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Making Public Display Content Accessible

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Abstract

Research in the domain of public displays has come a long way since the 1970s. This relatively new field is trying to overcome challenges that came up in finding a common ground for designing efficient techniques to get the most out of public displays. Attention grabbing and human-computer interaction are very important topics and are difficult to implement in a satisfying way. Gaze-based approaches are widely used when it comes to solving those problems. However, accessibility and assistive features are still rarely incorporated when dealing with public displays.

Visually impaired people in particular are mostly unaware of public displays and have very few means of approaching them and interacting with them. This thesis analyzes current problems visually impaired people have when dealing with public displays by interviewing them inside a focus group and by providing an online survey. Based on the gathered results a prototype was implemented simulating a public display environment. Users can interact with those public displays via their regular smartphones using a Bluetooth Low Energy connection. The application is running in the background and users get notifications when the public display is nearby. They get useful information at once and can query the public display for more information via the application on their smartphone without using the public display directly. A multi-user approach is used to support real-time communication through the public displays and to examine possible scenarios of interaction between users. Since this thesis focuses on accessible content, great attention is directed to give suggestions what kind of content is most suitable and how to appropriately make it accessible.

Visually impaired participants test this prototype in a user study. An evaluation of all the data outlines important feedback and gives valuable design implications when dealing with accessible public displays for future research topics.

Kurzfassung

Öffentliche Bildschirme - hier Public Displays genannt – werden seit den 1970ern wissenschaftlich untersucht und es werden dabei vermehrt grundlegende Standards gesucht, die einen erfolgreichen Einsatz dieser Technologie ermöglichen. Besonders im Fokus stehen aufmerksamkeitserregende Methoden und Mensch-Computer-Interaktionen, die viele Herausforderungen bei der Umsetzung bereithalten. Sehende Personen können bekannte Lösungsansätze viel besser einsetzen als sehbehinderte. Bisher wird wenig Augenmerk auf Barrierefreiheit und assistive Technologien im Umgang mit Public Displays gelegt.

Sehbehinderte Personen sind sich häufig nicht bewusst, dass Public Displays in der Nähe sind und können diese folglich weder gezielt ansteuern noch nutzen. Diese Arbeit untersucht Probleme, die Sehbehinderte im Umgang mit Public Displays haben, indem eine qualitative Befragung in einer Fokusgruppe durchgeführt wird und statistisch relevante Erkenntnisse einer Online-Umfrage beleuchtet werden. Ein Software-Prototyp wird basierend auf diesen Ergebnissen implementiert, der ein Szenario mit Public Displays ermöglicht. Benutzer dieses Systems können mit ihren üblichen Smartphones Public Displays benutzen, indem eine Bluetooth Low Energy-Verbindung aufgebaut wird. Es können zudem mehrere Benutzer das System gleichzeitig bedienen und damit Echtzeitkommunikationen einleiten, deren Mehrwert in verschiedenen Szenarios untersucht wird.

Sehbehinderte Probanden testen diesen Prototyp in einer Benutzerstudie. Eine anschließende Bewertung aller gesammelten Daten erstellt sinnvolle Leitlinien für den Entwurf solcher Systeme und gibt Aufschluss über wichtige Erkenntnisse, die für spätere Forschungsarbeit genutzt werden können.

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If you, dear reader, have any feedback - whether positive or negative or of whatever kind - please do not hesitate in writing me an email, I would be happy to read from you:

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1 Introduction

First, the motivation is given for this work and then the actual scope. An overview of the structure is provided at the end.

1.1 Motivation

Public displays have become a pervasive technology; nevertheless, this technology currently does not support communicating content to visually impaired passers-by. The content communicated by public displays becomes more and more important and should become accessible for all potential users including the population of visually impaired people. It is necessary to investigate what visually impaired users expect of an assistive technology to interact with public displays. With this knowledge, it is possible to think about a solution to the problem of how to make public displays more accessible.

1.2 Scope

In this work, we investigate the discoverability of public displays for visually impaired passers-by. Then we are going to establish the taxonomy of accessibility features for public displays and research the interactivity between visually impaired users and sighted users through the public display environment. We propose using broadcasting to make public displays discoverable and push interactive content to passers-by.

This thesis will investigate the feasibility of different approaches of discovering public displays. It should cover the two types of attention creation. The first is bottom up attention when a certain specific goal needs to be fulfilled with a public display and the second is top down attention when it is generated actively. Afterwards it should be defined more precisely what mechanisms could be used to achieve a discoverable public display in an accessible way.

We propose our first approach to use distributed non-visible public displays, which are wireless devices broadcasting content to the users' mobile devices. The content will be discovered by notifications. The notifications contain basic information about the display and a tagline about the display's content. It might be up to the user to either dismiss the notification and therefore ignore the display and its content, or engage with the content by clicking the notification and receive the contents of the display on the mobile phone, where it can be read out and interacted with.

Those approaches will be evaluated in a lab setting through a prototype that we built for Android devices. The prototype will assess the granularity of information pushed via notification. The notification defines how much information is adequate to assess about the relevance of a display's content.

A prototypical campus deployment over a certain period of time and with a suitable amount of sighted and non-sighted test subjects is required.

We will study the interaction between visually impaired population and sighted people through the content communicated by the public displays. We will design an interactive space where we can observe the possibilities and limitations of these interactions. Afterwards, we will combine our concept of non-visual displays and regular public displays to create this interaction environment.

The prototype consists of a set of Bluetooth [1] servers, which will be our non-visual public display. They will broadcast the content to users' mobile devices that present the content in an accessible format. We propose to use regular mobile devices as content broadcasters, which offer different types of connectivity including the capability to connect to regular screens to visually display the content.

For this research, we will be observing the presentation of different types of content. We propose to use non-interactive content such as regular news, weather information, public transportation schedules and interactive content such as booking services, communicative applications and navigation information.

We expect to get in contact with regional organizations for visually impaired people. Then we can get an important feedback from the target group of users to support the design of our concept.

This work would like to answer the question about how visually impaired people can interact with the content provided by public displays and with sighted people within a public display environment.

We will conduct a set of user studies to establish the taxonomy for discoverability of public displays and accessibility of content provided by them as well as observe the interactivity between visually impaired people and sighted people.

1.3 Structure

This chapter outlines the structure of the thesis and highlights major parts:

Chapter 2 Background and Related Work: Introduces the basics of public displays and shows related work that has been done on this topic, especially concerning assistive technology and accessibility.

Chapter 3 Concept: Describes the basic idea behind this thesis and how it is fleshed out. First, we describe the solution to the problem this thesis wants to solve. How todays' public displays can be used to integrate the solution is described afterwards. In addition, the interaction techniques are laid out.

Chapter 4 Technology: This chapter explains in detail how the solution can be realized with modern technology. Hardware components and software layers are described to show what important technical features and limitations are in place.

Chapter 5 Implementation: The software implementation is analyzed in this chapter. Key software components and their behavior are shown and major challenges when writing them are described.

Chapter 6 User Study**:** With the developed software solution, a user study with visually impaired and sighted participants is conducted and the results and their implications are discussed briefly.

Chapter 7 Evaluation: The gathered study results are processed and analyzed to give a picture of what can be learned from the study. In addition, interesting patterns and significant results are discussed more in depth.

Chapter 8 Conclusion and Future Work: This chapter finishes the work with the overall conclusion and summary of all topics. All overall results are discussed briefly and a possible new starting point for future research and work is proposed.

2 Background and Related Work

This chapter discusses the core topic of the thesis at hand and gives an overview of today's progress and its implications on the work that needs to be done. It establishes the taxonomy for understanding the problems this thesis wants to solve and highlights and explains the differences to other related work and research. Public displays, how they are used today and how they can be used are major topics in this chapter.

2.1 Background and Technology

To give an appropriate picture of what exactly is meant by a public display and what constitutes it, a historical and technological background is laid out in this chapter. But beforehand a small introduction explains important data points about visual impairment.

2.1.1 Visual Impairment

This thesis is not grounded in the domain of medical research and thus does not target to contribute something to this field. It mainly focuses on a software solution to a specific usability and accessibility problem. However, this thesis still has a medical background and mainly targets a specific demographic with a medical eyesight condition, so it has to address this topic appropriately.

Based on a well-founded research by the World Health Organization (WHO) [2] the estimated population of visually impaired people in the year 2010 is 285 Million. Based on the estimate of the global population of 6.737 Billion, this means that 4.24 % of the global population is visually impaired. Table 1 shows in more detail how these numbers are distributed based on age. It's important to notice that visual impairment is mainly caused by age related macular degeneration, glaucoma and diabetic retinopathy [3]. Coupled with the fact that the populations are ageing, the number of people with disabilities and thus also people with visual impairment are steadily growing – about 15% of the global population in the year 2011 has some form of disability [4]. That is also one of the reasons why it's more common that elderly people participate in user studies; they are simply in the majority with regards to visual impairment – more on this in later chapters.

Ages (in ages)	**Population (millions)**	**Blind (millions)**	**Low Vision (million)**	**Visually impaired (millions)**
0-14	1,848.50	1.421	17.518	18.939
15-49	3548.2X	5.784	74.463	80.248
50 and older	1,340.80	32.16X	154.043	186.203
all ages	6,737.50 (100 %)	39.365 (0.58 %)	246.024 (3.65 %)	285.389 (4.24 %)

Table 1: Global estimation of visually impaired people by age [3]

Another important fact is that most disabled people including visual impaired are living in countries with a low income [3]. Table 2 shows the distribution of disabled people by WHO regions.

		Blindness	Low vision	Visual Impairment
WHO Region	**Total population (millions)**	**No. in millions (percentage)**	**No. in millions (percentage)**	**No. in millions (percentage)**
China	1344.9 (20 %)	8.248 (20.9 %)	67.264 (27.3 %)	75.512 (26.5 %)
India	1181.4 (17.5 %)	8.075 (20.5 %)	54.544 (22.2 %)	62.619 (21.9 %)
Europe	889.2 (13.2 %)	2.713 (7 %)	25.502 (10.4 %)	28.215 (9.9 %)
South East Asia	579.1 (8.6 %)	3.974 (10.1 %)	23.938 (9.7 %)	27.913 (9.8 %)
Americas	915.4 (13.6 %)	3.211 (8 %)	23.401 (9.5 %)	26.612 (9.3 %)
Africa	804.9 (11.9 %)	5.888 (15 %)	20.407 (8.3 %)	26.295 (9.2 %)
Eastern Mediterranean	580.2 (8.6 %)	4.918 (12.5 %)	18.581 (7.6 %)	23.499 (8.2 %)
Western Pacific	442.3 (6.6 %)	2.338 (6 %)	12.386 (5 %)	14.724 (5.2 %)
World	6737.5 (100 %)	39.365 (100 %)	246.024 (100 %)	285.389 (100 %)

Table 2: Global estimation of visually impaired people by WHO region

This means that in our western society visual impairment occurs in about 10% of the population and counting. Since disabilities getting less common and being treated globally on a large scale is not yet in sight, Universal Design [5] is becoming ever more important.

2.1.2 Public Displays

A display is often used as a shorter term for display device that presents information in a visual or tactile manner. When talking about displays we nowadays mean electronic displays that can usually change the displayed information; in this context, static signs are therefore not called displays. When deployed in public, a display can be called public display to describe it more specifically. A public display serves a specific goal and is therefore located in a specific spot to fulfill its goal effectively. Since displays can be manufactured cost efficiently, more and more static signs get replaced by dynamic or even interactive public displays [6]. Public displays can be updated via different kinds of media storage devices or even over a network connection, so they can display the latest information [7]. Even cash machines, which have an interactive display, are considered as public displays. Because of their special use case of dealing with very private information, cash machines are not highlighted in this thesis.

Murray Lappe was a pre-med student when in April 1977 he developed a way to use a Plato Computer System and a plasma touch screen as a first attempt at a self-service interactive kiosk; he called it the PLATO Hotline [8]. It was capable of showing information about bus timetables, university courses and activities, movies, maps and directories. It was a huge success inside the campus area of the University of Illinois, where the system was deployed, of course also because of the novelty of getting in touch with a personal computer. However, widespread usage was not planned, so the larger population did not come to know about those kinds of first attempts of public displays for a longer time.

In November 1980, Kit Galloway and Sherrie Rabinowitz created a very special kind of public display mainly for arts and social research purposes: “Hole-In-Space” was an attempt of remote multi-user video communication via a public display [9]. Figure 1 shows how people from Los Angeles could communicate with New York and vice versa over a period of three days. It was one of the first times a large-scale scenario was created with public displays.

Figure 1: Hole-In-Space first Public Display [10]

In later years, public displays were used in a multitude of ways like in working environments [11], weather forecasts [12], pin boards for leaving text [13] or scribblings [14], room reservation management [15], music picker for restaurants [16] or even for games [17].

Figure 2: "Fancy a Schmink": Public Display serving a collaborative Game [17]

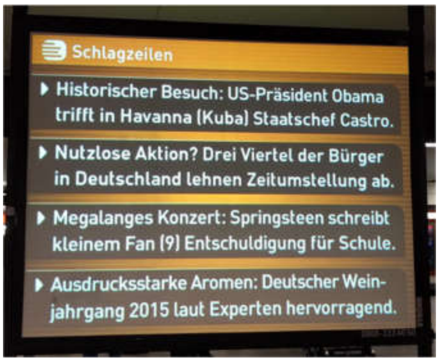
Through the years advertising played a major role when stakeholders of public displays decided to invest in researching them [18], but more and more research is done in interaction applications and different projects emerged like PD-Net (funded by European Union) [19]. One of those projects is also Digifieds, a distributed networked multi-purpose public display installation in Oulu, Finland [20]. Over the course of 6 months users could find information about the local area or make postings about different topics like selling things, housings, jobs or dating via their own mobile devices. Figure 3 shows how the sport event “Beach Tennis Cup 2011” is displayed by Digifieds and how more information could be transferred to a mobile device.

Figure 3: Digifieds - Interactive multi-purpose public display [20]

This and many other projects showed that users were really interested in local news, local events and liked the idea of an interactive public display.

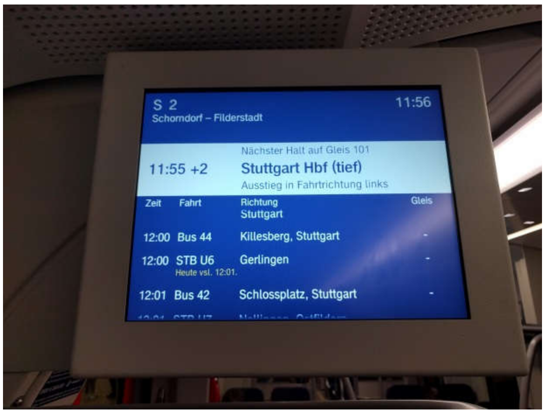
Everything points into the direction of giving passers-by of public displays a more interactive way of using them, sometimes even in conjunction with their wearable devices like smartphones.

Especially in bigger cities, public displays are pervasive and commonly known and used. Even so much that people developed new habits so they tend to subconsciously ignore them. This phenomenon is also known as (and metaphorically called) Display Blindness [21]. A major research focus when dealing with public displays is how to make people aware of public displays and grab their attention. Some public displays are helping users of public transportation and provide them with timetable-information about next departures, local news or weather forecasts. Sometimes they even entertain with little quizzes or picture puzzles. These kinds of displays are most often not interactive and serve as pure information displays. Figure 4 shows two examples of such public displays in the public transport platform areas of the Stuttgart Hauptbahnhof (Main Station). The first display cycles through different kind of information during the day. Technically, a Microsoft PowerPoint presentation is projected onto a projector wall that is located between two platforms. Other displays are located inside trains like in the Stuttgart S-Bahn wagons. The last photo of Figure 4 shows a public display with the latest departure times of different public transport types like busses or trains including the next station.



(photo shot at Stuttgart Hauptbahnhof / Main Station)

(photo shot at Stuttgart Hauptbahnhof / Main Station)



(photo shot at Stuttgart Hauptbahnhof / Main Station)

Figure 4: Examples for non-interactive public displays

Other kinds of displays have interactive screens. Interactive screens become a common tool and technology in today's society. Devices like smartphones or tablets use interactive screens to give an intuitive input method that lets users adapt to the system quickly. Even children are getting in contact with interactive displays at younger age and implicitly learn how to use a touch screen.

That trend gives many possibilities in using public displays.

2.1.3 Awareness and Attention Building

To even consider using a public display, a passer-by must first be aware of it. His attention must be grabbed somehow and when successfully done so, he can try to interact with it. This process is detailed in Müller et al. [6]. In short, this "Audience Funnel" can be dissected into the following topics:

1) Attention
    a) Passing by
    b) Viewing and reacting
    c) Subtle interaction
2) Motivation
    a) Direct interaction
    b) Multiple interaction
    c) Follow up action

The viewing and reacting part is the essential link that is completely missing when talking about visually impaired people. Having nearly no awareness about a public display prevents any interaction whatsoever. A sighted person is usually needed to notify a visually impaired person about a nearby public display. Due to the non-standardized user interfaces, public displays always need a bit of time to get used to them. In addition, accessibility features are mostly non-existent or have very limited functionality. Some public displays do not have any headphone jack that would enable visually impaired people to use them without having to worry about disturbing others in the surrounding area. Some do have accessibility features, but are lacking in giving all necessary information to be fully accessible for visually impaired. These are all reason why visually impaired people can hardly interact with them; they often simply do not know how.

