Detection, Localization and Picking Up of Coil Springs from a Pile
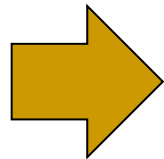
Keitaro Ono, Takuya Ogawa, Yusuke Maeda (Yokohama National University)

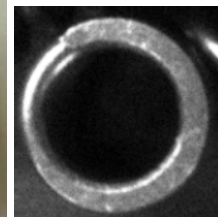Shigeki Nakatani, Go Nagayasu, Ryo Shimizu, Noritaka Ouchi (NHK Spring Co., Ltd.)

Background

- ## Robotic Bin Picking
  - More flexible than conventional parts feeders
  - Suitable to high-mix production
  - Many previous studies
    - E.g. [Shroff et al. 2011] [Liu et al. 2012]
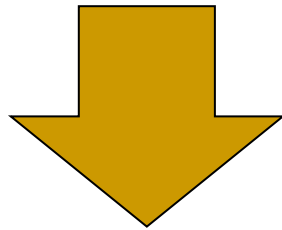 - Commercial products available

  ➡ Not Applicable to Coil Springs

Coil Springs

- Round shape: no vertices, no straight lines
- Succession of identical shapes
- See-through
- Highlights by specular reflection

Those make it difficult to apply conventional bin picking techniques

Objective

To Achieve Robotic Bin Picking of Coil Springs
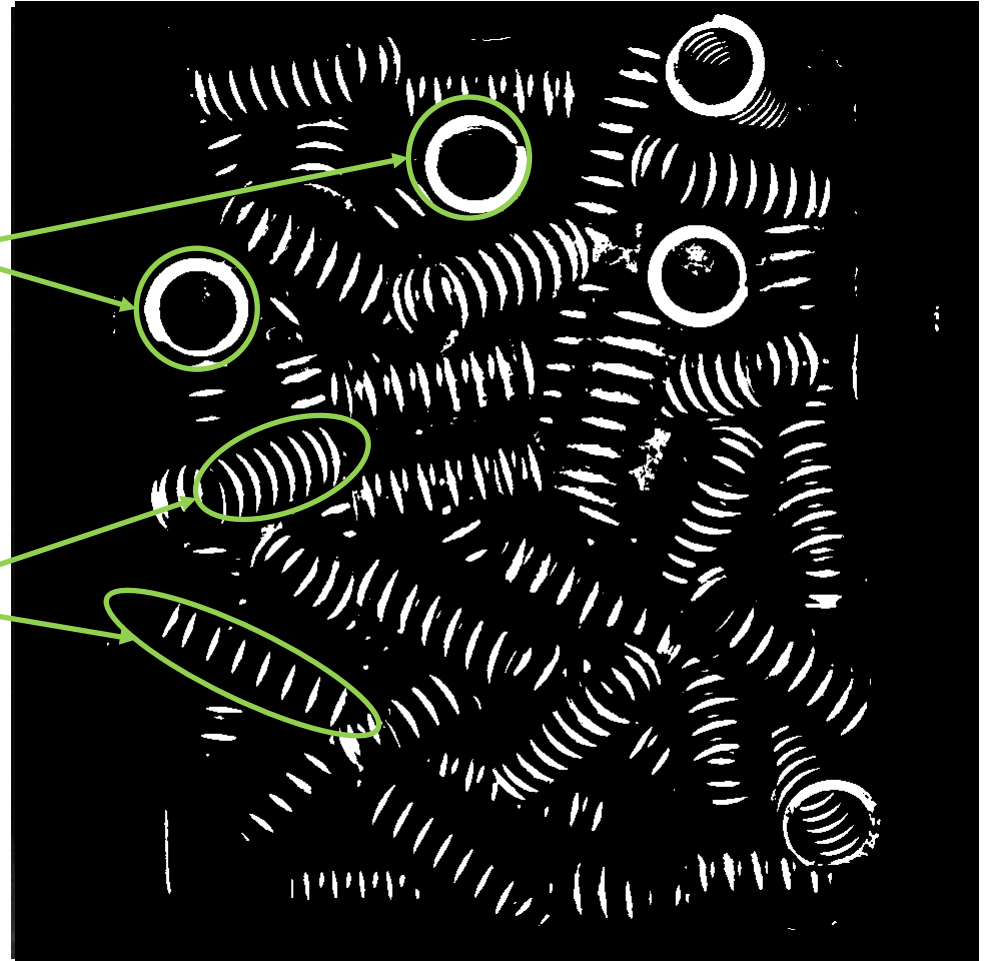
- Approach: Develop a technique dedicated to coil springs
    - Detection: Highlight-based
    - Localization: Stereo vision
    - Picking
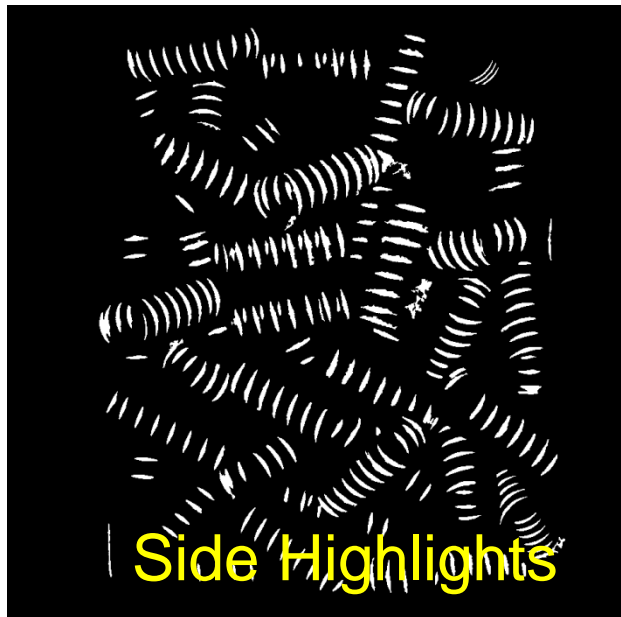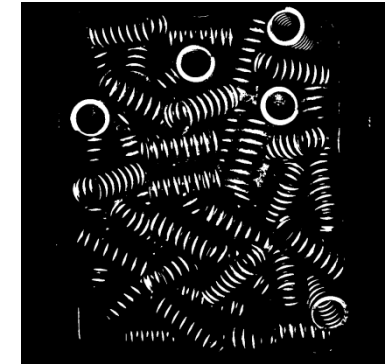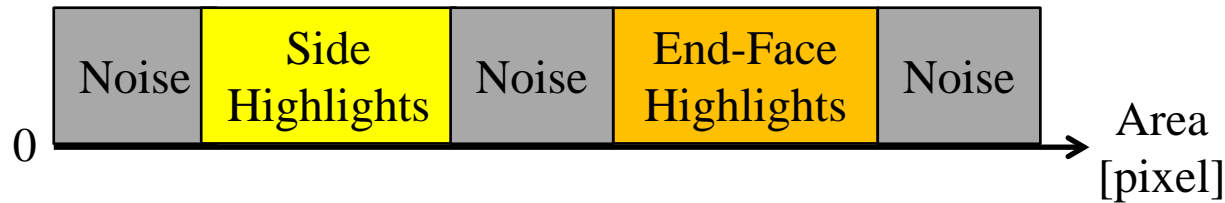
Highlight-based Detection of Coil Springs

