Embedding Imperceptible Codes into Video Projection and Applications in Robotics

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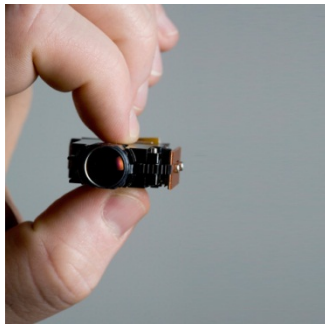
Introduction & Motivation



DLP Pico Projector

Mobile Phone

DC

DV

Previews Works

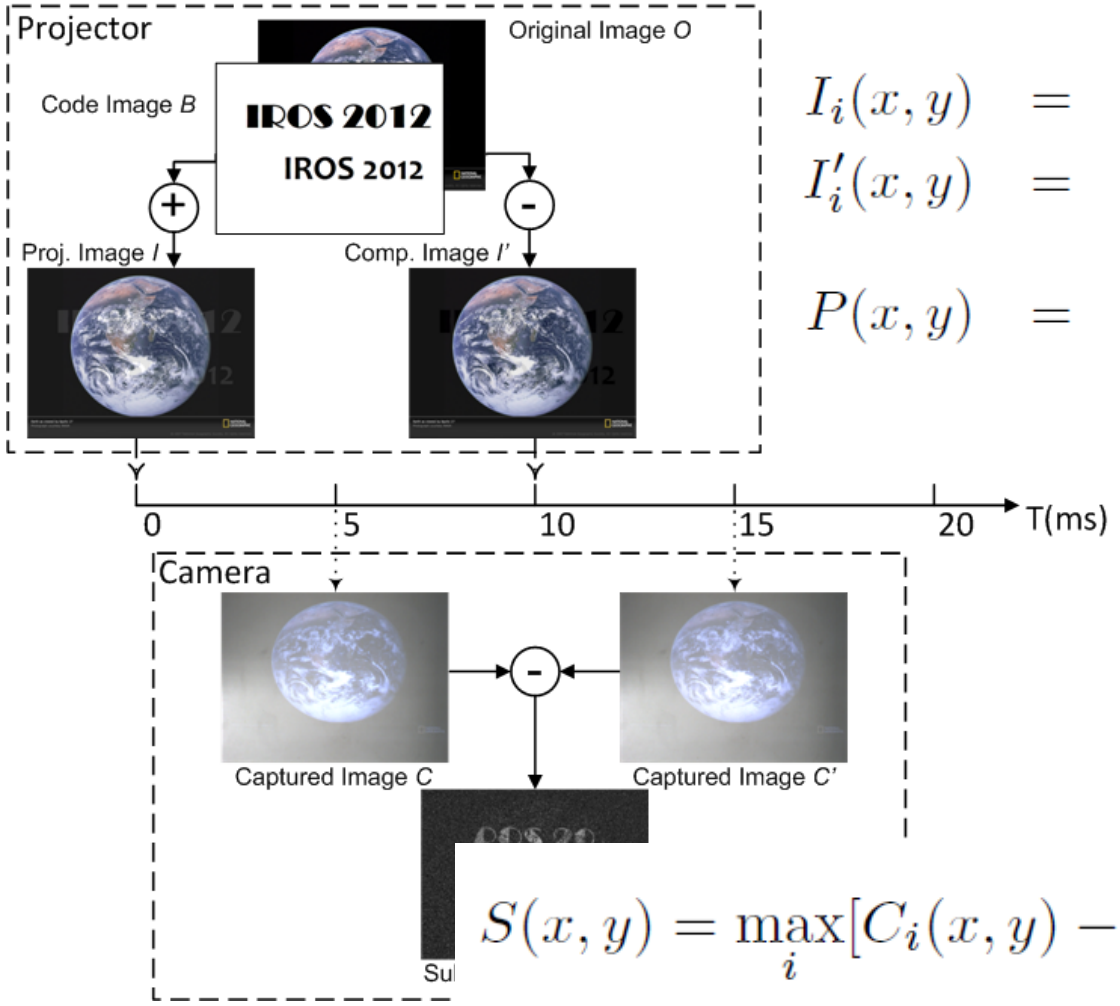
- **Non-Visible Spectrum (Infrared)**
  - *IR Projector + IR Camera (Kinect)*
  - *Normal Projector and Camera + IR Filters*
- **Imperceptible Structured Light (ISL)**
  - *[Raskar1998]* -- fist proof of ISL
  - *[Cotting2004]* -- micro-mirror states in DLP
  - *[Park2007]* – intensity adaption in YIQ color space
  - *[Grundhofer2007]* -- human contrast sensitivity function
  - *[Park2010]* -- subjective evaluation for ISL

To the best of our knowledge, few works focus on the decoding method in imperceptible code embedding configuration.

