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# Personal Digital Signage for Shared Spaces

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**Abstract.** A wayfinding is an everyday activity where the interaction design has traditionally based on landmarks, visual maps, signs, and social collaboration. In the mobile computing era, we have witnessed more techno-centric development of wayfinding and navigation where people turn to their mobile navigation applications rather than to cues in the surrounding environment. However, in many wayfinding situations, using mobile devices is not very applicable due to safety reasons, indoor limitations or practical needs. To overcome the identified challenges, this paper introduces a personal digital signage, which combines the benefits of traditional directional signs and an underlying mobile technology for wayfinding purposes. The paper begins with formulating the design problem and introducing the premises of the solution. We evaluate and refine the solution with usability studies in a mass event (N=24) and in a hurry situation in a campus building (N=58). Test results show that the proposed solution was highly acceptable and rated good in usability among participants. The effectiveness as reaching the target destination was excellent and the efficiency measured as time increased only moderately compared with the optimal performance. We conclude that the solution performs well in indoor spaces where the navigational accuracy depends on the amount and positioning of screens installed as is the case with traditional signs. The study calls for re-thinking the interaction design of navigation and wayfinding without use of mobile devices.

**Keywords:** Wayfinding, Personal Sign, Interaction Design, Usability.

## 1 Introduction

Wayfinding refers to the actions of people navigating from place to another in their environment. It is a common activity in shared spaces and surroundings, for example in office buildings and mass events, which are not previously familiar to us. In addition to navigational aids provided in the location, the effectiveness and efficiency of wayfinding depends on the route complexity, the disabilities of people, aging and their level of experience [1-4]. For example, if the route is very complex, it will cause less effective walking to the destination [2].

Fundamentals of wayfinding have remained the same since the Polynesian supernal navigation methods where plans and situated collaborative actions are our resources towards the target destination (cf. [5]). Today, wayfinding with mobile devices in outdoor environments is popular and efficient due to online maps and satellite positioning. On the other hand, technology-aided indoor navigation has not yet reached the same level of popularity, whilst many urban, shared spaces (e.g. sights in city centers, office buildings and airports) would benefit from indoor positioning and technology-supported wayfinding. These locations are usually designed for masses of people, local citizens, casual business visitors, and tourists alike. Indoor wayfinding even in a large shopping mall can be difficult[1]. Imagine a situation where you, as a first-time visitor, arrive at the main entrance of the university campus building. You are already late from an important meeting and fairly recall the name or the number of the meeting room (or the correct building in the campus area). Presumably, you look for navigation aid from physical signs, indoor maps, digital kiosks, apps or personal face-to-face communication (e.g. going to an information desk or asking people passing by), while, you are running in the hallway of the complex building, which contains hundreds of rooms and thousands of square meters.

The problem is that current technical and traditional navigation solutions are rather weak to support the above situation of hurry. First, indoor positioning technology and navigation applications are still coming to markets, although some products exist[2], which allow browsing, searching and getting directions to target locations in a digital map of the building. Second, even if the products were available for the wayfinding in the building, there are navigation situations when people are not able to use their mobile phones (e.g. when carrying a baggage in an airport) nor it would be very practical. Paying attention to the small screen on the mobile phone while walking and hurrying in traffic is a safety issue as well, as popular augmented reality games have demonstrated. Therefore, we turn our focus on traditional wayfinding aids, which do not require constant mobile phone interaction.

The efficient and effective use of digital kiosks in an urgent need of navigation help is deteriorated by that each type of kiosk has its own design, varying content and interaction pattern. Therefore, the kiosk suits better for peaceful and unhurried navigation situations. Orientation signs like maps in the wall and in the kiosk require the users to memorize the information and confirm the destination shown on them [6]. The memorizing problem exists with maps of the mobile apps as well, unless the device is continuously at hand and in sight. Oral directions and visual maps acquired in the situation can be misunderstood and get forgotten before reaching the destination. Digital kiosks can become entirely useless without adequate perceptual cues to right direction or relative distances [7]. Furthermore, using maps, kiosks and information desk services inevitably involve some delay in the hurrying situation as the person needs to stop, queue, interact, interpret and memorize the information content. The problem of physical signposts, and signage in general, are that those are less likely to exist for every destination. In our example above, unless the destination is one of the main places in the location (e.g. a frequently visited lecture hall), but just a meeting room among many other similar destinations, you rarely find a sign. Signs are static and are designed to serve the general needs of crowds rather than specific and situated

[1] One of the largest shopping malls in Finland, which opened on September 2018, has not attracted enough visitors. The visitors have claimed the mall about its navigational complexity, which has also been assumed as a one reason to poor volumes.

