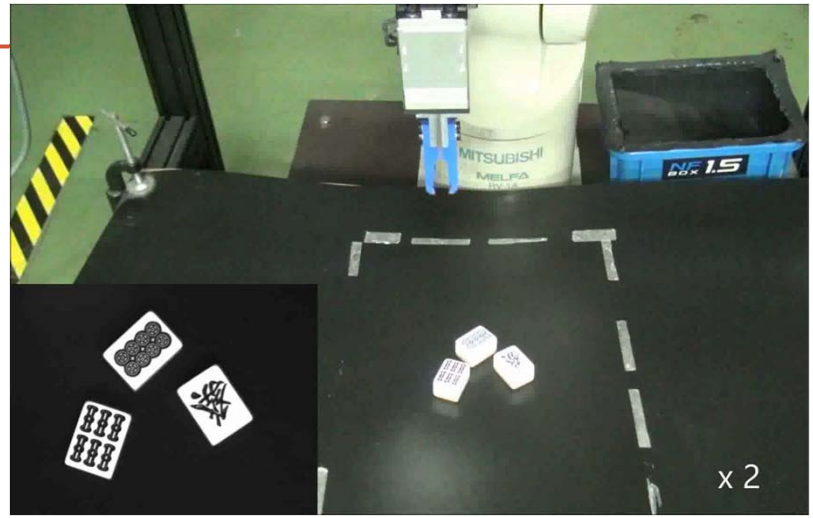
Unknown Object Detection by Punching: An Impacting-based Approach to Picking Novel Objects



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Background

- Object segmentation in a scene
  - For singulation, sorting, picking, …
  - Novel objects
  - Cluttered environment
- Difficult through passive perception
- **Interactive Perception**
  - Active perturbation to a scene for better perception

Related Works

- "Poking" and "prodding" for object segmentation [Metta and Fitzpatrick 03]
- Pushing for object singulation [Chang et al. 12] [Hermans et al. 12] [Katz et al. 14]
- "Spreading" and "tumbling" for object sorting [Gupta et al. 15]
- Pushing for 3D object segmentation [Schiebener et al. 14]

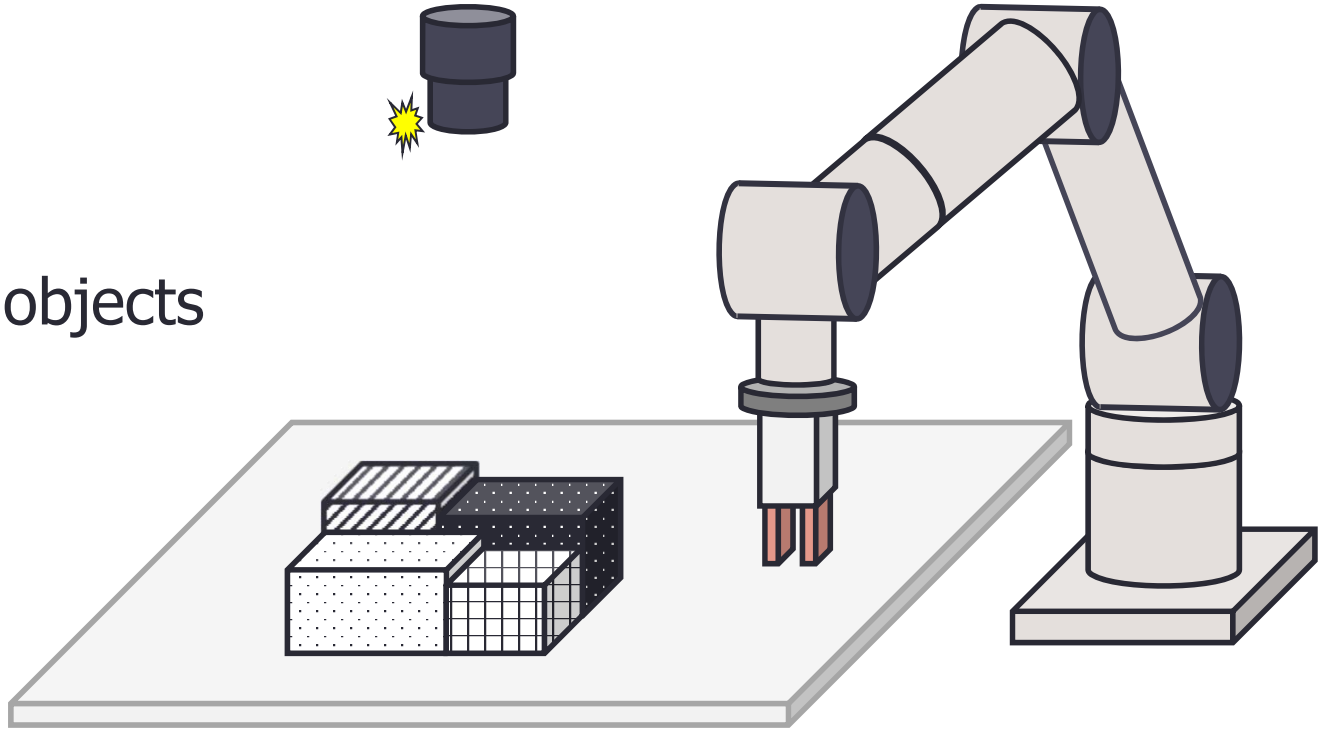
Local scene perturbation through **direct contacts** between the robot and objects

- Need to contact with target objects
- Occlusion by robot bodies
- Time required for perturbation

Objective

- Segmentation and picking of novel objects through "global" scene perturbation
- Approach: **Impacting**

  - 2D
  - Rigid objects



Overview of Object Segmentation (1/3)

