uLearn: Facilitating Ubiquitous Learning through Camera Equipped Mobile Phones

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Abstract

This paper describes a prototype application based on Smartphone devices which supports independent learners within a mobile environment. The techniques employed allow children to rapidly gain access to a large repository of multimedia information through the use of a camera equipped mobile phone or smartphone. More specifically, the use of visual codes [20] attached to locations and objects within a museum and park in Lancaster enable the retrieval of web based information to be triggered by capturing images using the integrated CCD camera. Moreover, the location and orientation of the phone are used as contextual parameters in order to control the specific information to be retrieved by the system. The prototype described in this paper is currently under evaluation by groups of children in Lancaster in order to evaluate the use of this platform for teaching and learning. Our aim was to establish whether or not this user interaction technique could be harnessed for education based applications targeted at young children.

1. Introduction and Motivation

The Network Research and Special Projects Unit (NRSP) is a new research group at Lancaster University with the specific aim of leveraging the Universities computer science research expertise within ubiquitous computing [4],[10] in order to develop and trial live systems within the local community. The NRSP group acts as a bridge between the Computing department and Information Systems Services (ISS) and is able to leverage expertise from both areas. This paper describes the initial experience of utilising visual code recognition software [19] and smartphone devices as an enabler for triggering context-based information retrieval within an educational application domain. The primary aim of the prototype development was to assess its suitability for use within a ubiquitous learning environment. The prototype described in this paper builds upon our previous work on mobile context-aware systems as part of projects such as GUIDE [10], MSRL [16], Equator [9] and more recently as part of eCampus [8].

One of the motivations for this work has been that camera equipped mobile phones are now widely regarded as the next big technology wave. More specifically, the proliferation of these devices onto the consumer market has a predicted growth from 178 million units sold (in 2004) to over 860 within 4 years. Furthermore, by 2009, camera phones are expected to account for over 89% of all mobile phone handsets sold worldwide [17].

One further motivating factor stems from Lancaster University's involvement with the Cumbria and Lancashire Education Online (CLEO) [6] and Cumbria and North Lancashire MAN (C&NLMAN) projects [5]. The CLEO Broadband Consortium is a regional LEA (Local Education Authority) partnership with several aims. These include the delivery of a cost effective broadband infrastructure to all schools, higher education and further education institutions and a programme for the development and delivery of multimedia content. Furthermore, the consortium also supports the CLEO web portal[1] which aims to provide regionally generated teaching and learning materials and offers an Internet based learning community (for all Lancashire and Cumbria's teachers, pupils and parents).

A recent focus of the CLEO project is to harness the characteristics of each region (through its museums and galleries) in order to develop an ongoing programme of multimedia content creation, such as ArtisanCam [1], Mission to Morecambe [13] and Magic Wall [7]. One recent area within this is to extend support for out-of-school learning in order to encourage learning beyond the classroom and outside of organised school outings (which are often time consuming to organise). To this end, we have recently been working in co-operation with CLEO learning consultants and a local park/museum in order to investigate the use of state-of-the-art technology for

[1] The CLEO Web Portal: http://www.cleo.net.uk/

enabling ubiquitous teaching and learning. More specifically, we are exploring the use of the current generation of camera equipped smartphones as a platform for context-based multimedia applications.

We believe that this platform offers significant benefits over PDA approaches since the proliferation of smart devices onto the consumer marketplace means that these types of devices are genuinely becoming ubiquitous, having well defined and well understood user interfaces. Furthermore, they are able to communicate over wide area data networks (i.e. IP over GPRS or 3G) and exploit an extensive communications infrastructure. This offers significant advantages over wireless PDA systems which rely heavily upon the deployment of a supporting wireless infrastructure [14, 18]. Although PDAs are well used within commercial or research environments they are not as ubiquitous as mobile phones within the consumer marketplace. Thus, by harnessing this class of mobile device, we are likely to have a greater user base for our user studies.

2. Overall Goal and Challenges

In this paper, we describe a mobile system for supporting independent learning based on Smartphone technology and GPRS data networks. In essence, we planned to evaluate the use of an integrated CCD camera as an input device and ultimately allow learners to ask questions such as "what is that". This is achieved by allowing users to take photos in order to retrieve multimedia content related to their current situational context.