- Image binarization to extract highlights

End-face Highlights

Side Highlights

Area-based Discrimination of Highlights

| Noise | Side Highlights | Noise | End-Face Highlights | Noise |

0 → Area [pixel]

Side Highlights

End-face Highlights
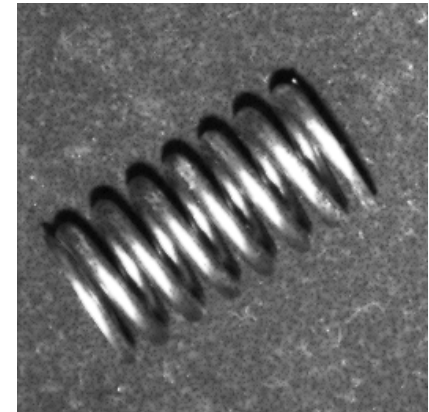
Recognition of Coil Springs

- **End-face Highlight**
  - ❑ Coil spring in an upright position
  - ❑ Ellipse fitting to obtain its representative point
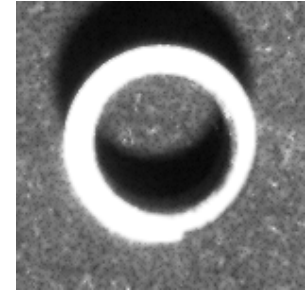
- **Side Highlight**
  - ❑ Grouping is necessary
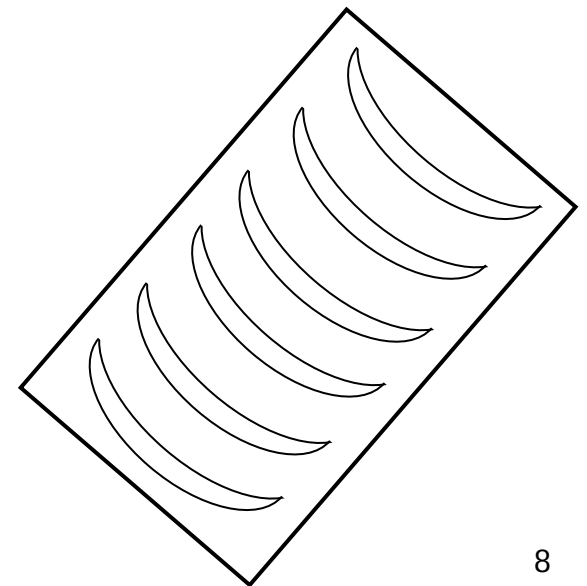
Grouping Side Highlights

- **Shape similarity**
  - Area
  - Direction of long axis
  - Magnitude of curve