- Before impacting

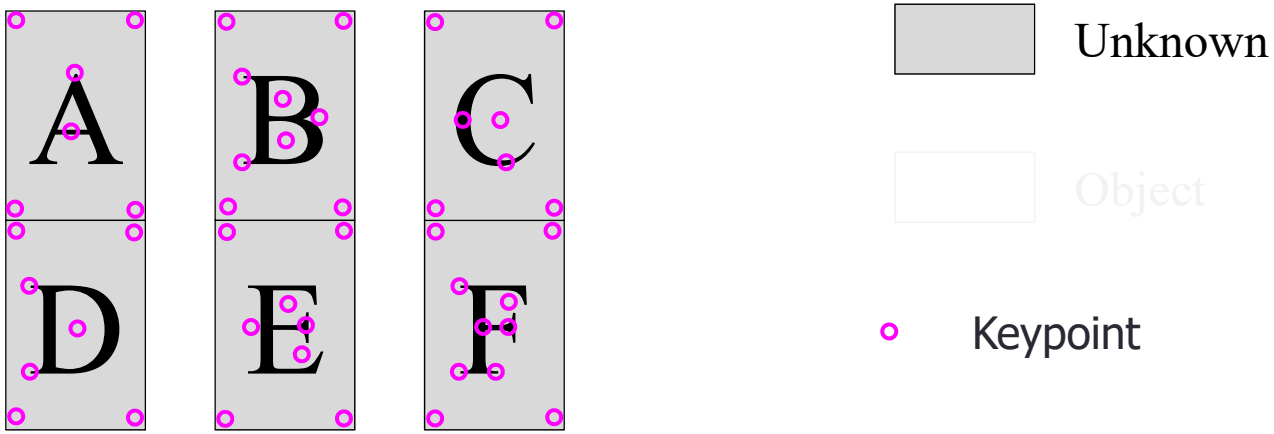
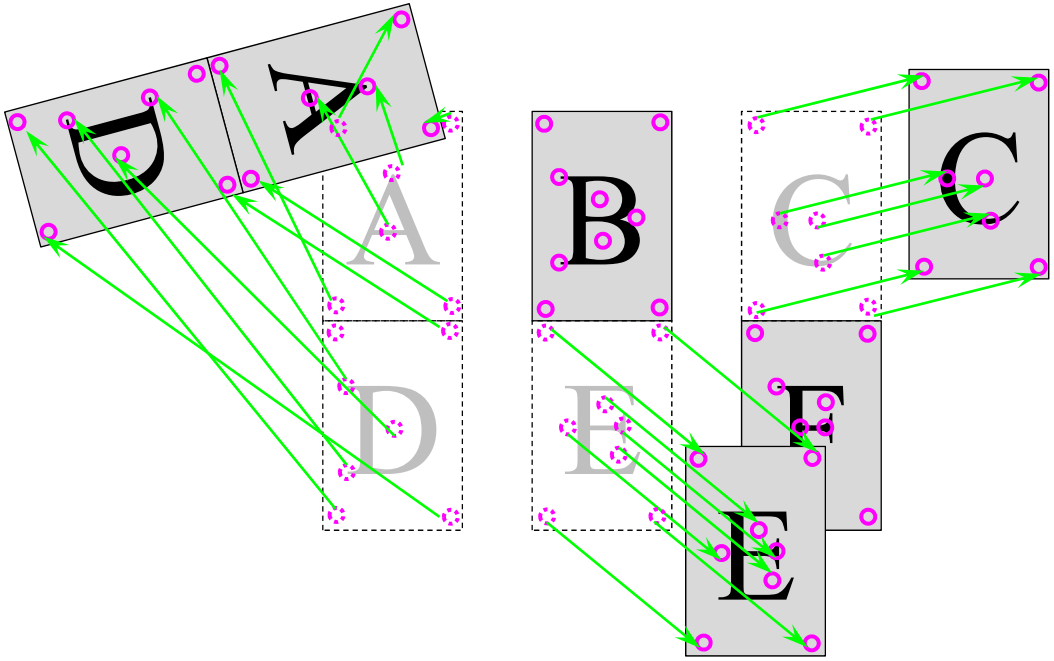
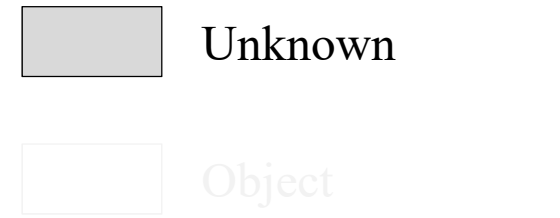


Image features are extracted as keypoints

Overview of Object Segmentation (2/3)

- After impacting





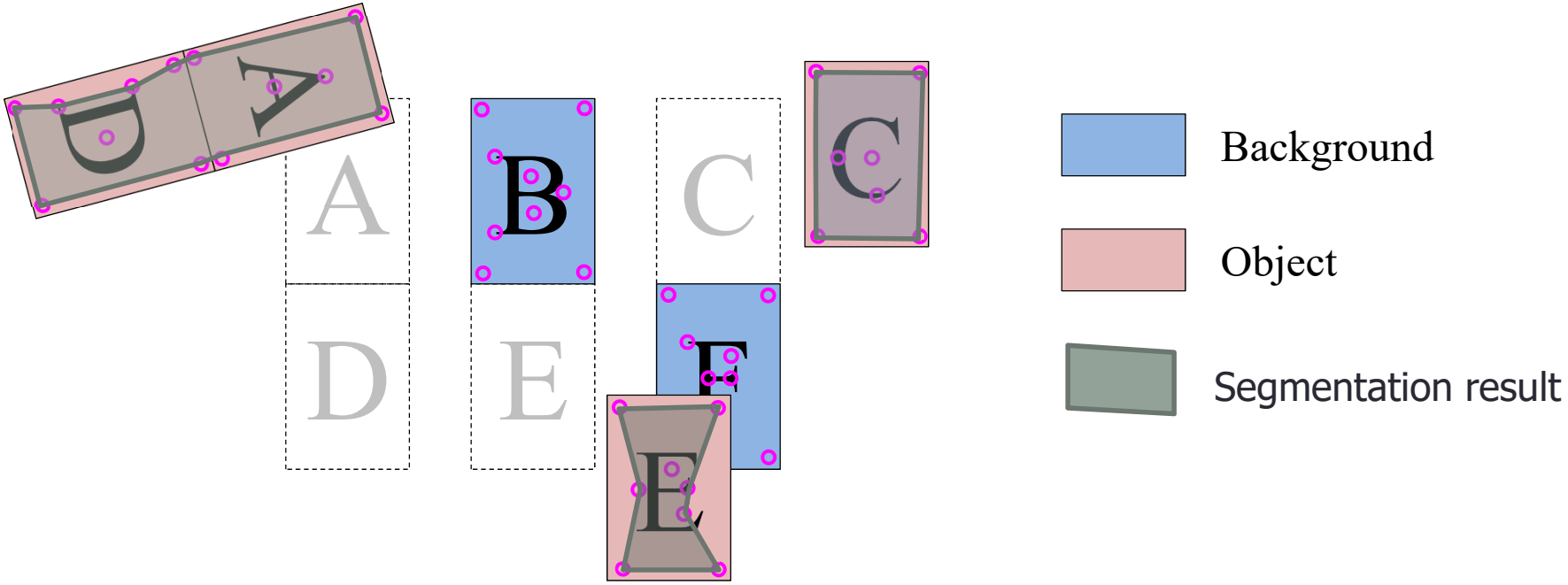
Keypoint after Impact

Keypoint before Impact

Keypoint tracking

Overview of Object Segmentation (3/3)

