



上海交通大学

SHANGHAI JIAO TONG UNIVERSITY



ConceptFactory: Facilitate 3D Object Knowledge Annotation with Object Conceptualization

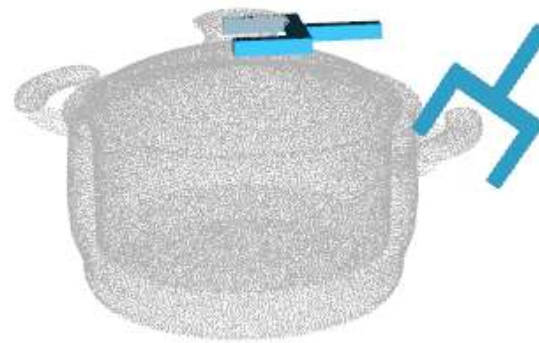
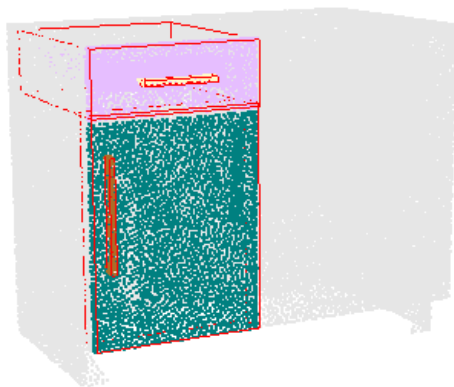
Jianhua Sun*, Yuxuan Li*, Longfei Xu**,
Nange Wang**, Jiude Wei**, Yining Zhang, Cewu Lu

