Augmenting the Landscape Scene: Students as participatory evaluators of mobile geospatial technologies

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Abstract

This paper provides a two-phase study to compare alternative techniques for augmenting landscape scenes on geography fieldtrips. The techniques were: a pre-prepared acetate overlay; a custom-designed mobile field guide; a locative media app on a smartphone; a virtual globe on a tablet PC; a head-mounted virtual reality display, and a geo-wand style mobile app. In one field exercise the first five techniques were compared through analysis of interviews and student video diaries, combined with direct observation. This identified a particular challenge of how to direct user attention correctly to relevant information in the field of view. To explore this issue in more detail, a second field exercise deployed 'Zapp', a bespoke geo-wand-style app capable of retrieving information about distant landscape features. This was evaluated using first-person video and spatial logging of in-field interactions. This paper reflects upon the relative merits of these approaches and highlights particular challenges of using technology to mimic a human field guide in pointing out specific aspects of the landscape scene. We also explore the role of students acting as design informants and research co-participants, which can be mutually beneficial in promoting a critical appreciation of the role of technology to support learning about the landscape.

Keywords: mobile geospatial computing, location-aware mobile computing, augmented reality, mobile visitor guides, fieldwork, critical incident analysis

1. Introduction

A fundamental part of human learning is people's ability to make sense of their surroundings and then apply this new knowledge for future action. Mobile technologies enable reflection in the field through the use of on-board sensors such as camera, voice recorder, positioning device, and compass, in addition to internet access. However, there is a distinction to be made between supplying rich media that is relevant to where the user is, and attempting to replicate a human field guide, with their physical gestures such as pointing to a location, so as to help that user associate information with particular parts of the landscape. This paper focusses on the latter by considering a range of approaches to augmenting the landscape scene in ways that help people make more direct associations between descriptive media and the parts of the landscape to which that media relates. The emphasis is on exploring techniques that can provide information on the landscape scene while a person is in the field rather than developing a virtual field course (Dykes, Moore & Wood, 1999; McMorrow, 2005) designed to provide information in the classroom before and after activities in the field.

Locative media is the general concept of delivering media via a mobile device, based upon physical movement through space, using a variety of locational triggers. In very small spaces, RFID tags and a wireless network can be used (Hwang, Shi, & Chu, 2011). In larger outdoor spaces GPS is normally used to locate the user. Media can relate to physical processes occurring in a place, such as photosynthesis as in the 'Ambient Wood' project (Rogers et al., 2004) but can also form instructions for taking physical measurements as in the case of the EcoMOBILE project (Kamarainen et al., 2013). In the case of Squire and Klopfer (2007) a system for taking virtual measurements was developed as part of a simulation related to contaminated groundwater.

In some cases a confined space is used to navigate through media relating to a much larger landscape, for example the sights and sounds of an African Savannah landscape were explored using GPS-enabled mobile devices around a playing field measuring 100m x 50m (Facer et al., 2004). Outdoor spaces of a similar size on a college campus were used in the context of geoscience education to allow students to explore the geological history of the Grand Canyon through physical movement outdoors (Bursztyn, Walker, Shelton, & Pederson, 2017). The same could be said for exploring the landscape through geocaching, which has been seen to promote shared learning experiences (Clough, 2010), although information and objects hidden in caches do not always relate to their specific locality.

Many applications of mobile technology support the benefits of acquiring spatial knowledge through fieldwork, which is considered important for integrating observations onto a common frame of reference (Ishikawa and Kastens, 2005). This is exemplified by Gentile et. al's investigation (2007) into collaborative experiences of urban environments, and also projects looking at data capture strategies (Clegg et al., 2006; Pascoe, Ryan, & Morse, 2000). Where technology is being used to help the user learn about the landscape then the role of a human guide could be replicated. Even the use of a map can be greatly enhanced by local expert knowledge (Brown and Perry, 2002) and indeed much research interest has focussed on the development of navigational aids for visitors (Kenteris, Gavalas, & Economou, 2010; Kray, Baus, & Cheverst, 2005) and understanding interactions between human, device and environment (Li and Longley, 2006; Li and Willis, 2006).

The focus of this paper is twofold: firstly, we use a two-phase study to analyse and reflect upon six different approaches for using technology to augment the landscape scene, in order to mimic a human field guide, through two separate field exercises. Secondly, we explore the role of geography fieldtrip students as design informants and co-researchers in the planning and evaluation of these technologies. Hence, they act in a different role to most fieldwork students, where typically they would engage in fieldwork to learn more about the landscape itself. In the case of this study their role was designed to engage them in metacognitive activities relating to fieldwork (i.e. learning how to learn), with the different technologies acting as 'boundary objects' (Adams, FitzGerald, & Priestnall, 2013) to facilitate discussion around geospatial technologies when used in the context of augmenting the user's surroundings. Boundary objects, defined by Star and Griesemer (1989), refer to physical objects than inhabit multiple social worlds and can reflect different points of view or different meanings to different stakeholders. For this study, we considered geospatial technologies as boundary objects, as our students have different levels of familiarity and confidence in using mobile technology, largely drawn from their past experiences with, and ownership of, personal mobile devices. We report findings from two separate field exercises on the same module, called 'Mobile and Field GIS', featuring a mix of third year undergraduate and taught postgraduate students from a UK university.

2. Issues and challenges of using technology to enhance understanding of the landscape scene

Approaches to supplying visitors with information related to the local area have been reviewed by Grün, Pröll, Werthner, & Retschitzegger (2008), with particular challenges being identified in accommodating different user requirements (Ardissono, Goy, Petrone, Segnan, & Torasso, 2002; Kaasinen, 2003; Pyo, 2005). The mScape platform demonstrated how visitor experiences could be created easily using location-based media defined by trigger zones (Stenton et al., 2007). The size of trigger zone and accuracy of positioning could influence whether information was supplied close to the target location, or not (Randell, Geelhoed, Dix, & Muller, 2006) which in some cases resulted in an unsatisfactory user experience. Often the supply of location-based multimedia aims to provide rich information generally relevant to a location but not necessarily mapped on to elements of the scene, for example in promoting engagement and learning about the history of archaeological sites (Efstathiou, Kyza, & Georgiou, 2018).

Attempting to understand and model how people associate locative media with their current situation and surroundings is a particular challenge (Bettini et al., 2010). Many studies of spatial context have been related to Location Based Services, defining automated contextual search strategies that suggest places of interest which are nearby and also geographically relevant in some way (Raper, 2007; Reichenbacher, 2009). There have been a few attempts to explore search filters other than proximity, for example showing information relevant to the area that could be visited within a certain timeframe, such as the WebPark recreational application (Mountain and MacFarlane, 2007). One filter discussed but not implemented in WebPark was the area visible to the user, although other studies have used the region from which a viewer can see a point of interest as a trigger for delivering information about that feature (Møller-Jensen and Egler Hansen, 2007; Bartie, Mills, & Kingham, 2008).