2.1.4 Accessible, Assistive Technology

Assistive technology is a big research topic and is benefitting a large number of people. E.g. in the case of text auto-correction, Swiffin and al. showed in their studies that this assistive technology in particular not only benefitted the targeted group of disabled people, but everyone in general for typing faster [22]. Nowadays auto-correction is used by almost anyone, although designed for a certain group. It shows that having a mindset of including Universal Design is good for everyone [5].

Hearing is a very important sense and extensively used by visually impaired people. Thus, assistive technology often uses audio clues or speech to convey information. Figure 4 shows a public display belonging to the bus station Fellbach Lutherkirche, which displays upcoming bus departure times and delays, their line numbers, destination and platforms. Additionally it hosts an assistive audio guide that can read out all the displayed information at once by pressing a yellow button. It works similar to an accessible traffic light button that gives audio clues like beeping or tactile clues like vibrating when pedestrians are allowed to walk.

Figure 5: Example for a non-interactive public display with an assistive audio guide (photo shot at Stuttgart-Fellbach Lutherkirche)

Lindsay et al. showed that auditorial help like auditory icons, earcons or spearcons in particular can be a helpful tool when dealing with human computer interactions [23] and improving the user performance. Spearcons are recorded speech samples that are played out very fast in the appropriate contexts and cannot be understood normally. It needs some practice and familiarization to distinguish them. However, after the user overcomes this hurdle, it gives him big performance improvements in using and navigating computers. Incorporating those can bring greater comfort and efficiency for visually impaired people when dealing with today’s complex user interfaces, especially within the mobile environment, where screen space is often stuffed with user interface elements and controls making them cumbersome to navigate for visually impaired.

It is important to consider a broad range of accessibility features when dealing with public displays and smartphones. The following chapter shows some related work having this in mind.

2.2 Related Work

Now that a broader knowledge of the topic is established, we can look at related projects trying to deal with accessibility, public displays and smartphones.

2.2.1 Smartphones as Input Devices

Smartphones can be used in a multitude of ways. One of them is as a remote input device for other devices. Ballagas et al. showed what techniques work best for certain use cases [24]. Some techniques like direct cursor manipulation by moving the smart device and video processing the movements are strenuous and only suited for a short usage time. However, those techniques require seeing where to stand; this makes it hard for visually impaired people to use them.

Today's smartphones have user interfaces that tend to have many interacting elements, requiring swipe gestures and visual tracking or a general idea where to swipe. Visually impaired users have problems with those kinds of interaction techniques because they cannot figure out how a gesture works without indications. Those indications are still missing frequently because smartphone manufacturers do not provide enough accessibility tools for their interfaces. Kane et al. showed that designing gesture-usable interfaces for visually impaired people needs special care [25], because they have their own expectations of what gestures to use and perform gestures differently in general.

That is why there are approaches of replacing the stock user interfaces with custom ones like Blind Shell [26]. This application enables visually impaired users to navigate the smartphone in a more comfortable and easy way. Menu options are dissected into less complex screens and basic functionalities like the alarm clock, phone dialer, contacts picker, calendar or sound recorder are customized for a more accessible experience. Figure 6 shows how typing messages is made easier by shrinking and focusing on just the main elements. This makes it easier for visually impaired people to use their smartphone in one hand and having the other hand free for using their canes.

Of course, that does not solve the problem of non-accessible applications in the open market, because those cannot be altered by these kinds of tools.

Figure 6: Blind Shell accessible Home Launcher [26]

Providers of smartphones pre-install accessibility services that help visually impaired people navigating their smartphones. E.g., Apple provides their mobile devices with VoiceOver [27]; Google provides their open operating system Android with TalkBack [28]. Only Google's accessibility service can be replaced with a custom implementation, giving full control over what the system should do when accessibility is turned on.

2.2.2 Accessible Spatial Navigation

Many research projects focusing on assistive technology and accessibility have spatial navigation as their main topic.

Florian Leiß researched different navigation methods that showed that visually impaired participants liked using their smartphones for navigation [29]. Auditorial clues like beeping or vibration were used to guide users from one Bluetooth Beacon [30] to another. Bluecon was the name of the resulting application giving this functionality. In-door navigation was the primary target of this research. In addition, it was focused on providing an accessible user experience by using a navigation pattern via lists to flatten the navigation into a one-dimensional path. Due to its heavy reliance on Bluetooth Low Energy, this work has many technical similarities with the implementation of this thesis.

BlindNavi [31] is another approach of dealing with an accessible navigation application. It provides handy features like shaking the phone to get the current position. It generates a notification when passing by important landmarks like stores, traffic lights, corners or lanes; similar to the way visually impaired people tend to orient themselves. Those are helpful suggestions of how to design a simple, intuitive and accessible user experience.

Figure 7 shows how a flat and less complex user interface can look inside Bluecon or BlindNavi.

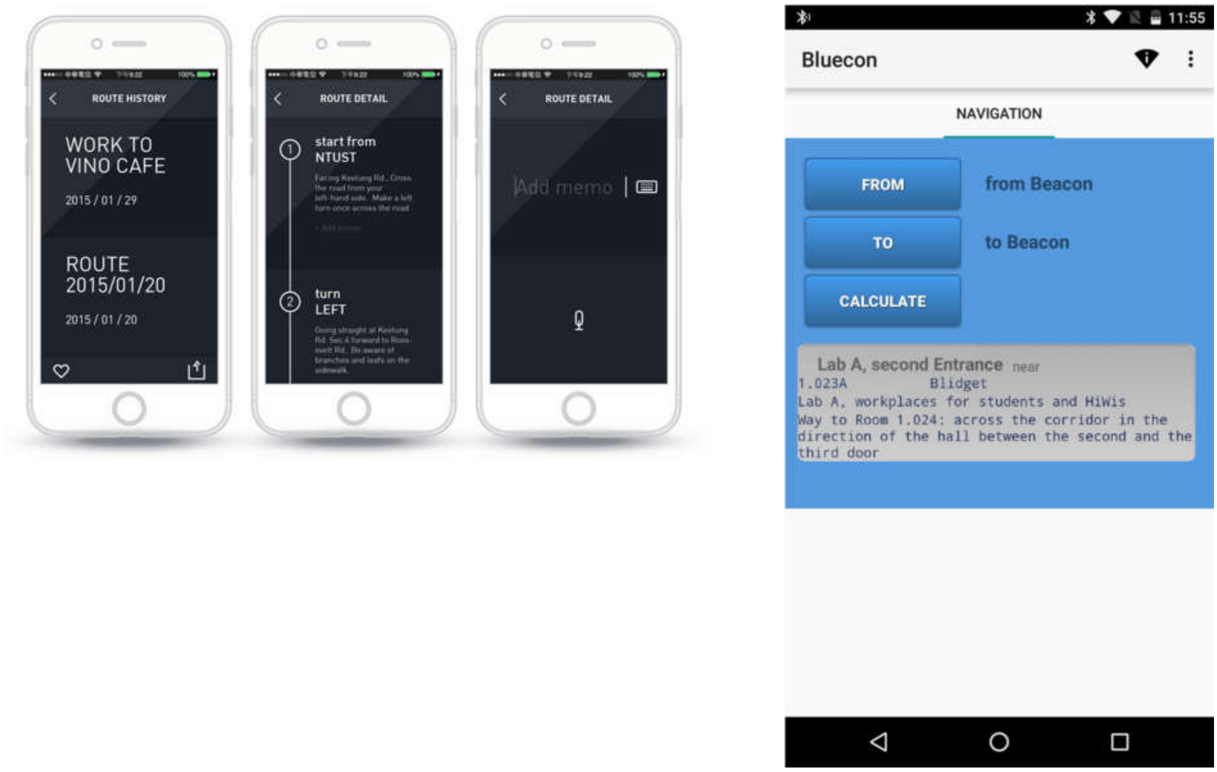


Figure 7: BlindNavi [32] and Bluecon [29] accessible navigation applications for visually impaired

With the additional effort of making the user experience more accessible, smartphones can provide valuable assistance for various tasks.

2.2.3 Fabric-, Textile- and Garment-based Devices

Newest research in smart garment-based application showed that it is becoming a future alternative for certain use cases. Alkis [33] investigated how sensor mats woven into clothes can detect body postures and give user feedback. Those implicit gestures could also benefit visually impaired in situations when interaction with public displays occur. E.g., pointing to the correct location of a public display or notifying nearby passengers in case of emergencies. Voit [34] showed how gesture detection could be incorporated in human-computer-interactions with smart garments. Expanding the interaction to the whole body brings improvements when executing tasks in motion. Visually impaired people could concentrate on the task rather than fiddling with their smartphones, especially when they are using it in parallel with their canes. However, those approaches had issues with the connection because the wires needed to be plugged into a computer for data processing.

Google's Project Jacquard [35] cooperates with the clothing company Levi Strauss & Co. to develop clothes stitched with conducted yarn. It can send sensory information wirelessly to be integrated into useful applications. Figure 8 shows the minimum setup the solution needs. Industrially made mass-market smart clothing still has a long way to go, but progression is steadily made, so that their uses can expand in manifold ways.

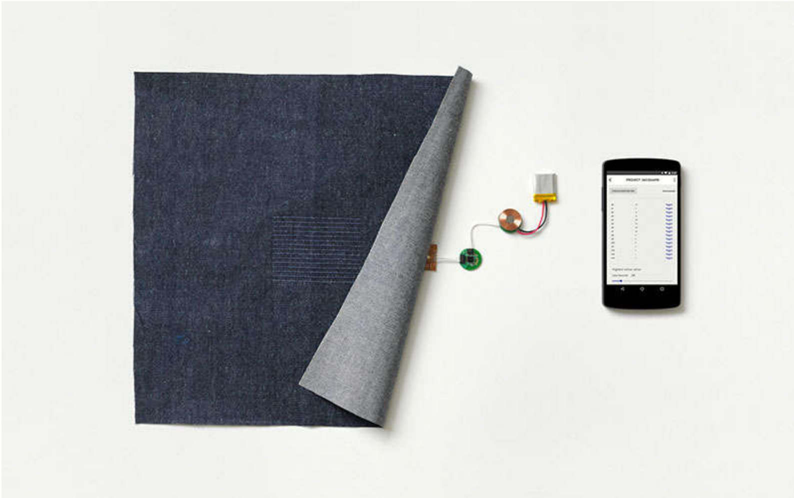


Figure 8: Project Jacquard Smart Garment Setup [35]

Other approaches are integrating sensors into shoes helping visually impaired people to navigate. Vibrators are stimulating the sole of the foot based on the direction to go. Velãzquez et al. [36] did different tactile perception tests based on shapes and pattern recognition. Results showed that it is easy to recognize very simple shapes by foot, but complex shapes were very hard to guess for the participants.

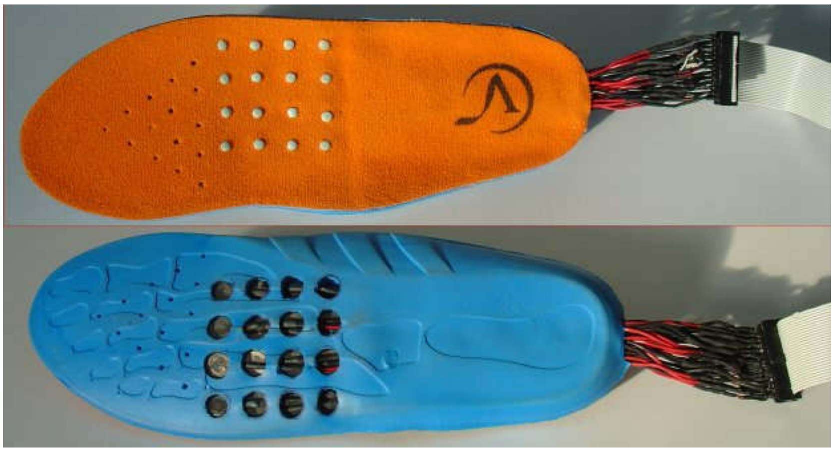


Figure 9: Tactile Display integrated into Shoes [36]

Figure 9 shows how the tactile display was integrated into to the shoe sole. A thick cable was necessary to be plugged into a computer to send the shape and directional information to the vibrators.

2.2.4 Other Assistive Wearables

Velázquez [37] observed in his studies that assistive wearable devices are still rarely used because acceptance is quite low. The issues for a visually impaired person using wearables are:

- Sensory overload: When only trying to convey information for one sensory modality like sound or tactile, users might soon be overburdened with stimuli from the surrounding environments. Mixing information channels with different senses in mind, gives users enough sensory buffers to switch their capacity between different senses.
- Long settling-in periods: Lots of effort and time is demanded from the user when trying to learn new human-computer-interactions. New wearable devices introduce new and different kind of interaction languages that are often complex and hard to grasp at first try.

- Long auditory feedback can cause distraction or even throw the user off balance. It should be limited to less than 30 minutes or just for reading applications.
- Tactile feedback can only be recognized precisely by the tongue or with the fingers. Every other part of the body is limited to simple information. Complex information requires high cognitive effort and constant activity. It quickly fatigues the user and causes deceleration.

That is why the cane and/or guide dog are still the most preferred assistive options for visually impaired. To overcome those issues, a very sensible, accessible design approach needs to be considered, having all these issues in mind.

Time factors are crucial when deciding what smart companion or wearable device to get. Tasks like getting a phone number of a contact or time schedules of a calendar are sometimes hard to do for visually impaired. Having those readily available with the touch of a button and not fumbling with the navigation of smartphone interfaces have brought up different assistive gadgets that do exactly that. One of those is the product Milestone of the Swiss company Bones Inc. that specializes on organizational and entertainment devices for visually impaired people [38]. Figure 10 shows the minimalistic and simple user interface of the device. It relies on six front-facing hardware buttons for all the main interactions.

Figure 10: Milestone Smart Assistant [38]

It combines a dictating machine, text-to-speech reader, radio, calendar, clock with alarm and stop watch functionality, music player, audiobook player with support for DAISY [39] (an accessible audio book and computerized text format) and other established audio formats, WLAN-functionality with Bluetooth in the works and even a LUA programmable interface [40]. All in a credit card sized form factor. It has attachments for color detection, barcode reader and CD-drives. The navigation is very fast and intuitive, so that everyday tasks can be performed in rapid succession without having to memorize complex gestures or menu structures. Although users can customize it via LUA-script applications and attachments, its use cases beyond the pre-built ones are limited. A multi-user interaction model is hard to implement with this device.

Camera-based assistive technology is also a new way of helping visually impaired people. Camera systems with high-resolution lenses can be far easier image processed today. OrCam [41] does use such cameras to read out information that the camera records and the system processes. The MyEye reads out information by pointing at the object. It can recognize faces and arbitrary objects as well as text. A bone conduction headphone reads out the information. Figure 11 shows how a simple pointing gesture is recognized and the magazine is read out to the user. The OrCam MyMe [42] (see Figure 12) incorporates a new angle on augmented reality called augmented attention powered by a sophisticated artificial intelligence engine. It can record audio and video data and give useful information based on the current context and data analyzation. It can give the user important hints and information when his own attention is directed to somewhere else and thus missing relevant events in his surroundings. Privacy concerns are resolved by refraining from using any flash memory and using only low transmission rate Bluetooth Low Energy for data transmission. Therefore, no audio or video data can be stored or send, because it would cost a lot of space that does not exist and a lot of bandwidth that Bluetooth Low Energy does not provide. It periodically sends small data chunks to the paired user device for further processing. With that, other applications can use the data to give users suggestions about their surroundings. An open software development kit provides the necessary programmable interface for that.

Figure 11: OrCam MyEye Usage [41]

Figure 12: OrCam MyMe [42]

Thermal cameras can also be used for user interactions. Abdelrahman et al. showed that those cameras could sense thermal reflections from every kind of surface and use this to extract human bodies and other shapes [43]. This could give visually impaired users a new way of human-computer-interactions by using their canes to draw gestures when using public displays or other systems.

Figure 13: Thermal Camera Interactions [43]

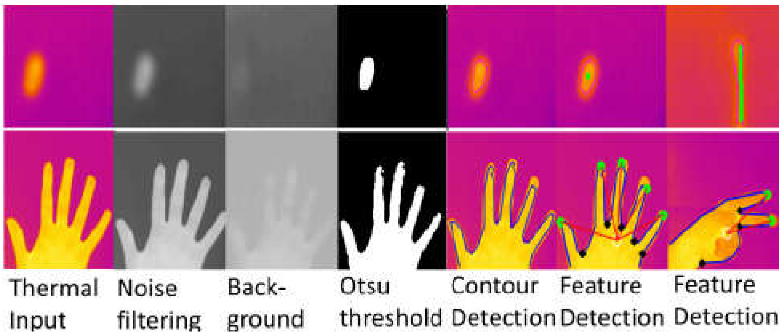


Figure 14: Thermal Camera Recognition [43]

Figure 13 and Figure 14 show how a person can be sensed fully and also how pattern recognition can be visualized.

