

Designing Mobile Augmented Reality Interfaces for Locative Games and Playful Experiences

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ABSTRACT

Mobile Augmented Reality (MAR) has predominantly been used in locative games and playful experiences for the presentation on virtual game objects in conjunction with separate 2-D maps for navigation. This distinct switch in interaction modalities can detract from the game play experience and will arguably be less relevant for AR glasses. Therefore this research considers the application techniques from graphic design to MAR interfaces to provide an effective means of navigation through a physical game space without maps. To illustrate this approach we present a MAR application that provides a playful way for visitors to explore a small rural village in both space and time in relation to its main cultural event, the annual Scarecrow Festival. In particular we present the considerations that designers must address when creating purely augmented reality navigation interfaces through the design, implementation, and user evaluation of the application scARecrow Time Machine.

Keywords

mobile, augmented reality, design, navigation

INTRODUCTION

The origins of this research date back to 2003 when the villagers of Wray¹, who had been campaigning for broadband to be made available to their community without much success, approached Lancaster University for help. In 2004 a new research project between the university and the community building a new wireless mesh test-bed within the village was initiated and was the start of the village becoming a 'living lab' through which many novel technological interventions were evaluated.

Proceedings of DiGRA 2014: <Verb that ends in 'ing'> the <noun> of Game <plural noun>.

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The research project discussed in this paper was initiated through the EPSRC²'s 'Telling the Tales of Engagement' program to represent this collaboration to a wider community and in the spirit of the original project it achieves this through two novel design interventions that form part of the village's main cultural event, an annual scarecrow festival that takes place in May. The interventions are i) an interactive digitally enhanced scarecrow, which will participate in the festival, and ii) a novel mobile augmented reality (AR) application to allow visitors to experience both the current and past scarecrow festivals in a playful way. In this paper we consider the design and development of the mobile AR application known as the 'scArecrow Time Machine' to investigate the design implications of a purely AR navigational interface.

AR is a term often used simply to describe the augmentation of real world objects and environments with virtual data, although the more specific description used within the research literature is the registration of computer generated graphical information on the users' view of the real/physical world (Wagner and Schmalstieg, 2006). This places AR on the virtuality continuum (Milgram and Kishino, 1994), which is a continuous scale ranging between the completely virtual, and the completely real, reality. The space between the two limits is generally referred to as mixed reality and AR represents a particular point on that continuum. Ronald Azuma provided the first clear definition of AR systems (Azuma, 1997) as exhibiting the following characteristics:

1. combining the real and the virtual;
2. interactive in real time;
3. and registered in three-dimensions (3D).

Mobile AR provides this functionality but without confining the users' operation to a particular location and is generally further sub-divided as either Wearable AR or Handheld AR. Wearable AR utilizes Head Mounted Displays (HMD) to provide an immersive view. Whereas in Handheld AR a device (typically a mobile phone) is used as a 'magic lens' through which an alternate non-immersive perspective on the world is provided. Handheld AR has generally been viewed as more practical for wide-scale adoption than Wearable AR as mobile phones supporting the required sensors are so widespread, and HMDs have been criticized for limiting the field of view, comfort, and inducing motion sickness. Despite proliferation of Handheld AR the recent launch by Google of Glass³ means we do not yet know which incarnation of mobile AR will ultimately dominate. Whatever the type of AR the processing pipeline for AR applications is:

1. Get video frame from the camera.
2. Estimate position and orientation of the camera.
3. Render the virtual objects onto camera view.
4. Render UI to process the user input.
5. Update the application, then repeat.

The significant difference in the implementation, and consequently their operation, comes in the estimation of the position and orientation of the camera that is generally referred to as pose.

Sensor based pose estimation approaches take advantage of increasing numbers of sensors such as Global Positioning System (GPS), accelerometers, magnetometers (digital compass), and recently gyroscopes on commercial mobile phones. Combining the readings obtained from such sensors allow the position and orientation of the phone camera to be estimated (Kähäri and Murphy, 2006) in relation to 3D space. Such systems are relatively easy to implement and are the basis of many of the AR browsers currently in the app stores such as Layar⁴ and Wikitude⁵. The main issue with sensor based techniques is that the use of GPS limits the approach to outdoors and the accuracy can be highly variable due to spatial scattering which will ultimately impact on the contextual sensitivity of the applications developed (Bamford et al, 2008).