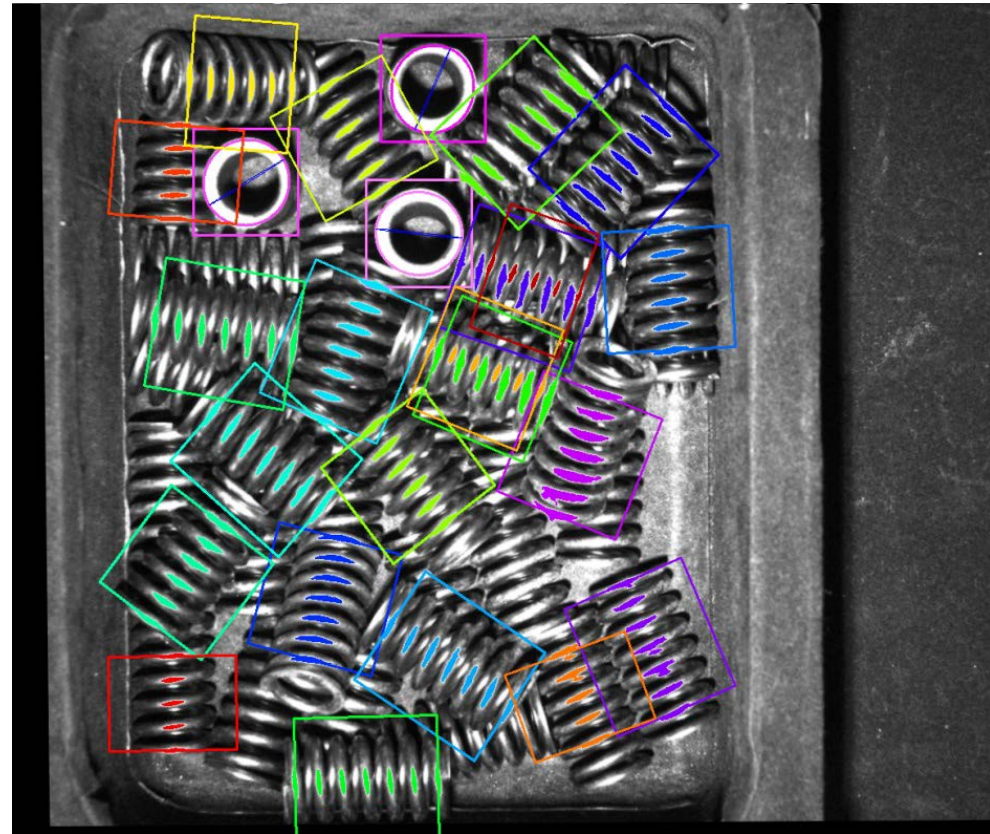 Calculated with image moments

- **Relative positioning**
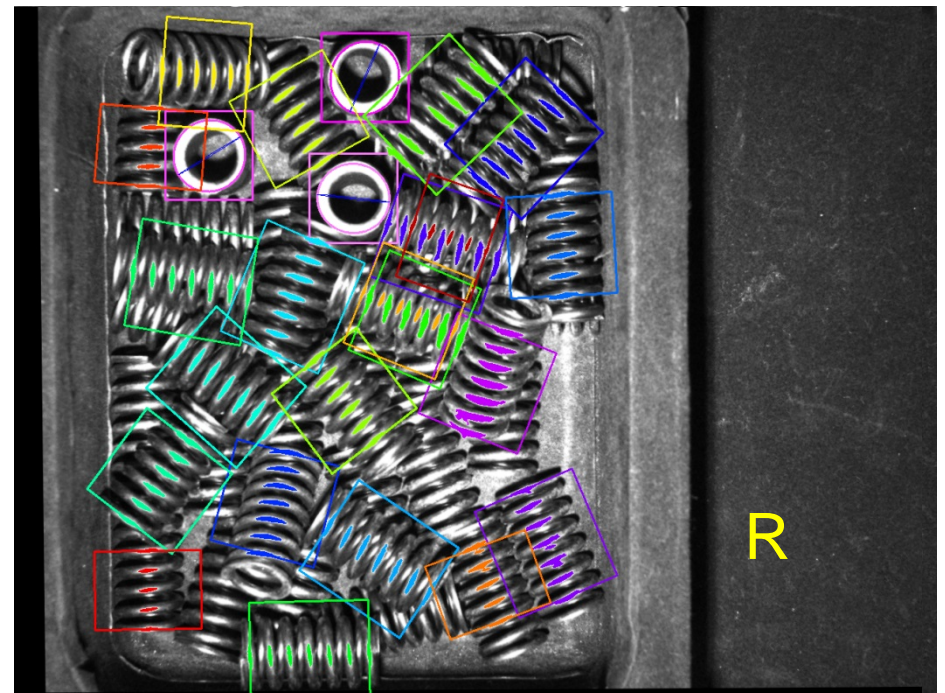 - Constant highlight interval
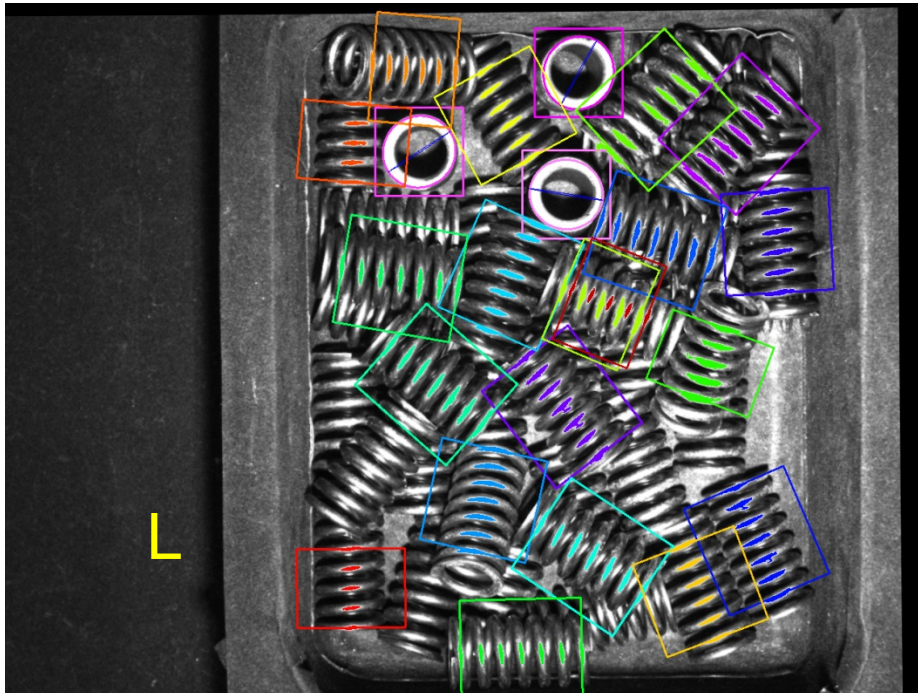 - In-line alignment

Example: Recognition

- Coil springs are successfully recognized
- False groups of inside highlights are harmless for picking

Localization of Coil Springs

- Recognize coil springs for left and right images separately
- Find stereo correspondence

Group-Level Correspondence

- ## End-face highlights
  - Correspondence between centers of fitted ellipses
- ## Side highlight groups
  - Correspondence between group centroids
  - Group similarity must be checked
    - Number of member highlights
    - Y-coordinates of group centroids
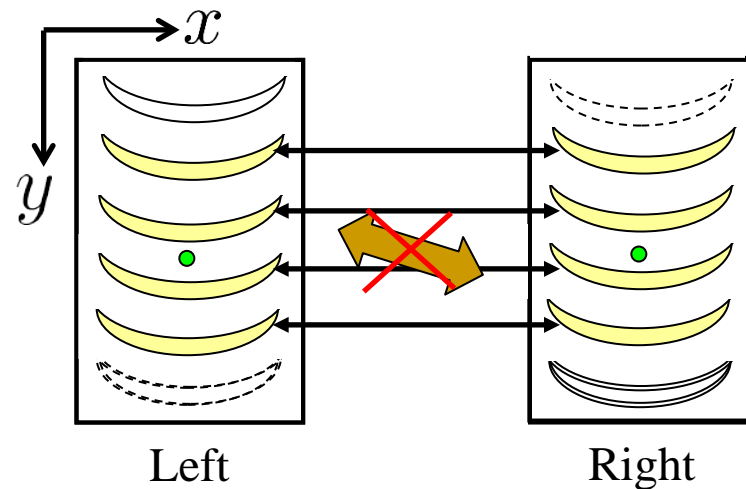   - Average highlight areas
    - Group orientation

