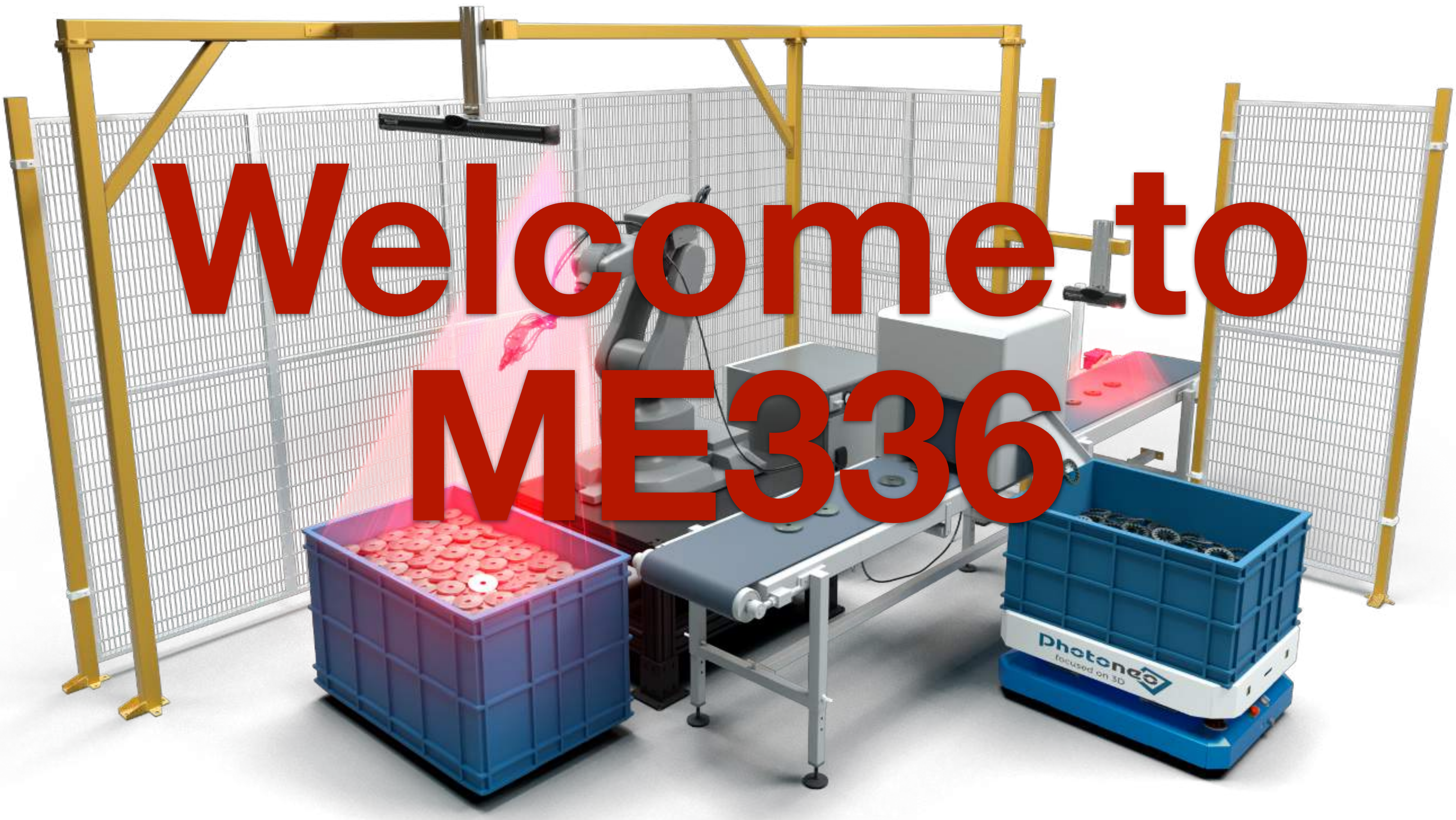
Welcome to ME336



mainDL.ancoraSIR.com

Machine Intelligence Design & Learning Lab

ME336
Collaborative Robot Learning

Week 01 Lecture 1

Wednesday, 1400-1550, Room 235, New Engineering Building

Song Chaoyang | Asst. Prof. | Department of Mechanical & Energy Engineering | SUSTech | songcy@sustech.edu.cn

Agenda

Week 01, Wednesday January 13, 2021

Collaborative Robots at Work

Robot Learning in Research

A Brief Review of Robot Manipulation Learning Problems

Course Overview

Cobot in Concept


Cobot at Work
Disc is placed in optical laser sensor to ensure proper alignment

Common Applications of Cobot in Automation

Highly repetitive tasks that require different levels of dexterity

- **Object Relocation**
  - Handling object from one location to another
  - Pick & Place | Machine Tending | Packing and Palletizing
- **Material Releasing**
  - Releasing material from the robot to the target location
  - Gluing | Dispensing | Welding | Screwdriving
- **Material Removal**
  - Removing material from the target object using the robot
  - Polishing | Grinding | Deburring
- **Information Gathering**
  - Collecting information using sensors attached to the robot
  - Quality Inspection

Object Relocation - Machine Tending

Object Relocation - Pick & Place

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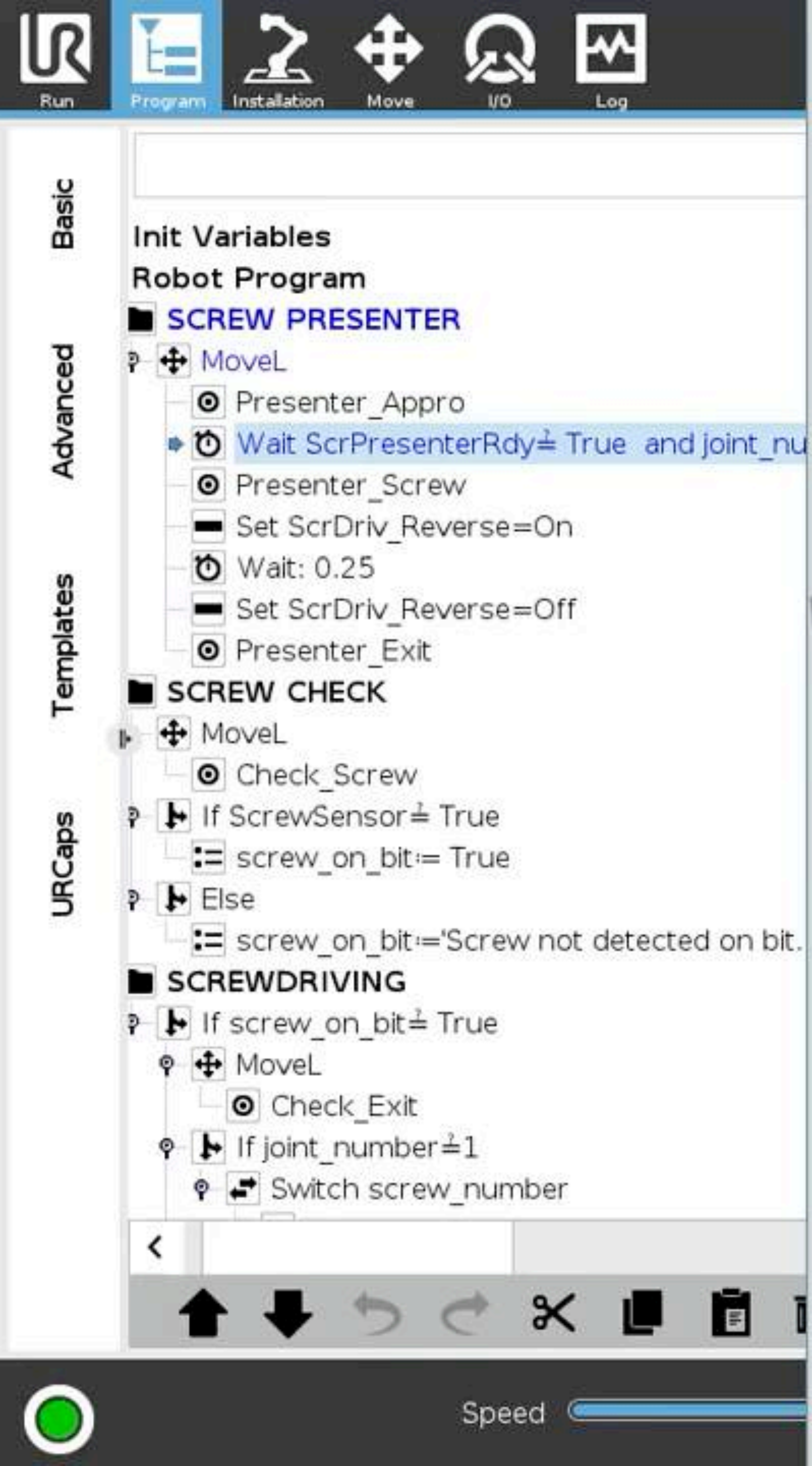

Material Removal - Screwdriving

Cobots, or collaborative robots, are robots intended for direct human robot interaction within a shared space, or where humans and robots are in close proximity. Cobot applications contrast with traditional industrial robot applications in which robots are isolated from human contact.

Collaborative Robot Learning

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Material Removal - Polishing

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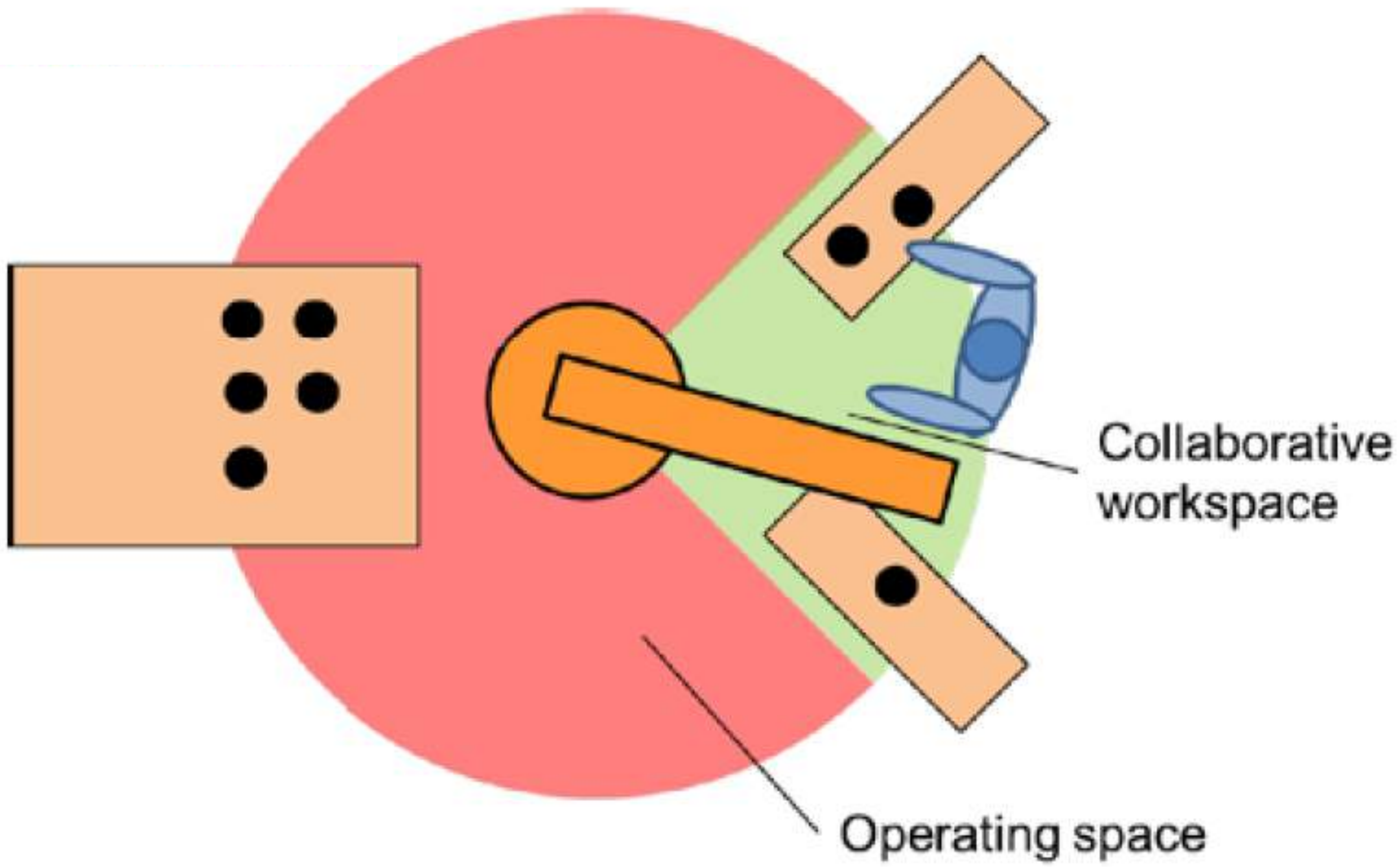
Information Gathering - Quality Inspection

How to define Collaboration with Robots?

