EGVE Symposium (2008)
B. Mohler and R. van Liere (Editors)

Visible Portion Estimation of Moving Target Objects for Networked Wearable Augmented Reality

K. Makita[1], M. Kanbara[1] and N. Yokoya[1]

[1]Nara Institute of Science and Technology, Japan

Abstract

This paper describes a new visible portion estimation method of moving target object for networked wearable augmented reality (AR) system. In annotation overlay applications using AR systems, it is important to improve readability and intelligibility of annotations in a user's view. View management makes it possible to appropriately generate annotation overlay images for users so as to intuitively understand annotations. For instance, overlappings of annotations and other objects can be prevented by using a view management technique. View management requires visible portions of 3D target objects in a 2D view plane. This paper proposes a visible portion estimation method for moving target objects based on positions and shapes of the moving target objects. The wearable augmented reality system obtains positions of target objects via wireless network for estimating visible portions of target objects in the user's view. Annotations are able to be overlaid by using view management techniques with our proposed visible portion estimation.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Information Interfaces and Presentation]: Artificial, augmented, and virtual realities

1. Introduction

Augmented reality (AR) can enhance the real world by superimposing virtual objects on a user's view. Augmented reality applications can be divided broadly into several categories. Above all, appearance simulation applications and annotation overlay applications have been extensively studied. In appearance simulation, virtual objects have to be drawn in an appropriate position and orientation as they are in real world [ES06, FBH+97]. On the other hand, the appearance of an annotation does not need to look like a real object. Figure 1 shows an example of an overlay image of annotations for users as moving objects. Annotation overlay applications give us additional information about real objects. It is absolutely essential for annotations to be understood as information of a target object in the real scene. In annotation overlay applications, therefore, it is important to improve readability and intelligibility of annotations in a user's view [TMN05, BFH01, AF03, ZS05, UMK+05, BFH02]. View management makes it possible to appropriately generate annotation overlay images for users so as to intuitively understand annotations. One critical issue with annotation view management is how to overcome overlappings of annotations with one another. The Hiding of unexpected objects by annotations must also be prevented. To overcome overlapping and hiding, annotation overlay systems have to estimate visible portions of 3D target objects in a 2D user's view.

Figure 1: *Example of annotation overlay image.*

This paper proposes a visible portion estimation method for view management techniques. The wearable augmented reality system obtains positions of target objects via wireless network for estimating visible portions of target objects in the user's view. Annotations are overlaid at appropriate positions without overlapping as much as possible by view management techniques.

2. Visible portion estimation for annotation overlay

Our proposed method to estimate visible portions of moving target objects in a user's view plane is to use positions and shapes of target objects. The proposed method includes the following two types of estimation methods.

- **Method A) Quadrangle estimation**
  The visible portion of the moving target object is estimated as a quadrangle.
- **Method B) Existing probability estimation**
  The visible portion of the moving target object is estimated as a probability map of location probability density.

Two types of estimation methods are shown in Figure 2 and 3, respectively. The following sections describe each method in detail.

2.1. Quadrangle estimation

Figure 2 shows an outline of quadrangle estimation method. The outline shown in Figure 2 takes for instance a wearable computer user as a moving target object. Each step of the estimation is described in detail in the following.

In first step, the wearable AR system obtains positions of target objects. In this study, we assume an environment where the wearable AR system can obtain positions of target objects in the real world by using a framework that we have already proposed [MKY06]. In the framework, high frequency of updating and low communication delay are achieved by using hybrid P2P network. Positions of target objects in a user's view are estimated based on positions of target objects, the user's position, and the user's orientation as shown in Figure 2(a).

In the next step, visible portions of target objects are estimated by using given shapes. In this case, a region of the target is approximated by using a rectangular solid. This approximation is based on an assumption that the position of the target's head is estimated as the target's position and the target stands vertically on the floor. Figure 2(b) shows an estimated region of the target object.

Finally, a circumscribed quadrangle of the rectangular solid is calculated as a region that is used for view management. This step is for simplification of calculation in checking overlapping and hiding. Figure 2(c) illustrates a rectangular solid and a circumscribed quadrangle. Figure 2(d) shows only a circumscribed quadrangle that is an eventual visible portion of a target object. Regions of target objects in a user's view are estimated as described.

2.2. Existing probability estimation

Figure 3 shows an outline of existing probability method. The outline shown in Figure 3 also takes for instance a wearable computer user as a moving target object. This method is designed by extending quadrangle estimation method by using probability density. Each step of the estimation is described in detail in the following.

In first step, as shown in Figure 2, the wearable AR system obtains positions of target objects (Figure 3(a)). In the next step, visible portions of target objects are estimated by parts of primitive models. Each primitive model is generated by subdivision of the shape in quadrangle estimation method, and existing probability is added. Figure 3(b) shows a group of primitive models. In this case, the original rectangular solid is divided into some rectangular solids. Next, each primitive model is drawn by off-screen rendering for the purpose of existing probability estimation. Figure 3(c) shows a group of primitive models colored by using existing probability. Each primitive model is drawn with permeation rate in inverse proportion to probability density.