One specific capability of the human field guide to ensure the information provided is relevant, is to physically point things out in the landscape scene. Attempts to mimic this using a mobile device have exploited on-board sensors including the digital compass to create 'geowands', by intersecting a directional vector from the user's device with discrete objects in a spatial database (Carswell, Gardiner, & Yin, 2010). An alternative approach is to overlay digital information onto the scene using some form of Augmented Reality (AR). AR has been demonstrated to be an effective tool in education using physical markers (such as QR codes) placed in books or on other objects to trigger multimedia, for example using codes printed on shirts worn by instructors in the marine ecology game described by Lu and Liu (2015). The effectiveness of in-class marker-based AR to help students understand contour maps was demonstrated by Carbonell, Saorín Pérez, & De la Torre Cantero (2018) by revealing an equivalent 3D block diagram through a marker placed to one side.

Physical markers can also be used in outdoor environments to control the exact placement of rich media, as shown in the ecological game developed by Hwang, Po-Han, Chi-Chang, & Nien-Ting (2016). Clearly, a disadvantage of this technique is the need to generate and place the actual markers. An alternative is to use patterns in the visual scene as the markers, termed 'auras', for example using images of parts of an artwork (Clini, Frontoni, Quattrini, & Pierdicca, 2014) or physical exhibits (Sommerauer and Müller, 2014) as triggers for multimedia. This can be applied to outdoor scenes, as with the example of a sculpture park in Bower, Howe, McCredie, Robinson, & Grover (2014) although it relies on authoring experiences based upon visually distinct objects rather than continuous landscape scenes.

AR techniques that do not rely on recognising elements of the visual scene can utilise both position and inertial sensors to match digital information onto the visual scene. Jamali, Shiratuddin & Wong (2014) provide an overview of such technologies including the development of mobile AR which can exploit magnetometer, accelerometer and gyroscope sensors to place digital content over the real world scene via the device's camera view. Attempting to overlay digital information onto real world objects using just the sensors in a mobile device can be difficult, however, and mismatches can lead to confusion in the user experience. Wither, Tsai & Azuma (2011) proposed an alternative in 'indirect augmented reality' where digital content was merged with panoramic images of the real-world scene which were then viewed in the field as geolocated media. This allowed digital content to be merged precisely with the images of the scene rather than attempting to match that content in real-time through the camera view of the device. Annotating images of the present day scene, or reconstructions of past or future versions of that scene, and delivering these as locative media, is a technique that was explored during the development of media for use within this study.

Given the diversity of approaches for augmenting someone's experience of the landscape around them, there is a need to evaluate these critically and ensure that the digital tools enhance fieldwork rather than in any way seek to replace it (McCauley, 2017).

3. Comparison of techniques for augmenting the landscape scene

3.1 Design of the field studies

We employed a qualitative approach to evaluate the users' experiences of the technologies, and the broader challenge of understanding how they make connections between information on the device and elements of the surrounding landscape. This contrasts with other approaches for user experience (UX) studies, which often utilise quantitative approaches such as Brookes' System Usability Scale (SUS) (Brooke, 1996). A large number of UX studies (which many researchers consider usability to be subsumed by) utilise questionnaires or surveys. However, from a meta-study carried out by Arnold et al (2010), many of these tools have not been tested for validity and reliability, and are open to misuse. They also tend to collect data, and report on results, from individuals, not groups. The value of using groups to report on usability is seen to be vital, given the current popularity of online communities, social networking and collaborative software. In addition, using group evaluations helps us to identify development needs for group methods. Arnold et al. also state that it is important to collect UX data in authentic situations, i.e. in genuine contexts of use, and that field trials provide much more realistic and reliable data than laboratory settings. With these issues in mind, we designed the research to involve students as participatory evaluators, with the work carried out in groups, in a field situation. This also allowed for a very open approach in which participants could use their own words to express their experiences, rather than pre-defined and potentially limiting existing UX instruments. The context for the two-phase study was a four-day residential field-trip module called 'Mobile and Field GIS', which enabled students to explore the use of digital geographic information in the field using a range of mobile devices and survey equipment. The students were a mix of third year geography undergraduates and MSc in GIS taught postgraduates (comprising an age range of between 20-23 years old), all of whom had undertaken a pre-requisite Geographical Information Science module. The first phase featured a comparison of five different techniques for augmenting landscape carried out with 30 students (25 undergraduate students and 5 postgraduate MSc students, consisting overall of 17 males and 13 females). A second phase with 20 students (16 undergraduate, 4 postgraduate students; 14 males and 6 females) ran two years later and featured a bespoke geowand style app called Zapp. The study site was the area around Keswick in the English Lake District, Cumbria, UK, an attractive upland environment popular with tourists and walkers. The area contains a fell (or mountain) called Cat Bells which offers panoramic views of the northern Lake District including the water body Derwentwater.

Students were given a general introduction relating to the geographic area and their assignment, which for both phases of the study was to evaluate technology-assisted approaches to augmenting the landscape scene around them. Students had to plan a route around the study area to include vantage points with distant and varied views. They had several hours in the field centre to familiarise themselves with a number of techniques that they would use to augment views along that route with information related to landscape history. They then had to assess the degree to which the various techniques helped to provide useful information about parts of the landscape scene. From the student's perspective, the learning objectives of the exercise focussed on developing a critical awareness of the degree to which technology could help augment their experience of the surrounding landscape.

3.2 Techniques

In the first phase of the study, each group was able to utilise five approaches to augmenting landscape. No prior experience of using these techniques was required. The techniques varied enormously in terms of the technological sophistication, the size and nature of device, the mode of user interaction, the use of audio, and the way in which information was represented. All techniques featured content relating to the geological and glacial history of the landscape to provide a basis for comparison, although the locative media app allowed users to explore additional content related to cultural heritage, given that such easy authoring was seen as an important capability of this technique. Another feature common to all techniques was that any digital data used in the field was cached locally on the devices, to remove problems with cellular network connectivity, which was known to be unreliable across the study area. In the second phase of the study the students used Zapp, an app which allowed users to retrieve information about the landscape scene, at any point, by targeting parts of the landscape through the camera view of their smartphone.

The following sections describe each of the techniques used, firstly the five techniques used during the first phase and then the Zapp app which was the focus of the second phase.

Technique 1. Landscape reconstructions on acetate

This technique involves holding acetates up to the landscape view at pre-determined viewpoints and orientations, attempting to match the translucent printed perspective views (derived from a Digital Terrain Model (DTM)) to the real scene. The printed views contained representations of the existing terrain augmented with geological information and landscape reconstructions such as ice glaciers. This technique proved successful on field trips for many years and is described in detail in Priestnall (2009). It was included in the exercise to offer a low-tech benchmark against which digital techniques could be compared. In the field centre students chose three viewpoints from which they rendered and printed perspective views using Bryce CAD software containing the DTM, image drapes and an additional textured DTM representing a glacial reconstruction. Further annotation, such as the names of mountain peaks, could be added to the basic landscape views as required. In the field the location of each view was reached with the aid of a handheld GPS if necessary, the acetates were held up and attempts were made to match the scene (Fig. 1).