In summary, children are able to use the prototype system we have developed to help them gather information pertaining to a range of reptiles, small mammals, insects, fish and birds both within an indoor and outdoor environment. Figure 1 below shows the mini-beast and animal cave (lower left) and the butterfly house (lower right) within Williamson Park[2] in Lancaster.

Figure 1 a) The mini-beast museum and, b) butterfly house in Williamson Park

At present, the museum offers relatively basic and more crucially static information which includes each animal's name, ecology and habitat in a textual format. Our prototype application extended this to include other forms of information and also includes audio (e.g. animal sounds) and video/animations, where appropriate. The retrieval of this information is triggered by taking a picture of a visual code located on or close to each enclosure, as shown in figure 2.

Figure 2 – Interacting with the uLearn visual code mobile application

Each learner is able to independently study and gather information about their immediate environment. In addition, each student is using their own personal device and is able to retrieve a wealth of information provided by the system as well as exploring the wider Internet (by way of hypertext links) for more information sources.

As described in [3] the characteristics of an independent learning model emphasize that learners are free to choose which activity to undertake and to learn about whichever animal they find interesting. Therefore our application provides a very simple interaction model in order to automatically initiate queries to our back-end systems.

Our learning environment presently consists of Nokia 7610 Symbian 7.0s handsets which are connected to the Orange GPRS data network. Each Nokia device includes an integrated mega-pixel (1152 x 864 pixels) camera with 4x digital zoom. The device weighs 118 g and its dimensions are 108.6 mm (H) x 53 mm (W) x 18.7 mm (D). The application we have developed will run on any Symbian 6.0 and above handsets[3]

By participating in the prototype evaluation, each learner was able to take pictures of the visual codes using

[2] Williamson Park: http://www.williamsonpark.com/

[3] Compatible handsets include Nokia N91, Nokia N70, Nokia N90, Nokia N-Gage, Nokia 6680, Nokia 6681, Nokia 6682, Nokia 3230, Nokia 6670, Nokia 6630, Nokia 6260, Nokia 7610, Nokia 6620, Nokia 3620, Nokia 3660, Nokia 6600, Nokia 3600, Nokia 3650 and Nokia 7650.

her own device, and download information such as: animal images, ecological data, and other related information to their own personal devices. Learners were able to joyfully and easily study the detailed information and ecological data about the animal they were observing in their own time.

3. The Overall uLearn Architecture

This section describes the overall system architecture relating to the uLearn mobile application. Firstly, we describe the server side infrastructure on which the system is based before describing the mobile client visual code recognition application and the interaction techniques currently supported.

3.1 Multimedia Content and Web Front End

Figure 3 shows a high level view of the uLearn architecture which consists of an ASP.Net web application and content library. The web application currently resides on a Pentium III 800Mhz Windows 2003 Server running IIS 6.0. The system requirements are not that substantial on the server side since all that is required is a PC capable of hosting a web server and a .NET web application. The web application we have developed listens for incoming request from mobile clients on the standard web port (port 80).

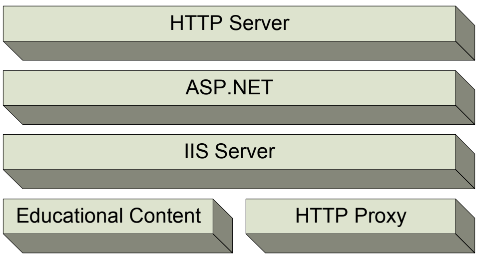

Figure 3 – The uLearn Server-side Architecture

The uLearn application inspects the incoming HTTP request and extracts the URL. At this point, the web application identifies the specific encoded visual code and processes it in order to identify the specific object for which information is required. The identified resource (say specific snake or bird) maps directly to a directory (or folder) held within the hypertext educational content database. If the URL does not contain a visual code object but is instead a URL referring to an Internet resource then the request will not be processed by our web application but will be satisfied by the target host just like any other HTTP request. The URL processing is described in more detail in the next section.

3.2 Mobile Clients and User Interaction

The overall architecture for the uLearn mobile client application is shown in figure 4 below.

