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Designing a Mobile Augmented Reality Tool for the Locative Visualisation of Biomedical Knowledge

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Abstract

Mobile augmented reality (MAR) may offer new and engaging ways to support consumer participation in health. We report on design-based research into a MAR application for smartphones and tablets, intended to improve public engagement with biomedical research in a specific urban precinct. Following a review of technical capabilities and organizational and locative design considerations, we worked with staff of four research institutes to elicit their ideas about information and interaction functionalities of a shared MAR app. The results were promising, supporting the development of a prototype and initial field testing with these staff. Evidence from this project may point the way toward user-centred design of MAR services that will enable more widespread adoption of the technology in other healthcare and biomedical research contexts.

Keywords:
Augmented reality, biomedical research informatics, consumer health informatics, mobile health, participatory healthcare.

Introduction

Consumer health informatics is attracting growing interdisciplinary research attention because of its potential to apply methods from the computing, information and behavioural sciences to the health information-related needs of patients and the public [1]. One such need is ensuring that biomedical research endeavours enjoy the support of the general public [2], and there is clear potential for new media technologies to facilitate public communication and participation for this purpose [3]. Mobile augmented reality is a technology whose potential usefulness in this area has been scarcely examined to date.

Mobile augmented reality (MAR) is the application of augmented reality technology to mobile computing devices such as smartphones, tablets and head-mounted devices, and allows the user to detect digital information that has been superimposed over the physical surroundings. This digital information layer is typically contextual in that it directly relates to the places or objects to which it has been applied.

MAR is gaining technological maturity, but has yet to reach mainstream adoption [4]. This may be due in part to the fact that MAR research and development to date has largely focused on technical issues, such as computer vision and interface advancements. Less attention has been paid to issues of user experience and acceptance of the technology [5, 6].

Public participation as an element of the MAR user experience has been examined in studies focusing on single, specific use cases, including MAR maps as tools for collaboration [7], MAR as a vehicle for public participation in urban planning [6] and user-generated locative annotations using MAR [8]. However, a user-centred approach is missing from the design of most MAR applications, resulting in services that often fail to address both the experiential and informational concerns of the user [5, 9].

Following a review of current and near future MAR technological capabilities and recent user experience studies, we have undertaken design-based research into a MAR service that addresses the information and interaction aspects of MAR use, in a health informatics application. The initial aim of this work was to create an information architecture for sharing knowledge with the general public *in situ,* using data drawn from four biomedical research institutes located in the Parkville Precinct, a major centre of biomedical research, and linked with the adjacent University of Melbourne.

The Parkville Precinct is home to several internationally renowned and architecturally significant biomedical and healthcare research institutions. This precinct therefore provided the opportunity to test the hypothesis that enabling people to discover information about science within the physical/geographical context in which it occurs may make this information more accessible and meaningful to them, and that MAR offers a location-sensitive way to support the dissemination of, understanding of, and engagement with biomedical and healthcare research.

MAR technical overview

The underlying technical capabilities of MAR can be considered in two parts: the method by which augmentations can be detected and triggered (commonly referred to as the registration method) and the means by which augmentations can be experienced (i.e., the type of output produced).

Registration methods

Registration is performed using one or more of the sensors built into the mobile device. The two most common methods are computer vision and location sensing. Computer vision uses the device's camera to detect a match between an image in the viewfinder and a database of images with associated augmentations. These images can be markers such as QR codes or, with newer technology, natural-feature images such as photographs or objects.

Location-based registration uses the GPS sensor in the device to search for augmentations that have been associated with nearby geographical coordinates. Using other orientation sensors built into the device, including compass, accelerometer and gyroscope, the application can further determine a user's position relative to an augmented point of interest.

To a lesser extent, MAR experiences are triggered by other sensors in the mobile device. For example, the iOS application Inception uses "just about every sensor and gizmo" [10] inside the device – including microphone, accelerometer, clock and camera – to monitor ambient noise and light levels and other environmental factors, augmenting audio feedback in real time as these data points shift.

Means of output

Broadly speaking, augmentation experiences provide three types of output: visual, auditory and haptic – though these categories are not mutually exclusive. Visual augmentations use the viewfinder of the device to overlay augmentations onto the view of physical reality. These augmentations can take the form of text, images, video, and static or animated 3D graphics. The visual MAR experience conforms most closely to the historical definition of augmented reality [11] and is still the prevailing means of output for most applications.

Auditory augmentations use the device speaker (or attached headphones) to deliver sound-based augmentations to the user. These augmentations may be stand-alone or paired with other outputs, for example, the audio track of a video-based augmentation.

