



# Semantic Grasping Via a Knowledge Graph of Robotic Manipulation: A Graph Representation Learning Approach

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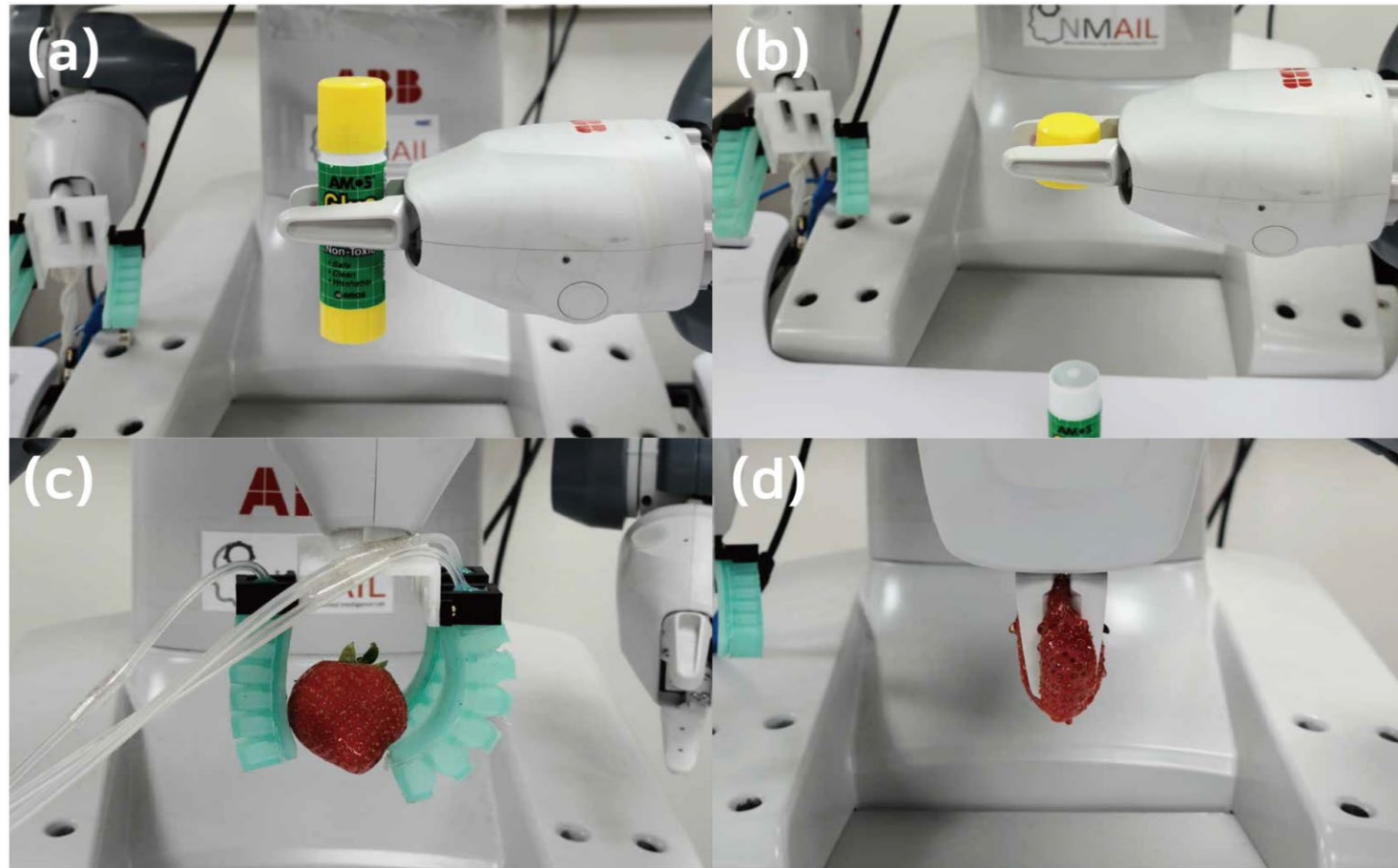
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\* : equal contributions

# : corresponding authors

# Motivation

- Semantic Grasping: stable grasps for specific object manipulation tasks



# Contributions

- Propose semantic grasping that considers three factors
  - **which component** a robot should grasp
  - **which gripper** a robot should use
  - **how strongly a robot should grasp** the target object
- **roboKG**, a novel knowledge graph representing human knowledge about desirable robotic manipulation for various tasks on various objects
- Predict appropriate robotic manipulation factors based on the semantic representations of the entities and relations in roboKG