Collaborative Robot Technical Specification ISO/TS 15066

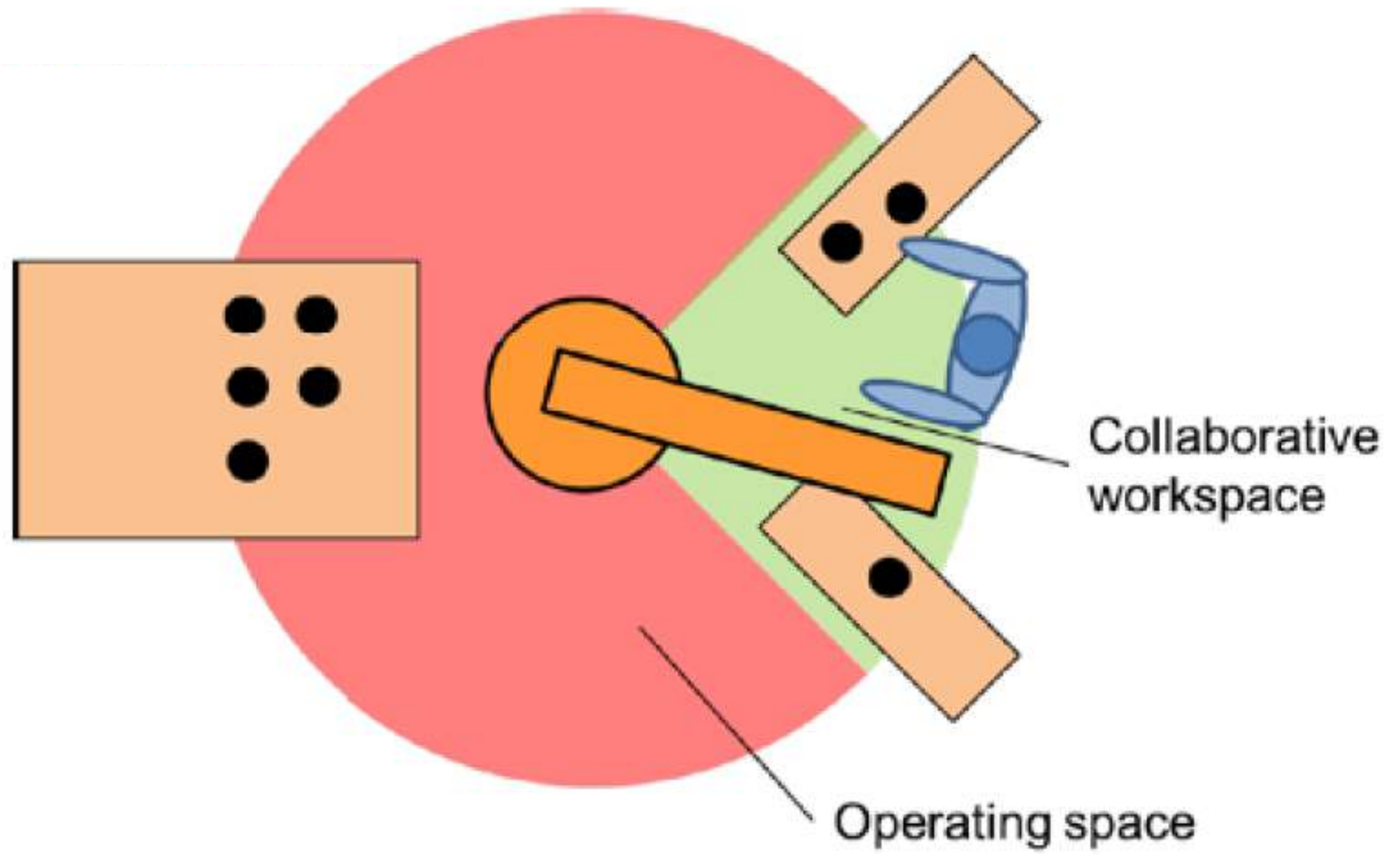


How to define Collaboration with Robots?

Collaborative Robot Technical Specification ISO/TS 15066

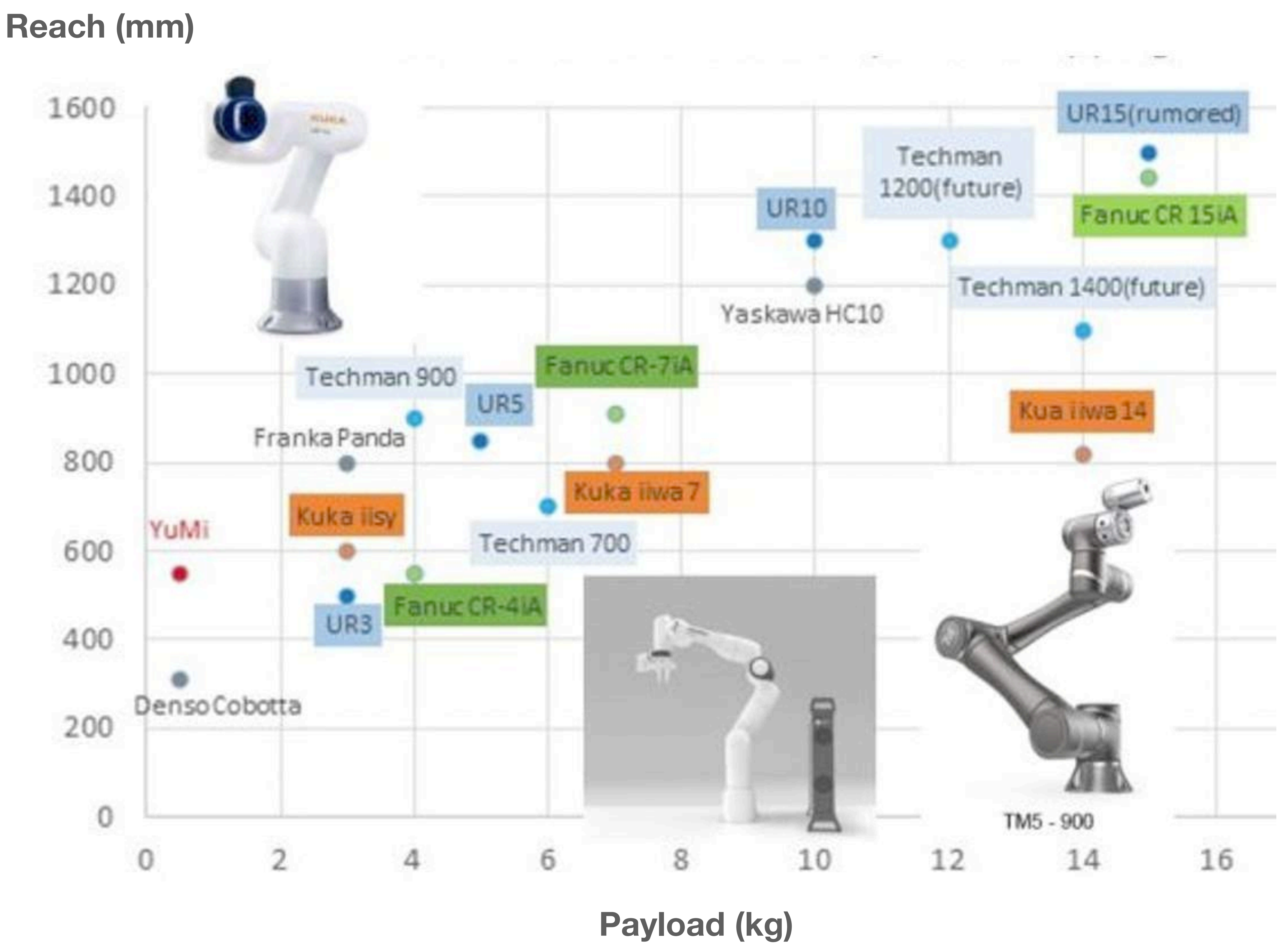
- A robot that **CAN** (capable) for use in a collaborative operation
    - purposely designed robot systems work in direct cooperation with a human within a defined workspace

Collaborative Workspace: space within the operating space where the robot system (including the workpiece) and a human can perform tasks concurrently during production operation.
- Robot: Robot arm & robot control
- Robot System: Robot, end-effector & workpiece



Safety vs. Risk against Cost

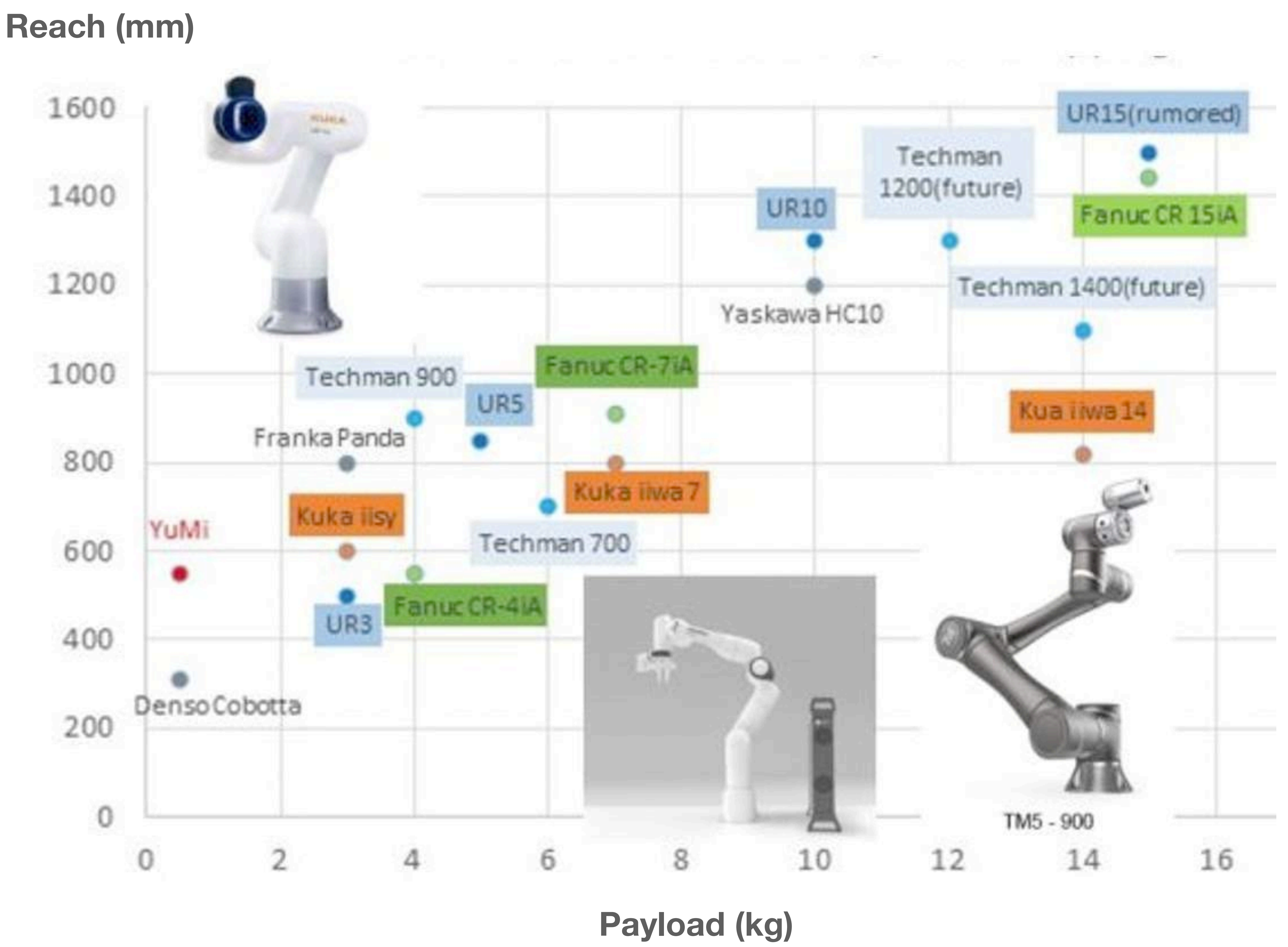
The Design Need for Robotic Collaboration



Safety vs. Risk against Cost

The Design Need for Robotic Collaboration

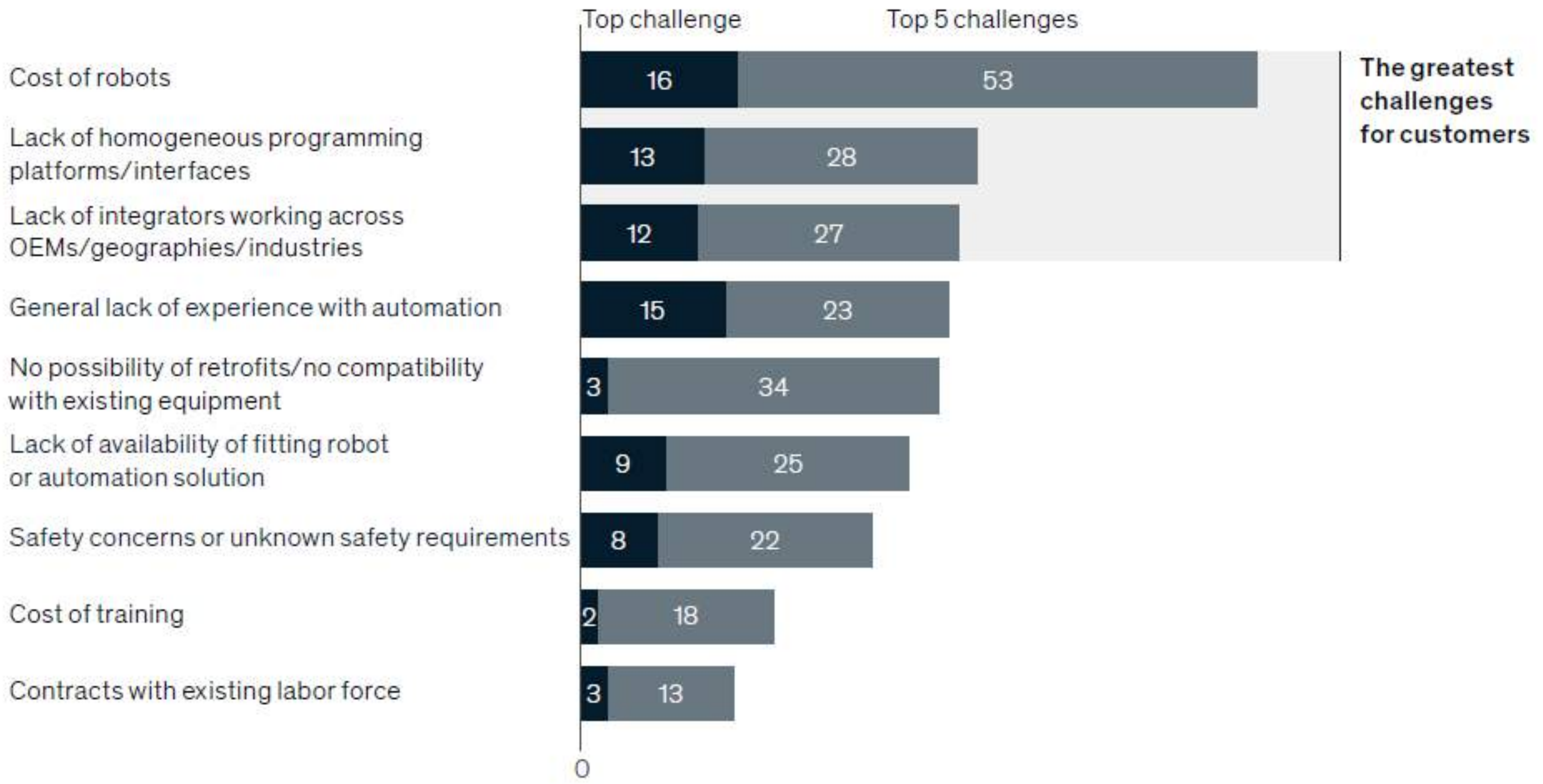
- **Small payload**
  - Force limiting for safe interaction
- **Small footprint**
  - Less disruption to the existing automation line
- **Highly repetitive**
  - Labor replacement for added value
- **Ease of integration**
  - Flexible implementation for the changing demand
- **Cost-Effectiveness**
  - Lower cost in purchase, use, and maintenance