The simplest and most widespread of the vision techniques involves the use of two-dimensional (2D) fiducial markers to provide a pose estimate relative to the environment (Wagner, and Schmalstieg, 2007). The problem with this approach is that the narrow field-of-view of many mobile phones cameras can cause significant issues when tracking markers in a real world environment and when coupled with the practicality of covering the world with such markers limits the possibilities of how easily it can be deployed.

The alternate approach is natural feature tracking which uses natural occurring features within the environment to produce the reference plane (Klein and Murray, 2007). However, this comes at the expense of high device processing which is always an issue when implementing mobile AR (Wagner, and Schmalstieg, 2009). Whilst there have been a number of systems developed using natural feature tracking on mobile devices (Wagner et al, 2008), Klein and Murray, 2009), many have required apriori knowledge of the environment to create a reference map. Recent research has shown that Simultaneous Localization and Mapping (SLAM) techniques, originally developed for robot navigation, can be successfully applied to natural feature tracking and positional estimation (Davison et al, 2007) to create a more dynamic system. However, there is some way to go in adapting these techniques such that they can be implemented on current mobile phones.

In relation to this research we will limit our discussion to projects that have utilized Handheld AR for outdoor use. Although many early applications combined PDAs with external sensors it is only relatively recently that cameras, GPS, and compass (magnetometer) have been combined within a single devices and that the Mobile Augmented Reality Applications (MARA) project from Nokia (Kähäri et al, 2006) that coupled the required sensors directly to the phone, most closely matches what can be achieved on current devices.

Applications using point of interest (POI) data is probably one of the most commonly occurring themes in mobile but in the case of this project the playful history tours of most relevance are REXplorer, that used phones to create a gesture based POI tour (Ballagas et al, 2007), and Guided by Voices which was an audio tour featuring wizards and trolls (Lyons et al 2000). In terms of playful augmented reality tours, TimeWarp created for Cologne is the most relevant (Herbst et al 2008) although it used HMDs and users suffered a number of technical issues which means it was never released publicly. In relation to the design of the interfaces all used traditional maps as the primary navigational aid.

In terms of Handheld AR experiences released in the wild, the augmented reality game Free All Monsters (Coulton et al 2010) is of most relevance as it coupled POI information with a game design that drew upon the family friendly experience of Geocaching to promote exploration and social walking. However, only the early prototype of Free All Monsters provided solely AR navigation (Coulton et al 2010) and this was rather simple use a hot, warm, cold icons to give a relative distance without direction as there was no compass available on the device used at that time.

SCARECROW TIME MACHINE DESIGN

The emergence of the Internet and networked media has opened cracks within the chronological representations of time allowing memories and stories to seep back through to the present. The aim of this application is to exploit this effect by allowing visitors to select a festival year to experience and then displaying scarecrow images from that year at the relevant locations as they move through the villages, thus, allowing them to traverse both time and space.

The following designs are the result of iterative prototyping and a user centred design approach to create version 1 of the application which is currently available in the App store⁶.

Mobile Client

As the application created in this research is to be used outdoors and primarily in a village where the buildings are generally well spaced and none are above two stories in height, a sensor based system was deemed most appropriate. In terms of the application design it was decided that an only AR view would be designed without being combined with a traditional map view as in the AR POI applications previously discussed. This was done in order to evaluate the design challenges that must be considered if such AR navigation becomes commonplace for pedestrians through either phones operating as a magic lens or AR glasses.

One of the design challenges was to provide a sense of depth (distance) within the AR view to the user. To this end, a number of common art techniques for adding perspective to 2D visualisations have been utilised as shown in Figure 1 (b) and together these go beyond the primary use of size and scale in the majority of geo-spatial AR applications.