Main Contributions

- **Using only off-the-shelf devices**
- **Robust codes design in coding stage**
- **Noise-tolerant geometrical primitives detection and classification in decoding stage**

Principle of Embedding Imperceptible Codes

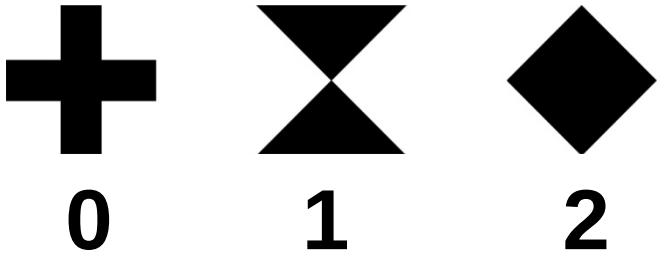


$$I_i(x,y) = O_i(x,y) + P(x,y),$$
$$I'_i(x,y) = O_i(x,y) - P(x,y),$$
$$P(x,y) = \begin{cases} \Delta, & when \quad B(x,y) = 1; \\ 0, & when \quad B(x,y) = 0. \end{cases}$$

$$S(x,y) = \max_i [C_i(x,y) - C'_i(x,y)], i = \{R, G, B\}.$$

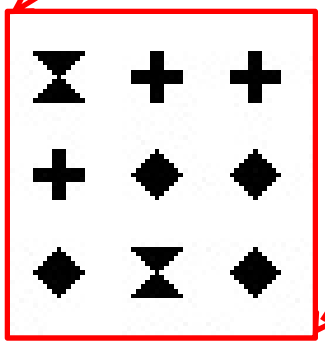
Design of Embedded Pattern

- **Primitive Shapes**
  - **Cross**
