Expert Systems with Applications 41 (2014) 2174–2185

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Mobile augmented reality based context-aware library management system

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ARTICLE INFO

Keywords:
Augmented reality
Library management
Mobile computing
Agent programming
Context-aware

ABSTRACT

Mobile augmented reality has gained popularity in recent years due to the technological advances of smartphones and other mobile devices. One particular area in which mobile augmented reality is being used is library management. However, current mobile augmented reality solutions in this domain are lacking in context-awareness. It has been suggested in the literature that agent programming may be suitable at overcoming this problem, but little research has been conducted using modern mobile augmented reality applications with agents. This paper aims to bridge this gap through the development of an agent-based, mobile augmented reality prototype, titled Libagent. Libagent was subjected to five experiments to determine its suitability, efficiency, and accuracy for library management. The results of these experiments indicate that agent-based mobile augmented reality is a promising tool for context-aware library management.

1. Introduction

With personalized smartphone applications rapidly gaining popularity in recent years, there has never been a greater need for the delivery of context-sensitive information. The portability of smartphone devices means that more often these devices are being used in the field to support a variety of occupations and scenarios. In many jobs, people are tasked with the management of sizeable inventories of items. However, due to the limited capacity of the human short term memory, we can only manipulate six or seven items concurrently (Keppel and Underwood, 1962; Miller, 1956). This limitation of our cognition can result in errors that amount to significant losses of time and money.

One particular domain in which this problem is evident is the library. In a library, contextual information is very important as books are organized geographically based on subject and catalogue number. Further, books are constantly being moved, loaned, or misplaced. Without additional support, a user may find the task of searching for books difficult, especially in larger libraries. On the other hand, librarians are tasked with the job of stack maintenance. Stack maintenance refers to the re-shelving of material that has been removed from a shelf, or shifting existing material within a stack to make room for new materials.

Current library systems rely on a searchable database, where users can enter keywords to locate catalogue numbers of desired books. Such systems require the user to first locate the correct shelf, and then visually scan through the catalogue numbers to find the appropriate book. Depending on the number of books in a particular category, the degree of similarity between each catalogue number will decrease, thus increasing the search space for the user and the difficulty of finding the book. Additional problems such as incorrect sorting of the books or books being misplaced within the library can also prove challenging. Research in the field of mobile Augmented Reality (AR) and agent programming may provide a solution for context-aware library management.

AR is a novel technology that can be used to enhance a physical environment by overlaying virtual content through a visual interface (Zhou et al., 2012). While the technology has been available since the 1990s, the rapid advances in mobile technology over the past decade have provided powerful and convenient platforms for AR applications (Van Krevelen and Poelman, 2010). The major benefit of mobile devices for AR is that the technology is ubiquitous and easily accessible to consumers. Additionally, the computing power of a mobile device can provide users with the tools to deal with large inventories of physical items, helping to reduce errors and increase performance.

An immediate benefit of AR technology for library management is that it can be used to replace the catalogue number with a simpler visual cue, for example a shape or a colour. Current catalogue numbers require users to scan a shelf and read several book spines to determine their proximity to the desired book. In contrast, an AR application could display a prominent visual cue (e.g. a yellow exclamation mark) over the spine of the desired book, thus significantly simplifying the task of searching for a book. Additionally,

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http://dx.doi.org/10.1016/j.eswa.2013.09.016

AR could be used to aid with sorting, for example visual cues such as arrows, ticks, and crosses could indicate the steps necessary to bring a shelf back to the correct order.

Agent programming could be used alongside AR technology to provide context-awareness to a mobile library management application. By definition, agents are hardware- or software-based entities that exhibit the characteristics of autonomy, social ability, reactivity, and proactivity (Wooldridge et al., 1995). These characteristics make agents ideal for providing context-sensitive information efficiently in dynamic environments. The fact that a library shelf can change its state regularly (e.g. books being moved, added, or erroneously sorted) means that up-to-date information is necessary to reduce frustration and improve efficiency of library staff and users. Researchers have claimed that agents have the potential to improve the delivery of personalized content, but little research has been conducted using agents with modern mobile applications (Maes et al., 1994).

The aim of the research presented in this paper is to determine the benefits of a mobile library management system based on agent programming and AR technologies. It is clear that there is a need for context-awareness in mobile AR applications. While studies in the 1990s (Maes et al., 1994; Nagao, 1998) and early 2000s (Zaslavsky, 2004) suggested the use of agents to approach this challenge, there are few examples of agent-based context-awareness in modern mobile AR literature. However, based on these early studies it is evident that agent programming concepts may vastly improve the user experience for mobile AR applications, in terms of spatial localization and user-centric information. To determine these benefits, we propose a prototype, titled Libagent, and subject it to several experiments. These experiments are designed to determine the correctness, robustness, usability and ease of use in both individual and collaborative environments. The results of these experiments indicate that our system utilizes these technologies effectively to improve on current mobile AR solutions for library management.