highlight   Group centroid

Left   Right
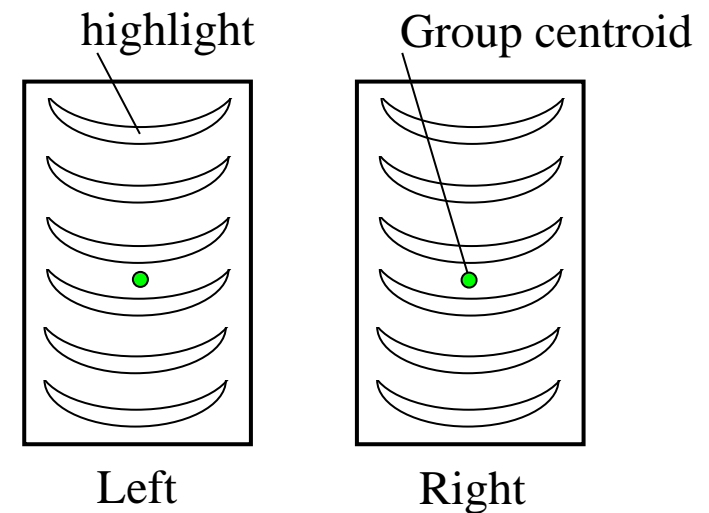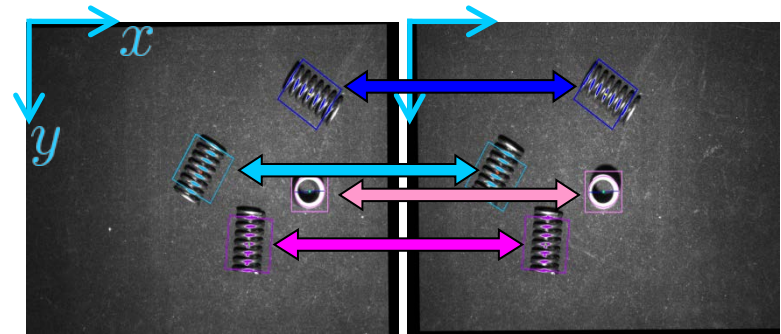
Example: Group-Level Correspondence
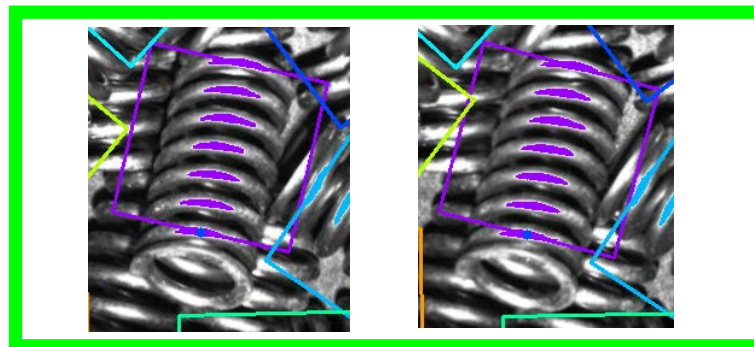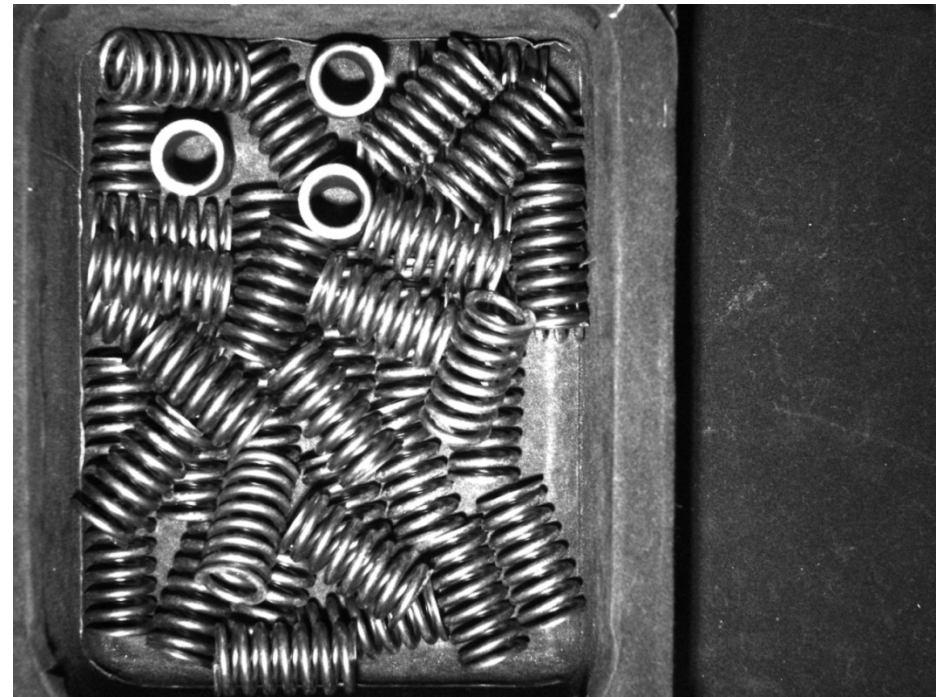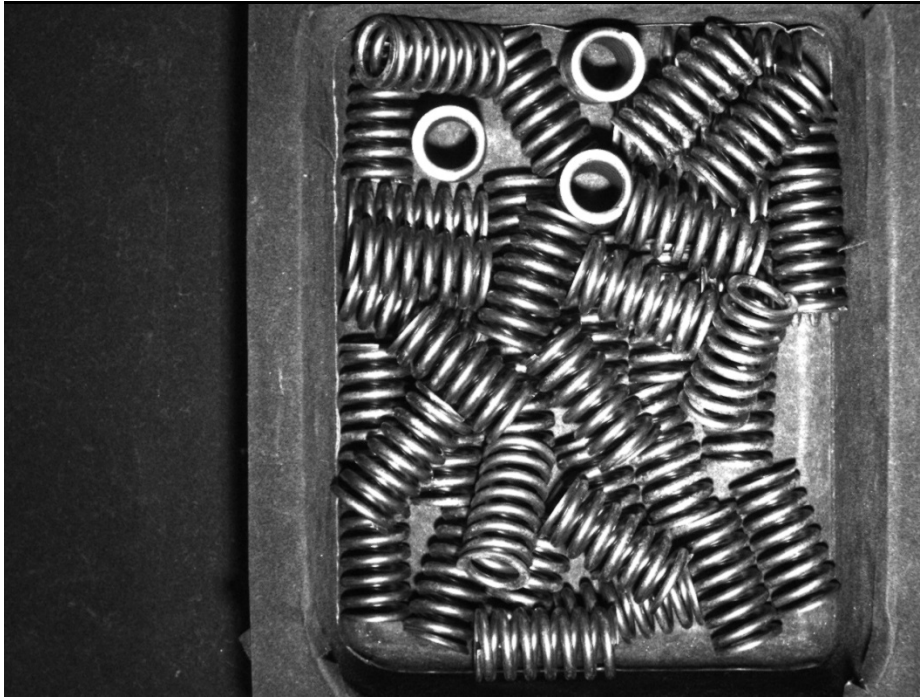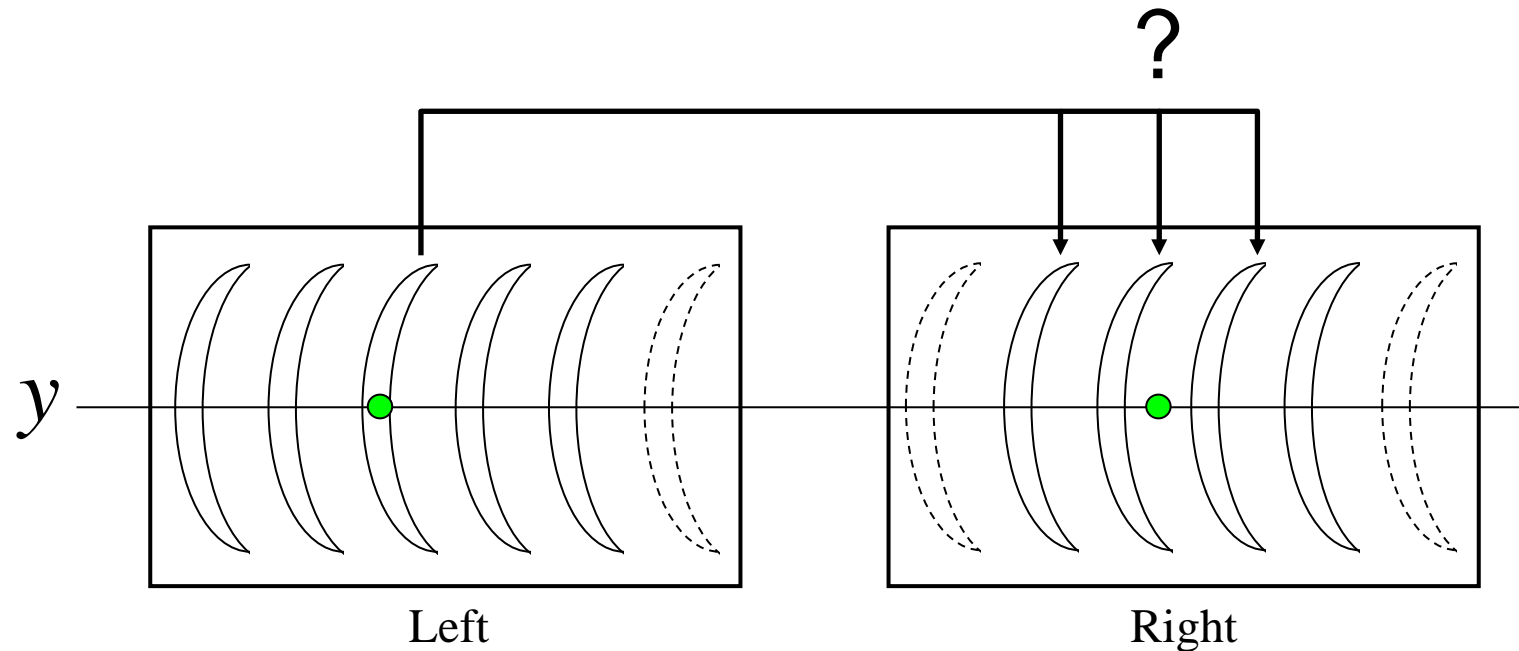
Highlight-Level Correspondence

