CAMAR: Context-aware Mobile Augmented Reality in Smart Space

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Abstract

*In this paper, we present a novel approach of Context-aware Mobile Augmented Reality (*CAMAR*) combining context awareness and mobile augmented reality.* CAMAR *is aware of a user's context through the user-centric integration of contextual information in smart space. Based on the user's context, it enables a user to experience augmented entities and to share them with other mobile users selectively in a customized way. We review technical challenges for realizing the proposed* CAMAR *and describe our approaches to meet these challenges. To show the effectiveness of our work, we have developed* CAMAR-*enabled applications for smart home environments. Ultimately, we have confirmed possibilities for* CAMAR *as a personalized AR interface in smart space.*

1. Introduction

With recent advance in hardware and software for mobile computing, many researchers have developed mobile augmented reality (AR) systems that enable a user to access and to manipulate computer generated content in real environments [1] [2]. Most of them have focused on seamless content augmentation over physical objects while a user is moving. However, these systems sometimes disturb the user by offering information unnecessary to the user's context.

To overcome irrelevant information augmentation, there are researches to apply context awareness [3] to AR systems [4] [5]. These researches have focused how to minimize information overload by overlaying relevant content over associated physical objects based on a user's context. However, current mobile AR enabling technologies (e.g., tracking, registration) are not enough to make a user believe computer-generated virtual objects coexisted in the same physical space as real objects because of the lack of processing capabilities (e.g., computational power). Thus, we need to consider how to enhance these technologies by exploiting contextual information with less computational cost. In addition, with the advent of social computing, it requires to support suitable social behaviors between mobile users through mobile AR systems.

In this paper, we introduce Context-aware Mobile Augmented Reality (*CAMAR*) to be capable of context awareness in mobile AR systems. Since there are technical challenges to achieve *CAMAR*, we present our approaches to overcome these challenges. Moreover, we have realized the concept of *CAMAR* through *CAMAR*-enabled applications. Finally, we plan future research directions for the *CAMAR*.

2. *CAMAR*: Context-aware Mobile AR

We define Context-Aware Mobile AR (*CAMAR*) that supports personalized information augmentation and selective sharing through mobile AR-based interaction [6]. A user's context is inferred on a mobile device based on contextual cues generated from sensors and services in smart space. Our *CAMAR* customizes information suitable for the context and overlays the personalized information over entities[†] seamlessly. In addition, it enables a mobile user to access augmented entities and to interact with them in the user-centric manner. *CAMAR* also allows the user to share personalized entities with others selectively. Figure 1 describes technical challenges that are significant in realizing the *CAMAR*.

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[†] We quoted the definition from A. Dey's work [7]. An entity can be a person, object, or a space.

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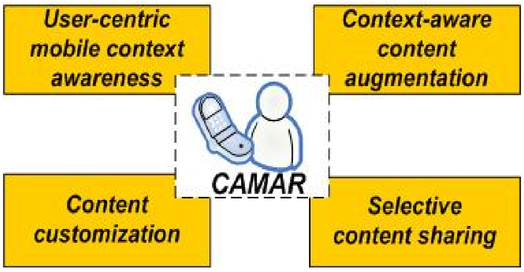


Figure 1. Technical challenges for *CAMAR*.

2.1. User-centric mobile context awareness

Mobile context awareness is material to a system which offers information suitable for a user's context regardless of the user's location. A mobile device carried by a user is needed to obtain information pertaining to a user's context. In addition, toward context-sensitive information provision, the device should keep an effective reasoning mechanism to infer the user's context from the obtained information with less effort.

In our *CAMAR*, we have exploited the *UCAM* [8], a framework for developing context-aware applications, to perceive a user's context through a mobile device. Thus, the mobile device forms an association with sensors and services in smart space and then gets information pertaining to a user's context. As shown in Figure 2, we integrate the set of acquired information in a user-centric manner. Furthermore, reasoning of a user's implicit context (e.g., intention) may be based on a standard classifier learning technique effective on a mobile device. Moreover, we keep the track of a user's context through a mobile device. Based on the context history, user profile containing the user's preference on content is inferred as it is needed.

