Affordances in Mobile Augmented Reality Applications

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Abstract—**This paper explores the affordances of augmented reality content in a mobile augmented reality application. A user study was conducted by performing a multi-camera video recording of seven think aloud sessions. The think aloud sessions consisted of individual users performing tasks, exploring and experiencing a mobile augmented reality (MAR) application we developed for the iOS platform named ARad. We discuss the instrumental affordances we observed when users interacted with augmented reality content, as well as more complex affordances rising from conventions from media content, AR and the traditional WIMP paradigm. We find that remediation of traditional newspaper content through the MAR medium can provide engaging, pleasing and exciting user experiences. However, the some of the content still suffers from being shoveled onto the MAR platform without adapting it properly. Finally, we discuss what content was most successfully mediated to the user and how the content impacts the user experience.**

Index Terms—**augmented reality, mobile computing, human computer interaction**

I. INTRODUCTION

Mobile augmented reality has become increasingly viable through less expensive (and recently free) systems development kits (SDK) and ever increasing technical capabilities of mobile devices. Wagner et al [1] pioneered "…the first completely stand-alone Augmented Reality client on a PDA." (p. 2) on handheld devices in the early 2000s. Since then stand-alone AR has gradually become more common as computing power on PDAs and smartphones increased.

A mobile augmented reality (MAR) or handheld mobile augmented reality (HMAR) application is in its most basic form a mobile device with a display to show an augmentation and registration technology and software that "...have the following three characteristics: 1) Combines real and virtual 2) Interactive in real time 3) Registered in 3-D". [2]

With the smartphone revolution as a backdrop, we decided to start developing a MAR application for distributing and presenting AR content in a newspaper – Verdens Gang – with a large circulation in Norway. The software we developed in collaboration with the newspaper iterated from concept and prototype, to the stable release now available on the AppStore. Through the iterations, we saw increasing requests for reuse of traditional media content the newspaper already had in its possession. These requests resulted in a final version of the application that supports remediating of content on markers in a newspaper.

The term remediation is coined in Bolter et al [3] book "Remediation – Understanding new Media". *Remediation* can be understood as taking existing content (pictures, videos, etc) adapted to a specific media outlet – for instance a printed newspaper – and remediated through a different medium, in our case an augmented reality application.

Trough a video based user study we have uncovered how remediation of traditional newspaper content has shaped our MAR application and how different affordances of the content itself affect the user experience of the application.

II. RESEARCHING MAR

Augmented reality as a term is broadly interpreted and to some degree diluted across media and academia alike. In this paper, we use Azuma's [2] definition of AR mentioned in the previous section to position this work. We can with confidence claim the ARad application to be augmenting reality as it incorporates Azuma's three characterizing properties.

In this paper, we focus on the interplay between the augmentation (the content) and how the user experiences the remediated content in our application.

This paper contributes to further the understanding of AR as a tool in a mobile multimedia context. Additionally it provides a detailed overview of the design of our application and provides design guidelines theoretically aligned towards affordances in human computer interaction (HCI).

III. MAR AS A MEDIUM

Bolter and Grusin [3] sees augmented reality as a hyper mediated visual space and "...the insistence that everything that technology can present must be presented at one time - this is the logic of hypermediacy." This definition is fitting since augmented reality seeks to enable us to see the world how we want it, with just the right amount of information. Macintyre et al [4] argues strongly for AR in general being a new media experience mainly because of a "...fluid blend of the physical and the virtual, and the inevitable tension between them, offers rich dramatic possibilities that are impossible in any other medium."

In Interactions [5], Bolter et al argues that the field of media studies is not responsible for providing design guidelines that the HCI community. However, as content and the interaction is becoming increasingly intertwined one might look to polyaesthetics [6] to shed light on aspects of new media. Polyastechics suggests media studies should be concerned with contributing knowledge

about the aesthetics of content since the interaction between content and interface creates the user experience.

We believe that *content in relation to the interface provides the complete user experience*. Poor content in an application with excellent user interface delivers a poor user experience and visa versa. This is paramount in the ARad application, as the content to some extent becomes the user interface itself.

AR technology promotes the ideal of a pure and fully transparent user experience, where the interaction with the medium is transparent to the user and just the experience of the content remains. Although some transparency is achievable on a handheld device, Rosenblum et al [7] believe "…if AR is to realize its full potential, hand-held form factors, de- spite much of the hype they are receiving now, simply are not adequate." (p. 445) We agree with Rosenblum to some degree. The handheld form factor can never create the same immersion that a totally transparent AR solution can. On the other hand, even with all its hype MAR has utility until this paradigm shifts.