Figure. 1. Computer-generated acetate showing glacial reconstruction (left), and in use in the field (right)

Technique 2. Landscape reconstructions via a location-aware custom app (GeoMoLe)

The GeoMoLe (Geographic Mobile Learning) app allowed the images that were printed onto acetate to be displayed automatically in the field via a GPS-enabled mobile device (see Priestnall and Polmear, 2006). The images from the acetates were uploaded to a mobile device, with the user entering the coordinates of each viewpoint in turn. In the field, the mobile device displayed the current user location and the viewpoint locations as icons over a basemap. Once within a threshold distance of a viewpoint location, the relevant image was displayed. The user could then switch between the perspective view of the present-day digital landscape model, the glacial reconstruction, and the geological overlay, the latter having an interactive legend. The user could sketch over any image displayed and save the result to a file. An additional experimental feature of GeoMoLe was the use of audio clips describing certain landscape features that should be visible from the user's current location. The audio files were based upon verbal descriptions of landscape features recorded during a previous geography fieldtrip to that area. If the user selected the audio option at a waypoint the app would play audio clips for features deemed visible according to visibility maps stored on the device that had been created earlier in the ArcGIS (Geographical Information System) software. A graphical summary of these features is shown in Fig. 2.

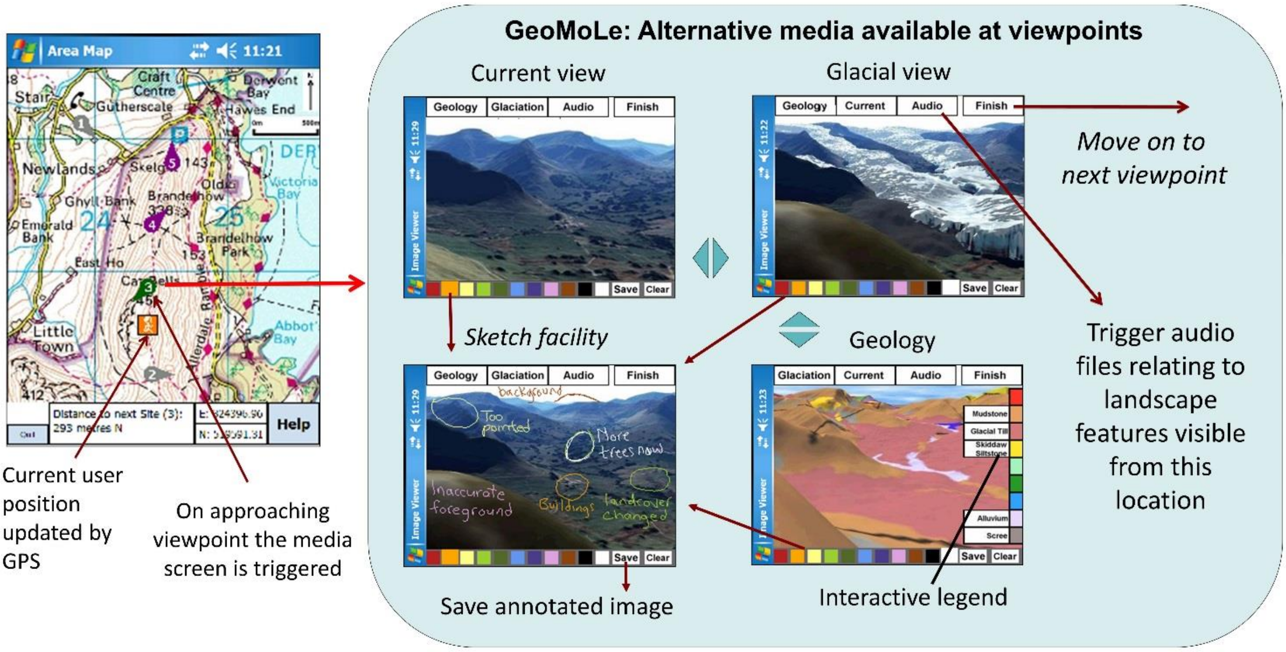

Figure. 2. Screenshots from the GeoMoLe application

Technique 3. Locative media app (mScape)

The mScape locative media app running on a GPS-enabled mobile device delivered digital media to a user automatically as they entered pre-determined regions on the ground. Unlike GeoMoLe, which only displayed sets of user-generated images at specific viewpoints, and any audio relevant from those points, mScape offered a full authoring environment to allow users to associate any piece of media with any region they defined on the map. The students as authors had to decide which pieces of descriptive media, either from a pre-created library or of their own design, would support learning about the landscape and also had to define the position, shape and size of the zones within which the media would be triggered in the field. This presented an opportunity to address broader issues relating to how media worked effectively in engaging people with specific locations or phenomena in the landscape. In the field, the user's location was displayed on a map backdrop as they walked through the landscape, then upon entering trigger regions, media was displayed, or played, and the user could then judge whether it was useful in helping them understand part of the landscape scene around them. Fig. 3 illustrates a screenshot from the authoring environment annotated with a media file.

Figure. 3. Example of authoring media for triggering in the field using the mScape platform

Technique 4: Google Earth on a tablet

Google Earth on a tablet PC offers the same functionality and interactivity as the desktop equivalent, but with the added feature of using the user's location from GPS input to centre the viewpoint. The user can adjust the tilt and orientation of the viewpoint, switch between layers of data overlaid onto the terrain model, and add placemarks of interest. Google Earth differs from the previous methods in that the user can browse a continuous virtual model of the area rather than relying on graphical snapshots from various pre-defined viewpoints. With the aid of GPS, the user can position the Google Earth view to match the real scene through use of the regular pan and rotate interface tools, albeit with a stylus rather than a mouse. The terrain data and aerial imagery were cached for use offline and additional map overlays allowed students to emulate views created using the other techniques, for example the geology map drape shown in Fig. 4.

Figure. 4. Geology map draped over the terrain in Google Earth (left) and the same data visualised in the field (right)

Technique 5: Head-Mounted Display

This technique allows the user to view a virtual landscape in real-time as they move their head, using GPS and an inertial device to automatically control the viewpoint within the model. In this exercise the virtual landscape featured the modern day terrain along with a reconstruction of the ice age features such as valley glaciers, and so was comparable to the ice age views created for use in most of the other techniques. The real-time rendering software was based upon the GeoVisionary visualisation system developed by Virtalis in collaboration with the British Geological Survey. The graphical display was provided through a Head-Mounted Display (HMD), which fills most of the user's central field of vision. The position within the virtual model is given by the Bluetooth connected GPS on the outside of the user's backpack, and the direction of view within the model is controlled in real-time by an inertial device on the user's head. A wireless gaming controller could be used to control various aspects of the display in the HMD via drop down menu bars. The components of this system can be seen in Fig. 5, and are described in more detail in Jarvis, Priestnall, Polmear, & Li (2008).