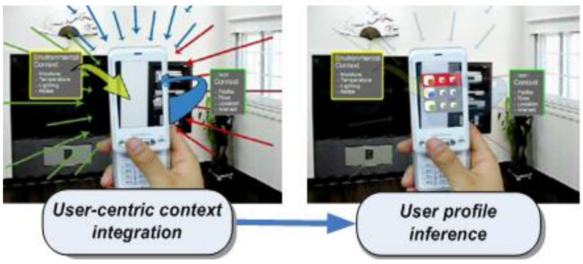


Figure 2. User-centric context integration and user profile inference.

2.2. Context-aware content augmentation

A mobile AR system lets a user experience augmented entities through a mobile device in the real space. Thus, the system should know which entities exist in real environment and track the position and orientation of physical entities. In addition, rendering computer-generated virtual entities over the physical entities in a realistic way is one of key challenges in *CAMAR*.

Here, we present context-aware entity recognition and tracking, and content augmentation over entities. Except non-visual tracking technologies (e.g., magnetic and ultrasound), there are two kinds of visual tracking technologies; a visual marker-based or a marker-less tracking [2]. We improve the performance of the two ways by exploiting contextual information. That is, we adjust a threshold value to recognize the marker by reflecting environmental context (e.g., a lighting condition) [9]. We also differentiate an entity tracking based on different approaches (e.g., natural feature detection, edge detection, planar methods) with respect to context. Moreover, by aligning computer-generated content with physical entities based on environmental conditions (e.g., sound, lighting), we increase a user's coexistence with augmented entities in the same real space [10].

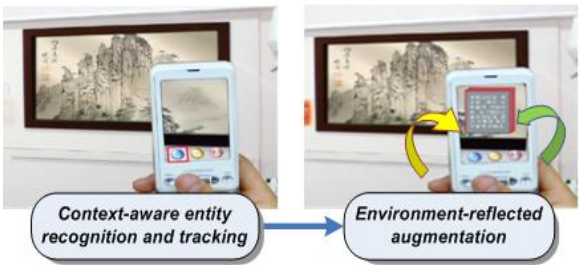


Figure 3. Mobile content augmentation based on context awareness.

2.3. Content customization

One of advantages of our *CAMAR* is to make a mobile user to experience augmented entities relevant to a user's context. Thus, it needs to select suitable information associated with a physical entity and visualize the information in an understandable way to the user. In addition, designing mobile user interface reflecting the user's experience is one of key challenges toward natural interaction with augmented entities.

We differentiate virtual content, which is annotated to entities, in accordance with a user's context. The customization is based on the context history including user preference on the content. At first, filtering proper information suitable for a user's context is to infer useful information or content by reflecting user feedback associated with similar situations in the context history. We then adjust the format of the filtered information to be acceptable to a user in accordance with user profile. The customized content is aligned with a real entity to be intuitive to a user. Whenever a context is changed, filtered information and its representation are also adjusted in real time. Furthermore, to enable a user to interact with augmented entities, we provide personalized user interface that consists of different properties (e.g., arrangement, representation, color) suitable for user's preference on the interface [11].

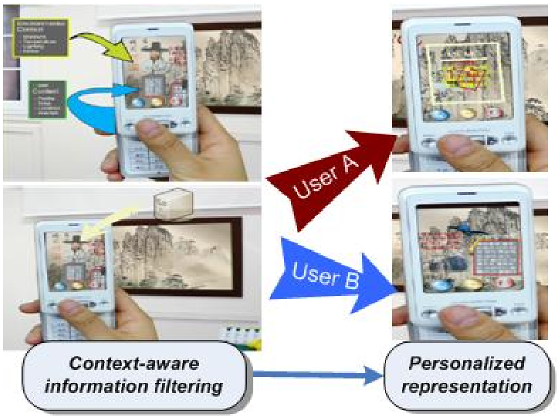


Figure 4. Content customization through context-aware information filtering and representation

2.4. Selective content sharing

Sharing information with others through a mobile device is required to support social behaviors between mobile users. Firstly, we need to generate physical or logical collaboration space where multiple users can interact with each other. To enhance the interaction between mobile users in the space, it also requires to offer a mobile user interaction for sharing information with others easily.

CAMAR allows a mobile user to share his or her personalized content with others selectively with respect to context. That is, we enable a user to generate the relationship to entities (i.e., resources, contents, and other mobile users) through a mobile device. Then, a community consisting of entities with a common goal is generated based on the relationship [12]. The community is also updated according to the user's changing context in real time. As shown in Figure 5, to enable a user to share or collaborate with others, we determine proper content to be useful to or to be satisfied with multiple users by harmonizing each user's preference on the content [13].