[2] Apple's Indoor Survey utility app combines WiFi and sensor data to enable indoor positioning, and applications like www.mapspeople.com, www.mazemap.com and https://proximi.io/.

needs of individuals. Nevertheless, in hurried navigation situations, the benefits of signage are evident. For example, metro stations, airports, and traffic in general all over the world, use signage, which is quickly observable, internationally interpretable and can release your hands from using the mobile phone to carrying a baby and a baggage or driving a car. Directional signs are used to help the users to follow instructions and to direct people to move straight ahead [6]. If signage is used, it must be consistently available, legible, and systematic [8]. The general-purpose signs, such as directional arrows are easier to comprehend than special or tailored signs. For example, healthcare related symbols in the hospital environment are not as understandable as the general signs [9]. In the mass events and very crowded places, signs at strategic positions provide helpful information both when approaching the site and inside the venue. Yet, the experiences of the event visitors can deteriorate if the signs are unclear, with too small font sizes, overcomplicated that are difficult to understand, absent or inappropriately positioned [10].

The question is how to design wayfinding interactions and navigational aid for hurrying situations in our shared spaces that would overcome the drawbacks yet preserve the benefits of physical signs? In the above described example situation, if you don’t observe any physical signs to your final destination, what you may see, are the aforementioned kiosks, larger digital displays or projections on the walls. Probably, these on-site TV screens welcome you to the current events of the campus or inform you the lunch menu of the student restaurant. Screens can have many kinds of digital content, but rarely those are navigational or serve and improve the experience of first-time visitors. However, the benefit of digital content in navigation is that the content is changeable and thus possible to personalize unlike static, physical signposts. Accompanied with digital image projections, every flat surface could be a potential place for a navigation sign.

Our answer and approach in this paper is to utilize on-site screens for personalized navigation help in shared urban spaces. Therefore, we created a solution called personal digital signage (PDS). To our knowledge, there are not existing solutions like PDS, which personalize signs and allow navigation without mobile device use. The study follows a constructive research tradition and the research process of a design science where the design and proofing its usefulness is central [11]. In this introduction part, we have formulated a research problem, which we aim to solve with the PDS. We empirically evaluate how useful and usable PDS is for navigation in a hurry situation in a university building (N=58) and in a mass event (N=24). Next, we introduce our solution and the evaluation results. Lastly, we conclude benefits and limits of our approach and ponder the future research and development questions.

## 2 Personal Digital Signage (PDS) Solution

The fundamental idea of the PDS solution is to exploit the benefits of a physical signpost, yet extend its ability to serve multiple destinations and users. The multiplicity requirement means that the content must be digital and implement rules, which could notify personal destinations even in a mass event. To preserve the other benefits of physical signs, the solution must implement true mobility i.e. users should focus on the signs and not on their digital devices. Third, using digital signs should not risk users' privacy in anyway, but work as similar as other physical signposts without digital content.

The proposed system[3] constitutes of a server, a SQL database, screens installed in the building with Bluetooth beacons (2-4 pieces per screen), and a mobile application for the user. For the testing purposes, the physical signs are large TVs/screens connected to Raspberry Pi computers with WLAN connection to the server. The Android-based mobile application works as a user interface for choosing a final destination from a given set of possible destinations loaded from the server/database (Figure 1). After choosing the final destination, the application communicates with the server by sending beacon group RSSI status changes and the user does not need to use the mobile application in the location. With the Bluetooth service turned on in the mobile device, the user can access the location/building where the screens with Bluetooth beacons communicate to users the direction to the next screen and the final destination. The mobile application has given the user an avatar, which is visible in the screen with the name of the final destination and the directional arrow. Arrows are represent directions towards cardinal and half-cardinal points and are implemented as 2D or 3D symbols. Screens are positioned at crucial guidance points in the building. Multiple users and directions can be served at the same time. The closest user of the screen appears in the top of the list (based on RSSI signal strength) and the fixed time of visibility (first in, first out –principle) guarantees that everybody gets served. The maximum amount of users visible at the same time depends mainly on the screen size.