Haptic augmentations use the small device motor that enables vibration to deliver tactile augmentations to the user. Haptic feedback is less common in MAR, though it has been identified as an area of possible growth [12, 13].

MAR in context: Organizational and locative use

Organizational context of MAR use

While the literature provides some accounts of the expectations and experiences of MAR service consumers or end users, it is much less common that research reports on how potential organizational sponsors of such services have been included in design-based research processes. In one such example, museum staff were invited to participate in the design of a multimedia guide of their institution [14]. Even though this participation was integral to the design process, the research findings still focussed primarily on the end user experience, and did not elaborate on the process of working with organizational stakeholders. There is a need to understand more about the factors that may affect organizational decision-making when establishing and operating a MAR service, and certainly to explore the data privacy and security factors that arise in many health settings. Accordingly we propose an expanded conception of the MAR user to include organizational stakeholders who would be responsible for the design and upkeep of a MAR service to be used by the public.

The project described in this paper involves the creation of a prototype MAR service to enhance public engagement with the highly specialised activities housed in buildings that are located in a specific urban precinct renowned for biomedical research. As such, our study includes two kinds of participant groups: not only “outsiders” (members of the public who do not ‘belong’ to these organizations but who by virtue of being in the place where the organizations are sited, become the target for its MAR service), but also “insiders” (i.e. organization stakeholders).

In the organizations whose premises are located in the precinct, insiders include people who have routine responsibility for outreach, i.e. staff working in areas such as communications, public relations and community engagement, as well as organizational leaders and managers of special projects (for instance, construction projects). Insiders may also have to consider supra-organizational factors, such as combining their outreach efforts with similar organizations in the precinct.

Locative context of MAR use

This aspect of our research is informed by a design-oriented ethnography [15] that sees locative technologies as evolving from "people's natural practices, tasks and activities and, in particular, from the context and meaning that they attach to those everyday activities" [16]. In designing the MAR service, our intention is to exploit this notion to engage people located in the vicinity of the Parkville precinct buildings, with the highly specialized information housed within them. The design is based on the concept of a MAR service associated with a discrete location, designed for the “outsiders” who find themselves in that location. Therefore, users of this service are not sight-seeing tourists but people in the street with more commonplace reasons for being there. These may include occasional or routine visitors to specialised facilities in the precinct, such as hospitals; regular passers-by or occasional transients in the precinct; and the local living and working population who are not organization staff.

We hypothesise that, by viewing the buildings in the Parkville precinct as a portal to systematic information and interaction, people who are in the vicinity as a matter of course, but do not have physical access, will be encouraged to become aware and engage constructively with biomedical research endeavours.

In the context of this project, we need to envision a MAR service that is continually refreshed by new content, and that offers a variety of interaction opportunities for different, possibly frequent, circumstances of use. For example, MAR-facilitated user interaction may extend to social-media-like fundraising / donating to research; recruiting participants / volunteering for research projects; direct interactions between researchers and the public about the work; and interactions around study and work opportunities in the institutes. While the data flow in the prototype created for this project is primarily one-way toward the user data could flow back to the organization, such as financial and personal details that the user provides to make a donation or register for an event. In these instances the prototype provides a link to a pre-existing, secure web page where the user may enter these details. A more fully developed version of the app will need to address issues of security and privacy, particularly if sponsoring institutes wish to track information about who is accessing the app.

It may be that as “outsiders”, people are not predisposed to access an organization’s information, so we need to carefully consider the locative characteristics of their presence in the precinct, and design with these in mind. In addition, the idea of mobility in MAR may need more scrutiny. Clearly, for reasons of safety and quality, the MAR experience may not be satisfactory for some of these outsiders: people who are driving a car or cycling; people who are moving through the area at speed; or people who need to pay attention to companions, children or pets, for instance.

Method

In 2010 we worked with lay people on initial usability and user experience testing of a prototype MAR app to engage the public with scientific research taking place in biomedical research institutes in the Parkville Precinct [17].

Based on promising results from that trial, we formally approached a cross-section of these research institutes to find out what such organizations might think about using MAR as a tool for public engagement with their activities and their physical premises. We briefed them that we were looking for ideas about how the use of MAR throughout the precinct might enable "more democratic involvement of citizens in science and technology related issues" and how it might "create collective or socially robust ... knowledge and consider all actors as members of sophisticated civic cultures" [18].

Since none of the institute staff were familiar with MAR, we gave them a white paper we had produced that described current MAR technology and use cases from many fields [19] as a prompt to help them to formulate their ideas.