Figure 5. A community-based selective content sharing

3. *CAMAR*-enabled applications

We designed a software platform for allowing developers to implement *CAMAR*-enabled applications. As shown in Figure 6, this platform consists of core components for context awareness, personalization, content sharing, and augmentation. Context awareness module reasons a user's context based on contextual cues from sensors and services, and infers user profile related to the context in real time. Sharing module determines a strategy for content sharing in a community. Based on the strategy, personalization module customizes the content to be preferable to a user according to user profile and generates control parameters to visualize the content. Finally, the augmentation part tracks physical entities and overlays the personalized content over associated entities suitable for a user's context.

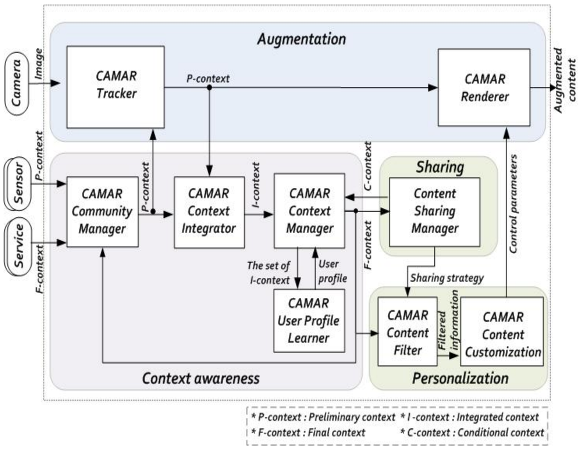
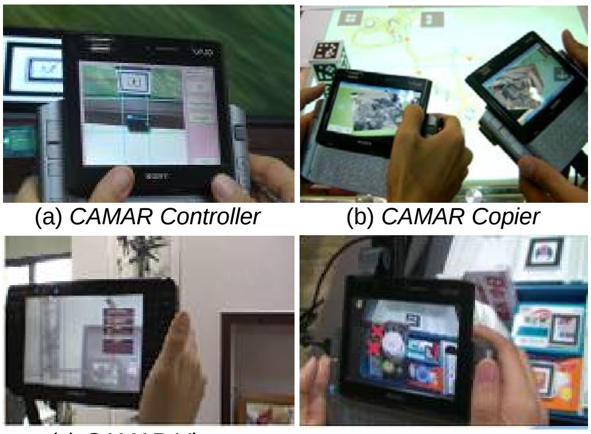


Figure 6. A software platform for *CAMAR*

Based on the above platform, as shown in Figure 7, we have developed *CAMAR*-enabled applications, to illustrate how *CAMAR* could be applied into smart space. Firstly, we developed *CAMAR Controller* which let a mobile user control smart objects with personalized control interface on the mobile device by reflecting user's preference [14]. We implemented *CAMAR Copier* for a mobile user's content sharing with others selectively [6]. It allowed the user to share personalized content with other mobile users with respect to common interest based on identity, time, place, and preference on the content. We introduced *CAMAR Viewer* visualizing invisible information suitable for a user's context. We also suggested a user-adaptive assistant, *CAMAR Companion*, which provided a mobile user with personalized information guidance augmented over entities continuously.



(a) *CAMAR Controller* (b) *CAMAR Copier*

(c) *CAMAR Viewer* (d) *CAMAR Companion*

Figure 7. *CAMAR*-enabled applications

4. Discussion

From above *CAMAR*-enable applications, we could find that our *CAMAR* could enhance a user's personalized experience through AR interaction. Firstly, contextual cues from various sensors in environments were acquired and a user's context associated with the cues is inferred in real time. Exploiting environmental context could enhance the performance of entity recognition and tracking on the mobile device. We also enabled a user to experience multimedia content customized to the user's context in implemented domains. By allowing a mobile user to share his or her personal experiences with others selectively, we could support a sort of social interaction between mobile users.

Of course still important aspects lie in the evaluation of the proposed *CAMAR*. That is, it is required to evaluate implemented applications in quantitative and qualitative ways. Thus, we plan to measure systematic performance of current implemented results. We also need to perform qualitative analysis through usability test about a user's experiences on *CAMAR*-enabled applications.

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