Camera Pose Navigation using Augmented Reality

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ABSTRACT

We propose an Augmented Reality (AR) system that helps users take a picture from a designated pose, such as the position and camera angle of an earlier photo. Repeat photography is frequently used to observe and document changes in an object. Our system uses AR technology to estimate camera poses in real time. When a user takes a photo, the camera pose is saved as a "view bookmark". To support a user in taking a repeat photo, two simple graphics are rendered in an AR viewer on the camera's screen to guide the user to this bookmarked view. The system then uses image adjustment techniques to create an image based on the user's repeat photo that is even closer to the original.

KEYWORDS: Augmented Reality, Repeat Photography, Rephotography, Camera Pose Navigation

INDEX TERMS: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—*Artificial, augmented and virtual realities*; H.5.2 [Information Interfaces and Presentation]: User Interfaces—*Training, help, and documentation*

1 INTRODUCTION

To observe or document changes in an object or scene, we often take repeat photos. In manufacturing, repeat photography is used for quality examination. Manufacturers may wish to compare an industrial part that has a problem with a correct part. Figure 1 shows an example of repeat photography of industrial parts. In Figure 1(a), the object has a black stain on its surface. Figure 1(b) depicts a correct control part. The pair of photos is useful for fixing a part, or may be included in a report on the problem causing the stain. It is not easy, however, for people to take a second picture of an object from precisely the same camera angle using a handheld camera.

We developed an Augmented Reality (AR) system that helps users take pictures from a specific pose. Previous research shows that augmented reality can aid users in finding an object [1]. AR with overlay graphics has been used to guide maintenance and repair workers through the steps of a procedure [2]. During the maintenance and repair of machines, workers sometimes have to move to a designated view angle to see particular parts. We are interested in using augmented reality to aid a user in navigating six degrees of freedom to find the desired camera pose.

Our AR system uses a 3D model of a target object, such as a CAD model, in a known position and established methods to estimate the camera pose [3]. The system provides a way to save the camera pose when a photo is taken as a "view bookmark". When the user chooses a view bookmark for repeat photography, two graphics, a ball and a cone, are rendered on the camera's video screen to indicate the bookmarked view, particularly the camera angle, toward the object. These graphics guide the user to the same bookmarked view for repeat photography. The user does not need to take the repeat photo in exactly the same position and exactly the same camera view angle as the first one. Our system
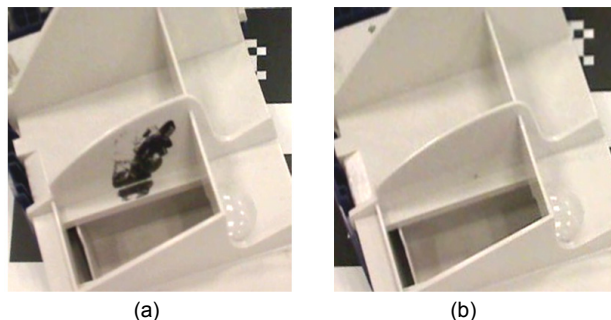

Figure 1: Repeat photography of an industrial part taken using AR navigation: (a) has a black stain and (b) is the original part.

uses image adjustment to obtain from the user's repeat photo an image from a view even closer to that of the first photo.

2 ESTIMATE CAMERA POSE FOR REPEAT PHOTOGRAPHY

In order to guide users to the same camera angle as a first photo, the geometric relationships between the object and the camera must be estimated. There are many methods to estimate camera pose, and to match photos of an object with its 3D model. We use an existing method to estimate camera position as implemented in ARToolKit [3]. Seventy markers are printed on the board and their 3D positions are known. The system has a 3D model of each object, and its 3D pose relative to the markers is manually adjusted. When the camera captures one or more of the markers together with the object, ARToolKit estimates the camera pose in real time, and computes the relative camera pose to the object.

3 ADDING VIEW BOOKMARKS TO THE AR SYSTEM

After the user takes a photo of an object, she can specify a region of interest by drawing a circle on the captured photo (Figure 3(a)). The system then calculates a 3D point T on the object corresponding to the center of the circle, using the 3D model of the object and the estimated camera position. From the radius of the user drawn circle, the radius s of the three-dimensional region of interest around the point T is calculated. The set of parameters and the photo are saved as a view bookmark.