Pavlik et al [8] gives an overview of the emergence of mobile AR in journalism in general. Content creators for the applications they identified (Aurasma, Layar, Wikitude World Browser, Junaio and Blippar) may benefit from the findings in this paper.

In Virtual Realities, Schmalstieg et al [9] discuss the first mobile augmented reality ad developed in 2007 by HIT Lab NZ for the Wellington Zoo. The application delivered a single static 3D model of a zoo animal augmented on a printed marker in the newspaper. They report that for mobile AR advertisement the "…most challenging aspects have been the content creation and application distribution, not the application programming." In addition, Schmalstieg et al points out, "Most of the published AR research has been on enabling technologies (tracking or displays, etc.), or on experimental prototype applications, but there has been little user evaluation of AR interfaces."[9].

In this paper we hope to contribute further to a field where there has "…to date been very little user-based experimentation in augmented reality." [10, p. 3]. Similarly, Zhou et al [11] call for more practical applications. In a more recent and extensive literature review De Sá [12] gather that "…despite the appeal and the growing number of services and applications, very few guidelines, design techniques and evaluation methods have been presented in the existing literature."

The motivation to write this paper comes from a wish to understand the nature of MAR applications, specifically the affordances in these applications. Accordingly, we aim to describe affordances and specify a set of design guidelines one may apply when *remediating* content on the mobile augmented reality platform.

IV. AFFORDANCES IN AR APPLICATIONS

Our application augments traditional media with virtual content. It enables us to create a new user experience for readers consuming traditional print media. By identifying how our MAR application *affords interaction* with this content, we seek to contribute prescriptive knowledge in the form of design guidelines intended for practitioners and academics alike in the field of interactive augmented reality mobile technologies.

To provide meaningful prescriptive knowledge about affordances we have adopted the sociocultural perspective of Kaptelinin et al [13]. This view, and its borrowing of "web of mediators" from Bødker [14]allows us to look at affordances in AR with a respect to the cultural aspect.

MAR is different from other media channels, and the content chosen for remediation needs to be adapted to the AR interaction paradigm.

Previous experience with different content types needs to be taken into account when designing user experiences for MAR. It requires the understanding of the combination of known usability conventions and conventions of aesthetics directly related to the content we are presenting. In this paper, we aim to identify how we can successfully present the content in an engaging manner on MAR.

The framework proposed by Kaptelinin et al [13] allows us to look at affordances from an individual perspective with regards to culture. Through Kaptelinin et al literature review, they find "A growing number of studies in HCI and related areas call for re-defining the notion of affordances to include social and cultural aspects of human interaction with the world." [13] Kaptelinin et al approach is named mediated action perspective and "is concerned with how humans act in their cultural environments, rather than with how animals act in their natural habitats." [13].

If we allow the discussion about affordances in HCI to include these aspects, we can study IT-artifacts with the cultural aspect in mind. This is fruitful in this study since we are creating an artefact relying on existing conventions from a wide range of interaction and content paradigms. These include the WIMP paradigm, the AR interaction technique, existing media content and smartphone conventions.

Through Bødker [14] they identify auxiliary affordances that take into account "complex relations within webs of mediation". This may be understood as there is often a need to perform indirectly or directly related actions to achieve an outcome. They identify maintenance affordances, aggregation affordances and learning affordances as examples of affordances technology may employ to achieve its intended purpose.

In this study, we will describe the *instrumental affordances* of our application. Further we look at the complex affordances that arise with bringing culture into understanding of applications.

Learning affordances: What steps do the users go through to learn how to interact with an AR application, and how we might improve these affordances.

Maintenance affordances: What needs to be taken care of to allow applications to function as effective mediators (maintenance).

Aggregation affordances: How is the application intertwined with analog and digital artifacts to achieve its outcome. Aggregation affordances illustrate the fact that some applications must be combined with other artifacts to achieve its indented purpose. AR`s character is to use the environment to provide augmentations and in this regard we aim to identify the essential aggregation affordances of a MAR application.

In addition, we propose a domain specific affordance - *Remediation affordances*: This affordance encapsulates the affordances associated with the content. Specifically,