Interactive AR Bowling System by Vision-Based Tracking

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ABSTRACT

This paper presents an interactive bowling system using vison-based tracking for AR. With the bowling system, a user can enjoy the bowling game by rolling a real ball down a bowling lane model placed on a tabletop in the real world. On the lane model, there are virtual pins generated with CG. The virtual pins are overlaid onto the input images, which are captured by a web-camera attached to a hand-held tablet PC, according to the camera motion. The camera motion is estimated by multiple 2D markers which are also placed on the tabletop around the lane model. The lane and the ball are also tracked by vision-based tracking. According to the detected ball's trajectory on the lane, the geometrical relationship between the real ball and the virtual pins is computed to judge whether the ball is touching any pins or not. After judging, the pins touching the ball are knocked down. Our vision-based tracking method can run in real-time, so it can also be applied to other interactive applications.

Categories and Subject Descriptors

I.4.9 [**Image Processing and Computer Vision**]: Applications

General Terms

Human Factors

Keywords

AR, vision-based tracking, interactive application, bowling

1. INTRODUCTION

This paper presents an interactive bowling system by vision-based tracking with the multiple markers as used in AR-Toolkit as shown in Fig. 1. Since the user interacts with our system by rolling the real ball, the ball might occlude the marker which should be always seen by the camera for vision-based tracking. This is a drawback caused by using the real ball for user's interaction. In our system, therefore, we employ multiple markers to make the camera always see any marker even when the ball occludes some markers. Multiple markers are normally needs to be aligned at measured intervals because the geometrical relationship of the multiple markers must be known. However, we employ our previous method [2] in which the geometrical relationship of multiple markers can be automatically estimated so that we can freely distribute the multiple markers at any place and any pose. Therefore we need not manually measure the distance between the markers and not align the markers at defined intervals. This system can be seen from favorite view points around the lane model and can be used by multiple users who hold monitors around the model. The user can enjoy this system by just distributing the markers at arbitrary positions and poses.

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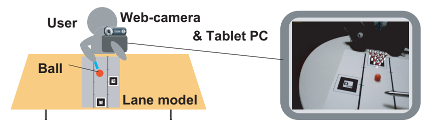


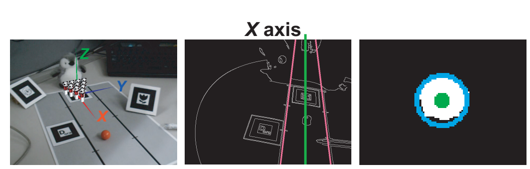
Figure 1: AR Bowling System.

2. PROPOSED METHOD

Fig. 1 shows our AR bowling system. First, the input images captured by the camera are used for marker tracking, lane tracking and ball tracking. After the tracking processes, the ball's position is transformed to the top view image to compute the geometrical relationship between the real ball and the virtual pins. Then collisions between the ball and the pins are computed according to their relative position. Finally, the pins are overlaid onto the input image by using the extrinsic parameters computed in the marker tracking process.

2.1 Multi-Markers Tracking and Integration

Multiple 2D markers placed on the lane model are detected from the input image using algorithm of AR-Toolkit [1]. From each detected marker, the extrinsic parameters of the camera are estimated frame by frame. In this system, one of the markers is placed between the two lines of the lane to define a 3D coordinate system and the positions of the virtual pins to the real lane model as shown in Fig. 2(a). The other markers are freely distributed on the tabletop because the geometrical relationship of the markers is calibrated by marker integration method using projective space [2]. Since the markers can be freely distributed by using this method, the user can move around the lane model and can watch it from favorite view points.



(a) (b) (c)

Figure 2: Detection Results.

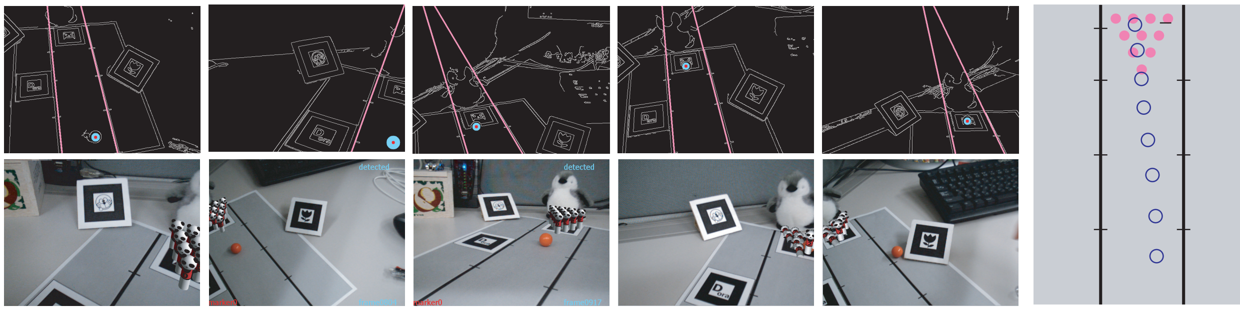


Figure 4: Resulting images on which virtual pins are overlaid.

