Location-based Services: User Interface for Pedestrian Navigation Systems

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ABSTRACT
The purpose of this report is to review the research field of location-based services, in particular, the user interface for indoor navigation systems. Indoor navigation system, also called pedestrian navigation system, is a growing research field. It is currently gaining more attention due to the development of alternative localisation methods that does not involve the use of GPS. Where GPS has always been the driving force behind outdoor navigation, it remains unsuitable for indoor navigation. The report breaks down the field of indoor navigation systems into the different types of devices and interfaces used by these types of navigation systems. Based on existing studies, the overall state of the field is described and possible gaps in the field are indentified.

Author Keywords
Location-based services; Pedestrian Navigation; Indoor Navigation; User Interface.

INTRODUCTION
Location-based service (LBS) is a type of information service which provides the service using location data. The main type of LBS currently used by general recreational users is location identifying services which often include navigation. For example, find the closest restaurant and navigation to the location of the restaurant. Such outdoor navigation is already a well-established industry with most systems using GPS signals to position users. However, indoor navigation has not gained as much attention due to its GPS problem.

Previously it was difficult to locate user in an indoor environment because GSP signals cannot be detected inside buildings, and other methods used were also inadequate. For example, indoor positions can be achieved with sensors such as infrared beacons, radio frequency and computer vision but these methods also require extension on the environment, such as installing sensors through the building. Another alternative would be to use dead reckoning, which incrementally update the users position from a known starting position. However, with drift, dead reckoning loses accuracy dramatically over time and requires readjustment [9].

It is only in recent years that indoor navigation has started to progress more due to alternative localisation methods aided by new technologies, and thus opening a new area of possible research. Though, with the opening of a new research field, more problems will arise, and in this case it is the problem of a suitable user interface. Due to the difference in the nature of the environment, interface of outdoor navigation systems cannot be directly used for indoor navigation systems. Outdoor navigation can often rely on location labels such as street names where as such information would not be available in an indoor setting. Also, since human intuitively use landmarks to position themselves, it is easier to lose ones way inside a building where there are less or no landmarks [4]. The above are all factors that may influence the requirements of a user interface.

There are currently a number of different devices and interfaces used for indoor pedestrian navigation systems. However, there is a lack in comparison studies to identify the most suitable user interface for indoor navigation systems. It is important to identify a suitable user interface because usability is directly affected by how well a user can interact with the system. If system is difficult to interact with users are less likely to accept and use the system.

Following the introduction, the main section reviews the major devices and interfaces used for navigation systems in recent studies. The main section will be succeeded by the evaluation which describes the most widely used evaluation method for these types of studies. Following the evaluation is the discussion. The discussion section will describe the current overall state of the field and possible gaps within the field. The review concludes with the summary of the overall findings.

SPECIFIC ASPECT OF LBS
The specific aspect of location-based services this review targets is pedestrian indoor navigation system, specifically the user interface of these navigation systems. Unlike outdoor navigation, indoor navigation is not a well-developed research field due to the GSP problem mentioned above. The progress made in mitigating the GPS problem has resulted in

the development of indoor navigation. However, the development of indoor navigation system has initiated yet another research problem. With the possibility of developing indoor navigation, the problem currently faced by most in the field is the development of an intuitive user interface for the navigation system. Hence, the main focus of this literature review is the user interface of indoor navigation systems. The main problem of developing an intuitive user interface can be divided into two sub problems:

- What navigation device is the most appropriate for indoor navigation systems?
- What interface is the most appropriate for indoor navigation systems?

EXISTING DEVICES FOR NAVIGATION SYSTEMS

Devices of pedestrian navigation systems refer to the hardware which the navigation system utilises. The main devices used are mobile, projector and wearable head mounted display/headsets.

Mobile/Smart Devices

Most navigation system utilises mobile devices as the physical hardware to deploy their interface [9, 6, 2, 4, 7, 1]. The main advantage of using mobile device as navigation hardware is the familiarity and accessibility that smart devices possesses. Since an increasing amount of people are starting to use smart phones, the accessibility of smart devices is high. Also, since most people use their smart phones on a daily basis, the general public are also familiar with the device. Both accessibility and familiarity are important aspect of usability. If a device is familiar to the user, not much learning is required and hence it would be easy to use. Accessibility promotes familiarity, if smart devices is accessible in everyday lives of the user, they will become familiarly with using smart devices. Due to these advantages, studies often opt for this form of device for their navigation system.

