasing the average response time. Our solution provided data streaming more stable.

Final Considerations and Next Steps

Based on this, we can answer our research question, "Can a data representation model and event-based architecture meet the requirements for interoperability in an AAL scenario without compromising the system?".

To give first insights for the R.Q., we developed the iAAL middleware. iAAL is a platform to connect AAL systems in an interoperable way. We designed iAAL with a modularized architecture to optimize its maintainability. We used RabbitMQ as a broker for data received from AAL Entities (e.g., sensors, other AAL systems) and a Publish-Subscribe communication paradigm. We proposed an agnostic data model for AAL scenarios and represented it using Protocol Buffers.

We conducted experiments in a Living Lab comparing the average response time of sensor-application communication in two setups: with and without the Entity Management Layer. The trials showed that the average response time of our strategy did not present significant losses. Besides, the solution using agnostic communication showed a more stable behaviour in terms of response time variation.

As future works, we intend to use iAAL to facilitate the data fusion process, improving synchronization of data received from the Entities and the intercorrelation among several Entities. These new steps will be added to the Data Management Layer.

Acknowledgements

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Mada Accessibility and Assistive Technology Glossary: A Digital Resource of Specialized Terms

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Abstract

The rapid and continuous evolution of developments in the field of Information and Communication Technology (ICT), Assistive Technology (AT), and Accessibility has lead to the creation of a vast foundation of specialized knowledge in these areas of work. The lack of centralized resources capturing these evolving concepts, ideas, and terminologies poses a challenge for professionals and relevant stakeholders to keep themselves informed and gain understanding about the latest developments. Being relatively new fields of work, the proliferation of professionals related to ICT, Accessibility and Assistive Technology is growing on a worldwide scale. In this paper, we present a centralized resource to highlight the key terminologies in the field of ICT, Assistive Technology and Accessibility to be available to a range of professional and stakeholders worldwide. This resource (Mada Accessibility and Assistive Technology Glossary) will serve as a unique repository of specialized knowledge to be available in multiple languages including Arabic to help increase the footprint of quality professionals in Arabic language speaking regions and worldwide.

Keywords: Arabic Assistive Technology, Information Communication Technology (ICT), Mada Accessibility and Assistive Technology Glossary, Accessibility, Mada

Introduction

The exercise of capturing information to define concepts can often be relatively subjective due to the nuances of a language allowing the flexibility to convey similar information with minor amendments in the use of vocabularies. We live in such age that is constantly innovating products and technologies, we continually use new terms and concepts in new ways, and we must translate and define these terms and concepts in a formal way. [1]. The process of developing the glossary to represent a body of knowledge consist of the core components of selecting the terminologies to be defined, formally defining these terminologies in the most accurate possible description, and finally appropriate translation and accurate description of terms preserving the context and comprehension. The translation of definitions of such terms involves the translator(s) not only have linguistic skills but must also possess technical expertise to the subject(s) matter.

In this paper, we discuss the process of combining various approaches to help select the pool of relevant terms by involving various stakeholders like professionals and end-users within the process. First, we collected pool of terms related to ICT Accessibility and Assistive Technology. Second, we segregated/filter the pool of terms to come up with the essential terms to proceed for being defined. And lastly, the defined terms were translated to Arabic language. In this paper we also discuss the approaches implemented to develop an appropriate translation of the terms.

Objectives

The Mada Accessibility and Assistive Technology Glossary is an explanation of Information Communication Technology (ICT) related Accessibility and Assistive Technology terms. It has been developed to contribute as a vital resource to build capacity within existing ICT, Accessibility, and Assistive Technology services in Qatar and the region. The glossary intends to serve as a foundation

towards educating its readers about key terms used in the fields of ICT, Accessibility, and Assistive Technology. This is a unique initiative that offers a formal resource in the Arabic language related to this specialized knowledge in this area of work.