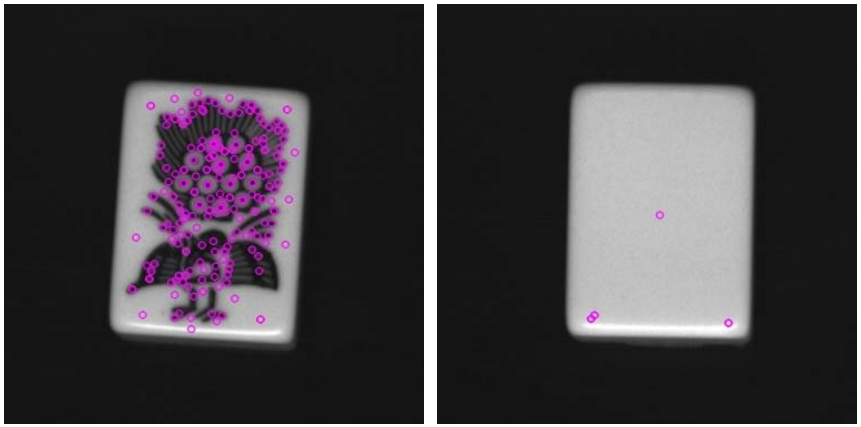
- After impacting



Grouping of tracked keypoints

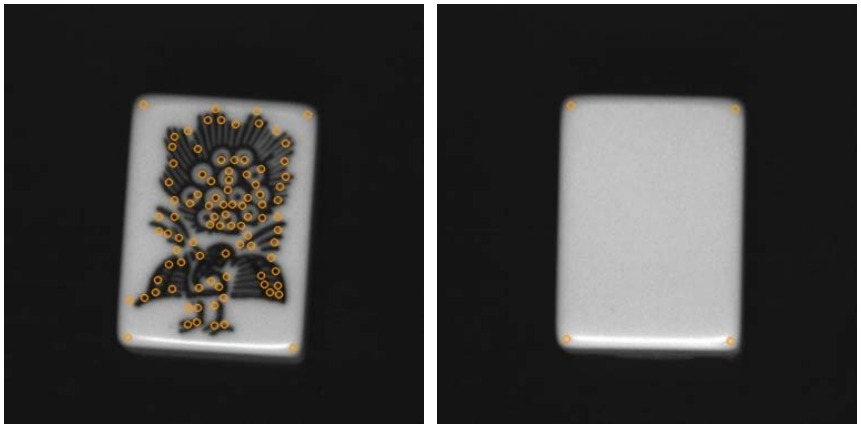
Features for Keypoint Detection

- SIFT



  - Mainly for textured objects

- Harris Corner

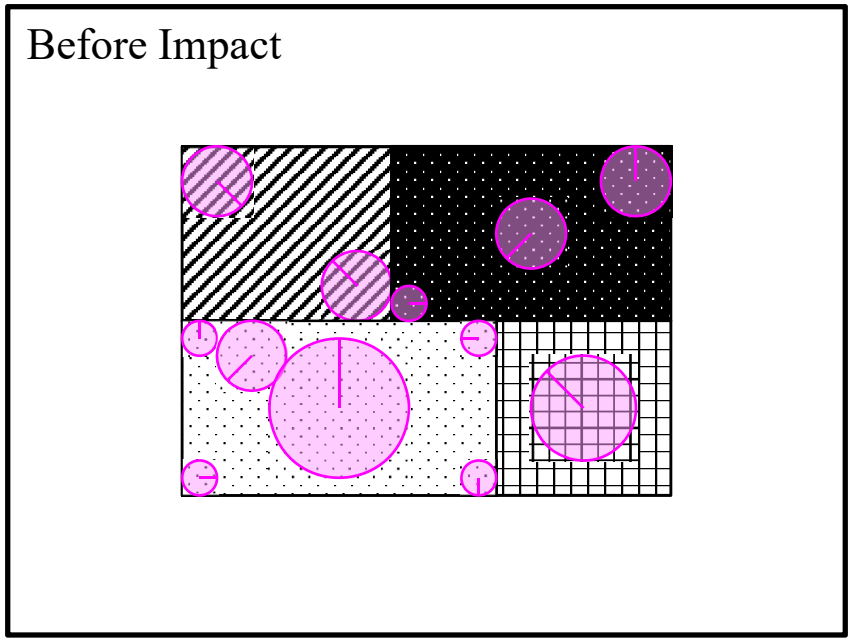


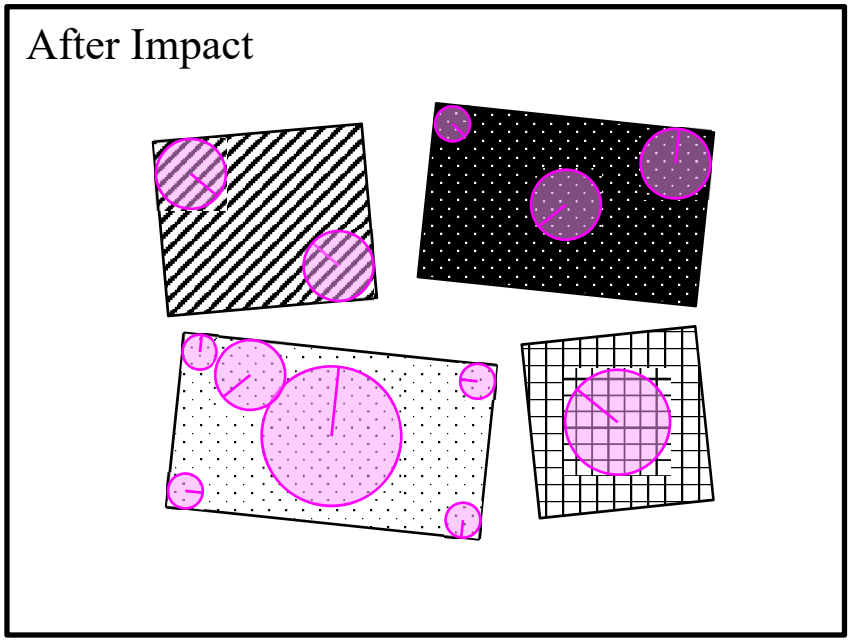
  - Mainly for textureless objects

128-dimensional SIFT descriptors are used for both

Keypoint Detection