Challenge to Adoption

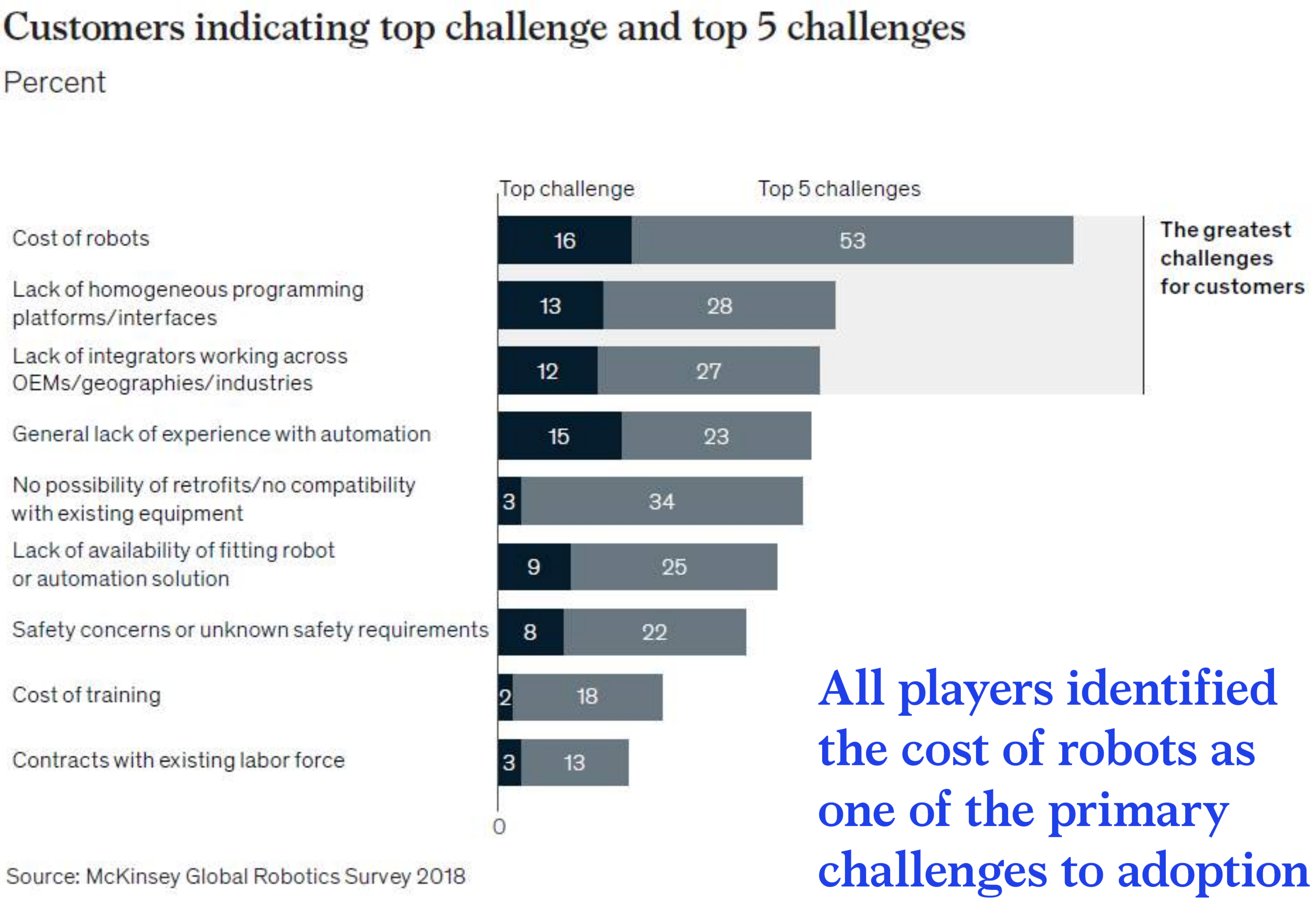
Customers indicating top challenge and top 5 challenges

Percent



Source: McKinsey Global Robotics Survey 2018

Challenge to Adoption



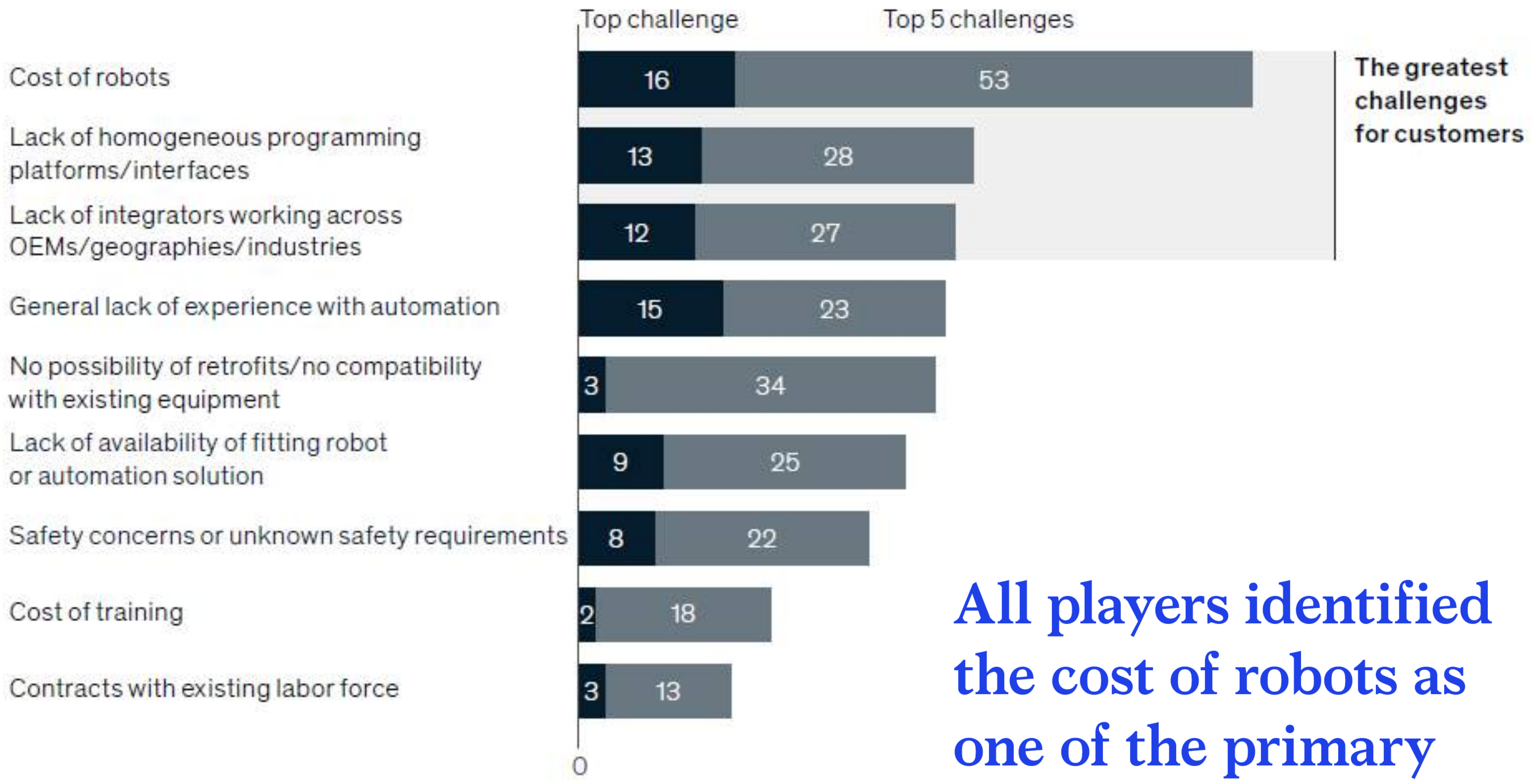
All players identified the cost of robots as one of the primary challenges to adoption

Challenge to Adoption

The cost of which is higher?
- **human or**
- **robot?**

Customers indicating top challenge and top 5 challenges

Percent



Source: McKinsey Global Robotics Survey 2018

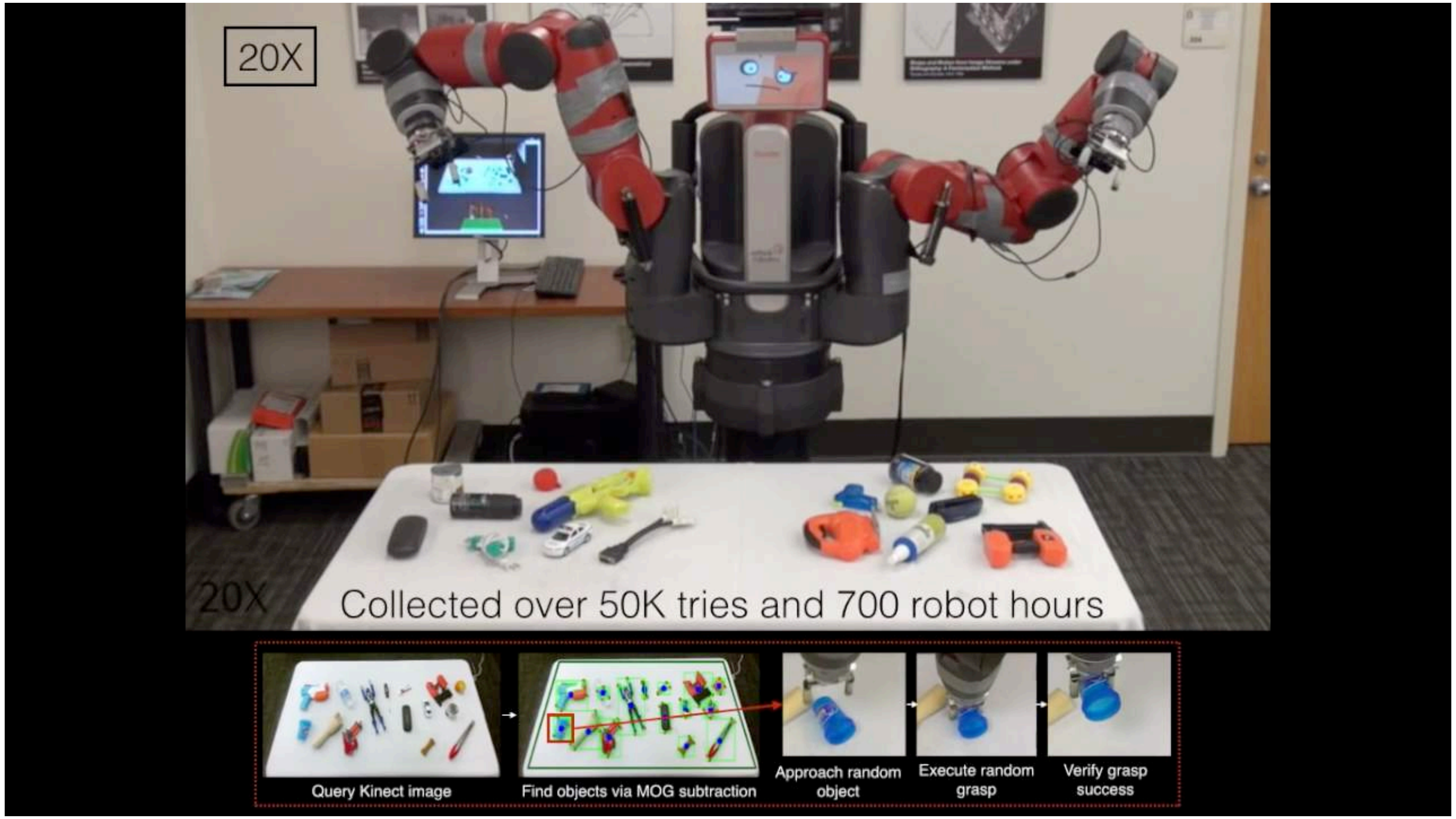
All players identified the cost of robots as one of the primary challenges to adoption