The remainder of this paper is structured as follows. Section 2 provides the definitions and context of the major technologies and paradigms used in our research, including mobile AR, agent-based AR, and library management systems. Section 3 explains the framework of our proposed library management system (Libagent), including tools used and main algorithms for library-based tasks. Section 4 describes the research methodologies and results of our experiments, including a discussion of these results in terms of limitations and improvements. Finally, Section 5 concludes the paper with final remarks and recommendations for future research in the field of agent-based mobile AR.

2. Preliminaries

2.1. Mobile augmented reality

AR refers to a live and real-world image that has been enhanced or diminished by virtual content through a camera interface (Zhou et al., 2012). AR technology aims to simplify everyday tasks by complementing the user's perception of and interaction with the real world. There are many possible applications for AR technology. Carmigniani et al. (2011) categorise four main types of applications that have been cited in AR research: advertising and commercial, entertainment, education, and medical (Carmigniani et al., 2011).

AR sits within the broader spectrum of mixed reality proposed by Milgram and Kishino (Van Krevelen and Poelman, 2010). The Reality-Virtuality continuum defines a spectrum of mixed reality applications ranging from no augmentation (real environment) to complete virtualization (virtual environment). In virtual environments (sometimes called virtual reality) and augmented virtuality, real objects are added to virtual environments. AR differs in that it provides local virtuality and consists of augmenting virtual objects into a real world environment.

In order to provide a dynamic experience, AR needs to register the virtual content with the real world. This process is known as tracking. There have been several different methods for tracking and orientation proposed in the AR literature. In general, these approaches can be divided into three classes: visual, non-visual, and hybrid (Zhou et al., 2012). Visual methods include fiducial markers, feature detection, and edge detection. Non-visual approaches rely on additional inertial sensors (e.g. compass and accelerometer) to provide location and orientation information. Hybrid approaches utilize a combination of both methods by complementing the visual system (a camera) with sensor-based data.

While the technology for AR has been available since the 1960s (Van Krevelen and Poelman, 2010), only recently has it experienced an explosion in popularity. This is partially attributed to the rapid advances in mobile technology. Due to the recent influx of smartphones, the challenge of providing context-sensitive information is at the forefront of the field. The fact that mobile devices have become portable and ubiquitous means that location-sensitive information is more important than ever. A report published by the Pew Internet and American Life Project found that 74% of smartphone owners use their phone to get real-time, location-based information (Zickuhr, 2012).

A study conducted by Olsson et al. (2013) gained information about the expectations of mobile AR users in the context of a shopping environment. The case studies involved in this research were conducted in 2009, when mobile AR was experiencing an upheaval due to the release of powerful smartphone devices. This research found that users expect multifaceted services and information from AR applications, including proactivity, relevance, and context-sensitivity. The research concludes that mobile AR has great potential to offer rich and contextual information that is very specific to a time and a place. There are many areas of mobile AR that can benefit from accurate context-awareness. One example use case for context-aware mobile AR is wayfinding. Wayfinding is the process of orientation used by a person to navigate through a physical environment. AR navigation requires a high degree of positional accuracy to succeed (Smit and Barnett, 2010). Recent solutions have attempted sparse localization by positioning fiducial markers throughout a building and offloading most navigational tasks to the user through activity-based instructions (Mulloni et al., 2011; Mulloni et al., 2012). While such a system is highly effective in a static environment, it lacks the ability to respond to dynamic changes in the environment that might affect navigation tasks.

GAT (Rodriguez-Sanchez et al., 2013) is a system that attempts to overcome the static nature of wayfinding applications by allowing users the ability to generate their own wayfinding applications. The system provides a multiplatform app generator so that users can deploy customized wayfinding applications to tourists on all of the popular platforms (e.g. Android, iOS, and Windows phone). GAT uses sensors (e.g. BlueTooth and GPS) alongside visual recognition of QR codes to gain a user's context, and crawls the internet to determine points of interest in the surrounding area. Benefits of GAT include support for both indoor and outdoor navigation and context-specific points of interest. Similarly, the MobileAR browser developed by Engelke et al. (2012) allows developers to create and deploy rich AR applications using web technologies, including HTML5 and JavaScript.

Another use case is to provide location-based information to tourists. MobiAR is an application developed for the Android platform that provides tourists with AR-based information about accommodation, restaurants, and other points of interest (Marimon et al., 2010). MobiAR utilizes both Global Positioning System