We then conducted separate semi-structured interviews with the communications directors of four institutes (in four different domains of biomedicine, with differing histories and scopes of operation, in different types of premises); we also interviewed representatives of the architectural firm responsible for the design of a fifth institute that was still under construction.

Interviewees in communications roles were asked about the strengths and challenges of public engagement at their institute; about potential uses for MAR that they could imagine for their institute – including ways in which MAR could foster interaction with the public; and about existing content that would work well in a MAR context. Interview participants in architectural roles were asked about the facility they had designed for the precinct. In particular they were asked to discuss design aspects that may not be immediately visible or apparent to the public; ways in which the building had been designed for social interaction; and how both insiders and outsiders might quickly orient themselves to the building and its distinct spaces.

Interviews were audio-taped and transcripts of each interview were analysed separately and coded manually by two team members. The aim of analysis was to inform a design specification for a prototype MAR app that reflected the institutes' input (absent from the 2010 prototype) as well as advances in MAR technology since 2010 (for example, use on smartphone and tablet devices).

Initially, interview data were classified into one of three categories: Information, Interaction or Interface. This was to help us differentiate conceptual angles of responses to MAR as a tool for engagement, and to establish that we had elicited adequate input in all three categories. Each piece of data across these three categories was further assigned to one additional category in a set of five that emerged from the data: Activity, Building, Organization, People or Knowledge Domain. For example, "3D virus models" was classified as Information and as Knowledge Domain.

Each item was then ranked according to each of the following five criteria, using a 1 (low) to 3 (high) scale:

- importance to the institute
- commonality of interest across the five institutes
- novelty (i.e. not trying to replicate an existing medium)
- suitability for MAR medium
- availability of appropriate content

Through this analytical process, shown in Figure 1, information, interaction and interface design of a prototype MAR application were developed. The interviewees were subsequently observed and video-recorded by two researchers, while using an iPad in the precinct to field-test the resulting prototype. Participants were escorted by researchers to each of the four included sites, where they took turns operating the iPad and were encouraged to "think aloud" and discuss their observations of the prototype with each other. As the prototype consists of an HTML-based mobile website rather than a true "app", no specialized knowledge of the iOS operating system is required. All participants had previous experience with touch-screen mobile devices, and were instructed on how to interact with the prototype.

Participants were prompted by researchers to discuss specific aspects of the prototype design, and were asked to elaborate on observations they had made. This was followed by a structured interview about the experience, which was audio-taped. Researchers then conducted preliminary analysis of recordings made during the field tests and transcripts of the interviews.

In a later stage of this research, after further refinement of the app and field-testing by members of the public, the organizational participants will take part in a shared focus group to review and comment on results of the public field tests.

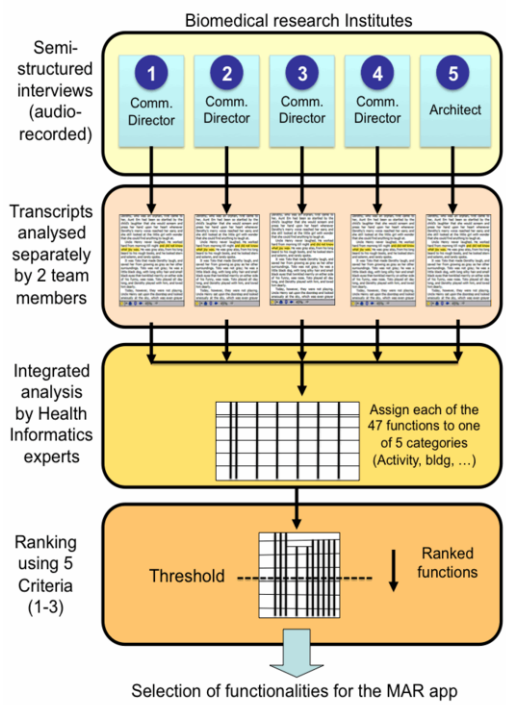

Figure 1- Methodology used to select functionalities for MAR application

Results

Information architecture

Analysis revealed 47 unique points of data (functions) across the five interviews, relating to specific informational content and interactive experiences that interview participants identified in regard to the development of a MAR service for their institute.

When ranked, no single function received the highest possible score of 15. Four functions received a score of 14, representing three of the five categories of Activity, Building, Organization, People and Knowledge Domain. The top four functions were: organizational identity (Organization); fly-through or internal tour of the building (Building); still and animated visualisations of research processes, i.e. cells and viruses (Knowledge Domain); information about the relationship between form and function in the design of the building (Building). Activity and People were not represented in the top four functions. Details are shown in Figure 2.