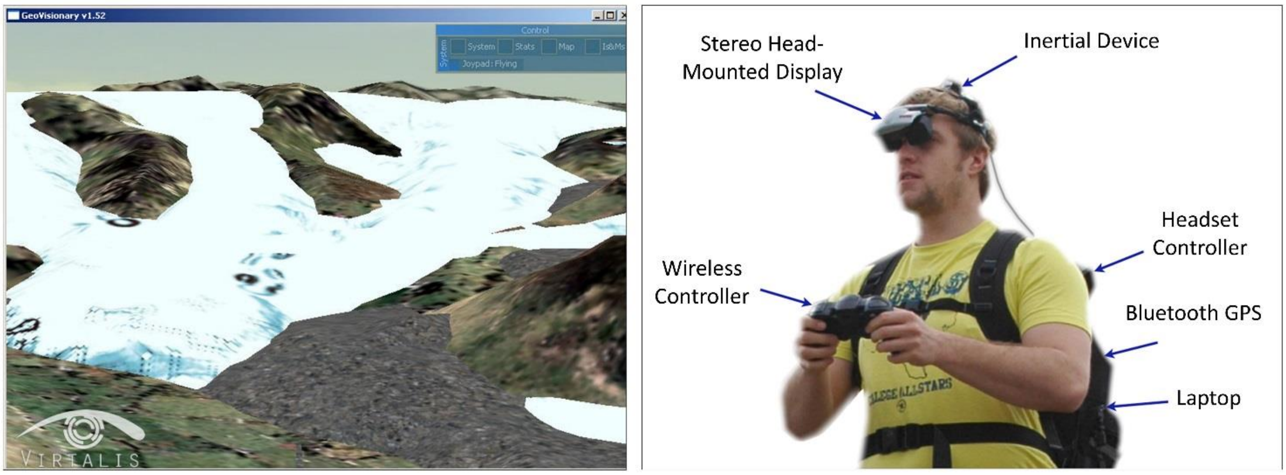

Figure. 5. Screenshot of the user's view through the Head-Mounted Display (left) and the system components (right)

Technique 6: Geo-wand app (Zapp)

Zapp (Meek, Priestnall, & Goulding, 2013) was designed to allow users to hold their smartphone up to the landscape as if taking a photograph and use a crosshair over the camera view as a target for either tagging a remote point on the landscape or retrieving information about that point. The app calculated a 3D vector projecting at right angles from the centre of the device, in the direction the camera was pointing, and intersected this with a gridded surface elevation model on the device to establish the grid coordinate of the point being targeted through the camera. It utilised a vector line of sight (LoS) algorithm (Fisher, 1993) with inputs from the mobile device's position, tilt and orientation sensors. When operating in retrieval mode, features of interest in the landscape were encoded in a similar way as trigger zones in mScape, but here the media was initiated when the user targeted that area remotely rather than walking into the area. The user did not see the target areas on the display but when the crosshair turned from blue to green the user knew that it was targeting a feature of interest which had media associated with it. Fig. 6 summarises the form of retrieval enabled by Zapp.

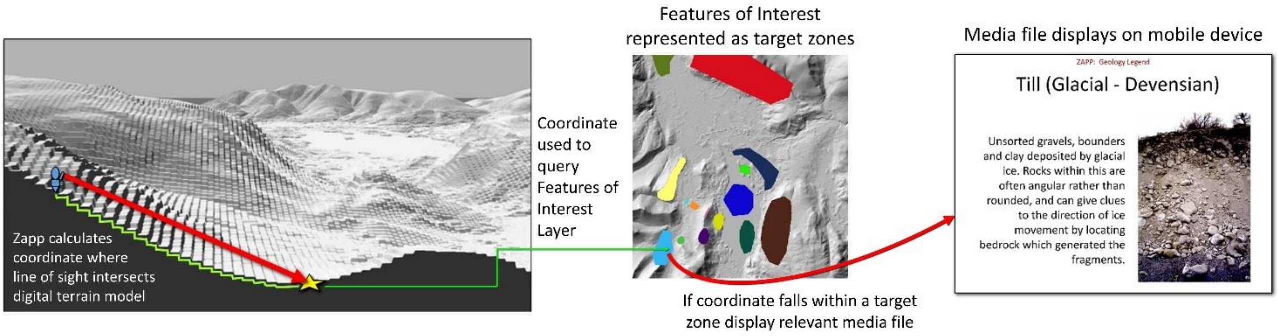

Figure 6. The Zapp application: Intersecting line of sight with a continuous model of the landscape

3.3 Methods of evaluation

A wholly qualitative approach was utilised, comprising of researcher observations both in the field and via student presentations in the evening; analysis of student video diaries; and analysis of transcripts from a focus group undertaken after the first fieldtrip. Zapp was evaluated using researcher observations, analysis of student video diaries, and first-person 'spy glass' video footage.

Research team observations.

These were text-based observations noted by the research team in relation to in-field student behaviours, interactions (both interpersonal and with the technologies) and feedback provided by the students. This latter aspect includes student presentations where they were asked to give their impressions of the different approaches. In-field observations included ad-hoc discussions with student groups at various locations around the landscape. The research team was comprised of five people: the module convenor (project lead); two further academic colleagues with expertise in mobile learning (project co-investigators, responsible for co-designing the research, overseeing the evaluation aspects and helping collect and analyse participant data); a research associate (responsible for distributing equipment, helping students with technical problems, collecting/collating research data) and a PhD student (lead developer for Zapp and collection/analysis of data).

Focus group.

A one hour focus group was conducted with nine participants approximately two weeks after the first field trip. The focus group consisted of seven undergraduate (six males, one female) and two postgraduate (MSc) students (one male, one female), Questions were drafted beforehand and used as prompts for asking the students about their experiences. The session was audio-recorded and a transcript of the audio was then analysed to elicit key themes which are described in Section 3.4.2.

Video diaries.

Students were asked to record their own video diaries of their experiences in using the different technologies, in part to aid their own aforementioned presentations but also as a way to collect a rich data set relating to the evaluation of these approaches. Approximately 24 hours of student-created video was obtained and subsequently analysed by the researchers. During the second phase of the study one group of students was also given head-mounted 'spy glasses' to give a first-person perspective on the interaction with the device and the landscape.

Our approach to video analysis was based upon the Critical Incident Technique (Flannigan, 1954). These incidents often constitute events where something either goes unexpectedly well (breakthroughs), or badly (breakdowns) (Carroll, Koenemann-Belliveau, Rosson, & Singley, 1993). These incidents can then be used to inform the design of further iterations of the approach under investigation. In education, the technique has been adapted to uncover breakthroughs and breakdowns in teaching and learning activity which are then probed through retrospective interviews with the participants (Anastopoulou et al., 2008).

For this paper, the research team worked together to form a consensus on how to describe and categorise incidents extracted from the videos, each category being given a description that, along with examples, is presented in section 3.4.3. Some incidents recorded were quite explicit in the sense that students recognised issues as they occurred, others were more subtle and only emerged when the research team analysed the videos.

3.4 Findings from data analyses

We now describe the main findings from each of our data collection methods. However, it is worth noting that the curriculum context for this exercise meant that the students were generally more tolerant of complex or unreliable technologies than a typical user might be, so we must be careful not to generalise when making observations about usability and user interaction. The learning objectives for the students included an increased awareness of the issues and problems with these technologies, so they tended to persevere where a casual user would be more likely to give up. Whilst the student experience did reveal some expected problems and benefits of the techniques being used, some interesting and more subtle issues emerged. It should also be noted that although a degree of comparative analysis is implied by this study, the students themselves made no standardised comparison between the six different technologies – this was instead carried out by the research team, by triangulating findings from the different evaluation approaches.