2.2.5 Public Transportation

A very important and challenging aspect in today's societies, especially for visually impaired people, is mobility and public transportation. Since visually impaired people do not have any means to drive motor vehicles, ride bicycles or use other means of transport on their own, they often have to rely on others when it comes to traveling. To support them in using public transports autonomously, not relying on additional human help, it is important to provide enough accessible information whenever they are needed.

To do that with today's infrastructure, it is necessary to come up with cost-efficient solutions. One of them is a project named YED (Yollar Engel Değil) located in Afyon, a middle-sized town in Turkey. Its purpose is to provide visually impaired people with a service that accompanies them from their starting point to their destination. For that, visually impaired people were tightly involved inside the development process, mainly due to the involvement of the Blind Association of Afyon and Izmir. The development team consisted of members of Izmir University at the Izmir Institute of Technology [44].

A clear, accessible and simple user interface for mobile devices gives users the possibility to find bus stations and initialize a start-to-finish navigation that guides them to each necessary waypoint. A unique feature is the tight integration with the infrastructure and the bus drivers themselves. Users can confirm that they would like to get a certain bus connection and the appropriate bus driver is notified of an upcoming visually impaired passenger. A pre-installed display or tablet shows the notification and the bus driver is therefore aware of the passenger. When the bus driver approaches the station, he can take proper measures like honking to ensure a safe and smooth boarding of the passenger. After that, the visually impaired user can confirm entering the bus and gets further instructions for his travel like when to switch buses. This way he does not need to constantly ask other people for help.

The system is based on a web-application, which mainly targets mobile devices. It runs even on old mobile phones inside their browser applications, so old systems featuring accessibility features like Symbian phones [45] can also be used. It is using plain and simple HTML tags without any pictures, just textual information. The displays installed inside the busses also use a browser to show information, but in a more graphical way. A SIM-card (Subscriber identity module) is also included for internet access over the GSM network [46]. Both driver and users use GPS [47] for tracking their position, which is transmitted to the system. This way the user also gets navigational guidance like "only 100 meters left to the bus station". The bus driver sees a map with a real-time representation of his position. A user login is needed for authentication, but the system is completely free of charge.

Due to its unique accessibility features, YED is a European Union-funded project, which is also planned to be deployed inside bigger cities like Izmir, Turkey. The costs for deploying such a system inside a bus are roughly €1000. This also helps keeping costs down for not needing to install accessible public displays at the bus stations themselves. In addition, problems like vandalism and resulting expensive repairs are avoided.

Figure 15: YED (Yollar Engel Değil) mobile application [48]

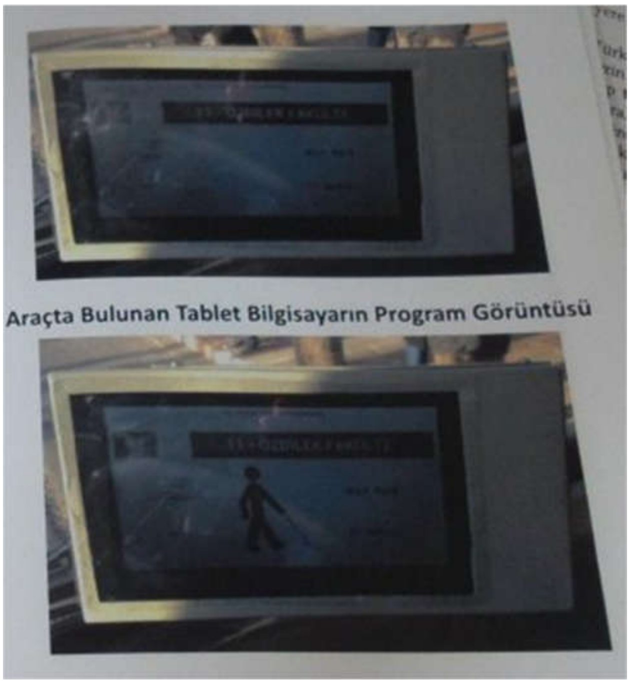


Figure 16: YED (Yollar Engel Değil) server application in busses [48]

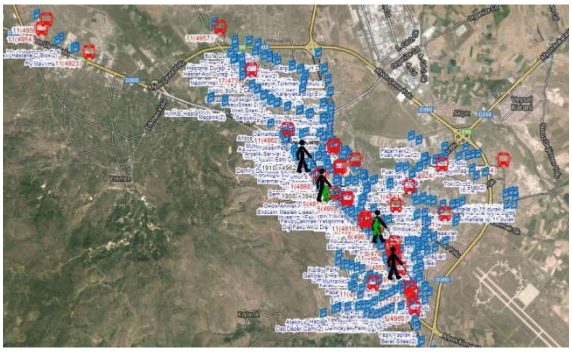


Figure 17: YED (Yollar Engel Değil) map of bus network

Figure 15 shows how the simple mobile application looks on a smartphone. White text on a black background ensures that all accessibility features on old mobile phones work with the website. Figure 16 shows how the system looks on the bus driver side. If a visually impaired passenger announced his boarding, the driver sees a graphical symbol for that case. Figure 17 is a map covering the whole bus network area the system is designed for.

A similar project still in its conception phase is Sinn² funded by the Ministry of Transport and Infrastructure Baden-Württemberg in Stuttgart [49]. The focus lies on accessible application for public transportation. It is still uncertain how their solution will work or look like but an open programmable interface will be provided for other developers to work with their data.

Relying on a constant internet connection does limit the systems to only certain areas where the connection is stable.

2.3 Social Issues

Huge problems for visually impaired people are social issues resulting from their lack of visual sense. E.g. trying to get assistance is a major hurdle for some people in certain cultural backgrounds. This leads to cases where visually impaired people rather stay at home in fear of having to face degrading, hurtful situations. Psychological distress, unhappiness and loneliness can be the consequences [50]. Providing them with more autonomous assistive technology could lessen those symptoms.

2.4 Summary

The bottom line is that the current landscape of public display technology holds many issues for visually impaired people. It shows that the mainstream models for public displays are not suited for an accessible interaction model. The problems are mainly present because public displays are hard to notice and when eventually noticed, hard to operate for visually impaired, because a clean and standardized interaction model is missing. Accessibility features are rarely incorporated into public displays making it nearly impossible for visually impaired to use them. Other missing aspects are personalized preferences that users could set to only get information they need and are not showered with useless information.

3 Concept

This chapter gives detailed insight about the thought process behind the solution to the problems visually impaired people have with using public displays. First, the basic idea and design are described. Then use cases for various interaction techniques are listed.

3.1 Preliminary Concept

To get some provisional ideas about how an accessible public display system could be designed, we convened some brainstorming sessions with experts in public display design: Prof. Florian Alt [51] and Tilman Dingler [52]. First, we worked out some general requirements that the system needed to fulfill. It was clear that a typical modern public display setup with a big screen and some networking features would not suffice; a different approach was needed.

3.1.1 Requirements

To serve an adequate public display system, a set of requirements was composed. The system should cover the following topics:

- Be accessible, so that visually impaired participants can fully use every feature.
- Be easy to use, so that even non-proficient computer or smartphone users can be acquainted with the system.
- Have means to get attention from passers-by not only based on their gaze, but also on other senses like hearing and tactile senses (top-down attention).
- Fulfill all necessary features public display users expect from such a system, when they need it (bottom-up attention).
- Support interaction from afar, so that when attention is built, interaction can be initialized directly. The interaction should also be possible without knowing where the public display is located exactly.
- Proximity is important, so interaction should only be possible in the surrounding area of a public display.
- Support multiple users at once, so that an interaction between them can take place with the help of the public display.
- Getting information and content should be almost instantly, without having to go through various steps.

3.1.2 Technical Requirements

Interaction from afar without knowing the exact location implies some kind of additional device to solve the requirement. Due to the fact that more and more visually impaired people use smartphones, it is an almost natural choice to use those as the additional device to initialize interactions. Most widespread smartphone models use either Apple's iOS [53] or Google's Android [54].

Another technical problem is the **proximity problem** of how to know when a public display is in range. There can be multiple ways to achieve this requirement. One way is the public display sends out information about itself that user devices receive and then know the presence of the public display. Thus, the public display has the active role. This can be achieved via different wireless technologies like Bluetooth or Bluetooth Low Energy [55]. Another way is that user devices actively search for public displays. This can be done via a registry that holds information about possible displays in the nearby area. A registry could be either accessed inside a network like the internet or ad hoc, or already be stored inside the user device. User devices could try to connect to those public displays and if they can successfully establish it, they would know that the display is in range. Of course, a mixture of those approaches could also be used.

Creating user attention is a very important requirement, not only because we do not want to annoy the user, but also because we cannot simply show a graphical notification. Depending on the platform and implementation, we can send out Push API [56] notifications based on the Promises API [57] via a web-application. However, this feature is not on iOS devices yet, it is still only working on Android devices [58]. When creating a native application, a full-blown notification API can be used on the appropriate platform of choice.

Supporting multiple users at once can be tricky when only one stationary public display is available, but when it can be accessed by smartphones, this requirement can be fulfilled quite easily. There are numerous different kinds of technologies to choose:

- Web: Web Server, Application Server
- Personal Area Networks (PAN) [59] like
    - Bluetooth: Master-Slave (2/3.X) [60], Client-Server (4.X) [55]

When choosing a smartphone as our primary point of access, a huge selection of **accessibility features** is available. From using a full-blown native application to a hybrid native-web-application to a pure accessible web-application there are many possible solutions.

3.2 Social Issues

Trying to have a solution for some social issues visually impaired people face in their everyday lives, is a major topic in this thesis. Therefore, we thought that some helpful functionality to get assistance when a situation comes up, where human interaction is needed, could provide some sensible data and feedback.

Those users who rarely ask for help because of former bad experiences or being shy are addressed by that. So when designing the system, some sort of accessible communication feature needs to be incorporated. It needs to give users the possibility to send out or receive text or pictures. This lets users reach out for help when needed or respond due to an incoming request.

Public transportation is another big issue and needs to be covered. The system should provide enough information very quickly, so that fast decisions can be made when a train, metro or bus are incoming. It should also give out information based on the preferences of the user, so that only the connections are presented, that are meaningful to the user.

3.3 Public Display Design

Having all considerations in mind, we like to design a robust and easy to develop public display system that enables us to conduct a study with all required features.

Because of the technical requirements, we choose to split the system in two parts:

- The first part consists of the public display side. We will call it the server or public display server. This part hosts the functionality responsible for the contents of the public display and distributes it. It can also show content if the users want to engage with the public display directly.
- The second part consists of the user side. We will call it the client or user client. This part is responsible for attention grabbing, connecting to the public displays, showing content and the most often interactions.

3.3.1 Platform of Choice

An important decision is selecting the platform that hosts the system on the client and the one on the server side. Having a choice between a web-based, native and hybrid application lets us weigh our priorities more flexibly:

- A web-based application lets us create content and their presentation very quickly and easily. Accessibility features are heavily based on the content of the website, so simple HTML tags and JavaScript are needed. Identifiers of the appropriate site can identify content. User clients can load content into their browsers, so technically even very old devices can be supported, based on the chosen wireless technology. Therefore, device penetration is the highest with this approach. However, only on newer browser implementations the Push API [56] can be used for notifications when a public display is in range. With this approach, we also cannot use every hardware feature on a device due to permission issues. E.g., Bluetooth Low Energy features cannot be accessed via web-based applications yet, so that limits us to fewer wireless technologies.
- A native application can use every hardware feature of a device, so it is the most powerful solution when targeting hardware-related features. Content can be presented in every way possible and accessibility features can be invoked at will. Since targeting multiple device operating systems at once can cause many implementation efforts, cross-platform development software can help [61]. Another thing to consider is what hardware features are required the most, since some platform-holders focus on different priorities.
- A hybrid application can be the best of both worlds, depending on the specific requirements. A mix of web-based content and native features can target many devices and split implementation efforts to just the platform-specific differences. However, tools and software used for implementing hybrid applications vary in features and documentation quality, so it’s very important to compare them (and even their versions) and see what fits best [62] [63].

Client

In the end, for the client we chose the Android platform with a native application approach. The advantages far outweighed all drawbacks we encountered. Some of the advantages are:

- Mature documentation of all necessary APIs and great support by the community
- Accessibility features can be chosen freely and even implemented by hand if the current ones are not sufficient
- Free development environment and tools
- Possibility to freely deploy software on any kind of device supporting the Android platform
- Advanced Notification API [64] with many customization options
- Mature Web Technology, Bluetooth and Bluetooth Low Energy support
- The most experience with the platform

Some disadvantages are:

- Most visually impaired people are more proficient with Apple iPhone devices. We do know that from other accessibility studies. It will be more troublesome for them to get used to the system with Android devices.
- Native Bluetooth Beacon Scanning support is only featured on iPhone devices at the time when conducting the study (an update to enable that is coming soon). Thus, distribution of the system in the real world is limited, yet (see chapter 3.3.5).

With the decision to use Android as the platform of choice, many other choices are implicit.

Server

The next big decision is how to design the public display server. A big touch screen device is not necessary for our study, because it focuses more on interaction from afar between the client and server. Besides, visually impaired people do not pay attention to those screens anyway. Thus, it can be simplified and abstracted to a device that hosts the content and can send it out when needed. Such a device can be an Android smartphone, too. Choosing a smartphone as a server can give us a cheap solution for our complex system. An Android smartphone nowadays has enough computational power for our use cases. Figure 18 shows a Nexus 5X as public display server.

Figure 18: Public Display Server

Wireless Technology

Bluetooth Low Energy [55] is our primary wireless technology for transmitting public display content. It solves the problem of proximity nicely by having a range of approx. 10 meters. Content can be broadcasted and received instantly via Advertisements and larger content can be transmitted via

Connections. It can also support eight and more clients at simultaneously without having to provide an own solution, which is an important aspect in our study.

3.3.2 Attention Creation

Grabbing the attention of the user can be done in various ways when targeting Android. A graphical notification can be shown, sounds can be played or a vibration pattern can be executed. As shown in previous scientific studies, relying on one sense can cause many different problems for visually impaired. Multiple sensory modalities should be covered.

At first, there are those interactive graphical notifications like on any modern smartphone. When user clients get a signal from a new public display server in range, a notification is displayed with the description of the public display and some preliminary information about what services the public display provides. The user can read the notification, dismiss it or initialize an interaction with the public display by clicking on the notification. This is the least disturbing kind of attention creation method, but also the least noticeable one when the device is not in use, e.g. in the pocket.

It can be used for both directions of attention creation: when the user gets a stimulus to use the system or when the user wants to use the system on their own. If the user is completely unaware of the system and does not have the application installed, Android does not provide a solution yet. For all the other cases, a graphical notification can provide a wide range of interaction possibilities.

3.3.3 Auditory Features

Playing sound is a very important tool to give visually impaired people the possibility to use smartphones. Selections, confirmations or text-to-speech are audio-based to give enough feedback to the user. Beeps, auditory icons, earcons and spearcons are all part of this solution and can be incorporated into the interaction with the application and for attention creation.

Audio can be very disturbing in certain scenarios, so it should be possible to turn it off immediately when needed.

Attention can be created very easily with an appropriate amount of sounds for different cases. Users can be notified that they passed a public display even when not holding or using the smartphone.

The user's preferences should also be taken into consideration. The sound itself, sound patterns (how many beeps in what succession) or when to turn off sounds should all be adjustable.

3.3.4 Tactile Features

Alternating vibration patterns can give useful indications when certain events occur even when the user device is currently not in use. This should also be adjustable by user preferences.

This approach strikes a balance between a more obtrusive attention creation mechanism like sound and a very timid one like graphical notifications.

3.3.5 Deployment

Deployment plays a big role for the longevity. If it is too cumbersome or not practical, the system will not be used by anyone. Having that in mind, the decision to focus on a two-application-approach with a bring-your-own-device concept has many advantages. A huge variety of devices can be used for servers or clients with this approach, ranging from smaller smartphones to medium-sized tablets to big displays to huge projector walls. A problem is how to bring the system onto the devices in the open. Users generally do not have an idea about such novel systems. To get a spotlight in the crowded mobile market is hard to do without a massive amount of advertisement budgets.

Nevertheless, there are some solutions, especially for this very localization-dependent application. When relying on Bluetooth Low Energy, a feature called Advertisements [55] can be used. Technically, it is a periodic broadcast of rarely changing information used to identify the broadcasting device. Those devices are often called beacons or Bluetooth Beacons. Different standards and formats emerged using this kind of technology. Apple's iBeacon [65] and Google's Eddystone [66] are two of them. Both use a custom UUID [67] and custom data.

The big difference is that Apple devices have native iBeacon scanning built into them, whereas Android devices still need previously installed applications doing the background scanning procedures and look for iBeacon and Eddystone beacons. This gives Apple devices the advantage to scan for iBeacon-compatible beacons and show the user a notification of their content. With that, it is possible to link to a specific application inside the app market. The user gets to know that it is a special kind of beacon working well with the featured application. It solves the problem of how to get a user in touch with our system when they pass by our special public display system.