  - **Sandglass**
  - **Rhombus**

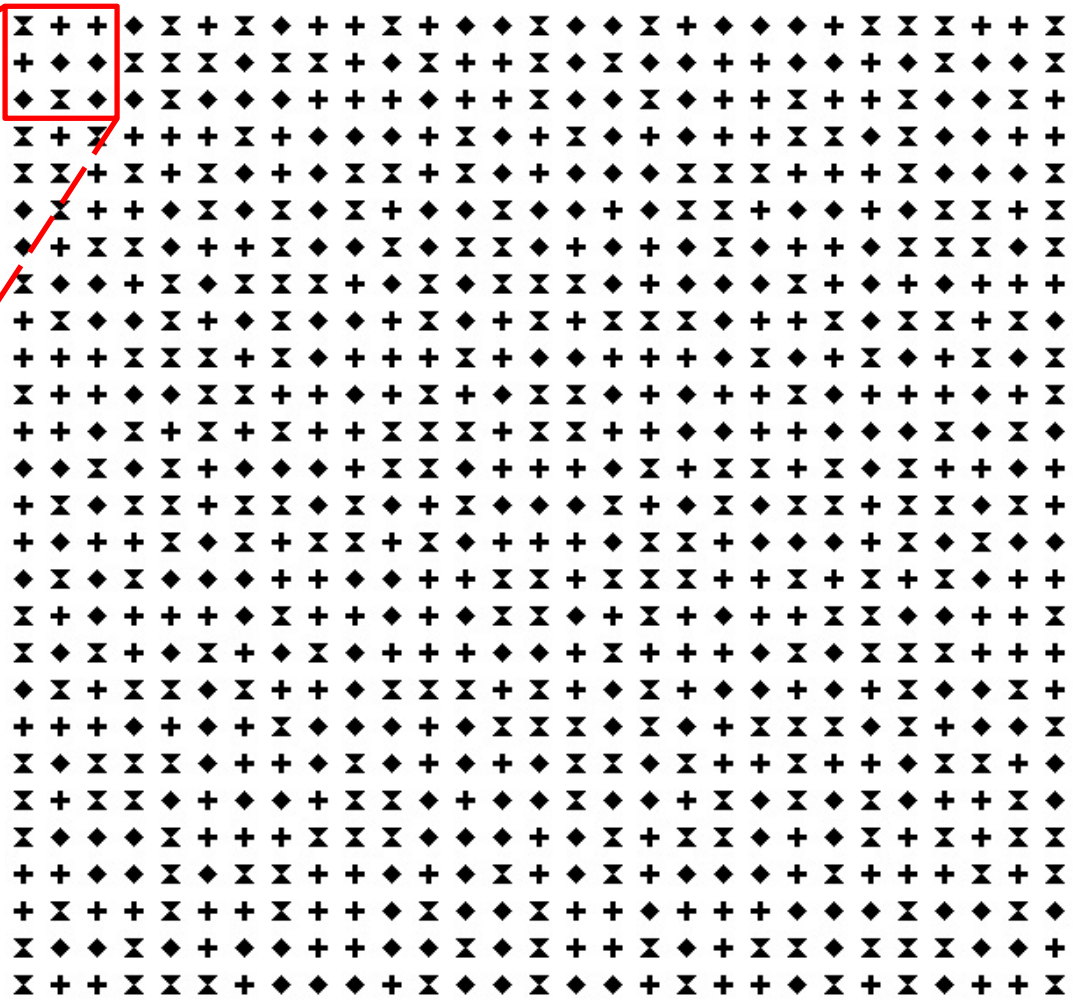


Design of Embedded Pattern

- **Pattern Image**
  - **Size: 27 * 29 = 783**



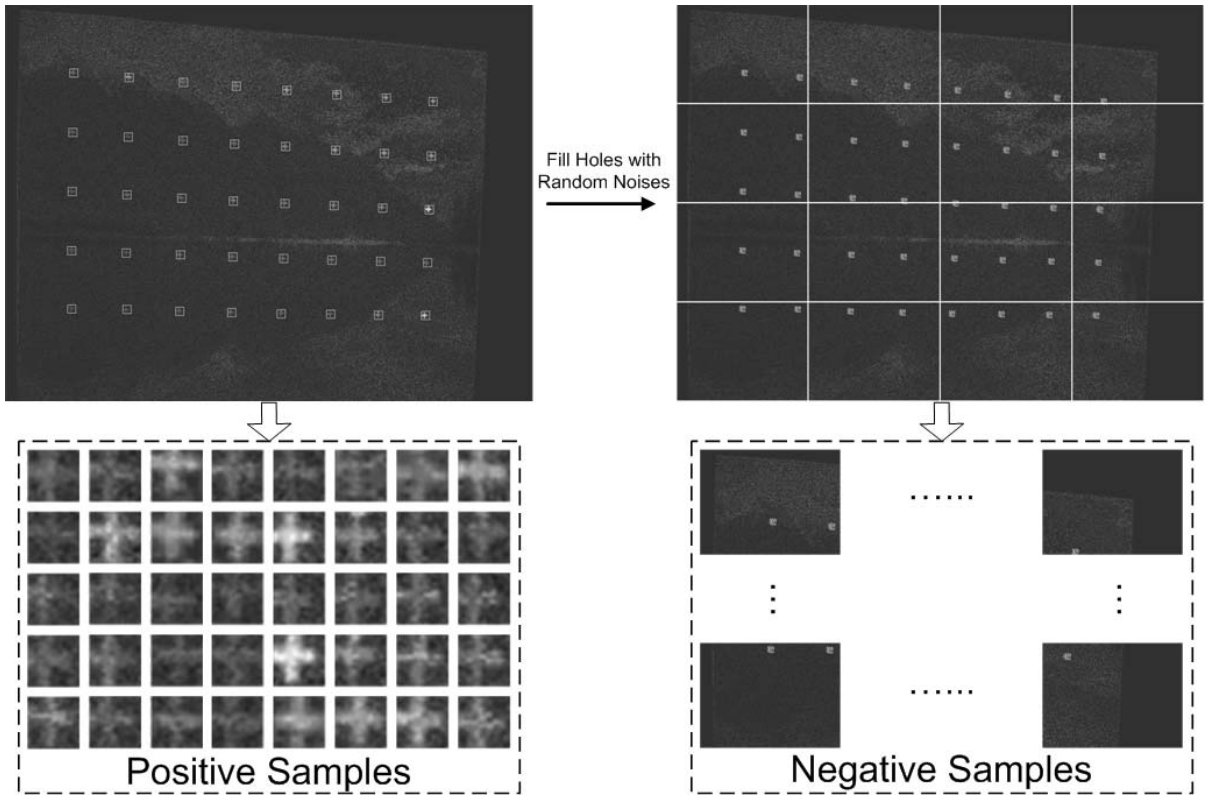
Code = 100022212



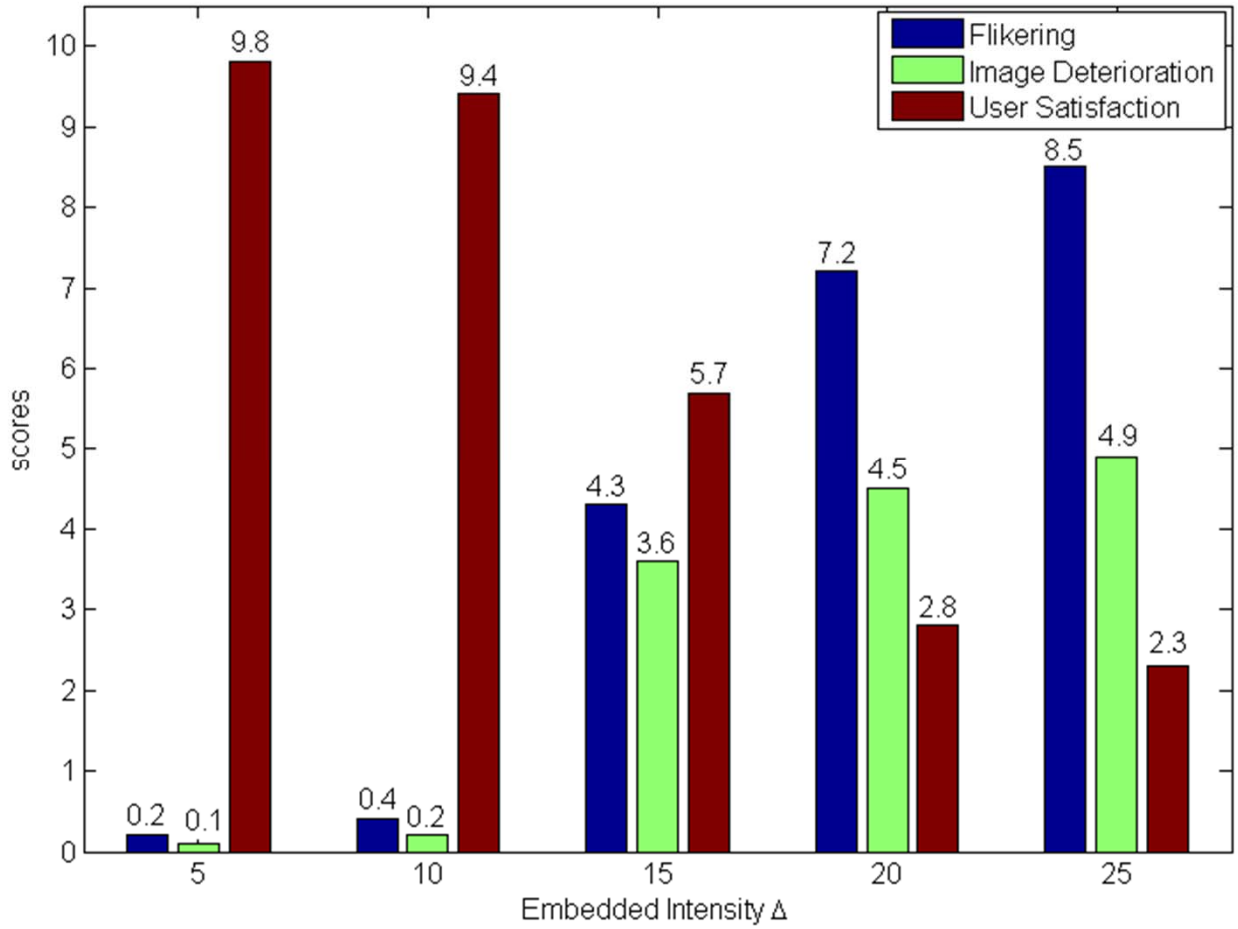
- $\bar{H} = 6.0084$
- $95.97\%\ (H \geq 3)$

