A literature review of Location-Based Services

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ABSTRACT
This paper looks into the ways in which Location-Based Services are able to change the way we interact with the world around us. Using Augmented and Virtual Reality, and combining them with the camera, Wireless, and GPS systems in mobile devices; or combining them with external devices, we are able to create navigation systems to assist users in finding their way around both indoor and outdoor settings.

Author Keywords
Location-based services; mobile navigation; indoor navigation; outdoor navigation; visual location recognition; visual localization; augmented reality; virtual reality; navigation for the visually impaired.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Due to the ever increasing popularity of mobile devices, Location-based services can be easily created and used to interact with the areas around us. Mobile devices with cameras can be used to navigate through areas using virtual or augmented reality; where an image is captured through the camera, and then overlaid with information to help a user navigate. Being that this field of user interaction is fairly new, this paper reviews three existing research papers in their exploration of the area, and how mobile devices can be used to recognise the world around a user and change how they interact it. The papers cover the use of a mobile device’s camera, wireless, and GPS systems to approximate the user’s location, and provide feedback through Augmented and Virtual Reality methods.

BACKGROUND OF LOCATION-BASED SERVICES
Location-Based Services (LBS) are able to assist the way people interact with the world. LBS is used almost exclusively for navigation, but there are many aspects of navigation which can be assisted with the use of this technology. Seeing that Location-Based Services are tied to the location of a user, navigation is perhaps the core use for LBS.

Forms of Navigation

Indoor Navigation
The idea of navigating through indoor spaces with mobile devices is not a new one, but constant advancements in both the technological capabilities and availability of these mobile devices has meant the ability to easily set up systems to navigate indoors is much easier. In later sections we will cover how indoor navigation is accomplished.

Outdoor Navigation
Navigation with the use of maps has existed for thousands of years, but with mobile devices users are now able to find their way through technological means such as GPS. Location-Based Services are able to build upon this foundation to provide more extensive assistance in the area of outdoor navigation.

APPROACHES TO LOCATION-BASED SERVICES
Location-Based Services have been implemented on mobile platforms in various ways. These techniques often use a combination of a mobile device’s Camera, Wireless, and GPS capabilities. In some cases, the potential to extend a mobile platform has been implemented through the use of external hardware. This section will cover existing research into implementations of Location-Based Services.

Vision Based Localisation
The most common form of LBS is achieved through Vision Based means, which make use of the mobile device’s camera. In the paper *A mobile indoor navigation system interface adapted to vision-based localization*, [5] Möller et al. use a technique called visual localisation to recognise their surroundings using a mobile device. This estimates a user’s location based on the information received by the mobile device’s camera, and can also request that a user focus in a certain position to improve the accuracy of a reading. This technique uses a method known as feature matching which queries reference images for matching characteristics.

Schroth et al. also compared various location approximation services in their paper *Mobile Visual Location Recognition* [6], but with a focus on outdoor Location-Based Services and outdoor location approximation. One of the most interesting methods used in this paper was similar to that of Möller et al. in that it used visual localisation, however it was altered in a way such that it would query Google Street View or Microsoft Side-Street Views to approximate the user’s location.
(see Figure 1). Again, this method uses visual localisation and feature extraction to query a database (in this case Google Street View) to get an approximation of the user’s location. The method used in this paper also used the most recently approximated location to assist in locating the next position (as the user can’t have possibly moved a great distance since last scanning). Features are matched between the local video and Google Maps as shown in Figure 2. Any matched with trees and plants are ignored as they would cause variance across seasons.

In Positioning and Orientation in Indoor Environments Using Camera Phones [3] Hile et al. also used visual localisation to get a user’s position. Under the synonym feature mapping, the feature is the same as visual localisation in that it creates a map of the user’s indoor surroundings such as; hallways, doors, and corners, then compares that with floor plans to get an approximate location for the user, as shown in Figure 3. This method required floor plans to work successfully, so would only be viable in buildings where a floor plan is readily available to be queried.

Wireless Local Area Network Polling

Möller et al. [5] also reviewed other methods of location estimation such as polling existing Wireless Local Area Network (WLAN) infrastructure, which uses the signal strength of nearby wireless access points to estimate the location of users. This method would be expensive to implement, as a large number of access points would be required, and would not scale well as there would need to be a constantly dense network of WLAN access points.

Similarly, in their paper Indoor Tracking and Navigation Using Received Signal Strength and Compressive Sensing on a Mobile Device[1], Au et al. also looked into the Received Signal Strength (RSS) from existing WLAN access points to approximate a user’s location, and found that RSS would be a better technique to use over Time of Arrival and Time-Difference of Arrival, as these methods would require additional hardware to generate accurate measurements. Location approximation using RSS requires an existing database of WLAN signal strengths at known locations. This technique is called location fingerprinting, and data is collected beforehand and stored in a database (As shown in Figure 4). The actual location of the WLAN access points is not known, as Au et al. outline, but their exact location is not necessary for the system to work.
The system proposed by Hile et al. [3] was intended for use in known environments, and as such, nearby WLAN sources are queried to get an approximate location to narrow the search. This provides a localised area to search within to map. This was expected to provide an accuracy of approximately 5 to 10 meters.