Headsets

The headset is worn on the users head and covers the users eyes. It allows the user to look through an eye piece or pieces to see a particular type of interface. An advantage of a headset is that it results in accurate navigation [4]. However, it is also impractical for everyday use. The disadvantage of headset is also enforced by [5] which evaluates the user experience of using wearable headsets for navigation. The study was done outdoors and it evaluated participants using the navigation system to locate a certain building. The navigation system displays an augmented reality view through a monocular attached to a Head Mounted Display (HMD). Most participants complained about the comfort of wearing the headpiece. Some participants commented on navigation problem while viewing the environment through an augmented reality, stating that it was difficult to focus on the surrounding environment while looking at the navigation information through the monocular. This can potentially be a major problem as the evaluation was undertaken outdoors, and the participants said they often had problem noticing oncoming traffic while using the headset to navigate.

Another study which also utilises head piece highlights similar advantages and disadvantages. Study conducted in [10] identify the possibility to not only navigate to a location with wearable devices but also to navigate human behaviours. Hence they commenced a study to evaluate the feasibility of using wearable headset to record first aid treatment process by a having a professional complete the necessary steps with a wearable device and have the image transferred to a user at the place of the accident or where the first aid treatment was needed. This paper identified the shortcomings of HMD, noting that it is expensive, user would require a learning period to use the device, and some participants experienced motion sickness while using the wearable device. However, it was believed that future progression in hardware would reduce the disadvantages of wearable devices.

Both [5, 10] identified the main advantage of wearable devices as being a hands-free device. Unlike conventional maps and navigation with mobile devices, wearable devices allow users to have both their hands free to complete other tasks. This advantage is highlighted in [10] where the users are able to perform first aid treatment while navigating through the process of performing the treatment.

Projectors

Similar to wearable headsets, a projector as a navigation device also has the potential of hands-free interaction. As proposed by [11], a navigation system can be built using a projector which augments the real-world environment directly by projecting an arrow which the user would follow. The projector can be made hands-free by wearing the device on the users belt or attached to other clothing worn by the user. Other methods of using projectors include projecting a 2D map with the route displayed on the map [1].

Both studies which use projectors highlighted the same advantages, and disadvantages. The main disadvantage was the privacy concerns that users may have when using projectors which display the navigation information to their target destination publically on the ground in front of the user. However, projectors have an ease-of-view advantage. As compared to a screen, a projector has a much wider space to display the output [11]. Furthermore, the study tries to amend the privacy problem by turning it into a type of advertisement. The paper argues that since the application is used in a shopping mall and the user is navigating towards a certain store, when bystanders see where the user is going, it may entice them to visit the same shop. However, this advantage is only valid in shopping malls, where the level of expected publicity is higher than usual. It was shown to be invalid in normal settings where users still opted for mobile devices because they felt that their privacy was invaded when using the projector as a navigation device [1]. Furthermore, with the simple arrow projection, users felt they had less control over the navigation procedure. Hence the system proposed by [11] will likely result in the same conclusion.

Even though both projectors and wearable headsets provides the advantage of hands-free interaction, projector out performs wearable headsets as it is not as expensive as a headset, and it allows more control for the users. However, because headset navigation forces the user to constantly view the environment through a monocular or some other fixed display, it is more likely to result in motion sickness. Unlike for a projector and mobile screen, users are allowed to choose when they use the device. The higher degree of freedom develops high user satisfaction and hence better usability.

EXISTING INTERFACES FOR NAVIGATION SYSTEMS

The interface of a navigation system refers to the type of navigation information presented to the user of the system. The main types of interfaces used currently are augmented reality/world-in-miniature, virtual reality, activity-based and text instructions.

Augmented Reality/WIM

Augmented reality (AR) is a view of a real-world environment with specific elements having undergone computer-generated enhancement. This visualisation has been used in a number of interfaces for navigation systems, but in different ways. Furthermore, AR is often used with World-in-miniature (WIM) view. WIM is a type of view which displays a map of the complete space, which in most cases, is the building in which the user is navigating through.

For example, [9] use augmented reality with WIM to show a 3D map of the building at specific information points. The information points are coded diagrams placed at discrete intervals throughout the building which users can point their device at to see a WIM view of the whole building and the path to their destination, as seen in figure 1. The advantage of using augmented reality as described above is the ability to show the path in both 2D, which is quick to convey route information, and 3D, which is better at showing landmarks. Furthermore, the WIM augmented reality was proven to be useful, through user study, for matching interface to the real world. High level of mapping between the interface and the real-world is important as it helps the user with orientation and hence allows them to find the destination more efficiently. Another usage of augmented reality, which is more widely used, is displaying navigation information over a live view of the real-world environment. Navigation information normally takes the form of an arrow in the direction of the destination [6]. The user would have to look through a type of device to view the direction of the arrow, as shown in figure 2. The AR used in the study by Kerr [5], which is for outdoor navigation, augments the destination building when the user gets close enough to see it.