We aim to develop a centralized resource to highlight the key terminologies in the field of ICT, Assistive Technology and Accessibility to be available to a range of professional and stakeholders worldwide. This resource (Mada Accessibility and Assistive Technology Glossary) will serve as a unique repository of specialized knowledge to be available in multiple languages including Arabic to help increase the footprint of quality professionals in Arabic language speaking regions and worldwide.

Methodology

The corpus of specialized terms in the field of ICT Assistive Technology and Assistive Technology is extensively vast. This project aims to start off with a set of the core definition terms to be included in the Mada Accessibility and Assistive Technology Glossary during its initial implementation phase. It was decided to develop the glossary in English language first due to the availability of all existing data and terminologies in this language.

The process initiated by collecting potentially relevant terms related to ICT, Assistive Technology, and Accessibility through filtration of keywords from existing resources like research papers, journal articles, etc. This step was followed by conducting focus groups with professionals in the field. The goal of the focus groups was to review the pool gathered terms and filter out the most essentials core terms to be prioritized to be included in the first phase of the Mada Accessibility and Assistive Technology Glossary.

Table 1. Process to identify terms to be included in the Mada Accessibility and Assistive Technology Glossary.

Step 1	Step 2	Step 3
Keyword Filtration from ICT, Accessibility and Assistive Technology related resources (148 resources)	**Focus Group**	**Prioritized Terms to be defined**
Peer Reviewed Journal Articles (96)	Therapists (Speech, Occupation & Physio)	Assistive Technology Terms
Research Papers (37)	Special Education Teachers	Accessibility Terms
Books (15)	Education Psychologists	ICT Terms
	Assistive Technology Specialists	
	Accessibility Experts	

The next stage of developing the glossary involved defining the prioritized terms. Professionals and experts in the field of ICT, Accessibility and Assistive Technology were engaged to define the identified terms in English. The professionals and experts involved in the term definition process had a minimum work experience of 5 years in the field and with extensive involvement of subject-matter literature. The defined English terms were reviewed by the focus group members mentioned in table 1 prior to

agreeing on the final version of the definitions for each term. Following are a sample of the key questions addressed by the focus groups during the development process of the definitions.

1. Do you find the terms relevant to the theme of ICT specific AT & e-Accessibility? If no, please explain.
2. Are the terms defined in a way that can be easily interpreted by readers with no background in the field of AT and e-Accessibility? If no, please explain.
3. Are there any specific terms for which you would like to improve the definition? If yes, then which ones and please suggest improvements.
4. Would you like to suggest any potential references or terms that we can utilize or add to the glossary? If yes, please indicate it below.
5. How do you rate the Arabic translation? (1 being unacceptable and 5 being excellent)

As the purpose of the Mada Accessibility and Assistive Technology Glossary is to be multi-language resource, it was translated in Arabic language due to its lack of subject-matter resource. The specific nature of the terms and related technical nuances meant that the translated terms and definitions needed to be not only meaningful from a linguistic point of view but also required to be appropriate from contextual and interpretational aspects. The Arabic translation of the defined English terms were carried out in collaboration with the Translation and Intrepretation Institute (TII) from Hamad Bin Khalifa University (HBKU) in Qatar. The final stage of the translation process involved reviewing each translated terms and definintions. The review process comprised of evaluating each translated term and definition to ensure that it represents the correct meaning with the appropriate level of linguistic and technical complexity suitable for the intended audience. Following key rules were strictly applied to accept the proposed translation of each term and its associated definition.

Table 2. Applied rules of acceptance for translated terms and definitions.

Rule 1	The translated term and its definition are expressed as exactly as possible to represent the enterity and meaning of every word.
Rule 2	The translated term and its definition is meaningful (linguistically and contextualy) in the translated language and does not read or sound like a translation.