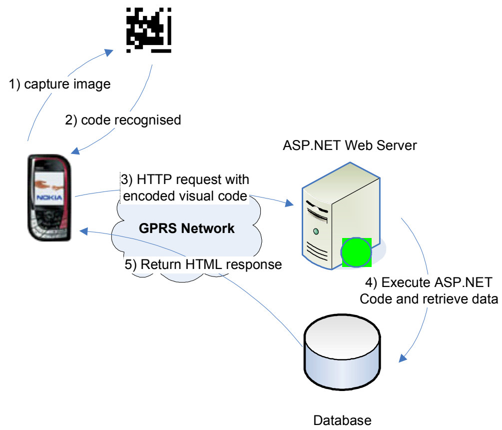

Figure 4 – Overall System Architecture

In essence, each learner was asked to run the uLearn application on their Nokia 7610 Smartphone. This application is able to recognize any visual code which is detected by the inbuilt camera. When a visual code is recognized, a yellow rectangle is placed around the code (as shown below in figure 5).

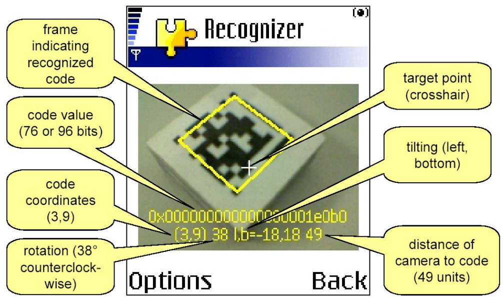

Figure 5 – The Visual Code Parameters [20]

The visual code system described in [20] forms the basis for the proposed interaction techniques, and is beyond the scope of this paper. In summary, the recognition algorithm has been specifically designed for mobile devices with limited computing capabilities. Furthermore, the algorithm is able to detect multiple codes within a single camera image. The recognition algorithm provides a number of orientation parameters (see Figure 5). These include the rotation of the code in the image, the amount of tilting of the image plane relative to the code plane, and the distance between the code and the camera. The algorithm also senses the movement of the camera relative to the background. It is worth noting that no calibration step is required in order to compute the orientation parameters shown in figure 5. For the purposes of this application, the prototype currently captures a single image using the devices' in-built camera and produces a code information object for each detected code within a captured frame. This code contains the following data items, which are then used as parameters in the query passed to our server application.

- the code value,
- the pixel co-ordinate of the crosshair
- the rotation angle of the code in the image,
- the amount of horizontal and vertical tilting,

3.2.1 Recognising a Visual Code

Once a code information object has been produced, the application establishes a connection with the GPRS network (if not already connected) and launches the default web browser. The browser makes a request to our web server with the code (containing a 76 bit representation of the encoded visual code) as a parameter in the HTTP GET request.

The uLearn application residing on the web server processes incoming HTTP requests. The incoming URL string supplied by the mobile device is used to help identify the object the learner wishes to learn about, for example, a particular insect or bird.

The visual code represents an identifier which specifies which animal, bird or fish to which the code was attached. This data is used by the uLearn application in order to retrieve the relevant content and return the requested content to the mobile device. The response is sent to the mobile device which is then rendered by the default browser.

3.2.2 Supported Interaction Techniques

To establish the overall effectiveness of the phone for use in an educational context, we decided to focus on two main interaction primitives supported by the visual code recognition algorithm, namely:

i) **Pointing**. The pointing interaction primitive requires targeting an area using the crosshair shown on the device display. The borders of an area are highlighted on the phone UI (in yellow) when the associated visual code is recognized and the focus point is inside that area.

ii) **Rotation**. The rotation interaction primitive can be used to associate regions with discrete information items. The visual code recognition algorithm is capable of recognizing postures which present an indication of direction such as "north", "south", "east" or "west".

3.2.3 The System in Operation

For the purposes of the prototype application we attached visual codes to a number of locations within the butterfly house and mini-beast museum within Williamsons Park. As children explored the museum they were free to use the application as they wished in order to find out more information about the animal they were interested in. No specific tasks or goals were set for the learners and our aim was to observe the system in use and simply to establish the overall success of utilising the phone's camera for triggering information retrieval. The application described above was tested using a number of Symbian based Nokia 7610 smartphones, running the Symbian 7.0s operating system. The Recogniser application is launched from the Nokia mobile device home screen. For the initial prototype application the functionality supported by the application was based around the point and click metaphor.