The grid provides linear perspective by creating a vanishing point, which is then enhanced by adjusting the size and scale of the scarecrow icons that also utilize atmospheric perspective by adjusting their transparency. To avoid clutter within the AR view the scarecrow icons traverse along three horizontal lines that represent distance ranges as the phone is rotated. The only distance shown is that from the user to the closest scarecrow, which is shown by a different colored icon. When the user gets within five metres (approximately 16 ft) of its position the icon changes to a fully-fledged scarecrow and the photo button is activated as shown in Figure 1 (c). The photo view is also an AR view, Figure 1(d), and shows the name of the scarecrow, its builder, the year it was made (users can select the year they will to travel too on the main screen), alongside a photo of the scarecrow. The image is deliberately set to one side to allow the user to take a photo that could include themselves, their family or friends, or indeed the current scarecrow alongside the image. The users' photos are stored in the list view, shown in Figure 1(e), which provides a history of the users' interaction and ability to view stored images as shown in Figure 1(e).

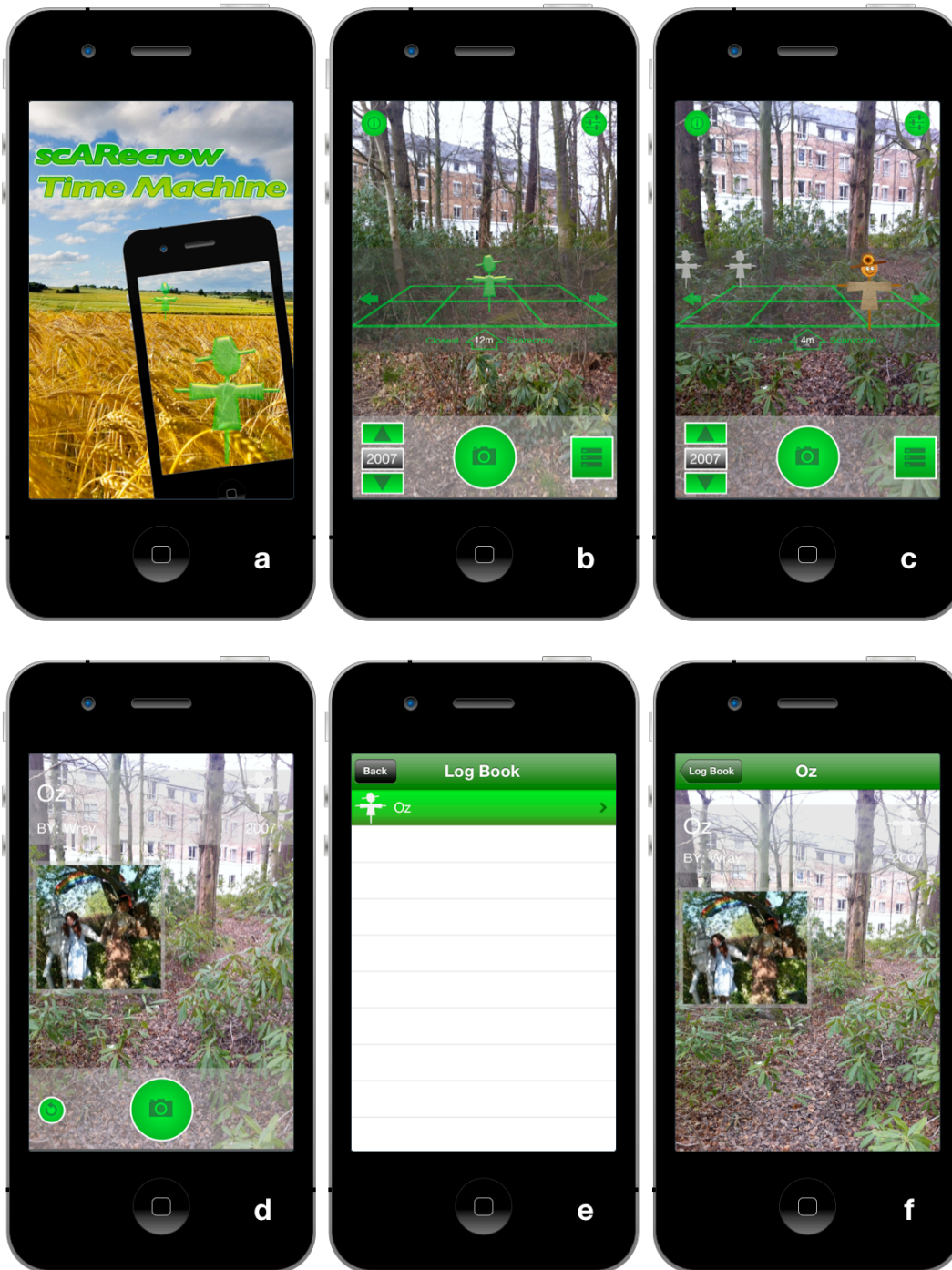


Figure 1: scARecrow Time Machine screenshots.