Shanghai Jiao Tong University

* and ** denote equal contribution

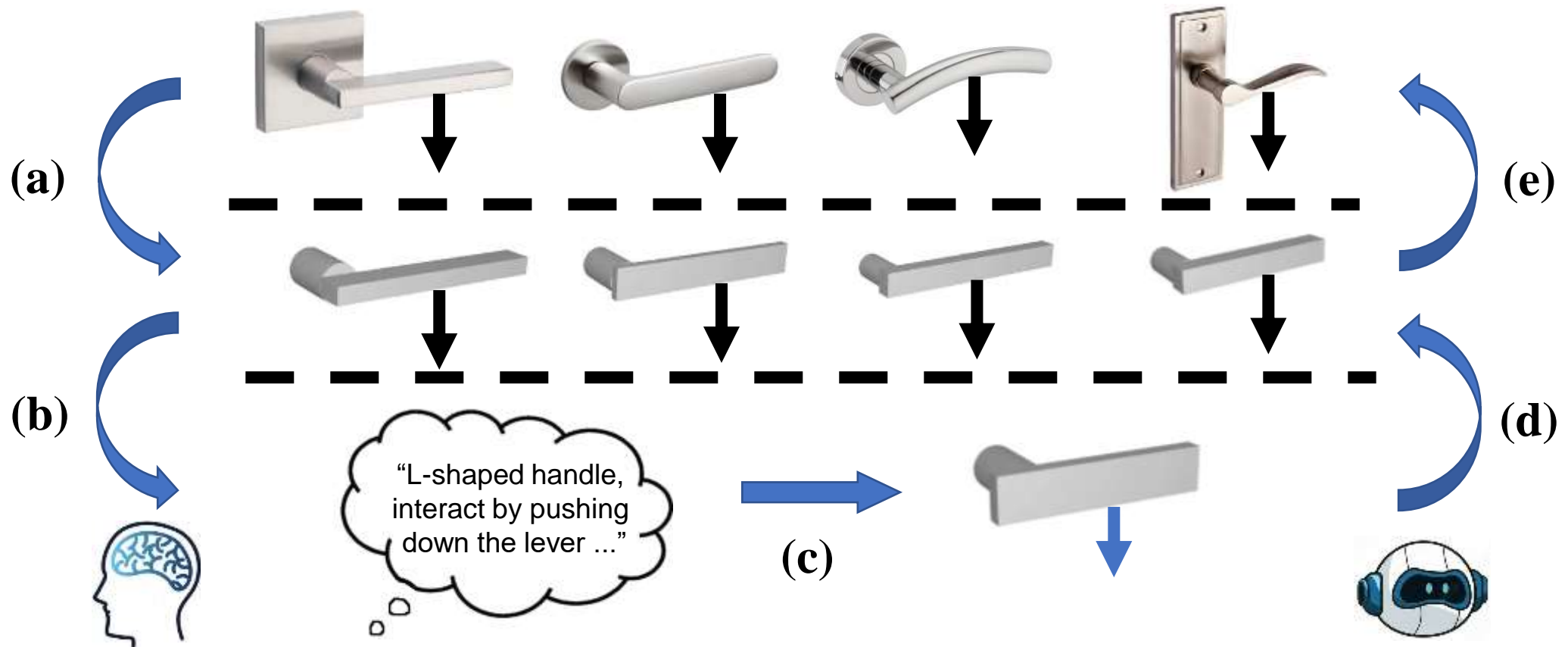
Troubles in 3D Object Annotation

- **Various types of knowledge**
 - A wide range of object understanding tasks like segmentation, pose estimation and manipulation
 - Semantics, poses, and affordances...
- **Highly complicated to manually annotate**
 - Manually annotating a 3D shape requires the annotator to constantly change viewing angles
 - Especially for affordance knowledge, which is less definitive and task-specific



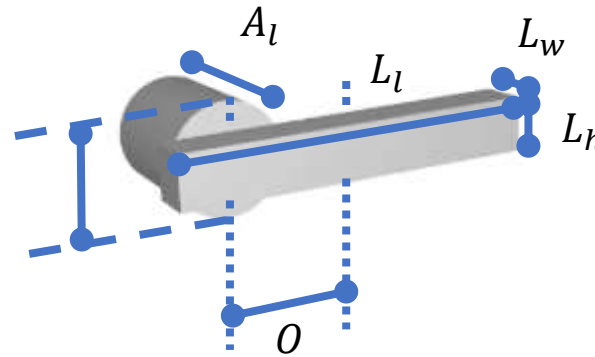
Philosophy of Object Recognition

- **Recognition-by-Components:** Recognizing objects through generalized concepts



Describing Concepts as Program Templates

- Concepts as Templates:
 - **Parameters:** Variations within concept instances
 - **Constructor:** Describe the essence of a concept



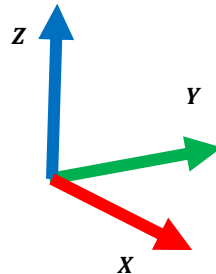
Parameters

A_l : Axis Length; A_d : Axis Diameter;
 L_l : Lever Length; L_w : Lever Width; L_h : Lever Height;
 O : Axis-Lever Offset