In essence, we wanted to relate the pointing of the camera and the pressing of the 5-way navigational key (i.e. to capture an image) to be the trigger for retrieving contextual information. To provide learners with the ability to retrieve a variety of information using this single mechanism we chose to utilise the rotation feature as a contextual attribute when constructing queries to the uLearn application. More specifically, we assigned different functions to the rotation attribute captured within the visual code. When processed by the web server, the uLearn application uses the rotation attribute to decide which action to take and what results to return to the user. Initially, it was possible to use the device to capture an image in two main ways. Firstly, the device could be held as normal (i.e. upright) and in this case, the server would respond with the homepage for the animal requested (as shown in figure 6). For example, in the case where a code is located next to a bird cage, the server presents a HTML page containing information pertaining to that particular bird. If the handset is held upside down, the server responds with just an image or photograph of the animal in question, offering the user a close-up view.

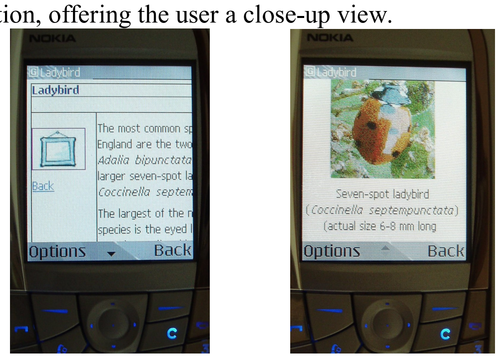

Figure 6: Homepage for an insect and its corresponding close up picture

4. Evaluation and Results

Having ascertained the technical feasibility of the approach by developing the prototype application a two stage evaluation was planned. Firstly, we wanted to carry out an initial user study with a small group of children before, secondly, investigating the overall performance of the system.

4.1 Aims and Objectives

In addition to evaluating the technical feasibility of adopting the visual code technology for use within a ubiquitous learning environment, we also planned an initial user study in order to gain feedback from young children whom would use the system to learn about animals within Williamson park. The main aims were therefore to:

i) determine the overall impression (positive or negative) the adoption of this system would present to the children and teachers.

ii) determine whether the interface and interaction styles chosen were intuitive and more importantly suited to operating in both indoor and outdoor environments.

4.2 Initial Technology Evaluation

Before the trial began, the children were shown the basic operations of the Nokia handset we used. That is, we briefly explained how to navigate the main screen using the 5-way directional keypad and how to select the recognizer application. Furthermore, we demonstrated how to capture an image, use the web browser and how to return to the recogniser application in order to take further pictures. Following this, each child was asked to run the application and take a picture of a visual code before the trial began (to be sure they understood the process of capturing an image). After the initial training, the children were free to explore the museum with the help of our system if and/or when they needed it.

Our initial technology trial comprised of 8 children aged 9 years old (4 boys and 4 girls). All the children were computer literate (i.e. had used ICT at home and at school) and also were familiar with the use of mobile phones, although not the Nokia handsets we used. The aim was to establish whether they were able to use the inbuilt CCD camera adequately to discover more information pertaining to the animals they were looking at within the museum. Although only a small number of users were used, this was intended as our first attempt so that we could identify and address any problems or add any improvements before conducting our more thorough user study. Our evaluation at this stage focussed on observations and asking the participants questions after using the system.

Overall the feedback was positive with all learners having enjoyed using the system. Initially, all the learners had difficulty in taking an image and capturing a visual code despite the short tutorial session. In essence it took between 3 and 5 attempts at first to capture an image (only for the first visual code). After this initial problem, the learners were able to use the yellow rectangle drawn on the UI as a guide before pressing the keypad to take a picture. The main problem being that the device normally moved slightly as each learner pressed the capture button, causing the camera to lose focus and be unable to recognize the visual code.

Although we expected some negative comments relating to the time taken to download information (see the next section), the learners themselves did not mention or seem to be overly concerned with the speed. We suspect that a combination of the novelty factor and the fact that there were lots of things to look at meant that the children were not really aware of the time taken to download the content.

With respect to the user interface, we chose to have a 2 column table layout with links shown on the left and content to the right, as shown in figure 6. This layout meant that learners had to scroll horizontally as well as vertically, which in some cases caused confusion. More specifically, when a user scrolls right to see the main body of the text and then scrolls down to read the information the links (in the left column) to other pages are not visible since they scroll off-screen. Often the children were unsure as to what to do next. We have since changed this layout such that all text is word-wrapped and links to related pages now appear both at the top and bottom of each page, thus removing the need for horizontal scrolling altogether.

