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Unified Context-aware Augmented Reality Application Framework for User-Driven Tour Guides

Choonsung Shin, Hyejin Kim, Changgu Kang, Youngkyoon Jang, Ahyoung Choi, Woontack Woo
GIST U-VR Lab.
1 Oryong-dong, Bukgu
Gwangju, S. Korea
{cshin, hjinkim, ckang, yjang, achoi, wwoo}@gist.ac.kr

Abstract—**We propose a unified context-aware augmented reality application framework that supports intelligent guidance and enables users to participate in content generation in museum guidance. It helps a user find personal interesting artifacts in art galleries by exploiting context-based behavior generation. The framework also enables them to combine augmented contents with different information to change the shape of content according to their preferences. Furthermore, it allows the users to label real objects for attaching new contents over the objects. Through demonstration in an art gallery, we found that the resulting system effectively guided users to visit and enabled them to participate in tour guidance.**

Keywords: Augmented Reality, Context-Awareness, Mobile Computing, Ubiquitous Virtual Reality.

I. INTRODUCTION

With new computing paradigms, smart spaces are evolving toward meeting residents' desires and improving experience [1–3]. Among spaces, museums are popular places where people spend a great deal of time with their friends and family to learn about cultural and historical artifacts. The cyberguide, a context-aware electronic tour guide, provides patrons with rich information in addition to the real artifacts in a museum [4]. Furthermore, mobile guidance systems based on augmented reality can improve the tour experience by presenting information over real objects. Unlike traditional tour guides, augmented reality based ones can change user experiences by intuitively providing information over real objects [5]. Therefore, it is a promising approach to use mobile augmented reality and context awareness in tour guidance.

To encourage user experience in museums, many frameworks have been developed to effectively support museum guidance. Initially, heavy devices supported mobile tour guidance [5]. Then, handheld devices such as PDAs and UMPCs also demonstrated the possibility of guidance based on mobile AR [6–8]. Recently, various smart phones are considered the most popular devices for mobile tour guidance [9]. As a result, a number of applications have appeared on various platforms such as iPhone, Android, and Windows Mobile. However, the previous approaches have focused on how to provide users with existing content by presenting virtual content over real objects, which are mainly offered by service providers. Due to this vertical relationship between content producers and content consumers, it is very difficult to reflect users' opinions and desires. Besides, user experience and knowledge that is gained during tours is not shared and reused among different visitors.

To solve these problems, we propose a unified, context-aware, augmented reality application framework oriented toward tour guidance. It offers a basic workflow to develop applications with the combination of context-awareness and augmented reality. It also allows users to generate and share content about real objects through object tagging and content mashup. We also developed a tour guide application on a smart phone by using the framework and its core components and explored the potential of various applications to enhance the tour guidance.

Hereafter, we first describe the overall architecture of our framework and its core components, as well as detail their implementation for an art gallery. Finally, we conclude with upcoming studies.

II. UNIFIED CONTEXT-AWARE AUGMENTED REALITY APPLICATION FRAMEWORK

To provide a basic framework for user-driven guidance systems, we exploit users' participation as well as the fusion of the real and virtual space. The fusion is supported by the integration of object recognition and tracking, along with that of content visualization. Users are empowered to participate in content generation by mobile authoring and mashup over real objects. For this purpose, we extend context-aware mobile AR (CAMAR), which offers a basic framework to combine context-awareness and augmented reality on mobile devices [10, 11]. In particular, we add content adaptation and space management to allow users to participate in content generation and content sharing. The content adaptation part allows users to tag real objects and add contents over the objects with only a few inputs. It also enables users to connect and mix different databases with the object. The space management part stores, manages, and distributes content that is generated from service developers and end-users.

The overall architecture for the unified context-aware augmented reality application framework is illustrated in Figure 1. The proposed framework is composed of two main parts: an authoring platform and a content server. The authoring platform consists of context-awareness, object recognition and tracking, content adaptation, and visualization. The dual space manager manages contents generated and users.