The main drawback of AR which provides navigation information though directional arrow is that the placement of the arrow is extremely important as users are sensitive to change when using AR interfaces. For example, participants of user study were often uncertain which turn to take since the tip of the arrow did not match the entrance of the intersection exactly. Also when the arrow is slightly off centre the majority of users would change the side on which they were walking [8].

Virtual Reality

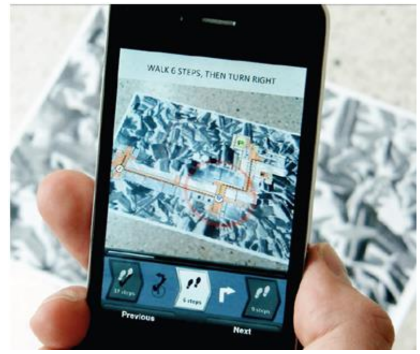

Figure 1. An image of the augmented reality interface which shows a WIM view of navigation space.

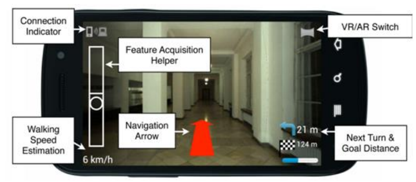

Figure 2. An environment which displays an augmented arrow. Arrow act as the navigation information.

Virtual reality (VR) is a completely computer generated environment which can simulate real world or synthetic environments. For example, [6] used VR by pre-recording the image and then rendering an arrow onto the image. It is one of the few studies which utilised VR views, and it claims that it is more users friendly and more accurate since the navigation arrows are hard-embedded onto the image.

Study conducted in [9] also use VR to provide navigation information. However, it is only used when localisation information is not available, which is when the user is moving between information points. A VR image of the path the user is on is used to direct users to the next information point. However, one major disadvantage of this method is the lack of flexibility. Since there are no means of localisation when users are in between information points, the system will not be able to know the current location of the user, nor would the system be able to verify whether or not the user is still on the correct path. The system hence assumes that the user is on the correct path until the user reaches the next information point, at which the system will check if it is indeed the information point the user should have reached if they were on the correct path to the destination.

Activity-Based

Activity-based visualisation is another method to communicate navigation information to the users. It consists of a series of previous and upcoming directional activities, such as take 20 steps, as shown in figure 3. Activity-based method was developed due to the success in detecting human motion such as standing, walking, climbing and using the elevator, using mobile device sensors. This method is most useful for situations where the path has already been taken before by the user or someone else, and the user needs to retrace their steps. For example, it would be suitable for trying to find parked cars in

Figure 3. An image of activity-based interface which shows the individual navigation activities users should follow.

a large shopping complex, or find a colleague in an unfamiliar building.

Activity-based method is a desirable alternative to GSP maps and indoor localisation because it does not rely on preconstructed maps of the infrastructure. Hence it can be used at any location without the need to gather data in advance. Nor does activity-based method require absolute positioning, which is one of the main problems for indoor localisation. Used in [9, 2, 7] activity-based navigation is an alternative interface for navigation systems. However, [2] was the only study which relied solely on activity-based instructions, where [9, 7] both had other forms of navigation visualisation, such as mixed reality and AR. Through [2], the activity-based method was evaluated in detail. It showed that activity-based navigation method provides poor information with only simple instructions such as step counts. The user study reveals that participants find step counts difficult to follow. The option which only utilises step counts rated first in frustration, effort and second in mental demand level. Most participants felt that directional information, such as compass direction, was also necessary. There was also an option which used photos that were taken on the path. However, this method was also not beneficial, with many participants losing their way trying to find the location where photo was taken.

Similar to other navigation interfaces, activity-based navigation lacked real-time feedback. Also, as discovered in the user study, when participants strayed off the correct path it was extremely difficult to return to the correct path and find the destination.

Text Instruction

Many systems also utilises text instruction alongside other visualisation methods [9, 4, 7]. However, user study from [4] shows that participants disliked the textual instructions, with most preferring a graphical interpretation over plain text.

EVALUATION

In the studies reviewed, the navigation systems were almost always validated by user study on a small group of participants. Using the prototype developed, participants are given a particular route to follow or a destination to reach using the navigation system prototype. Most user study utilised the think aloud method where participants were asked to voice their thought process. This helps the observer understand certain behaviours of participants.

Some studies used the Wizard-of-Oz (WOZ) approach. WOZ is a type of research experiment which is often used in user studies. The participants interacts with the computer interface while unknowingly, the interface is controlled by an unseen human. The WOZ approach allows research conductor to control the position and orientation throughout the user study, and it allows the research conductors to create comparable conditions for all participants. This results in a more controlled experiment, unlike in a live system where it is difficult to reproduce the same behaviour in all trials [6].