The inclusion of a small number of mp3 audio files for some of the animals received very positive feedback. The learners liked to hear the noises the various animals made. This could be for a number of reasons; firstly, not all the animals make sounds all of the time and, secondly, for those animals within the cave (inside glass enclosures), the noises cannot be heard at all (such as small insects and snakes).

An unexpected result also arose during the first trial. Since there were only a small number of visual codes deployed for the technology trial, the children were not able to retrieve information relating to every animal in the museum. This resulted in the children not only looking for animals (e.g. butterfly's), but also looking for the next visual code which could have been anywhere inside or outside the museum. We therefore decided to harness this novelty factor in a subsequent trial and built a very simple nature trail application. In this second version of the visual code recogniser, learners were able to hold the mobile device both upright and upside down as before. Additionally, learners were able to hold the device at 90 degrees to the upright position (i.e. pointing left or right, or back and forward), as shown in figure 7. We decided to exploit this feature such that by taking a picture of a visual code with the handset held at 90 degrees, the system does not return any information on that object but instead carries out a navigation function. More specifically, we relate pointing of the device left and right to equate to back and forward (as found and used within the browser metaphor) which directs the learner toward the next or previous animal in the trail. Although we were not sure if this interaction technique would translate well into the physical world, our initial experiment with the same six learners provide very positive. It appears that this interaction technique was intuitive to use and the children had no problems associating this with its desired outcome. This we find very interesting, since it shows a relatively complex mental model at work even at a young age, since the learners were easily and readily able to relate left and right in the real world to back and forward in the virtual (hypertext) world.

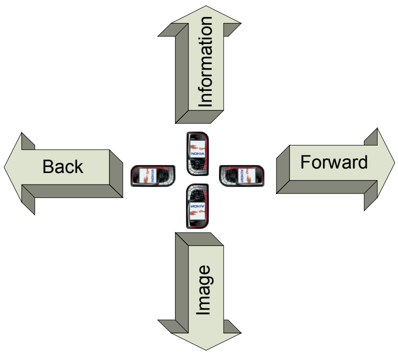

Figure 7: Detecting rotation for information retrieval

4.3 Technical Evaluation

The aim of the technical evaluation was to assess the overall performance of the system. In particular we wanted to ascertain whether or not the performance of the overall process of capturing an image and awaiting a response affected the usability of the application. Each of the scenarios presented above require that the mobile recogniser application makes a HTTP request from a server located at the University. The resulting HTML page response from the server may contain data such as PNG images (representing animals) or hypertext information. We anticipated beforehand that a significant factor likely to affect the overall performance was the GPRS data connection establishment process and communication.

In summary, the experiments show that the process of satisfying a request can be divided into three distinct phases. The first phase occurs once a user clicks the 5-way navigational key to capture an image once a code has been successfully recognized. This launches the default web browser. Following this, the device establishes a GPRS data connection with the service provider (the second phase) before communicating with the remote server and making an explicit request which can then be rendered by the browser (the final phase).

Our results show that it takes approximately 8 seconds for the Nokia 7610 handsets to launch the default browser application once the visual code has been recognised. A similar value was also experienced when we trialled the same application on a Symbian 6.0 based Nokia 6600 handset.

The GPRS data communication phase between the handset and the service provider takes a further 8 to 9 seconds. We have not yet attempted to test alternative network providers but would expect similar results.

Once a connection has been initiated and the browser launched, the time taken to communicate with the remote server and retrieve a response which can then be rendered by the browser ranged between 6 and 10 seconds, with an average time of 8 seconds. These results were based on 50 explicit user requests, which were not part of the user trial.

It is worth noting that once a GPRS connection has been established and the browser is running, the timings for the initial two phases do not affect any subsequent visual code requests. Therefore, in general user requests are satisfied within the 6 – 10 second time interval. This time variation is dependant upon the data being queried by the uLearn application which is used to generate the response. We therefore feel that the mean time of 8 seconds per web request is adequate for the purposes of information retrieval via the mobile phones browser, since this is no different to any other form of web request made via the GPRS network.

5. Related Work

This paper describes the retrieval of real-time multimedia information based upon the recognition of visual codes. At present, we are unaware of any other real world deployment or case study of an equivalent system for use in an educational setting. So far, work in this area has focused on designing visual tag formats and developing recognition software that will run on camera-phones. The contribution of the research is an interaction technique that enables users (i.e. learners) to interact with remote information services via their camera-phones and visual codes. In particular, long-range wireless communications to remote services over high-latency networks which differs from other work that tends to be PDA based involving wireless and/or ad-hoc communications networks [3, 4].