Scarecrow Management Portal

To enable the villagers to update the application to include scarecrows in future years a simple image management portal has been provided that allows new images to be uploaded along with all the relevant contextual information (name of scarecrow, location, year built, builder). At present the functionality and the intention is that this will be developed further through participation design with the villagers.

USER EVALUATION

To investigate whether users' are able to successfully navigate using the AR only navigation to find the scarecrows a user study was undertaken. It was decided create a specific version of the application in which five scarecrows were distributed at specific locations.

The study involved ten users over a period of five days at Lancaster University and they were aged between 21 and 50 of which 70% were male. Note that while the names of the scarecrows were changed from person to person the five GPS coordinates remained the same. The users were asked to use the iOS application to guide them towards each of the scarecrows using the instructions provided within the application. The instructions stated that the closest scarecrow is represented as green on the screen and the distance to this scarecrow is shown below the scarecrow overlay. Each user began their walk from the same place but were left free to choose which order they collected the scarecrows. In the background the application recorded the users GPS position, their direction bearing, time, and the capture of a particular scarecrow at the frame rate of the application. Note that each user was followed during the test but no interaction or help was given.

To evaluate this details of the users navigation the data captures we adopted the used of space-time paths (Coulton et al, 2008) as they illustrate how a person navigates their way through a spatial-temporal environment and are thus well suited to the evaluation of location based games (Coulton et al, 2008). The physical area is reduced to a two-dimensional plane with these dimensions representing a person's top-down position (e.g., longitude and latitude). Time is represented by the vertical axis. These three dimensions combine to form a world representing a specific portion of space and time. The path of a stationary individual will appear as a vertical line between the starting and ending times at a specific location. If an individual moves between two geographical locations at a constant velocity, the graph will show a line with a fixed trajectory that joins the start and end points. The slower an individual travels, the greater the line's vertical gradient. Therefore, the vertical gradient of the plot is inversely proportional to the user's ground-based velocity.

Figure 2 shows the space-time paths for all the users in the study with each user represented by a different color. A map of the area is shown on the base of the plot with buildings shown in dark blue. The large light blue area indicates a woodland area through which an un-surfaced path ran which is not shown on the map. Using such plots it was easy to establish that whilst 70% of the users spotted the scarecrows in the same order the route through they took was often very different. To illustrate this more clearly Figure 3 shows separate space-time paths for four different users. In these figures the green line is the route, and the red labels are the names of the scarecrows at the point at which they were spotted. Note that the top two paths show two users who collected the scarecrows in the same order but took a different route in particular whilst one user decided to take the shortest path through the woodland the other decided to take the paved route which went round the woodland. The other two plots represent two of the users who collected the scarecrows in a different order. Whilst it may seem strange the users took a completely different routes if they all started from the same point and all five positions of the scarecrows was fixed it is most likely due to the fact that these users performed the activity on different days when would be different as the GPS satellites would be in very different positions causing differences in the spatial scattering (Bamford et al, 2008) which affects the accuracy of the positional information.

