A Roadmap to Mobile Augmented Reality

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Abstract: *Even if Augmented Reality (AR) is a research area that dates back to 1960, Mobile Augmented Reality (MAR) is a newly formed research area which started evolving when mobile devices use exploded. This paper aims to review MAR literature, identify key research fields and finally present corresponding design.*
Keywords: *mobile, augmented reality, review*

1. DEFINING MAR

Ivan Sutherland developed the first augmented reality system. Sutherland's invention was the starting point for major research areas including MAR. Since then several scientists studied and developed MAR systems while few of them provided corresponding definitions. To share common understanding of MAR characteristics and enable reuse of the knowledge domain there is a strong need to clearly understand MAR. Considering the nature of MAR research, it would be difficult to group the literature under any specific discipline. Further evidence of this can be seen from the fact that Augmented Reality articles are scattered across various journals in fields such as virtual reality, location based services, user interfaces, hybrid mobile devices, information technology (IT), and information systems (IS).The literature search was based on the descriptor, "mobile augmented reality" or "MAR" with a combination of keywords in Figure1. The search was also limited to peer-reviewed journal articles. More than 150 articles were found in the initial search of the literature. The full text of each article was reviewed to eliminate those articles that were not actually related to MAR. Many of articles were excluded because they did not meet the selection criteria. So we focused in gathering the most popular articles concerning the field of Mobile Augmented Reality according to the number of citations each one received. We queried CiteSeer-X, IEEE e-databases and Google Scholar with specific keywords and retrieved 13 papers. The keywords used are shown in figure 1.

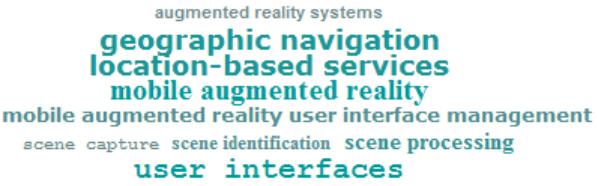

Figure 3: Mobile Augmented Reality keywords

Every description contained a specific amount of information, summarized in the following terms: A. Object Registration in 2D and 3D, B. Mix of real elements and electronic information, C. Location and orientation tracking, D. Extension of perception capabilities (Information is available on every object a , E. Use of mobile devices ,F. Real time interaction. According to these terms, the following table was developed:

Table 1: Distribution of Description Terms

Term	A	B	C	D	E	F
Reference						
(Azuma, 1997)	X	X				
(Jing, et al., 2010)	X	X		X		X
(Hollerer & Feiner, 2004)		X				X
(Yu, Jin, Luo, Lai, & Huang, 2010)	X					X
(Billinghurst & Henrysson, 2009)		X	X	X		X
(Butchart, 2011)		X			X	
(Chang & Tan, 2010)	X	X	X			X
(Ekengren, 2009)	X	X				X
(Izkara, Pérez, Basogain, & Borro, 2008)		X		X	X	X
(Lopez, Navarro, & Relano, 2010)	X	X				
(Reitmayr & Schmalstieg, 2000)	X				X	
(Renevier & Nigay, 2001)		X	X			
(Schmalstieg & Wagner, 2007).	X			X	X	
Total	8	10	3	4	4	7

A complete description of MAR has to satisfy all the terms mentioned in the table, but no one seems to do so. Moreover, the terms that appear less frequently, are C and E. The combination of location and orientation tracking with the use of mobile devices lead to setting the framework of context-aware devices, since "context-awareness is defined as the model in which an application or a device could discover and use the surrounding information (user location, date and time, other devices)"(Bougiouris, 2004).

2. MAR AND USABILITY

MAR, as a newly formed research area, changes rapidly and fundamental elements have to be modified so as to keep up with current trends. The proliferate deployment of MAR applications brings on the need for standardization of certain aspects that haven't been completely related to the needs and concept of the field itself. One of these aspects is usability evaluation. "It must be stressed here that until very recently the Usability Evaluation of such interfaces had not been systematically examined" (Kostaras & Xenos, 2009). During a big period of time, the majority of MAR developers and researchers were concerned mostly about the proper registration of the virtual elements to the real world. This behavior leads to neglecting Usability Evaluation issues. In this work an attempt is made to synthesize a set of guidelines specifically for MAR, through specific information from papers, which already presented usability-related information directly applied to, or abstracted into, a design/evaluation guideline. Usability issues arise mainly from three sources: "1) results of inquiry methods (questionnaires and interviews), 2) inspection methods and 3) test methods" (Kostaras & Xenos, 2009). After analyzing various resources, we created a synthesis of most significant issues that appeared more frequently and the proper usability guidelines for each one.

