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ADDITIVE MANUFACTURING APPLICATION FOR THE INCLUSION OF THE VISION IMPAIRED POPULATION IN PUBLIC TRANSPORT

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Abstract

This paper shows how additive manufacturing applications can be used to help people with vision impairments. There are many 3D printed tactile maps, books or individually customized hearing devices that can help for their inclusion. As a potential solution, a 3D printed eco box was designed and created. Small box with a separable and replaceable 3D printed QR code on the front side, tactile map on top and space for the integrated speaker inside of the box. 3D printing process allows each box and QR code to be unique, quickly designed and produced. They can be placed on tram, bus, train, or metro stations or at the airport. Scanning QR code with specialized app on the phones, gives detailed voice instructions about current location, timetable, guide marks and other important information. Product can be also used by general community, for the same purposes. This paper provides detailed instructions for product design and 3D printing.

Keywords: 3D printing; tactile; QR code; assistive products

1. Introduction

Global estimates number of people with visual impairment in 2020 is 1.1 billion people, where approx. 45 million people are completely blind and approx. 300 million have moderate to severe vision impairment. These individuals face broad challenges that affect their quality of life, which make difficulties in performing many activities in their life. Fig. 1 clearly shows increase in the number of people with vision disability through the past decades, which will unfortunately continue to increase in the future [1].

Public transport play one of the most important roles in the life of the visually-impaired and blind person in their productivity, community involvement, seeking education, medical care, work, independence and total integrity. Despite all of the advantages, visually-impaired persons experience difficulties in using public transport [2]. Some of the biggest issues they challenge are: identifications of correct transport vehicle, access to the timetables, routes other important information, non-adaptive signs, lack of sound information and so on.

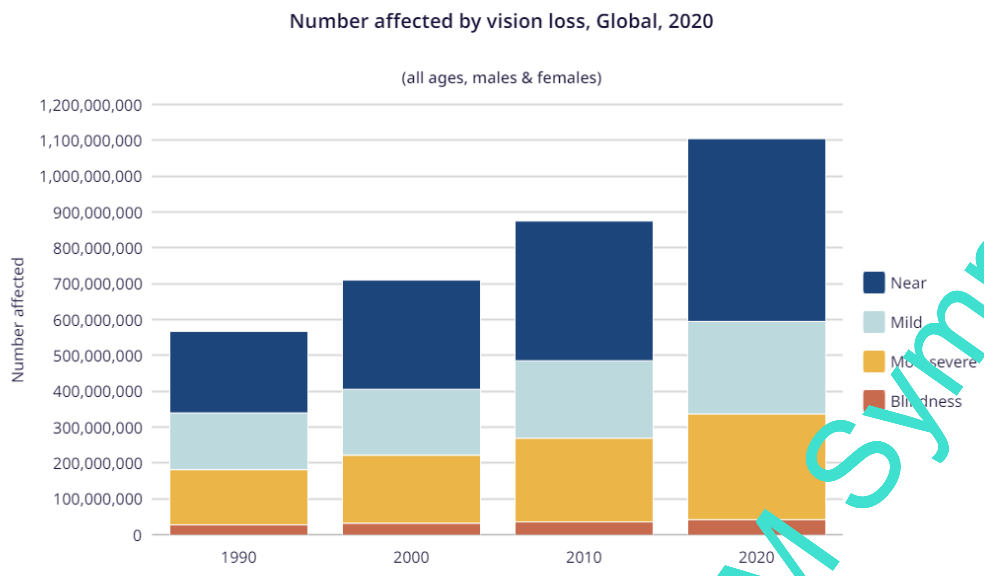

Fig. 1. Number of people affected by vision loss in 2020

Visual loss, unfortunately, greatly reduces information access to the visually impaired people in today's world of knowledge and information. About 90% of the all information processed by brain is visual, so efforts should aim for the development of public transport navigation for the people with visual disability.

Advances in technology especially in information technology (IT) and mobile technology synchronized with cheap, simple and quickly developed products, using additive manufacturing (AM), can greatly improve inclusion of visually impaired population in public transport systems. Technology has the potential to enhance individual's ability to participate fully in societal activities and to live independently [3].