Finally, the probability map is generated by using the result of off-screen rendering. A color of a point on the image generated by off-screen rendering can be treated as a existing probability of the moving target object at the point. So the probability map can be generated in response to a property of each view management method.

3. Experiment

3.1. Experimental Environment

We have carried out several experiments using the proposed method in indoor environment where wearable AR systems can use a wireless LAN. We have developed a network-shared database of annotation information in a user information management server (CPU: 3.0GHz, RAM: 3.25GB). We have also pasted invisible visual markers on the ceiling for wearable computer users to estimate their position and orientation [NKY05].

In this experiment, four wearable system users exist in the environment as moving target objects. Users' positions are estimated by their wearable systems and are transmitted to wearable AR systems. The hardware configuration of the wearable AR system is as follows. (PC CPU: 2.0GHz, Memory: 2.0GB, Camera: Original).

To generate annotation overlay images, position and orientation of a camera which is attached to user's head are needed. In experiments, the wearable system estimates the position and orientation of the user's viewpoint by using the conventional marker-based registration method [NKY05]. The position and orientation errors of this method are about 5 centimeters and 3 degrees. Each wearable computer user is equipped with an infrared camera on the user's head for the purpose of estimating user's position and orientation.

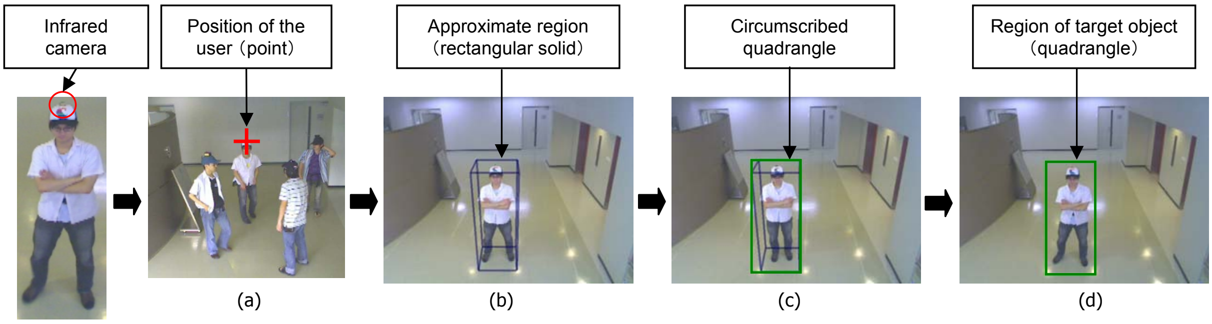


Figure 2: *Estimation procedure of a visible portion of a target object using a quadrangle.*

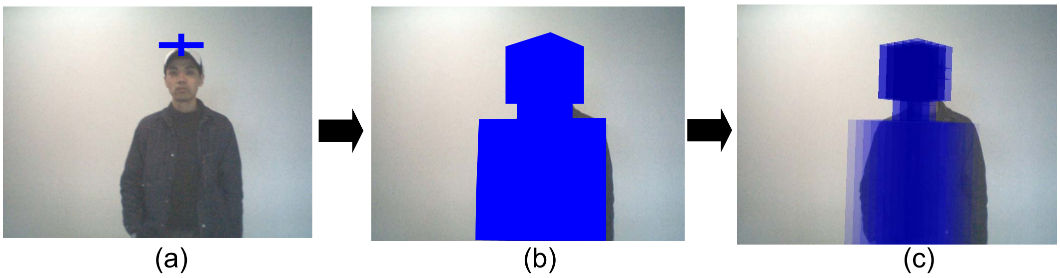


Figure 3: *Estimation procedure of a probability density of the target object.*

3.2. Estimation of visible portions of target objects in a user's view

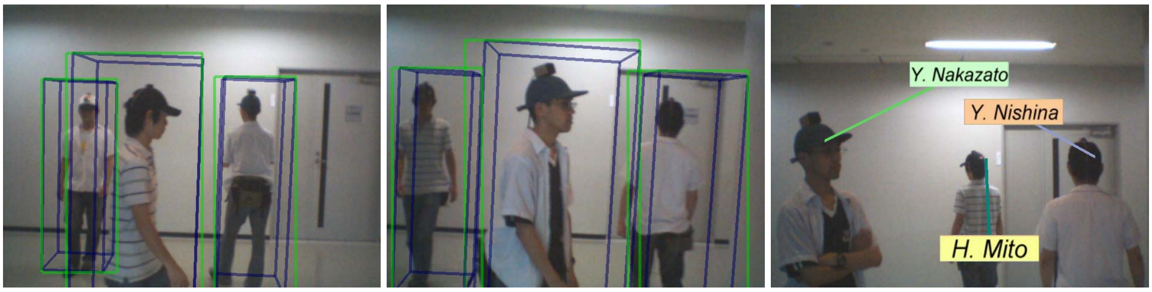
- **Method A) Quadrangle estimation**
  The visible portion of the user is approximated by using a rectangular solid stands vertically on the floor. The center point of the upper surface of the rectangular solid corresponds to user's head. Both the upper and lower surfaces of the rectangular solid are square in shape and 60cm on a side. Figure 4(a) and (b) show experimental results by using quadrangle estimation. A camera of the wearable AR system dynamically changes its position and orientation. This is because the wearable AR system has a certain margin of estimation error.
- **Method B) Probability density estimation**
  In this experiment, we use four groups of rectangular solids. Because human body is not a rigid, we divide the body of the target into 4 parts; head, neck, upper body, and lower body. Furthermore we divide each zone by using a rectangular solid. Both the upper and lower surfaces of rectangular solids are square in shape and 5cm on a side. Next, we set up a probability density for each rectangular solid. We can conclude that the head has high probability density because the camera is set to the head. The lower body has low probability density to the contrary. We use weight to each zone, weights (head: 0.7, neck: 0.5, upper body: 0.3, lower body: 0.1) are used as an alpha value by off-screen rendering to acquire probability density map in real time. Figure 5(a) and (b) show experimental results using probability density estimation. Rectangular solids are shown in figures to confirm the result. In a normal situation, rectangular solids are used only off-screen rendering.