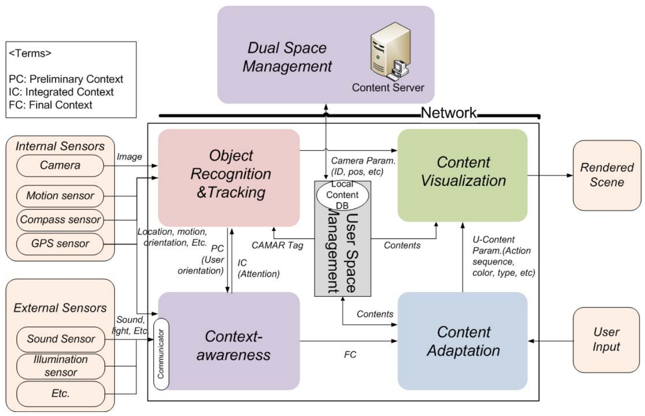


Figure 1. Unified Context-Aware Augmented Reality Application Framework

As seen in Figure 1, the authoring platform acquires sensory information from internal and external sensors and visualizes contents over real objects by combining context-awareness, object recognition and tracking, content adaptation, and visualization. The adaptation component supports interfaces through which developers may create their desired applications.

A. *Context-Awareness*

Context-Awareness is the first step to gather and integrate low-level contexts to generate high-level contexts through context fusion, reasoning, and matching.

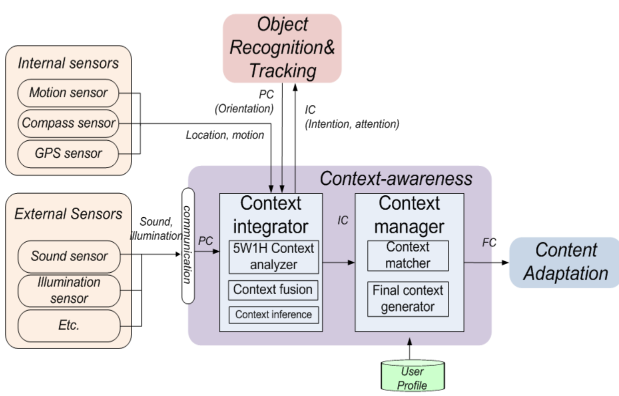


Figure 2. Context-Awareness

For this purpose, we utilized the 5W1H context model [13] and the core Unified Context-Aware Application Model (UCAM) [12] for smart spaces. The context model describes various situational information about a user based on the Who, What, When, Where, Why and How structure. It describes a low-level context as a preliminary context, a high-level context as an integrated context, and a selected context as a final context. The UCAM core consists of a context integrator that integrates preliminary contexts and of a context manager that stores the integrated contexts and delivers a final context corresponding to one of the conditions in a user profile.

As illustrated in Figure 2, the Context-Awareness component first integrates preliminary contexts generated from internal and external sensors. It then analyzes and merges the contexts based on the 5W1H (Who, What, When, Where, Why and How) structure. It also infers high-level contexts from the merged contexts and preliminary contexts. The context manager then matches the resulting contexts with conditional contexts to generate a final context that describes a particular action corresponding to the situation.

B. *Space Management*

The User Space Management component manages location contents and synchronizes them thanks to the Dual Space Management component located in a content server. The local contents include user-defined visual tags, images, texts, audio, etc. The component downloads relevant contents from the server by exploiting context elements such as location and orientation. It also updates the contents when a user modifies and adds contents associated with real objects. Figure 3 shows the details of the space management component.