4 AR NAVIGATION FOR TAKING REPEAT PHOTO

The purpose of the AR navigation is to assist the user in taking a repeat photo that matches a first photo. Users must move the camera so that the repeat photo captures the entire surface of the object that is captured in the first photo. Two issues must be considered: the field of view and occlusion. When part of the target region is out of the field of view, it cannot be captured. Similarly, the more the direction of camera from the object for the second photo differs from that the first photo, the greater the likelihood that the target object occludes itself or is occluded by other objects. Occluded areas are difficult to compensate for in
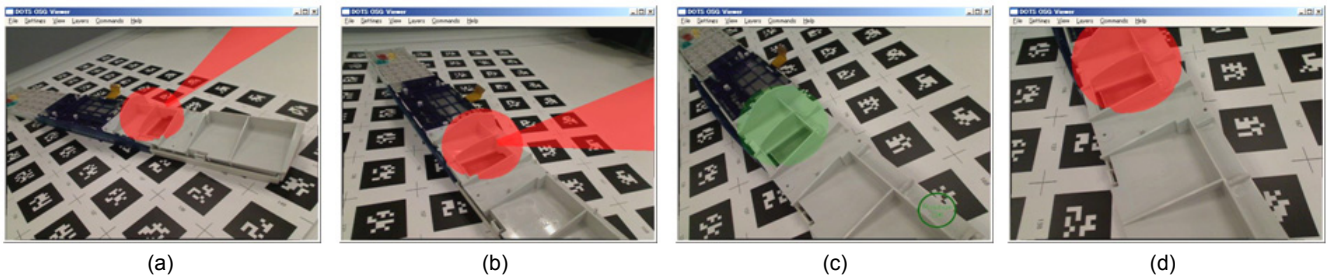
Figure 2. (a) Our AR navigation renders ball and cone graphics to show users a bookmarked camera pose. (b) The poses of the graphics are updated as the user moves the camera. (c) When the camera is inside the cone and the entire ball can be seen, the camera pose is good. (d) When a part of the ball is out of window, the color of the ball becomes red to tell the user to adjust the pose.

the final image adjustment step of our system. The difference of the distance between object and camera is not as critical in terms of occlusion as the difference in direction, so a photo from a different distance can be adjusted.

The AR navigation uses two graphical elements, a ball and a cone, to guide the user to a desired camera pose (Figure 2(a)).

Ball: The target region of the object is indicated as a ball overlaid on the camera image. The ball is rendered with center T and radius s. When the entire ball is seen in the AR viewer, the target region is in full view of the camera.

Cone: The cone indicates the direction of the camera from the target in the first photo. When the camera is inside the cone, the difference in direction between the current view of object point T and that of the bookmarked pose is less than a predetermined angle. The vertex of the cone is placed at T, and the cone's axis points toward the bookmarked camera position.

Figure 2 shows how our AR navigation works. The half transparent ball and cone overlaid on the target object indicate a bookmarked camera pose (Figure 2(a)). As the user moves the camera, the orientation and size of the ball and cone are updated in real time (Figure 2(b)). When the camera is inside the cone and the entire ball is visible, the camera pose is good for taking a repeat photo. When the user succeeds in moving the camera inside the cone, the color of the ball turns green and the message "Position OK" appears in the camera's viewer window (Figure 2(c)). When the camera is inside the cone, the cone is no longer visible. When a part of the ball is not fully visible to the camera, the color of the ball is red to tell the user to adjust the camera pose (Figure 2(d)).

We performed an informal user evaluation on 10 users previously unfamiliar with the system. They were able to take acceptable repeat photos (within 5 degrees of the correct angle) quickly (an average of less than 15 seconds) using our system.

5   IMAGE ADJUSTMENT

Post-processing by the system means that the user does not need to obtain the exact bookmarked pose. The image adjustment step can transform a good repeat photo taken by the user into an image with almost precisely the same pose as the first photo. The camera poses of the first and repeat photos are known. Snavely et al. used a proxy plane to create an image warping between different photos [4]. We create a proxy plane that is located at object point T and parallel to the image plane of the first photo. Using the proxy plane, the user's photo can be perspective transformed and cropped to mimic the image region of the first photo. Figures 1 and 3 show examples of this image adjustment. Figure 3(a) is the first photo, where a red circle has been drawn by a user to specify a region of interest. The system crops the first photo to obtain a version of the photo

cropped closely around the region of interest, as shown in Figure 1(a). Figure 3(b) shows a repeat photo taken using our AR navigation. The direction from the target object is the same as the first photo, but the distance and position of the region of interest in the image are different. After image adjustment, the repeat photo is transformed to Figure 1(b), which is easier to compare with Figure 1(a).

6   CONCLUSIONS

We developed an AR system that helps users take pictures from the same position and camera angle as a previous photo. The system provides a way to take a first photo and to save a view bookmark. Given a view bookmark, ball and cone graphics rendered in the AR viewer indicate the desired camera angle towards the object. The graphics guide the user to a close match in view for repeat photography. Using the camera pose of the first photo and a repeat photo taken by a user, the system makes fine adjustments to obtain an image from a viewpoint closer to that of the first photo. Preliminary interactions with users suggest that our navigation system is useful in guiding users to designated views.

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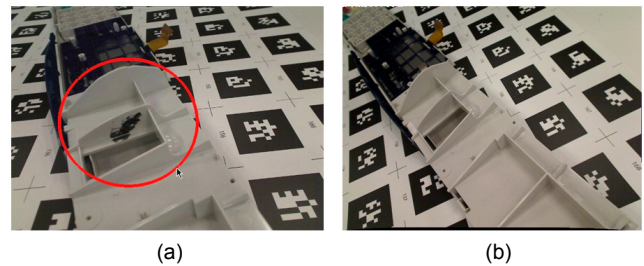
Figure 3. (a) is the first photo and (b) is a repeat photo taken using our AR navigation. After image adjustment using the proxy plane, photos (a) and (b) are aligned as Figure 1 (a) and (b), respectively.