3.4.1 Research team observations

The relative merits (or otherwise) of the different approaches revealed by both direct and indirect student feedback are summarised in Table 1.

Table 1. Summary of research team observations

Technology used:	Pros:	Cons:
Landscape reconstructions on acetate	Simple, easy to use format Information was easily visible Ability to easily swap focus from the acetate to the distant scene Having the horizon represented on the acetate offers a reliable frame of reference for matching additional content to the landscape scene Not reliant upon batteries	Lack of flexibility/dynamic updating or interactivity in terms of the content Did not work well in windy conditions (could be overcome by using frames for more sustained use)
Landscape reconstructions via location-aware custom app (GeoMoLe)	Generally acceptable in function and screen size Sketching facility was recognised as being particularly useful, as was the interactive legend Audio was very popular	Some instances of potential misinterpretation were observed, where students were looking at one geographical feature whilst listening to an audio description of another. Some stability issues were reported, in particular in relation to GPS positioning Some images proved difficult to see particularly when the device was used in bright sunlight
Locative media app (mScape)	The 'drag and drop' authoring interface was recognised as a powerful tool for producing customised experiences. The basic concept of location-triggered media proved easy to engage with using this technique The mScape application was robust and reliable	The repeated triggering of media when at the edge of a trigger zone proved confusing on occasions (though this could be prevented through additional coding) Occasions of incorrect associations being made were observed, where the student was looking at a different landscape feature to that being described The size and visibility of the device screen was a major problem
Google Earth on a Tablet PC	The large screen was a benefit Screen visibility in bright sunlight was slightly better than the smartphones being used for the previous two approaches The familiar Google Earth interface with switchable layers was popular	Stylus-based interaction proved extremely difficult. It was clear that this application, designed for the desktop, was not easily usable in an outdoor setting The default Google Earth view, featuring photo-draped landscape models, often resulted in a dark and indistinct display The battery life of the tablet proved a problem, made worse by the need to run a large screen at maximum brightness
Head Mounted Display	This was a popular technique, which proved effective in engaging the user with the graphical content being displayed Provided excellent visibility, due to the shielding effect of the glasses	The configuration featured many components, many wires, and was cumbersome both to set up and to carry around Initial set-up and alignment with magnetic North proved unreliable on many occasions

	Real-time orientation within the virtual model driven by the head-mounted inertial device proved intuitive	The equipment was heavy and not waterproof
Geo-wand app (Zapp)	Simple 'point and shoot' interface was intuitive Generally reliable in the field	Difficult to retrieve information for distant features which became very small targets when viewed obliquely through the small screen of the device

3.4.2 Focus group

The focus group recording was transcribed and then analysed. Issues were organised thematically into the following broad categories: the task in hand; usability and user-friendliness; problems faced by the students; and future technologies.

The task in hand

Students had a good recollection of the tasks they had been asked to engage with; they enjoyed the practical/hands-on aspects and the freedom to experiment with the devices, (e.g., experimenting with the size and placement of trigger regions, and deciding what media to associate with them).

Safety was a major concern, since the nature of the task meant users might be staring at a small screen rather than watching where they were walking. This also helped shape the students' ideas about how to improve future interactions with the devices.

Students said the amount of work they were asked to do was appropriate and they had sufficient time to do it. However, one downside was that, since one person in each group took responsibility for testing out one specific device, they were not able to engage much with the other devices. It was suggested that future course iterations could provide opportunities to allow the students to rotate between the devices.

Usability and user-friendliness

The HMD was felt to be obtrusive for the wearer and it was suggested it was important that end users did not feel conspicuous by technology visibility. It was also heavy, as was the ruggedized tablet, but the potential for use on smaller lighter devices was recognised. Students stated that the devices should work automatically and with minimal set-up required by the end user. One of the issues raised in the focus group was that "all the devices […] were always going wrong" and so this would have to be resolved before widespread adoption could occur. In particular, whilst the HMD worked well once in use at a location, the technology was only suited to specialist use by an individual user at the time.

Orientation was felt to be very important, with the use of directional audio mentioned as a possibility for orienting the user via the left/right speakers in headphones.

When mentioning personalisation, students considered both older and younger users, though interestingly seldom other age groups, i.e. people aged between 18-65 years. Children were seen as an important type of end-user, with a requirement for "some kind of interactivity", whereas the students were sceptical about the ability of older people to interact with the technology.

The students referred continually to the best solutions being the most simple and intuitive, such as the acetates. They suggested that the key to an effective experience was the additional information and overlays, or added value that could be provided to the user, but making it simple to use. It was generally agreed that this kind of technology adoption would be fostered by usability, simplicity and intuitive interfaces, both in the device and the application used to deliver the information. In these studies, just over

50% of students owned GPS-enabled mobile phones, with the remainder showing little interest in the capabilities of location-aware apps.

Problems faced by the students

Students mentioned how weather caused problems in the field: strong sunshine resulted in screen glare, whilst high winds made it difficult to hear audio delivered through in-built speakers without having to use headphones. Students also noted that the geolocated media was sometimes triggered at inopportune times, such as climbing halfway up a steep slope or when they had the devices in their pockets. This meant that not only did the media not relate directly to the scene in many cases but that the students did not realise it was playing, and could not always replay it. Students suggested that an audible alarm should be added to notify the user that they were at a geographical ‘trigger region’ and that a ‘replay’ function should be added.

The mScape trigger regions were particularly problematic. Setting a large radius would make the media more discoverable, particularly in open rural areas, but reduced the number of media trigger zones that could be fitted onto a particular part of the landscape. There were also issues with the media stopping playing when the user moved out of the trigger region, or stopping then replaying if the user went back into the trigger region.

Students were also unsure how much information to provide when designing their own media and were aware that too much may prove a distraction to many people.

Future technology

It was suggested that the HMD could be replaced by hi-tech sunglasses that would include some visualisation projection, so that users could both experience the augmentation and see the landscape, which would also be safer. However, some students mentioned that they did not find the visualisation on the head-mounted display to be appealing or relevant. It was felt that visualising past glacial landscapes could be achieved through a simple photograph rather than using an expensive and heavy piece of equipment to create an immersive experience.

One student mentioned being able to upload information in advance of a visit, possibly with user-generated content in addition to more ‘authoritative’ or ‘professionally-produced’ media. It was thought that personalisation could help manage the information being presented to users. In addition, it was suggested that organisations such as the National Trust could ask its visitors to create relevant content, such as trails or walks, for other visitors to use.

3.4.3 Analysis of in-field video

The videos were analysed using the critical incident technique, grouping incidents into themes as shown in Table 2, with quotations being transcribed from the audio track of the video.

Table 2. Categories of incidents extracted from the video diaries.

