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Physical query interface for tangible augmented tagging and interaction

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ABSTRACT

A new physical query interface is proposed for tangible augmented tagging and interaction using two types of context-aware AR interfaces, visual and invisible interfaces. In visual interfaces, augmented reality markers are utilized for supporting intuitive interactions and manipulations with digital contents. RFID is used as an invisible interface for supporting line-of-sight, direct and query interactions. By combining the advantages of visual and invisible interfaces, more natural interaction with digital contents can be provided, which can remove the difficulty of using typical AR paddles, cubes and gadgets that are widely used in AR interactions. Semantic ontology is adopted in order to effectively support physical querying, filtering and grouping through the combination of multiple RFID tags. The proposed approach has been applied to a variety of multi-media interactions, such as digital product review and digital catalog or book interaction. We show the effectiveness and the advantages of the proposed approach by demonstrating several implementation results and by a usability study.

1. Introduction

In knowledge sharing and collaboration, paper-based documents are still mainly used to verify the feasibility of related digital contents. This preference can be attributed to the convenient availability of the physical documents. However, it takes time to physically access paper documents, even when their locations are known. Moreover, the user must often combine the information of two or more separate documents (Mackay & Pagani, 1994; Terry, Cheung, Lee, Park, & Williams, 2007). This is tedious and prone to error. Digital media, on the other hand, allows one to precisely create and edit digital contents with ease, and can be searched and accessed very quickly. However, digital media cannot replace physical objects in order to support knowledge sharing, design review, and collaboration, which implies that both should be combined to complement each other. For this reason, a growing number of tangible user interfaces (TUIs) have shown that TUI can couple digital information to physical objects and their ambient space in a seamless manner (Ishii & Ullmer, 1997).

Most TUIs make a direct "one-to-one" mapping between physical objects and related digital information. This implies that they have difficulty in providing interactive tangible queries that are crucial to seamlessly linking between physical objects and digital ones. While large aggregates of information are common for digital operations such as querying, sorting and grouping, such operations may be difficult to express, view, and build upon if data elements are individually embodied. Instead of using physical objects to directly represent individual information elements, it is important to use physical objects to indirectly reference information by representing queries that hold over large aggregates of information (Ullmer & et al., 2008).

Recently, in TUI environments, augmented reality (AR) and radio frequency identification (RFID) have been considered as core components that can merge real and virtual objects to produce a new environment where they can co-exist and interact (Azuma et al., 2001; Grønbæk, Ørbæk, Kristensen, & Eriksen, 2007; Kato, Billinghurst, Poupyrev, Imamoto, & Tachibana, 2000). We can expect that RFID and AR will play a major role in providing effective, wireless, and tangible interfaces in various applications.

Augmented reality (AR) can naturally complement physical objects by providing an intuitive and collaborative interface to a three-dimensional information space embedded within physical reality (ARToolkit, 2007; Azuma et al., 2001; Billinghurt, Kato, & Poupyrev, 2001; Kim & Dey, 2010). However, although an AR interface provides a natural environment for viewing spatial data, it is still challenging to interact with and change the virtual content. One way to overcome this is through a type of TUI called tangible AR. Park, Moon, and Lee (2009) proposed an approach to tangible augmented prototyping of digital handheld products using AR-based tangible interaction and functional behavior simulation. Kato et al. (2000) addressed the problems of virtual object interaction and user tracking in a table-top AR interface. Meanwhile, as a tangible interface tool, RFID has received much attention as an interface technology with physical objects. As RFID tags can be attached to everyday items, they may be used to support various ubiquitous and tangible services (Broll & Hausen, 2010; Khoovirajsingh S., 2009; Riekki, Salminen, & Alakarppa, 2006). It is well known that

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RFID technology has many benefits over other identification technologies because it does not require line-of-sight alignment, multiple tags can be identified almost simultaneously, and the tags do not destroy the integrity or aesthetics of the original objects (Florerkemeier & Lampe, 2004). Grønbæk et al. (2007) introduced the notion of physical hypermedia, addressing the problem of organizing material in mixed digital and physical environments. Thus, we can expect that visual AR markers and invisible tangibles would be gradually integrated to compensate for each other.

To make TUI more user-centric in the AR environment, context-awareness should be utilized. This is called *context-aware tangible AR interaction*. The context-aware tangible AR interaction is used to provide a more user-oriented interface by utilizing TUI contexts (Henricksen, Indulska, & Rakotonirainy, 2002; Lee, Seo, & Rhee, 2008; Yau, Karim, Wang, & Gupta, 2002). There have been few previous works which effectively support context-aware tangible AR interactions. One of the important issues in providing context-aware tangible AR interactions is how to provide natural tangible queries and interactions.