Constructor

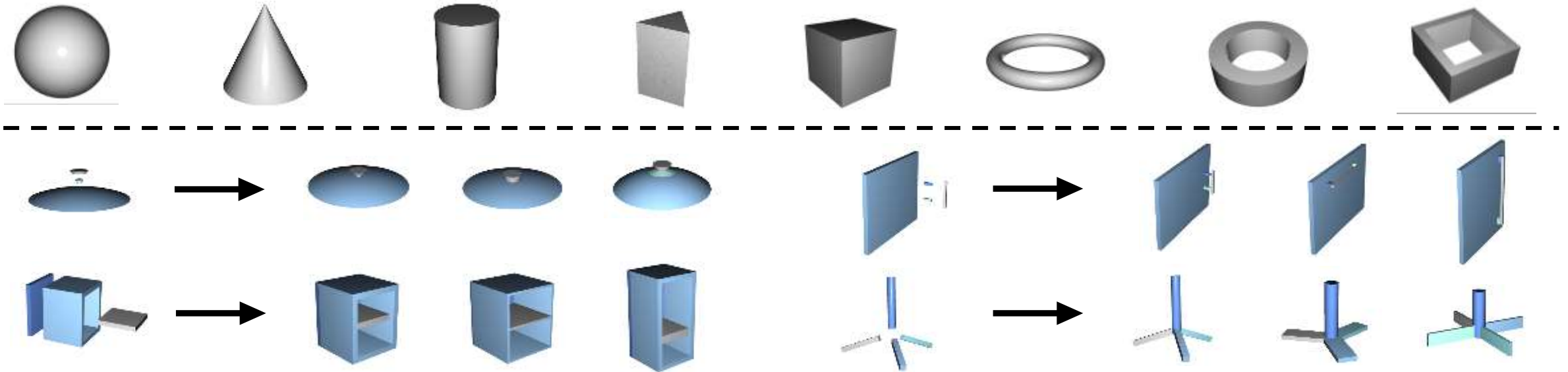
```
def __init__(self,  $A_l, A_d, L_l, L_w, L_h, O$ )  
    axis_size = [ $A_l, A_d$ ]  
    axis_position = [ $0, 0, 0$ ]  
    lever_size = [ $L_l, L_w, L_h$ ]  
    lever_position = [ $(A_l + L_w) / 2, O, 0$ ]  
    self.axis = Cylinder(axis_size, axis_position)  
    self.lever = Cuboid(lever_size, lever_position)
```

- Template Composition:
 - **Geometry Templates:** Basic geometries, defined from scratch
 - **Concept Templates:** Complex shapes, composed by existing templates