Primitive Shape Identification and Decoding

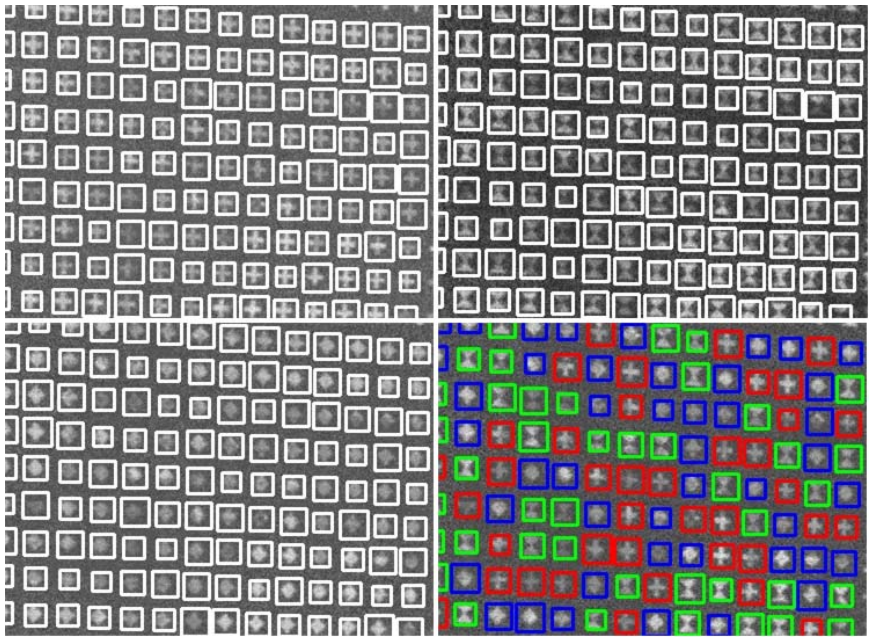
- **Adaboost Training**
  - **Harr-Like** Features
  - Positive Sample Size
    20 * 20
  - Pos./ Neg. Sample Num.
    7000 / 3000
  - **16-stage** cascade classifier