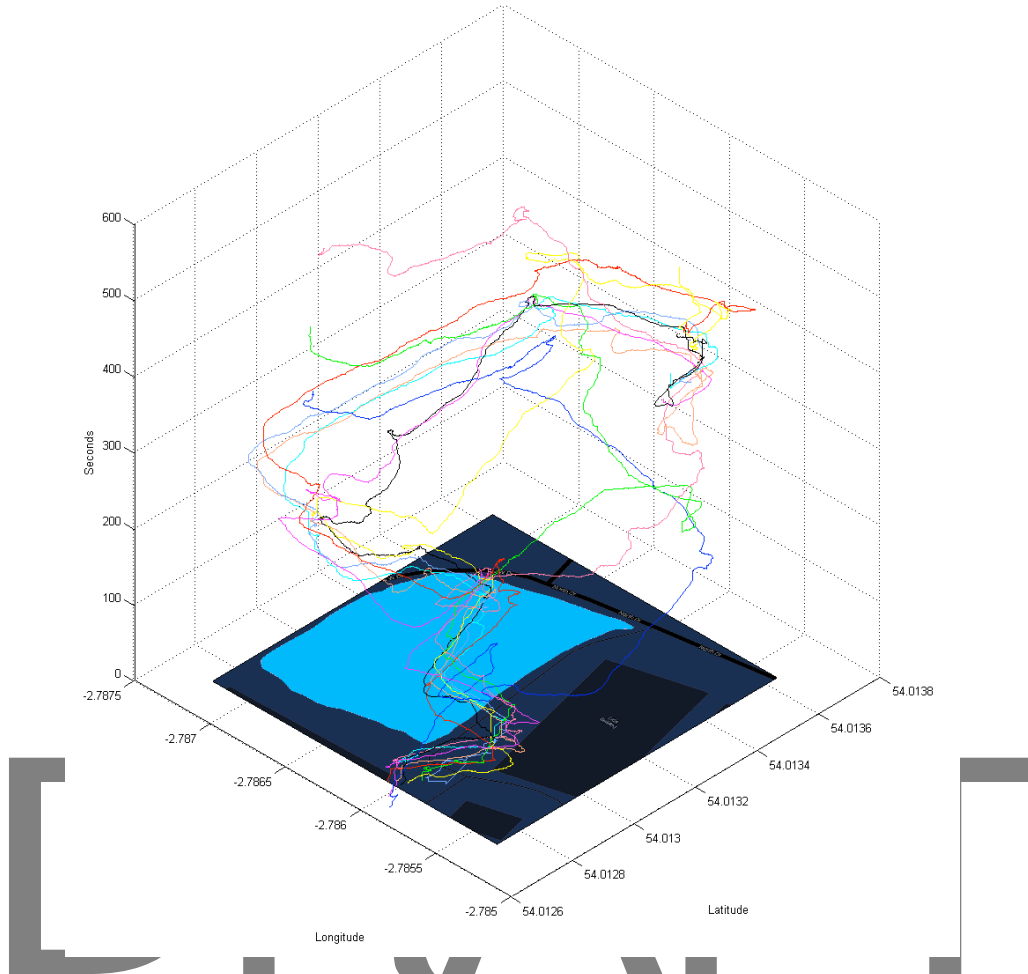


Figure 2: Space-Time Paths for All Users.

Whilst the GPS data provides part of the navigational information from the users the bearing information provides an insight into how easily the users were able to navigate through the space using only this AR view. In figure 4 we show the space-time path of one user that has been augmented with bearing information. In this figure the red numbers represent occasions where the user has turned through an angle greater than 40 degrees in any one second. Note that 40 degrees was chosen as it allows us to only consider points outside the average deviation observed from all the user data. From this it was apparent that these points appear to be clustered around the positions at which the users get close to the scarecrows and immediately afterwards. This was not the expected outcome prior to the users trial as it was thought that these would be more prevalent after capture when the user was searching for the direction to the new scarecrow. However, this tallied with our direct observations of the users which revealed that on some occasions when the users came in close proximity scarecrows the scarecrow would suddenly disappear from the field of view (FOV) shown on the phone screen and the users would turn quickly in order to find the scarecrow once again, sometimes going through multiples of 360 degrees. Upon reflection of this effect it was considered to be a result of the interface design that currently does not adjust the represented FOV on the phone screen as the user gets closer to a particular scarecrow.