Table 2: Usability Issues and Proposed Guidelines

Issue	Proposed Guideline	References
Different level of IT knowledge among users	User classification in groups and development according to the needs of each group	(Grubert, Langlotz, &Grasset, 2011), (Gabbard, et al., 2002), (Bowman, Gabbard, & Hix, 2002)
Missing Functionality in Case of Serious Error	Implementation of error recovery mechanisms	(Gabbard, et al., 2002), (Bindschaedler, Knoche, & Huang, 2011)
Incompatibility among Devices and OS	Applications need to be interoperable among different kinds of devices and OS	(Belimpasakis, Selonen, & You, 2010), (Kirkpatrick, 2009), (Lamantia, 2009), (Cooper, 2011)
Low User Satisfaction	User involvement with testing and feedbacks in every phase	(Gabbard, et al., 2002), (Bowman, Gabbard, & Hix, 2002)
Help, Documentation and Support Provided	Embedding first-use tutorials in applications	(Lamantia, 2009)
Available Network Resources	Alternative options for lightweight versions when network availability is limited	(Gabbard, et al., 2002), (Hamidian, Palazzi, Chong, Gerla, &Körner, 2010)
User Motivation and Behavioral Patterns	Relevance of user expectations and technology components used	(Olsson &Väänänen-Vainio-Mattila, 2011), (Grubert, Langlotz, &Grasset, 2011), (Bindschaedler, Knoche, & Huang, 2011), (Bowman, Gabbard, & Hix, 2002)
Device Size and Resources Limitations	Analytical design on device size and resources limitations	(Schmalstieg & Wagner, 2007)
Lack of Flexibility for User Content Creation	Adoption of Augmented Reality 2.0 technology	(Guven & Feiner, 2003), (Schmalstieg, Langlotz, & Billinghurst, Augmented Reality 2.0, 2011)
Security, Privacy and Ethics	Adoption of policies and mechanisms for preserving security and privacy	(Haller, Billinghurst, & Thomas, 2007), (Aryan & Singh, 2011), (Cheng, Zhang, Bertino, & Prabhakar, 2006)
Placement of Advertisements	Adoption of standardized framework	(Huang, Hao, & Yu, 2010)
Information Overflow	Information filtering according to users' interests	(Cooper, 2011)

2.1 User classification in groups and development according to the needs of each group

The knowledge of use of third generation mobile devices is a prerequisite for the use of mobile augmented reality applications. Therefore, not every potential user has the same amount of experience. As a result, users have to be classified in different groups according to their knowledge level and their needs have to be taken highly into consideration for further guidance inside the application to be developed.

2.2 Implementation of error recovery mechanisms

Whenever an error, caused whether by the user or the software itself occurs, it should be checked how the rest of the functionality is affected and the time period the application needs to recover from it.

2.3 Applications need to be interoperable among different kinds of devices and OS

Application developers also need to pay attention to the behavior of several different devices for the same kind of software. They have to run tests in various devices in order to check attributes, characteristics or standard features that may not be functional in some of them. As a result, they will eliminate lack of user satisfaction as far as it concerns the API functionality. Applications should be developed in a way that they are designed in one platform and run everywhere.

2.4 User involvement with testing and feedbacks in every phase

This is mainly an attitudinal factor, but significant enough when expressed in a massive way. Developers have to be aware of what users think about an application. This can be achieved by the use of beta testing periods before an application is released and by user provided feedbacks afterwards. In this way, developers will have a permanent data stream concerning features and attributes they need to add, modify or remove.

2.5 Embedding first-use tutorials in applications

There are a number of users that may stop using an application if they face difficulties using it for the very first time. The nature of mobile application makes the use of a manual in electronic form (.pdf, .doc or web page format) an additional barrier, since it will not only use more resources on a device with limited ones, but also discourage the user from using the application, because reading a long text is not the proper solution for someone using a mobile device and desires quick forms of interaction. On the other hand, the development of first-time use tutorials within the application content may be helpful and a nice experience for the upcoming user.