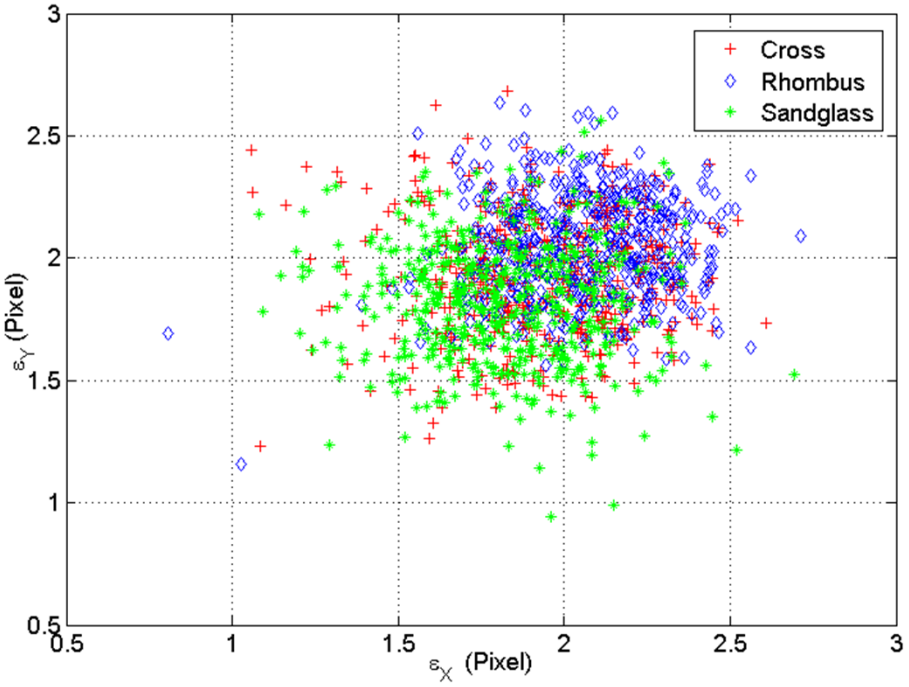


Experiments –
Imperceptibility Evaluation



Experiments -- *Accuracy Evaluation*





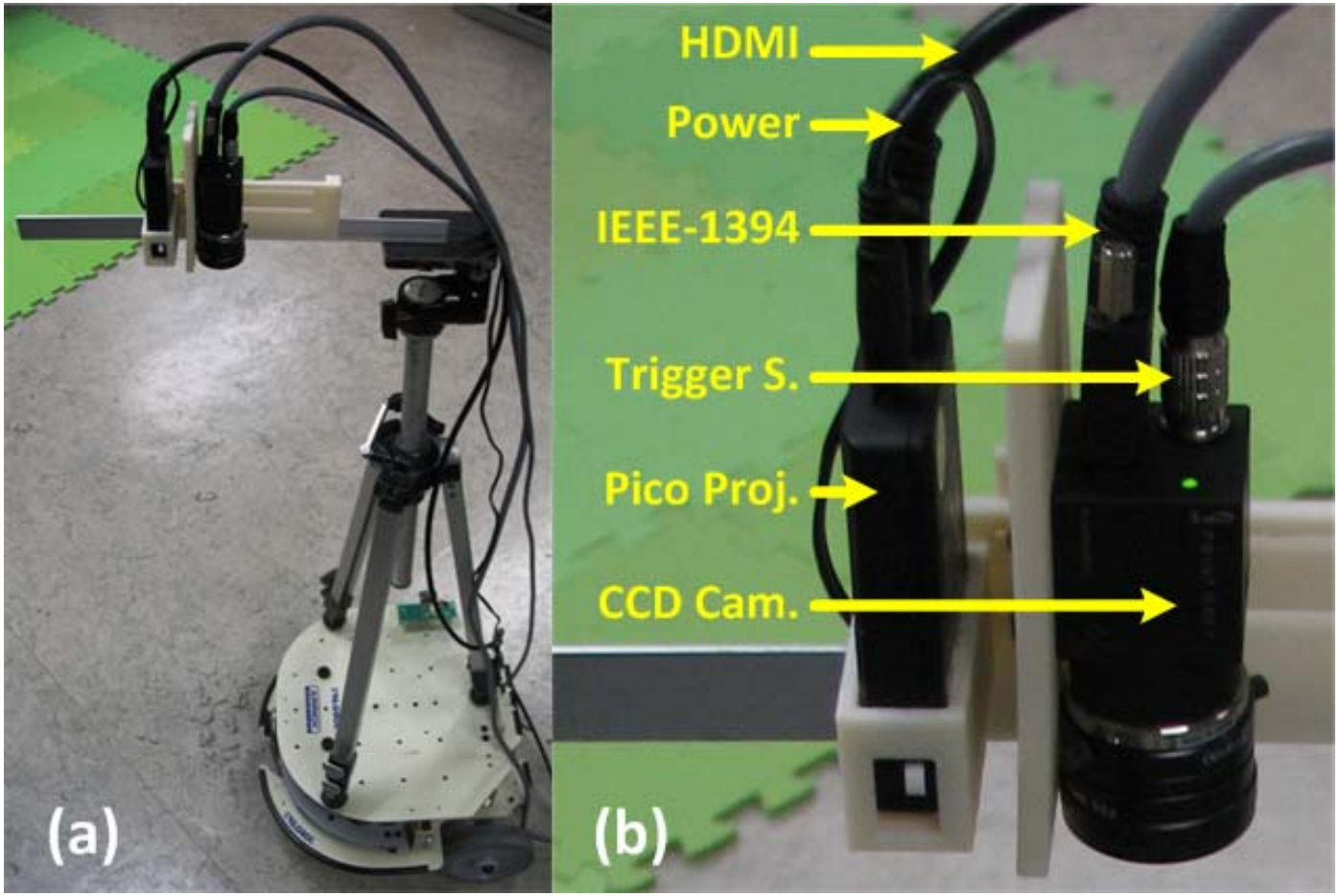
Experiments –
Accuracy Evaluation

	Hits(%)	Missed(%)	False(%)	$[\epsilon_X, \epsilon_Y]$(pixel)	Corr. Acc.(%)
Cross	86.21	11.63	2.16	[1.931, 1.927]	—
Rhombus	85.83	12.57	1.60	[2.056, 2.051]	—
Sandglass	87.49	11.64	0.87	[1.816, 1.821]	—
Whole Pattern	86.33	11.06	2.61	[2.013, 2.043]	91.23