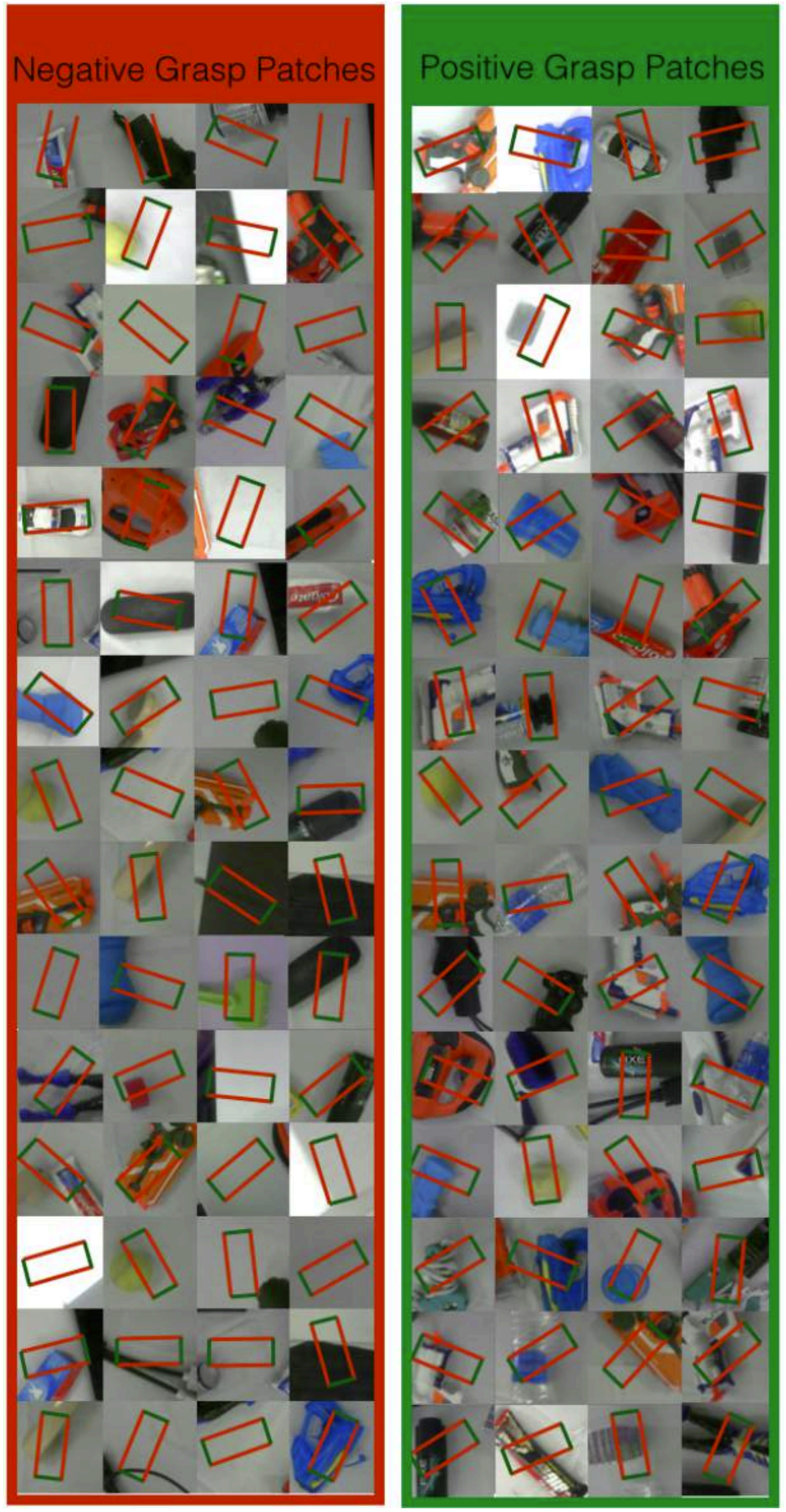
A research field at the intersection of machine learning and robotics that studies techniques allowing a robot to acquire novel skills or adapt to its environment through learning algorithms.

Collaborative Robot Learning

Supersizing self-supervision

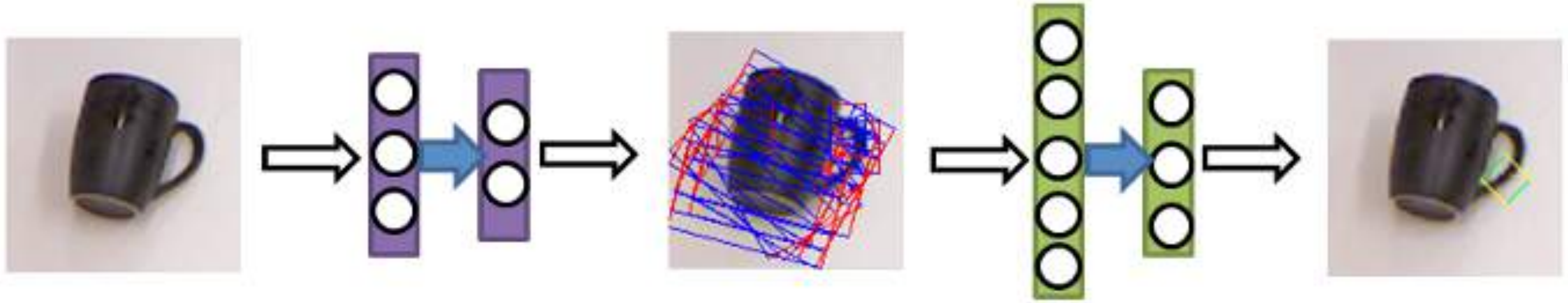
By Pinto, Lerrel, and Abhinav Gupta @ CMU

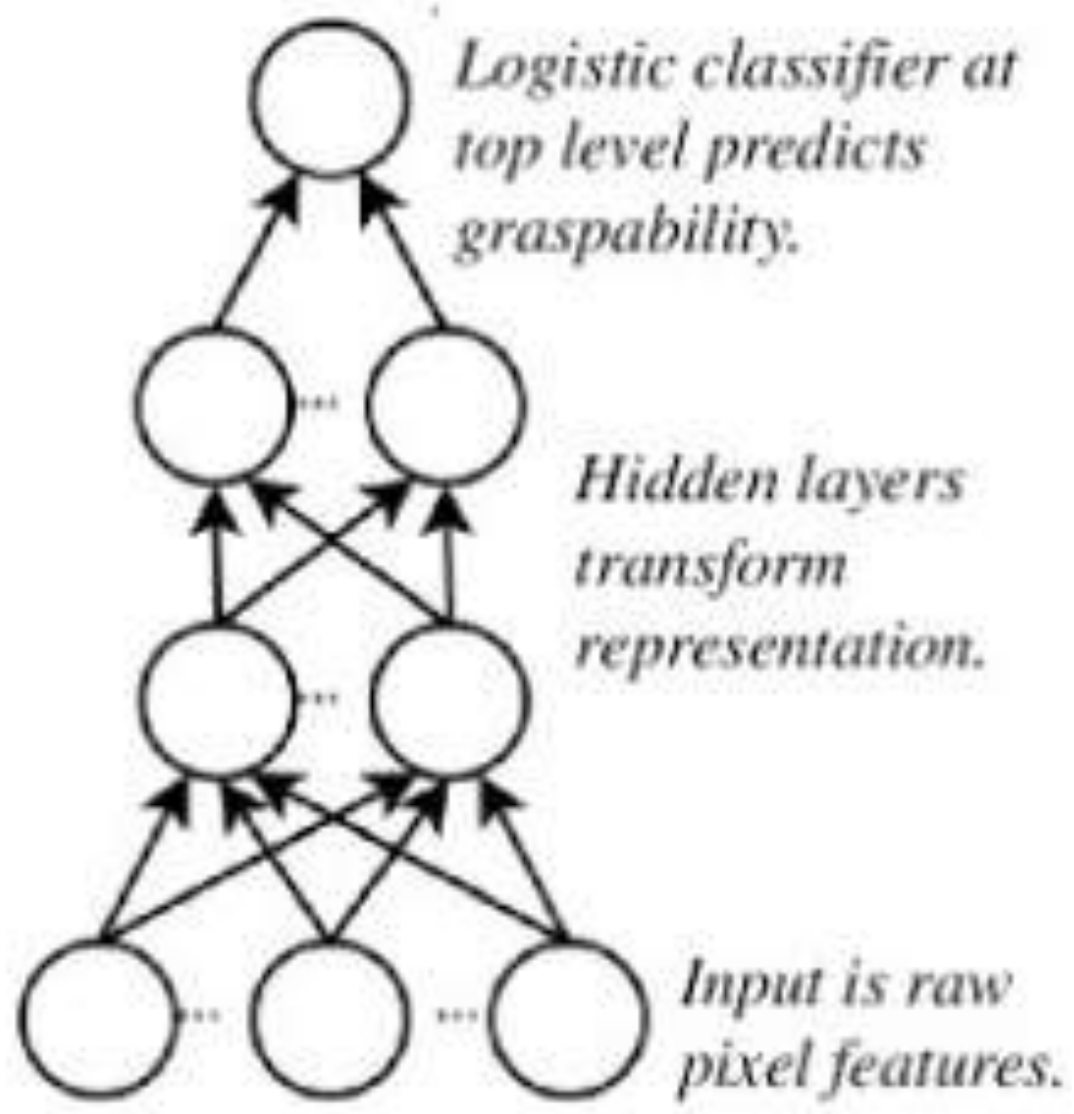


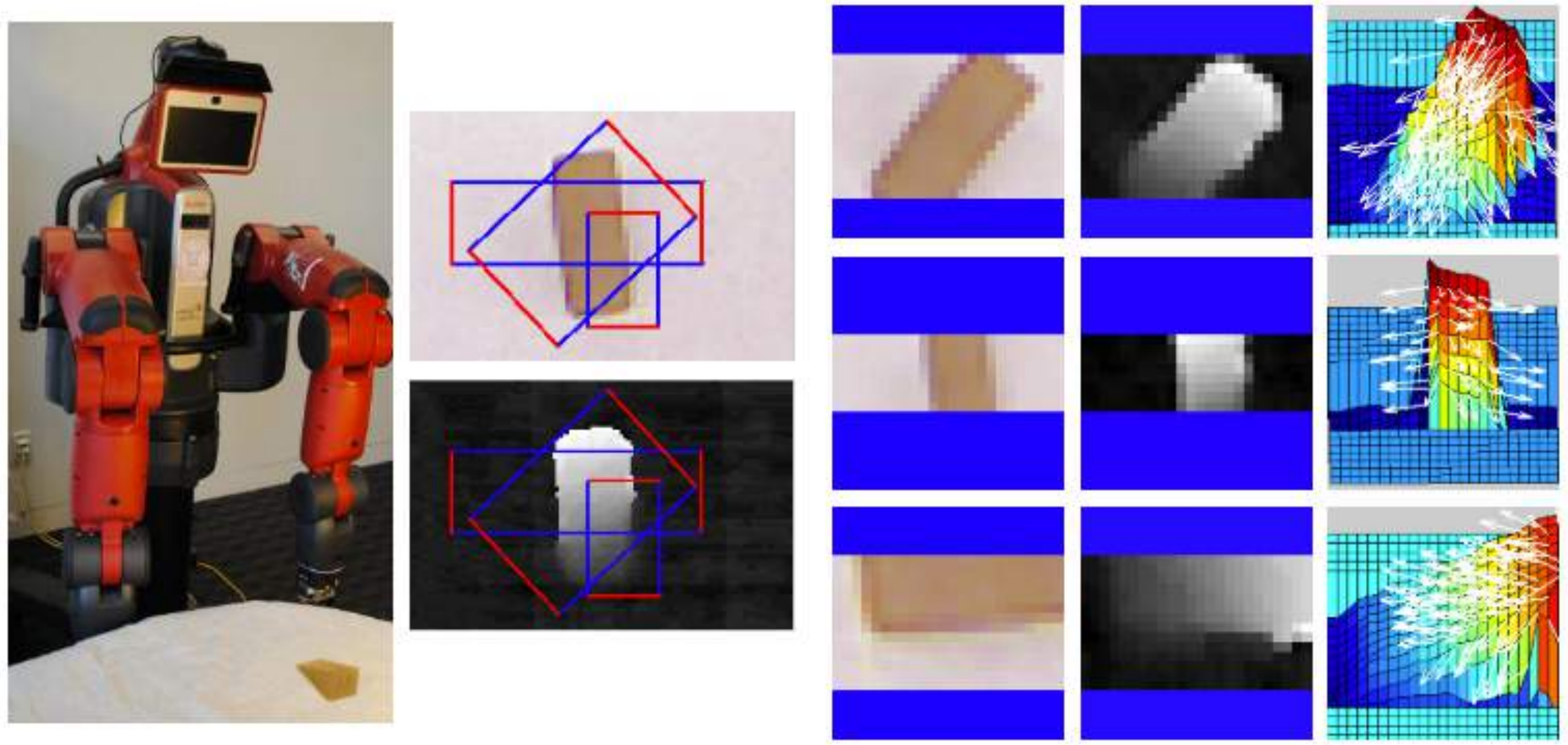


Deep Learning for Detecting Robotic Grasps

By Ian Lenz, Honglak Lee, and Ashutosh Saxena @ Cornell







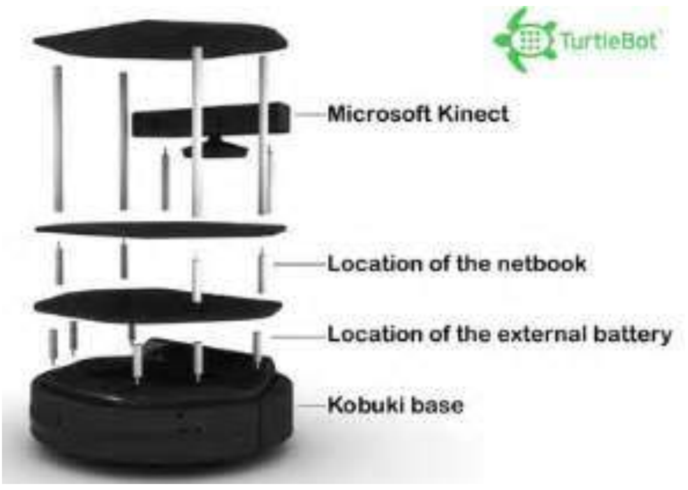
- http://pr.cs.cornell.edu/deepgrasping/

Why Making the Robots to Learn?

Autonomous Vehicles

Research Challenge (Science 1st)

Consumer Electronics (Cost 1st)



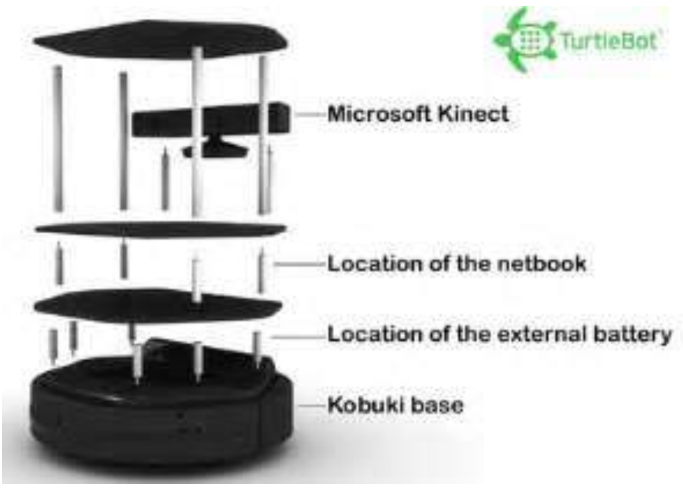
Service Integration (App 1st)

Why Making the Robots to Learn?

Autonomous Vehicles | Autonomous Drones

Research Challenge (Science 1st)

Consumer Electronics (Cost 1st)



Service Integration (App 1st)

Why Making the Robots to Learn?