Theme	Category of incident	Description	Typical Example
Disjunction between base and field	Breakdown	This refers to differences between students’ expectations when they designed the media and what occurred in the field.	Students design their mScape experience in the lab which is then either out of sight or irrelevant in the field: *“Limitations of not knowing the area before making a map is that you cannot even see the car park anymore and its only just now that the phone has gone back to the map”*. With Zapp, distant features become relatively insignificant targets: “*Over here we are trying to pick up the tarn, or possibly*

			the hanging valleys and as you can see it registers the feature sometimes very briefly".
Environmental conditions	Breakdown	These breakdowns related to problems with wind, sunlight, or environmental noise.	The wind is too strong and the acetate cannot be held still so as to register with the landscape
Group dynamics	Breakdown	Issues related to group cohesion or dominance by one group member. This was particularly apparent when students were attempting to identify features using the technology.	When challenged to answer questions by an instructor, a student shows frustration and does not want to engage with the task, removing himself from the discussion: *"I don't even know where we b***** well are!"*
Hardware feature	Breakthrough and breakdown	Where the technology either performed well or caused issues, for example by crashing.	Sometimes the GPS on the devices failed for no visible reason: "*Well we're technically at site 1, but the umm, but it stopped updating quite a while ago, so we've got like no idea where it is*"
Learning in situ	Breakthrough	The focus was to evaluate technologies for engaging visitors with the landscape, but occasions where informal learning and reflection were observed were also of interest.	The student picks out a prominent landmark and then proceeds to use it a point of reference to understand the landscape: *"It's quite easy to see, there's a big pointy mountain ... it's easy to pick out on here" [points to the map] "From there you can work out the other ones around it."*
Prior student knowledge	Breakthrough	In this category a student, sometimes unknowingly, brought prior knowledge, as someone studying geology and interested in technology, into the field and used it to understand issues.	The student shows an interest in the content of the acetate rather than the pros and cons of the technology: *"It's quite good though, cause you can see over there where the glacier would have been."*
Technology capability	Breakthrough and breakdown	There were examples where the technology performed part of its purpose but was limited by the technology's capability, for example the lack of compass in mScape.	This is an extract from a conversation between three students having reached a point, trying to understand what they should be looking at: *S1: "I don't think it's got a compass in." S2: "You should be able to orient it using the map." S3: "Yeah, use the map, go back to basics."*
Technology design	Breakthrough and breakdown	Where the technology performed well from a hardware perspective, but one or more decisions made by the designers caused a breakthrough or breakdown.	Breakthrough: the acetate, which was highly rated by students for its size and simplicity: *S1: "What would you say was easier?" S2: "Without doubt it's the acetate, it's easier than the phone, its bigger, it's better laid out and its more clear to me, there's more detail. So I prefer the acetate personally."* Breakdown: where design aspects have been overlooked or not included: *"I can't really see where we're supposed to be going because the little running man is in the way!"* (student commenting on the 'You Are Here' graphic on GeoMoLe)
Technology workaround	Breakthrough and breakdown	Where students encountered a problem and adapted their behaviour accordingly	An example of this is where the tablet PC re-centred the screen on the student's current location every time it updated which meant that they tablet could not be used to explore the map as it would continuously re centre. The workaround was to remember their position and then turn off GPS and zoom in.
Serendipitous discovery	Breakthrough	Where trigger/target zones could reveal interesting information unexpectedly	Zapp: where a student scanning the scene for a large feature unexpectedly discovers a small one "*So we just found the waterfall, which is over there. I don't think we would have noticed it without the app*".

It can be seen from Table 2 that the meaning of the terms 'breakthrough' and 'breakdown' are contextually bound. Generally, a breakthrough occurs when a student's interaction with the technology, others in the group, or the technology itself, has a positive effect on the experience. Breakdowns also depend on context and generally are incidents where the technology or the activity functions in unexpected and unfavourable ways.

3.4.4 Spatial patterns of interaction

In the second phase of the study which featured Zapp, users could in theory interact with the app at any point in the landscape, so the video was useful in revealing some of the challenges they faced when attempting to find features that were known to have media associated with them, from different vantage points. Often such features became very small targets when viewed from a distance at oblique angles especially when seen through a small screen as seen in Fig. 7 where a student is attempting to target a 'hanging valley'.

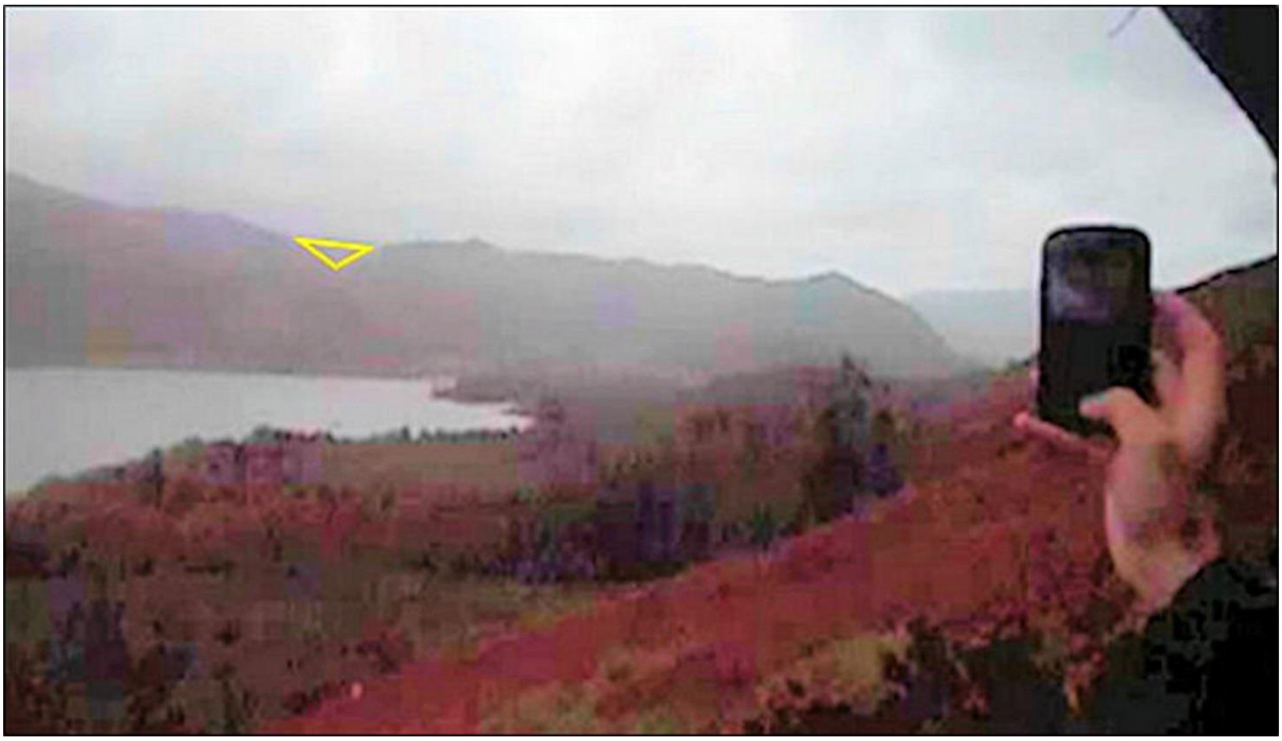

Figure 7. Difficulty with targeting distant objects at oblique angles

There was video evidence of user interactions with Zapp at various points during the exercise, but this did not show if users were interacting with Zapp continuously along the route or not. Whilst the techniques used during the first phase worked from predetermined waypoints the Zapp approach could be used from anywhere and so there was interest in exploring the spatial patterns of such interaction. Whilst the interaction patterns shown by the students would not necessarily represent those shown by other users, for example ramblers, it was useful to explore the spatial interaction patterns to establish the extent of 'free roaming' interaction. To this end, GPS traces and also the locations where Zapp was invoked were extracted from the devices. The sample rate for the GPS positioning was set to 15 seconds, which had proved adequate previously for discriminating speed of movement along this type of trail. Each group had just one device with Zapp loaded but of the five groups only three data logs were successfully recovered from the devices. Fig. 8 shows the density of GPS points for the three groups indicating hotspots along the route where the user was either moving very slowly, or had stopped altogether (in red), and where the user was moving relatively quickly (in yellow). Locations where the user chose to search for target zones within the landscape using Zapp are shown by black dots.