This disadvantage will be solved in the upcoming months when native background scanning will be part of the stock Android system.

For Android devices, exist powerful libraries that help with the discovery and deployment of beacons. The Proximity Beacon API [68] helps with the configuration of deployed beacons. It can push content to them and registers them in a registry, accessible with the Google Services APIs. The Nearby API [69] gives Android devices search mechanisms for finding other nearby devices through a publish-subscribe mechanism. It can use wireless signals like WIFI, Bluetooth or ultra-sonar and gives ways to communicate between them. The registry for all the subscribers and publishers is accessed through the internet.

Both APIs can be used intertwined to have possibilities to send arbitrary data to nearby beacons.

3.4 Use Cases

With the requirements and technical solutions in mind, a set of use cases was designed, that should cover many possible and interesting situations when a public display is used. As an inspiration, we looked at current public displays in the city center of Stuttgart and other big cities. This gave us ideas what the most common services public displays provide are. We grouped them into two sets based on their interaction level.

Every use case is designed with a scenario in mind, where users pass by the public display and get the appropriate information.

3.4.1 Non-Interactive Use Cases

Non-interactive content is the most common form of content shown by public displays. Often mixed with advertisements, this kind of content is consumed quickly and does not need a lot of cognitive effort. Due to its short lifespan, this content also needs to be available quickly and easily or users will not be bothered with it.

Weather

A very common feature are weather forecasts to notify passers-by about the current local or national weather. On usual public displays those information is often exchanged and cycled through with other content. Our server can broadcast weather information constantly and update the current temperature periodically. Users can get information about the current weather instantly when passing by the public display.

The server constantly broadcasts live weather data, so a weather data provider needs to be found. OpenWeatherMap [70] has a very functional and easy to use API. It even gives out forecasts for up to 16 days free. It is easy to get weather forecasts even by localization data, so when the server is placed somewhere else it gets the correct local weather information.

Public Transportation

One of the most important use cases for visually impaired people is public transport information. A suitable way needs to be found to get sophisticated data. It is possible to query DEFI [71] for that. Each state has its own linked transportation system that provides DELFI information about the local public transports. However, data handling is quite complex with XSLT [72] queries and huge data transmissions.

Alternatives are smaller wrappers that on the one hand provide a subset of all the capabilities DELFI offers but on the other hand simplify the data handling immensely.

For the Stuttgart region, a recent project did exactly that. META API [73] facilitates using the local transportation information. The project's result is a service called metaEFA [74] [75]. It can be queried to get JSON [76] data for more efficient data parsing.

It is also possible that users can request certain public transport connections or retrieve them automatically based on their most recent connections or even based on their user preferences.

News

As shown before, local news and events are especially important for public display users. They give them helpful insight about what is going on in the nearby area. Google has a large selection of news categories and lets news be retrieved as RSS feeds [77]. Google News [78] is an appropriate tool for filtering news and giving users the news they are most interested in. User preferences are suited for that task.

3.4.2 Semi-Interactive Use Case

This use case is a hybrid of non-interaction and interaction. It is primarily intended to be consumed quickly but the user can still start small interactions with it.

Shout-outs (Post-Its)

This feature is like a virtual pin board for providers or users of the public display. It is intended to be used as a point to gather interesting local information placed by users, shops, restaurants or other points of interest. E.g., when our public display system is inside a shopping plaza, users could drop information about recent sales, inconveniences or give hints. Local establishments could also use that to announce interesting information.

It can also warn about dangerous situations or emergencies and guide people to exits. Instructions for how to behave in those situations are also possible.

3.4.3 Interactive Use Cases

Interactive use cases are more complex and time consuming than non-interactive ones. They generally need a longer introduction to explain what to do with them.

Booking (Restaurants/Theatre/Cinema)

This use case is a derivation of the Shout-Out use case. Nearby restaurants, theatres, cinemas and other similar establishments can use public displays to announce programs, campaigns, sales or other interesting announcements and give passers-by the possibility to interact with the announcement. E.g., a restaurant can announce a special lunch menu. When passers-by get the announcement they can book a table and the menu on the fly and retrieve navigational information about how to get to the restaurant.

Communication (Chats)

This use case is the most complex one. Computer-based human intercommunication can be achieved in many different ways. We use texts and pictures as our main media to let users communicate through the public display system. Visually impaired users can interact with sighted users to start conversations or ask questions. This approach is novel in the domain of public displays so its primary objective is to gain qualitative or statistical data about what users think of it.

Filtering

Disturbing the user with too much information is not a user-friendly design. To cope with that problem, filtering is used. Users can filter incoming public display information so that only those of interest are coming through. Different filter profiles help switching between filters when different contexts apply. E.g. on the way to work only news and public transport data is of interest, whereas on holidays and weekends only booking information is needed.

3.5 Online Survey

To get useful insights about what visually impaired people think about and expect of public displays, we created an online survey. The answers can be used to improve our public display design and shape the next proceedings. The online survey was done with the provided tool LimeSurvey [79].

We distributed the survey through the newsletter of the Blinden- und Sehbehindertenverband Württemberg e.V. [80] and an issue of Kreis Böblingen Regional [81], an audio newspaper for visually impaired people in the region of Böblingen. This way we could get many participants for the survey.

3.6 Focus Group

Prof. Florian Alt also suggested conducting a focus group to get more qualitative feedback. We asked voluntaries of the upcoming user study if they would be willing to participate in a focus group. With the feedback we could gain inside the focus group, we could improve the system for the user study.

The moderated focus group meeting is set for one and a half hours. With around six participants, this should give enough information to get a picture of what visually impaired and sighted people think about public display and what they expect from the system.

4 Technology

This chapter discusses the technology behind the provided solution. The platform running the software is described first, to show what capabilities are needed and how they can be leveraged. Secondly, the underlying Bluetooth software stack is presented. Important features and interfaces are elaborated to describe how all necessary Bluetooth features can be used.

4.1 Android

Android [54] is an open platform developed by Google [82] and the Open Handset Alliance [83]. Its most important characteristic is the openness of the platform, so that everyone can create compatible devices that can run every kind of software built for Android. Its base is a Linux kernel [84] that hosts every other software layer built on top of it [Figure 19]. This open nature allows developers to freely develop software for their devices and gives them full control over it. Android provides a favorable environment when it comes to mobile devices and its applications and is often used in research projects. The broad range of possible device targets can easily be managed by the provided Android build chain which makes it possible to write applications for smartphones, tablets, TVs, watches, glasses, cars or even exotic hardware like watering systems, all at the same time. Android supports all different kinds of technology and standards, thus giving developers a powerful and low cost platform.

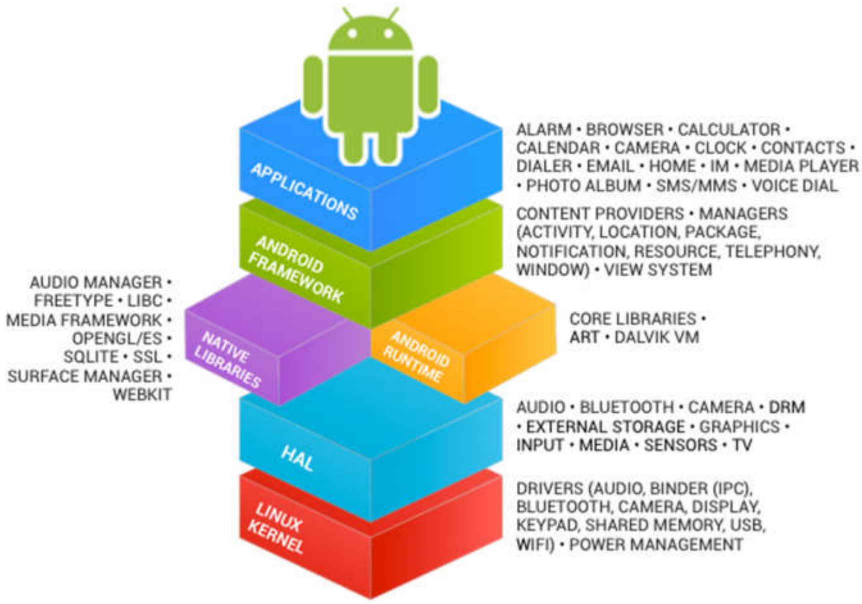


Figure 19: Android software stack [85]

When it comes to Bluetooth features, Android provides a clean and simple API to create full-fledged applications that can use all the newest interfaces the Bluetooth standard provides. To highlight the importance of some features [60], they will be explained in more detail in the next few chapters.

4.1.1 Multi-device support

One of the most important aspects of the idea that this thesis proposes is the interaction between multiple users and their devices. Multiple devices are used to communicate with each other so the technical side should have a way to support that. Bluetooth Low Energy [55] beacons usually do not support multiple connections at once, so it is necessary for the clients to take turns when they want to communicate with the beacon. In technical terms, it means that usually a single slave (beacon) does not have multiple masters (clients). This behavior causes delays, especially when complex data is transferred like in the application of this thesis. So when looking for a solution, a more sophisticated approach is used. Newer Android devices support a Bluetooth peripheral mode, that lets the device act like a beacon that supports multiple clients. It can broadcast advertisements and connect to multiple clients in parallel. This is a very important requirement that lets users interact with the public display freely even from afar and without any technical limitation.

4.1.2 Large Payload Transmission

The Android API provides means to increase the maximum payload transmission size (MTU) from 23 Bytes to 517 Bytes [86]. This facilitates sending large amounts of data without the need to chunk the data beforehand. Chunking the data would also increase the implementation effort to synchronize packets across multiple devices.

4.1.3 TalkBack

Google provides its own accessibility service for Android called TalkBack [28]. Its features include screen reading, explore the screen by touching it, explore elements by swipe gestures, vibration feedback, keyboard echoing and customizable gestures. TalkBack can be customized by own accessibility services or custom accessibility calls. TalkBack is using Android's built in text to speech engine.

4.2 Bluetooth

Bluetooth is a wireless radio frequency transmission standard used for close ranged networks. Because our public display server should only send information in its proximity area, this technology is suitable for our solution. Bluetooth is separated into different version. One is Bluetooth Basic/Enhanced; the other is Bluetooth Low Energy. Both work completely different and are used in different contexts. Bluetooth Basic/Enhanced is the "classic" widely known version, often used in entertainment and in industrial devices. It has higher bandwidth and the range can go from 10 meters to an extended range up to 100 meters. Bluetooth Low Energy has a very low power limit of 0.5 mW, so it cannot go beyond 10 meters. It is used in cases where low energy consumption is prioritized. Another interesting feature is that Advertisements can be transmitted and received without any manual pairing of the devices like in the case of Bluetooth Basic/Enhanced [55]. Advertisements are small data packets, which contain customizable data up to 31 Bytes. In our case, this gives us the possibility to passively look out for suitable devices that are our public display servers. This can be done via filtering the UUID set inside the Advertisement. Whenever we find such a device, we establish a connection in the Connection phase and can receive more information.

4.2.1 Bluetooth Low Energy

Understanding how Bluetooth Low Energy works is crucial for designing the correct software architecture that relies on it. It is essentially split into two phases called Advertisement phase and Connection phase. In less powerful or less performant devices, those phases take turns. It always starts with the Advertisement phase and when connections are initialized by clients, the Connection phase starts and the Advertisement phase is stopped until the Connection phase is done. However, in our case the server can manage both phases at ones. It can open multiple connections at once and still advertise data.

Advertisement data is a very simple and small data blob consisting of up to 31 Bytes of customizable data. The client side can only receive it and get the Bluetooth MAC address to initialize a connection.

Connection data is structured inside a GATT (GENERIC ATTRIBUTE PROFILE)-Server [55] and is far more complex and has multiple ways to be transferred. Mainly, it can be read, can be overwritten or be broadcasted. Broadcasts work in a publish-subscribe-model and can be periodical or initiated by overwriting data interpreting them as requests. Data can be structured into GATT Services containing GATT Characteristics containing a Value and multiple optional Descriptors. Figure 20 shows the structure in detail.

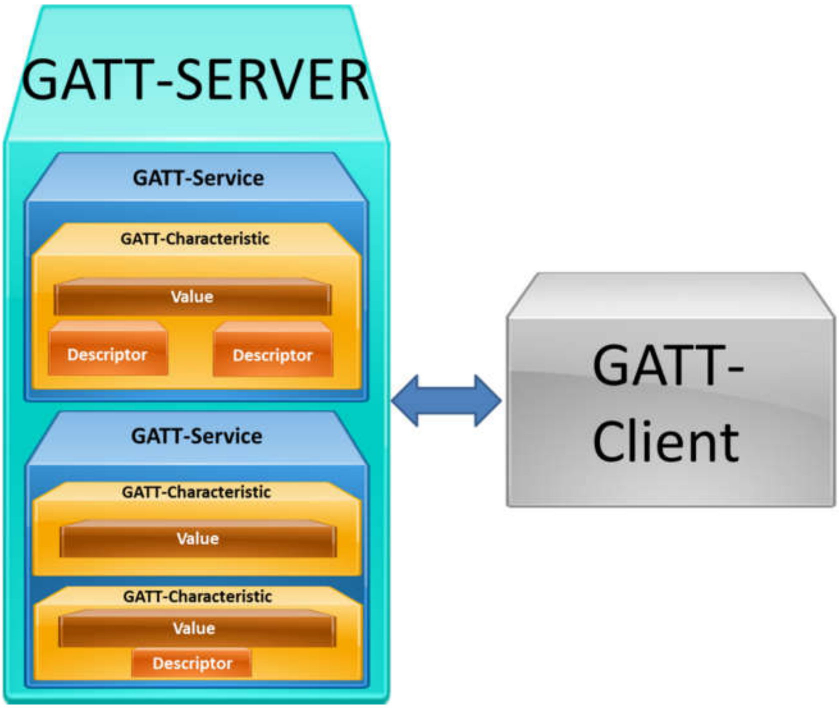


Figure 20: GATT Overview

4.2.2 Eddystone

Google's Eddystone is a format and protocol used with Bluetooth Low Energy devices. It facilitates compatibility between the devices complying with it. It can shrink the data to a minimum to extend the battery life. A short URL is the most important part and points to a webpage that the user can interact with when needed. This simple process is called Physical Web and is an approach to make many smart devices be usable by anyone without having to know about a specific application [87]. Right know Android does not support it natively, since it relies on a specific Chrome Beta version.

4.3 REST APIs

REST is the most common architectural style used for the World Wide Web. State operations on resources are what drives the web and can be invoked by the four REST methods GET-, PUT-, POST- and DELETE. GET and PUT are the most common REST methods. Every time a URL is called, a REST method is invoked in some way. All the external APIs are rest methods including the Nearby or Proximity Beacon API. The following chapters explain what formats can be expected when invoking those services.

4.3.1 XML

The Extensible Markup Language (in short XML) [88] is a powerful standard for data representation and commonly used for complex data that should still remain human-readable (caveat: only when talking about the recommended standard XML Infoset). Due to its strict syntax, computer programs can easily parse it.

On Android, there are many libraries for helping to parse XML. One of it is Simple XML [89]. It uses a domain model to map data from textual XML representation to POJOs (Plain Old Java Objects). The mapping follows rules that are set on the domain model itself. Java Annotations set those rules. An example for a simple rule would be:

```
@Root
public class Point {

   @Element
   private int x;

   @Element
   private int y;
}
```

Listing 1: Simple XML Domain Model Example

This class can represent the following XML:

```
<point>
  <x>10</x>
  <y>4</y>
</point>
```

Listing 2: Simple XML Example

4.3.2 RSS

RSS is essentially XML, so parsing it will follow the same exact rules. Loading news from the Google News RSS feed can be done via a REST HTTP GET. An example for ten German news with the topic "Stuttgart" would be
https://news.google.com/news/feeds?num=10&ned=de&q=Stuttgart&output=rss

4.3.3 JSON

JSON [76] like XML is a data representation standard. Unlike XML, it is less human-readable, but has a far smaller footprint. Therefore, it is used for less complex data and more often in common web environments where performance is more important than data readability.

On Android, an established JSON parsing library is Google's GSON [90]. It works very similar to Simple XML and supports Java Annotations for setting rules to map from POJOs to JSON and back.

```
public class Something {
  @SerializedName("field")
  private final String someField;
  private final String anotherField;
}
```

Listing 3: JSON Domain Model Example

This class can represent the following JSON packet:

```
{
   "field":"first",
   "anotherField":"second"
}
```

Listing 4: JSON Example

5 Implementation

Implementing the application to do the study with was a major part of this thesis, thus all-important steps are described in this chapter. The architecture design in particular is a crucial part that needs a lot of attention, because a clear structure is necessary to handle the many components the application has to provide for covering the study requirements. The application was implemented from scratch, so every design decision was made with the clear goal of facilitating the study execution.

5.1 Architecture

Since the implementation needs to make sure that one or more public display servers and one or more public display clients work in parallel, it is important to separate those two different entities. So servers and clients have different applications installed that serve different functionality.