Autonomous Vehicles | Autonomous Drones | Arm-Type Robots

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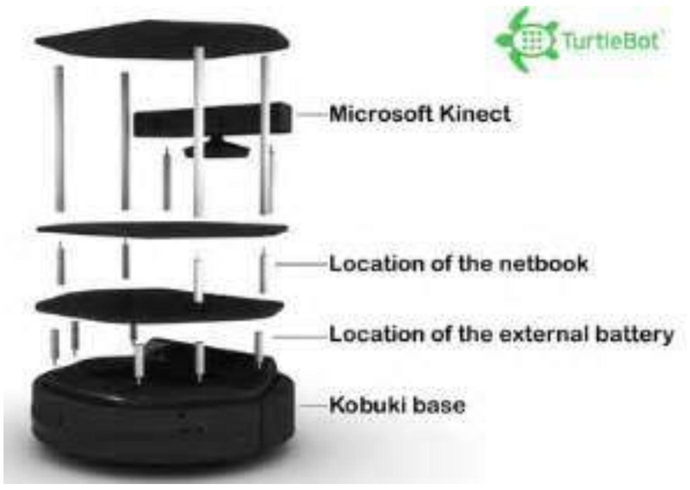
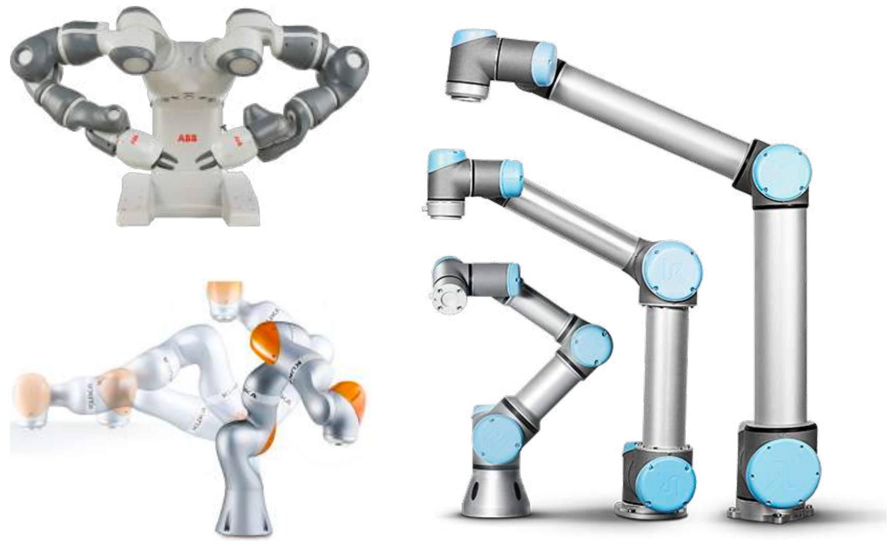
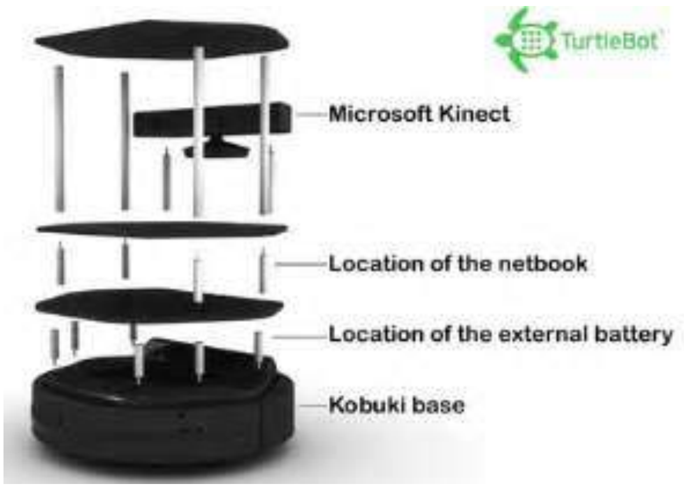
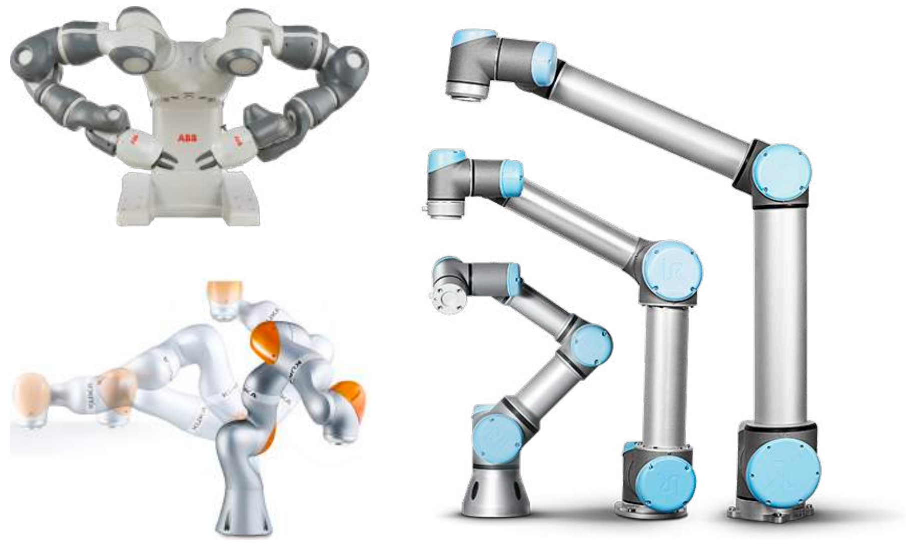


Service Integration (App 1st)



Still **Expensive** to buy/integrate,
Difficult to use/learn,
Un-safe to work with, …

Why Making the Robots to Learn?

	Autonomous Vehicles	Autonomous Drones	Arm-Type Robots	
Research Challenge (Science 1st)				Industry Need
Consumer Electronics (Cost 1st)				?
Service Integration (App 1st)			Still **Expensive** to buy/integrate, **Difficult** to use/learn, **Un-safe** to work with, …	Service Penetration

Why Making the Robots to Learn?

Translating Success in Machine Learning for Robotics

- Computing Unit
- Advanced Algorithms
- Big Data

Why Making the Robots to Learn?

Translating Success in Machine Learning for Robotics

- Computing Unit ✓
- Advanced Algorithms ✓..
- Big Data ✘

Why Making the Robots to Learn?

Translating Success in Machine Learning for Robotics

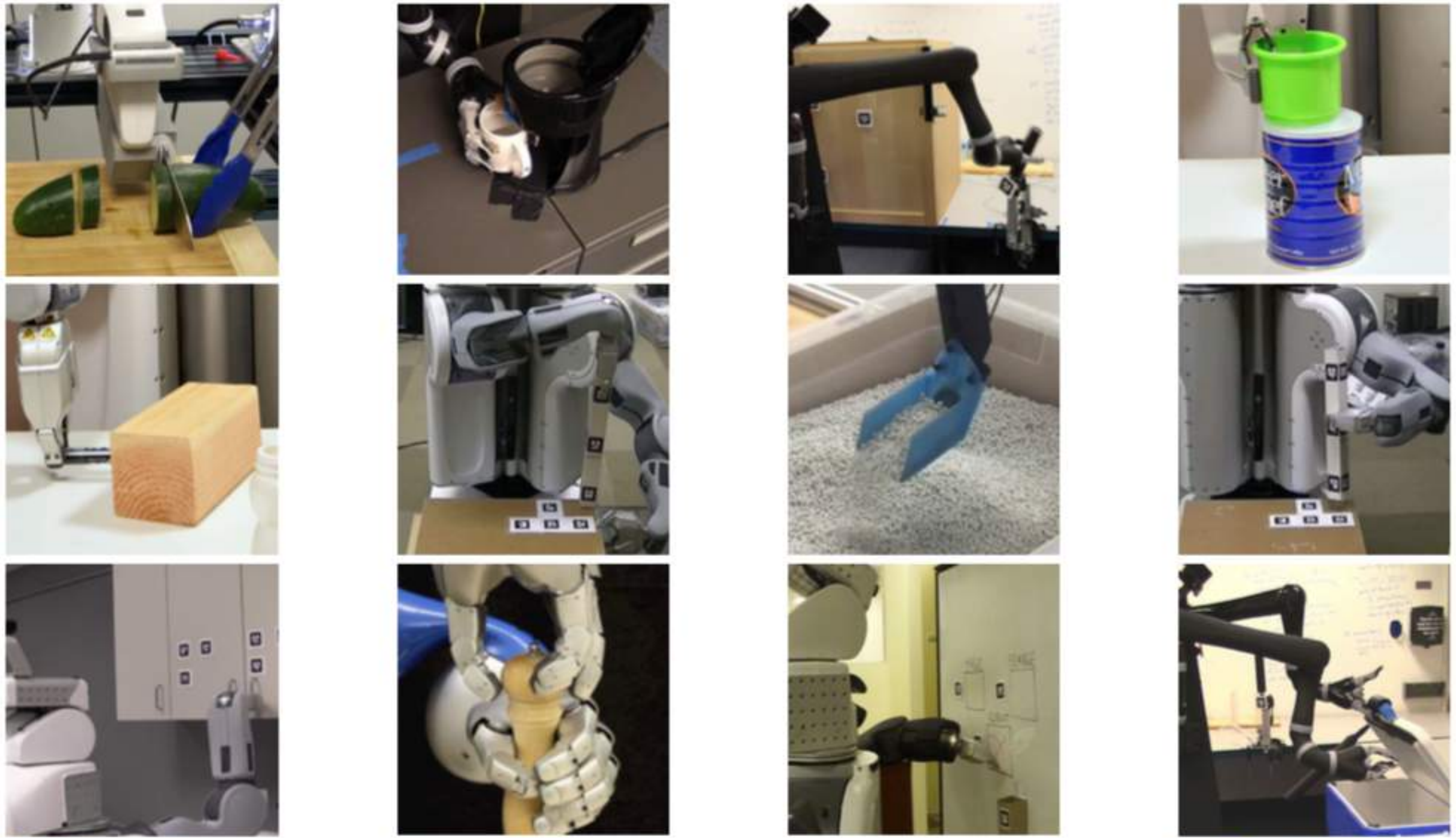
- Computing Unit ✓
- Advanced Algorithms ✓..
- Big Data ✘

- *How to cost-effectively acquire large, quality, robotic data for learning?*

A Brief Review of Robot Manipulation Learning

Robot Manipulation

How a robot should learn to manipulate the world around it



- Example manipulation skills:
  - inserting,
  - stacking,
  - opening,
  - pushing,
  - cutting,
  - screwing,
  - pouring, and
  - writing …

Common Concepts in Learning for Manipulation

Internal structure of a manipulation task

- Manipulations as Physical Systems
  - Laws of physics and the structure they impose provide strong prior knowledge
  - Exploit such concepts using learning algorithms and making learning skill tractable

Common Concepts in Learning for Manipulation

Internal structure of a manipulation task

- Underactuation
  - The DOFs of the physical environment can be easily
  - larger than those of the robotic system

Common Concepts in Learning for Manipulation

Internal structure of a manipulation task

- Nonholonomic Constraints
  - a system whose state depends on the path taken in order to achieve it.
  - (Controllable DOFs ≠ Total DOFs caused by non-integrable constraints)

Common Concepts in Learning for Manipulation

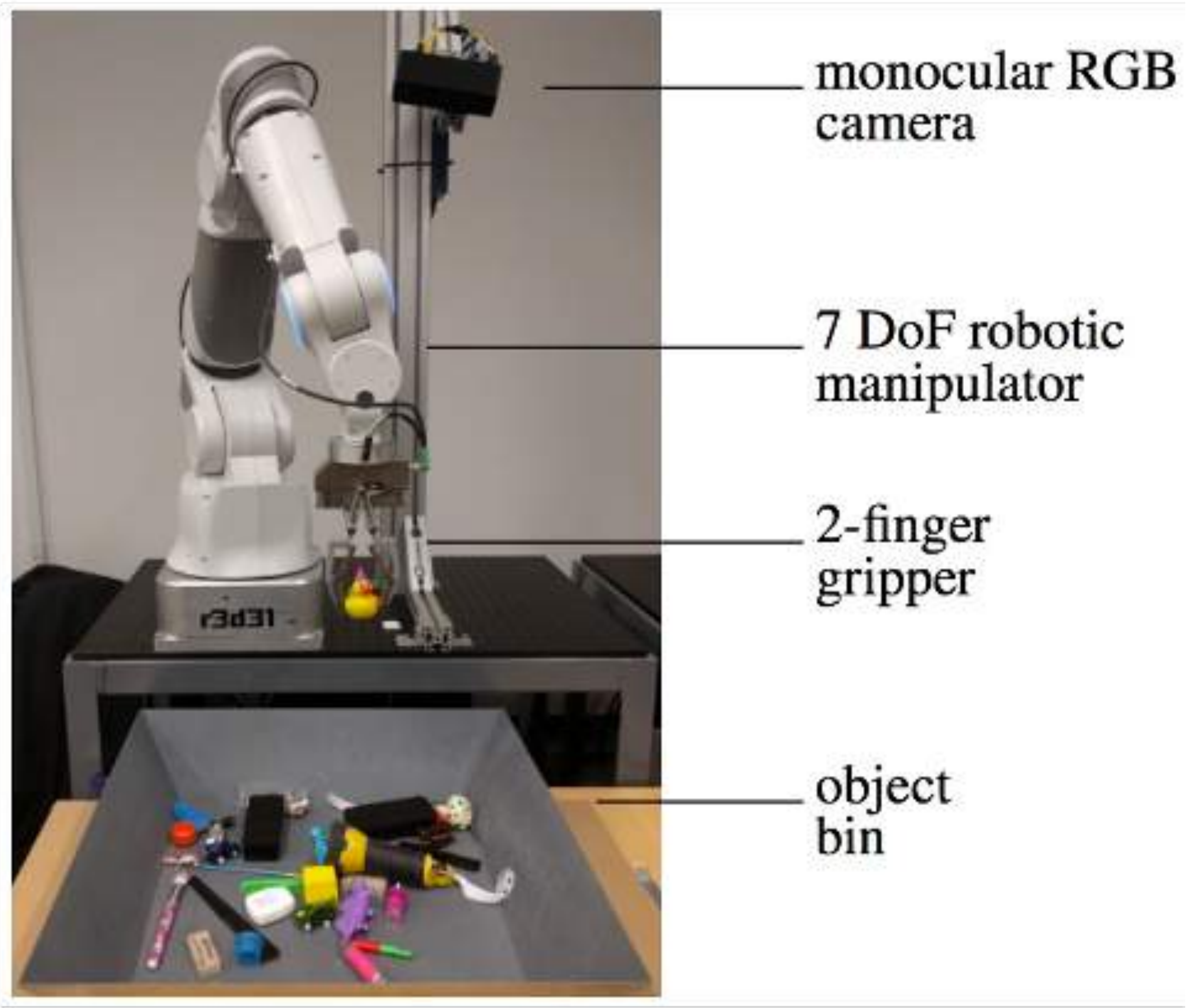
Internal structure of a manipulation task