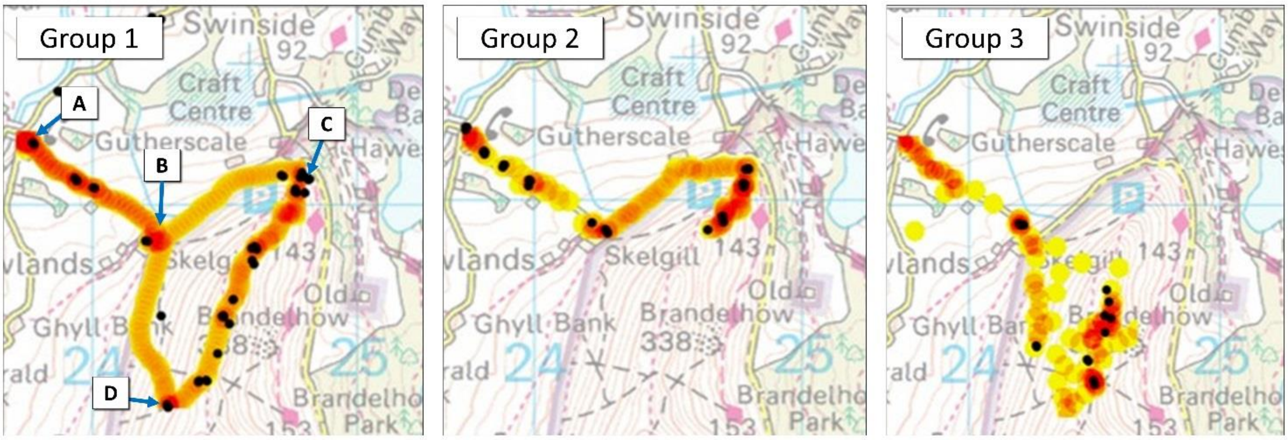

Figure 8. Spatial patterns of interaction with Zapp

Location A indicates the start and end of the trail, with location B marking a decision point where the trail splits. The segment connecting C and D follows a ridge and represents the highest part of the trail. It can be seen that interactions with Zapp occurred sporadically, often occurring in clusters coinciding with the red patches on the GPS trace indicating users stopped at certain points for some time to interact. The decision point in the trail appears to have been a common stopping point with the sections up to the start of the ridge being almost completely devoid of any interactions with Zapp. Clearly topography has a significant influence on interactions with many occurring along the ridge but it was evident that the change in vista promoted interactions for example with groups 1 and 2 who followed the trail from point B to C. Fig. 9 highlights the major change in vista occurring around point C by comparing viewsheds (maps of visibility) for two points along the trail separated by 100m. The large yellow area to the south east represents the opening up of a large vista overlooking Derwentwater and Borrowdale and with it new interest in the visual scene (the view in Fig. 7 was in this direction).

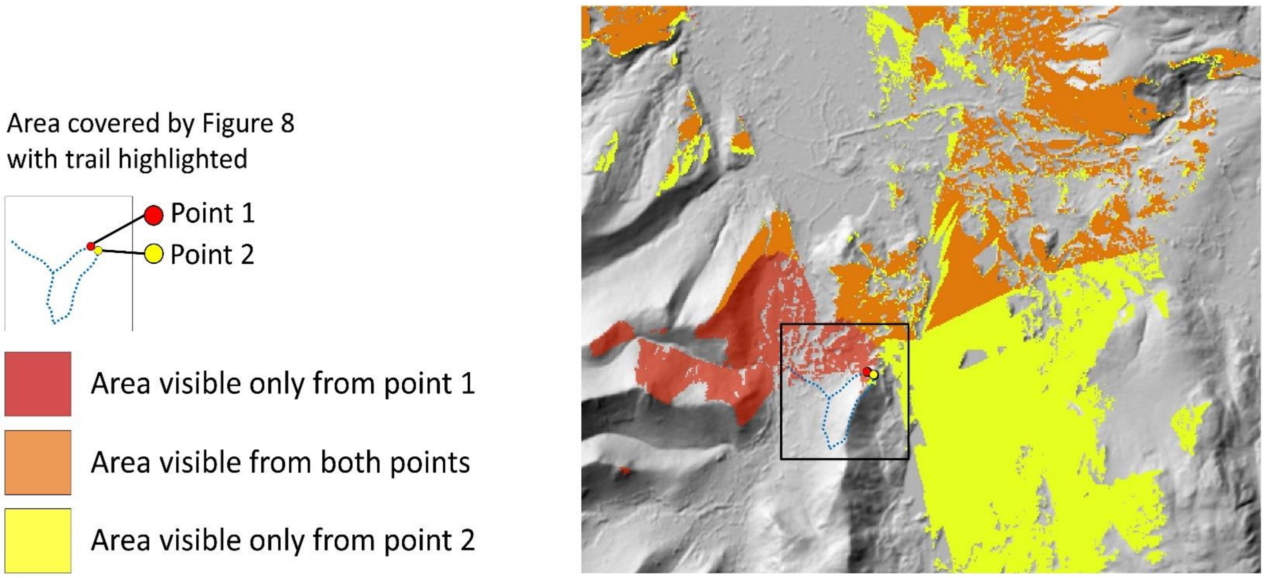

Figure 9 Example of change in vista when following the trail

4. Discussion

A number of findings have emerged, some of which could have been anticipated as general usability issues, but others are more subtle and have broader implications for the design and testing of certain aspects of mobile geospatial technology.

Simple added value

For all approaches it was clear that ease of use and simplicity of interaction design were extremely important. A recurring theme was the desire for 'simple added value' to the visitor experience and the acetate proved useful to maintain focus on the relationship between content, technology and the user experience. Given the experience students have with using commercial apps that are generally robust and well-designed one would expect some frustration with usability problems, as emerged during the focus group. However, given the pedagogical task, the students persisted in using the technologies even if they crashed or were not intuitive to use, whereas other end users would likely give up.