Availability

The Mada Accessibility & AT Glossary is available for free at http://madaportal.org/mada-glossary/. There are 354 terms and associated definitions published in the resource. The bilingual (English and Arabic) user interface of the Mada Accessibility & AT Glossary has been designed using Web Content Accessibility Guidelines (WCAG) standards to be accessible for Persons with Disabilities (PWD). In addition to providing definitions, the Mada Accessibility & AT Glossary also supports the following features in order to convey a better understanding of each term:

1. Accurate phonetics and verbal pronounciation of each term is offered by including the option to hear the audio feedback pronouncing each term.
2. Cross-referencing feature is available to provide references of each term in alternative languages supported by the resource
3. Where applicable, a suitable visual illustration has been provided for the terms.
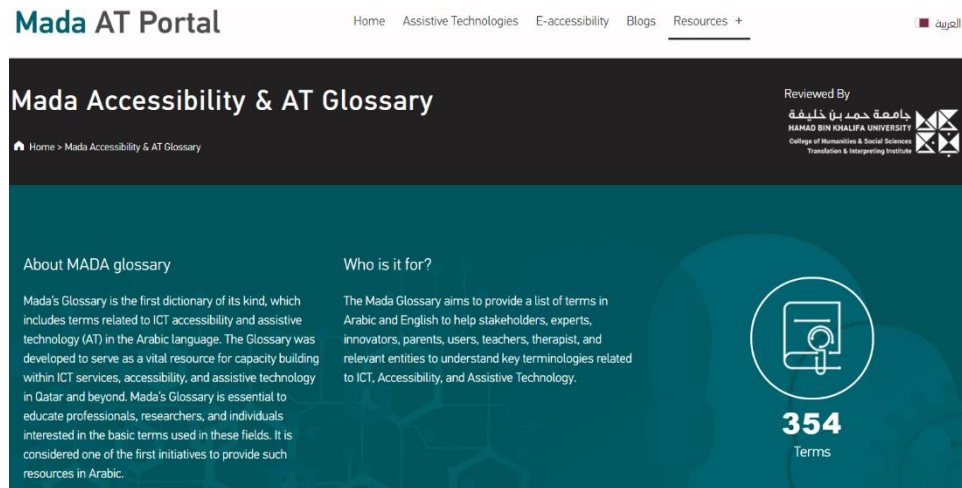4. Below a set of screenshots of the online resource

Fig. 1. Screenshot of the Mada Accessibility and AT Glossary from http://madaportal.org/mada-glossary/
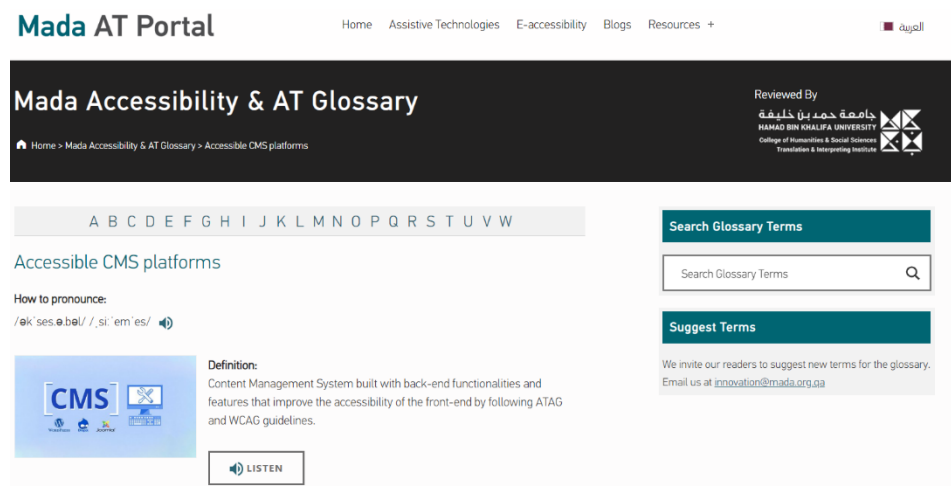

