Undistorted Projection over Screen & Mobile Region of Interest Using an Uncalibrated Camera

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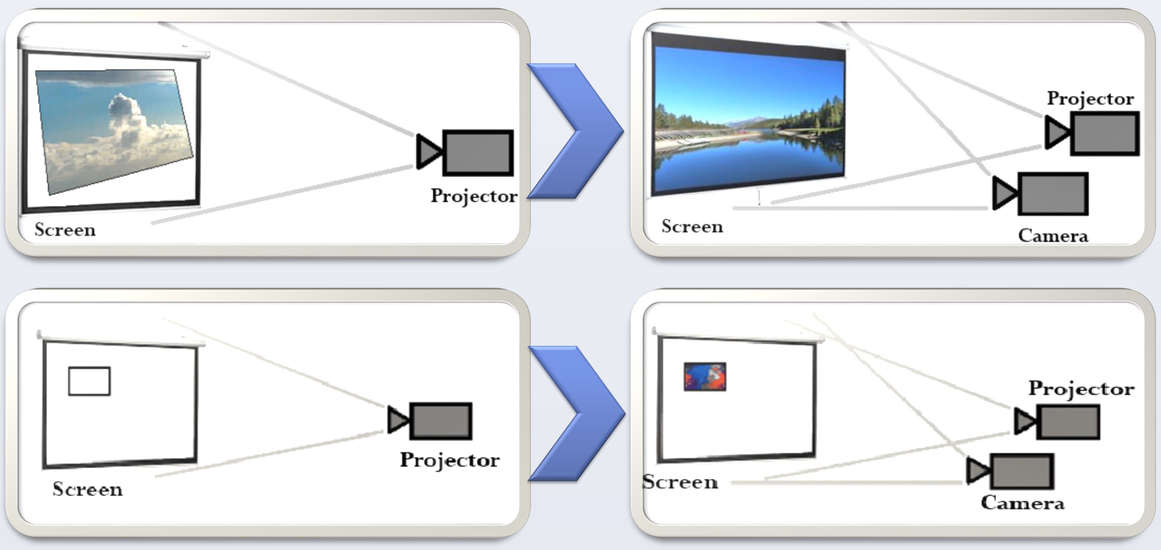
INTRODUCTION

This poster presents a system designed for projection over arbitrarily placed screen and mobile region of interest. The region of interest is supposed to be moving in an arbitrarily placed screen. 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. The system is 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, the projection follows and reforms until it fits the moving region.



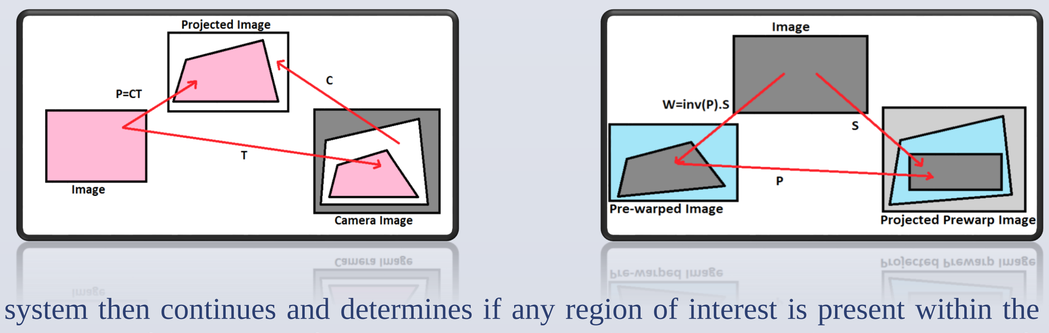
METHODOLOGY

The methodology includes projecting a source image and an image of this projection is taken by the camera. The source image and the camera image are then used to formulate a homography relation between projector and camera H_{pc}. The camera then takes in an image of planar surface without any projection over it. 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}.

$$\begin{pmatrix} x_p \\ y_p \\ 1 \end{pmatrix} \approx H_{pc} \begin{pmatrix} x_c \\ y_c \\ 1 \end{pmatrix} \text{ and } \begin{pmatrix} x_c \\ y_c \\ 1 \end{pmatrix} \approx H_{cs} \begin{pmatrix} x_s \\ y_s \\ 1 \end{pmatrix}$$

The effect of H_{cs} can be excluded from the relation calculated previously.