User experience

Initial insights from field testing of the prototype application (pictured in Figure 3) revealed that research institute stakeholders were inspired by the potential of the format, and found it to be a different experience than viewing information while not *in situ*. One participant commented specifically on the locative nature of the experience, noting: "It's kind of weird standing in front of the building that you're watching on screen. But for some reason – it might just be because I'm ... in an older generation – I still find that quite fascinating. That [the video] seems more credible to me than that [the building], and I don't understand that relationship. But we get so much fed to us visually now, through screens, so I think this is a real winner."
Participants liked the "Did you know?" facts at the top of the screen (which the user can refresh to get a new fact) but felt that the initial fact needed to provide more "big picture" context about the identity and mission of the institute for subsequent facts to bear relevance. Participants also felt the visual material was effective at engaging the user, particularly the video content. "It makes us want to dive in there, doesn't it? I want to know what they're saying," said one participant. Another participant commented: "The fact that there's moving images there just makes me want to go straight to it."

Discussion

The initial findings from working with biomedical research institutes using a health informatics methodology have supported the prototyping of a shared MAR application. Further field testing by organizational stakeholders and a formal thematic analysis of data are pending. The findings will lead to refinement of the prototype and end user testing with a cross-section of lay people in a subsequent phase of this research.

Twenty members of the public will be observed while field-testing the prototype application on a mobile device and will complete a follow-up structured interview. We have chosen to target two specific groups in the general public: (a) ten people who travel by foot through the precinct on a regular or semi-regular basis and thus have time and attention to spare without sacrificing personal safety; (b) ten people who attend healthcare facilities in the precinct on a regular basis as carer or patient, and thus have time and attention to spare while waiting.

Figure 3- MAR application prototype

In this phase we will be particularly interested in the participatory potential of the MAR app. Interestingly, in studies exploring user expectations of future MAR services, participants frequently identify social interaction and connectivity as a

1 = Importance
2 = Breadth
3 = Novelty
4 = AR-appropriateness
5 = Content availability

Category	Function	ORG 1	ORG 2	ORG 3	ORG 4	ARCHITECTS	Total Score	1	2	3	4	5
Organisation	Identity (the individual org versus the building; scope of activities)	x	x		x	x	14	3	3	2	3	3
Building	Fly-through/internal tour	x	x				14	3	2	3	3	3
Knowledge Domain	Still and animated visualisations of research (cell/virus imagery)			x	x		14	3	2	3	3	3
Building	Architectural information (form + function design details)	x				x	14	3	2	3	3	3
Building	5-star energy rating and related environmental issues (treatment plant)					x	13	3	1	3	3	3
Building	Ways in which the building has been designed for collaboration					x	13	3	1	3	3	3
Activity	Student recruitment			x	x		13	3	2	2	3	3
Activity	A way to invite public into the building			x			13	3	1	3	3	3
Activity	Information about and invitation to participate in public trials	x					13	3	1	3	3	3
Building	Time lapse documentation of construction		x	x			12	2	2	2	3	3
People	3D lenticular portraits of founders				x		12	2	1	3	3	3
Activity	Public events at the instutute (lectures, symposiums, tours, open days)	x			x		12	3	2	1	3	3

Figure 2 - Biomedical research institutes' priority information and interaction functionalities for an MAR outreach service

desirable – and in fact, fundamental – feature of the MAR experience [13]. Conversely, in the studies of active MAR users, participants rate their experience of social connectedness quite low; one even noting: "Felt like I was totally alone, the only user in an empty augmented world." [9]. This implies that "current AR applications hardly serve as tools for social interaction or building a user community around them." [20].

Conclusions

This project is extending previous research into the feasibility of using a MAR app to engage the public with scientific research taking place in an urban health and biomedical precinct. In so doing it is contributing to the scarce research to date into MAR applications in healthcare.

The research reported here uses a health and biomedical informatics perspective to explore the potential of this new media technology to influence the paradigm shift underway from science communication to public engagement in science [21]. Enabling publicly funded institutes to improve public outreach and engagement may assist with a critical part of their mission. Enabling people in the street to find out about the work going on inside these institutes may make it accessible and meaningful to them.

Through this biomedical research use case, this project investigates the unexplored potential for a uniquely MAR user experience that has a clear organizational, locational and social context. In terms of MAR research, this project can be seen as "a first step towards treating technology designed for use in socio-technical settings not as isolated IT solutions, but rather as 'ensembles emerging from design, use and ongoing refinement in context'" [16].

In future, evidence from this project may point the way toward user-centred design of MAR services that will hold more appeal for mainstream users, and enable more widespread adoption of the technology in other healthcare and biomedical research contexts. Potentially these include medical education, clinical care, health promotion, and disaster management.

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