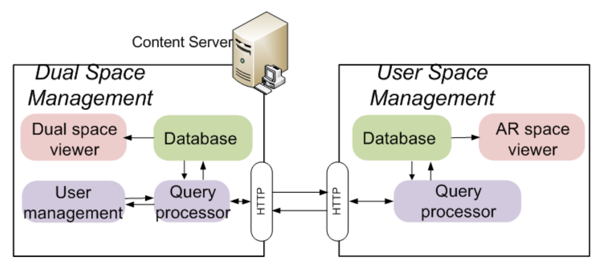


Figure 3. Space Management

C. *Object Recognition & Tracking*

The Object Recognition and Tracking component obtains camera parameters and object identification from a sequence of camera images. To robustly track and recognize objects, this component uses sensory information and the integrated contexts from the Context–Awareness component and then selects the most appropriate algorithm among available tracking methods.

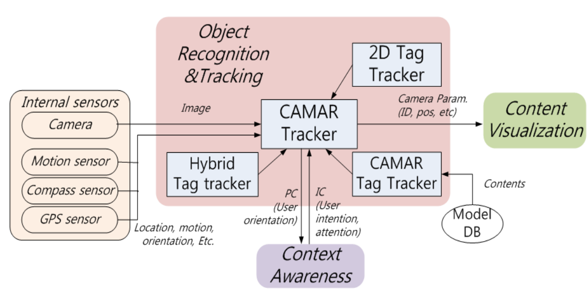


Figure 4. Object Recognition and Tracking

There are three tracking methods: 2D fiducial marker tracking, hybrid visual tag tracking, and user-defined tag tracking. The 2D fiducial marker tracking is a well-known method that uses a set of marker patterns attached to real objects. The hybrid visual tag tracking, which combines marker tracking and natural feature tracking, is robust against occlusion [14]. The user-defined tag tracking uses the features indicated by users [15].

D. Content Adaptation

After recognizing an object and being aware of a user's situation, appropriate contents are selected and customized based on a final context from the Context-Awareness component. This context describes the situation involving a user and his/her surroundings. Users are also allowed to generate contents over real objects. Users tag and attach contents. They also can connect existing databases and functions to real objects as a mashup. Figure 5 illustrates the Content Adaptation component.

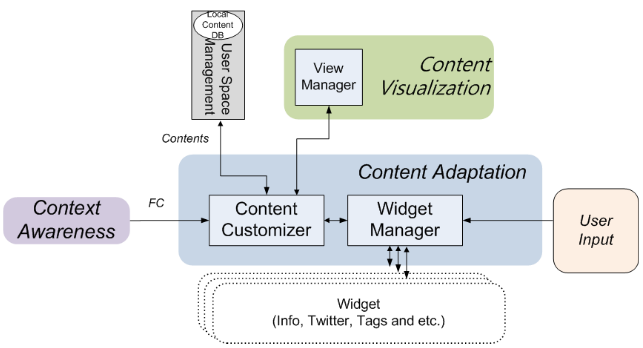


Figure 5. Content Adaptation

For support application development, each service is realized through a widget, which has a particular functionality, and shares other components. The widget allows content to react to the situation according to context-events from the Context-Awareness component. It retrieves and modifies contents stored by the User Space Management component. Each widget also generates a set of parameters corresponding to the selected contents and delivers it to the Content Visualization component.

E. Content Visualization

The selected contents are shown on the screen thanks to the Content Visualization component that draws texts, images, polygons, and video clips over real objects. It also overlays contents associated with objects upon a given camera image. For this purpose, it gathers camera parameters from the Object Recognition & Tracking component, content parameters from the Adaptation component, and contents from the User Space Management component. Figure 6 details how the Content Visualization component exploits world coordination and model view coordination.

