Exploiting Context-awareness in Augmented Reality Applications*

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Abstract

In this paper, we study how to exploit the context-awareness in augmented reality (AR) applications to take advantage of the context in both the high-level and low-level processing. We propose an AR system architecture that works with a context-awareness framework. In the system, both the preliminary and the final context is provided to the process that needs the context. We provide two scenarios that exploit the context in AR applications in the low-level processing and show implementation results with the proposed system. In the first scenario, we adopt a light sensor to enhance the marker detection performance under the varying lighting condition. In the second scenario, we exploit the context in the marker recognition stage where a single color marker is recognized as several different sub-markers based on the context. By adopting the context in the low-level processing, it is possible to address the problems that are hard to be solved by the computer vision techniques only.

1. Introduction

In ubiquitous computing environment, there exist many mobile devices and sensors distributed in the environment. These devices provide us with useful information called the preliminary context, such as location, time, temperature and a user's profile. From the preliminary context, the final context, which contains meaningful information, can be extracted through the context-awareness frameworks [5, 3]. In many applications, both the preliminary context and the final context have been used to support the activities in our daily life.

With the emerging trend of ubiquitous computing paradigm, many AR applications also have adopted the context as important information to enhance the user's experience. Höllerer *et al.* proposed a methodology that provides user interfaces actively managed by the available context in mobile AR system [2]. Suh *et al.* proposed a system that aims personalized control of the smart objects and provision of the personalized contents [6]. In their system, many users in the same smart space can control appliances and services with their own mobile devices, simultaneously. However, most of context-aware AR systems have exploited the context only in the high-level processing such as contents selection and interaction. They have not took advantage of the available context in the low level processing, such as marker detection and recognition which are fundamental, but important in the marker-based AR systems. In addition, the current context-aware AR systems exploit the preliminary context, e.g. sensor signal, without further reasoning about the situation.

In this paper, we study how to exploit the context-awareness in AR applications to take advantage of the context in both the high-level and low-level processing. We propose an AR system architecture that works with a context-awareness framework. In the system, both the preliminary and the final context is provided to the process that needs the context. By adopting the context in the low-level processing, it is possible to address the problems that are hard to be solved by the computer vision techniques only. In addition, the context-awareness can also contributes to the provision of the personalized AR services by changing the displayed contents according to the available context.

We provide two scenarios that exploit the context in AR applications in the low-level processing in an AR system. In the first scenario, we adopt a light sensor to enhance the marker detection performance under the varying lighting condition. The data from the sensor is passed to the marker detection stage through a context-awareness framework. The threshold value for binary image generation is adaptively changed based on the measured intensity of the ambient light. In the second scenario, we exploit the context in the marker recognition stage where a single color marker is recognized as several different sub-markers based on the context. We extract sub-markers from a color marker

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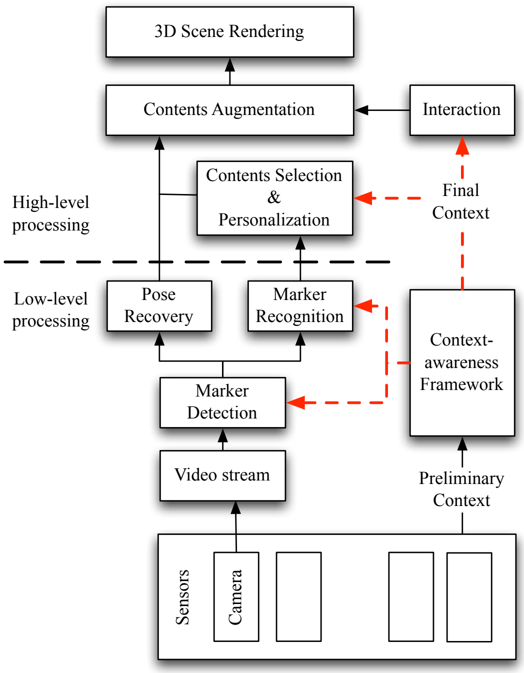

Figure 1: Proposed context-aware AR system

by color segmentation. The color to be segmented is determined based on the context.