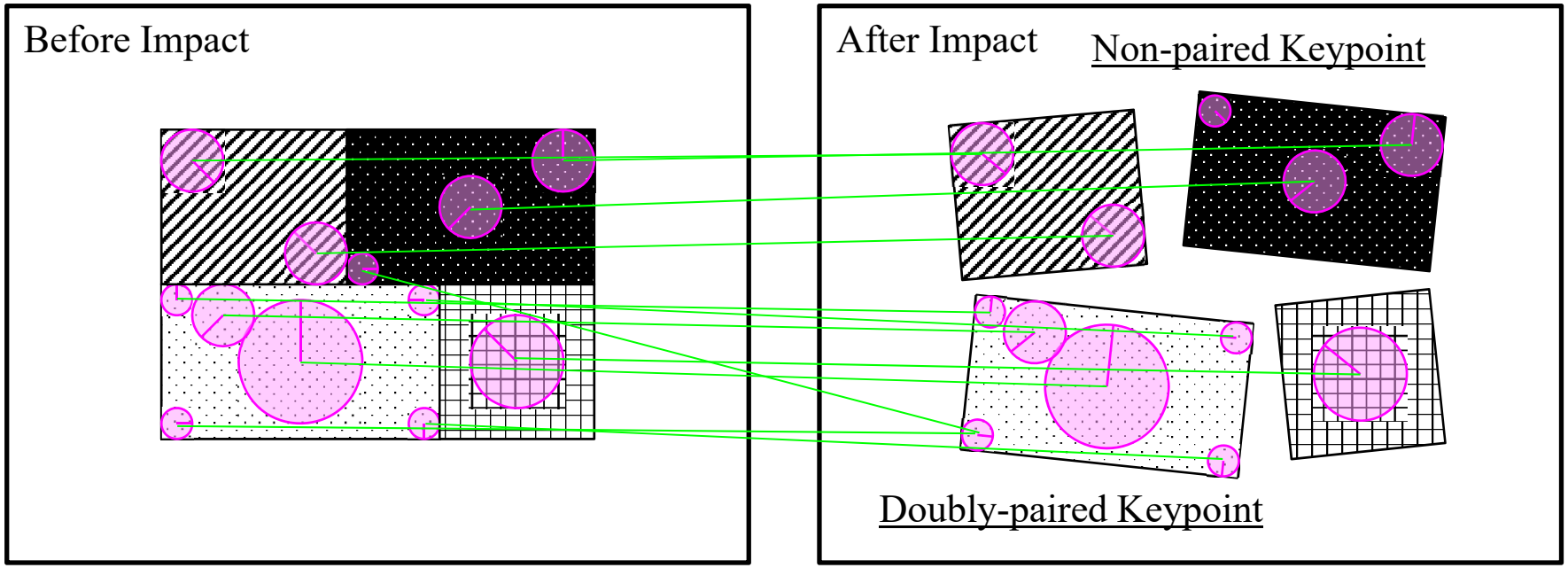
- SIFT
- Harris Corner





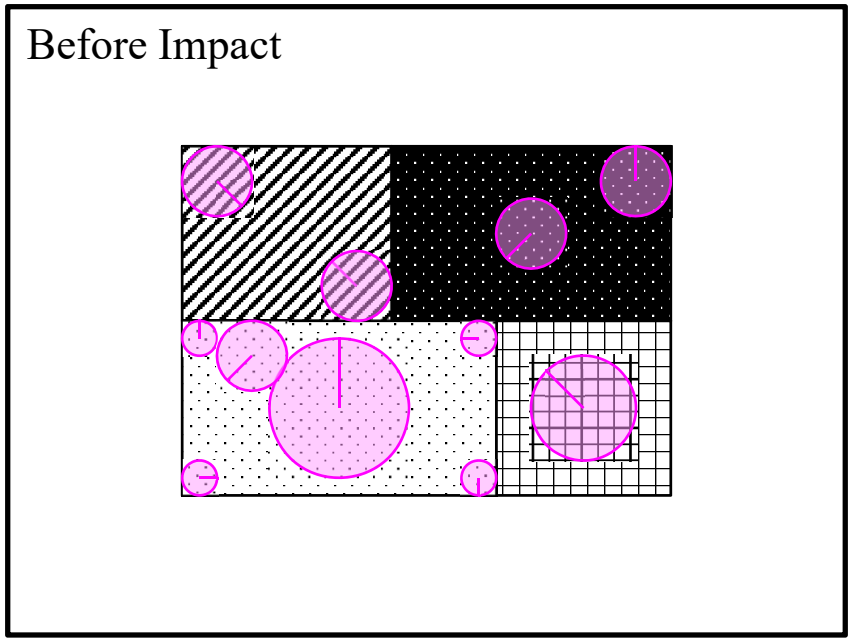
Keypoint Tracking

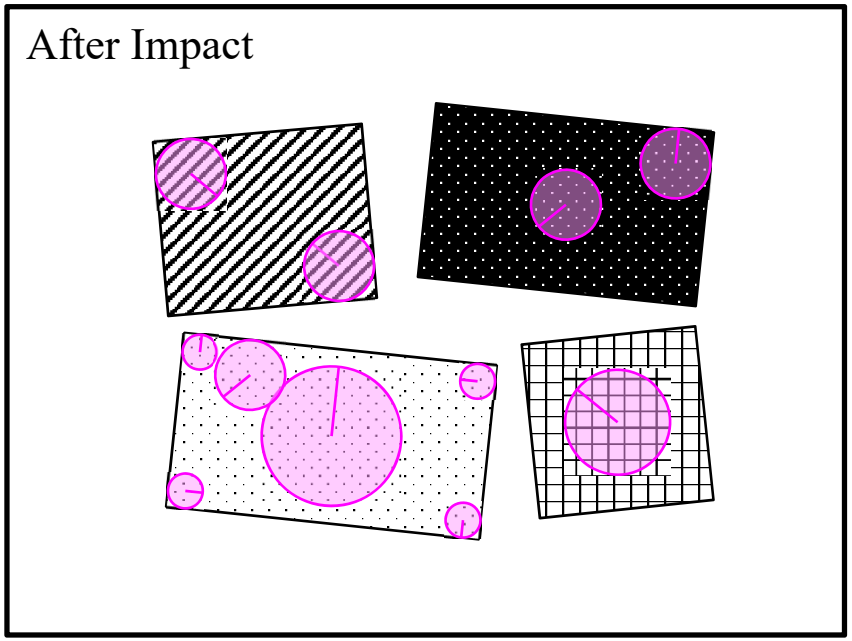
- Matching according to Euclidean SIFT distance
- Assumption: Keypoint movement is small



Keypoint Grouping

- RANSAC-based grouping of keypoint pairs consistent with a rigid-body motion

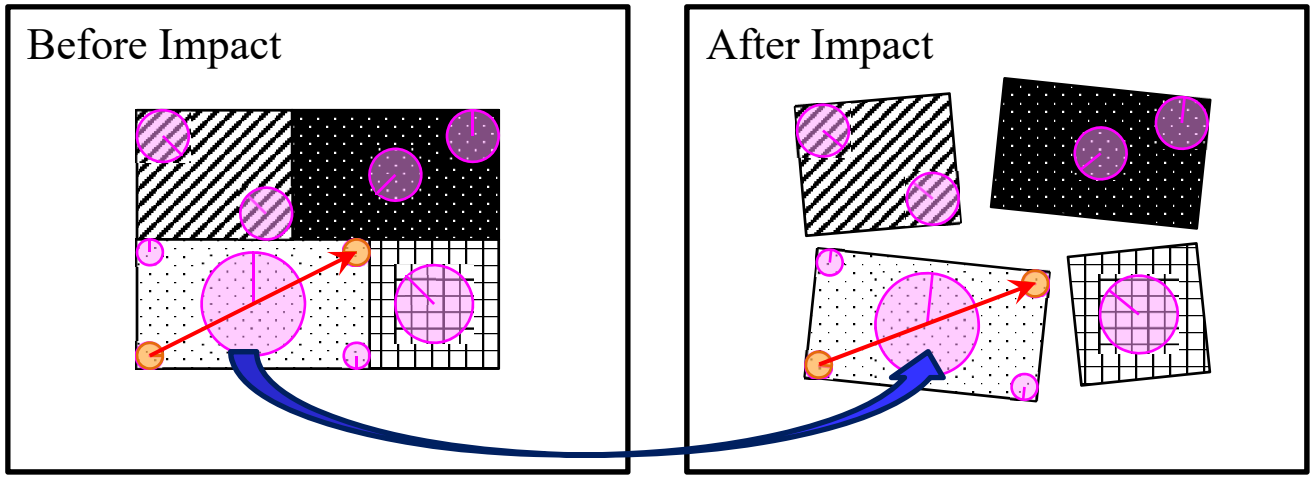




RANSAC-based Keypoint Grouping (1/3)