# Overview

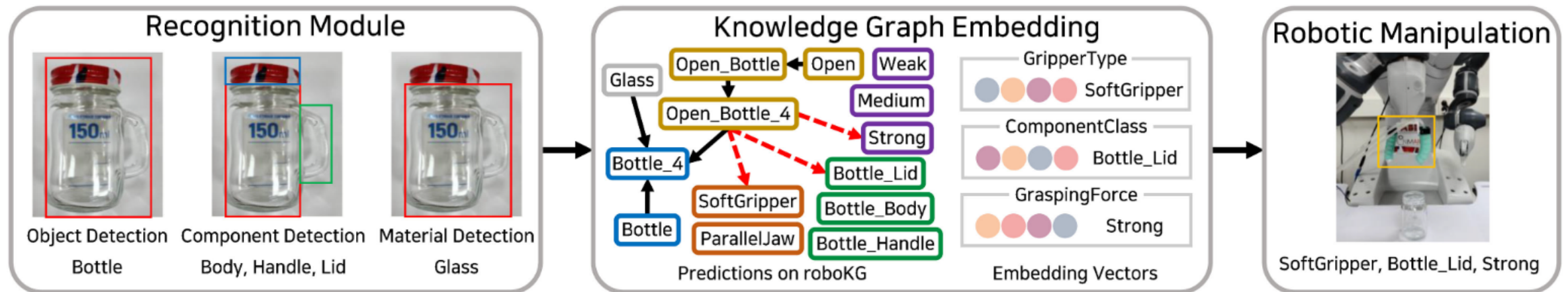
- **Recognition Module**

- Detect the object, its components and material

- **Knowledge Graph Embedding**

- Predict the appropriate grasping component, gripper type, and grasping force

- **Robotic Manipulation**



# roboKG: Knowledge Graph of Robotic Manipulation

- roboKG contains 1,524 entities, 10 relations, and 4,588 triplets.
- **Object-related Information**
- **Task-related Information**
- **Manipulation-related Information**

Entity Type	Example	Freq.
ObjectClass	Bottle, Apple, ...	94
ObjectInstance	Bottle_1, ...	153
MaterialClass	Ceramic, Fabric, Food, ...	11
ComponentCategory	Body, Handle, Lid	3
ComponentClass	Bottle_Body, Bottle_Handle, ...	126
TaskCategory	Grasp, Lift, Open, ...	7
TaskClass	Grasp_Bottle, Open_Bottle, ...	422
TaskInstance	Open_Bottle_1, ...	703
GripperType	ParallelJaw, SoftGripper	2
GraspingForce	Weak, Medium, Strong	3

Relation	Triplet Type
InstantiateObject	(ObjectClass, InstantiateObject, ObjectInstance)
Make	(MaterialClass, Make, ObjectInstance)
SpecifyComponent	(ComponentCategory, SpecifyComponent, ComponentClass)
IsComponentOf	(ComponentClass, IsComponentOf, ObjectInstance)
SpecifyTask	(TaskCategory, SpecifyTask, TaskClass)
InstantiateTask	(TaskClass, InstantiateTask, TaskInstance)
Include	(TaskInstance, Include, ObjectInstance)
WhichGripper	(TaskInstance, WhichGripper, GripperType)
WhichForce	(TaskInstance, WhichForce, GraspingForce)
WhichComponent	(TaskInstance, WhichComponent, ComponentClass)

# roboKG: Knowledge Graph of Robotic Manipulation

- roboKG contains 1,524 entities, 10 relations, and 4,588 triplets.