This paper is organized as follows. In section 2, we describe how to exploit the context-awareness in AR applications. The example scenarios and the implementation results are depicted in section 3. Discussions and conclusions are given in section 4.

2. Exploitation of Context in AR applications

Generally, a marker-based AR system works as follows. In the low-level processing, markers in the incoming image frame are detected and recognized by the system. During the recognition stage, a unique ID is assigned to each marker. At the same time, the pose of each marker is computed. In the high-level processing, the contents corresponding to the marker IDs are selected from a database. The selected contents are changed by user interactions and displayed in a virtual scene based on the estimated pose of a camera and finally the augmented scene is generated by 3D rendering process. In most AR systems exploiting the context, context-awareness has been mainly used in the high-level processing, such as selecting the contents and interacting with them.

The proposed context-aware AR system is depicted in the Figure 1. In the proposed system, there is a context-awareness framework, which gathers the preliminary context from the sensors and generates the final context. It provides the preliminary and the final context to both the high-level and low-level processes to enhance the relevance of the AR applications by understanding the situation where the system works. The context provides the information we cannot extract from images for the low-level processing. We can improve the performance of the AR system through the additional information of the context. In addition to enhancing the low-level processing, the final context can also be used for selecting and changing the displayed contents through contents personalization. Note that the preliminary context can be directly passed from the sensors to a process if time-delay caused by the context-awareness framework is not desirable or if the process requires only the raw signals. For example, there is no need of context-awareness in capturing the images from a video camera for AR applications where the real-time performance is required.

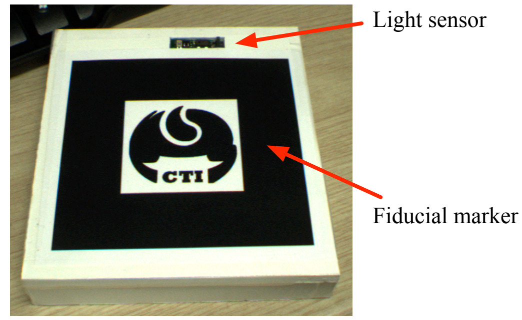

Figure 2: The smart marker system

3 Proposed Scenario

In this section, we describe two scenarios of context-awareness exploitation in the AR system. In the first scenario, we utilize the preliminary context for the marker recognition under varying lighting condition. A light sensor is used to measure the intensity of the light incident on a marker and the threshold for image binarization is adaptively changed. In the second scenario, the marker recognition benefits from the context. According to the context, a color marker is recognized as several different markers. The details of the scenarios and the implementation results are given in the following subsections.

3.1 Marker Detection with a Light Sensor

When we use a fiducial marker in an AR system, markers are detected in the binary image of the incoming image frame. If the lighting condition is static, image binarization with a pre-defined threshold value works relatively well. However, this approach encounters problems when