Although, some may not expect for visually impaired persons to use smartphones, tablets and internet due to their disability, researches show they are catching up to that of non-disabled consumers as shown in Fig. 2. These graphs indicate, that indeed assistive technologies should focus on the mobile and internet technologies combined with traditional solutions for inclusion of visually impaired people which relies on the haptic and audio senses [4].

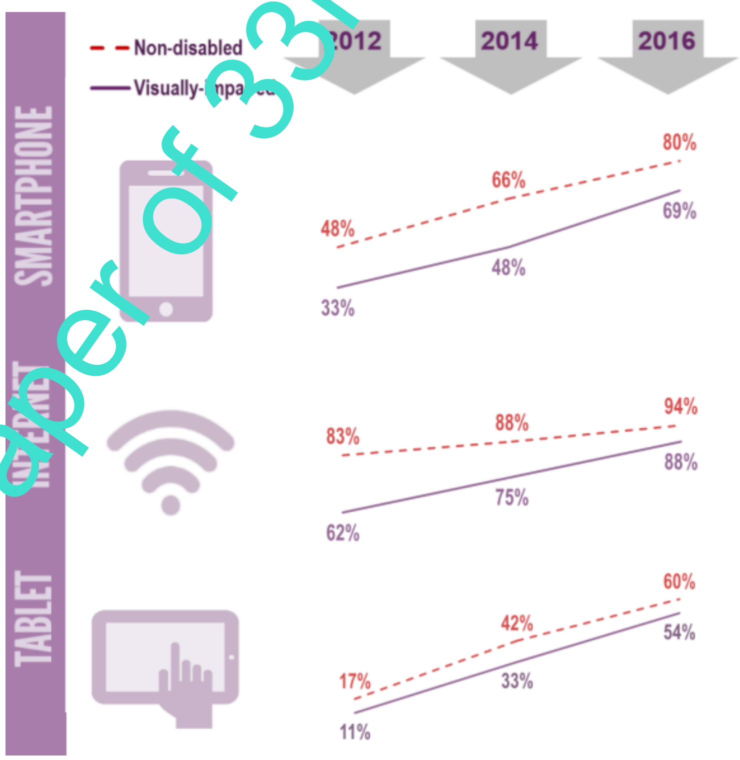

Fig. 2. Access to devices and services in the period from 2012 to 2016

Mobile phones, in particular smartphones, offer a massive cluster of features and applications which helps people with visual impairments. Innovations in these areas has explored usage of sensory modalities other than vision – for example speech recognition, screen reader, haptic feedback, text-to-speech – to reduce dependence on demanding visual which are helping people with visual impairments navigating through their mobile phones [5].

There are some systems which are integrated into public transport systems. For example *RAMPE* system is based on Wi-Fi enabled smart devices carried by users, fixed base-stations installed at bus stop and central server system that is connected with both bus stop and buses. This system allows user to choose stop where he wants to connect in order to get relevant information about timetables, routes, list of stops along the bus line and other. Position of the bus would be tracked using GPS (Global Positioning System) [6]. Similarly, mobile navigation and orientation systems for visually impaired users where introduced in a *Metrobus* environment. The systems is based on usage of smartphones, GPS and compass device which communicate via Bluetooth, which provides audible interface to help visual impaired user to listen relevant information about location and orientation of the user within *Metrobus* environment [7].

On the other hand, GPS can be inaccurate and can have slow response time. Some researches propose other technology for connections between visual impaired users and public transport system, like Radio Frequency (RF) communication to improve the success rate of visually impaired to board correct buses and getting to the right destination. One of the main purposes of using RF is to take advantage of its short distance communication, since the communication between a bus and a bus stop will be possible only when the bus approaches the stop. During the journey of the person with visual disability, a GPS-based application could inform the person about his/her location, but when approaching the stop the GPS could fail, and that is where the short range communication of the RF technology plays a key role [2].

From the above, knowing that the visual impaired people use smartphones in a great scale via assistive applications, and knowing that there are possibility of connecting visual impaired users with desired public transport vehicle, central database system via mentioned technologies, our task was to make product using AM which can help visually impaired person for their inclusion.