- **Object-related Information**

- (Bottle, InstantiateObject, Bottle\_4), (Glass, Make, Bottle\_4)
- (Lid, SpecifyComponent, Bottle\_Lid), (Bottle\_Lid, IsComponentOf, Bottle\_4)

Entity Type	Example	Freq.
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# roboKG: Knowledge Graph of Robotic Manipulation

- roboKG contains 1,524 entities, 10 relations, and 4,588 triplets.
- **Task-related Information**
  - (Open, SpecifyTask, Open\_Bottle)
  - (Open\_Bottle, InstantiateTask, Open\_Bottle\_4)
  - (Open\_Bottle\_4, Include, Bottle\_4)

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InstantiateTask	(TaskClass, InstantiateTask, TaskInstance)
Include	(TaskInstance, Include, ObjectInstance)
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WhichForce	(TaskInstance, WhichForce, GraspingForce)
WhichComponent	(TaskInstance, WhichComponent, ComponentClass)

# roboKG: Knowledge Graph of Robotic Manipulation

- roboKG contains 1,524 entities, 10 relations, and 4,588 triplets.
- **Manipulation-related Information**
  - (Open\_Bottle\_4, WhichGripper, SoftGripper)
  - (Open\_Bottle\_4, WhichForce, Strong)
  - (Open\_Bottle\_4, WhichComponent, Bottle\_Lid)

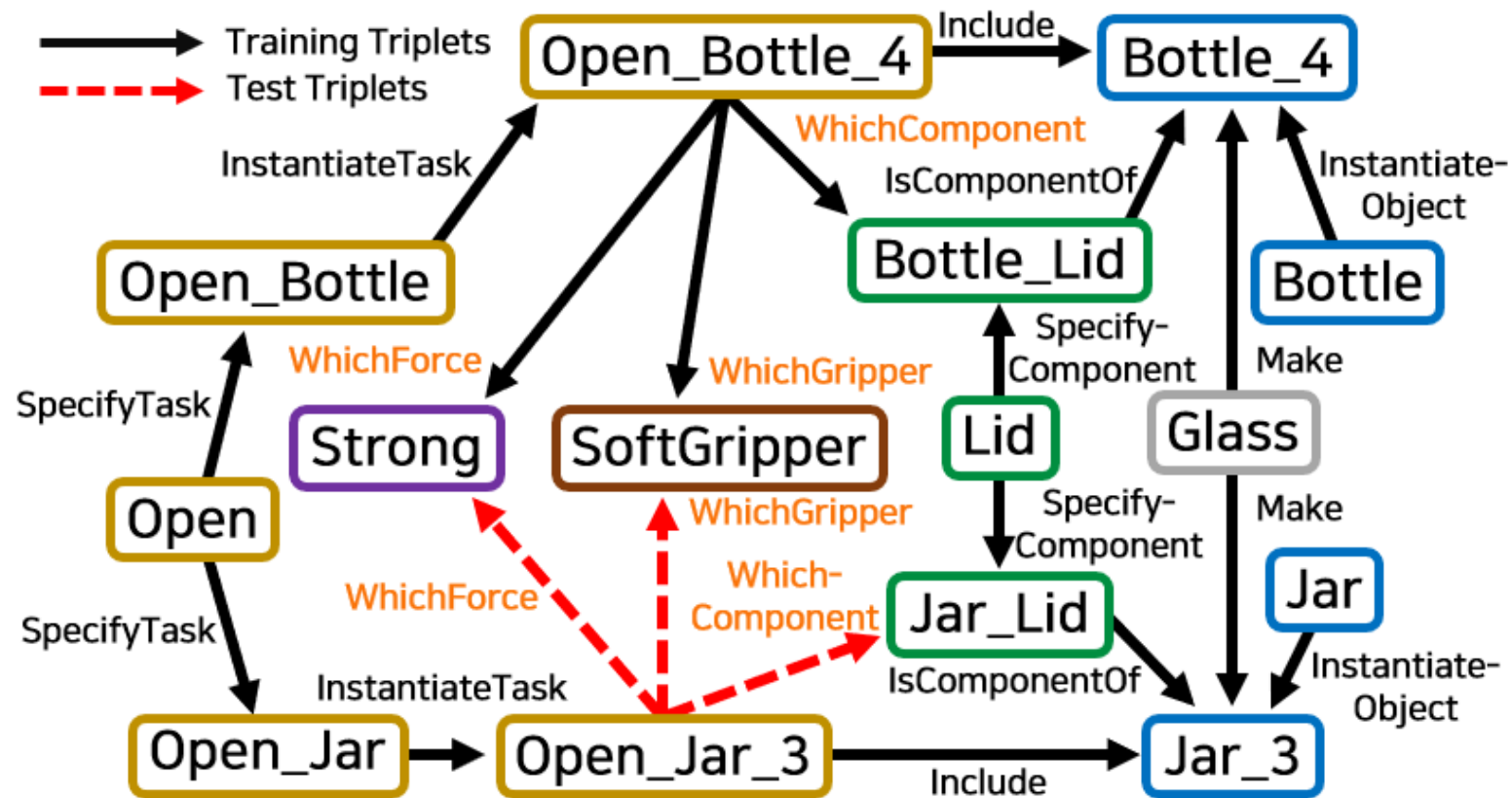
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WhichComponent	(TaskInstance, WhichComponent, ComponentClass)