■ Group-level correspondence cannot be found in some cases

■ Highlight-level correspondence for localization
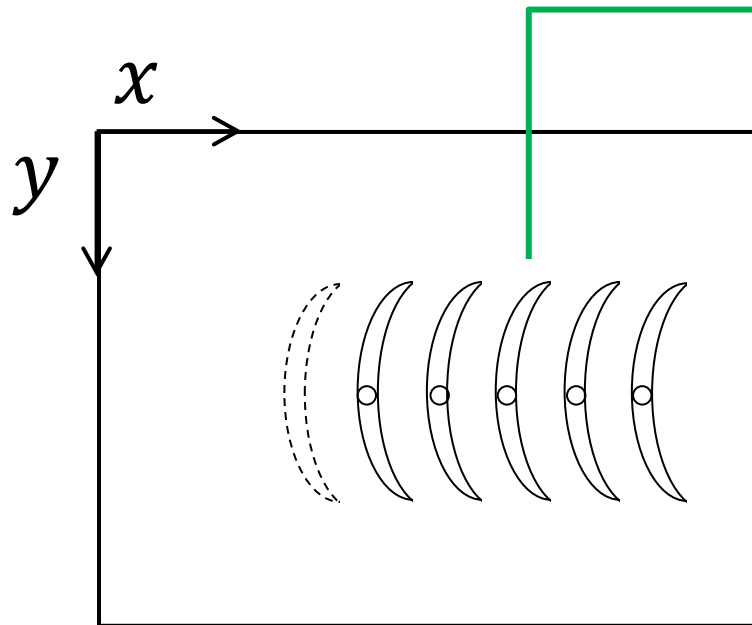 ❑ Y-coordinates of highlights

Highlight-Level Correspondence for Horizontally Aligned Highlights

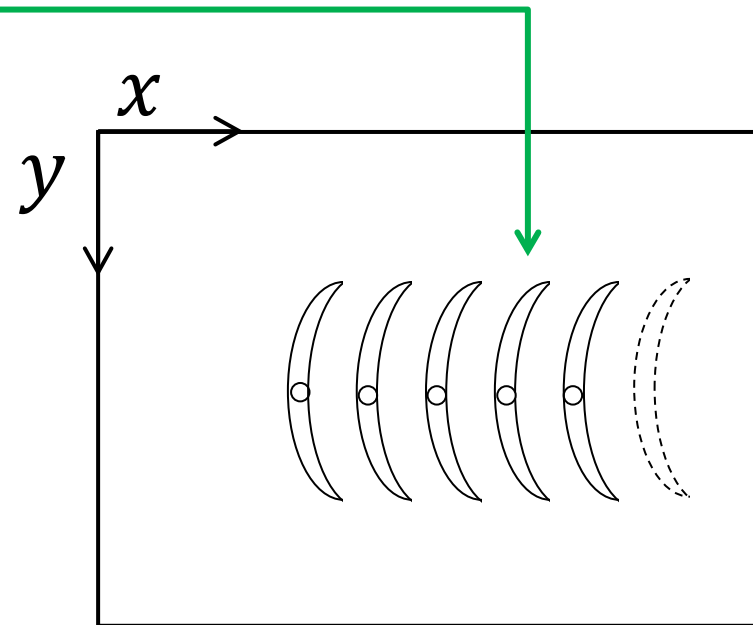- Cannot find unique highlight-level correspondence

Highlight-Level Correspondence for Horizontally Aligned Highlights

- Use original grayscale images to find correct highlight-level correspondence
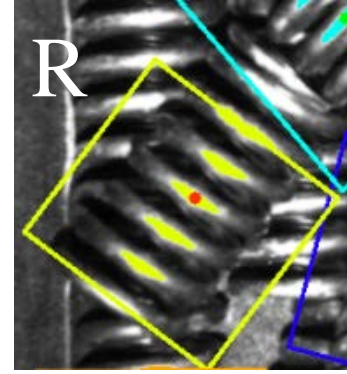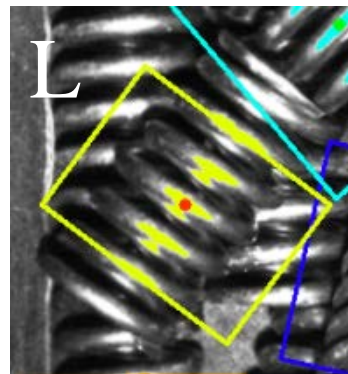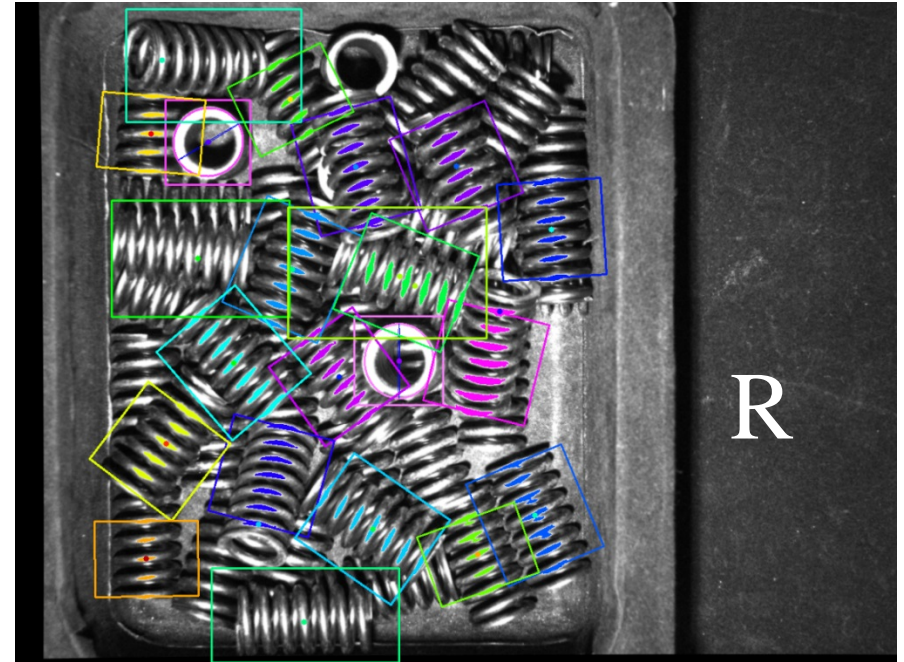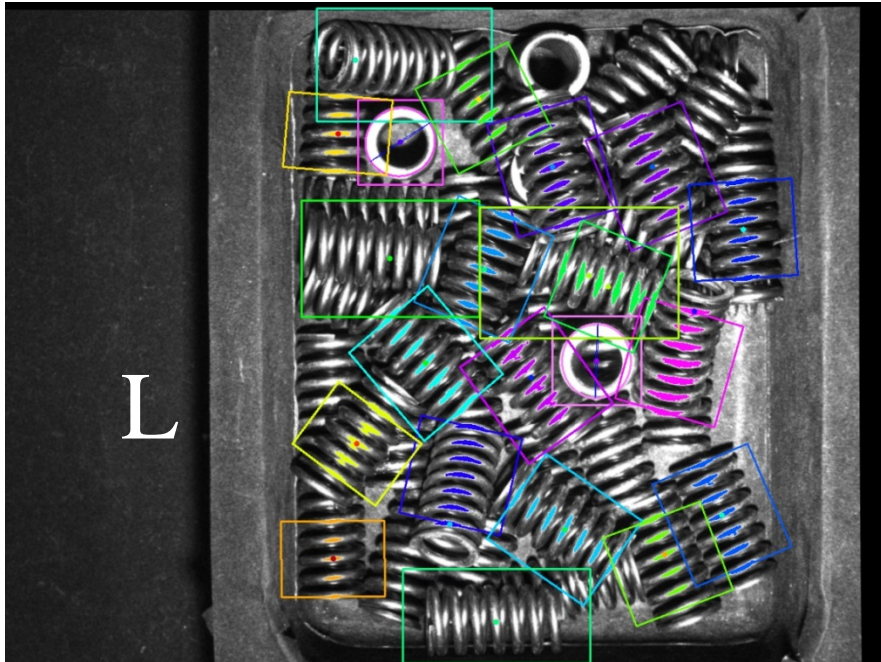 - Block matching