Alternative mechanisms for utilizing a mobile phone as an input device include The C-Blink [15] system, Microsoft's AURA [21] and SpotCodes [22]. The C-Blink system uses the phone screen as an input device where the user runs a program on the phone to rapidly change the hue of the phone screen. By waving the phone in front of a camera mounted on the large display the motion can be tracked in order to control a cursor on the large display. Madhavapeddy et al [11, 12] introduce techniques that use visual tags known as SpotCodes. In this system, interaction involves using a camera phone to scan tags or to manipulate tagged GUI widgets. The main distinction between the use of SpotCodes and Visual Codes is that it can be used to select any arbitrary pixel, where Madhavapeddy's work only allows the user to select or manipulate tagged objects. Microsoft's Advanced User Resource Annotation system (AURA) system uses mobile devices to interact with physical objects in order to retrieve information about them. In the AURA system, a user can associate text, threaded conversations, audio, images, video or other data with specific tags. Users are able to point an Aura device (PDA) at a barcode and the code displays a list of Web links with information about the bar-coded entity.

6. Future Work

At present our prototype supports information retrieval of web based information triggered by the capturing of visual codes. We have carried out an initial technology trial of the system and are now in the process of carrying out a larger trial in co-operation with local primary schools in Lancaster. Our first series of trials will be carried out during the last weeks of the summer school term (i.e. late June and early July 2005) since this coincides with when school's normally organise their school excursions to local attractions (such as Williamson Park). Our target was to develop the basic functionality and ascertain the appropriate user interaction technique before embarking upon a more thorough user trial.

We now have a final prototype ready for use and are currently working with Williamson Park to contact local school to participate in the trial. During this trial period we also hope to evaluate some additional features, currently being implemented. More specifically, we would like to offer more interactive services rather than just using the device for information retrieval purposes. That is, exploit the relative focus position, rotation angle, and tilting of the camera phone as described in [2] in order to support item selection using checkboxes and other graphical user interface widgets. The aim is to allow children to participate in quizzes or complete exercises by interacting with the system using only the Smartphone application on the mobile device. This would enable us to develop an electronic equivalent to the paper based exercises children can already complete when visiting Williamson Park.

We would also like to modify the system such that learners are able to create multimedia "post-it" style notes. More specifically, we would like to provide the facility for learners to record sound, take photos and write textual notes (using the T9 input mechanism) as they explore and learn. The aim would be to enable these to be saved for later retrieval (via the CLEO education portal) and perhaps to be left as virtual notes that may be triggered when other users visit the same location [10].

Finally, the inclusion of user profile (stored locally on the mobile device) may also offer additional advantages. At present, we have one content base for all age groups, however, by utilising a profile which stores information such as age and preferred reading language (i.e. English) we could offer personalised content. More specifically, we could dynamically render content based on these additional contextual attributes. To achieve this, we will adopt a similar technique to that employed in GUIDE [10]. This would allow two users of different ages to take a picture of the same visual code but to receive different HMTL pages. For example, pages aimed at the lower age group could include shorter and simpler sentences and perhaps larger font sizes.

7. Conclusions

In this paper we have introduced our initial work on exploring the use of visual codes and camera equipped mobile phones to support ubiquitous learning. More specifically, we have detailed how learners were able to make use of a novel interaction technique based around camera equipped mobile phones in order to trigger the retrieval of multimedia web based information.

Our preliminary technology evaluation has provided us with encouraging results and positive user feedback from both the children involved and also the Williamson Park staff members whom supported our work. As a result of our initial prototype study we are keen to further develop and widen the use of visual codes within Williamson Park and other local educational sites. In the first instance, our goal is to offer the range of material currently offered by Williamson Park[4] for schools and educational trips through the smartphone device. At present, this includes a maths trial, bug hunt, orienteering and the Lancaster sundial. Our large scale user trial of the system next month will hopefully offer some valuable insights into the use of this technology as a vehicle for ubiquitous learning within mobile environments, and subject to the paper being accepted, these would be included in the camera ready version.

[4] Williamson Park educational content homepage: http://www.williamsonpark.com/Pages/education.html

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