# Predictions with roboKG

- Knowledge graph embedding methods learn embedding vectors by reflecting the structure of a given knowledge graph



# Manipulation Tasks

- Considered tasks and criteria of successful trials

Task	Criteria of Successful Trials
Open	Whether a robot separates the body and the lid
Pour	Whether a robot tilts 30 degrees after lifting the object
Rotate	Whether a robot rotates the object for 30 degrees on the ground
Lift	Whether a robot lifts the object 10cm off the ground
Push	Whether a robot pushes the object forward for 10 cm
Squeeze	Whether a robot grasps the object and changes the shape of the object
Grasp	Whether a robot grasps the designated component of the object without changing the shape of the object

# Task Examples – Pour



# Task Examples – Grasp



# Experiments – Link Prediction

- Knowledge graph embedding methods: HAKE, MuRP, ConE
- Baseline Methods
  - Naïve Bayes Classifier (NBC)
  - Random Prediction (RD)
  - Distribution-based Random Prediction (DRD)

	HAKE	MuRP	ConE	NBC	RD	DRD
WhichGripper (G)	<b>0.959</b>	0.957	0.952	0.657	0.505	0.539
WhichForce (F)	<b>0.976</b>	<b>0.976</b>	0.963	0.666	0.341	0.832
WhichComponent (C)	<b>0.967</b>	0.940	0.953	0.753	0.720	0.780
Which G & F & C	<b>0.908</b>	0.888	0.875	0.371	0.118	0.320

# Experiments – Robotic Manipulation

- **Without** recognition module

- 42 ObjectInstance of 34 different ObjectClass

	HAKE	MuRP	ConE	Rule	Centroid
No. of TaskInstance	188	188	188	188	188
No. of Successes	<b>179</b>	177	178	170	171
Accuracy	<b>95.21%</b>	94.15%	94.68%	90.43%	90.96%

- Rule

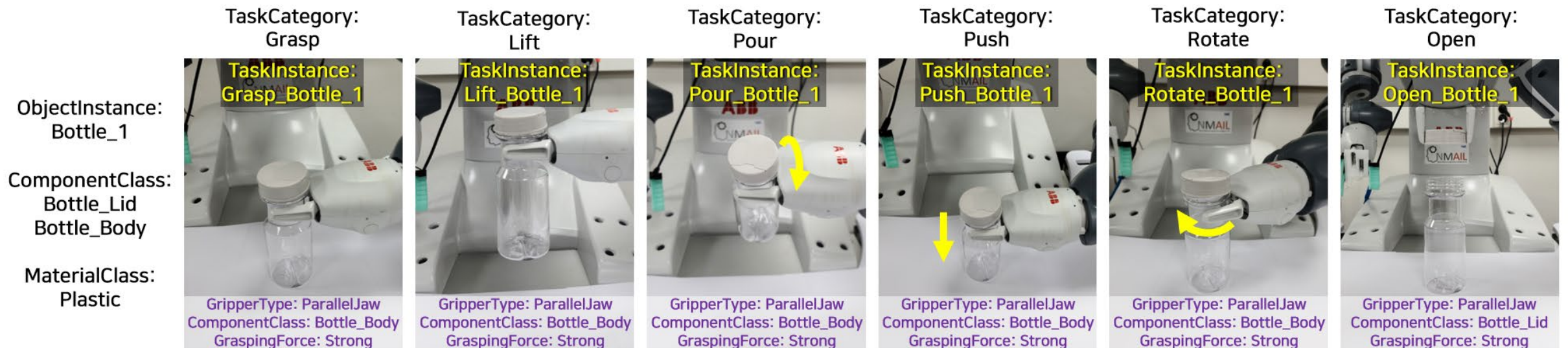
- Gripper type: a soft gripper for the objects made of ceramic, food, and glass
- Grasping component: lid if the task is Open, handle if the object has a handle, and body otherwise
- Grasping force: strong if the task is Squeeze, and medium otherwise