Our solution is printable 3D QR code which is integrated in the printable box, which would be fixed at the pole at the bus/metro/tram or metro station, or even at the airport and would be easily accessed by visually impaired person following the tactile paving. This product consist of changeable frontal plate and box with u clamp. Frontal plate has 3D QR code and short information about that station written in braille. Exterior of the box, consists of holes for speaker, USB or mobile charger, while inner space is meant for electronics, loudspeaker and charger. Once visual impaired person approach and examines the box, by a mobile phone can scan QR code and can get connected to the central system or get all available information about timetable, routes and approaching public transport. User could also communicate with public transport central system via application and signals could be sent to the driver of desired vehicle, which can trigger additional features. In this paper detailed instructions about design and manufacture of product using additive technologies are presented, as well as examples of installation in the public transport.

2. Product design

For the proper design of the product, a project plan is set, which includes problems, possible solutions, design, 3D printing and the finished product shown in Fig. 3. Primary goals of designing such a device is easy and cheap manufacturing, assembling and installation on site, and to be adaptable to different locations. In addition, when designing, attention was paid to the fact that the housing of the device, alone, can provide some information to visually impaired person using braille.

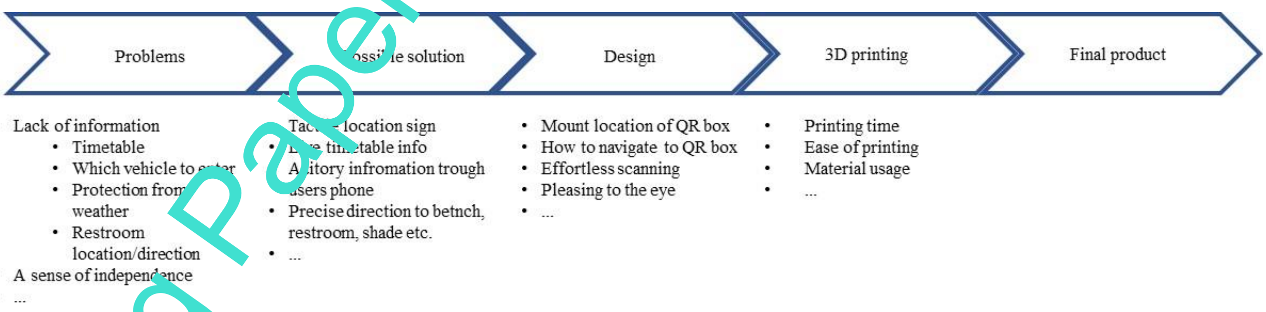

Fig. 3. Design flow

After analysing the problems and possible solutions, two different solutions were designed. The first solution can be mounted on flat surfaces. Second design are meant for mounting on cylindrical surfaces such as pillars using additional u clamp, which is also printed. Different solutions are shown in Fig. 4.

Fig. 4 . Two different designs – first for flat surface (left), second for pole mounting (right)

The dimensions of the box are designed so that both solutions have space for the implementation of a micro-computer, a Wi-Fi module, a loudspeaker and a USB port for charging smartphones. After defining the dimensions of the box and the QR code, the case is designed to meet two additional conditions. Protection against vandalism and ease of 3D printing. Protection against vandalism was achieved by sliding the QR code plate into the housing prior to installation on a pole or wall so that it would be secured. In order to achieve the simplicity of 3D printing, overhangs were avoided so that it is printed without the need for support material, which would mean saving on printing time and material. Also, 3D printed support structures are a common cause of failed prints.

In Fig. 5 exploded-view of an assembly is shown. Steps for correct assemble of the product which will be mounted on the pole are:

1. Insert elecronic components inside box,
2. slide in QR plate from bottom,
3. slide in lower lid from behind,
4. place it on pole,
5. screw in u-clamps.