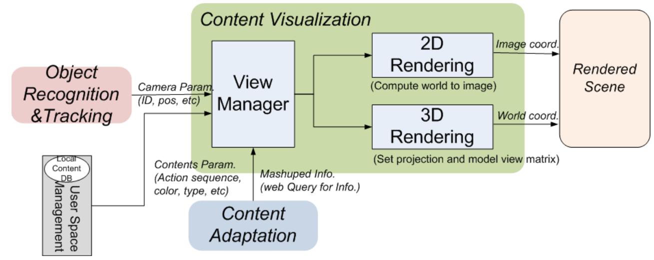


Figure 6. Content Visualization

III. IMPLEMENTATION

We implemented our framework with Visual Studio 2008 on a Samsung T*Omina phone that possesses a touch screen, an accelerometer, and Bluetooth and Wi-Fi capabilities. We developed an external compass sensor and connected it with Bluetooth communication. Furthermore, we used OpenCV to process images [12] and OpenGL ES to render contents [13]. Furthermore, we implemented the content server with MySQL and Open Scene Graph (OSG) to manage contents used in tour guidance.

Based on these, we then developed a tour guidance application that incorporated several widgets for a small art gallery test-bed that has different types of paints for prototyping. It exploits the CAMAR navigation widget, the CAMAR tagging widget, and the CAMAR mashup widget. The CAMAR navigation widget allows users to find their way during a visit by providing a 2D arrow.

(a) Augmentation with an Arrow (b) Augmentation with an Annotation

Figure 7. CAMAR Navigation Widget

As illustrated in Figure 7, the widget displays an arrow pointing towards the next area and changes its orientation according to the angle of the smart phone. The widget also displays annotations about artifacts when the camera faces a wall that holds a painting.

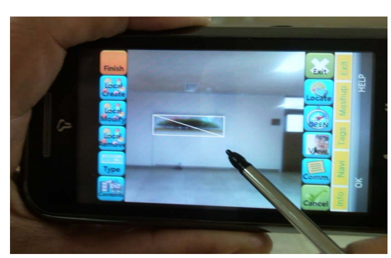
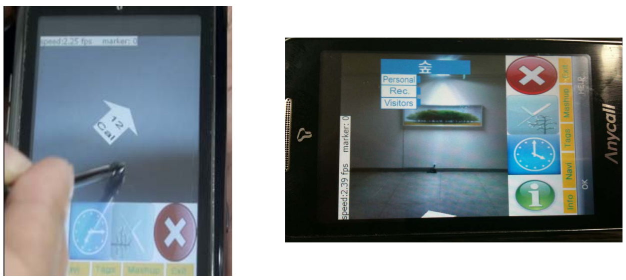


Figure 8. CAMAR Tagging Widget

The CAMAR tagging widget enables users to tag physical objects in real space. It allows a user to first register a reference object to set a global reference. Afterwards, other objects are tagged with a few clicks as illustrated in Figure 8. Users can attach images and texts over tagged objects.

The CAMAR mashup widget enables users to change overlaid contents according to selected styles [16]. The users can change the arrow type when they connect a database to the arrow. For example, the information in the arrow can be changed according to the database it accesses, as shown in Figure 9(a). Furthermore, the annotation of an artifact can also be updated when the user clicks the recommendation related to the artifact, as illustrated in Figure 9(b).



(a) Arrow Mashup (b) Rating Recommendation

Figure 9: CAMAR Mashup Widget

Although we only demonstrated part of the service for tour guide applications, countless services may be developed for museums. For example, a visual and audio explanation service could automatically give users additional details about artifacts when the artifacts are recognized.

IV. CONCLUSION

We proposed a unified context-aware augmented reality application framework for guidance in art galleries exploiting context-aware and mobile augmented reality as well as users' participation. The combination of context-awareness and mobile augmented reality enabled users to intuitively find their way to reach and see additional information about artifacts. The users' participation allowed them to generate, mix, and share contents, thereby improving engagement during museum tours.

This is our first step toward software framework for user-driven mixed reality tour guidance; thus, numerous challenges still remain to be solved. We plan to enhance the accuracy of camera pose by matching real scenes with corresponding 3D virtual models. We also plan to combine various types of open databases to support dynamic mashup over real objects. Finally, we plan to use social contexts to provide better recommendation and discovery of information generated by other users.

Acknowledgement

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