x

y

x

y

Template Region (Left)

Matched Region (Right)

Example: Highlight-Level Correspondence

Localization of Coil Springs

- **Standard triangulation**
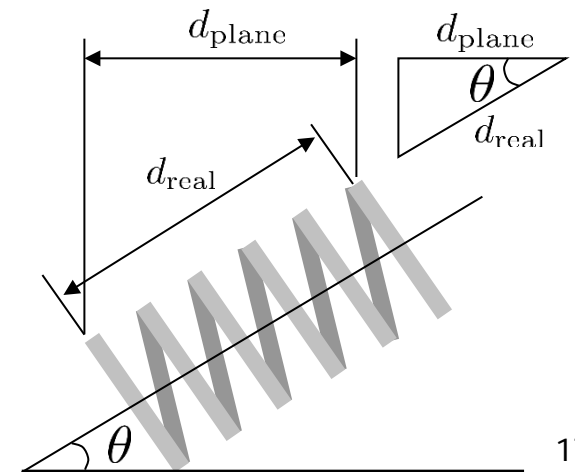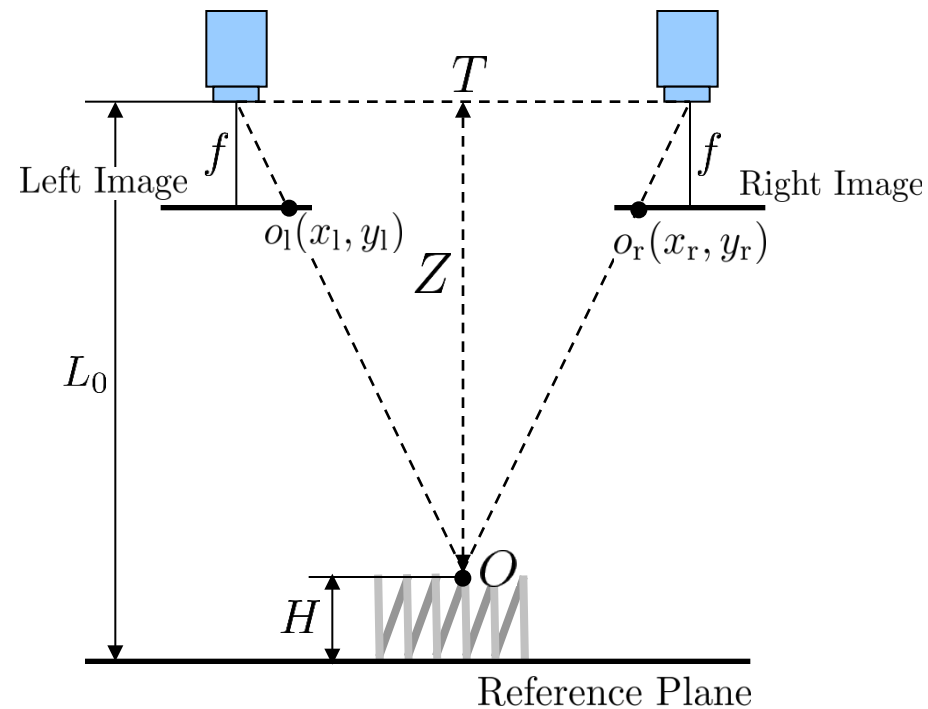
- **Height**

$$H = L_0 - Z = L_0 - \frac{fT}{(x_l - x_r)P_s}$$

  - pixel size: P_s
  - Distance to ref. plane: L_0
  - focal length: f
  - baseline length: T
  - disparity: $x_l - x_r$

- **Tilt angle** $\theta = \cos^{-1}\left(\dfrac{d_{\text{plane}}}{d_{\text{real}}} \dfrac{Z P_s}{f}\right)$

  - highlight interval d_{plane} [pixel]
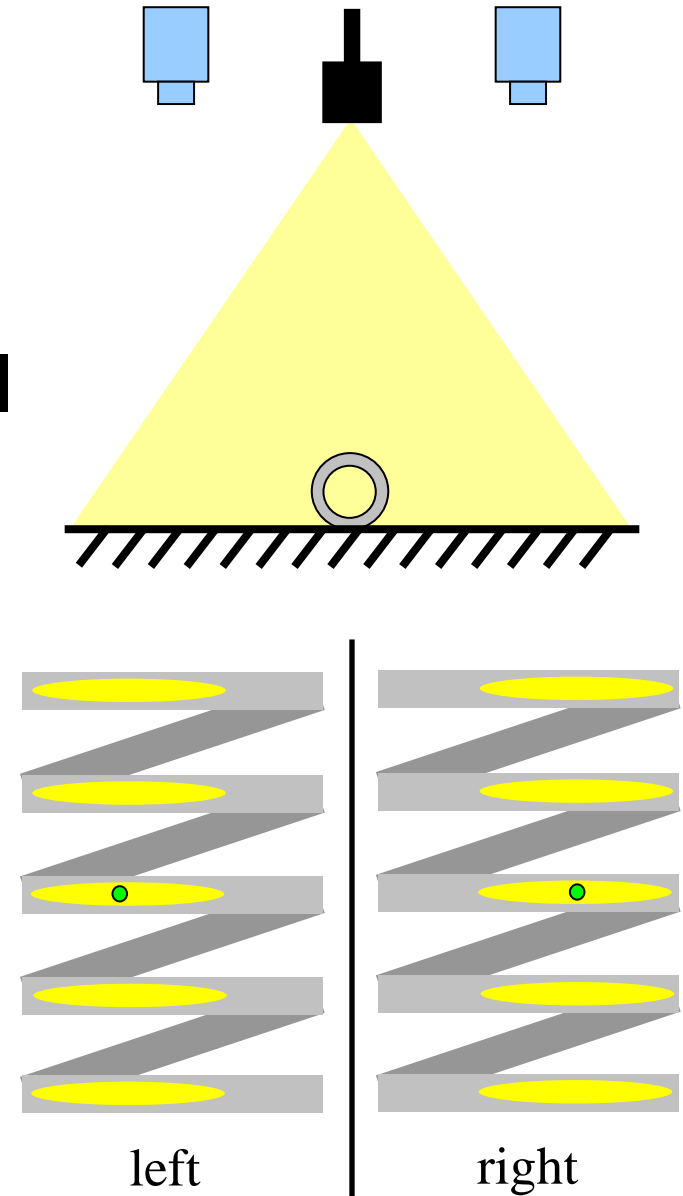 - pitch: d_{real} [mm]