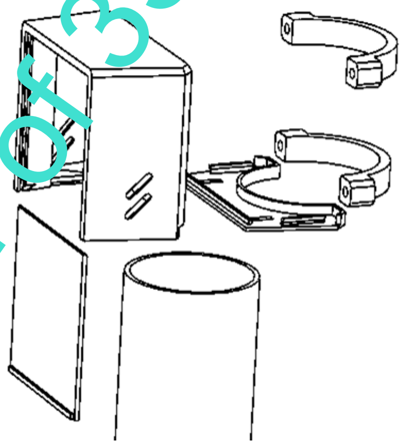

Fig. 5. Exploded-view of an product assembly

3. 3D Printing and materials of the product

Additive manufacturing is technology that is often used for producing of different products with complex geometries. One of the most popular AM technology today is fused deposition modelling (FDM) [8]. It is one of the types from 3D printing technique group, where a molten thermoplastic material (filament) is laid out layer-by-layer, creating a full-scale part in shorter cycle time and lower costs compared to the traditional manufacturing processes [9]. After creating a 3D CAD model of the product, next step is converting it to 3MF or another similar format, and using "Slicer" software, which generates G-code with all printing parameters. G-code is then used by 3D printer in order to create a final piece, layer by layer [10].

There are many 3D printers and slicing software available on the market, but for purpose of this research, Ultimaker S5 Pro was used for 3D printing and Ultimaker Cura software for generating the G-code. The main idea throughout the whole design process was to create a model that could be easily 3D printed by any FDM 3D printer, with basic knowledge about 3D printing in general. Both box and QR code plate don't have any overhangs and can be 3D printed without any supports and its' volumes are perfect size for most of 3D printers used worldwide. An important thing for this research is understanding of filaments for FDM printing. Material has to be easy to print, resistant to standard environmental conditions and, probably most important, be eco-friendly.

Combining everything listed with the economic side, there are two potential solutions – PLA and PETG, any brand. So, after creating the final model and choosing right material, next step is choosing right parameters for 3D print. The most important ones are represented in Table 1.

	PLA	**PETG**
Layer height [mm]	0.2	0.2
Printing Temperature [°C]	205	245
Print Speed [mm/s]	70	60
Fan Speed [%]	100	20

Table 1. Important printing parameters

Based on standard parameters, printing time is shorter when using PLA, but it is important to mention that PETG is a better option when it comes to printing boxes for outdoor use (public bus stops, tram stations etc.). Next step, after finalising the parameters, is to automatically generate a G-code using the „Slice" button. File is now ready to be sent to a 3D printer, using an SD-card, USB stick or simillar method to communicate with the 3D printer. Printer itself must be correctly calibrated and ready to use with enough material for 3D printing process.

The best option for 3D printing of the QR code plate is printing it in one piece, not connecting the black and white parts aftewards. To achieve that, there are two options; using a dual extruder 3D printer (like Ultimaker S5) where both colors can be used at the same time, or, the most common way because most of 3D printers are single extruder – using a script for filament change at predefined height. In Cura, scripts can be found under „Extensions" tab where user selects „Modify G-Code" option. For this particular case, plugin is used as presented in Fig. 6.