For making sure that both mechanisms of the Bluetooth Low Energy technology (namely Advertisement and Connection) are covered, each mechanism is also encapsulated in its own component.

Figure 21 shows an overview about the dataflow when advertising and connecting at once. Advertisement data always flows from the server to the clients. Connection data flows between clients and server back and forth. Server-specific data is stored inside a database on the server; client-specific data is stored inside a database on the client.

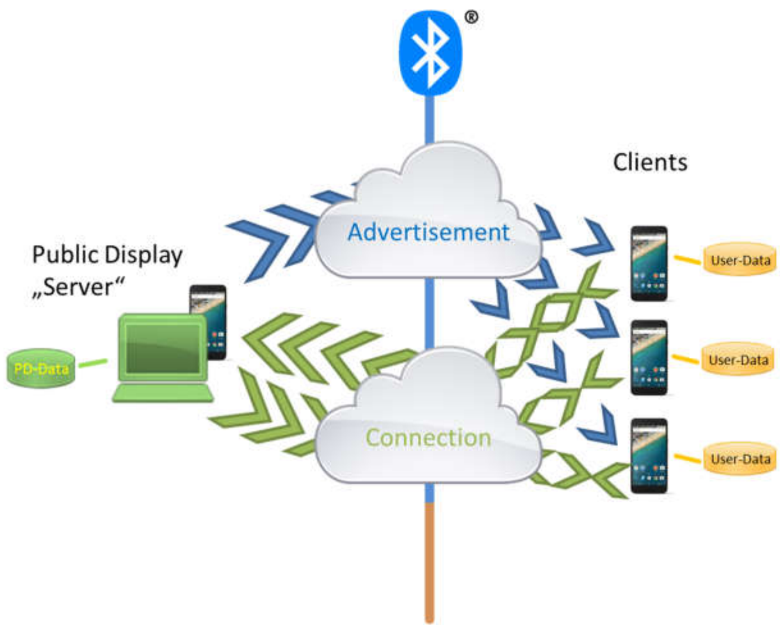


Figure 21: Architecture overview

All icons were provided by [91]

The server is also the component providing all the necessary data it gets from various providers. News, public transportation, weather or local information are all part of the servers information gathering process at startup. It checks every 15 minutes for new news, every 5 minutes for new public transportation information and every 60 minutes for new weather information. Figure 22 shows that the server forwards the information to the clients. This is done during Advertisements and Connections.

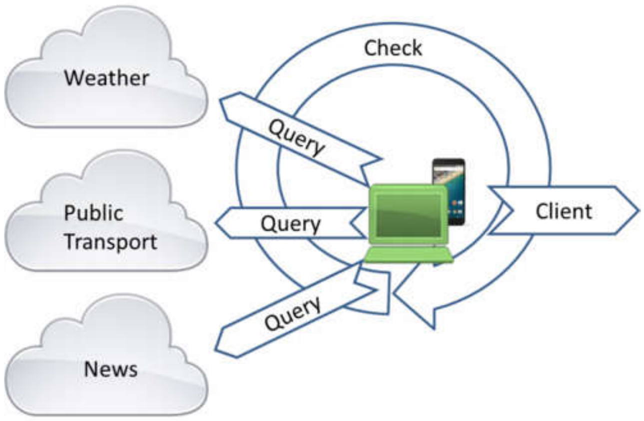


Figure 22: Public Display Service Checking

When updating the Advertisements side, a new advertiser needs to be initialized that broadcasts the new data. This is due to the inability to alter advertisement data directly. Updating the connection side, all clients need to be iterated over and get the new data. See Listing 5.

```
public void changeGattChar(UUID servUuid, UUID charUuid, byte[] value) {
       BluetoothGattCharacteristic c = getServer().getService(servUuid).
                                       getCharacteristic(charUuid);
       c.setValue(value);
       for (BluetoothDevice dev : getConnDevices()) {
           getServer().notifyCharacteristicChanged(dev, c, false);
       }
}
```
Listing 5: Updating Connection Clients

Synchronizing all direct GATT-Services manipulations is another task that needs special care, because concurrent access can cause the server to crash and restart. Therefore, a message queuing mechanism has to be in place to process all incoming requests sequentially with enough time between them for the server to set everything in place. Due to the nature of Android's single process and single main threaded architecture, it is necessary to outsource longer running setups into separated threads to not let the user interface stall.

On the GATT-Client side, it needs even more special care to make 100% sure that no multiple queries are sent out simultaneously. This can cause that one or more queries will be ignored by the outgoing GATT-Connection, so data loss needs high attention.

5.2 Asynchronicity

We encapsulated every longer running GATT-related process inside its own thread to make sure that the user interface is always responsive. Therefore, we created a work scheduler that checks the worker queue of new incoming work and schedules them appropriately. See Listing 6.

```
public void checkWork() {
    if (!getAccessGatts().isEmpty()) {
        e.schedule(getAccessGatts().poll(), 1000, TimeUnit.MILLISECONDS);
    }
}
```
Listing 6: Asynchronous work scheduling

5.2.1 Proxy API

We needed more flexibility when creating responsible user interfaces and multiple GATT-invocations that need to be put inside a queue. Therefore, we created a small component called AsyncAction that integrates into our user interface and GATT-Connection. Based on the Java Proxy API [92], it takes care of implementing one or multiple Java Interfaces on the fly. In addition, our implementation separates each invocation of the implemented interfaces into three phases. The first phase is running inside the same as the invocation. The second phase puts a thread inside a thread pool and starts it when it is possible. The thread takes care of all long-going work and when ready can start an optional third phase. This will post a runnable into the user interface-working queue so that the user can be notified about the work that has been done.

5.3 Use Case Implementation

All use cases could be successfully implemented with real live data, except for the booking use case. We could not find a simple and easy to use API to book any kind of restaurants, cinema or theater tickets or other interesting stuff. We could only either show a website of the vendor himself where the user can book something or just implement mockup data that the user could interact with. We chose the latter.

Interacting with the smartphone during accessibility mode can be done via swiping with one or two fingers, double tapping or doing other gestures (e.g. “reversed L” goes a screen back). Some gestures differ with the ones on the iPhone that visually impaired people are used to, but they are still easy to memorize. For better comfort when using the smartphone in one hand, the upper part of the user interface is intentionally left blank. Experience shows that the swipe gestures are constantly being misinterpreted. The system is often selecting elements that are beneath the swipe although they were not intended to be selected.

All use cases can be accessed either via notification or by selecting a public display in the list of public display in the nearby area.

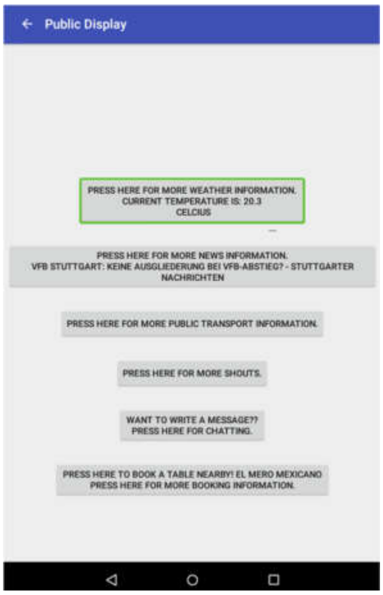


Figure 23: All Use Cases View

5.3.1 Non-Interactive Use Cases

Weather, public transport and news data are collected very similarly.

For weather data an open library OWM JAPI [93] was used. With it a more streamlined data handling is provided. During the Advertisement phase, the current temperature is provided. See Figure 24. During Connection phase, more weather data is collected and displayed when the user initializes the weather functionality.

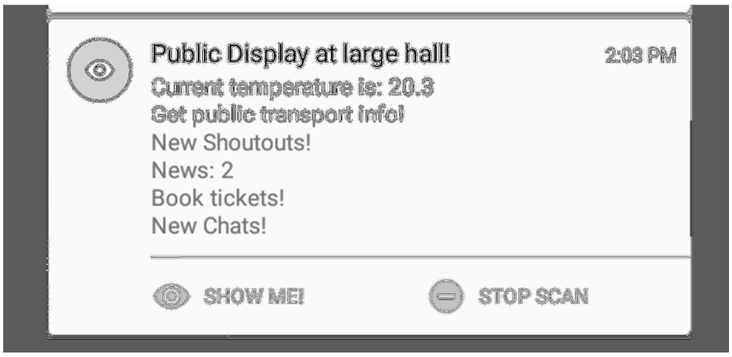


Figure 24: Public Display Notification

For the representation of all data, we chose text. Thus, it does not get in the way of the accessibility service. For sighted people we can use graphics and other more fancier controls. Figure 25 and Figure 26 show a sample of the weather and public transportation view.

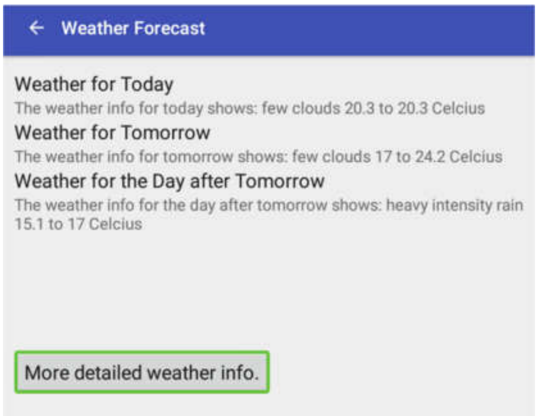


Figure 25: Weather View

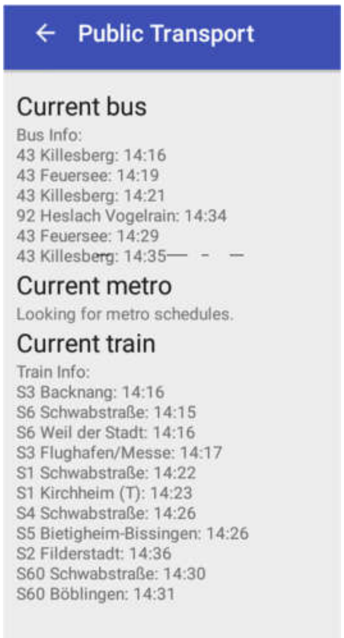


Figure 26: Public Transport View

All other non-interactive use cases work in the same way.

5.3.2 Interactive Use Cases

These use cases are more complex and require extra care. Limiting the amount of controls is key to get a comfortable user experience for visually impaired.

The mockup data we use for the booking part consist of existing restaurants and a selection of their menus. The process of booking a table is split into five sequential steps:

1. Selecting the amount of persons (mandatory)
2. Selecting a preferred table (optional)
3. Selecting the reservation time (mandatory)
4. Selecting the food (optional)
5. Getting a reservation code

All five steps are implemented using standard Android controls like time picker, text inputs or selection spinners.

For the chat application, we chose to use a normal text input field. The standard text input also supports speech to text conversion, so visually impaired are not dependent on typing. Users can also define text templates to send out a predefined text message when certain events reoccur. E.g., when they need help finding their way, they can send out a message asking for help. Setting a user name for the chat application is optional. In addition, a photo can be sent with an optional message tagged onto it. Pictures bigger than 400 Bytes are getting chunked and sent over multiple connection requests.

Every chat message is tagged with an optional user name, a timestamp and a unique identifier for the device it was sent from. Chat histories older than fifteen minutes are erased on the server for privacy concerns.

5.4 Audio Notifications

Generating sound is very easy with the built in Android Audio API. We generate a sine wave at a given frequency then convert it into a 16-bit PCM format and play it (see Listing 7). This way we can create various sound patterns and customize it based on the users preferences.

Separating it inside its own thread is necessary to not block the user interface.

```
public static void playExampleBeep(double freqOfTone, int duration) {
        final int    sampleRate     = 8000;
        final int    numSamples     = duration * sampleRate;
        final double sample[]       = new double[numSamples];
        final byte   generatedSnd[] = new byte[2 * numSamples];

        for (int i = 0; i < numSamples; ++i) {
            sample[i] = Math.sin(2 * Math.PI * i / (sampleRate / freqOfTone));
        }

        // convert to 16 bit pcm sound array
        // assumes the sample buffer is normalised.
        int idx = 0;
        for (final double dVal : sample) {
            // scale to maximum amplitude
            final short val = (short) ((dVal * 32767));
            // in 16 bit wav PCM, first byte is the low order byte
            generatedSnd[idx++] = (byte) (val & 0x00ff);
            generatedSnd[idx++] = (byte) ((val & 0xff00) >>> 8);
        }
        AudioTrack audioTrack = new AudioTrack(AudioManager.STREAM_MUSIC,
                sampleRate, AudioFormat.CHANNEL_OUT_MONO,
                AudioFormat.ENCODING_PCM_16BIT, generatedSnd.length,
                AudioTrack.MODE_STATIC);
        audioTrack.write(generatedSnd, 0, generatedSnd.length);
        audioTrack.play();
            }
        });
}
```

Listing 7: Sound generation

For a more streamlined way of generating audio, the Android ToneGenerator [94] can be used.

5.5 Tactile Vibration Notifications

Generating tactile notifications via vibrations is as easy as generating sound. We can specify to which specific use case the vibration is used with the AudioAttributes parameter. This helps the Android system schedule the vibration. See Listing 8.

```
long[]  pattern_long_long        = {0, 300, 0, 300};

private void vibrateFunc(long[] pattern) {
        vibrator = getVibrator();
        audioAttributes = getAudioAttr();

        vibrator.vibrate(pattern, -1, audioAttributes);
}

public static AudioAttributes getAudioAttr() {
       audioAttributes = new AudioAttributes.Builder().
                         setUsage(AudioAttributes.USAGE_ASSISTANCE_ACCESSIBILITY).
                         setContentType(AudioAttributes.CONTENT_TYPE_SPEECH).
                         build();
       }
       return audioAttributes;
}
```

Listing 8: Vibration Algorithm

5.6 Text-To-Speech

We use text-to-speech functionality when the standard accessibility service TalkBack does not provide enough information for the user. E.g., to conceive that a complex event occurred like booking a table, it is not always helpful to just generate an abstract sound. For that we generate a spoken text message that gets read out by the default text-to-speech engine.

When something inside the user interface changes, we can provide a special attribute called AccessibilityLiveRegion for the given control. This attribute indicates that changes should be read out to the user. See Listing 9.

```
<TextView
            …
            android:accessibilityLiveRegion="polite"
            …
/>
```

Listing 9: Accessibility Attribute for Live Regions

6 User Study

This chapter shows how the user study was designed and what steps were necessary to conduct it.

6.1 Preparations

Before the user study a set of preparations were carried out.

6.1.1 Focus Group

A focus group is conducted to get a clearer and qualitative view on a certain topic. In our case we wanted to know what our main user group thinks about public displays. The questions are similar to the ones we asked in the online survey but in a focus group, those can be answered in more detail.

The focus group is always moderated and directed to a certain topic the group has to focus on. Moderators have to be careful to let everyone take part in the discussion address everyone in the group.

All our focus group questions can be found inside the Attachments 8.7.

6.1.2 Reconsiderations

After doing the focus group and looking at the online survey, we reconsidered some of the tasks of our study design and focused on getting high-qualitative feedback from the users and their experience with the system. A massive scaled user study could not be done at this point, because it was clear that each participant has to invest a lot of time into doing the study. Spontaneous passers-by are excluded now, because they would disturb our participants in using the system. That would take more time away and the participants could not finish their tasks and have less time in figuring out how the system works.

6.2 Design

The study was designed with the help of Prof. Florian Alt. Based on previous user studies in this field we put a lot of effort into introducing the participants to the system. Qualitative feedback is more important than getting performance related data, because the whole setup is quite complex. Users have to be acquainted with the system and need a lot of guidance to complete all use cases because of unfamiliarity with the devices and the system itself. Approximately one hour was reserved for each participant or each participation group.

A NASA TLX was used to get subjective feedback about the workload.

One public display server will be deployed to broadcast different kind of information like (local) news, weather, nearby public transport arrivals/departures and the ability to send information to passers-by. The public display server and user devices (smartphones) are communicating with each other. An application on the user devices is installed to handle the communication with the public display server. The whole user study consists of the public display, the smartphones and the appropriate applications.

For each of the six tasks, the user has to start from scratch and evaluate how fast, comfortable or functional the task could be completed.

Our claim predicts that our proposed public display system provides a useful, novel and sensible approach to let visually impaired people get content that was not accomplished in a satisfying way yet. They can compare our approach with their usual methods to get information and give their opinion what works best and what still needs improvements.

6.3 Running the Study

For the study, we had twelve participants. Eleven were visually impaired. Nine of those were legally blind. One of those nine had minimum remaining sight. Two of the eleven had severely impaired vision. One was a sighted participant. Three participants were born blind; eight got their impairment later in their lives.

Seven participants were male; five were female. One was between 25 and 35, one was between 36 and 50, seven were between 51 and 65, and three were over 65 years old. All participants are living in Germany or have a German background.

The study was conducted in a course of four days in the Blinden- und Sehbehindertenverband Württemberg e.V. inside a meeting room. No other participants were allowed besides those twelve, so spontaneous passers-by were excluded.