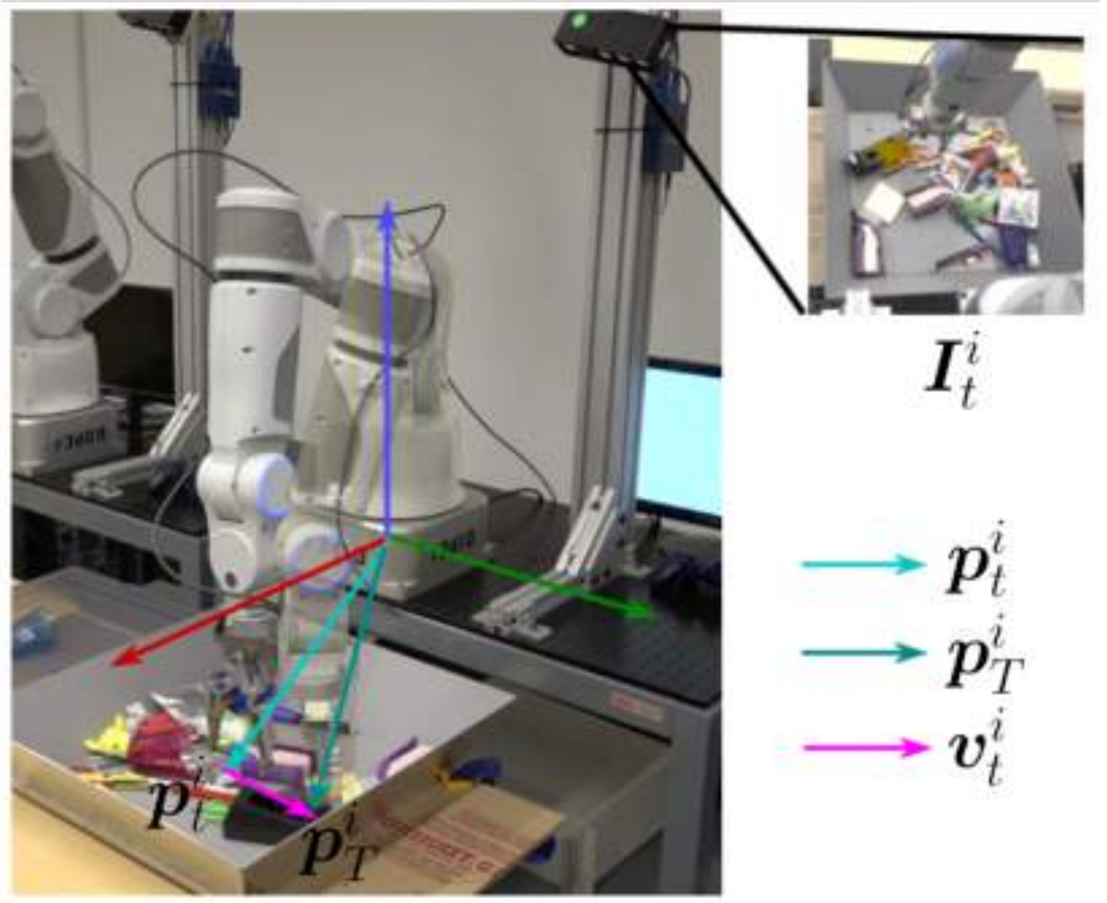
- Modes in Manipulations
  - Breaking or making of contacts, i.e. collision with obstacles
  - A modular structure for convenient implementation, but will make the manipulation tasks inherently discontinuous
  - The robot must reach a suitable mode before it can perform a desired manipulation

Interactive Perception and Verification

Paving the pathway for supervised learning

- **Interactive Perception** enables the robot to perceive latent object properties by observing the outcomes of different manipulation actions
- **Verification** is usually done through interactive perception to get the ground truth value for supervised learning with passive perception
- **Active learning** is the process of actively selecting samples to label to maximize learning performance, often used together with interactive perception





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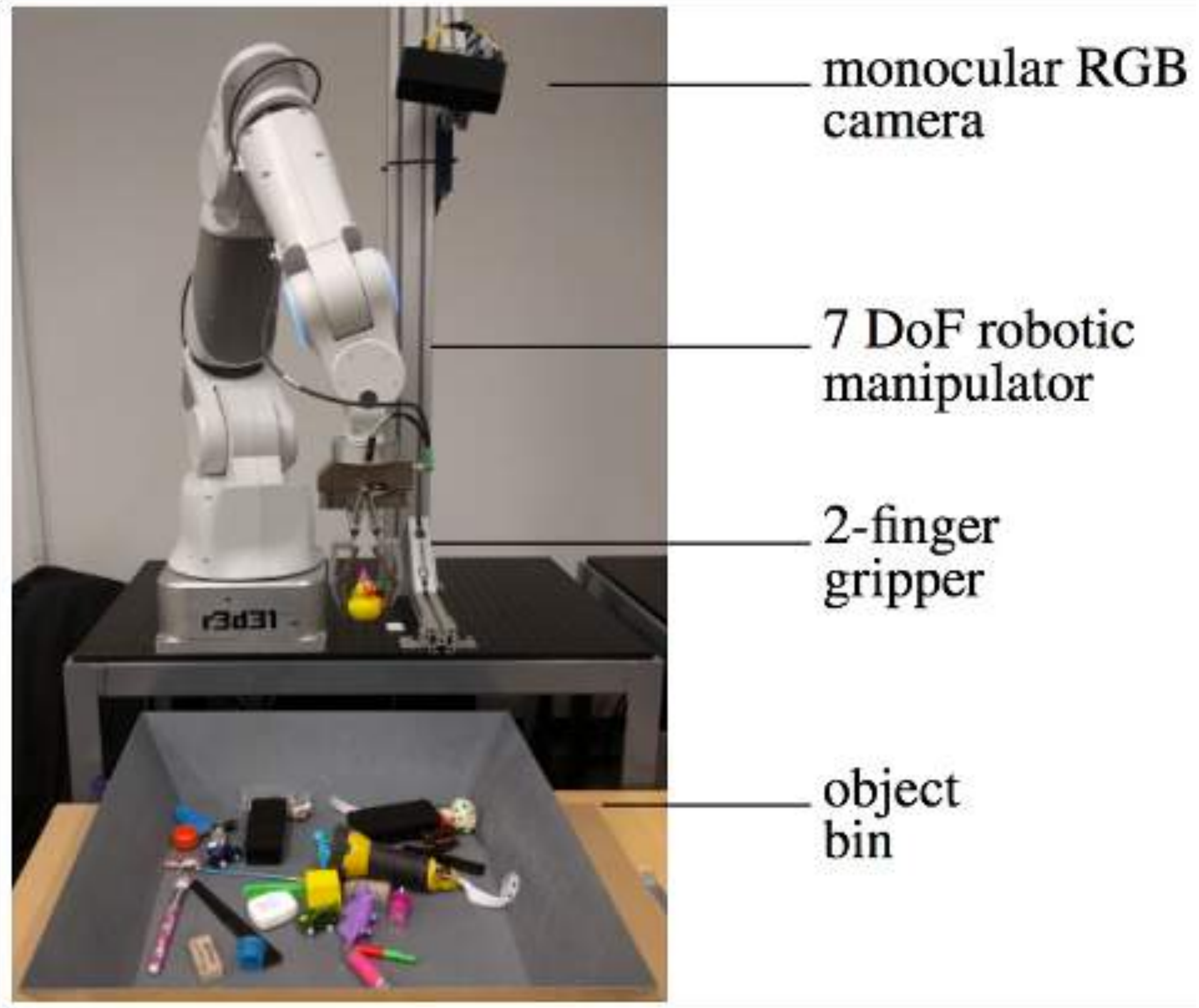

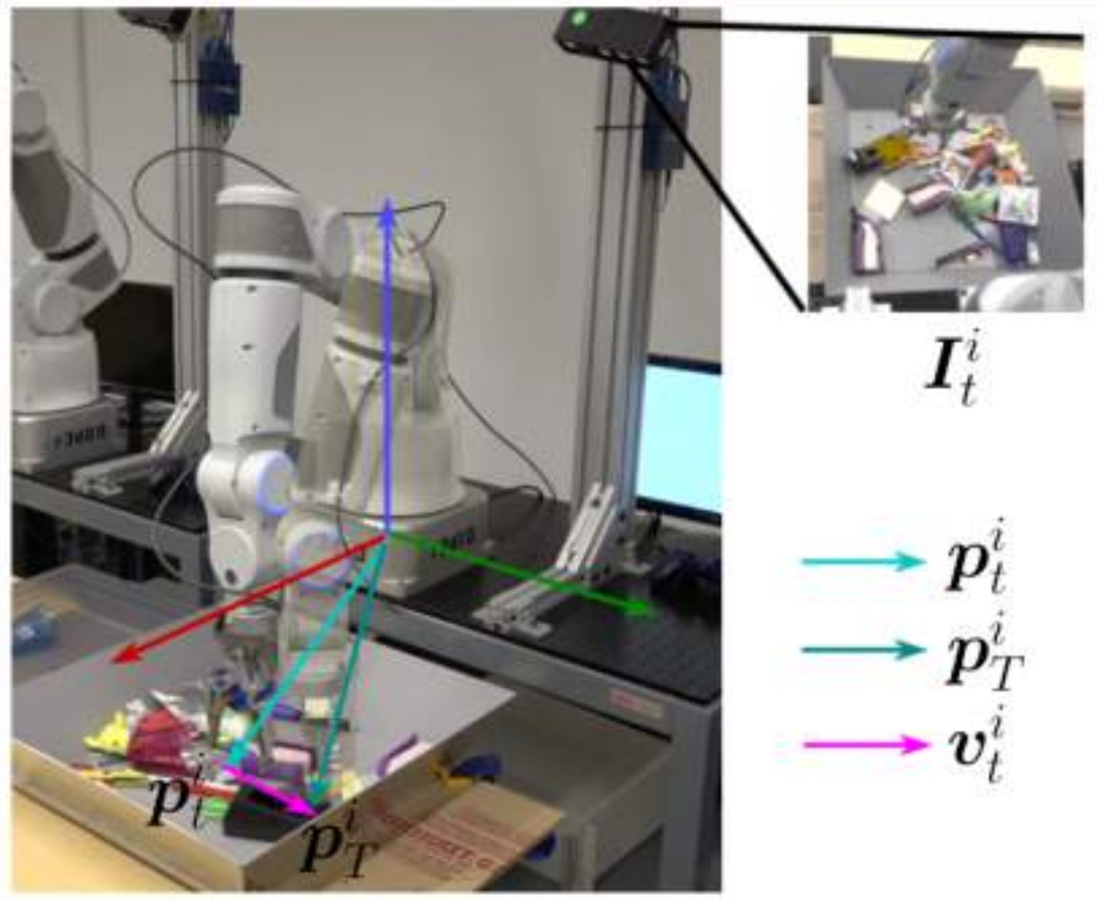

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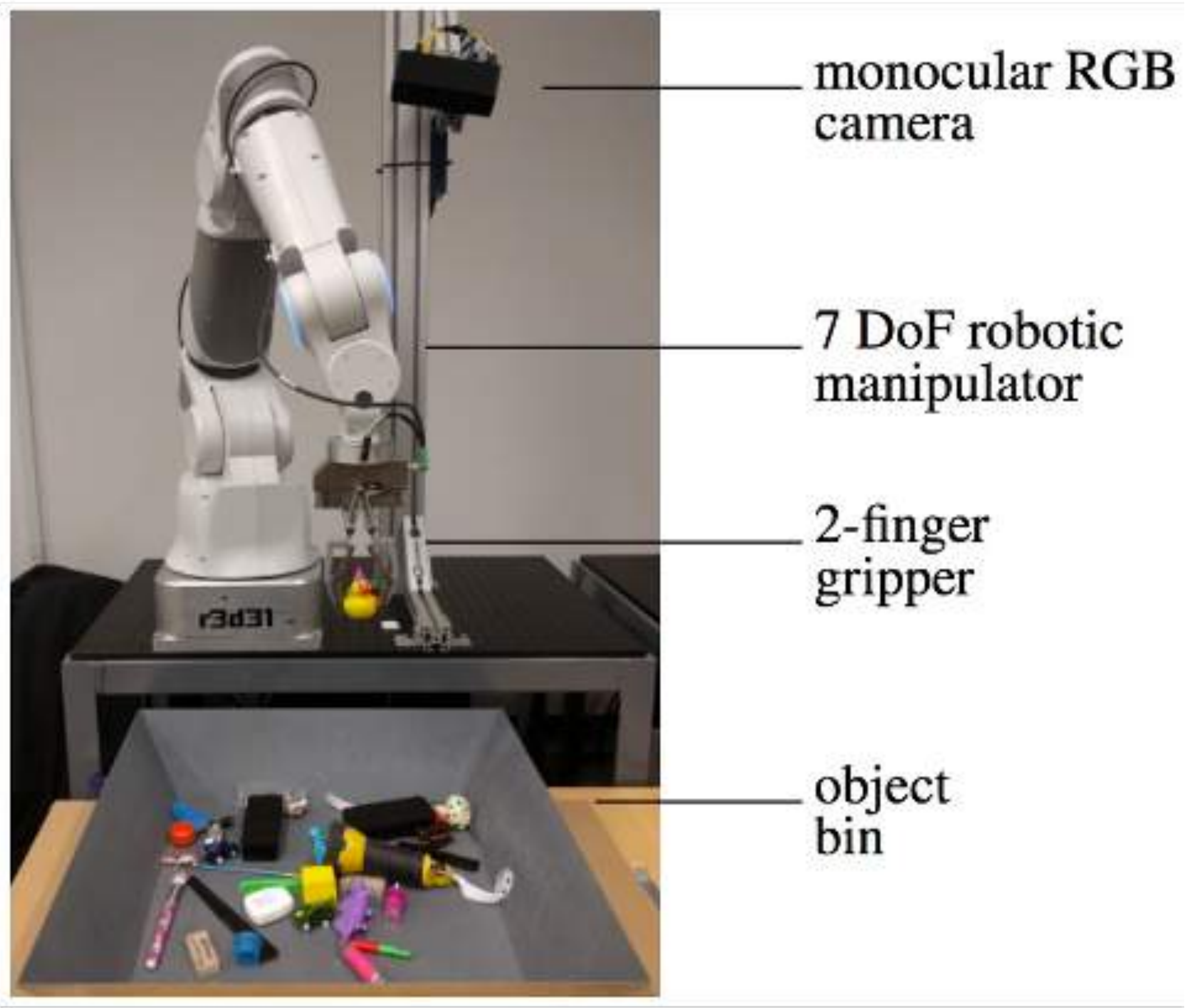