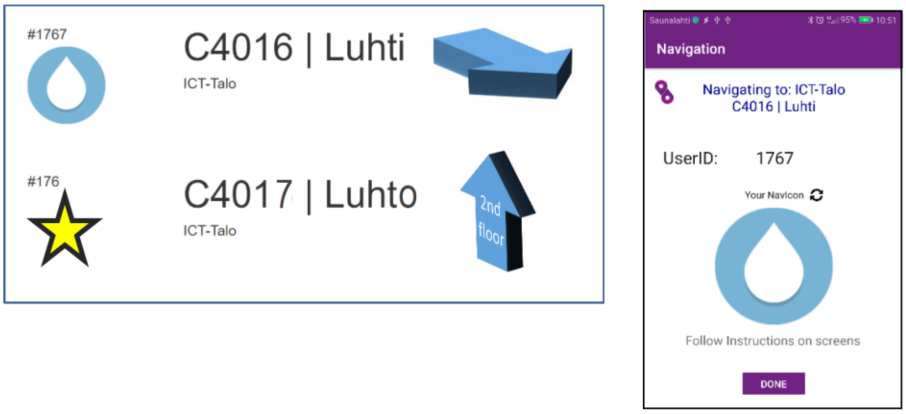


**Fig. 1.** On the right: The user interface of the mobile application with the avatar (waterdrop) and the destination information. On the left: An example of a screen showing the direction to two different destinations with 3D arrows (2nd floor and behind on the right).

[3] The video of the PDS system is available here: https://kutt.it/SCN4Jc

# 3 Evaluation Results

We evaluated the PDS in two different settings: In a mass event (business festival) and in an office building (university campus). In the latter context, we organized two separate evaluation rounds and after each round we improved the system following the principles of design science. Evaluations aimed at confirming usability and usefulness of the PDS in these settings as well as guiding the subsequent development. In order to quantify users' satisfaction, perceived efficiency and effectiveness, we applied System Usability Scale (SUS) questionnaire [12], which is a brief and highly reliable usability scale [13], which shows also correlation to market success [14-15]. In addition to SUS, the questionnaire included background information, such as age, job title and visitor profile, and subjective ratings on statements about PDS efficiency and effectiveness: S1) I think that with this product I would find different rooms and places quickly S2) I think that this product would improve my navigation performance in the locations I am not familiar with S3) I visit rooms and buildings unfamiliar to me very often S4) I have had difficulties finding rooms and buildings unfamiliar to me during the past year. These were answered similarly to SUS with 5-point Likert scale from strongly disagree (1) to strongly agree (5). Open answers were collected with the question: What were the most important elements that made your navigation task easy / difficult? In addition, participants measured themselves the actual navigation time and reported the completion success in the campus tests.

## 3.1 Business people in the mass event

The test took place in a business festival, which draws hundreds of business people from different domains. The total number of participants was 24 and half of them (50 %) agreed visiting new places very often (question number S3), but only 29 % have had difficulties in navigation during the past year (S4). We offered a possibility to try the app for people passing by our festival stand/room. Outside the room, the app was given to the participant, who was asked to select one destination to navigate to. The destinations in the application included several stands and common festival areas. Next, the participant moved inside the room, where one large screen attached to the wall informed the participant of the right direction to the selected location. In such an on-hands introduction, participants got an understanding of the application logic although they did not navigate further. Participants rated the usability of PDS with SUS score 74. They acknowledged especially the simplicity of the application logic, fast response time of the signs, use of personal user icons in the signs and the absence of the mobile phone during the navigation task. The interpretation of the SUS score is that the users consider the system highly acceptable, and as an adjective, the score means good usability [15]. In the open answers, participants thought that the amount and positioning of screens would be the main problem in practice. However, the participants evaluated the efficiency (S1) and effectiveness (S2) of PDS very high: 88 % of the participants agreed or strongly agreed that the system would help them finding locations quickly, and 83 % of the participants agreed that the system would improve their performance. This encouraged us to continue the development.