The maximum amount of concurrent participants was three, because test devices were limited to three. One Nexus 5X smartphone was used as a server, the other client devices were:

- one Nexus 5X smartphone
- one Nexus 7 tablet
- one Sony Xperia 5 Compact smartphone

Because all except for one visually impaired participant used iPhones as their own device, they could not bring their own device to the study. The one with an Android device had an old model that could not be used for the study.

For each participant we prepared a set of questions before all use cases were sifted through. Afterwards there was another set of questions regarding the study. All questions can be found in the Appendix 8.9.

7 Evaluation

To evaluate the results of the online survey, the focus group and the user study, the data was first cleaned up. All blank fields were filtered out and not included in the evaluation.

7.1 Online Survey

For the online survey, we had 106 answers, 94 of those could be used for the evaluation.

We grouped the results based on age, visual impairment, origin, gender and proficiency levels. Further evaluation also looked into the free text answers.

Most of the participants were between the age of 51 and 65. This was already expected because of the fact that visually impaired people are mostly elderly people. 40% are between 51 and 65, 28% are between 36 and 50; ages between 25 and 35 and also over 65 are almost the same amount (15% vs. 17%). No participant was below 25. See **Fehler! Verweisquelle konnte nicht gefunden werden.**. Grouping into age and visual impairment shows that far more blind people

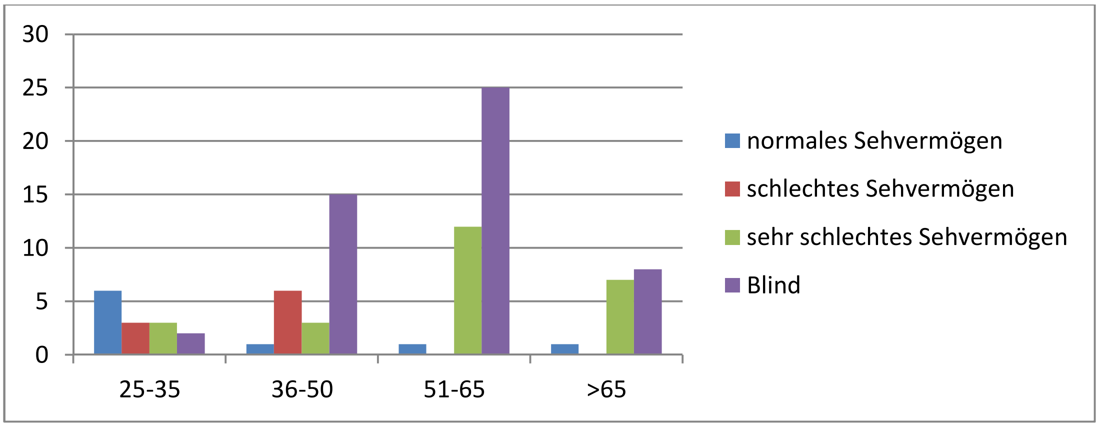


Figure 27: Online Survey Age-Sight Relation

Looking for gender showed that 60% were male and 40% were female. Only one participant has not specified the gender. The gender-sight relationship shows that 60% of all male participants were blind, whereas 45% of all female participants were blind. Only 11% of all male and 8% of all female participants were sighted people. Around the same amount of male and female participants were familiar with computers.

Relation between visual impairment and smartphone proficiency shows that sighted and blind people are far more familiar with smartphones than middle or severely impaired people are. Computer proficiency is far more equally distributed. See Figure 28.

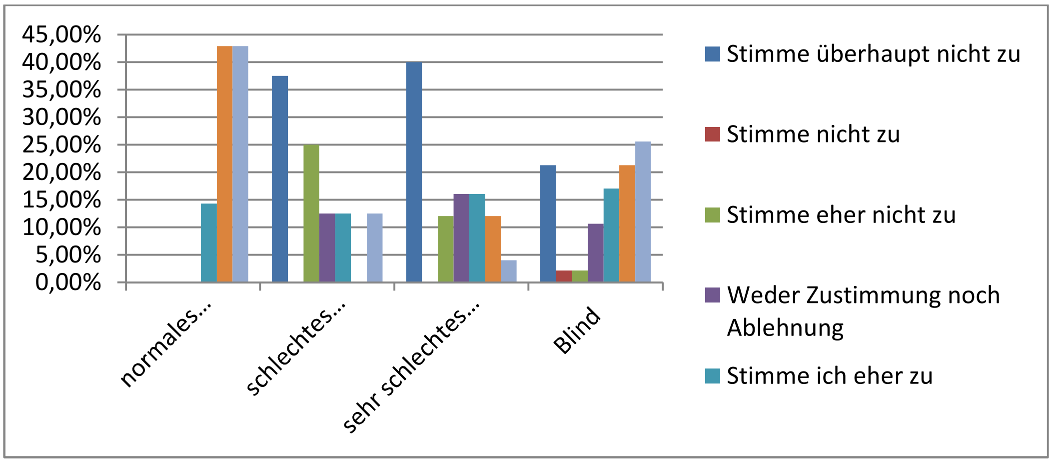


Figure 28: Diagram visual impairment to smartphone proficiency (relative to sample size)

65% of all participants think that a stable internet connection is important when they are on the go. Most of those are blind or severely visually impaired people.

More than 75% of all participants rarely use social networks. 70% of all sighted people use social networks, whereas only 12% of all visually impaired do the same.

90% of all participants know about public displays, only 33% use them. Less than 10% of all blind, less than 20% of all severely impaired and less than 25% of all middle-impaired participants use them.

The following table shows what participants think which kind of information could be useful for public displays:

Information	Like % of all participants	Dislike % of all participants
Weather	36	36
Public Transportation	98	1
Shopping	45	29
Rebates, promotions, sales	50	22
News (local)	45	25
Cinema, theater, etc. program	45	27
Booking restaurants, cinema, theater, etc.	28	44
Chatting, contacting people	15	63

Table 3: Online Survey Public Display Information Evaluation

Data shows that far less people like the idea of complex interactions through public displays. Booking or contacting other people is met with much restraint. This was expected as these interactions imply giving out information that is more private and take a longer time to achieve. To overcome these biases takes a lot of time and experience.

7.2 Focus Group

The focus group (see Figure 29) showed that all participants have an interest in public displays but could not image how they could use them in a satisfying way. They brought up interesting ideas what use cases could be covered by an assistive public display based on the needs of visually impaired.

1. Guidance to the emergency exits
2. Being notified about incoming public transportations

3. Being notified about construction sites and have alternative route suggestions how to avoid them
4. Being notified about huge events and have alternative route suggestions how to avoid them

Figure 29: Focus Group

The focus group took about two full hours, so a bit longer than planned.

7.3 User Study

Participants of the study had a diverse background, so their answers give many insights about different users' expectations.

Some statistical data: The average age was 57.5 . All except for one participant have high computer proficiency (M = 5.4 , SD = 1.3). Most of the participants are experienced smartphone users (M=4.58 , SD = 1.8). GPS for navigation is rarely used, only two use it regularly (M = 2.9 , SD = 1.8). A constant and stable internet connection is mostly important for eight participants (M = 4,25 , SD = 1.8). All participants do know public displays, but almost none of the visually impaired participants use them actively, only the sighted and the severely impaired (M = 1.8 , SD = 1.5). None of the participants think that public displays grab their attention (M = 1.6 , SD = 0.9). Half of the participants think that public display content is very important (M = 5 , SD = 2). See Figure 30.

Weather information is easy to get for all participants (M = 6.4 , SD = 0.76), news also (M = 6.5 , SD = 0.49). Most do get help easily; one participant with severe impairment has problems because no cane is used (M = 5.5 , SD = 0.95).

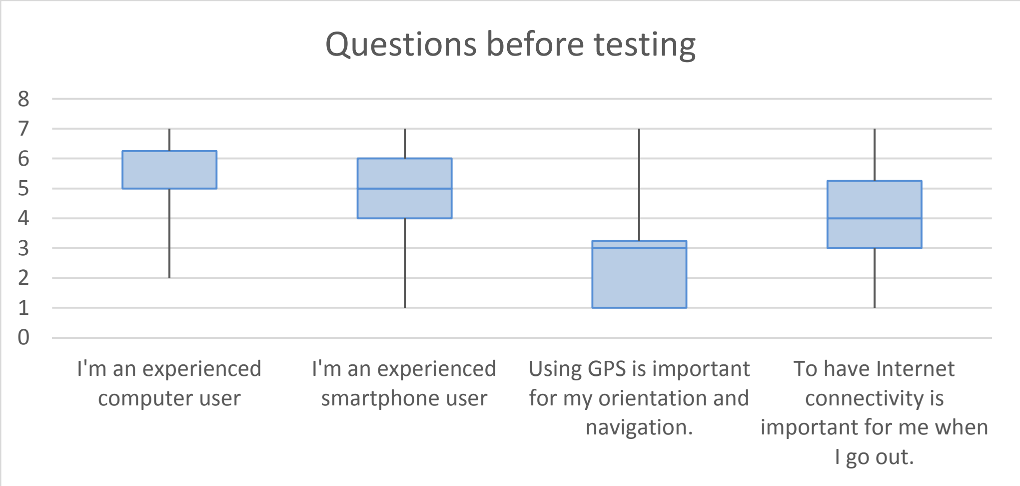


Figure 30: User Study Starting Questions Boxplot

The user study brought up some interesting results. First, participants rated the use cases positively in general. Only two ratings overall were below average (M = 5.2 , SD = 0.9). This shows that the solution does get positive reception from visually impaired people and from sighted people.

Ratings for all the separate use cases are shown below:

- Weather info
  - Performance/Speed: M = 5.8 , SD = 1.3
  - Usability: M = 5.8 , SD = 0.9
  - Functionality: M = 6.0 , SD = 0.7
  - Level of insecureness M = 2.3 , SD = 1.6
  - Level of discouragement M = 1.7 , SD = 0.86
  - Level of irritation M = 1.7 , SD = 0.75
  - Level of stress M = 1.5 , SD = 0.9
  - Level of annoyance M = 1.3 , SD = 0.64
- Public Transport info
  - Performance/Speed: M = 6.3 , SD = 1.26
  - Usability: M = 5.4 , SD = 1.2
  - Functionality: M = 5.6 , SD = 1.0
  - Level of insecureness M = 2.2 , SD = 1.5
  - Level of discouragement M = 1.8 , SD = 0.87
  - Level of irritation M = 1.6 , SD = 0.66
  - Level of stress M = 1.5 , SD = 0.95
  - Level of annoyance M = 1.4 , SD = 0.68
- Booking table
  - Performance/Speed: M = 4.5 , SD = 1.8
  - Usability: M = 4.5 , SD = 1.3
  - Functionality: M = 5.4 , SD = 0.9
  - Level of insecureness M = 3.7 , SD = 1.66
  - Level of discouragement M = 1.8 , SD = 0.8
  - Level of irritation M = 2.3 , SD = 1.0

- Level of stress M = 1.7 , SD = 1.0
- Level of annoyance M = 1.8 , SD = 1.0

- Chat
  - Performance/Speed: M = 5.3 , SD = 0.89
  - Usability: M = 5.0 , SD = 1.0
  - Functionality: M = 5.0 , SD = 1.1
  - Level of insecureness M = 2.9 , SD = 1.5
  - Level of discouragement M = 2.0 , SD = 0.9
  - Level of irritation M = 2.1 , SD = 1.0
  - Level of stress M = 1.6 , SD = 1.0
  - Level of annoyance M = 1.6 , SD = 1.0

Results show that users can handle less interactive use cases better but still do well on average. This is also due to the inexperience they have with using smartphones or the Android interface. The given feedback suggested that Android devices have another sensitivity compared to iPhone devices when it comes to registering gestures. This confuses experienced iPhone users. This means that having our solution realized on iOS devices might improve their acceptance and satisfaction even more.

The overall positive resonance agrees with our prediction that such a system is indeed welcome and sensible.

8 Conclusion and Future Work

Public Displays became an inherent part of our interconnected world, especially in bigger cities. More and more research is done in this domain today to discover interesting and more meaningful fields of application, because advertisements still have the biggest share. Touchscreens, camera controls, smartphones and other technologies give public displays new possible ways to interact with them. However, we think that accessibility is not as intrinsic for them as it should be. In fact, public displays are severely lacking ways for visually impaired or disabled people to get any kind of explicit use from them. Most of the times they have to rely on sighted people helping them out to notice content displayed on public displays. This is very unsatisfying and inadequate in today's time.

Smartphones can be a game changer with regards to making public display content more accessible. Especially in the light of the fact that visually impaired people, do tend to use smartphones more often in their everyday lives. Accessibility features have matured sufficiently so that smartphones can be considered practical companions for visually impaired. By bringing public display content over to the smartphone in an appropriate way, those accessibility features can be used to make content more accessible.

8.1 Conclusion

In this work, we showed that there are viable and sensible ways to get visually impaired people in touch with public displays. A set of analyzes in the form of an online survey, a focus group and a user study showed what visually impaired people think about and expect from public displays. All these insights were used to implement a custom public display system to test ideas and get enough feedback for improvements. Using smartphones for attention building and interactions with public displays was well received and give enough possibilities to realize all kinds of interaction techniques.

Those valuable information and conclusions can and will be used to improve existing and upcoming systems aiming for accessibility. Conversations with people responsible for projects like Sinn² [49] or YED show that there are still many unsolved problems and upcoming challenges. Cooperating with these people to find standards for accessibility in the public display world is severely needed.

As for the system itself, it showed that focusing on simplistic user interfaces and giving a lot of accessibility feedback in the form of sound and tactile information like vibrations, is necessary. Fortunately today's accessibility features are mature enough. With those, visually impaired users can comfortably use our solution and get a considerable benefit. Assistive solutions like ours help them empower their independence and feel more comfortable in their everyday lives.

8.2 Future Work

A prototype is never a mature enough solution to show the full potential of the given ideas of this work. There is still a lot to do, especially regarding the quality and stability of the software solution; although there are many things that can be built upon. Advertisements and Connections of Bluetooth systems help overcoming problems of attention building and proximity. Due to small bandwidth, other technologies can also be incorporated into our solution to give a more comprehensive coverage.

To really deploy such a system, it needs the help of providers of public displays, especially the ones responsible for public transportation systems, as these are the most interesting applications for visually impaired people. Interactions between people in the nearby area still appear to be problematic because of privacy concerns. For those cases, maybe other solutions can be explored.

Integration into the “Physical Web” as Google calls it is another challenge, because specific standards, formats and interests of the different smartphone vendors need to be considered. Coping with these problems needs a lot of time and funding. Future projects like Sinn² can benefit from the implications of this work and have already expressed interest in starting conversations with us. This gives a positive outlook of the things to come up from these conversations.

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Appendix

8.3 Introduction

To understand the following questions, a short introduction is given.

Most of the participants were native German speakers, so nearly all questions were asked in German. All survey or interview questions are first stated in German. An appropriate English translation is given afterwards.

A **7 Points Scale** means one of the following options: (first table is in German, second table in English)

Stimme überhaupt nicht zu
Stimme nicht zu
Stimme eher nicht zu
Weder Zustimmung noch Ablehnung
Stimme ich eher zu
Stimme ich zu
Stimme ich vollkommen zu

Table 4: 7 Points Scale in German

Strongly Disagree
Disagree
Rather Disagree
Neither Agree nor Disagree
Rather Agree
Agree
Strongly Agree

Table 5: 7 Points Scale in English

8.4 Online Survey

Questions marked with an asterisk (*) are mandatory.

8.4.1 German

Making Public Display Content Accessible 2.0

Vielen Dank, dass Sie sich die Zeit nehmen, um an dieser Umfrage mitzumachen.
Wir bereiten eine Benutzerstudie vor, die sich mit der Frage beschäftigt, wie man Sehbehinderte mit öffentlichen Displays besser interagieren lässt. Die Studie wird von Mitarbeitern und Studenten der Universität Stuttgart durchgeführt, die sich auf barrierefreie Nutzung neuer Technologien spezialisiert haben.

Falls Sie Interesse haben mitzumachen, melden Sie sich bei Alexander Dridiger per Email alexander@dridiger.com oder unter der Telefonnummer 0151/56054312. Auch Nicht-Deutschsprechende sind gerne eingeladen.
Sie werden ca. 15 min. brauchen, um alle Fragen zu beantworten.

Manche Fragen sind offen gestellt, bei denen Sie die entsprechenden Felder ausfüllen können, während andere Fragen eine Einfach- oder Mehrauswahl haben.
Alle Antworten werden anonymisiert behandelt.
Diese Umfrage enthält 28 Fragen.