GPS Localisation
Dünser et al. in their paper *Exploring the use of handheld AR for outdoor navigation* [2] use a system which combines GPS with a mobile phone’s built in accelerometer and compass to provide data on the location and orientation of a user. This information was used to determine the location of a user and assist them with navigation along a path. Schloth et al. [6] speculated that GPS was only viable in an outdoor setting with very few obstacles, as a device would need to be visible by 4 GPS satellites. They found that the most inaccurate readings were given in urban environments where tall structures obstructed the view of the satellites. Similarly, Legge et al. [4]

In *Positioning and Orientation in Indoor Environments Using Camera Phones* Hile et al. also state that with GPS systems they could potentially move their solution to map outdoors areas as well - decreasing the search area by getting a user’s GPS coordinates and then attempting to user feature mapping from there. This method is somewhat similar to the methods proposed by Schloth et al. in *Mobile Visual Location Recognition*.

External Hardware
In *Indoor Navigation by People with Visual Impairment Using a Digital Sign System* [4], Legge et al. explore the use of additional hardware to assist the visually impaired with navigation indoors. Currently, outdoor navigation is widely available thanks to GPS, and as such visually impaired individuals are able to navigate outdoors using speech based GPS navigation systems. However, indoor environments are not suitable for GPS navigation and as such must be dealt with differently. Additionally, Vision and WLAN based systems are too unreliable for the visually impaired as they have huge difficulty in the area of error detection [4]. Legge et al. propose a "Digital Sign System". This technique required an additional tag reader and bluetooth headset to be connected to a mobile phone as shown in Figure 5. The Tag Reader would pick up on tags placed around points of interest inside buildings and relay to the user navigational information.

User Interfaces
The interfaces which provide a user with access to the Location-Based Services are vital to their usability. Some of the papers reviewed had functioning prototypes with different kinds of interfaces. Those not mentioned here are simply prototypes which were created as proof-of-concepts to demonstrate their ability to work.

Augmented Reality
Möller et al. experimented using a mixture of Virtual and Augmented Realities to provide navigation services to users. The Augmented Reality (AR) takes the mobile device’s camera input and overlays an image which provides the user with the information required to navigate, like a directional arrow pointing towards a goal for example. This method required the user to hold their phone in a set position which had the issue of user fatigue. (see Figure 6-a) This issue was partially solved in virtual reality.

Dünser et al. produced three implementations of their solution, the first being Augmented Reality, the second being
a Map interface (using Google Maps API) and the third being a combination of both interface options, with a button to switch between modes. (see Figure 7). The interface changed the size of the overlain AR location pointer as the user moved closer to it, transforming it to a 3D cube when the user is closer than 50m to the location. The bottom-left corner of the screen also showed a radar-view which gave the user a general idea of their surroundings. (see Figure 7).

**Virtual Reality**

The implementation used by Möller et al. for Virtual Reality displays used a prerecorded image of the user’s location, which is panoramic and can therefore render every direction around the user (see Figure 6-b). This also reduced the issue of arm fatigue as the users were not required to hold the phone near eye-level.

**External Hardware**

The implementation used by Legge et al. used a Tag Reader as shown in Figure 5. The user interface for this implementation was geared towards the use of the system by the visually impaired and as such used a bluetooth headset to feed information to the user. The system ran on a Windows Phone with the standard 12 buttons (0-9, *, #). Again, this is allowable and preferable as the intended audience is the visually impaired.

**APPLICATION AND EVALUATION OF LOCATION-BASED SERVICES**

**Indoor Navigation**

Indoor navigation was achieved using vision based recognition [5, 6, 3], WLAN Polling [5, 1], and Tag Recognition through external hardware [4]. These services provided accurate representations of the user’s location and were viable for use within indoor environments.

Vision Based systems proved most accurate, with the feature matching implementation of an indoor navigation system by Hile et al. able to produce consistent indoor results with an accuracy of 30cm. This was significantly greater than what is currently achievable with GPS and WLAN polling. Hile et al. also found that such a small error margin meant that the overlain image was acceptable when used.

Schroth et al. found that due to the ready availability of cameras in mobile devices, this system is easy to implement as it requires no additional infrastructure or components for the end users. They were also able to produce a system with a 2-3 second response time, which is key in enabling users to use the system – as many users would find a slower response time acceptable.