2.2 Lane Tracking

The lane consists of two parallel lines, and there is a marker between the two lines. To detect and track the lane, some lines existing in the input image are detected by Hough Transform. From the detected line group, the lines which have similar slope to X axis are selected as candidate lines of the lane. Then two lines closest to X axis are selected on the both sides of X axis, respectively, as shown in Fig. 2(b).

2.3 Ball Tracking

In this system, we assume that the color of the ball should be quite different from the lane model. So we use a red ball on a gray lane model. For detection of the ball, first, red regions are detected from the input image by dividing it into R,G,B channel images. Finding the minimal circumscribed circle (contour) for the detected region, the center of the circle is considered as the 2D ball's position in the input image as shown in Fig. 2(c).

2.4 Transformation to Top View Image

Using homography $\boldsymbol{H}$ computed by the extrinsic parameters from the markers, the ball's position on the input image is transformed onto the top view image that provides a geometrical relationship between the ball and the pins on the lane model. As shown in Fig. 3, the trajectory of the ball can be obtained. This trajectory is used to detect the collision between the ball and the pins, and compute the directions which the pins are knocked down.

2.5 Collision Detection of Ball and Pins

For detecting a collision between the ball and the pins, the distance between the ball and each pin is computed from the top view image at every frame. The collision is detected by compuaring distance and radius as shown in Fig. 3.

2.6 Overlay Virtual Pins

After the collision detection, the pins are generated with CG and overlaid onto the image. If the collision is detected, the pins are gradually inclined and knocked down. The direction of knocking down is defined by trajectory of the ball. As shown in Fig. 3, the direction is computed by a motion vector of the ball, which is decided by ball's positions in previous and current frames, and a vector from the ball to each pin. The generated pins are superimposed onto the image by the extrinsic parameters computed by 2D markers. The user can see the virtual pins according to the motion of the camera and the rolling ball.

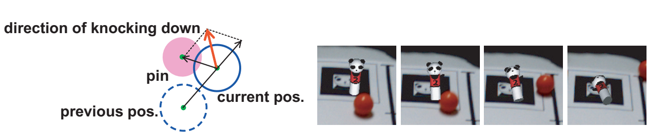


Figure 3: Direction of knocking down.

3. DEMONSTRATIONS

Fig. 4 shows the detected lane and ball's trajectory and example scenes where the virtual pins are overlaid according to the camera motion. Both of the lane and the ball can be correctly detected and tracked over all frames by our tracking method according to the camera motion. The ball's position is also successfully transformed onto the top view image by the homography computed by 2D markers.

Even though particular markers are not continuously captured over the frames, the virtual pins can be correctly registered on the lane model as shown in Fig. 4 by estimating the geometrical relationship between every marker using [2]. If we use only one marker for overlaying the pins, the registration becomes impossible when the ball is rolling over the marker because the marker can not be detected.

Moreover, since the collision of the real ball and the virtual pins are successfully detected, some pins are knocking down by hitting of the ball. The pins existing behind the hit pins are also knocked down as a chain reaction of the front pins by computing the direction of knocking down from the trajectory.

4. CONCLUSIONS

In this paper, we have presented the AR Bowling System. The geometrical relationship between the real ball and the virtual pins can be interactively computed by vision-based tracking of the lane and the ball. The multiple markers used for overlaying of the virtual pins can be distributed at arbitrary positions and poses by using automatic marker calibration method. Thus this system can be easily performed anywhere in the real world like the tabletop and is also available on-line with only a PC, a web-camera, and a ball.

5. REFERENCES

[1] M. Billinghurst et al. Magic book: Exploring transitions in collaborative ar interfaces. *Proc. of SIGGRAPH*, page 87, 2000.

[2] Y. Uematsu and H. Saito. AR registration by merging multiple planar markers at arbitrary positions and poses via projective space. In *Proc. of ICAT*, pages 48–55, Dec. 2005.