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Disparity Correction

- Shapes of left and right highlights are not strictly identical
    - Due to positional relationship among a coil spring, the light source and the cameras

- Disparity is corrected using an experimental formula

$$d_{\mathrm{p}} \rightarrow d_{\mathrm{p}} + (a\phi + bd_{\mathrm{p}} + c)$$

left   right
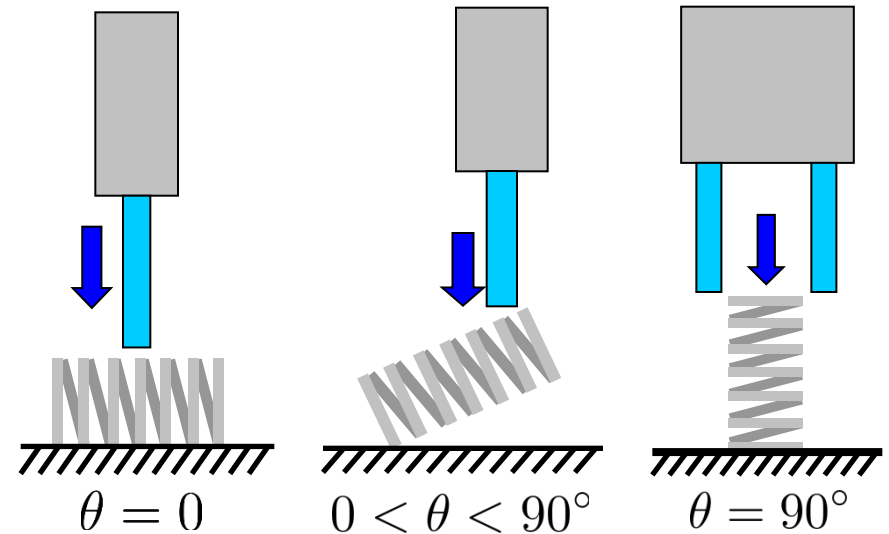
Picking Strategy

- **Picking Order**
  - Highest-First
  - Try second highest after picking failure

fail
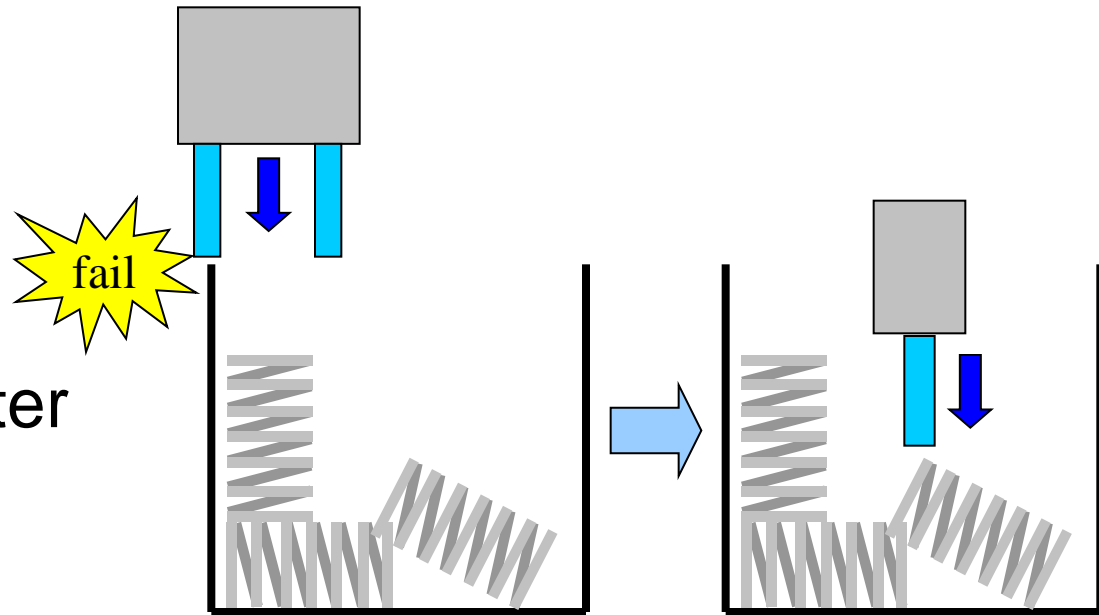
- **Picking Approach**
  - Different approaches depending on tilt angle

