Expert Systems with Applications 42 (2015) 810–820

Contents lists available at ScienceDirect

Expert Systems with Applications

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

Design and application of augmented reality query-answering system in mobile phone information navigation

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ARTICLE INFO

Article history:
Available online 27 August 2014

Keywords:
Augmented reality
Data mining
Mobile phone information navigation
Query-answering system
Technology acceptance model

ABSTRACT

This study proposed an augmented reality query-answering system (AR-QAS) based on mobile cloud computing to provide natural language informational navigation services. Empirical research was performed to examine the effectiveness of the system in actual use. This study confirms that the new model developed by combining technology acceptance model (TAM), media richness theory, and the factors of self-efficacy can be applied to relevant AR research. The experiment results revealed that the average question classification accuracy of QAS when combined with artificial neural network and ontology was 98.76%. Moreover, the perceived media richness was found to be positively related to self-efficacy, perceived usefulness, perceived ease of use, user attitude, and use intention. Furthermore, this study reveals that combining the TAM and media richness theory provides a stronger explanation than does the TAM alone. Before new systems are created, designers are suggested to consider the four factors of media richness theory (i.e., multiple cues, language variety, timely feedback, and personal focus), to greatly improve user attitudes toward and behavioral intentions to use new technologies.

1. Introduction

In recent years, mobile devices and services have become ubiquitous. For consumer electronics techniques, with the rise in popularity of mobile devices installed with integrated cameras, such as iPhones, Android phones, or tablet computers, augmented reality (AR) and query-answering system (QAS) have been discussed for and implemented in interactive mobile services. Copious literature has explored the technology and use of AR, but most studies have focused on computer vision methods or the design and use of AR service interfaces and systems (Carmigniani et al., 2011; Lee, Seo, & Rhee, 2008; Verbelen, Stevens, Simoens, Turck, & Dhoedt, 2011). Studies have examined QASs (e.g., SIRI by Apple Inc.) that automatically reply to user questions by using natural language (García-Cumbreras, Martínez-Santiago, & Ureña-López, 2012; García-Santiago & Olvera-Lobo, 2012; Song, Liu, Gu, Quan, & Hao, 2011). However, few studies have focused on the use of AR and QAS in mobile information navigation. Therefore, this study proposes and implements an AR-QAS that includes mobile devices and cloud servers. Mobile devices provide AR functions to recognize camera images and to present 3D objects on device screens. A cloud server provides a QAS based on data mining and expert system techniques to analyze the mobile device messages and to reply to questions. This paper presents a case study of a mobile phone informational navigation service based on an AR-QAS.

For user behavior analysis, the current study combines the technology acceptance model (TAM) (Davis, Bagozzi, & Warshaw, 1989) and media richness theory (Daft & Lengel, 1984) to explore whether using AR positively benefits informational navigation. Specifically, a natural language query AR navigation system was designed in this study, and user attitudes and behavioral intentions to use the system were examined. The study comprised the design of the natural language query AR navigation system and the use of empirical research to determine the acceptance of and behavioral intention toward the system, which was used as an informational navigation guide at a museum.

The remainder of the paper is organized as follows. Related technologies and the background to the study are discussed in Section 2. In Section 3, an AR-QAS is presented and evaluated. In Section 4, the TAM and media richness theory are employed to explore user attitudes and behavioral intentions toward AR-QAS. Finally, conclusions and suggestions are provided in Section 5.

2. Literature review

The research background and relevant technology are discussed as follows: (1) AR, (2) mobile cloud (MC), (3) QAS, (4) TAM, (5) media richness theory, and (6) hypotheses.

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http://dx.doi.org/10.1016/j.eswa.2014.07.050
0957-4174/

2.1. Augmented reality

AR is a 3D imaging technology that imposes data produced by computers onto objects or geographical locations in the real world (Berryman, 2012). The principles of AR differ from those of virtual reality (VR). In VR (e.g., Second Life), all the objects are virtual, digital, and realistic, and virtual images replace the real world. The perceived visuals are used to experience, explore, and interact with the artificial environment. Unlike VR, which presents and facilitates interaction with virtual environments, AR interweaves the real and virtual worlds (Normand, Servieres, & Moreau, 2012). Although AR was developed from VR technology, the use of AR is based on the real world, supplementing elements not existing in the real world instead of creating an entirely artificial world. Thus, physical realism is an essential element of AR, because AR is the technology that integrates digital information into reality and seeks to integrate the digital and the real attempting to blur their boundaries (Berryman, 2012).

Specifically, AR users use webcams or other mobile devices, such as mobile phones, to integrate virtual 3D images and the real world, allowing users to immerse themselves in the real world and concurrently interact with virtual objects. This blurs the boundary between real and virtual, achieving complete immersion for the user. Furthermore, few studies have explored the use of AR in informational navigation conducted using mobile devices. Based on the theory of reasoned action and media richness theory, this study examined whether using AR positively benefits informational navigation. Specifically, this study explores the use and effect of AR as an informational navigation guide at a museum. Users scanned the image of an advertisement flyer by using their mobile phones and a virtual guide then appeared with a brief description of the museum that users could query using voice input. This use of AR technology allowed users to experience a guided navigation through the museum.

