2016 한국 CAD/CAM 학회 학술발표회 논문집
Proceedings of the Society of CAD/CAM Conference

보정되지 않은 카메라를 이용한 이동 가능한 영역 상의 프로젝션 왜곡 보정

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Undistorted Projection over Mobile Region of Interest Using an Uncalibrated Camera

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ABSTRACT:
This paper presents a system designed for projection over mobile region of interest. The region of interest is supposed to be moving in an arbitrarily placed planar surface. The designed system consists of a projector, a laptop and an uncalibrated camera. Our method is based over the concepts of homography and computes mappings between camera, projector and planar surface. The techniques used for this system exclude the calculations for calibration parameters of the camera and the projector; hence, knowledge of intrinsic and extrinsic parameters is neither given nor calculated. The positions of projector, camera, and the surface are considered to be unknown as well. The system is also capable of shape identification of the region of interest and projects over it while it moves with a certain constant speed. Upon abrupt motion of the region of interest, the projection follows and reforms until it fits the region of interest.

Key Words: Undistorted projection, uncalibrated camera, mobile surface, projector-camera system.

1. Introduction

Projector systems are widely used for the purpose of entertainment, work, and even as public displays. These systems often retain few problems; one of these problems is of distorted projection. Unless the projector is carefully aligned with respect to the display area, the projected image appears keystone distorted. The second problem is of fixed projection, the projector is unable to project over a mobile surface unless for a designed or fixed circumstance.

In this paper, we apply the techniques of homography to the projector-camera system to counter these problems. We explain how we use these simple relations to render the image that fits the moving region of interest with proper alignment.

The designed system consists of a laptop connected with the projector and an uncalibrated camera. The mobile region of interest is supposed to be moving within a planar domain. The system is also capable of correcting the keystone distortion, when only a display screen is in consideration. Our system excludes hefty calculations of calibrations of the camera, as well as the projector. The intrinsic and extrinsic elements of the projector and the camera are totally ignored and the process excludes all of such relations with these elements. The system also considers positions of projector, camera, and planar surface to be arbitrary.

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2. Procedure

In order to project over the mobile surface, some assumptions are made for our system. The mobile surface is supposed to be any of the three shapes (rectangular, triangular, or circular) and it should have a white surface with black boundaries.

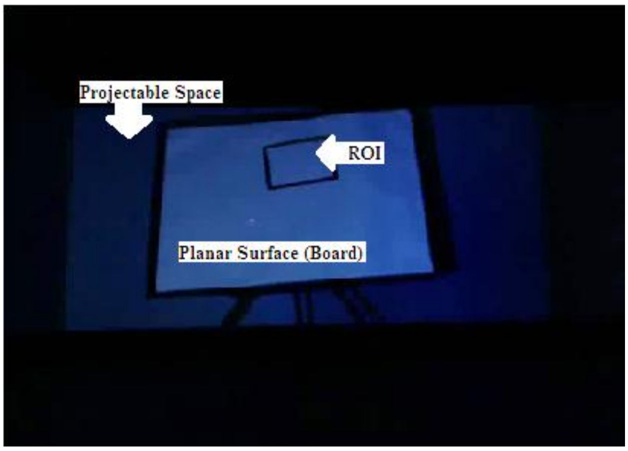

Fig. 1 Planar Surface (Board) and the Region of Interest (ROI) within it, as seen by the camera. Projector (not shown) is projecting a black image to represent projectable space.

The methodology includes projecting a source image of a white rectangle with a background of black color and an image of this projection is taken by the camera. The source image and the camera image are then used to relate the two rectangles and formulate a homography relation between projector and camera denoted as H_{pc}.

The camera then takes in an image of planar surface without any projection over it; the planar surface may or may not include the region of interest at this point. This image is used to identify the boundary of the planar surface. Using corners of the boundary, we can form a homography, referred as H_{cs}.

$$\begin{pmatrix} x_p \\ y_p \\ 1 \end{pmatrix} \approx H_{pc} \begin{pmatrix} x_c \\ y_c \\ 1 \end{pmatrix} \quad (1)$$

and

$$\begin{pmatrix} x_c \\ y_c \\ 1 \end{pmatrix} \approx H_{cs} \begin{pmatrix} x_s \\ y_s \\ 1 \end{pmatrix} \quad (2)$$

In (1) and (2), (x_p, y_p), (x_c, y_c), and (x_s, y_s) are corresponding points in the projector domain, camera domain, and the planar surface domain respectively. The effect of H_{cs} can be excluded from the relation calculated previously.

$$\begin{pmatrix} x_p \\ y_p \\ 1 \end{pmatrix} \approx {H_{cs}}^{-1} * H_{pc} \begin{pmatrix} x_s \\ y_s \\ 1 \end{pmatrix} \quad (3)$$

The system then continues and determines if any region of interest is present within the planar surface or not. If the region of interest is absent then the system considers the same surface as a display screen and merely projects over it. Otherwise, if the region of interest is present then the system determines its position in the surface domain. As the original aspect ratio of the ROI is known, hence we can also form a homography H_{sroi} for the ROI and planar surface. The expression can be stated as:

$$\begin{pmatrix} x_s \\ y_s \\ 1 \end{pmatrix} \approx H_{sroi} \begin{pmatrix} x_{roi} \\ y_{roi} \\ 1 \end{pmatrix} \quad (4)$$