Personenspezifische Angaben

Geben Sie bitte Ihr Geschlecht an. *

Bitte wählen Sie nur eine der folgenden Antworten aus:
weiblich, männlich, keine Angabe

Wie alt sind Sie? *
Bitte geben Sie Ihre Antwort hier ein:

In welchem Land leben Sie? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

AD - Andorra, AE - United Arab Emirates, AF - Afghanistan, AG - Antigua and Barbuda, AI - Anguilla, AL - Albania, AM - Armenia, AO - Angola, AQ - Antarctica, AR - Argentina, AS - American Samoa, AT - Austria, AU - Australia, AW - Aruba, AZ - Azerbaijan, BA - Bosnia and Herzegovina, BB - Barbados, BD - Bangladesh, BE - Belgium, BF - Burkina Faso, BG - Bulgaria, BH - Bahrain, BI - Burundi, BJ - Benin, BL - Saint Barthelemy, BM - Bermuda, BN - Brunei, BO - Bolivia, BR - Brazil, "BS - Bahamas, The", BT - Bhutan, BV - Bouvet Island, BW - Botswana, BY - Belarus, BZ - Belize, CA - Canada, CC - Cocos (Keeling) Islands, "CD - Congo, Democratic Republic of the", CF - Central African Republic, "CG - Congo, Republic of the", CH - Switzerland, CI - Cote d'Ivoire, CK - Cook Islands, CL - Chile, CM - Cameroon, CN - China, CO - Colombia, CR - Costa Rica, CU - Cuba, CV - Cape Verde, CW - Curacao, CX - Christmas Island, CY - Cyprus, CZ - Czech Republic, DE - Deutschland, DJ - Djibouti, DK - Denmark, DM - Dominica, DO - Dominican Republic, DZ - Algeria, EC - Ecuador, EE - Estonia, EG - Egypt, EH - Western Sahara, ER - Eritrea, ES - Spain, ET - Ethiopia, FI - Finland, FJ - Fiji, FK - Falkland Islands (Islas Malvinas), "FM - Micronesia, Federated States of", FO - Faroe Islands, FR - France, "FX - France, Metropolitan", GA - Gabon, GB - United Kingdom, GD - Grenada, GE - Georgia, GF - French Guiana, GG - Guernsey, GH - Ghana, GI - Gibraltar, GL - Greenland, "GM - Gambia, The", GN - Guinea, GP - Guadeloupe, GQ - Equatorial Guinea, GR - Greece, GS - South Georgia and the Islands, GT - Guatemala, GU - Guam, GW - Guinea-Bissau, GY - Guyana, HK - Hong Kong, HM - Heard Island and McDonald Islands, HN - Honduras, HR - Croatia, HT - Haiti, HU - Hungary, ID - Indonesia, IE - Ireland, IL - Israel, IM - Isle of Man, IN - India, IO - British Indian Ocean Territory, IQ - Iraq, IR - Iran, IS - Iceland, IT - Italy, JE - Jersey, JM - Jamaica, JO - Jordan, JP - Japan, KE - Kenya, keine Angabe, KG - Kyrgyzstan, KH - Cambodia, KI - Kiribati, KM - Comoros, KN - Saint Kitts and Nevis, "KP - Korea, North", "KR - Korea, South", KW - Kuwait, KY - Cayman Islands, KZ - Kazakhstan, LA - Laos, LB - Lebanon, LC - Saint Lucia, LI - Liechtenstein, LK - Sri Lanka, LR - Liberia, LS - Lesotho, LT - Lithuania, LU - Luxembourg, LV - Latvia, LY - Libya, MA - Morocco, MC - Monaco, MD - Moldova, ME - Montenegro, MF - Saint Martin, MG - Madagascar, MH - Marshall Islands, MK - Macedonia, ML - Mali, MM - Burma, MN - Mongolia, MO - Macau, MP - Northern Mariana Islands, MQ - Martinique, MR - Mauritania, MS - Montserrat, MT - Malta, MU - Mauritius, MV - Maldives, MW - Malawi, MX - Mexico, MY - Malaysia, MZ - Mozambique, NA - Namibia, NC - New Caledonia, NE - Niger, NF - Norfolk Island, NG - Nigeria, NI - Nicaragua, NL - Netherlands, NO - Norway, NP - Nepal, NR - Nauru, NU - Niue, NZ - New Zealand, OM - Oman, PA - Panama, PE - Peru, PF - French Polynesia, PG - Papua New Guinea, PH - Philippines, PK - Pakistan, PL - Poland, PM - Saint Pierre and Miquelon, PN - Pitcairn Islands, PR - Puerto Rico, PS - Gaza Strip, PS - West Bank, PT - Portugal, PW - Palau, PY - Paraguay, QA - Qatar, RE - Reunion, RO - Romania, RS - Serbia, RU - Russia, RW - Rwanda, SA - Saudi Arabia, SB - Solomon Islands, SC - Seychelles, SD - Sudan, SE - Sweden, SG - Singapore, "SH - Saint Helena, Ascension, and Tristan da Cunha", SI -

Slovenia, SJ - Svalbard, SK - Slovakia, SL - Sierra Leone, SM - San Marino, SN - Senegal, SO - Somalia, SR - Suriname, SS - South Sudan, ST - Sao Tome and Principe, SV - El Salvador, SX - Sint Maarten, SY - Syria, SZ - Swaziland, TC - Turks and Caicos Islands, TD - Chad, TF - French Southern and Antarctic Lands, TG - Togo, TH - Thailand, TJ - Tajikistan, TK - Tokelau, TL - Timor-Leste, TM - Turkmenistan, TN - Tunisia, TO - Tonga, TR - Turkey, TT - Trinidad and Tobago, TV - Tuvalu, TW - Taiwan, TZ - Tanzania, UA - Ukraine, UG - Uganda, UM - United States Minor Outlying Islands, US - United States, UY - Uruguay, UZ - Uzbekistan, VA - Holy See (Vatican City), VC - Saint Vincent and the Grenadines, VE - Venezuela, VG - British Virgin Islands, VI - Virgin Islands, VN - Vietnam, VU - Vanuatu, WF - Wallis and Futuna, WS - Samoa, XK - Kosovo, YE - Yemen, YT - Mayotte, ZA - South Africa, ZM - Zambia, ZW - Zimbabwe

Welche Größe hat die Stadt, in der Sie leben? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

Landstadt (bis zu 5000 Einwohnern)
Kleinstadt (bis zu 20.000 Einwohnern)
Mittelstadt (bis zu 100.000 Einwohnern)
Großstadt (bis zu 1.000.000 Einwohnern)
Millionenstadt

Welchen Grad an Sehbehinderung haben Sie? *

Bitte wählen Sie nur eine der folgenden Antworten aus:

Blind
sehr schlechtes Sehvermögen
schlechtes Sehvermögen
normales Sehvermögen

Erfahrungen mit neuen Technologien

Ich bin ein erfahrener Computernutzer *

Bitte wählen Sie nur eine der folgenden Antworten aus:

7 Points Scale

Ich bin ein erfahrener Smartphonebenutzer. *

Bitte wählen Sie nur eine der folgenden Antworten aus:

7 Points Scale

Ich nutze aktiv GPS, um mich zu orientieren und zur Navigation. *

Bitte wählen Sie nur eine der folgenden Antworten aus:

7 Points Scale

Wenn ich unterwegs bin, ist mir eine Internetverbindung wichtig. *

Bitte wählen Sie nur eine der folgenden Antworten aus:

7 Points Scale

Ich nutze soziale Netzwerke wie Facebook, Twitter, etc. sehr häufig. *

Bitte wählen Sie nur eine der folgenden Antworten aus:

7 Points Scale

Ich bevorzuge es Informationen über das Wetter, öffentlichen Nahverkehr sowie Kinoprogramme über meinen Computer zu Hause einzuholen. *

Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich bevorzuge es Informationen über das Wetter, öffentlichen Nahverkehr, Kinoprogramme über mein Smartphone unterwegs einzuholen. *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Interaktion mit öffentlichen Bildschirmen

In vielen Bus oder Bahnstationen und Einkaufszentren sind feste öffentliche Bildschirme aufgebaut, die verschiedene Informationen für Fußgänger anzeigen.
Sind Sie sich bewusst, dass solche öffentlichen Bildschirme aufgebaut sind? *
Bitte wählen Sie nur eine der folgenden Antworten aus:
Ja
Nein

Ich finde die Informationen, die auf öffentlichen Bildschirmen angezeigt werden, wichtig für mich. *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich nutze diese Informationen sehr häufig. *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich finde, dass die Informationen, die auf öffentlichen Bildschirmen angezeigt werden, für mich gut zugänglich sind. *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Welche Informationen möchte ich durch ein öffentliches Display zugänglich haben?

Ich denke, dass es nützlich wäre folgende Informationen von öffentlichen Displays, die an Bus oder Bahnstationen und Einkaufszentren zu finden sind, zu bekommen:
Wettervorhersagen *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich denke, dass es nützlich wäre folgende Informationen von öffentlichen Displays, die an Bus oder Bahnstationen und Einkaufszentren zu finden sind, zu bekommen:
Abfahrtszeiten öffentlichen Nahverkehrs *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich denke, dass es nützlich wäre folgende Informationen von öffentlichen Displays, die an Bus oder Bahnstationen und Einkaufszentren zu finden sind, zu bekommen:
Anzeigen durch Läden und Geschäften *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich denke, dass es nützlich wäre folgende Informationen von öffentlichen Displays, die an Bus oder Bahnstationen und Einkaufszentren zu finden sind, zu bekommen:
Sonderangebote und Rabatte *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich denke, dass es nützlich wäre folgende Informationen von öffentlichen Displays, die an Bus oder Bahnstationen und Einkaufszentren zu finden sind, zu bekommen:
Schlagzeilen, lokale Nachrichten *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich denke, dass es nützlich wäre folgende Informationen von öffentlichen Displays, die an Bus oder Bahnstationen und Einkaufszentren zu finden sind, zu bekommen:
Kino oder Theaterprogramme *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich würde gerne Kino oder Theaterkarten buchen oder Tischreservierungen bei Restaurants über ein öffentliches Display vornehmen können. *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Ich würde gerne mit Hilfe eines öffentlichen Displays Nachrichten an andere, sich in der Nähe befindliche Personen Nachrichten verschicken können, um auch z.B. auf Angebote hinweisen zu können. *
Bitte wählen Sie nur eine der folgenden Antworten aus:
7 Points Scale

Bitte teilen Sie uns mit, welche Informationen Sie sich noch nützlich finden würden, die man auf einem öffentlichen Display anzeigen könnte.
Bitte geben Sie Ihre Antwort hier ein:

Bitte teilen Sie uns mit, ob Sie schon mal in einer Situation waren, in der Sie ein öffentliches Display benutzt haben. Gibt es irgendetwas, das gut funktioniert hat? Haben Sie Verbesserungsvorschläge jeglicher Art dazu?
Bitte geben Sie Ihre Antwort hier ein:

Bitte teilen Sie uns mit, ob Sie schon mal in einer Situation waren, in der Sie ein öffentliches Display gerne benutzt hätten? Sowohl für den Fall, dass eines vorhanden war oder auch nicht.
Bitte geben Sie Ihre Antwort hier ein:

Ende Email

Bevor wir die Umfrage beenden, würden wir Sie noch fragen, ob es möglich wäre, Sie für weitere Umfragen oder Studien zu kontaktieren. Falls Sie Interesse haben, geben Sie bitte Ihre Email-Adresse an und geben uns Erlaubnis dafür.

Bitte wählen Sie die zutreffenden Punkte aus und schreiben Sie einen Kommentar dazu:
Ich gebe meine Erlaubnis später unter dieser Email-Adresse kontaktiert zu werden:

Sie haben nun das Ende der Umfrage erreicht. Alle Ihre Antworten werden für unsere Studie ausgewertet.
Wir möchten uns nochmals für Ihr Feedback bedanken.
Übermittlung Ihres ausgefüllten Fragebogens:
Vielen Dank für die Beantwortung des Fragebogens.

8.4.2 English

Making Public Display Content Accessible 2.0

Firstly, many thanks for your attention.
We're conducting a user study that tries to help visually impaired people to interact with public displays. The study is done by members of the University of Stuttgart that are specialized on accessible technology. If you have interest in being part of this study, please contact Mauro Avila via email Mauro.Avila@vis.unistuttgart.de or Alexander Dridiger via phone 0151/56054312 or via email alexander@dridiger.com.

It will take you about 15 to 25 minutes. Some questions are answered openly and some have multiple or single choice answers. All your data will be dealt with anonymously.
There are 28 questions in this survey

Demographics

Your gender is *

Please choose only one of the following:
female
male
not specified

How old are you? *
Please write your answer here:

In which country do you live? *
Please choose only one of the following:

AD - Andorra, AE - United Arab Emirates, AF - Afghanistan, AG - Antigua and Barbuda, AI - Anguilla, AL - Albania, AM - Armenia, AO - Angola, AQ - Antarctica, AR - Argentina, AS - American Samoa, AT - Austria, AU - Australia, AW - Aruba, AZ - Azerbaijan, BA - Bosnia and Herzegovina, BB - Barbados, BD - Bangladesh, BE - Belgium, BF - Burkina Faso, BG - Bulgaria, BH - Bahrain, BI - Burundi, BJ - Benin, BL - Saint Barthelemy, BM - Bermuda, BN - Brunei, BO - Bolivia, BR - Brazil, "BS - Bahamas, The", BT - Bhutan, BV - Bouvet Island, BW - Botswana, BY - Belarus, BZ - Belize, CA - Canada, CC - Cocos (Keeling) Islands, "CD - Congo, Democratic Republic of the", CF - Central African Republic, "CG - Congo, Republic of the", CH - Switzerland, CI - Cote d'Ivoire, CK - Cook Islands, CL - Chile, CM - Cameroon, CN - China, CO - Colombia, CR - Costa Rica, CU - Cuba, CV - Cape Verde, CW - Curacao, CX - Christmas Island, CY - Cyprus, CZ - Czech Republic, DE - Germany, DJ - Djibouti, DK - Denmark, DM - Dominica, DO - Dominican Republic, DZ - Algeria, EC - Ecuador, EE - Estonia, EG - Egypt, EH - Western Sahara, ER - Eritrea, ES - Spain, ET - Ethiopia, FI - Finland, FJ - Fiji, FK - Falkland Islands (Islas Malvinas), "FM - Micronesia, Federated States of", FO - Faroe Islands, FR - France, "FX - France, Metropolitan", GA - Gabon, GB - United Kingdom, GD - Grenada, GE - Georgia, GF - French Guiana, GG - Guernsey, GH - Ghana, GI - Gibraltar, GL - Greenland, "GM - Gambia, The", GN - Guinea, GP - Guadeloupe, GQ - Equatorial Guinea, GR - Greece, GS - South Georgia and the Islands, GT - Guatemala, GU - Guam, GW - Guinea-Bissau, GY - Guyana, HK - Hong Kong, HM - Heard Island and McDonald Islands, HN - Honduras, HR - Croatia, HT - Haiti, HU - Hungary, ID - Indonesia, IE - Ireland, IL - Israel, IM - Isle of Man, IN - India, IO - British Indian Ocean Territory, IQ - Iraq, IR - Iran, IS - Iceland, IT - Italy, JE - Jersey, JM - Jamaica, JO - Jordan, JP - Japan, KE - Kenya, KG - Kyrgyzstan, KH - Cambodia, KI - Kiribati, KM - Comoros, KN - Saint Kitts and Nevis, "KP - Korea, North", "KR - Korea, South", KW - Kuwait, KY - Cayman Islands, KZ - Kazakhstan, LA - Laos, LB - Lebanon, LC - Saint Lucia, LI - Liechtenstein, LK - Sri Lanka, LR - Liberia, LS - Lesotho, LT - Lithuania, LU - Luxembourg, LV - Latvia, LY - Libya, MA - Morocco, MC - Monaco, MD - Moldova, ME - Montenegro, MF - Saint Martin, MG - Madagascar, MH - Marshall Islands, MK - Macedonia, ML - Mali, MM - Burma, MN - Mongolia, MO - Macau, MP - Northern Mariana Islands, MQ - Martinique, MR - Mauritania, MS - Montserrat, MT - Malta, MU - Mauritius, MV - Maldives, MW - Malawi, MX - Mexico, MY - Malaysia, MZ - Mozambique, NA - Namibia, NC - New Caledonia, NE - Niger, NF - Norfolk Island, NG - Nigeria, NI - Nicaragua, NL - Netherlands, NO - Norway, not specified, NP - Nepal, NR - Nauru, NU - Niue, NZ - New Zealand, OM - Oman, PA - Panama, PE - Peru, PF - French Polynesia, PG - Papua New Guinea, PH - Philippines, PK - Pakistan, PL - Poland, PM - Saint Pierre and Miquelon, PN - Pitcairn Islands, PR - Puerto Rico, PS - Gaza Strip, PS - West Bank, PT - Portugal, PW - Palau, PY - Paraguay, QA - Qatar, RE - Reunion, RO - Romania, RS - Serbia, RU - Russia, RW - Rwanda, SA - Saudi Arabia, SB - Solomon Islands, SC - Seychelles, SD - Sudan, SE - Sweden, SG - Singapore, "SH - Saint Helena, Ascension, and Tristan da Cunha", SI - Slovenia, SJ - Svalbard, SK - Slovakia, SL - Sierra Leone, SM - San Marino, SN - Senegal, SO - Somalia, SR - Suriname, SS - South Sudan, ST - Sao Tome and Principe, SV - El Salvador, SX - Sint Maarten, SY - Syria, SZ - Swaziland, TC - Turks and Caicos Islands, TD - Chad, TF - French Southern and Antarctic Lands, TG - Togo, TH - Thailand, TJ - Tajikistan, TK - Tokelau, TL - Timor-Leste, TM - Turkmenistan, TN - Tunisia, TO - Tonga, TR - Turkey, TT - Trinidad and Tobago, TV - Tuvalu, TW - Taiwan, TZ - Tanzania, UA - Ukraine, UG - Uganda, UM - United States Minor Outlying Islands, US - United States, UY - Uruguay, UZ - Uzbekistan, VA - Holy See (Vatican City), VC - Saint Vincent and the Grenadines, VE - Venezuela, VG - British Virgin Islands, VI - Virgin Islands, VN - Vietnam, VU - Vanuatu, WF - Wallis and Futuna, WS - Samoa, XK - Kosovo, YE - Yemen, YT - Mayotte, ZA - South Africa, ZM - Zambia, ZW - Zimbabwe

In which town or city do you live? *
Please choose only one of the following:
County town (up to 5000 citizens)
Town (up to 20.000 citizens)
Medium sized Town (up to 100.000 citizens)
City (up to 1.000.000 citizens)
Megacity

Which is your level of visual impairment? *
Please choose only one of the following:
Blind
Severe low vision
Low vision
Normal vision

Use of technology

I am an experienced computer user. *
Please choose only one of the following:
7 Points Scale

I am a well-experienced smartphone user. *
Please choose only one of the following:
7 Points Scale

Using GPS is important for my orientation and navigation. *
Please choose only one of the following:
7 Points Scale

To have Internet connectivity is important for me when I go out. *
Please choose only one of the following:
7 Points Scale

Select one of the options:
I frequently use social networks like Facebook or twitter. *
Please choose only one of the following:
7 Points Scale

I prefer accessing information about weather, public transportation or cinema show times with my computer at home. *
Please choose only one of the following:
7 Points Scale

I prefer accessing information about weather, public transportation or cinema show times with my smartphone while on the go.
* Please choose only one of the following:
7 Points Scale

Interaction with public displays

Are you aware of such displays?
* Please choose only one of the following:
Yes
No

Information on such displays are important to me *
Please choose only one of the following:
7 Points Scale

I frequently use such information. *
Please choose only one of the following:
7 Points Scale

Information on such display is accessible for me. *
Please choose only one of the following:
7 Points Scale

What kind of information I want to access through a public display?

