Sensitivity Evaluation of Embedded Code Detection in Imperceptible Structured Light Sensing

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Introduction & Motivation

- Projector-Camera Systems in Robotics
  - Augmented Reality
  - Human-Robot Interaction
  - Some Other Applications

- Imperceptible Structured Light Sensing (ISL)

Display Device

Show Video Content

3D Sensor

Derive the 3D information
Introduction & Motivation


Coding

- specifically designed shapes
- large hamming distance

Decoding

- Pre-trained shape detector
Robotic Applications – Sensing Surrounding Environment

Robotic Applications –
Natural Human-Robot Interaction

Sensitivity Evaluation

Training Stage

Operation Stage

Scenarios

Differences

Sensor-Object Localization

Projection Surfaces

Surrounding Environment

Hardware Platforms
System Setup

PROCAMS-A

PROCAMS-B
## Hardware Configuration

<table>
<thead>
<tr>
<th></th>
<th>PROCAMS-A</th>
<th>PROCAMS-B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projector</strong></td>
<td>Mitsubishi EX240U Projector 1024 * 768</td>
<td>TI DLP Pico Projector Development Kit 2 640 * 480</td>
</tr>
<tr>
<td><strong>Camera</strong></td>
<td>Point Grey Flea3 FL3-U3-13S2C 1328 * 1048@120fps</td>
<td>Point Grey Flea3 FL3-FW-03S1C 648 * 488@120fps</td>
</tr>
<tr>
<td><strong>Lens</strong></td>
<td>Myutron FV1520 f15mm</td>
<td>Myutron FV0622 f6mm lens</td>
</tr>
<tr>
<td><strong>Pro-PC</strong></td>
<td>VGA</td>
<td>HDMI</td>
</tr>
<tr>
<td><strong>Cam-PC</strong></td>
<td>IEEE-1394</td>
<td>USB 3.0</td>
</tr>
<tr>
<td>Distance</td>
<td>800mm</td>
<td>500mm</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Orientation</td>
<td>0°</td>
<td>10°</td>
</tr>
<tr>
<td>Orientation</td>
<td>40°</td>
<td>50°</td>
</tr>
<tr>
<td>Shape</td>
<td>Planar</td>
<td>Convex</td>
</tr>
<tr>
<td>Texture</td>
<td>White</td>
<td>Green</td>
</tr>
<tr>
<td>PROCAMS</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>

When the scenarios of **training stage** and **operation stage** are almost the same, about **95%** primitive shapes can be detected and identified correctly.
Sensitivity Evaluation: Working Distance

In training data collection: Working Distance: 800mm

500mm 1200mm 1600mm
Sensitivity Evaluation: Projection Surface Orientation

In training data collection: Surface Orientation: $\theta = 0^\circ$

$\theta = 10^\circ$  $\theta = 20^\circ$  $\theta = 30^\circ$  $\theta = 40^\circ$  $\theta = 50^\circ$
Sensitivity Evaluation: Projection Surface Shape

In training data collection: Projection Surface: **Planar**

Convex Surface  Concave Surface  Plaster Statue
Sensitivity Evaluation: Projection Surface Texture

In training data collection: Surface Texture: White Paper

Green Paper  Cork Board  Poster
Sensitivity Evaluation: PROCAMS

In training data collection:
PROCAMS: PROCAMS-A

Captured Image

Cropped Patt.

Resized Patt.
## Sensitivity Evaluation: Conclusion

<table>
<thead>
<tr>
<th>Condition</th>
<th>Hits (%)</th>
<th>Missed (%)</th>
<th>False (%)</th>
<th>Ed (pixel)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benchmark</strong></td>
<td>94.53</td>
<td>3.95</td>
<td>1.52</td>
<td>1.632</td>
</tr>
<tr>
<td>Distance (500mm)</td>
<td>86.21</td>
<td>11.63</td>
<td>2.16</td>
<td>1.814</td>
</tr>
<tr>
<td>Orientation (50 degree)</td>
<td>85.91</td>
<td>12.03</td>
<td>2.06</td>
<td>2.728</td>
</tr>
<tr>
<td>Surface (Plaster Statue)</td>
<td>84.81</td>
<td>13.33</td>
<td>1.86</td>
<td>2.028</td>
</tr>
<tr>
<td>Texture (Poster)</td>
<td>91.74</td>
<td>6.63</td>
<td>1.63</td>
<td>2.024</td>
</tr>
<tr>
<td>PROCAMS (Cropped Pattern)</td>
<td>80.23</td>
<td>14.43</td>
<td>5.34</td>
<td>3.028</td>
</tr>
</tbody>
</table>

For more detailed sensitivity evaluation results, please refer to the paper.
Conclusion and Future Works

Sensitivity evaluation of embedded code detection in imperceptible structured light sensing.

Future Works

- Extending imperceptible structured light sensing to a variety of robotic applications.
THANK YOU!!

If you have any questions, please contact

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