Construction of a Projection-based Augmented Reality System based on Shape Measurement using Flexible Marker for Design Support

Yuichiro Fujimoto, Tomohisa Yamada, Takafumi Taketomi, Goshiro Yamamoto, Jun Miyazaki, Hirokazu Kato
Nara Institute of Science and Technology, Japan
Designing for product development

- For developing sales products, it is important to make prototypes and improve product’s design.

- If developers or designers want to change the color or texture of prototypes, they have to remake the prototype. → very high cost

918 spyder porsche, http://www.porsche-design.com/international/jp/
Projection-based AR for design support

- This system can change the appearance of the target object without the need of remaking it every time
- Multiple people can observe the target object simultaneously.

Limitation of current system for design support

- Only the appearance can be changed easily
- Useful if the shape of the object is able to be changed too

**Factors for design**

- Appearance ✔
- Shape ✗

**Method**

- This is possible if deformable materials can be used to make prototypes.
Goal and overview of completed system

- Geometrically-correct projection onto a object which can be reshaped by hand

Several projector-camera systems, axes of which are corresponded with each other. Target object made of deformable materials

(Project with University of South Australia)
Required factors to achieve geometrically-correct projection

**Factor 1.** Recognize the local positions on the target object

**Method to achieve it:**
Place (retro-reflective) markers which can be detected by an IR-camera on the target object

**Factor 2.** Appropriate projection by several projector-camera systems
Method to recognize the local positions on the object

We develop a deformable marker and its recognition

Projector + IR-camera

Projected texture

Deformable marker using retro-reflective materials
Overview of current system

For a first step, one projector-camera system is used

Instead of using a projector-camera system axes of which were corresponded, gray code patterns were used to take correspondences between a projector and a camera.

- Projector
- Camera (switchable RGB-to-IR function)
- Target marker
1. Can be recognized partially, because the whole marker cannot always be observed.

2. Can be recognized even if the marker is bent (by hands).
Related works: Pattern marker

Pattern marker which can be recognized as long as a 4 × 4 grid region is observed

1. Can be recognized partially when the whole marker cannot always be observed

2. Can be recognized even if the marker is bent

Overview of proposed deformable marker

The shape of this marker can be easily changed by hand.
ID for each location on the marker

- Marker has dot patterns (retro-reflective material)

Using an IR-camera, these patterns are used as the ID of each location in the marker.
Approach for marker recognition

For “2. Can be recognized even if marker is bent”

Need a new recognition algorithm

It is difficult to acquire the whole shape information using the whole region at one times

Divide into small regions, recognize smaller patterns and then merge all
Flow of marker recognition processes

1. Detect points
2. Divide regions in a hierarchical way
3. Create grids in each segment
4. Matching between detected grid points and points on the reference pattern
5. Merge all grids and reject errors

Problem to be solved (meaning of recognition)
Calculate corresponding points on the reference pattern

(project a texture onto the marker)
Each step of recognition (1/4)

1. Detect points
2. Divide regions in a hierarchical way
Each step of recognition (2/4)

3. Create grids in each segment
Each step of recognition (3/4)

4. Matching between detected grid points and points on the reference pattern

A part of detected marker

Reference pattern
Each step of recognition (4/4)

5. Merge all grids and reject errors

Point ID in the reference pattern
Projection results
Another projection results

Projected image
Accuracy of projection

- Project grid points (red points) and measure the distance between each projected point to each corresponding retro-reflective point on the marker.

<table>
<thead>
<tr>
<th>Shape of marker</th>
<th>(a)</th>
<th>(b)</th>
</tr>
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<tbody>
<tr>
<td>Mean error (mm)</td>
<td>1.8</td>
<td>1.6</td>
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Problems and next steps

Marker is partially recognized only.

Reason 1.
Retro-reflective points are not observed on the surface, which normal is oblique toward the light axis of the camera.

difficult to observe

Reason 2.
Current marker recognition algorithm is too depend on heuristics.

How do you decide the size of segment and hierarchal steps?

How do you detect detect threshold of voting number to reject error matching between detected points and reference points?

...
Summary and future work

◆ Goal
Geometrically-correct projection onto the material which can be reshaped by hand for design support

◆ Method
development of a deformable marker and its recognition method

◆ Achievement
Can project texture images onto the correctly-recognized part of the deformable marker

◆ Next step
- Improving the accuracy of the marker recognition
- developing how to project by several projector-cameras simultaneously