3.3. Annotation overlay experiment

Annotations are placed using visible portions of target objects in a user's view estimated in the previous step. In this paper, the shape of annotations is a rectangle and fixed in size. We apply a greedy algorithm based on the result of a previous survey of evaluating label placement [AF03]. As advance preparation, 21 slate points for placing an annotation are set around and inside the region of a target object. Each point has search priority.

Figure 4(c) shows an example of annotation overlay image generated by using quadrangle estimation. In this experiment, four users are walking in the area and the AR user receives other users' positions at about 20 times per second. Annotations in Figure 4(c) are placed without overlappings or hiding. We have generated annotation overlay images at a rate of about 15 frames per second in this experiment.

Figure 5(b) and (c) show examples of annotation overlay image generated by using probability density estimation. In this experiment, we apply a new method based on greedy algorithm with our proposed probability map. We have defined an annotation energy function as a sum of existing probability. The energy is a sum of color density of points both included in an area of annotation and off-screen rendering. In



(a) (b) (c)

Figure 4: *Experimental result using quadrangle estimation.*

(a) (b) (c)

Figure 5: *Experimental result using probability density estimation.*

this experiment, energy minimization calculation is always done around the annotation.

4. Summary

This paper has proposed a new visible portion estimation method for annotations on moving objects in networked wearable augmented reality. By using our proposed method, users of an annotation overlay system can intuitively understand relationships between annotations and moving target objects. We have demonstrated the feasibility of the method with experiments in indoor environment. In the future, we should upgrade the layout quality of annotations by using better approximation of the region of a target object.

References

[ES06] J. Ehara and H. Saito: "Texture Overlay for Virtual Clothing Based on PCA of Silhouettes," 5th IEEE and ACM Int. Symp. on Mixed and Augmented Reality (ISMAR 2006), pp. 139–142, 2006.

[FBH+97] S. Feiner, B. MacIntyre, T. Höllere, and A. Webster: "A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment," Proc. 1st Int. Symp. on Wearable Computers, pp. 74–81, 1997.

[TMN05] R. Tenmoku, M. Kanbara, and N. Yokoya: "Intuitive annotation of user-viewed objects for wearable AR systems," Proc. IEEE Int. Symp. on Wearable Computers, pp. 200–201, 2005.

[BFH01] B. Bell, S. Feiner and T. Höllere: "View Management for Virtual and Augmented Reality," ACM Symp. on User Interface Software and Technology (UIST 2001), pp. 101–110, 2001.

[AF03] R. Azuma and C. Furmanski: "Evaluating Label Placement for Augmented Reality View Management," Proc. 2nd Int. Symp. on Mixed and Augmented Reality (ISMAR 2003), pp. 66–75, 2003.

[ZS05] F. Zhang and H. Sun: "Dynamic Labeling Management in Virtual and Augmented Environments," 9th Int. Conf. on Computer Aided Design and Computer Graphics(CAD/CG 2005), pp. 397–402, 2005.

[UMK+05] K. Uratani, T. Machida, K. Kiyokawa and H. Takemura: "A Study of Depth Visualization Techniques for Virtual Annotations in Augmented Reality," Proc. IEEE Virtual Reality (IEEE VR), pp. 295–296, 2005.

[BFH02] B. Bell, S. Feiner and T. Höllere, "Information at a glance," *IEEE Computer Graphics and Applications*, Vol. 22, No. 4, pp. 6–9, 2002.

[MKY06] K. Makita, M. Kanbara, and N. Yokoya: "Personal information annotation on wearable computer users with hybrid peer-to-peer communication," Proc. 16th Int. Conf. on Artificial Reality and Telexistence (ICAT 2006), pp. 217–227, 2006.

[NKY05] Y. Nakazato, M. Kanbara, and N. Yokoya: "A localization system using invisible retro-reflective markers," Proc. IAPR Conf. on Machine Vision Applications (MVA2005), pp. 140–143, 2005.