- Centroid

- Centroid-based grasping, gripper type: a rigid parallel jaw, force: medium

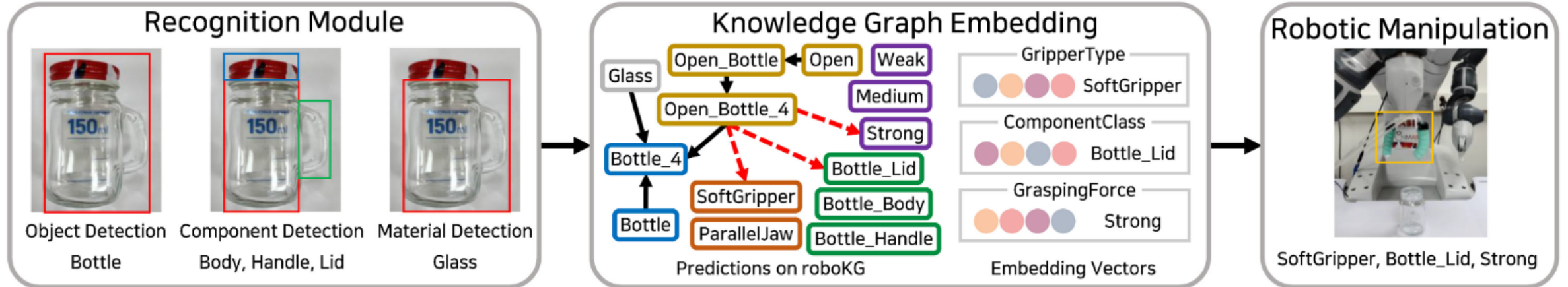
# Experiments – Robotic Manipulation

- **With** recognition module
  - Nine ObjectInstance
  - 34 success out of 43 TaskInstance (79.07%)

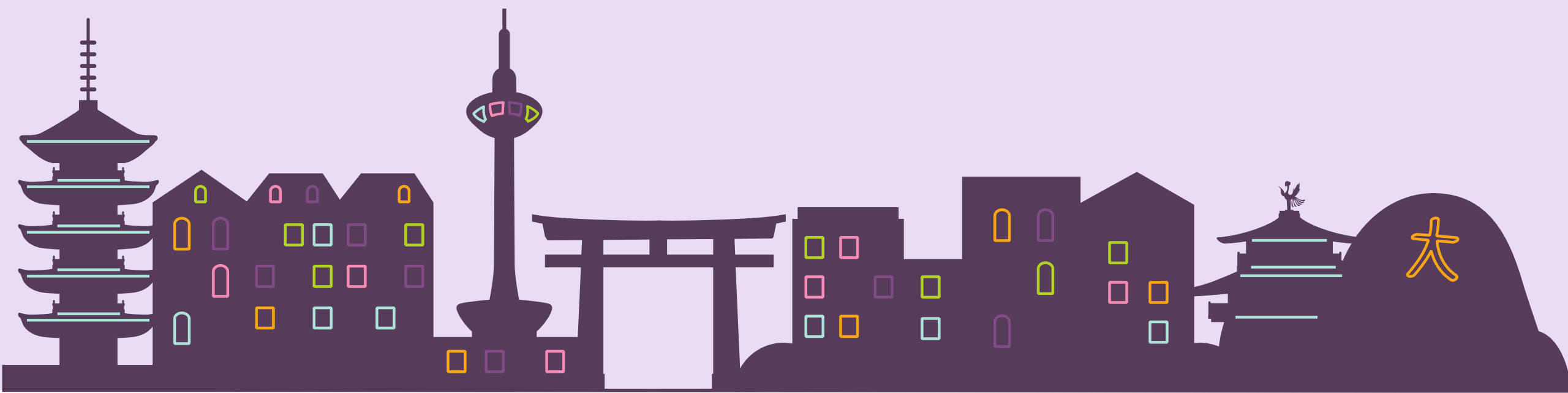


# Summary

- Define roboKG, a knowledge graph for semantic grasping
- Generate semantic representations of the entities and relations in roboKG to make predictions on a gripper type, a grasping component, and a grasping force
- A real robot succeeds in accomplishing various tasks based on the predictions







# Thanks!

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