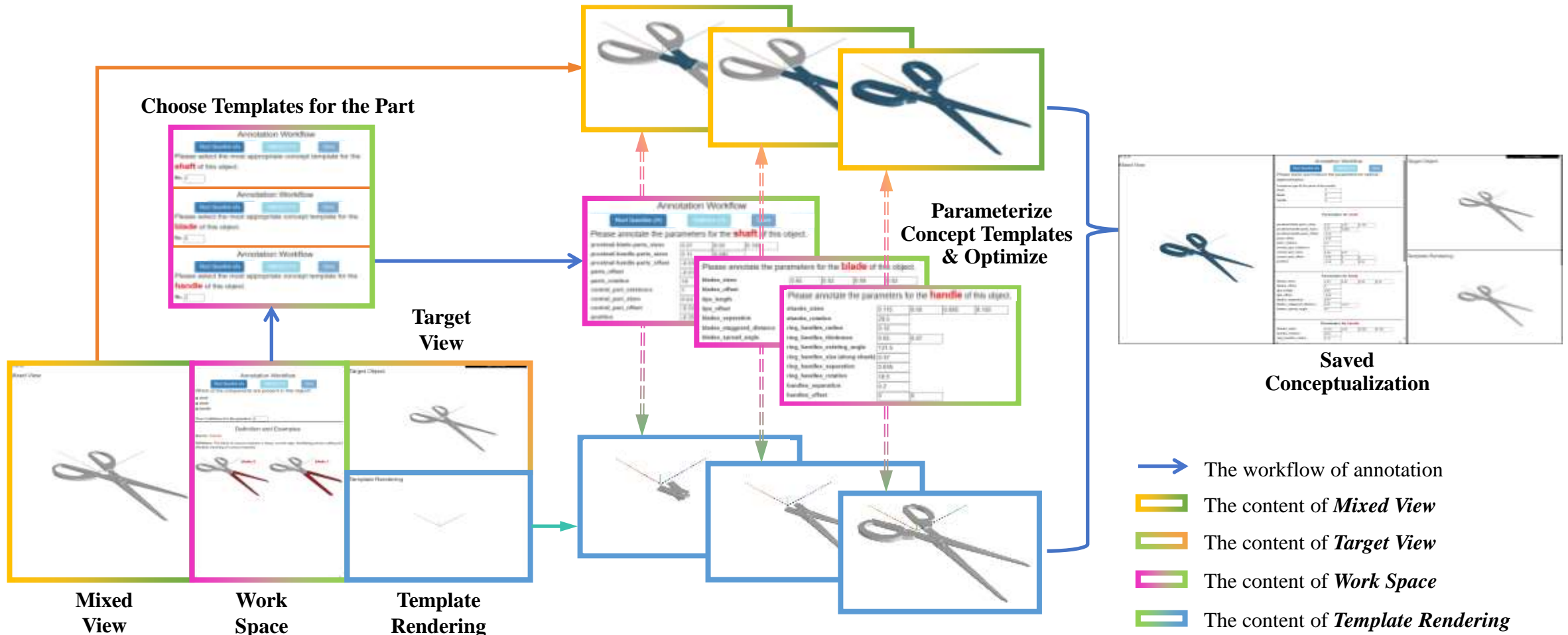


ConceptFactory Suite: STL-C

- Standard Concept Template Library
 - More than 200 types of templates
 - Fully mathematically defined and physically grounded



ConceptFactory Suite: Conceptualization Platform



ConceptFactory Suite: Procedural Knowledge Annotation

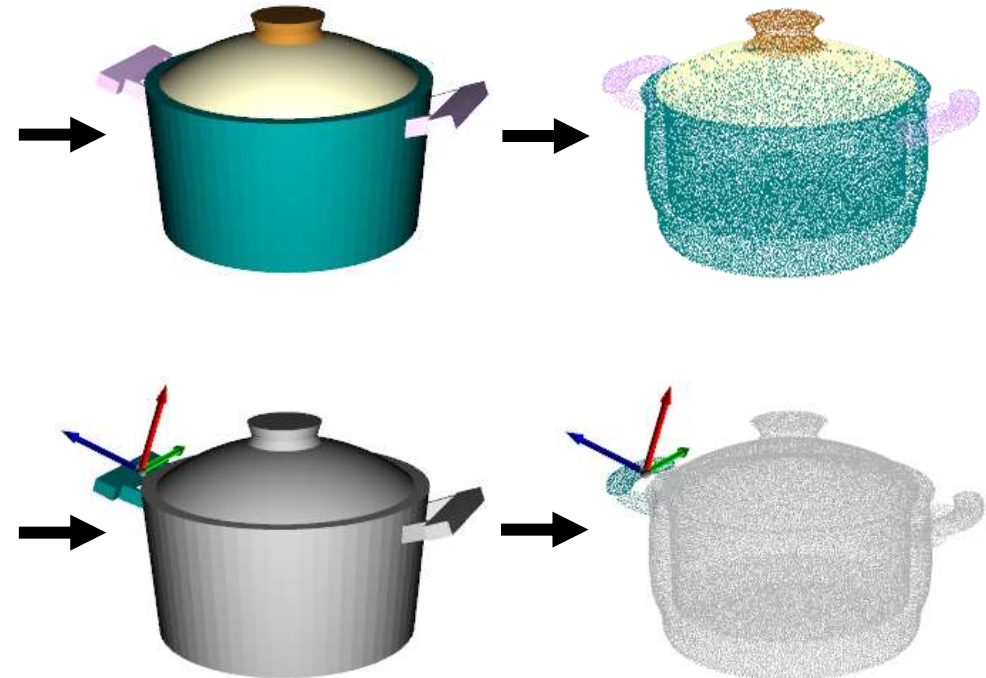
- Analytic definition of knowledge
 - Various types of object knowledge can be analytically defined on concept templates
 - Knowledge propagation from template to object as annotations

```
● ≡ lid.is_handle;      ● ≡ lid.is_body;  
lid_handle <- discriminate(lid, ● );  
lid_body <- discriminate(lid, ● );  
main_container <- ...;  
...
```