Usability of interface

Some design decisions made with simplicity and clarity in mind, such as the large 'running figure' icon to show the user's position in the GeoMole app, were distractions from the use of the underlying map as a navigational device. In the case of Google Earth on the tablet, the design was familiar but the stylus interface appeared to make normal interactions frustratingly difficult. In the case of the HMD, evaluation data revealed the exciting possibilities of real-time in-field virtual reality, such as the strength of visual immersion allowing the user to focus on the virtual content. It was also evident however that the equipment was cumbersome to set up and that there were problems with aligning the virtual model to reality. The focus group proved useful in that students were able to reflect later on the longer-term possibilities of some approaches like this, especially with the likely convergence and miniaturisation of the individual components involved. This approach also prompted questions of safety which related to most of the other techniques, in that users recognised the demands made on their visual attention, in situations where walking was difficult. It should be acknowledged that the six techniques may be influenced differently by changes in environmental conditions such as sun, wind, and rain. Screen visibility in bright light affected the techniques that used mobile device screens, the acetates became unusable in windy conditions, whereas rain would disrupt the use of the HMD equipment. Also there is potential for a future study to consider how a range of techniques might compare when augmenting urban landscape scenes. Such environments would inevitably present different factors which would influence the perceived effectiveness of a particular technique, for example users may feel more self-conscious using certain approaches such as acetates or HMDs.

Orientation in the landscape

Many remarks heard in the videos related to users struggling to orientate themselves with the landscape. In the broader context of location-based services and the emerging market for AR browsers, the filtering of geographic information according to what is relevant in the landscape context is a major research challenge in itself. During this exercise the majority of media being used on the devices had been deliberately placed with a view to being relevant from a particular observer position, yet even here the process of associating these media with the aspects of the real scene to which they related proved difficult. Occasionally this was exacerbated by media being delivered in the wrong place caused by errors in GPS positioning or by the size and position of the trigger zone being used. Generally however it revealed a major challenge in attempting to replicate one of the functions of a human field guide, to point something out in the scene, which is often achieved through a combination of gesture and speech. This could be termed *spatial deixis* and from the perspective of human computer interaction has become relevant in attempting to model human spatial cognition in relation to the design of robots (Hato, Satake, Kanda, Imai, & Hagita, 2010).

Audio guidance

Although there was a heavy reliance upon visual augmentation during the studies, there was also an opportunity to explore audio. Standalone audio descriptions of features in the landscape are open to as much misinterpretation as graphical media, as seen in video evidence where a group looked at one feature whilst listening to audio describing another. Audio may, however, have a powerful role in guiding the attention of the user to points, or areas, of interest in the landscape. In the context of a field trip this has potential to allow for more self-guided in-field learning rather than the one-to-many model often used, where one instructor attempts to describe various aspects of the surrounding landscape to a large group. In such circumstances it can be difficult for students to hear the instructor, for example if it is windy, or to be able to see where they are pointing to in the landscape. Self-guided learning about the landscape has the potential to allow students to utilise a wide range of media themselves in the direct context of the landscape scene, which in fact offers capabilities beyond those achievable by a human field guide unaided. Moreno and Mayer (1999) described the spatial-contiguity effect of closely associating text and images in enhancing learning and this benefit of multimedia learning could be made to work effectively in the field to help to explain elements of the visual scene.

Pointing at landscape features

The Zapp app demonstrated that it is technically possible to augment landscape directly and attempt to mimic the act of pointing to something in the landscape, though major research challenges remain. As with the creation of locative media trigger zones so there are issues with defining the target zones used by Zapp. Video evidence revealed the problem of trying to target areas of interest even when the user knew they should be visible due in part to the areas being so small when targeted through the screen of a mobile device. Even when target areas were large in map terms they would often have very little presence on the screen due to being viewed at an oblique angle often from a great distance. On occasions this resulted in the serendipitous discovery of information which was seen as a positive in the context of a geoscience fieldtrip, encouraging students to scan the landscape carefully, but it may be less useful for mobile visitor guides where a more consistent and reliable user experience is required.

Sensor inaccuracies

The open rural environment used in this study presented relatively few issues in relation to GPS accuracies but had the study been undertaken in an urban area then there may have been issues with positioning accuracy in urban canyons resulting in media being triggered at greater distances from the intended locations with implications for the user experience. Difficulties in targeting areas of interest with Zapp were compounded by inaccuracies in the sensors underpinning the intersection algorithm and also the reliance upon the user maintaining a steady hand (Meek, et al., 2013). The students had some understanding of how Zapp was working but for casual users or members of the public it is likely that they may have much higher expectations of the targeting capability of Zapp. These issues have relevance to the way AR browsers attempt to portray spatial information via an oblique perspective view on a mobile device screen often relying upon the same sensors used by Zapp.

Importance of waypoints

Whilst an approach like Zapp offered the freedom to search for information in the landscape at any time it was clear that users were unlikely to want to do this. When used in the context of walking a trail there was evidence that decision points, elevated vantage points and changes in vista tended to prompt interaction. One model of interaction to be explored in the future would be to allow Zapp-like interaction from a selection of vantage points, or waypoints along a trail, as with a human visitor guide, which would also allow target zones to be designed more effectively to work from a limited number of observer positions.

Students as design informants

The methodological aspects of this study have themselves offered interesting avenues for ongoing research, and have informed the design of subsequent field exercises focussing on the critical evaluation of different geospatial technologies. In addition, the role of students as design informants (Scaife, Rogers, Aldrich, & Davies, 1997) meant that they were not simply being used to test the effectiveness of a particular technique to support their learning about landscape, but were fully engaged in the process of exploring technical and usability issues with the technologies being used. Given the pedagogic context, they almost certainly persevered with technical and usability issues much more than other types of users, so it is likely that the design and usability issues identified could be even more significant for informal learning about the landscape in the field.

5. Conclusions

A broad range of techniques has been used in the context of two geospatial technology field trip exercises, engaging students as design informants to explore the challenge of augmenting the landscape scene. The pedagogical focus of the study was unusual, but ultimately successful, in that it aimed to develop a critical awareness of the degree to which technology can help us learn about our surroundings, rather than actually learning about the landscape itself. An aim from both a technical and design perspective was to mimic the human field guide in pointing things out in the landscape scene rather than just deliver information related to the immediate location of the user. Techniques to deliver multimedia using locational trigger zones have been shown to have a problem with directing the attention of the user to the specific part of the landscape scene to which the media relates. This is influenced by whether the design of the media reflects the exact view the user sees at the point it is triggered, and this can be disrupted a combination of positioning errors and the spatial extent of the trigger zone. Attempts to allow viewing of a continuous virtual model, for example in the HMD technique, were still prone to positional inaccuracies but were also fraught with technical complexity. Evidence gathered from all sources supports the notion that simplicity of design is important. With this in mind, the development of Zapp allowed a ‘point and shoot’ style of direct interaction at any point in the landscape scene, yet analysis of log data demonstrated that usage was intermittent and determined by decision points and changes in vista. Successfully identifying a target feature via an onscreen crosshair proved problematic due to the often very small screen presence when viewed obliquely at distance. This issue relates closely to the challenge faced by AR browsers in labelling the scene on such a small screen, relying on a range of on-board sensors to match labels to the real world features to which they relate. Due to the nature and context of this study the participants demonstrated a greater perseverance with the technology than might be expected from a more general audience. So whilst technology offers exciting possibilities for augmenting the landscape scene, in ways that a human field guide could not do unaided, there remain technical and design challenges when attempting to replicate the ability of a human to point things out in that landscape.

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