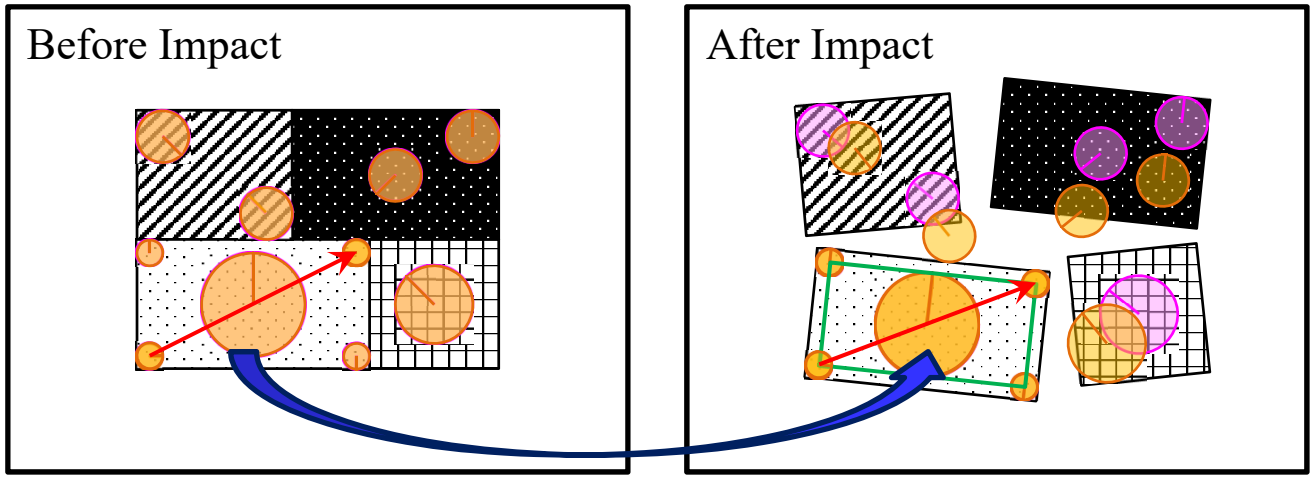
Repeat these steps

1. Sample two keypoint pairs.
2. Calculate a homogeneous transformation that corresponds to the sampled pairs.
3. Vote a similar existing transformation, if any.
4. Select homogeneous transformations with sufficient votes for object candidates.



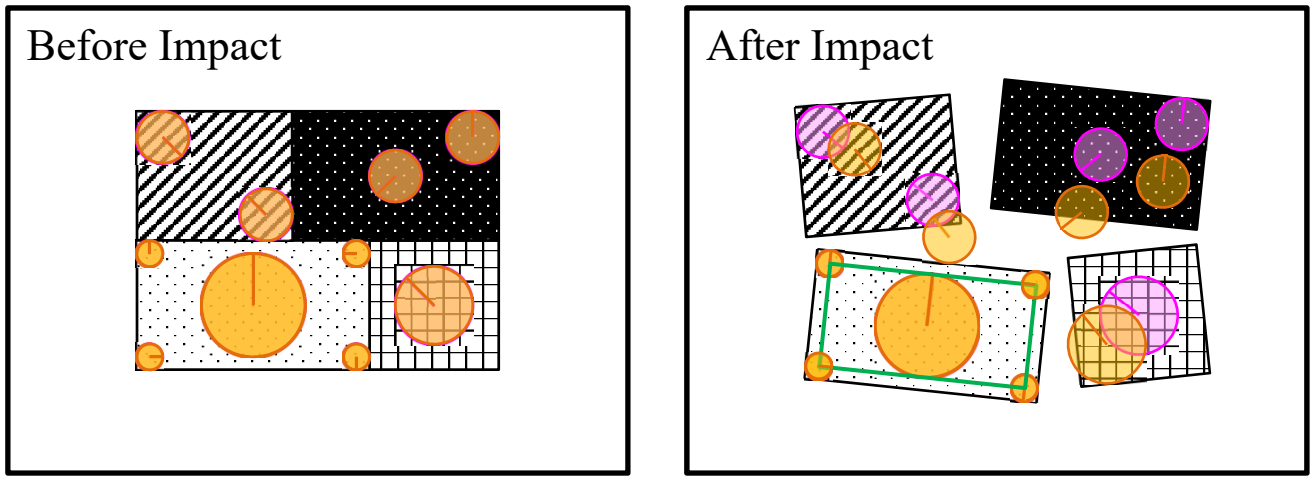
RANSAC-based Keypoint Grouping (2/3)

5. Collect all the keypoint pairs to be grouped for each of candidate homogeneous transformations



RANSAC-based Keypoint Grouping (3/3)

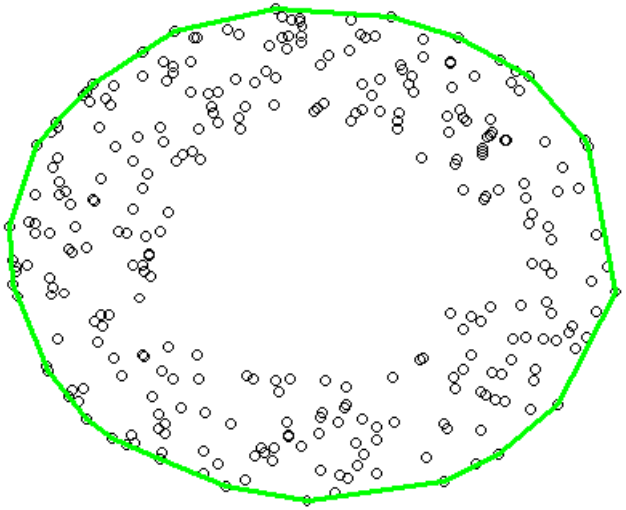
6. Re-calculate homogeneous transformation using all the grouped keypoint pairs [Arun et al. 87]
   - Initial homogeneous transformation might have nontrivial errors
7. Re-group keypoint pairs using the new transformation