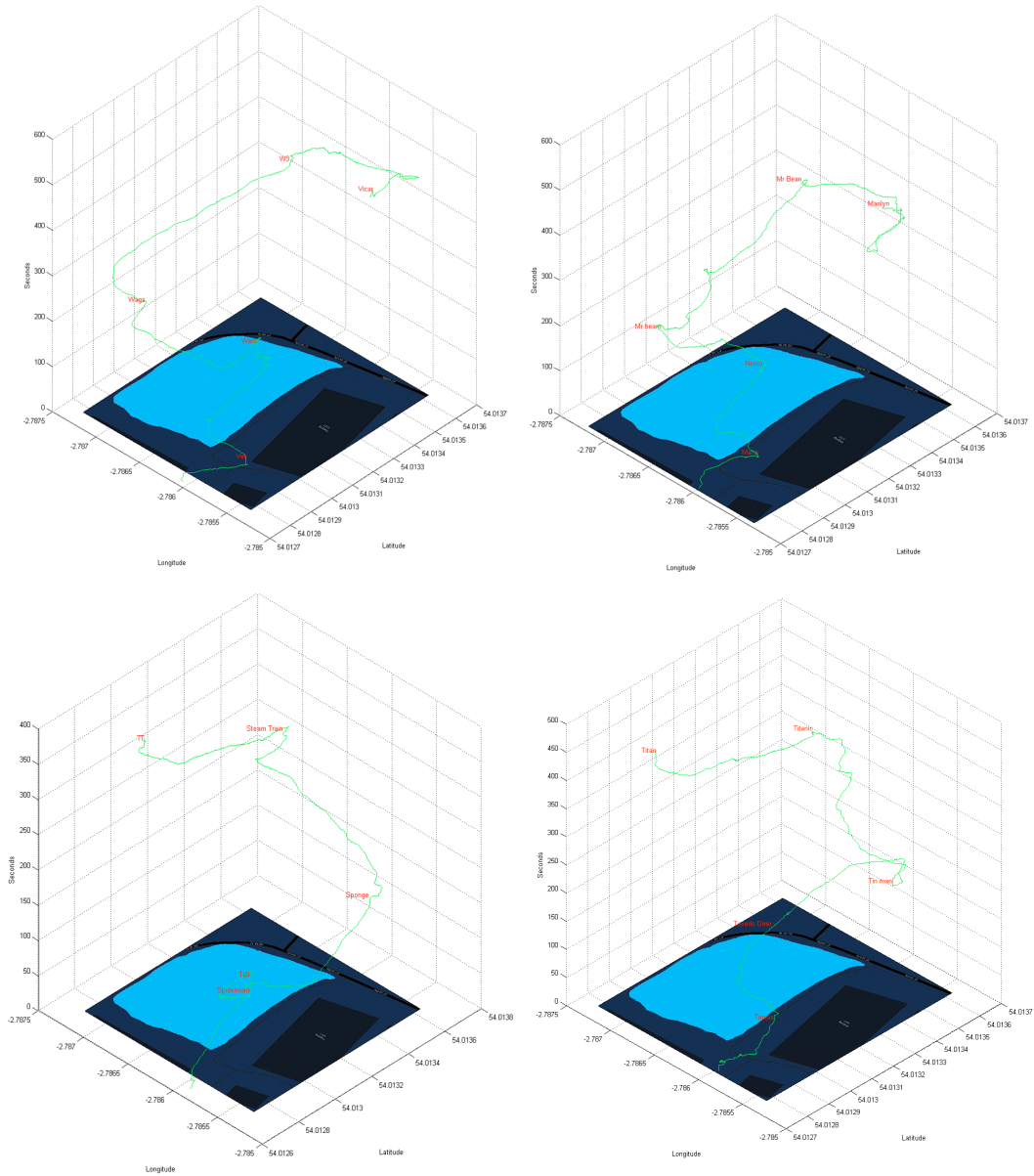


Figure 3: Space-Time Paths for Four Different Users.

However, this was not the only reason users rapidly changed direction as it was also observed to occur when a user holds the phone and does not use the screen for guidance instead relying on guesswork from the distance guide to estimate where the next scarecrow would be. These users often dropped their hand holding the phone to their side and did not concentrate on keeping the closest scarecrow front and centre on the screen. This may have been a result of these users experience when navigating using traditional paper maps although this could not be verified from the data captured during these trials and would require further studies.