We propose a new physical query interface for tangible augmented reality using two types of context-aware AR interfaces, visual and invisible interfaces. In visual interfaces, augmented reality markers are utilized for supporting intuitive interactions and manipulations with digital contents. RFID is used as an invisible interface for supporting line-of-sight, direct and query interactions. By combining the advantages of visual and invisible interfaces, more natural interaction with digital contents can be provided, which can remove the difficulty of using typical AR paddles, cubes and gadgets that are widely used in AR interactions. One of the main characteristics of the proposed approach is to provide context-aware tangible AR services by combining RFID and AR for effective physical querying, filtering and grouping. To make this interaction possible, the proposed approach adopts semantic ontology to effectively represent and reason about RFID-related physical and digital semantics, which can support more natural and intuitive interactions with AR information. We show the effectiveness and the advantages of the proposed approach by demonstrating implementation results of digital product review and AR pamphlet or catalog. We also present an analysis of a usability study. Section 2 briefly reviews related work. Section 3 overviews the proposed approach. Section 4 presents how to support physical tangible queries by combining visual and invisible tangible interfaces with context-awareness. Section 5 shows implementation results and an analysis of a usability study to compare the proposed approach with other well-known AR interactions. Finally, Section 6 concludes with some remarks.

2. Related work

Many researchers have considered how users will interact with AR information and how to effectively present information on AR displays. However, most AR approaches have concentrated on displaying information registered in the real world without significant concern for how users would interact with these systems (Azuma et al., 2001). Thus, it is very difficult to interact with purely virtual information. One attempt to provide intuitive and natural AR interaction is integrating the physical world through tangible interfaces. Tangible interfaces support direct interaction with the physical world by the use of real, physical objects and tools. In particular, tangible AR combines the intuitiveness of tangible interfaces with the realistic rendering capabilities of AR. There are two main approaches in tangible AR interactions: (1) AR marker-based and (2) AR-tangible-based.

The AR marker-based approach can utilize visual AR markers such as AR paddle, AR cube or AR-glove. The easiest way for supporting tangible interfaces is to use an AR paddle. For example, a user can move a paddle to manipulate furniture models in a prototype interior design application. Through pushing, tilting, and other motions, the user can select pieces of furniture and place them in a desired location, and remove them from the room (Kato et al., 2000). One of the big problems in using the AR paddle is occlusion. For partially solving occlusion problems, Lee and Woo (2010) introduced a tangible spin cube for a 3D ring menu, which was implemented by a multi-marker AR cube for 3D menus. Although the AR paddle or cube can be utilized for simple interaction and manipulation, it cannot support effective and intuitive query interaction with the physical world. As another AR interface, an AR-glove can also be used. A big advantage of adopting glove-based interaction is the intuitive use of gestures such as pointing, grabbing, and selecting. One of the most popular implementations is based on light-weight pinch gloves which trigger actions by hand gestures (Lee, Rhee, & Seo, 2010). Usually, fiducial AR markers are attached around the hand to track gestures from the user (Buchmann, Violich, Billinghurst, & Cockburn, 2004). However, wearing gloves with attached markers is cumbersome and inconvenient.

In addition to AR marker-based interactions, different kinds of AR tangibles such as RFID, rapid prototyping, and interaction tray have been used for interactions and interfaces. There have been a few studies which tried to apply RFID for visualization and interaction. Grønbæk et al. (2007) introduced the notion of physical hypermedia, addressing the problem of organizing material in mixed digital and physical environments. They presented a prototype of a physical hypermedia system which could run on an augmented architect's desk and digital walls utilizing RFID tags as well as visual tags. Rashid, Bamford, Coulton, and Edwards (2006) proposed PAC–LAN, mixed-reality gaming with RFID-enabled mobile phones, which showed possibility of incorporating RFID readers with mobile phones for mixed-reality entertainment experiences. Africano et al. (2004) presented a design concept for an interactive play system and learning tool for children using RFID. However, RFID was just used for simple ID matching between virtual and physical objects such that only a limited set of capabilities of RFID could be utilized. Other tangibles have also been utilized. Park et al. (2009) proposed a tangible interaction method using augmented reality and rapid prototyping for supporting collaborative design evaluation of digital handheld products. Some have proposed mobile touch and physical user interfaces with NFC-based mobile interactions (Broll & Hausen, 2010; Khoovirajsingh & Enrico, 2009). Terry et al. (2007) introduced Jump, a prototype computer vision-based system that transformed paper-based architectural documents into query interfaces. Ullmer et al. (2008) introduced core tangibles: physical interaction elements which serve common roles across a variety of tangibles and embedded interfaces such as tangible menus and interaction trays. These previous works showed that AR tangibles made it possible for physical objects to be equally important as virtual ones.

Considering previous research works, we can expect that AR tangibles can compensate for conventional AR marker-based interfaces including AR paddles and AR cubes, which can provide more effective, intuitive, and tangible interfaces in various applications. Nevertheless, there have been few studies which support context-aware tangible AR interactions in AR environments. Context-aware tangible AR interaction should extend the existing capabilities of TUI and AR to provide more valuable features such as tangible querying, filtering, and grouping.

3. Overview of physical query interfaces

The proposed physical query interface for context-aware tangible AR interactions combines the power of augmented reality and