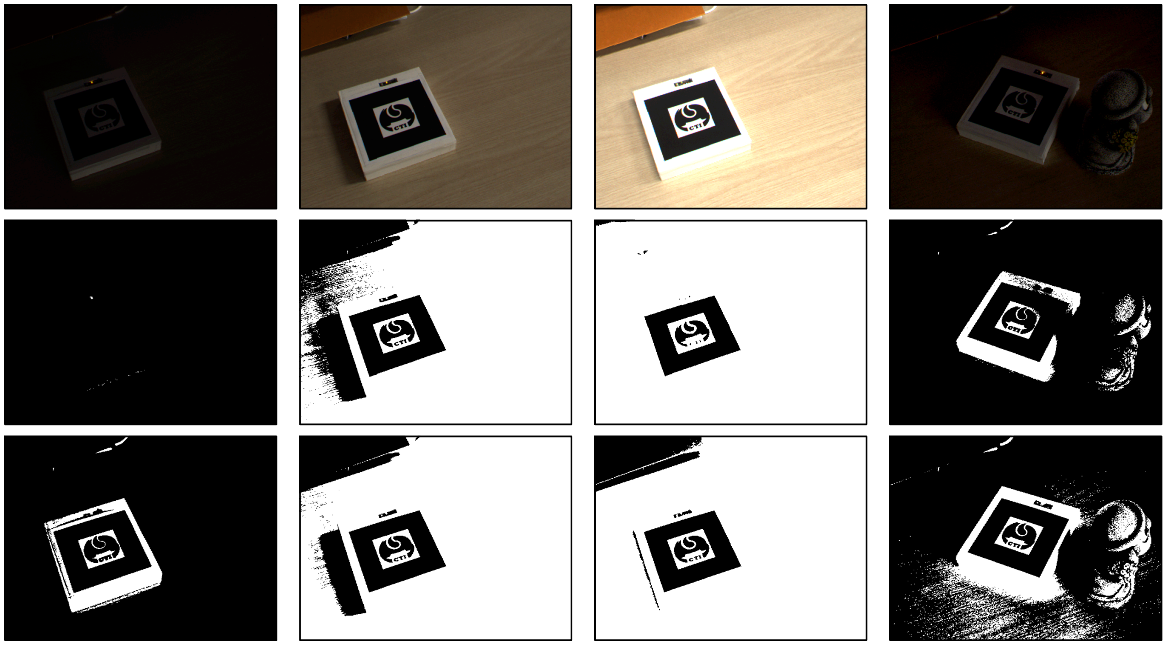

Figure 3: Binary image for marker detection. The input images (top row), the corresponding binary images generated by a fixed threshold (middle row), and by the adaptive threshold with our smart marker (bottom row).

the lighting condition of the environment varies. For instance, the brightness, direction and intensity of the light sources can change. In this case, the binarization causes bad result or the shadows of objects near the marker make marker detection difficult. Finding a good threshold value is one of basic problems in the marker-based AR system and it is difficult to be addressed by the computer vision techniques only.

Our solution to this problem is taking advantage of the external information available from the context. We adopt a light sensor, which estimates the intensity of the ambient light of the environment. The light sensor sends the measured data as a preliminary context to the context-awareness framework. Then, the context-awareness framework provides the data to the marker detection stage. Finally, the threshold value is changed according to the measured lighting condition and the enhanced binary image is obtained.

We developed a smart marker system that actively sends the intensity of ambient light around a marker. The smart marker is the integration of a commercial light sensor [1] and a fiducial marker as shown in Figure 2. The experimental results are shown in the Figure 3. The top row depicts the captured frames of video frames. The corresponding binary images obtained by the fixed threshold value and by the adaptive threshold value are shown in the middle and the bottom row, respectively. When we use the fixed threshold value, the marker detection fails under the bad lighting condition. The threshold is too high (column 1) or too low (column 3) compared to the intensity of the ambient light. In these cases, the marker is not identified or some of patterns are lost. In the case shown in the last column, the direction of the light is changed and the object near the marker casts its shadow on the marker. The shadows disturb the marker detection since there is no square in the binary image obtained by the fixed threshold. In contrast, the marker detection is successful with the adaptive threshold with the light sensor as shown in the bottom row.

3.2 Color Marker Recognition

In this scenario, we exploit a user's profile in both the low-level and high-level processing. In the low-level processing, the marker recognition process benefits from the context for color marker recognition. In the high-level processing, the contents are personalized according to the user's preferences. When a user sees a color marker through a device with a built-in camera, the color marker is detected in the image at first. The context-awareness framework receives the user profile and select one of the colors existing on the color marker. With the specified color information, one of pattern region is extracted from the color marker by color segmentation in the marker recognition stage. By composing the segmented regions, a sub-marker is generated from the color marker for the user. Then, the contents corresponding to the extracted sub-marker is selected. The selected contents are personalized based on the final con-