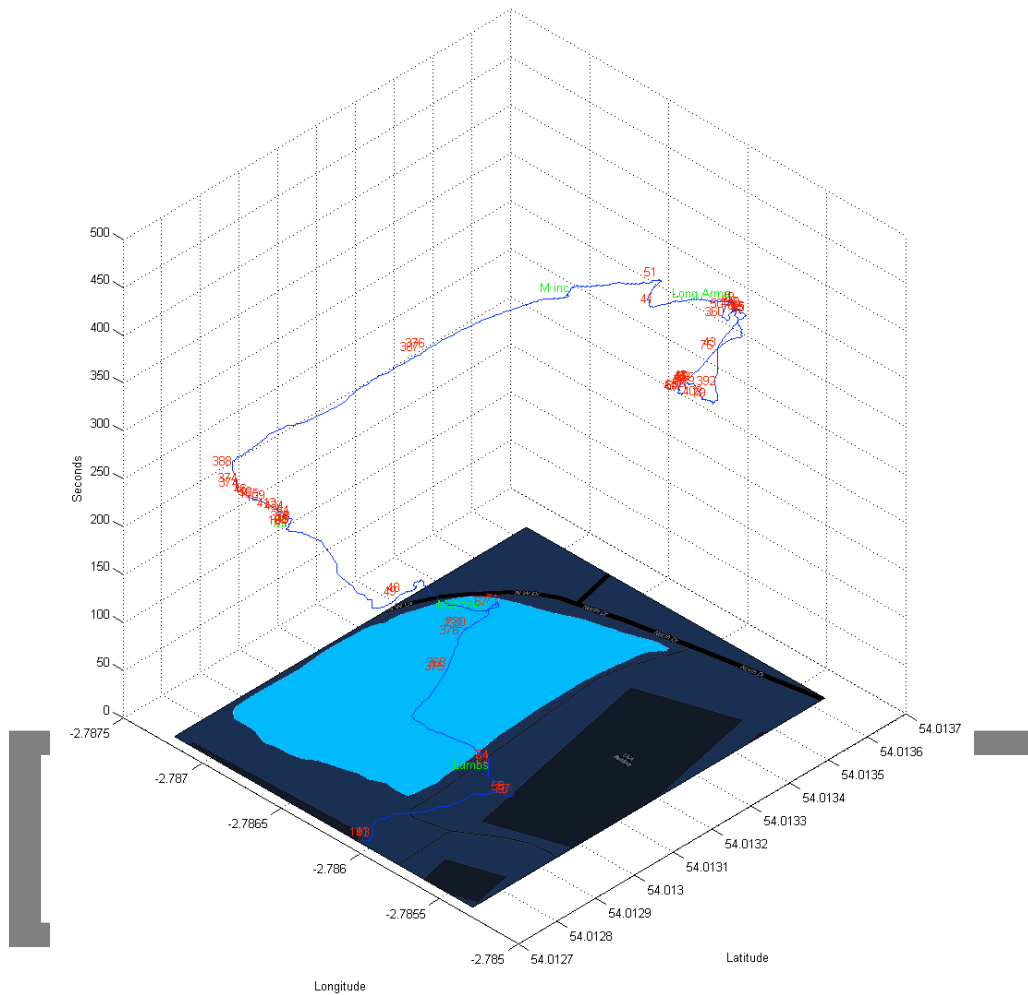


Figure 3: Space-Time Including Points of Significant Bearing Change

CONCLUSION

Arguably, many current AR applications utilise AR as an interesting novelty presented alongside existing functionality and failing to address the challenge of designing new affordances that AR only operation requires. In the paper we have considered the challenge of designing for AR only navigation through the creation of a playful mobile AR POI application created for a local village scarecrow festival.

The current design has been evaluated using a combination of space-time paths and direct observation and reveal that the design approaches for providing distance perspective allows users to successfully navigate s given space without too much difficulty. This has clear implications for designers of such interfaces particularly in relation to the how the FOV is represented on the screen in relation to the users distance from a particular point.

Currently, the application does not address the challenge of encouraging or enabling long-term use, as its function is primarily one of raising awareness of the scarecrow festival rather than community building around the activity. If this was to become the focus then additional features such as: users being able to add their own scarecrows, tasks

around specific groups i.e. all scarecrows from a particular place or year, likes, comments, etc could be used, but this would reduce the prominence of Wray.

Overall, we would argue that AR is a useful approach for enabling users to interact within a mixed reality space and it is important for designers to consider carefully how it can be used as the primary mode of interaction rather than as a novelty as highlighted through the design of the scARecrow Time Machine application presented in this paper.

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ENDNOTES

¹ Wray, Lancashire, UK.

² Engineering and Physical Research Council in the UK

³ www.google.com/glass/start/

⁴ www.layar.com

⁵ www.wikitude.com

⁶ <https://itunes.apple.com/gb/app/scarecrow-time-machine/id640062000?mt=8>

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