Projector-camera Based Solutions for Simulation Systems

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Overview

- Motivation
- Projector-camera based system
- Previous work
- Problem definition
- Our approach
Office of the future

- Ceiling mounted digital cameras and projectors.
- Anywhere multi-projector display.
Projector Based System

- Offers dense pixels over wider area.
- Advantages of projector based system
  - Size of projector
  - Size of displayed image
  - Multi-projector Display
  - Blending of heterogeneous image
  - Display surface
Issues Regarding Projector Based System
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- **Geometric Issues:**

  ![Diagram of Geometric Issues](image)

  - Single Surface Display
  - Planar display Surface
  - Continuous Display surface
  - Discontinuous display
  - Multi Surface display
Issues Regarding Projector Based System

- **Geometric Issues:**
  
  ![Diagram showing Single Surface Display (a), Multi Surface display (b), and Discontinuous display (c)]

- **Image Intensity and color:**
  - Non-uniform Intensity
  - Overlapped region
Projector-camera based System

- Display surface
- Projectors
- Stationary cameras
- Projector-camera homography

\[
\begin{pmatrix}
xw \\
yw \\
w
\end{pmatrix} =
\begin{pmatrix}
p_1 & p_2 & p_3 \\ p_4 & p_5 & p_6 \\ p_7 & p_8 & p_9 
\end{pmatrix}
\begin{pmatrix}
X \\ Y \\ 1
\end{pmatrix}
\]
Previous Work

- Automatic keystone correction
- Laser pointer based presentation control
- Multi-planar display system
- Multi-Projector display system
Automatic Keystone Correction

What is Keystone ?
Automatic Keystone Correction

What is Keystone?
Distortion in projected image due to misalignment between projector and display surface.
Automatic Keystone Correction (contd.)

- Why it is undesirable:
  - Distracting to user
  - Detrimental to interpretation of visual information
Automatic Keystone Correction (contd.)

• Why it is undesirable:
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• How it can be prevented:
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• How it can be prevented:
  – By aligning projector’s optical axis perpendicular to screen.
Automatic Keystone Correction (contd.)

• Why it is undesirable:
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• How it can be prevented:
  – By aligning projector’s optical axis perpendicular to screen.
    ∗ But suitable for fixed projector.
    ∗ Alignment will be tedious for portable projector.
Solution using Projector-camera System

- Determine the rectangular region in the camera image where contents should appear.
- Use the Homography to back-project this rectangle into projector coordinates.
- Determine the projective transform that warps the slide to this desired quadrilateral.

\[
P = C^{-1} T
\]
Results of Projector-camera Based Solution

- Projector image
- Camera image
- Audience sees
Results of Projector-camera Based Solution

Projector image  Camera image  Audience sees

What about alignment of camera?
Improved Solution using Projector-camera System

- Need to model Projector-screen distortion.
- Apply the pre-warp so that application image appear rectilinear and best-fitted after projection through misaligned projector.

\[ W = P^T S \]

\[ S \]

\[ P \]

\[ \text{Pre warped image} \]

\[ \text{Source Image Frame} \]

\[ \text{Physical Screen} \]

\[ \text{Corrected Image} \]

\[ \text{Projected image} \]
Results of Improved Projector-camera Based Solution

Projector image  Camera image  Audience sees
Laser-pointer Based Presentation Control
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- **Traditional ways**: Keyboard or mouse.
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- **Pointer device for projector camera system:**
  - Laser pointer is tracked in camera image.
  - Mapping is derived from projector-camera homography.
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- **Interface provided**: 
  - Active regions
  - Freehand drawings
Multi-planar Display

- **Simple projector system**: single-projector single-planar.
Multi-planar Display

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• Planar surface is not always available.
  – Can make use of room corners, columns, desktop.
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  - All point on display surface should be undistorted when viewed along the surface normal.
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• **Shape adaptive projector:**
  – All point on display surface should be undistorted when viewed along the surface normal.
  – Need to determine the mapping between input image and corresponding areas on display surface.

Before correction  After correction
Multi-projector Display System
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• **Need:**
  – Large single logical display.
  – High cost of single high resolution projector.
Multi-projector Display System

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- **Solution:** Scalable alignment of multi-projector displays.
  - Images formed on the visible display surface originate from more than one display device.
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  – similar to single projector display system.
  – Should use a common world coordinate system.
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- **Issues:** Brighter image at overlapped region.
  - Can be corrected by attenuating projector pixel intensities in the overlapped regions.
Multi-projector Display System

Images from individual projector
Multi-projector Display System

Images from individual projector

Image before and after brightness correction
Problem Definition

The aim of our project is to create a virtual environment, for shooting range simulation using projector-camera based solutions.
Our Approach

- Projector creates simulated environment.
- Shooter(s) are sitting in a simulated environment.
- Shoots with the laser-gun on a screen.
- The camera(s) captures the hit screen.
Important Components

- **Virtual World:**
  - Created by system.
  - Rendered as First Person View.
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- **Projector-camera system:**
  - Projector projects virtual world.
  - Camera detects the hit.
Algorithm

1. The **virtual world** is created inside the computer.
2. The **scene** is rendered as first person view.
3. It is projected **anywhere** irrespective of **projector** position.
4. **Shooter** is positioned in front of display surface, facing the screen.
5. Shooter is asked to shoot the target on screen by **laser-gun** (Gun with laser pointer attached). The Laser point will help to detect the hit.
6. The **hit** by laser-gun will be detected by camera.
7. From projector-screen-camera homography, we can determine the actual hit in virtual world.
8. From target and hit information, accuracy of shooting can be determined.
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- **Pointer detection:**
  - Important for accurate detection of Hit.
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- **Pointer detection:**
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- **Homography between screen and projector:**
  - Required for accurately mapping back screen coordinate to virtual world coordinate.
Action Plan
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1. Implementation for single shooter planar display.
Action Plan

1. Implementation for single shooter planar display.
2. Displaying on any surface.
Action Plan

1. Implementation for single shooter planar display.
2. Displaying on any surface.
3. A multi-shooter team arena situation.
THANK YOU !!