Where (x_s, y_s) and (x_{roi}, y_{roi}) are corresponding points in surface domain and ROI domain respectively. The relation between the projection domain and the ROI can be formed by using this homography. For this computation, we modify the previously calculated mapping in (3), so the mapping or homography between ROI and a projector can be stated as:

$$\begin{pmatrix} x_p \\ y_p \\ 1 \end{pmatrix} \approx H_{sroi} * {H_{cs}}^{-1} * H_{pc} \begin{pmatrix} x_{sroi} \\ y_{sroi} \\ 1 \end{pmatrix} \quad (5)$$

$$H_{proi} = H_{sroi} * {H_{cs}}^{-1} * H_{pc} \quad (6)$$

Where H_{proi} is the homography relation between the projector and the ROI. This homography can then be used to pre-warp the image to be projected.

3. Results

The system is tested for several instances and it takes less than 8 seconds to project and capture images.

Fig. 2 Planar Surface is used a display screen, while ROI is not provided. The projection is keystone corrected and does not bleed out of the planar surface.

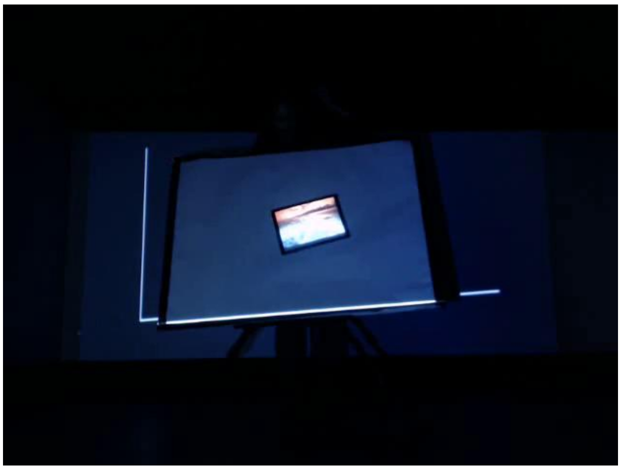

Fig. 3 Projection fits the rotated rectangular ROI with proper orientation and position precisely. The projection fits the ROI when it is moved with a constant speed.

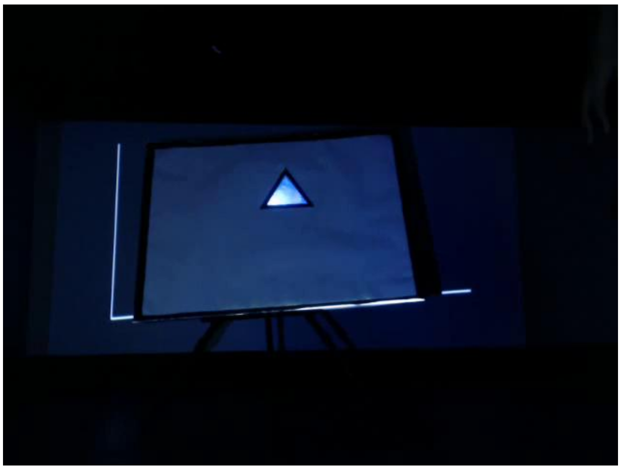

Fig. 4 Triangular ROI is introduced over the planar surface and projection over it.

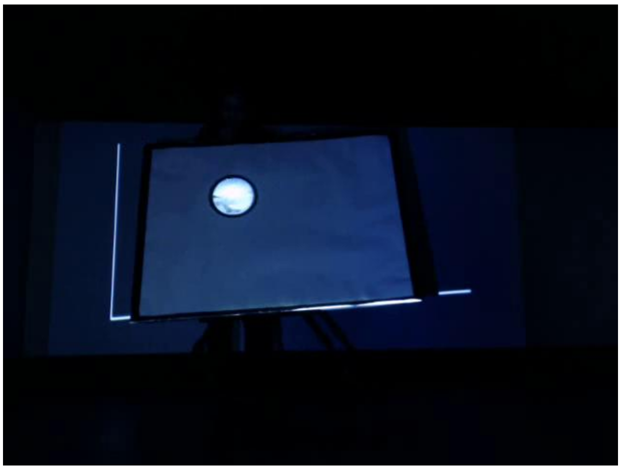

Fig. 5 The instance of circular ROI with image projected over it. The projection for this complex shaped ROI overlays entirely without any bleeding.

4. Conclusion

We have designed a simple system for projection over mobile region of interest by using an uncalibrated camera. The system tracks and projects over the region of interest with true orientation and scale, while the region of interest moves with a certain constant speed. It takes minimal information to form homographies between projector, uncalibrated camera, and the planar surface with ROI in it. The system is provided with no information about the intrinsic and extrinsic parameters and neither calculates these. It is assessed to be efficient enough for projection over the ROI without bleeding out of it. As other researches depend over specialized equipment to track the mobile projection area, our system excludes all such specialized apparatuses and equipments. Our system can also utilize the in-built camera of the laptop or even of a cell phone for this purpose, making it suitable for common use

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