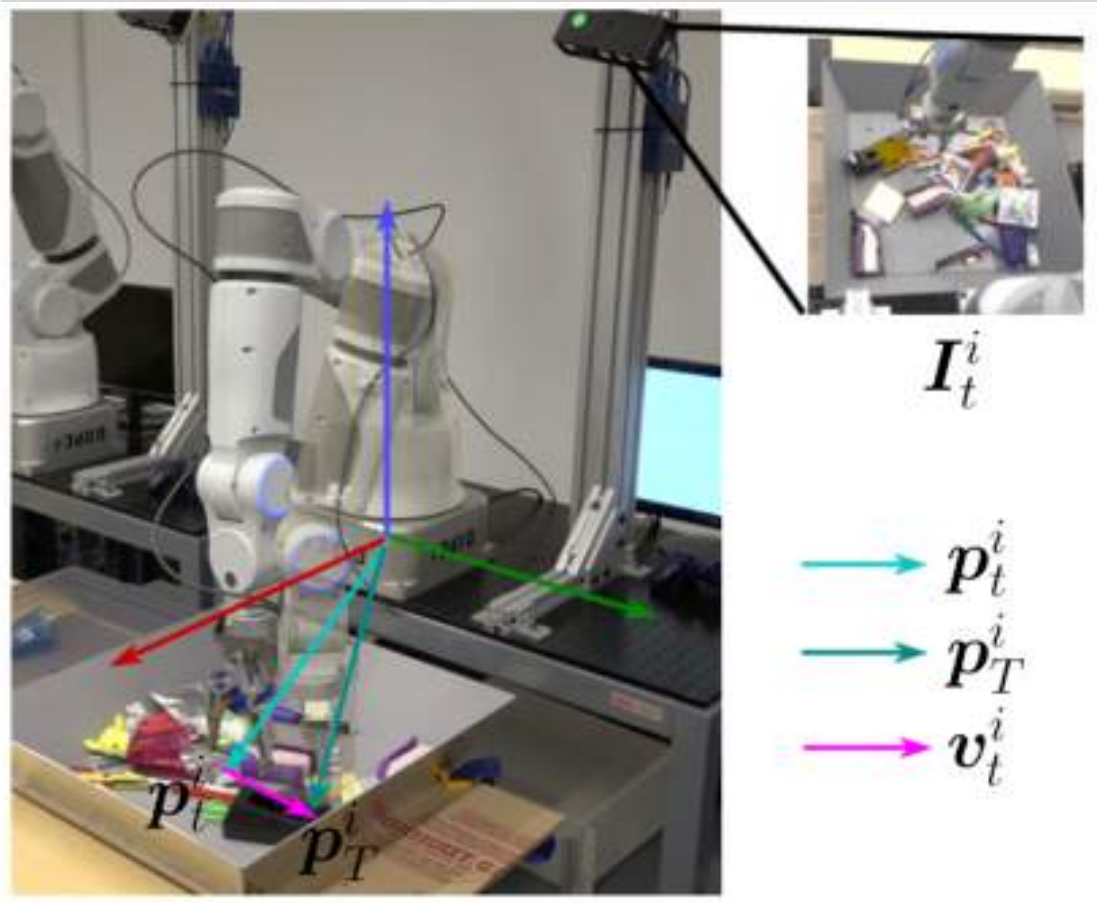

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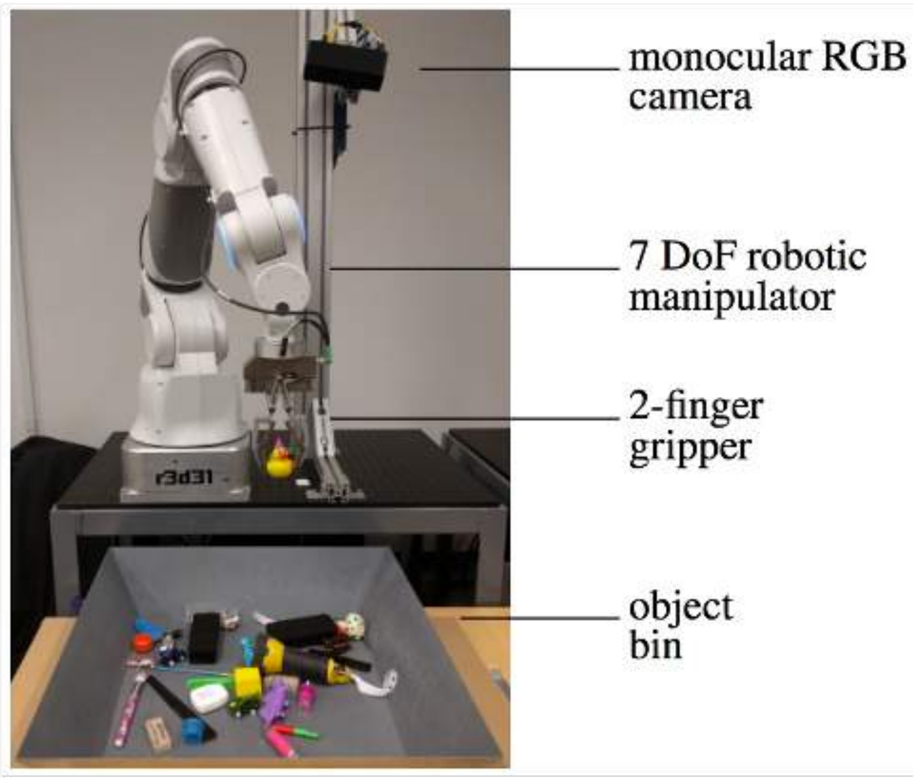
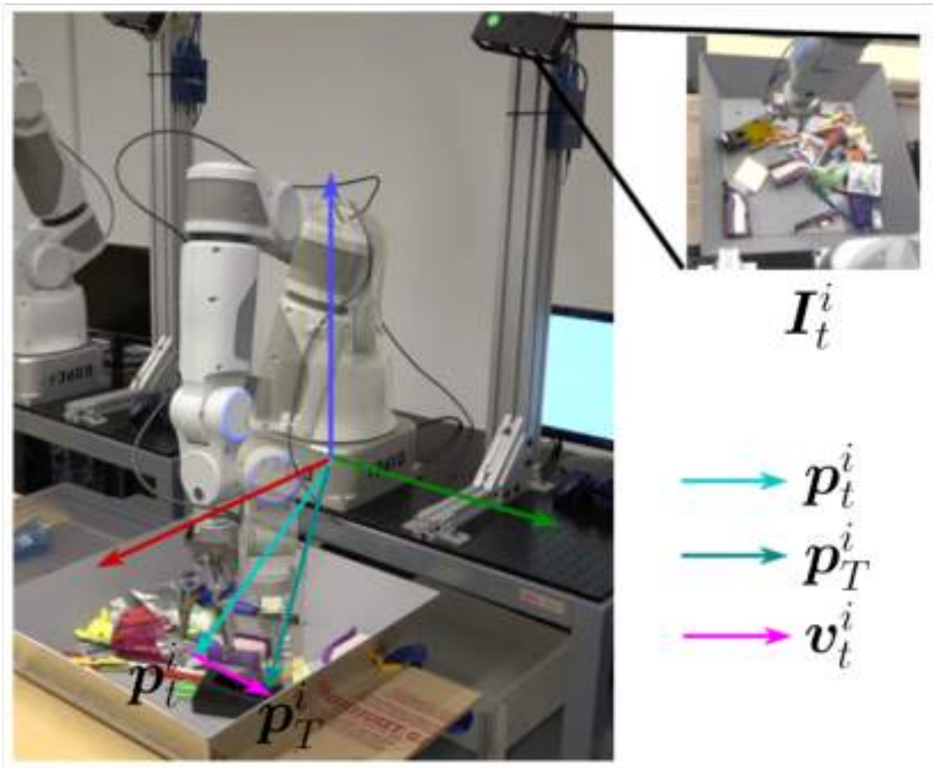
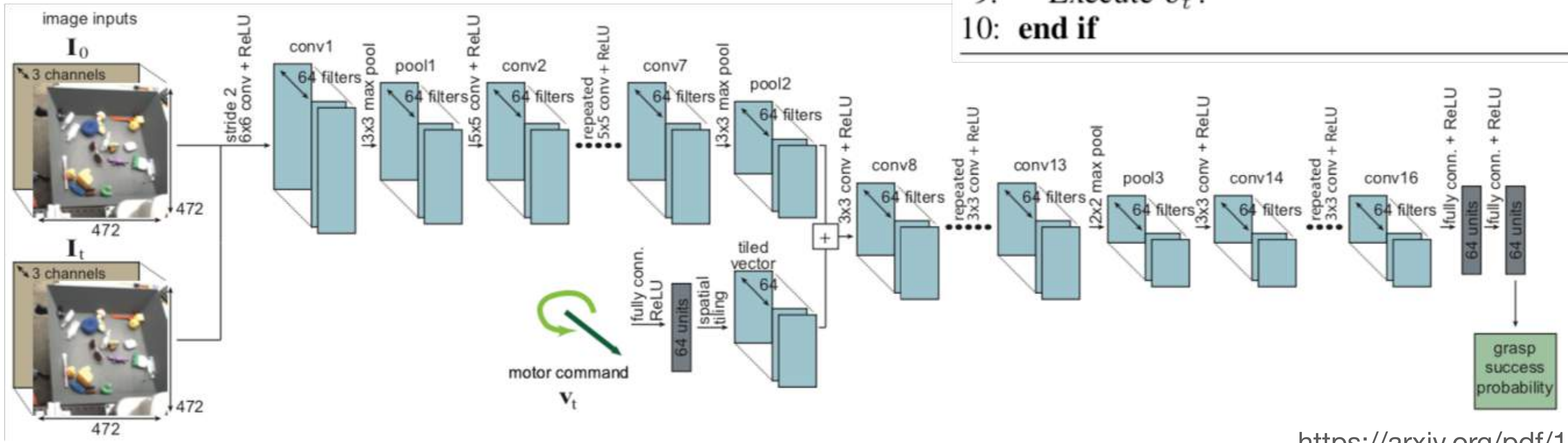




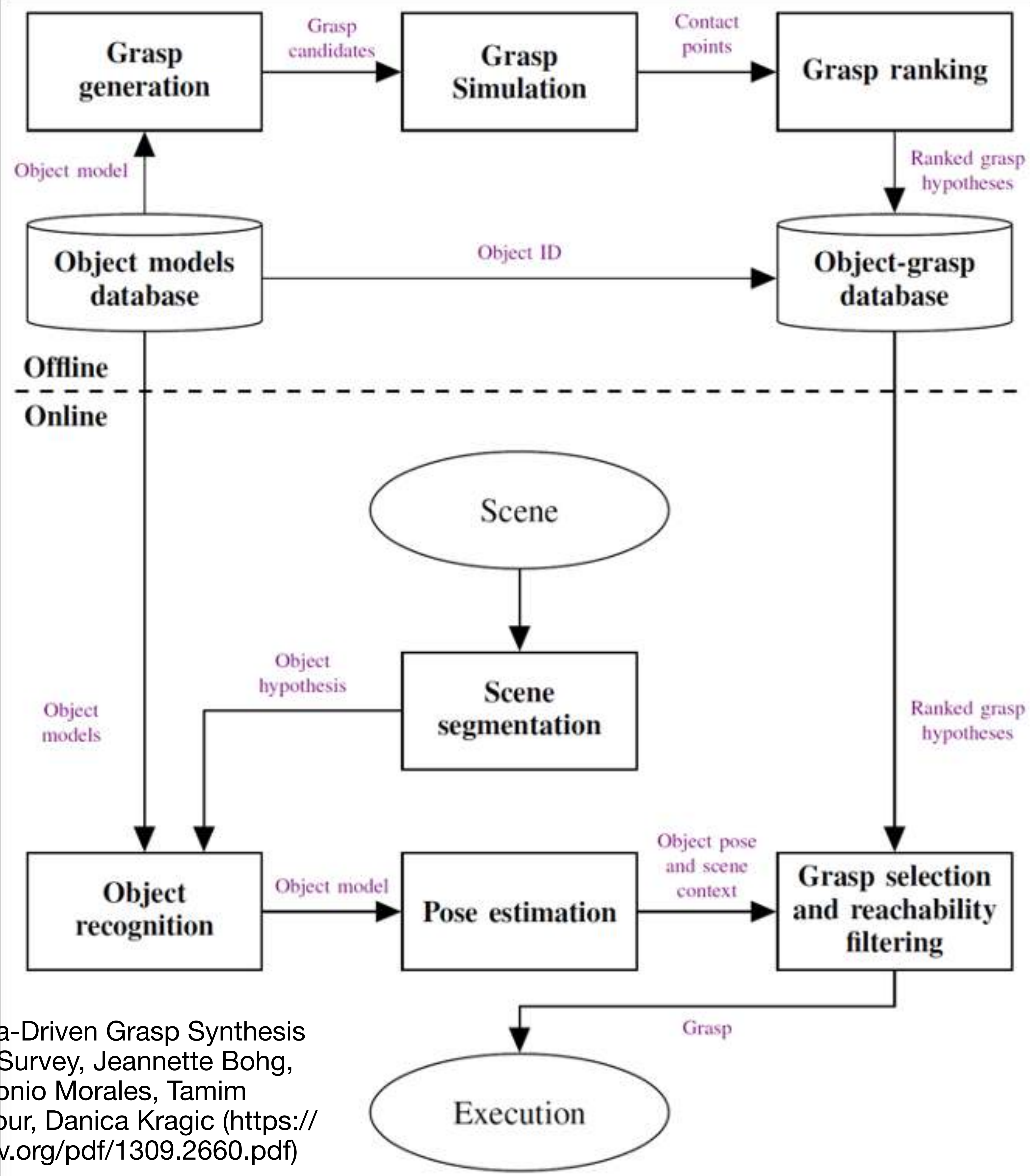
Algorithm 1 Servoing mechanism $f(\boldsymbol{I}_t)$