Region-Based

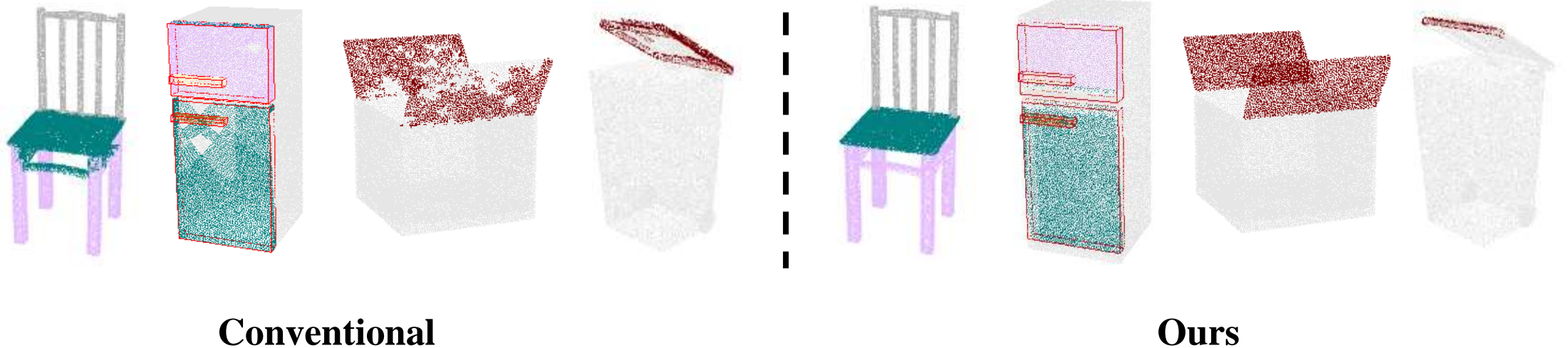
```
side_handle_1_pose =  
  side_handle.handle_1_pose * side_handle.pose;
```

Pose-Based



ConceptFactory Suite: Procedural Knowledge Annotation

- Better way to acquire knowledge annotation
 - Enable accurate annotation for certain types of knowledge like affordances
 - Easy to provide abundant knowledge among objects sharing the same templates
 - Better consistency and less noise



ConceptFactory Asset: Statistics

- Large scale and great diversity
 - More than 4000 objects across about 40 object categories
 - Including both real-world scan and CAD models
- Fine-grained conceptualization information
 - Totally 39k geometry template instances and 295k parameters
 - An average of 9 geometry template instances and 67 parameters per object
- Abundant knowledge is provided to facilitate vision and robotics tasks
 - Including part semantics, part pose, different kinds of object affordance...

Vision and Robotics Experiments

- Vision Tasks (Top)

- Minor discrepancies proves that our annotations possess high quality on par with original ones.

- Manipulation Tasks (Bottom)

- The capability of providing high-quality affordance knowledge is one of our major advantages

	Semantic Segmentation		Cross Category Segmentation		Part Pose Estimation		
	mAcc	mIoU	mAP	mAP ₅₀	mIoU	A ₅	A ₁₀
Original	88.8	67.2	30.0	37.7	42.6	29.1	55.7
ConFac	88.8	67.3	30.6	38.5	42.8	30.3	56.9
Δ	0.0	0.1	0.6	0.8	0.2	1.2	1.2

	Where2Act	Where2Explore
Original	23.7 / 8.4	33.0 / 15.6
ConFac	30.0 / 10.6	37.4 / 18.5
Δ	<u>6.3</u> / <u>2.2</u>	<u>4.4</u> / <u>2.9</u>





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Thank you for watching!

For more details (including codes and data) on both
ConceptFactory Suite & ConceptFactory Asset,
please visit

<https://apeirony.github.io/ConceptFactory>

or scan the QR code.