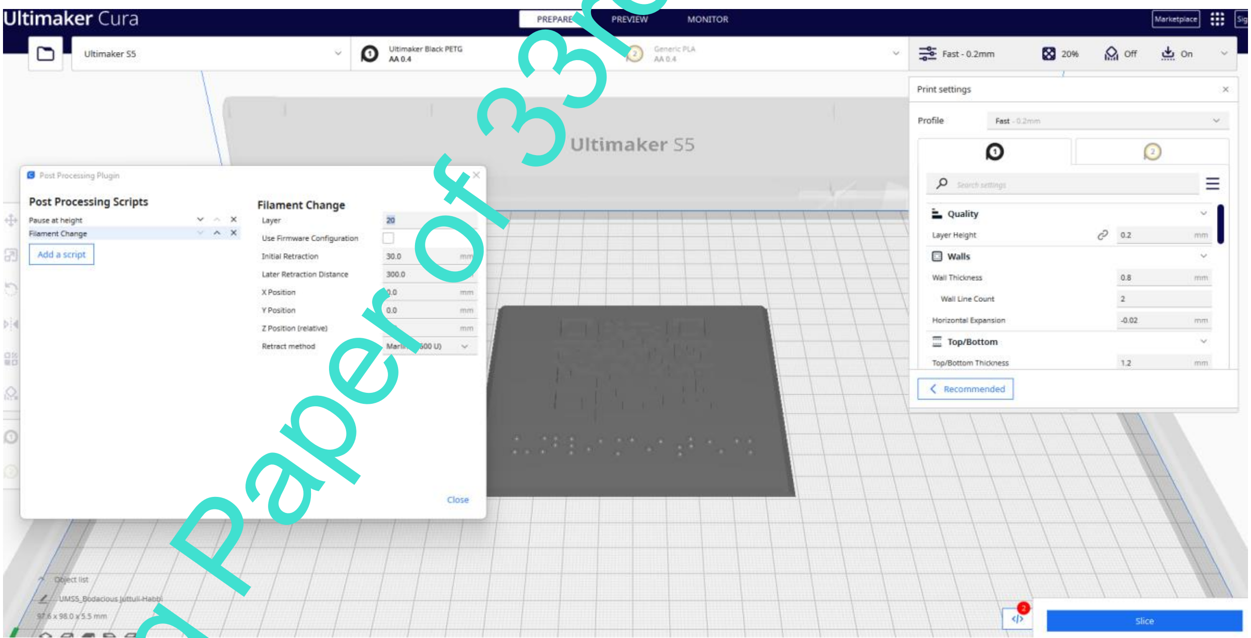

Fig. 6. Post Processing Scripts

It is important to understand that two different type of filaments can not be combined when performing filament change because of their different melting temperatures. If a slicer software doesn't have an option to perform filament change by using a script, it can be done manually while printing by pausing the print at certain height, changing the filament and resuming the process. After the printing is finished and build plate is cooled down, product is ready to use, no post-processing required. In Fig. 7**Error! Reference source not found.**, modeling and final preparation of the frontal plate with 3D QR code is shown, as well as creating it with AM technology.

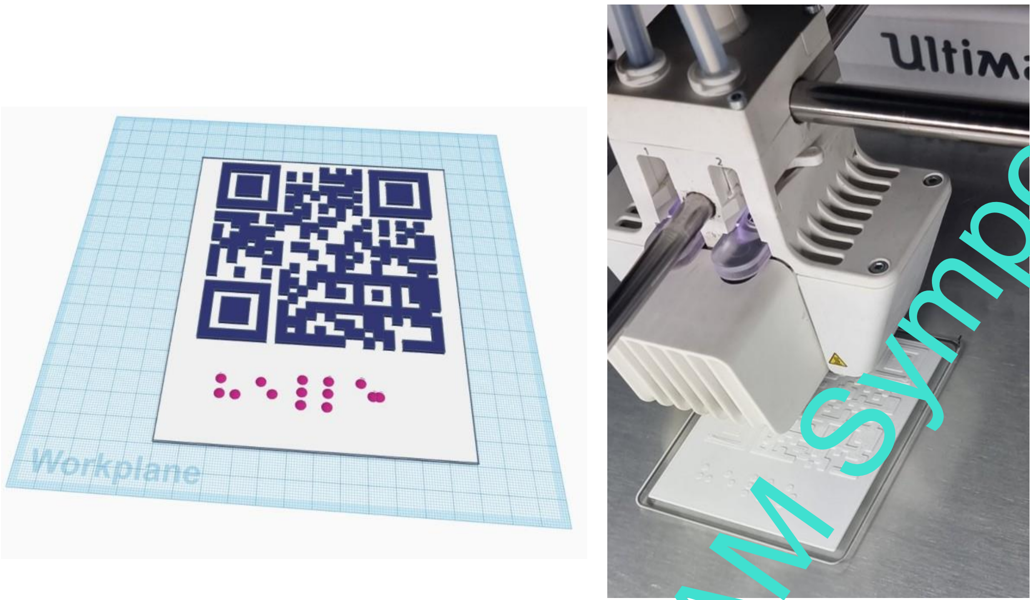

Fig. 7. Modeling and printing frontal plate with QR code

4. Examples of product applications

An essential feature of the design is that it enables easy scanning of the QR code even for those who are completely blind. Therefore, an appropriate QR code size was selected that could be easily read from the length of an average cubit – distance from elbow to fingertips. It would be scanned by holding the phone on the inside of the elbow facing the fingers of the other hand resting on the tactile letters on the case. Demonstration of scanning and example of application at metro station or airport is shown in Fig. 8**Error! Reference source not found.** left, as well as example of applications at the bus station in Sarajevo Fig. 8 right.