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



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.

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

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,

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

$$H_{proi} = H_{sroi} * {H_{cs}}^{-1} * H_{pc}$$

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. The transformation yet needs scale and correct positioning, the scale is calculated using original dimensions of the screen while the positioning calculated by detecting the top left corner of the ROI in camera domain and then transforming that position into projector domain using the mappings.

Image dimensions: 960x540 pixels

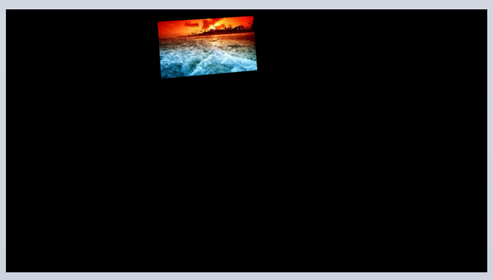


Image Dimensions: 1920x1080 pixels

REFORMATION

For detection of the ROI we use a series of morphological operations and track the region using Kalman filter. The projection shows two significant problems namely reprojection error and projection clipping. The reprojection error is caused by the approximation error, so we calculate this reprojection error and modify our transformation matrix. Secondly, the clipping problem is caused by the rotational factor in the transformation matrix. The rotational factor rotates the image in out of bound area. To solve this problem, we transform the boundary points beforehand and calculate the out of bound error to reform transformation matrix.

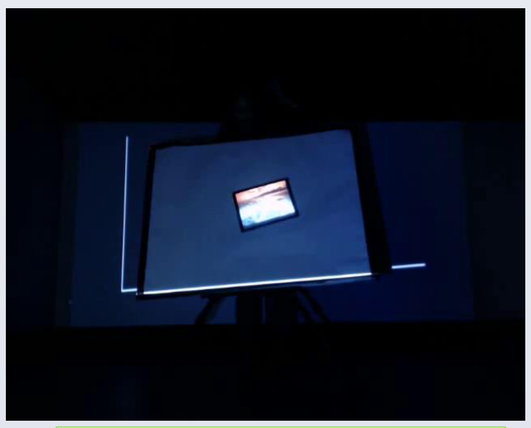
Re-projection Error causing offset

Clipping error causing image distortion

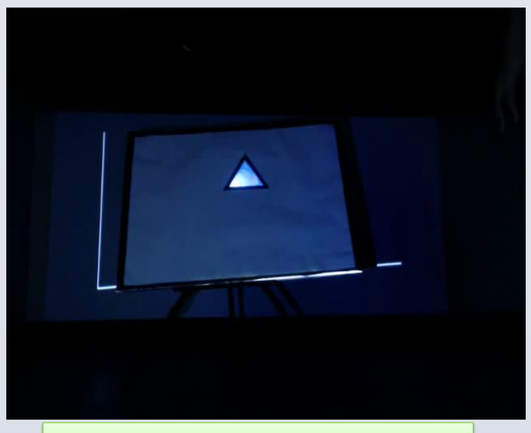
RESULTS

The system is tested for several instances and it takes less than 8 seconds to project and capture images for total calibration. The projection fits over the screen and the ROI perfectly and fits over the ROI while it moves with a constant speed.

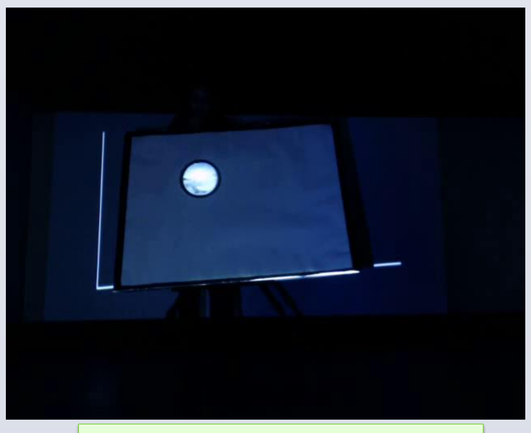
Full Screen Undistorted Projection



Mobile Rectangular ROI Projection



Mobile Triangular ROI Projection



Mobile Circular ROI Projection

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. 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 equipment. 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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