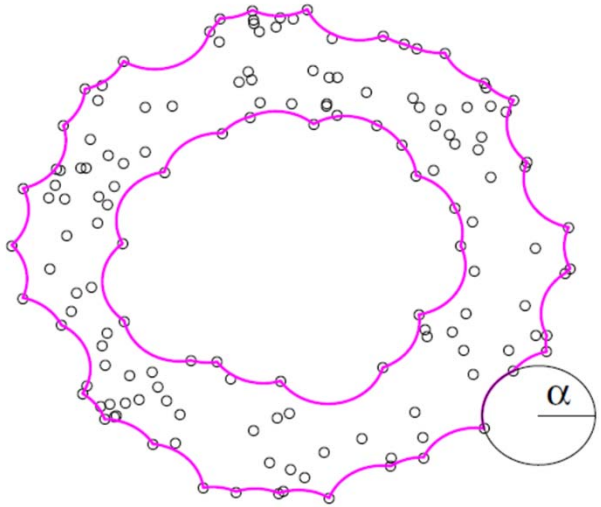
Object Segmentation

- Grouped keypoints are segmented as an α-shape

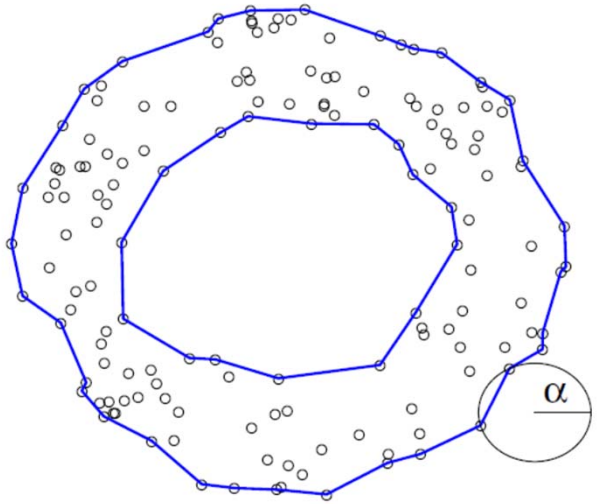
➢ Convex hull



➢ α-hull



➢ α-shape



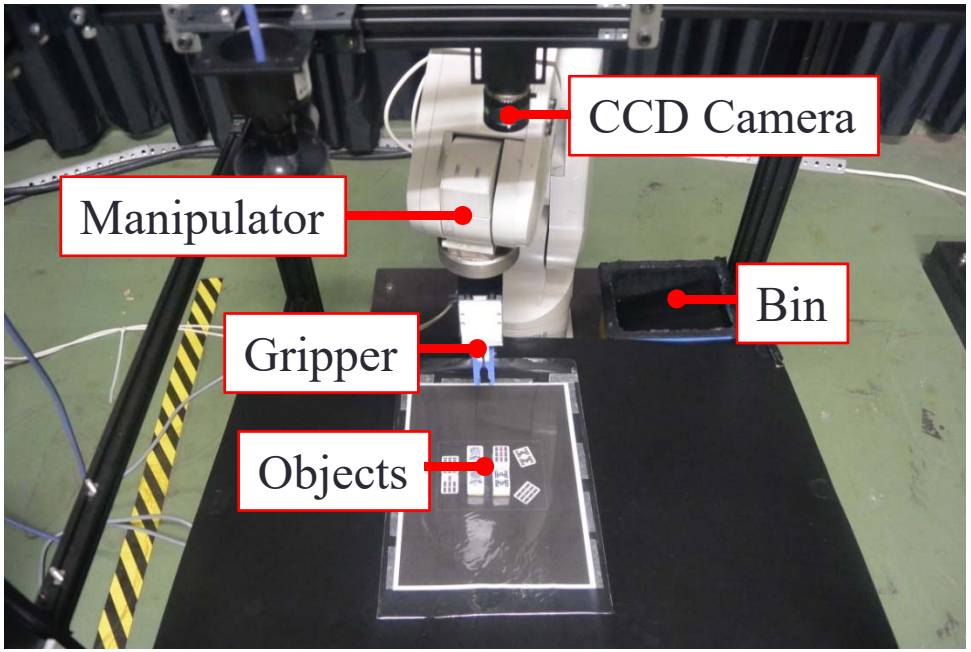
[Pateiro-López and Rodrguez-Casal 2010]

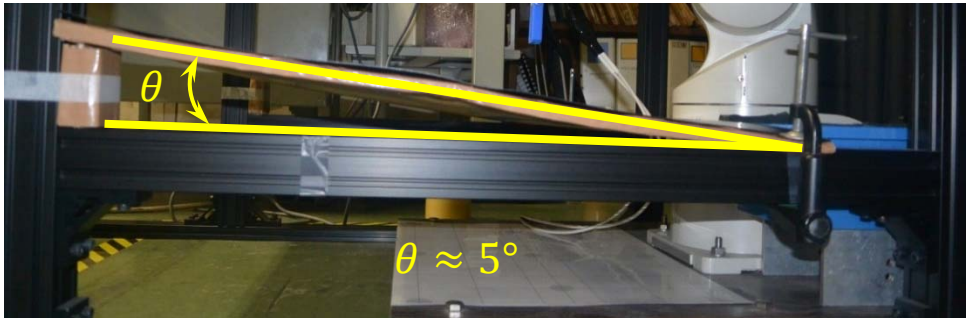
Concave shapes can be segmented

- We use minimum α that keeps the segment connected

Experimental Setup

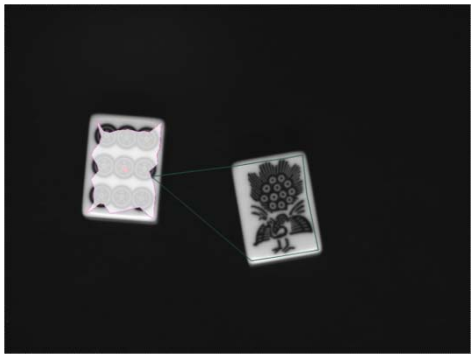
Object: Mahjong tiles
Camera: 1296x964 grayscale
Parallel-jaw Gripper: shock-absorbing spring installed