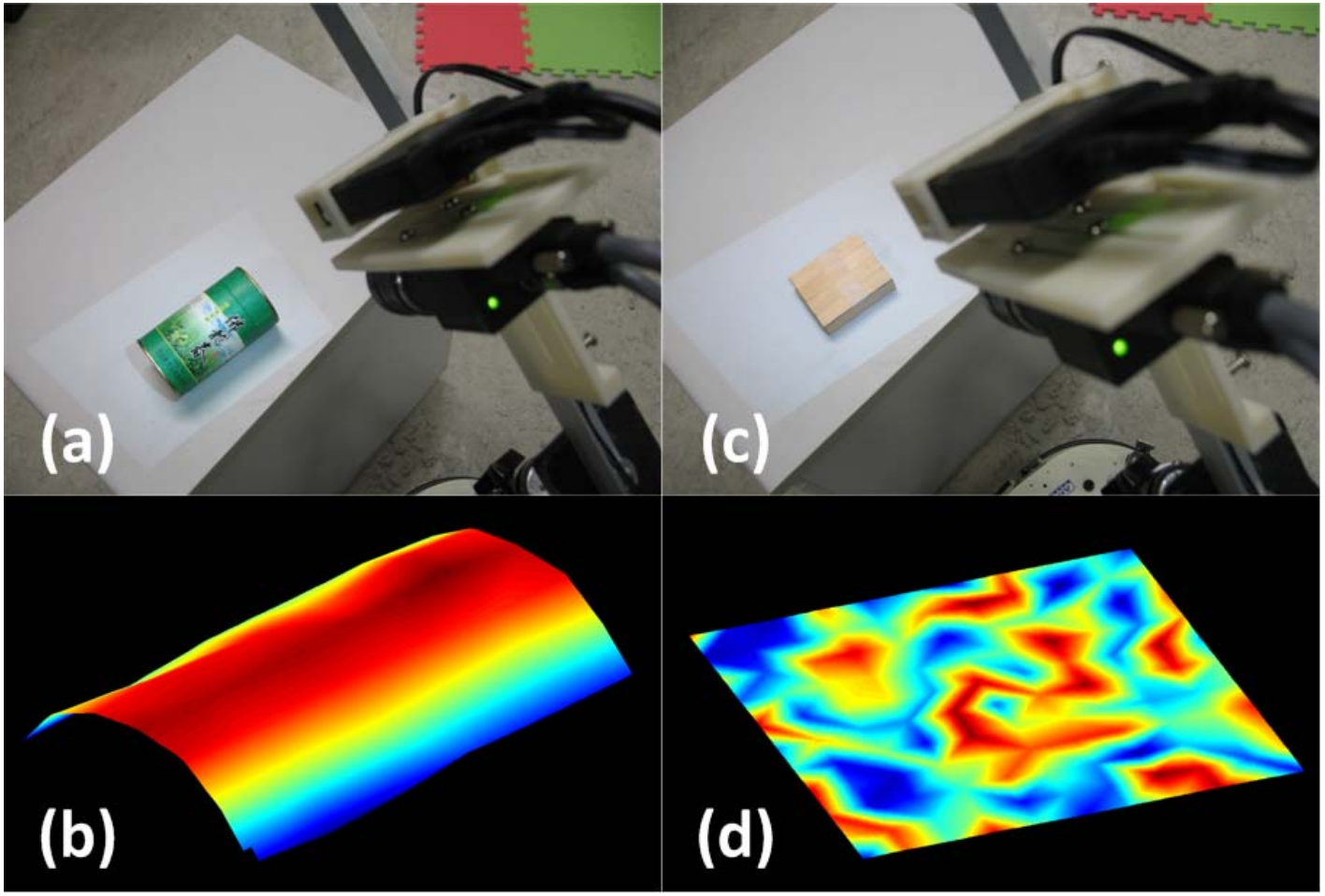
Table 1. The quantitative experiment results on (embedded) code detection accuracy.