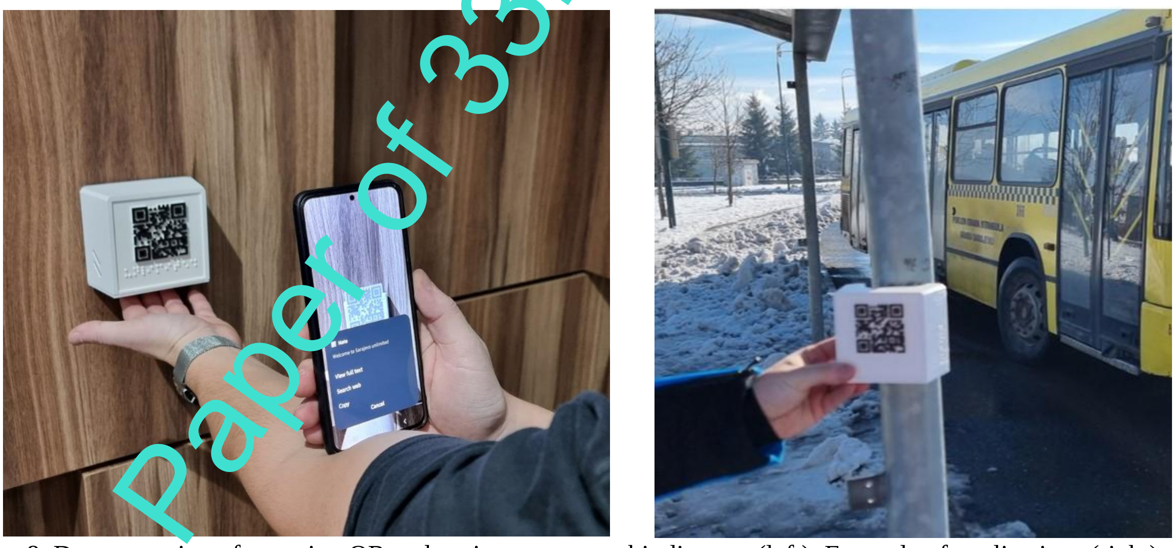

Fig. 8. Demonstration of scanning QR code using average cubit distance (left); Example of applications (right)

5. Conclusion

This research successfully showed how additive manufacturing can be used in order to create a friendly environment for vision impaired population. Product described in this research represents an innovation in fields of customizable product design and pointed out advantages of AM through practical application. It provides a great opportunity in massive usage of AM for creating final solutions for inclusion of visually impaired people in public transportation. Producing of presented 3D printed boxes and QR-code plates is a process that could be done by institutions on every level of government system by following our research. A very important thing is that the product is fully customizable for every place, eco-friendly and has short 3D printing time. This type of research is a solid base for exploiting additive manufacturing benefits in upcoming years and upgrading existing products that help humanity in many different ways. It will be interesting to follow constant exponential growth of AM science and connecting it with everyday life for whole population. AM based products can be combined with works of experts from different professions to create powerful devices with unlimited possibilities, such as creating a complete interface for 3D printed QR-codes and turn them into entrances to virtual guiding world for all users. Main future goals are to provide instructions and 3D models to as many associations for visually impaired people as possible and help them with implementation of product in cooperation with governments. In this way, the network of users will grow, creating a large database of feedback. Additionally, reviews will help us in recognition of the downsides, allowing us to create a more powerful version of design and final product. Furthermore, presented product need a software applications that will be custom made for helping visually impaired people to find their way around in public transport better, so this could be next step in this research.

6. Acknowledgments

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