I consider this info relevant to be accessed by a public display located in bus stops, train stations or shopping malls:
Weather forecasts. *
Please choose only one of the following:
7 Points Scale

I consider this info relevant to be accessed by a public display located in bus stops, train stations or shopping malls:
General public transportation timetables. *
Please choose only one of the following:
7 Points Scale

I consider this info relevant to be accessed by a public display located in bus stops, train stations or shopping malls:
Advertisement from shops and stores. *
Please choose only one of the following:
7 Points Scale

I consider this info relevant to be accessed by a public display located in bus stops, train stations or shopping malls:
Special offers and sales. *
Please choose only one of the following:
7 Points Scale

I consider this info relevant to be accessed by a public display located in bus stops, train stations or shopping malls:
News headlines. *
Please choose only one of the following:
7 Points Scale

I consider this info relevant to be accessed by a public display located in bus stops, train stations or shopping malls:
Billboards of cinemas and theaters. *
Please choose only one of the following:
7 Points Scale

I would use the public displays to make reservations (e.g., cinema, theater, tables at restaurants). *
Please choose only one of the following:
7 Points Scale

I would like to use public displays to send messages to friends. *
Please choose only one of the following:
7 Points Scale

Please tell us which other information you would like to access through a public display.
Please write your answer here:

Please describe a situation in which you used a public display before? What worked well? Where do you see space for improvement?
Please write your answer here:

Please describe a situation in which you would have liked to be able and use a public display?
Please write your answer here:

End Email

We're nearly at the end of our survey, only two questions left.
Are you interested in more future surveys or interviews? If so, you can

provide us with an email address and give us permission to contact you.
Please choose all that apply and provide a comment:
I give permission to be contacted via my email address:

Now you've reached the end of the survey. All questions will be used as a base for our study.
Thank you for your important feedback.
Submit your survey.
Thank you for completing this survey.

8.5 Preliminary User Study Design

8.5.1 Purpose

A user study to show how our approach can benefit visually impaired people to use and approach today's public displays that are in range with the help of smartphones and Bluetooth technology. A set of use cases is used to show how interaction between users of public displays can be accomplished in a simple and easy to understand way. In addition, other means of information discovery are compared with our approach to see if there's any meaningful difference.

8.5.2 Setup

Inside the Blindenverband Stuttgart a set of public displays will be deployed to broadcast different kind of information like (local) news, weather, nearby public transport arrivals/departures and the ability to send information to passers-by. The public displays and user devices (smartphones) are using Bluetooth Low Energy to communicate with each other. A special app on the user devices is installed to handle the communication with the public displays. The whole user study system consists of the public displays, the smartphones and the appropriate apps.

- All study participants will get a smartphone that can communicate with the displays and get the opportunity to play around with the system and get an introduction how to use it.
- A set of use cases is played through afterwards:
    - User passes by and gets newest and forecast weather information
    - User passes by and gets newest local news
    - User passes by and gets public transport information
    - User passes by, gets newest chatter stored on the public display and can by himself send a message to other users
- To have a reference point, each public display tells the user where it's currently located and gives the user the possibility to engage with it directly or via smartphone and app.
- A set of users will be tasked to get the information that they need by other means and compare it to the system:
    - their own smartphone with and without internet connection
    - a pc with or without internet connection
    - radio
- All study participants will be asked for an interview after all use cases are played through and asked for their opinion about their experience with the system.
    - A rating system is used to give users the possibility to rate how

- good or bad the experience was
- good or bad the usefulness of the use case was
- good or bad was their attention created
- good or bad were their needs fulfilled

All data will be collected to give insight of how the proposed system fares against other methods of information delivery.

8.6 Focus Group Consent

8.6.1 German

Einverständniserklärung zur Fokusgruppe „Barrierefreie Nutzung öffentlicher Displays“

Teilnehmer-Nr.: __________ Vorname: _________________________

Name: _________________________

Mir wurde der Zweck der Fokusgruppe erläutert und ich wurde darüber informiert, dass ich die Fokusgruppe jederzeit abbrechen kann. Ich wurde des Weiteren darüber in Kenntnis gesetzt, dass die während der Fokusgruppe gesammelten Daten zur Auswertung der Fokusgruppe herangezogen werden. Sämtliche Daten werden für die wissenschaftliche Nutzung gesammelt und hierbei vertraulich behandelt. Es wird gewährleistet, dass meine personenbezogenen Daten nicht an Dritte weitergegeben werden. Bei der Veröffentlichung in einer wissenschaftlichen Zeitung wird aus den Daten nicht hervorgehen, wer an dieser Untersuchung teilgenommen hat. Meine persönlichen Daten unterliegen dem Datenschutzgesetz.
Ich weiß, dass ich jederzeit meine Einverständniserklärung, ohne Angabe von Gründen, widerrufen kann, ohne dass dies für mich nachteilige Folgen hat.

☐ Ich erkläre mich damit einverstanden, dass ein Video der Fokusgruppe angefertigt wird, um die gesammelten Ideen festzuhalten und diese zur wissenschaftlichen Analyse zu nutzen.
☐ Ich erkläre mich damit einverstanden, dass das Gespräch der Fokusgruppe aufgezeichnet wird, um die gesammelten Ideen festzuhalten und diese zur wissenschaftlichen Analyse zu nutzen.
☐ Ich erkläre mich damit einverstanden, dass mehrere Fotos der Fokusgruppe angefertigt werden, um diese gegebenenfalls in einer wissenschaftlichen Präsentation zu nutzen.

Mit der vorstehend geschilderten Vorgehensweise bin ich einverstanden und bestätige dies mit meiner Unterschrift.

Stuttgart, den Unterschrift:

______________________ ____

8.6.2 English

Participants Consent Form for the Focus Group „Making Public Display Content Accessible“

Participant No.: __________ Name: __________________________

Surname: __________________________

I have been informed on the procedure and purpose of the focus group and my questions have been answered to my satisfaction. I have volunteered to take part in this focus group. All gathered information may only be used for research and teaching purpose. I understand that my participation in this focus group is confidential. No personal information and individual results will be released to third parties without my written consent. I understand that I can withdraw from participation in the focus group at any time.

☐ I agree that during the focus group all information is video recorded to preserve all gathered ideas for research analyzation.
☐ I agree that during the focus group all information is audio recorded to preserve all gathered ideas for research analyzation.
☐ I agree that during the focus group some photos may be taken to be shown inside a scientific presentation.

Stuttgart, date: ________________________

Siganture: ____

8.7 Focus Group – Questions about Public Displays

8.7.1 German

1. Kennen Sie Public Displays? Wissen Sie, dass Sie überall sind?
2. Was wissen Sie über Public Displays?
3. Was denken Sie, welche Informationen öffentliche Displays darstellen?
4. Was glauben Sie, wie notwendig sind Public Displays? Haben sie prinzipiell einen Nutzen für Sie?
5. Was müssten Public Displays bieten, um für Sie einen Nutzen zu haben?
6. Welche Informationen wünschen Sie sich von Public Displays?
7. Welche Anreize könnte es geben, damit Sie Public Displays nutzen würden? Was würden Sie gerne bekommen? (Wenn diese irgendwie barrierefrei wären)
8. Wie könnte Barrierefreiheit aussehen?
9. Was würden Sie sich für das System wünschen?
10. Was denken Sie über das Konzept?
11. Falls Public Displays Ihnen interaktive Hilfe anbieten würden, wie sollte diese aussehen und würden Sie diese auch nutzen?
12. Was würden sehende Leute denken, wenn sie Hilfe-Gesuche von Blinden sehen würden?

8.7.2 English

1. Do you know Public Displays? Do you know that they are common?
2. What do you know about public displays?
3. What content do you think is displayed by public displays?
4. How necessary are public displays? Do you see a utility for it in principal?
5. What should public displays offer to give you any use for them?
6. What information would you like to get from public displays?
7. What incentives could you think about to get from public displays to use it more frequently/at all? What would you like to get? (if they could be accessible)
8. How could accessibility work in the context of public displays?
9. What features would you like to have?
10. What do you think about the concept of our system?
11. Imagine public displays would grant you interactive help. How could it be done? Would you use it?
12. What would sighted people think when getting help requests of visually impaired people by the system?

8.8 Study Consent

8.8.1 German

Einverständniserklärung zur Studie „Barrierefreie Nutzung öffentlicher Displays“

Teilnehmer-Nr.: __________ Vorname: __________________________

Name: __________________________

Mir wurde der Zweck der Studie erläutert und ich wurde darüber informiert, dass ich die Studie jederzeit abbrechen kann. Ich wurde des Weiteren darüber in Kenntnis gesetzt, dass die während der Studie gesammelten Daten zur Auswertung der Studie herangezogen werden. Sämtliche Daten werden für die wissenschaftliche Nutzung gesammelt und hierbei vertraulich behandelt. Es wird gewährleistet, dass meine personenbezogenen Daten nicht an Dritte weitergegeben werden. Bei der Veröffentlichung in einer wissenschaftlichen Zeitung wird aus den Daten nicht hervorgehen, wer an dieser Untersuchung teilgenommen hat. Meine persönlichen Daten unterliegen dem Datenschutzgesetz. Ich weiß, dass ich jederzeit meine Einverständniserklärung, ohne Angabe von Gründen, widerrufen kann, ohne dass dies für mich nachteilige Folgen hat.

☐ Ich erkläre mich damit einverstanden, dass während der Studie Fotos gemacht werden, um die Nutzung des Systems zu zeigen.

Mit der vorstehend geschilderten Vorgehensweise bin ich einverstanden und bestätige dies mit meiner Unterschrift.

Stuttgart, den Unterschrift:

_______________________ ____

8.8.2 English

Participants Consent Form for the Study „Making Public Display Content Accessible“

Participant No.: __________ Name: _________________________

Surname: _________________________

I have been informed on the procedure and purpose of the study and my questions have been answered to my satisfaction. I have volunteered to take part in this study. All gathered information may only be used for research and teaching purpose. I understand that my participation in this study is confidential. No personal information and individual results will be released to third parties without my written consent. I understand that I can withdraw from participation in the study at any time.

☐ I agree that during the study some photos may be taken to show my interaction with the system.

Stuttgart, date: Siganture:

______________________ ______________________________________

8.9 Study Questions

8.9.1 German

Bitte geben Sie Ihr Geschlecht an:

Bitte geben Sie Ihr Alter an:

Haben Sie eine Sehbeeinträchtigung?
Ja
Nein

Haben Sie Ihre Sehbeeinträchtigung seit Geburt oder erst später bekommen?
Seit Geburt
Später

Aus welcher Stadt kommen Sie?

Haben Sie diesen Test schon einmal durchgeführt?
Ja
Nein

Wie schätzen Sie Ihre Erfahrung als Computernutzer ein?
7 Points Scale

Wie schätzen Sie Ihre Erfahrung als Smartphonebenutzer ein?
7 Points Scale

Nutzen Sie aktiv GPS, um sich zu orientieren und zur Navigation?
7 Points Scale

Wenn Sie unterwegs sind, ist Ihnen eine Internetverbindung wichtig?
7 Points Scale

Kennen Sie Public Displays?
Ja
Nein

Benutzen Sie Public Displays?
Ja
Nein

Wie sehr erregen Public Displays ihre Aufmerksamkeit?
7 Points Scale

Ich finde die Informationen, die auf öffentlichen Bildschirmen angezeigt werden, wichtig für mich.
7 Points Scale

Ich nutze diese Informationen sehr häufig.
7 Points Scale

Wie gut können Sie normalerweise Wetterinformationen bekommen?
7 Points Scale

Womit bekommen Sie normalerweise Wetterinformationen?

Wie gut können Sie normalerweise Nachrichteninformationen bekommen?
7 Points Scale

Womit bekommen Sie normalerweise Nachrichteninformationen?

Buchen Sie Restauranttische übers Internet?
Ja
Nein

Wie gut können Sie normalerweise Restaurantbuchungen durchführen?
7 Points Scale

Wie gut bekommen Sie Hilfe allgemein?
7 Points Scale

Womit suchen Sie normalerweise nach Hilfe?

Welches mobile Gerät benutzen Sie?

App-Fragen

Wetter

Nahverkehr

Nachrichten

Meldungen

Buchung

Chat

Einschätzung der …

Geschwindigkeit:
7 Points Scale

Bedienung
7 Points Scale

Funktionalität
7 Points Scale

Wie verunsichert waren Sie?
7 Points Scale

Wie entmutigt waren Sie?
7 Points Scale

Wie irritiert waren Sie?
7 Points Scale

Wie gestresst waren Sie?
7 Points Scale

Wie genervt waren Sie?
7 Points Scale

Welche Informationssuche ist Ihrer Meinung nach die schlechteste oder beste?

Haben Sie Anmerkungen oder Empfehlungen um die App zu verbessern?

Haben Sie Anmerkungen oder Empfehlungen um präferierte Geräte zu verbessern?

Haben Sie Anmerkungen oder Empfehlungen um die Sprachunterstützung zu verbessern?

Sonstiges Feedback?

8.9.2 English

Your gender is:

How old are you?:

Do you have any visual impairment?
yes
no

I have my current level of visual impairment since:
birth
later on

In which town do you live?

Have you done this study once before?
yes
no

I am an experienced computer user.
7 Points Scale

I am an experienced smartphone user.
7 Points Scale

Using GPS is important for my orientation and navigation.
7 Points Scale

To have Internet connectivity is important for me when I go out.
7 Points Scale

Do you know Public Displays?
yes
no

Do you actively use Public Displays?
yes
no

Are you aware of such displays?
7 Points Scale

Information on such displays are important to me.
7 Points Scale

I frequently use such information.
7 Points Scale

Getting weather information is easy for me.
7 Points Scale

How do you usually get weather information?

Getting current news is easy for me.
7 Points Scale

How do you usually get current news?

Do you book restaurant tables over the internet?
yes
no

Booking restaurant tables is easy for me.
7 Points Scale

Getting help is easy for me.

7 Points Scale

How do you usually search for help?

What mobile device do you use usually?

App-related Questions

Weather

Public Transport

News

Shout-outs

Booking

Chat

The rating I would give for …

Level of Performance:
7 Points Scale

Usability
7 Points Scale

Functionality
7 Points Scale

Level of insecureness
7 Points Scale

Level of discouragement
7 Points Scale

Level of irritation
7 Points Scale

Level of stress
7 Points Scale

Level of annoyance
7 Points Scale

What is the worst or best information gathering system in your opinion?

Any feedback or recommendations regarding the tested application?

Any feedback or recommendations regarding your preferred used devices?

Any feedback or recommendations for improving the accessibility speech features?

Any other feedback?

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

place, date, signature – Alexander Dridiger