DISCUSSION

Even though there are a number of different devices and interfaces for pedestrian navigation systems, there are limited studies on comparing the different systems in terms of user interface. User interface is an important aspect of any system which includes human interaction, as high level of human acceptance towards a system is influenced heavily by the usability of the system.

Many studies claim to be achieving satisfactory results from their user studies. However most user studies either does not compare with other type of interfaces, and simply evaluate their system by observing the errors made by participants, or comparison was made with paper maps [4, 8]. Evaluating against traditional methods, such as paper maps, is a type of validation on performance but only in the most basic sense.

The field of pedestrian navigation system user interface currently lacks a comprehensive study on comparing the major devices and interfaces. Studies were conducted compared mobile and projectors as navigation devices, and map and arrow (augmented reality) as interfaces, as shown in figure 4, and 5. It was found that participants preferred mobile devices over projectors. Such preference is likely to be caused by users familiarity of using smart devices. The study predicted that arrow interface, where the arrow pointing to the destination is projected, would be preferred, as arrow interfaces involves less workload. This assumption is often present in studies which use projectors. Most of which claims projectors allow users to focus on the path and hence are considered superior to mobile devices. However, the user study did not fulfil this hypothesis and most participants opted for a map interface, expressing that they felt lost with lack of navigation information a projected arrow provided.

It would be beneficial if more comprehensive studies were conducted to compare the different types of devices and inter-

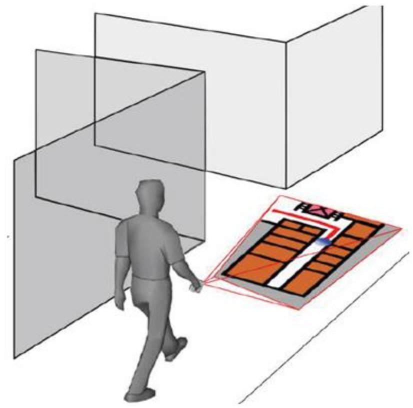

Figure 4. Navigation with a projector device and map interface.

faces for pedestrian navigation systems. A possible method to evaluate the usefulness of different interfaces is by using different combinations of the more widely used interfaces, such as augmented reality, activity-based and text instructions. It has been shown that a combination of all displays results in satisfactory usability level, but by stripping each method individually one can evaluate the benefit each interface brings to the whole system.

From current individual studies it can be concluded that for navigation devices, mobile devices are preferred, but most likely because it is a hardware that is most integrated into our everyday lives. It does not have the advantage of free-hand navigation which is provided by projectors and headsets. However, both of which have their own disadvantages, such as headsets motion sickness problem and projectors privacy problem.

An alternative to a hands-free device for navigation is the Google Glass, which was released in 2013. Google Glass is a wearable technology with head-mounted display. Since Google Glass is a relatively new technology, not much research has been conducted on it and even less in regards to indoor navigation. However, many are already looking into the possibilities Google Glass may bring to their existing research [3]. Due to the nature of Google Glass it would eliminate the privacy problem of projectors. It may still have the motion sickness problems of a wearable headset. However, it will most likely be more comfortable compared to existing navigation headsets as it is approximately the same weight and shape as an average pair of glasses. Since car navigation with Google Glass is already available, it would be intriguing to expand the use of it to pedestrian indoor navigation as well.

The use of Google Glass as the device for a pedestrian navigation system is a research area that has yet to be fully explored. Hence opens a potential academic interest. A possible study could be to compare using mobile devices to using Google Glass, with a combination of different user interfaces.

CONCLUSIONS

There are currently a number of different ways to construct a pedestrian navigation system. Possible hardware devices that can be used include mobile, headset, and projector. There are also a number of different ways to create interfaces which visualise navigation information. For example main interfaces used include augmented reality, virtual reality, activity-based, and text instructions. Studies are often conducted individually and therefore lack a comprehensive comparison of the major devices and interfaces. This gap in the field of indoor navigation system proposes a possible future academic study.

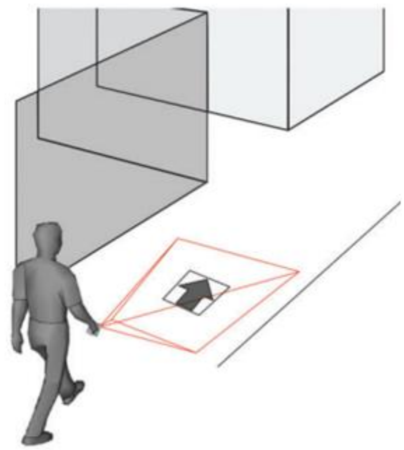

Figure 5. Navigation with a projector device and augmented reality interface.

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