Möller et al. argued that WLAN infrastructure would be problematic to setup and would not scale suitably, but insisted that Vision Based approaches were more suitable.

The WLAN implementation produced by Au et al. found that the Received Signal Strength sample time of 1 sample per second was not fast enough, and as a result were limited to having user’s of their system move slowly.

Legge et al. found that sighted people were able to faster navigate with their system than those that were visually impaired. But this was expected, and was not seen to be an issue as they had everyone complete their navigation tasks successfully. The only issue being that tags were placed in very specific locations, and users had to have the tag reader facing the tag to recognise it.

**Outdoor Navigation**

Outdoor navigation was achieved using vision based recognition [6] and GPS systems [6, 2]. GPS location approximation was also proposed by Hile et al. to extend their navigation system [3].

Dünser et al. used GPS systems to get the location of their users. They found that the was a margin of error that was at most 48m for the entirety of their study. This was outweighed by a minimum of 2m, resulting in an average of 7m for the entire study, which is appropriate considering they are navigating in outdoor environments. The error was likely due to interference with GPS systems, as speculated by Schroth et al.

Schroth et al. used Vision Based recognition primarily to match the surrounding areas with nearby locations on Google Street View. This implementation also stated that it could...
be extended to use GPS to better estimate the location of the user, and where to start the search.

**Navigation for the visually impaired**

Legge et al. looked into the application of Location-Based Services using Tag Readers. They tested their implementation with 4 groups, those with normal vision as a control group, those with normal vision but blind folded, a group with a slight vision impairment, and a group of blind people. They found that with their system, visually impaired groups were able to correctly navigate through an indoor environment. Au et al. also tested their implementation with visually impaired users and had an overall success rate of 93.3%. The authors suggested that their system was suitable for guiding visually impaired through indoor environments.

**User Interfaces**

Möller et al. found that Virtual Reality was seen to be a more reliable navigation system, as it was ”less influenced by inaccuracies”. The Virtual Reality solution was also better in that it allowed users to rest their arms by not having to hold them up at eye level. Augmented Reality was also perceived to be more inaccurate as an incorrect orientation was seen more negatively than an incorrect location reading, as the super imposed arrow pointed completely in the wrong direction. Düner et al. found that users preferred a mixed implementation which offered more options, as they were provided with a mix between the Augmented Reality and Map implementation. They found this most satisfying to use through a user study.

**SUMMARY**

The paper A mobile indoor navigation system interface adapted to vision-based localization, [5] explained how Möller et al. were able to approximate a user’s location then provide them with a functional navigation service. The authors used the mobile device’s camera exclusively, approximating the location with visual localisation, and applied an Augmented or Virtual Reality overlay to provide information to the user. Schroth et al. used a similar method, but this time with outdoor capability using a mobile device’s camera alongside Google Street View to approximate the user’s location. The system queried Google Street View to find a location that matched what the user’s camera input provided. Hile et al. in the paper Positioning and Orientation in Indoor Environments Using Camera Phones provided better accuracy for Augmented Reality in an indoor setting. This paper was also using location-based services to provide navigational support. The system outlined in this paper was significantly more accurate not only in location, but in direction of a user – which was the main pitfall faced by Möller et al. Düner et al. used an outdoor navigation system with an Augmented Reality System and Google Maps implementation. This Provided users with multiple options for wayfinding and was seen as a more favourable approach than AR alone. Au et al. used a WLAN system which matched the Received Signal Strength with a fingerprinting database to get the user’s location. In their study they found that both sighted and visually impaired people could use such a system, but were confident their system was significant in helping the visually impaired navigate through indoor spaces, as they received a 93.3% success rate in a user study. Legge et al. used a tag reader system to navigate through indoor spaces. They tailored their solution to assist the visually impaired, and as a result their solution was successful when tested with both blind and low vision users.

**CONCLUSION**

There are a number of different applications for Location-Based Services, as well as a number of different methods to provide them. If we are to use Augmented Reality, we need to be sure that we correctly and reliably get the direction a user is facing, as an incorrect heading has more of a negative impact on usability. The camera on a mobile device, coupled with WiFi and GPS positioning seems to be most accurate when approximating a user’s location, and may even be coupled with Google Street View, or additional external devices. These methods can be used to provide user’s with a new way to interact with the world around them, and allow anybody to easily navigate unfamiliar territory.

**FUTURE WORK**

The area of Location-Based Services is still relatively new and quite under-developed. An application could still be developed to make use of all the systems available, as the current implementations - as outlined in this report - are somewhat disjointed in both their approach and opinion of what will work. A system which could make use of GPS positioning when outdoors, and WLAN RSS when indoors to get an approximate location could then utilise that information when using Vision Based Localisation to get a user’s location could be used to create a more robust location-based navigation service.

**REFERENCES**