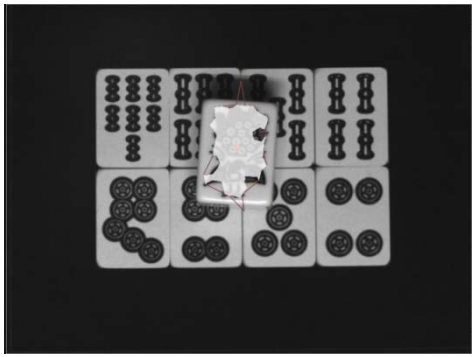




Experiments on Object Segmentation

- α-shape with minimum area is selected as a picking target

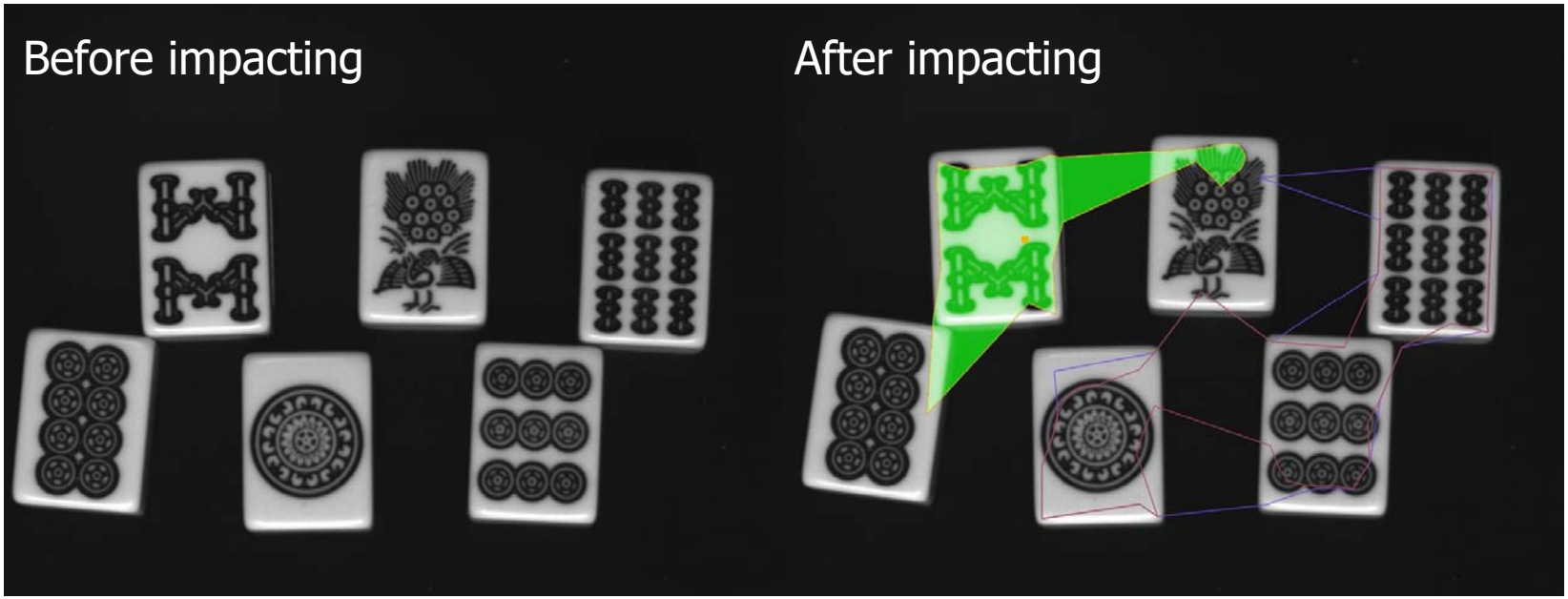




Successful segmentation was possible in most cases

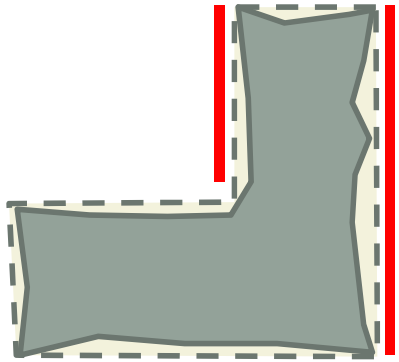
Experiments on Object Segmentation

- A typical segmentation failure



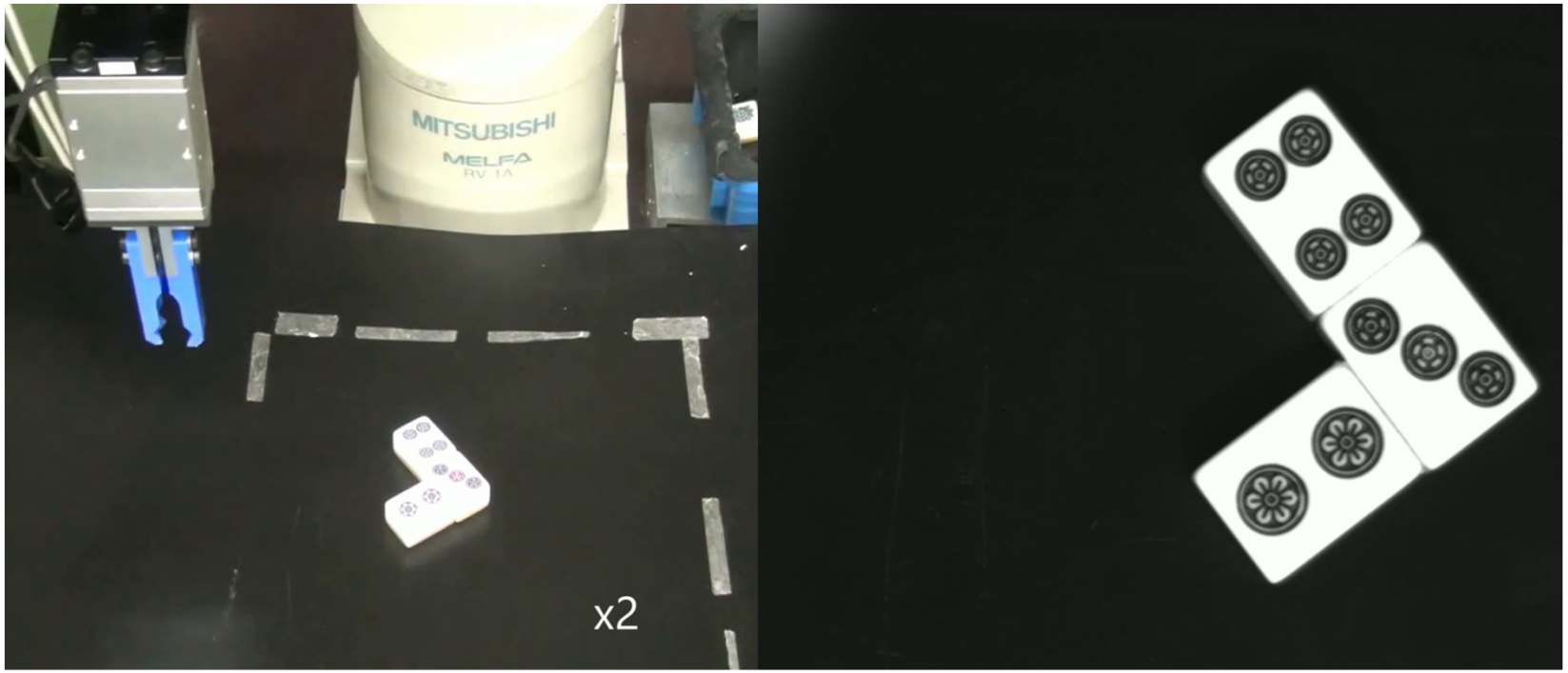
Grasp Synthesis for Segmented Object

- Finding near-parallel edges for parallel-jaw gripper
  - Adapt the method by [Harada et al. 2011] for 2D cases



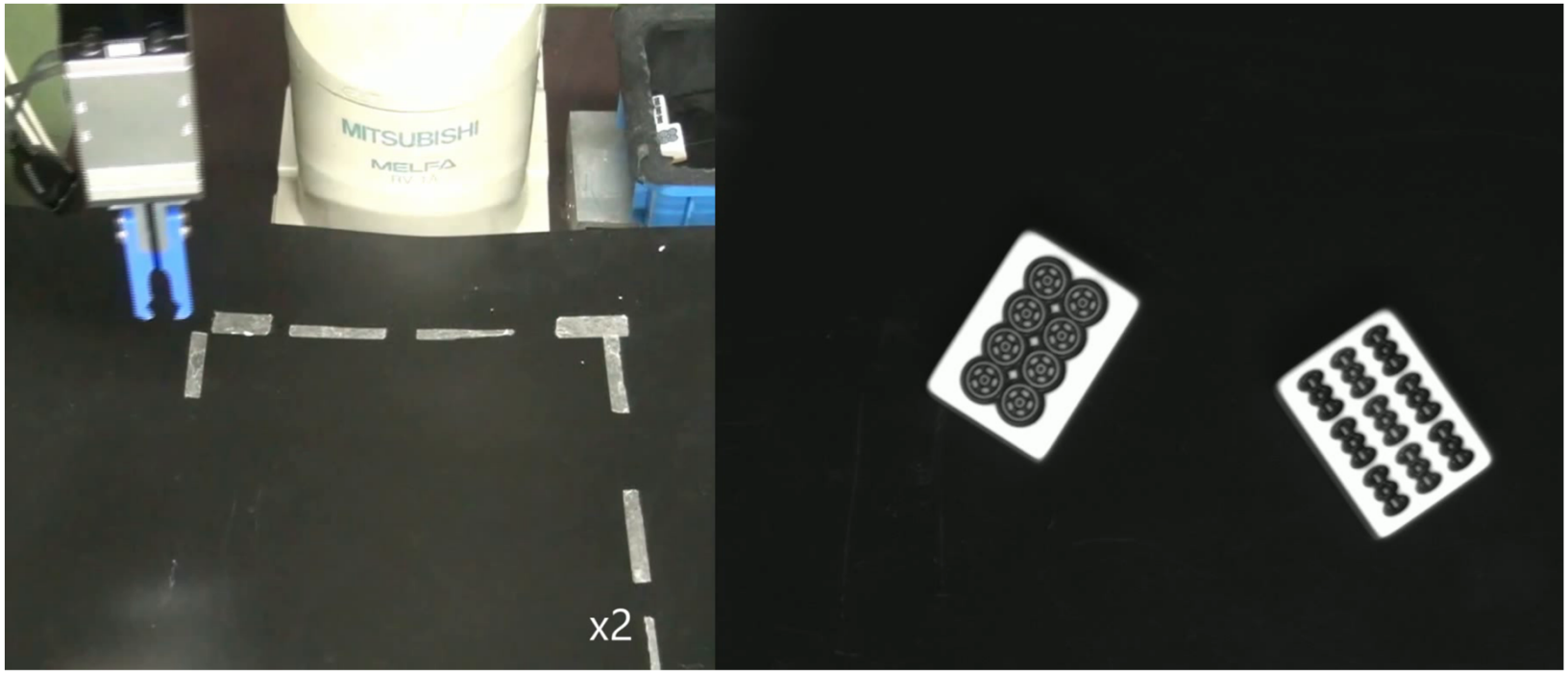
Picking Experiment (1/4)

