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An Installation of Privacy-Safe See-Through Vision

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1. Introduction

Increasing number of surveillance cameras has realized better public security in our society. However, as there are no other apparent merits to ordinary people who are monitored by these cameras, it is often criticized by the negative effects of monitoring such as privacy problem. In order to ease the criticism and make our life much better, a new service on which people can directly feel the advantage of the existence of these cameras should be delivered.

We propose a privacy-safe see through vision (P-S Vision for short) which utilizes images of the cameras (we won't call the cameras "surveillance cameras" because they are beyond the surveillance cameras). This new and unique enhanced vision lets them directly understand the good aspect of the camera existence. P-S Vision is privacy-safe because we designed the system to work only when the privacy is not violated.

P-S vision is an extended system of original see-through vision[1]. The original see-through vision is a mixed reality based service that allows users to see objects behind occluders such as walls, covers, etc. Users hold a mobile computer that has a video camera (mobile camera) on it and direct it to occluders. Then they will see objects behind the occluders on the screen of the mobile computer. The images of the objects to be superimposed to the screen are actually captured by environmental cameras (Fig. 1).

Whereas the system allows users to see through a variety of places, the system provides a privacy-safe vision service. If the subjects of environmental camera have some relationship with the user, in other words if they share the same privacy level each other, the system shows clear and detailed images of the subjects obtained by environmental cameras on line. If not, that means the subjects are not acquaintances of the user, the system show blurred images and put human shaped icon like illustrated in Fig. 2. This privacy-safe presentation requires identification mechanism of subjects that will be given by a technological result of the "Content Engineering for Social Use of Sensing Information"[2].

We had demonstrated the system in a market place in Kyoto. To realize our system, the system needs to know extrinsic parameters of both the environmental cameras and the mobile camera. We used ARToolkit[3] and devised indirect parameter estimation for placing subjects in MR fashion.

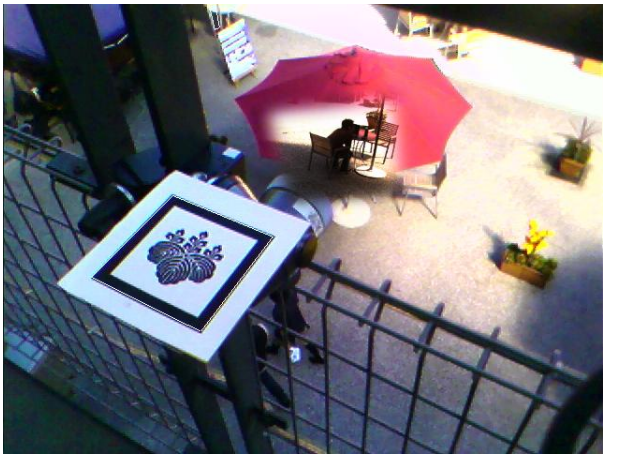

Fig. 1: An image of See-Through Vision. User can observe invisible space by using image from environmental camera.

2. Marker based See-Through Vision

To realize see-through vision like Fig. 1, we need to align image segments of the subjects to right position in 3D space. Therefore, we need to calibrate both the environmental cameras and the mobile camera. For the environmental cameras, we calculate their projection

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matrices from correspondences between 3D points of which the position are known and 2D points in the image, since they do not move. Whereas the projection matrix determined by this approach is accurate and reliable, we couldn't apply the same approach to the mobile camera because it is hard to detect a sufficient number of known 2D points in the image of the mobile camera by computer vision. Hence we exploit ARToolkit[3] in order to estimate extrinsic camera parameter of the mobile camera.

We assume a situation illustrated in Fig. 3. There is a parasol on the ground level and a user is on the second-floor. An environmental camera is shooting the target space beneath the parasol where the user cannot see directly, since the parasol occludes the space. As for preparation, we first put a large AR marker on the ground in order to locate the target space under the parasol precisely and fix a small AR marker, which is used to estimate the pose of the mobile camera, to handrail of second-floor. By taking both the large and small markers in one frame, the relative position of the target space against the small marker is estimated. Then we remove the large marker from the scene.

We also set a rectangle region in the frame of the environment camera to cover the target space. Live texture of the rectangle region is sent to the mobile computer via a sensor network. The mobile computer renders the live texture so as to align it to the frame of the mobile camera. The texture is rendered on line on a billboard, which is placed at the target space virtually. For privacy-safe visualization, the system blurs the texture and draw human shaped icons so that the user can count how many people are there.

3. Experiment

We installed the P-S Vision system at a market place named "Shinpukan" in Kyoto and conducted demonstration. We installed two environmental cameras and selected two parasols. Fig. 1 is a snapshot of the demonstration. Although some users reported uncomfortable feeling about difference of view angle between the user and the environmental cameras, they are satisfied with the functionality of watching the people doing beneath the parasols. They also reported that presentation of privacy-safe visualization is good in this situation.

Fig 2: Privacy-safe See-through Vision. A user cannot see the details when subjects are not acquaintances.

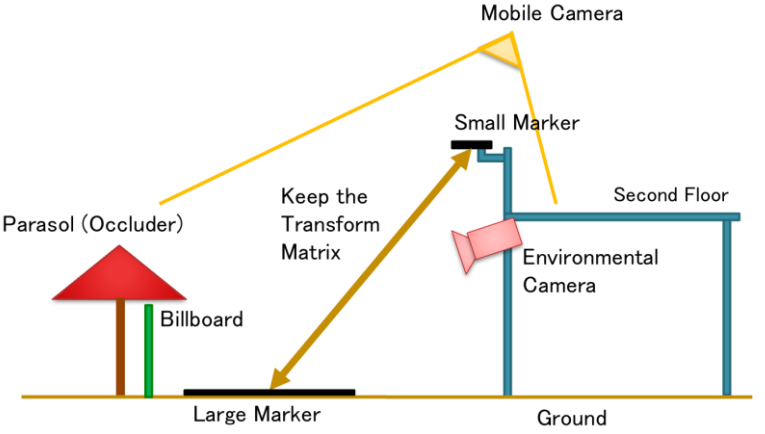

Fig. 3: Layout of experiment at a market place. Two markers are installed at preparation. After the calibration is made, the large marker is removed.

References

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