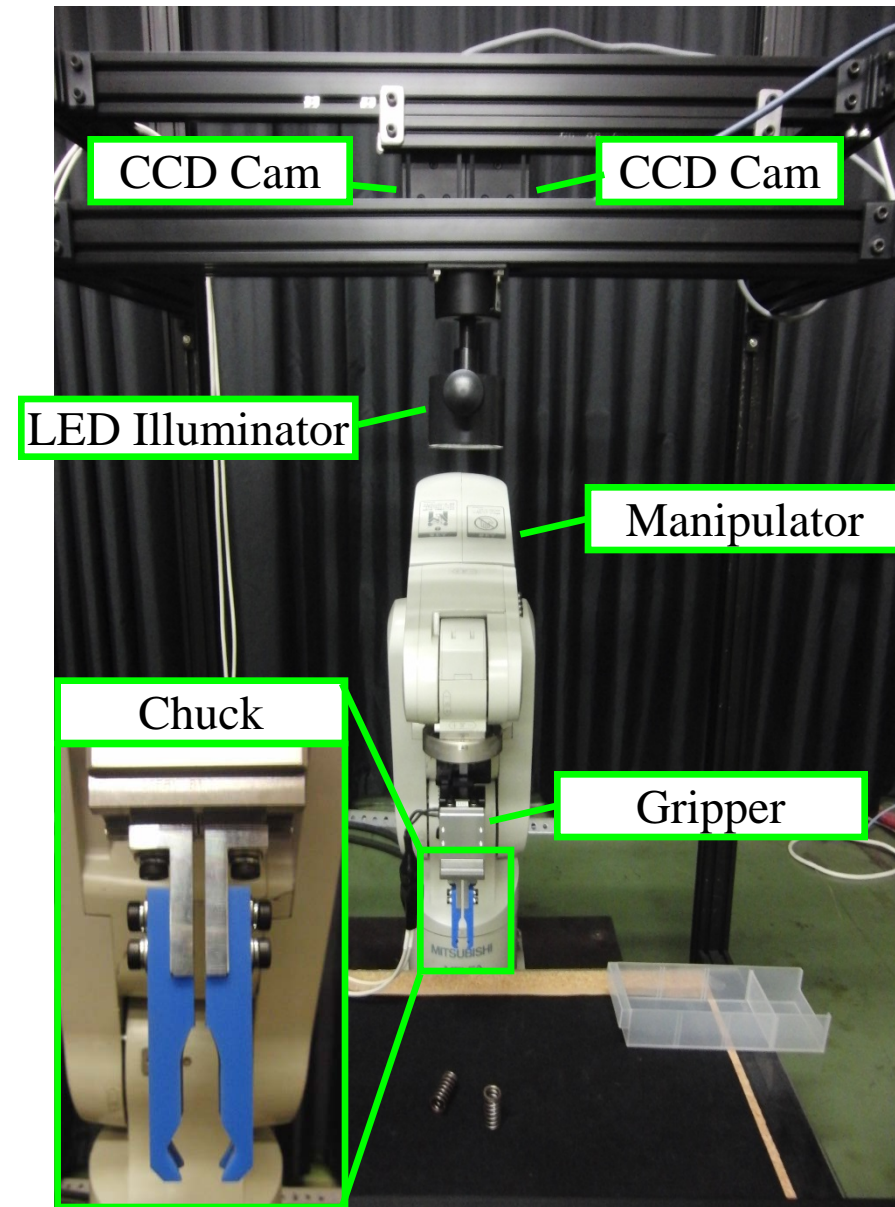$\theta = 0$ $0 < \theta < 90°$ $\theta = 90°$

Experimental Setup

- ## CCD Cameras
  - Grayscale
  - 1296 × 964
- ## LED Spot Illuminator
- ## Manipulator
  - RV-1A (Mitsubishi Electric)
- ## Electric Gripper
  - ESG1-SS-2815 (TAIYO)
- ## Linux PC
- ## Coil Springs

34 mm

18 mm

CCD Cam

CCD Cam

LED Illuminator

Manipulator

Chuck

Gripper

Video: Picking Experiment

Picking Results in Five Experiments

- 77% success for each picking trial
- 94% success for each spring (with multiple retries)

Legend:
- Number of Picking Trials
- Number of Picked Coil Springs
- Total Number of Springs
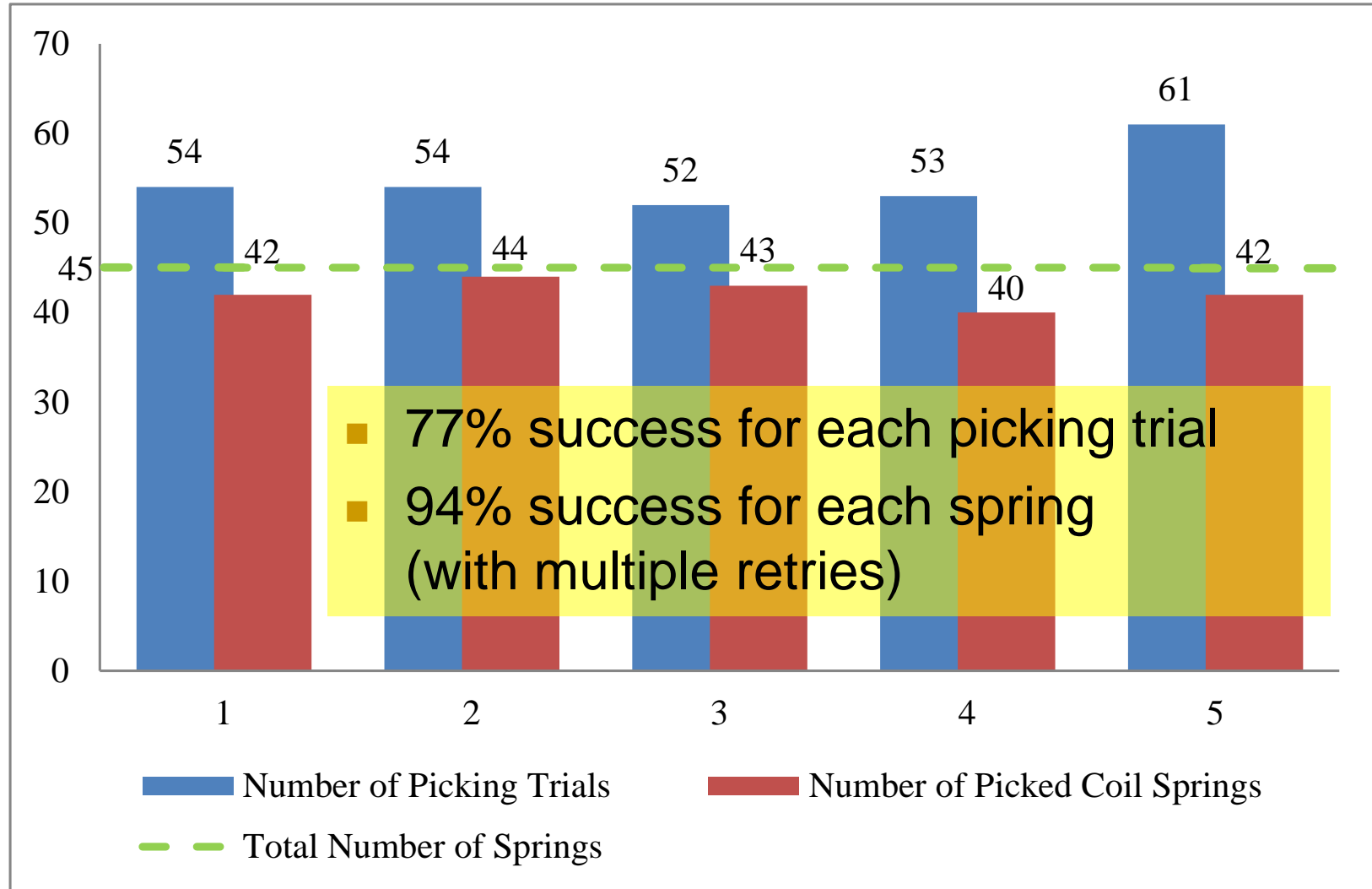
Picking Failures

x4

- Collisions between chuck and part box
- Collisions between chuck and other coil springs

- Collision-free approaching should be implemented

Summary

- ## Conclusion
  - A bin picking method dedicated to coil springs was presented
  - Coil springs can be detected with highlights on them and localized with stereo vision
  - Successful bin picking was demonstrated

- ## Future Work
  - Collision avoidance to reduce picking failures