2.2. Mobile cloud

The MC brings more convenience to a user. The user can easily access mobile services that provide environment-sensing data anytime and anywhere through sensor-equipped mobile devices (Lane et al., 2010). In addition, cloud computing provides scalable and efficient computing power for mobile services (Armbrust et al., 2010).

2.3. Mobile sensing

The various sensors are included in mobile devices (e.g., smart phones and tablet PCs) to sense real-time environment data and to enable new applications (e.g., healthcare (Lo, Chen, Cheng, & Kung, 2011) and transportation (Chen, Chang, Su, Lo, & Lin, 2013)) known as mobile sensing (Lane et al., 2010) applications. For example, the iPhone 4 includes eight sensors (accelerometer, GPS, ambient light sensor, dual microphones, proximity sensor, dual cameras, compass, and gyroscope) and provides more computation, memory, storage, sensing, and communication bandwidth for interactive multimedia applications (Lane et al., 2010).

Lo et al. proposed a mobile merchandise evaluation service platform (MMESP) that classifies pictures from mobile phones with a camera sensor and enables companies to recognize user merchandise and offer buying recommendations (Lo et al., 2011). Although MMESP could combine mobile sensing technology and quickly provide the merchandise prices and user evaluations, the user still had to review written information presented to him or her on the mobile phone screen.

This study uses mobile sensing technology to collect image data from a mobile phone sensor (i.e., a camera) to generate a 3D image of an advertisement flyer. Furthermore, this study uses QAS to improve interaction between humans and computers.

2.4. Cloud computing

Cloud computing can support virtualization and distributed computing to provide a flexible high-performance computing ability and a vast amount of data analysis (Lin, Chen, Chang, & Lo, 2011). The National Institute of Standards and Technology defined the cloud model as comprising five essential characteristics (on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service), three service models (Software as a Service, or SaaS; Platform as a Service; and Infrastructure as a Service), and four deployment models (private cloud, community cloud, public cloud, and hybrid cloud) (Mell & Grance, 2011).

Regarding cloud-based recommenders, Chen et al. proposed and implemented a cloud-based recommender system (CBRS) that combined multiple document summarization and a cloud computing algorithm based on the MapReduce program (Dean & Ghemawat, 2008). CBRS considers positive and negative comments, collects and analyzes user comments from blogs and forums, and rapidly generates comment summaries for the user's reference (Chen, Yang, Shih, Lee, & Lo, 2011). However, the study only analyzes comments and does not provide QAS. Therefore, this study designs and implements a QAS based on cloud computing to provide an SaaS.

2.5. Query-answering system

This study defines the concerns of QAS as requirement-classification problems to classify questions. In recent years, various requirement classification systems have been proposed and implemented (Ko, Park, Seo, & Choi, 2007; Lo et al., 2011). The procedures inherent in those systems consisted of the follows: (1) preprocessing, (2) the construction of a set of centroid-sentences as training data for each topic category, and (3) a learning classifier procedure (Ko et al., 2007).

Procedure (1) includes (i) segmenting requirements into sentences and (ii) extracting content words (Ko et al., 2007). For sentence segmentation in Chinese, the CKIP system is a useful Chinese segmentation system that includes methods for resolving unknown words (Ma & Chen, 2003). Although these approaches are serviceable, they possess insufficient energy resources for special domains, such as an informational navigation guide at a museum. For example, a specific Chinese word "牛汶水 (Niu Wenshui),"which is a type of Hakka snack, is segmented into three Chinese words "牛," "汶," and "水."

Procedure (2) includes (i) generating a keyword list for each category, (ii) extracting keyword sentences, and (iii) measuring word and sentence similarities (Ko et al., 2007). For measuring similarities, Fan and Friedman compared two methods that included a corpus-based semantic similarity (CBSS) and an ontology-based semantic similarity (OBSS) (Fan & Friedman, 2007). The study indicated that CBSS cannot support semantically classified ontological concepts. In this study, AR-QAS applies OBSS to calculate similarities.

For Procedure (3), several classification techniques including regression methods (Kung, Chen, & Ku, 2012), Naïve Bayes (NB) classifier methods, k-Nearest Neighbor (kNN) methods (Chen, Lin, Lin, Liu, & Lo, 2012), and artificial neural networks (ANN) (Kung et al., 2012; Lin & Chen, 2013) have been discussed. The NB classifier, which is a probabilistic generative model, can be calculated quickly and favorable results can be obtained without the use of numerous samples. However, the main assumption is that all the data or terms involved should be conditionally independent, which rarely occurs in real life (Ko et al., 2007). Ishii et al. proposed a