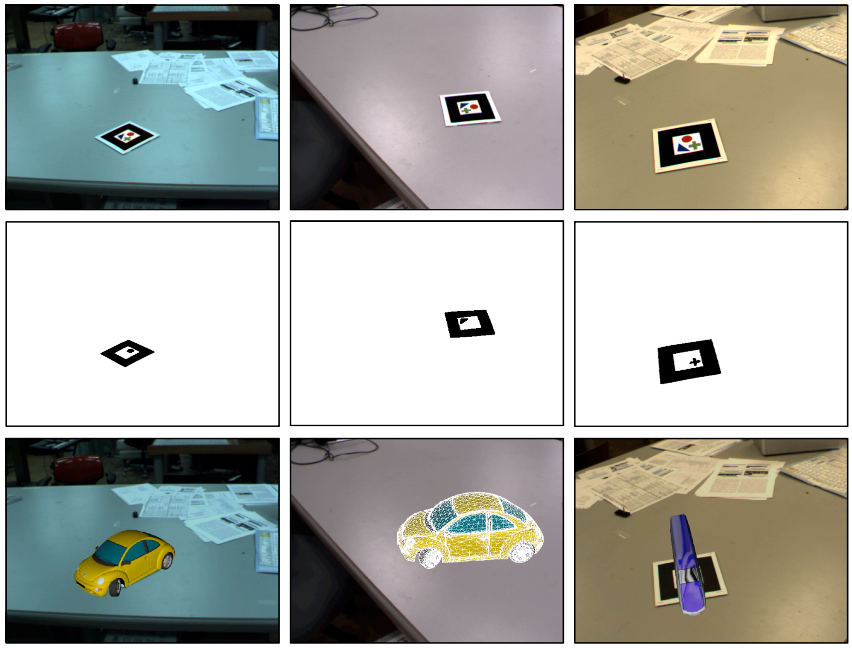

Figure 4: Marker recognition results. The columns correspond to the users' view. According to the context, the color marker is recognized as different sub-markers and the corresponding personalized contents are displayed.

text generated by the context-awareness framework and displayed on the screen of the user's device.

We used the users' identities as the context for the color marker recognition and the users' preferences for contents personalization in the implementation. We assumed that both of them are stored in the user's mobile device and the mapping between the user's identities to a specific color is pre-defined. The marker tracking and recognition is implemented with ARToolkit [4]. In Figure 4, each row corresponds the view of a user, the binary image of the extracted sub-marker, and the displayed contents. According to the user's identity three different sub-markers are extracted. The two users shown in the column 1 and 2 see the same 3D model of a car, but one of them sees a textured 3D model while the other sees the wireframe of the 3D model. It is because they have different preferences on rendering style. The third user who has different preference on the contents type sees a 3D model of a train model instead of a car.

4. Conclusion

In this paper, we proposed two scenarios that exploits context-awareness in AR applications and showed prototype implementation results. In the scenarios, the preliminary context is utilized in the marker detection stage to enhance binary image generation step. In both examples the context provides useful information for relevance of AR system by improving the performance of the low-level processing and for enhancement of the user's experience through the personalized contents. As a future work, we will focus on how to integrate the AR application with the context-awareness framework efficiently. In addition, the user study on how much the context can enhance the user's experience is necessary to confirm the usefulness of the context in AR applications.

References

[1] Particle web site (http://particle.teco.edu/).

[2] T. Höllerer, S. Feiner, D. Hallaway, and et al. User interface management techniques for collaborative mobile augmented reality. *Computers and Graphics*, 25(5):799–810, 2001.

[3] S. Jang and W. Woo. ubi-ucam: A unified context-aware application model. In *Context*, volume 2680 of *LNAI/LNCS*, pages 178–189. Springer, 2003.

[4] H. Kato and M. Billinghurst. Marker tracking and hmd calibration for a video-based augmented reality conferencing system. In *Proc. of the 2nd International Workshop on Augmented Reality*, pages 85–94. IEEE Computer Society, 1999.

[5] D. Salber, A. K. Dey, and G. D. Abowd. The context toolkit: Aiding the development of context-enabled applications. In *Proc. of CHI '99*, pages 434–441. ACM Press, 1999.

[6] Y. Suh, Y. Park, H. Yoon, Y. Chang, and W. Woo. Context-aware mobile ar system for personalization, selective sharing, and interaction of contents in ubiquitous computing environments. In *HCI International (2)*, pages 966–974, 2007.