### 3.2 Student visitors in the campus building

The test took place in the ICT building located in the university campus area. The building contains offices, meeting rooms and lecture halls on six floors (Figure 2). The building has an information desk near the main entrance, which employees handle about 30 requests in a day related to indoor navigation. On a day of a mass event (conferences, student events), the amount of requests is much higher.

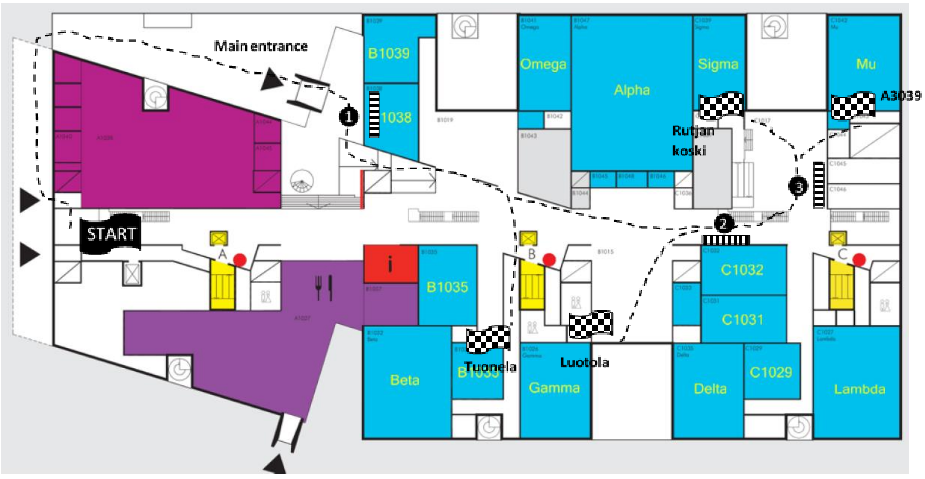


**Fig. 2.** The map of the ICT building including optimal paths (dashed lines from start) and four screens (numbered) on the way to target locations (goal flags).

The application was tested with engineering and business students on June 2018 (N=28) and the second time on February 2019 (N=10), same time with visitors from a primary school (N=10). Of these participants, only 29 % visit unfamiliar places very often (S3). However, during the past year, 47 % of participants have experienced difficulties in navigation (S4).

In the first test, we had four different target destinations in the first floor of the building and three large screens for the wayfinding interaction towards these destinations (Figure 2). Based on the insights of business festival, the positioning of three screens was planned to support the minimum amount of screens needed for navigation, yet we did not use any stationary screens but installed new ones into the most appropriate positions concerning finding the destinations. With the specific positions, we could also study the different types of directional arrow symbols showed in the screens and their effect on the PDS usability. We implemented 2D arrows (Fig. 3), which directed to (half-)cardinal points (e.g. south-east) and could include a 90 degree angle (around the corner -arrow) as well. Participants were orally instructed to hurry, because they were already late from the meeting time mentioned in the scenario (an email invitation). Participants were sent in one minute intervals to different destinations, in order to avoid participants directly following each other in the building, yet allowing multiple directions to appear in the same screen.

Participants in the first test of the ICT building rated the usability of PDS with SUS score 74. The result is good despite that half of the participants in the study suffered from poor WiFi network connection in one Rasperry Pi device, which meant the users had to wait their avatar appearing on the screen, if at all. The subjective efficiency decreased (71 %) compared to business festival, although PDS was considered a bit more useful (89 %) in the complex building. The problem increased their navigation times as well. On average, the navigation times were 55 seconds more (+ 45 %) than the fastest possible route to the destination (optimal time on routes varied between 90-130 seconds). Less than a minute increase in navigation time can still be competitive against maps and desk services. Another difficulty were the directional arrows as signs (8 mentions out of 42 in open questions). As one participant puts it: *"I accidentally went upstairs on the first try, cause the arrow was pointing North-East"*. Especially, arrows pointing to half-cardinal points were difficult to interpret in flat 2D representation. The compulsory U-turn back from the screen 2 indicated by the arrow to the south-east made the route to Luotola destination more complex to the users. On the other hand, the arrow with the 90 degree angle caused the highest number of turn backs and screen visits needed (the destination Tuonela in Fig. 2). Either the angle was not understood correctly or the screen position (the screen #1 in Figure 1) combined with the building layout was not appropriate for the arrow sign with angle. The participants who required to use this sign (Tuonela) gave the poorest efficiency ratings for the whole system (3.42/5 on average). Interestingly, the same users rated SUS scores (85) and the perceived usefulness as positively as others. The best performance and satisfaction among participants were achieved with the furthest destinations in the building (Rutjankoski and A3039 in Fig. 2). One explanation is that compared with the other two destinations, these routes continue straight from the main entrance and include more screens near the destinations (screens numbered 2 and 3 in Figure 2). The actual effectiveness of the system was high, because only one participant out of 28 did not find the destination before giving up the task.