- L-shaped object



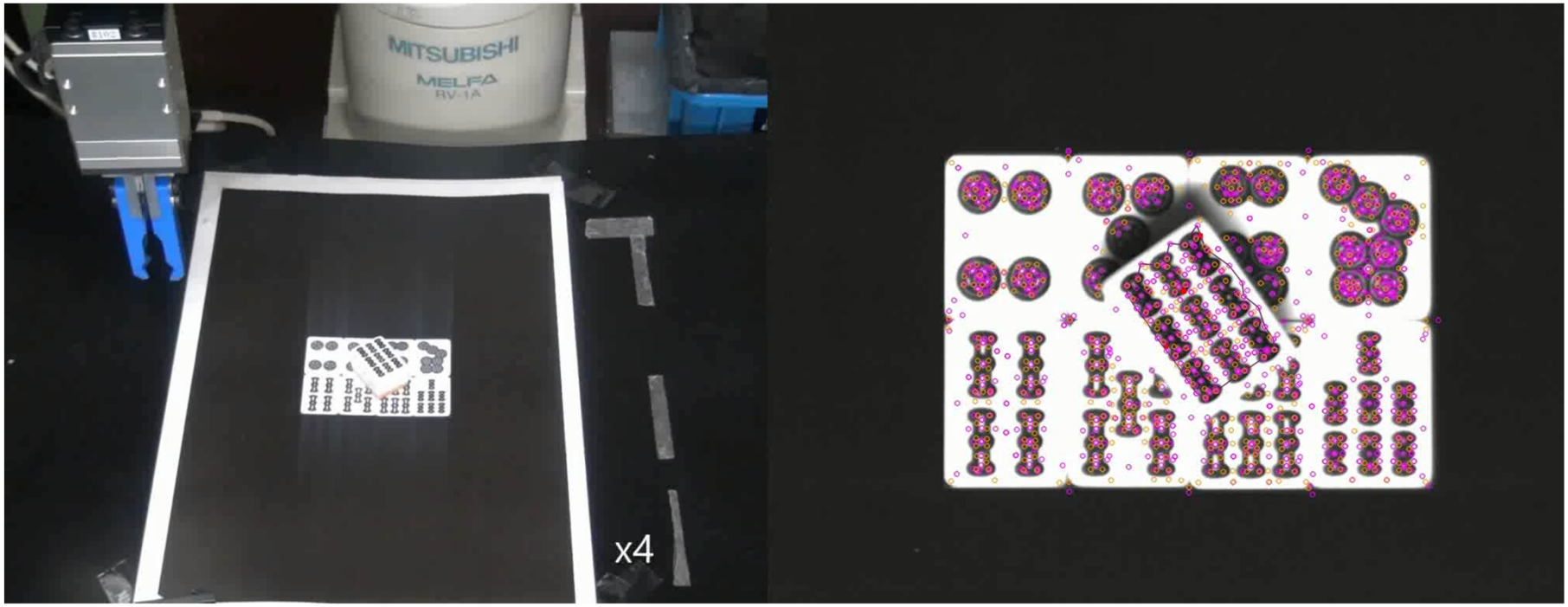
Picking Experiment (2/4)

- Two objects



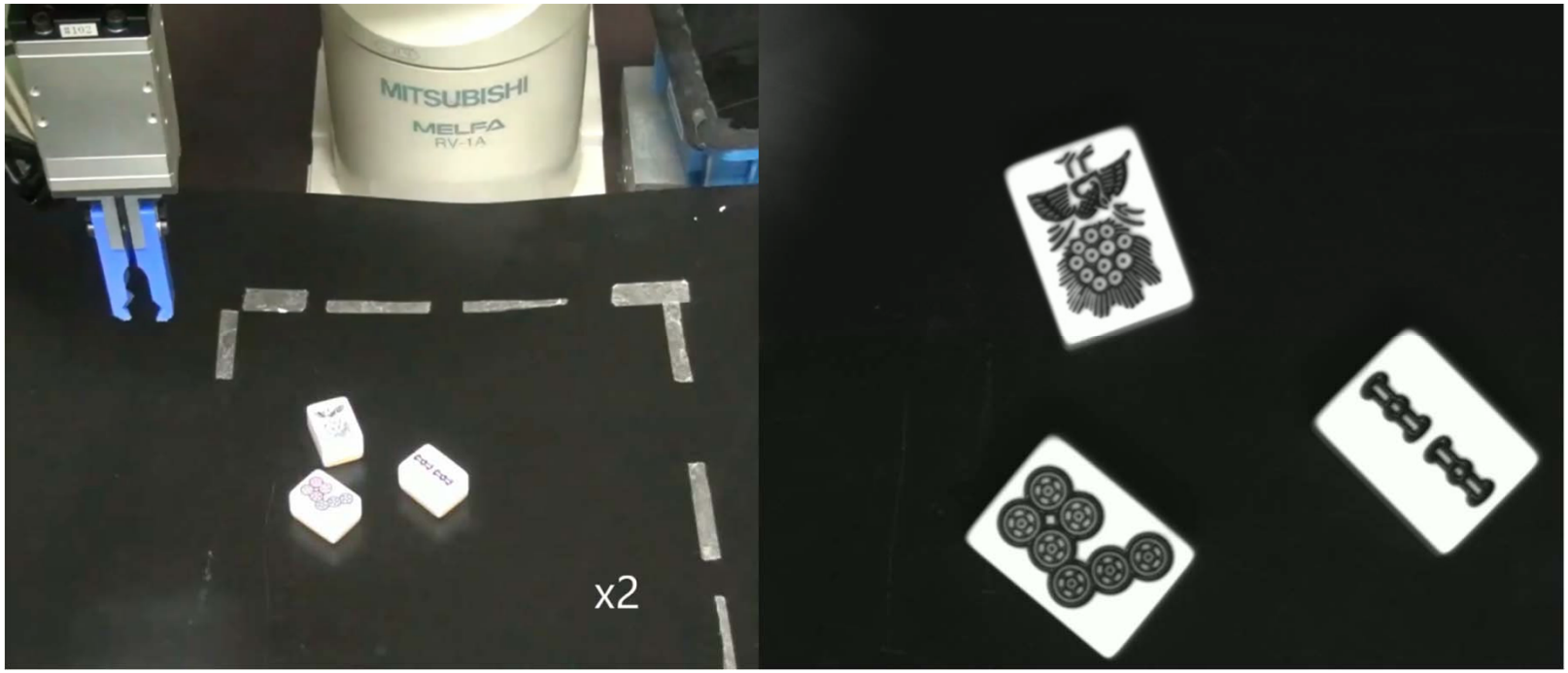
Picking Experiment (3/4)

- One object on fake objects



Picking Experiment (4/4)

- Unsuccessful Picking



First object: incorrect segmentation (larger than actual)

Third object: grasp attempt for longer sides

Conclusion

- Object segmentation through impacting
  - Successful segmentation and picking of mahjong tiles demonstrated

Future Work

- Better accuracy
- Wider variety of objects
- Single impacting for multi-object picking
- Efficient computation
- Extension to 3D