Figure 2. Available information: term, definition, how to pronounce and illustration
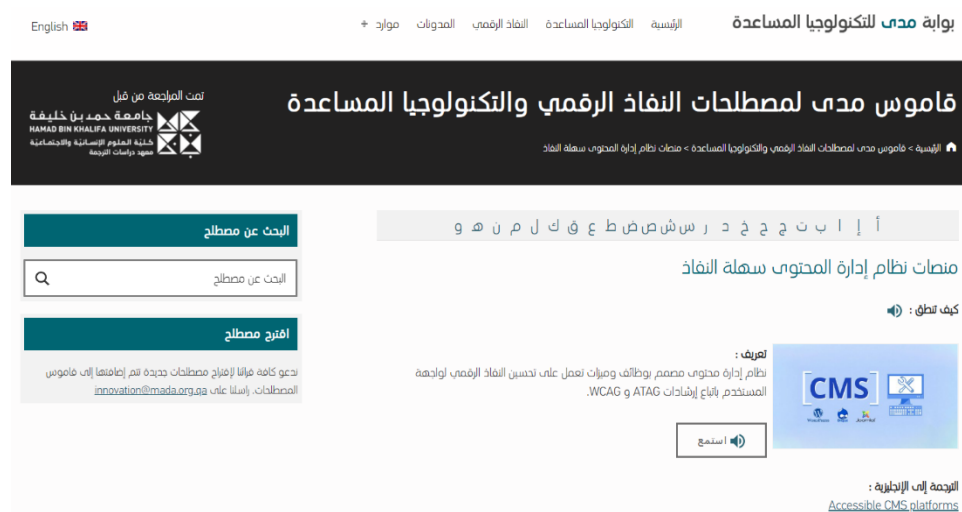

Figure 3. Available information in Arabic: term, definition, how to pronounce and illustration

Sustainability and Updates

The field of Assistive Technology and Accessibility is rapidly evolving in nature due to the constant advancement of technologies. This translates to the emergence of new applicable terms for the glossary. As part of the sustainability model of the resource, an annual review process had been put in place. This process involves reviewing all the existing terms and defining additional new terms to be incorporated into the glossary. The review process will be conducted through the engagement of the following groups:

Table 3. Groups engaged for the Mada Accessibility and Assistive Technology Glossary.

Group 1	Advisory board comprising of members from regional Arabic speaking countries and international Accessibility Experts
Group 2	Persons with Disability User Focus Group
Group 3	Relevant Entrepreneurs and Innovators Associations

The review process evaluates the existing terms with regards them being relevant to the latest industry standards to be updated accordingly. Additional new terms are also incorporated into the glossary during every review cycle using the applied rules in Table 1 and Table 2.

Conclusion

The outcome was the creation of the Mada Accessibility and Assistive Technology Glossary, a bilingual resource in English and Arabic languages. The Mada Accessibility and Assistive Technology Glossary contains 354 terms. The resource was created using the methodology and implementation process to identify, evaluate, and translate using the set of rules. This ensured the meaningful translation of these specialized terms to expand the range of knowledge among relevant professionals worldwide.

Acknowledgement

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Author Index

This is it: The very first digital edition of the ICCHP open access compendium "Future Perspectives of AT, eAccessibility and eInclusion". It took 17 ICCHP editions and more than 30 years to go this last step towards an additional publication to reach a 360° view on AT, Accessibility, ICT with and for people with disabilities and older adults.

The idea to collect these hidden gems and precious contributions that typically get forgotten in mere theoretically based conference proceedings was in our heads for more than 10 years now – to put together these practically oriented gems within all this theory and compile a hands on, user driven, open access and accessible compendium out of it that makes our proceedings "whole" again. AT, eAccessibility and eInclusion are user, practice and service driven domains. Progress and success are very much based on the interaction with, contribution by and participation of all stakeholder groups (e.g. users, end user organizations, service providers, policy, administration, industry, NGOs). Every voice counts in the exchange on the impact of R&D on practice and in domains in need of creative and innovative R&D and co-operation.

Enjoy, use, learn and discuss - and maybe be part of Edition 2!