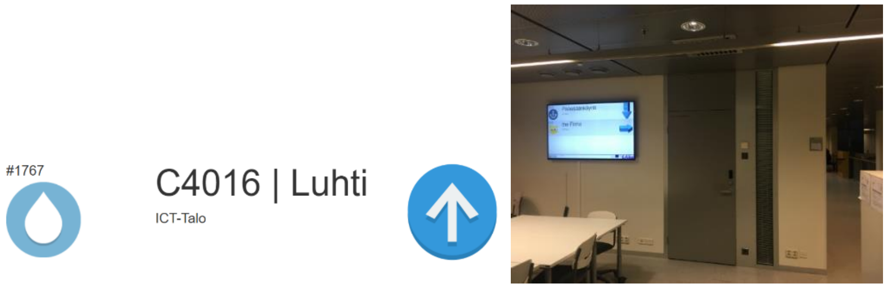


**Fig. 3.** Left: 2D arrows used in the first test were vague (up or forward?). Right: Stationary installed screens in the lobby were used in the second test.

For the second test in the same building, we made few improvements and changes to the system. First of all, we redesigned the arrows to 3D format (Fig. 1) due to earlier misinterpretations related to directions. Second, we expanded the available destinations to three different floors instead of guiding the users in the ground floor only.

Third, instead of installing only new screens, we used three stationary installed screens of the building (Fig. 3). Participants were instructed as in the first test. They rated the usability of PDS with SUS score 82, which is better than in the earlier tests in the business festival and in the ICT building. Both the perceived efficiency (90 %) and the perceived effectiveness (90 %) improved slightly from the first tests. Every participant found the target destination, and on average the navigation time was 29% (52 seconds) more than the fastest possible time to reach the target, which was an improvement as well. In open answers, participants considered the 3D arrows as clear and informative about the right path, whereas the amount and positioning of screens got negative feedback. Thus, the accuracy of navigation and user experience would improve if the screen positions are planned for the navigation purpose. Currently, the stationary screens of the ICT building fit for approximate navigation only.

## 4 Conclusions

In the mobile computing era, the development of wayfinding and navigation has been fast, yet rather techno-centric. As its materialization, numerous of different mobile navigation applications require that people concentrate on their smart phones rather than on navigational cues in the real surroundings. A theoretical contribution of this study is that it calls for re-thinking the interaction design of indoor wayfinding with the modern technology from more human, socio-technical and practice-based perspective than just as a technological advancement to come. More traditional wayfinding techniques and elements, such as directional signs, are still appropriate in many navigation situations where the (constant) use of mobile devices is not. Probably, this notion and our study results encourage others to exploit the most recent technology for getting people to non-interact with the technology (i.e. requiring less concentration on your technology in everyday life).

Our approach is ubiquitously simplistic and embedded: It leaves the mobile on the background and exploits navigation aids that are personalized and familiar to everybody. Our evaluation cases with PDS show that people find such personalized and digitalized navigation guidance based on traditional signs both usable and useful. Most challenging is the amount and positioning of screens, which set the limits for the navigation accuracy and user experience in practical implementations. Another challenge is to find a proper model for user visibility in the screen i.e. when and how long one should appear on the screen in a mass event or in a building with hundreds of navigators in a minute. This is also an implementation site specific question. Yet, even with few existing screens in the tested location, the proposed system is able to effectively and efficiently guide the visitor and improve their visiting experience. Therefore, the practical implication of the study lies in this proof-of-concept and its usefulness, which invite HCI community to design future wayfinding interactions more socially sustainable than technical.

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