Applications –

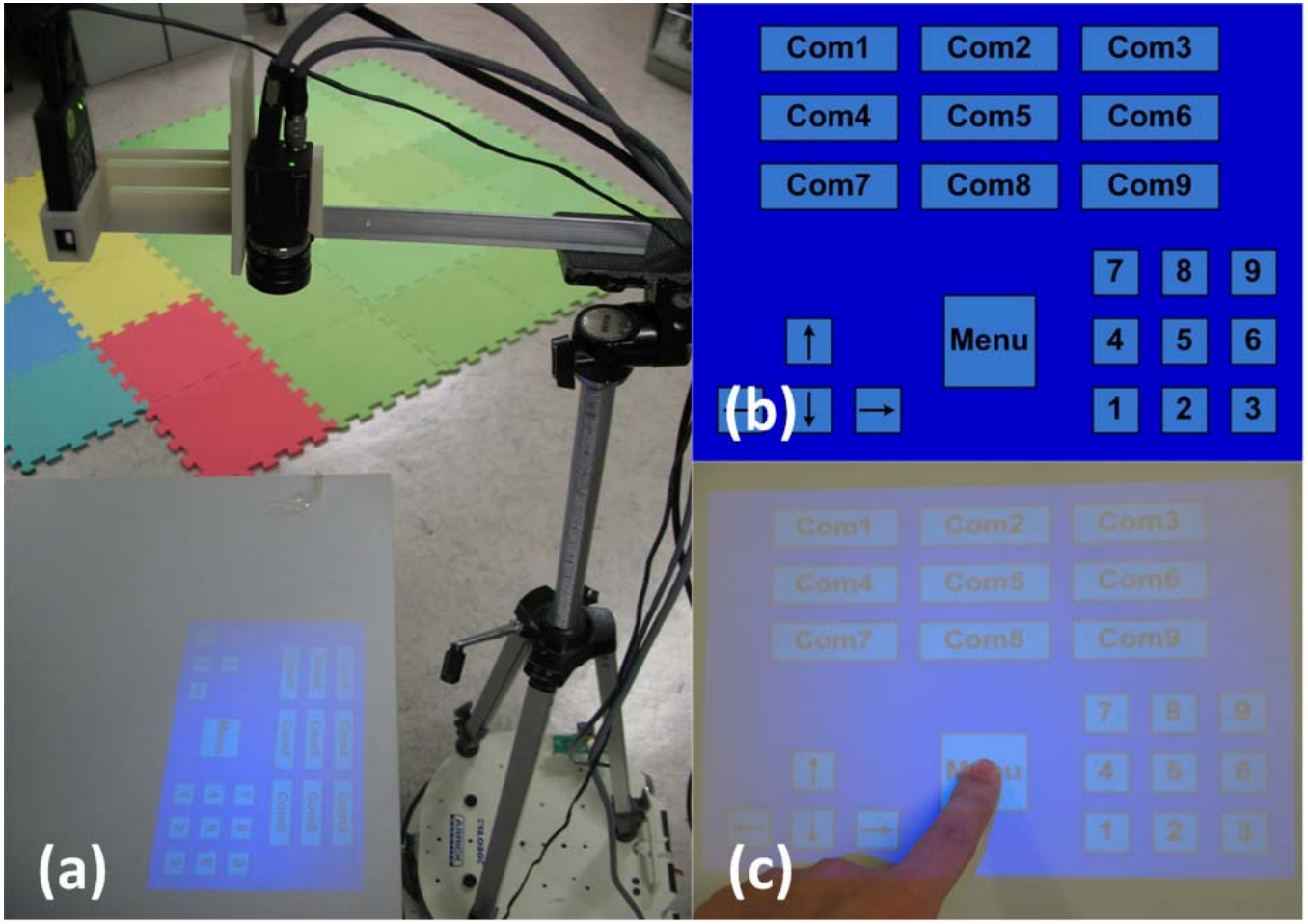
Integration with Mobile Robot System



Applications –
Sensing Surrounding Environment



Applications –
Natural Human-Robot Interaction



Conclusion and Future Works

A novel system of embedding imperceptible structured codes into normal projection.

- ***Coding:*** noise-tolerant schemes (specifically designed shapes and large hamming distance)
- ***Decoding:*** pre-trained primitive shape detectors are used to detect and identify the weakly embedded codes

Future Works

- ***Denser Coding***
- ***Motion Compensation***