2.6 Alternative options for lightweight versions when network availability is limited

Connectivity is a major issue for applications that need an online interaction mode. Poor in coverage or expensive to use network resources can discourage the potential users. Few things can be done from the developers' side though, since network resources are a responsibility of ISPs and cell phone network operators. Developers can create lightweight versions of applications, settings of which will be automatically adjusted when connectivity provided is relatively poor.

2.7 Relevance of user expectations and technology components used

Developers have to predict which expectation a potential user may have from the application, according to the nature of it. Afterwards, they will need to embed the appropriate "technology components" (Olsson & Väänänen-Vainio-Mattila, 2011). For instance, when a user expects to broaden his perception and memory capabilities by interacting with augmented content and the information provided for it, the technology components that must be taken into consideration are embeddedness and context sensitivity. Embeddedness serves for enhancing the real elements with content and possible interactions, whereas context sensitivity tracks changes in the surroundings.

2.8 Analytical design on device size and resources limitations

It is one of the limitations that appear most frequently in bibliography and also the primary factor that must be taken into consideration before the design phase of an application. Every attribute and element has to be examined in order to comply with the limitations that arise. For example, in a Mobile Augmented Reality Browser, the size of an object tag has to be big enough in order to be visible and small enough in order not to cover a big area on the screen. Every element also has to be resizable for different screen sizes.

2.9 Adoption of Augmented Reality 2.0 technologyfor user content creation

Many Mobile Augmented Reality applications still use the 1.0 technology, where users are able to see the content of a point of interest, but are unable to comment on it, or create a new form of interaction. A useful approach is the development of AR 2.0 (Schmalstieg, Langlotz, & Billinghurst, Augmented Reality 2.0, 2011), a form based on Web 2.0 attributes, where users can interact with points of interest in various ways, such as adding their opinion about the spot, uploading pictures or other multimedia, or even creating their own.

2.10 Adoption of policies and mechanisms for preserving security and privacy

Every kind of application that uses live-stream capturing devices provokes ethics and privacy concerns, since information concerning someone else's personal data can be tracked and recorded. Moreover, when using short-ranged bandwidth networks, such as Bluetooth and WiFi, it is easy for an attacker to deploy an eavesdropping or spoofing attack, in order to acquire information about the mobile device, or even install mobile malware. "Since location based services (LBS) are one of the major applications of the AR, it is important to have a privacy-aware management of location information, providing location privacy for clients against vulnerabilities or abuse" (Aryan & Singh, 2011). Additionally, application developers must create sets of policies and rules according to each application needs and function.

2.11 Adoption of standardized frameworkfor advertisements placing

Abusing the available screen space for advertising purposes has to be avoided when implementing an MAR application. A model for advertisement placement was designed where the authors proposed "extracting straight lines from the image and then identifying the vanishing points. From two sets of parallel lines corresponding to respective vanishing points, they detect a dominant rectangular planar structure that satisfies corner verification and dominant direction verification for ads insertion" (Huang, Hao, & Yu, 2010).

2.12 Information filtering according to users' interests

An excessive amount of information provided within an application can disappoint some of the users. For example, a vegetarian considers certain types of restaurants as unnecessary. This piece of information can disappear from his/her personal view of the landscape if the proper options are embedded in the application. This can also be achieved with "like and dislike" mechanisms, i.e. the application will not show disliked content to the user (Cooper, 2011).
MAR application design and development can theoretically be based on traditional usability and systemic theory models, such as the "Usability Engineering Lifecycle" (Gomez, 2004), but this will never allow the implementation of a separate framework and a great number of usability requirements will not be taken into account because of the different priority that will be given to other types of services. A proper framework could consist of the classic iterative process, enhanced with the newly formed usability requirements and the permanent contribution of context-awareness from the external environment. User involvement must be present throughout the whole procedure, in order to ensure the continuous fulfilment of usability requirements. When usability requirements will be applicable to a great number of applications and have a certain form, they can become standardized.

3. Conclusion and Future Directions

It has become quite obvious that Mobile Augmented Reality needs its own usability guidelines. Given the fact that it is a newly formed research area, changes will take place frequently. Researchers must continuously update their research efforts and findings in order to create a set of design guidelines that helps MAR programmers to create more informative and useful MARS UIs for different application scenarios. Compromises will have to be made, and the set of dependent and independent variables will have to be carefully selected. In the future we plan to conduct more studies to quantify the benefits of MAR usability interface, as well as developing a wider range of interaction techniques in the hope of further exploring the possible design space.

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