Given current image $\boldsymbol{I}_t$ and network g.
Infer $\boldsymbol{v}_t^\star$ using g and CEM.
Evaluate $p = g(\boldsymbol{I}_t, \emptyset)/g(\boldsymbol{I}_t, \boldsymbol{v}_t^\star)$.
if $p = 0.9$ **then**
  Output $\emptyset$, close gripper.
else if $p \leq 0.5$ **then**
  Modify $\boldsymbol{v}_t^\star$ to raise gripper height and execute $\boldsymbol{v}_t^\star$.
else
  Execute $\boldsymbol{v}_t^\star$.
end if



https://arxiv.org/pdf/1603.02199v1.pdf

Structured Decomposition of Vision-based Picking



- Data-Driven Grasp Synthesis - A Survey, Jeannette Bohg, Antonio Morales, Tamim Asfour, Danica Kragic (https://arxiv.org/pdf/1309.2660.pdf)

Structured Decomposition of Vision-based Picking

Hierarchical Task Decompositions and Skill Reusability

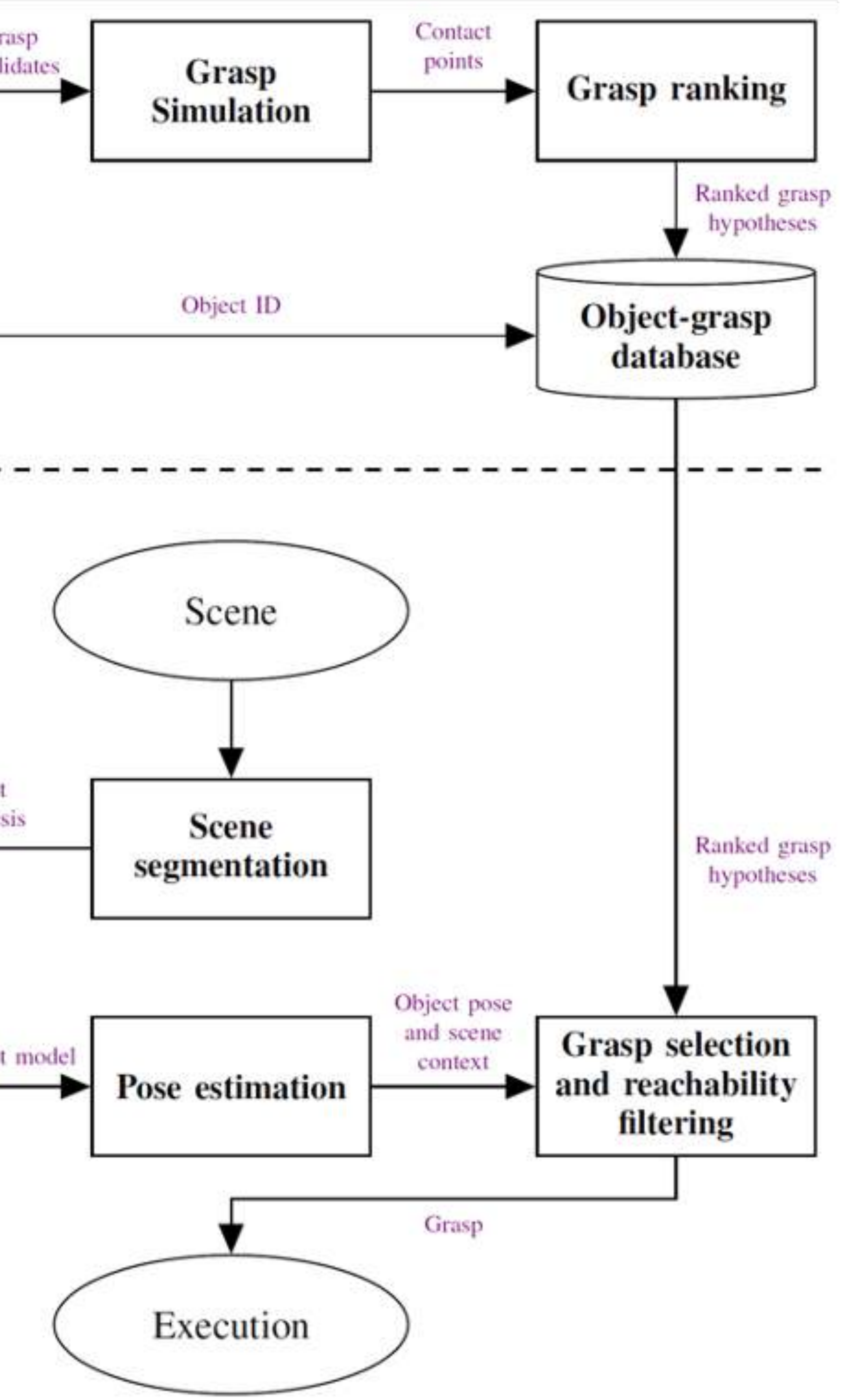
Scene Segmentation
- What we are going to interact with …

Object Recognition
- Representation & Classification

Pose Estimation
- Object & Picker

Pick Planning
- Picker & Arm

Pick Execution
- MoveIt & PickIt



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System Integration of Object-centered Robotic Manipulation

Object-Centric Generalization

- **Generalization via objects**
  - across different objects, between similar (or identical) objects in different task instances
- **Usually enough to generalize across task instances**
  - Generalizing across different objects will require both motor skills and object models that adapt to variations in object shape, properties, and appearance.

System Integration of Object-centered Robotic Manipulation

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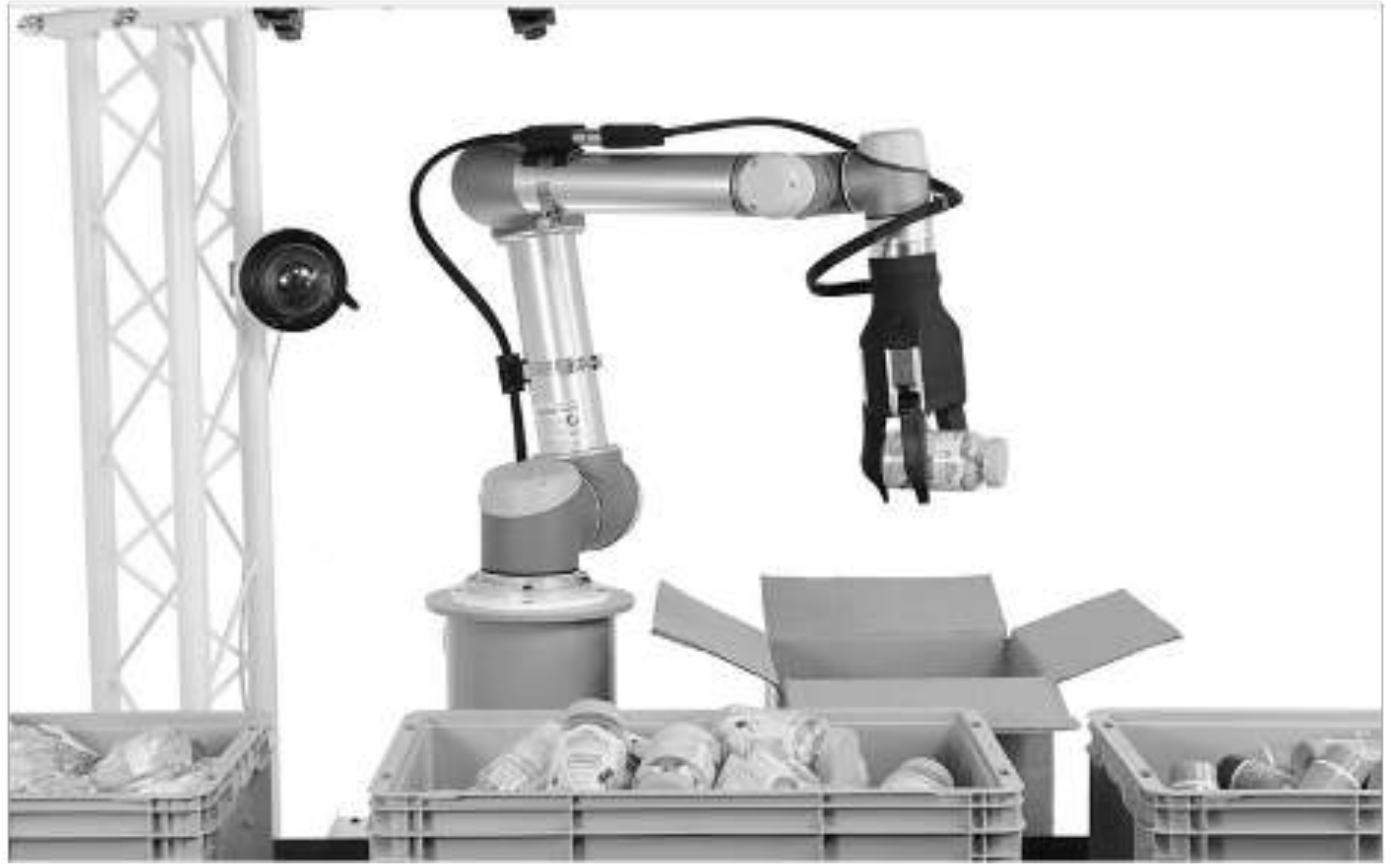
System Integration of Object-centered Robotic Manipulation

Object-Centric Generalization

- **Abstract representations**
  - Find a representation under which we can consider a family of objects to be equivalent or identical, even though they vary substantially at the pixel or feature level.



System Integration of Object-centered Robotic Manipulation

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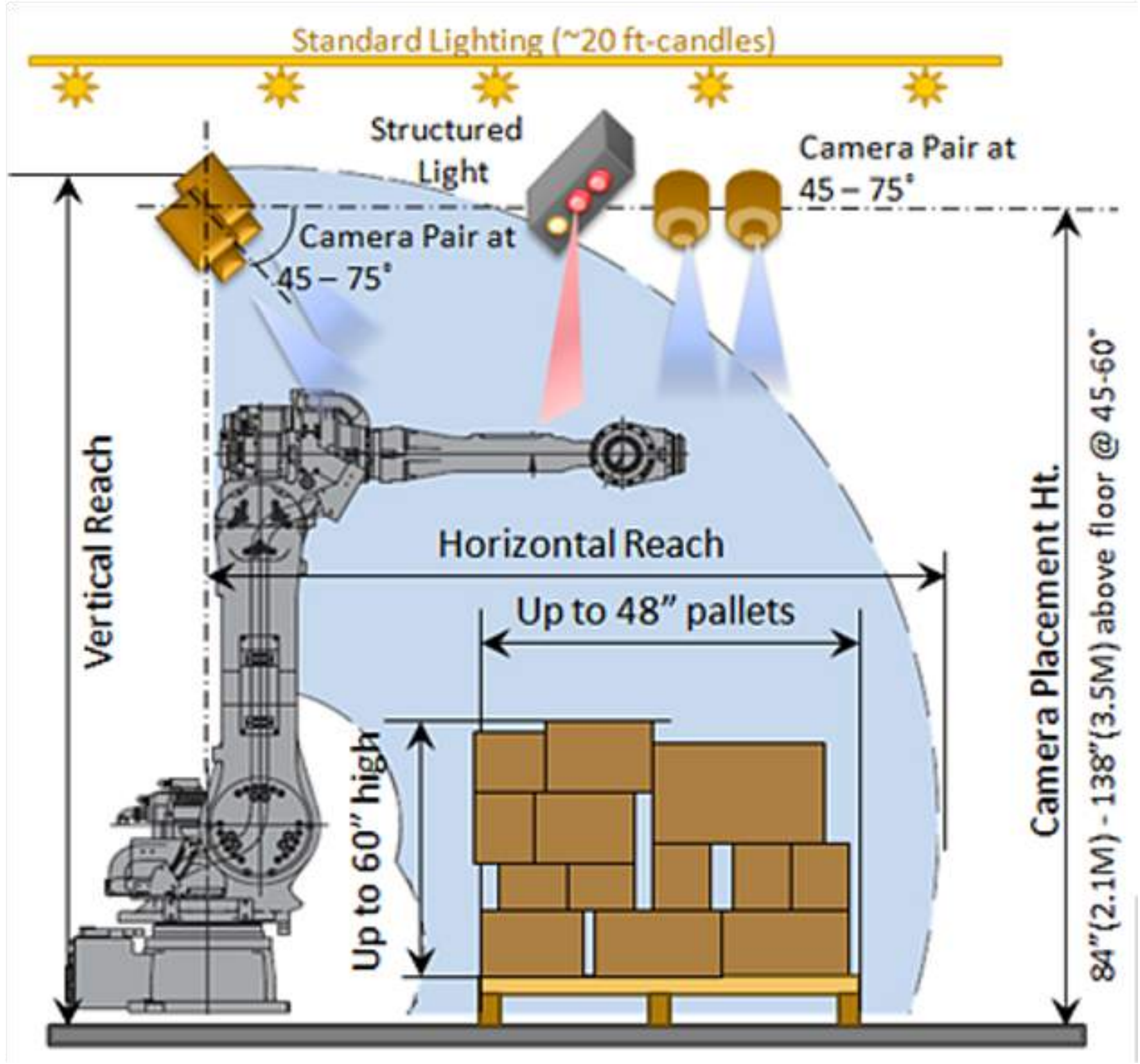
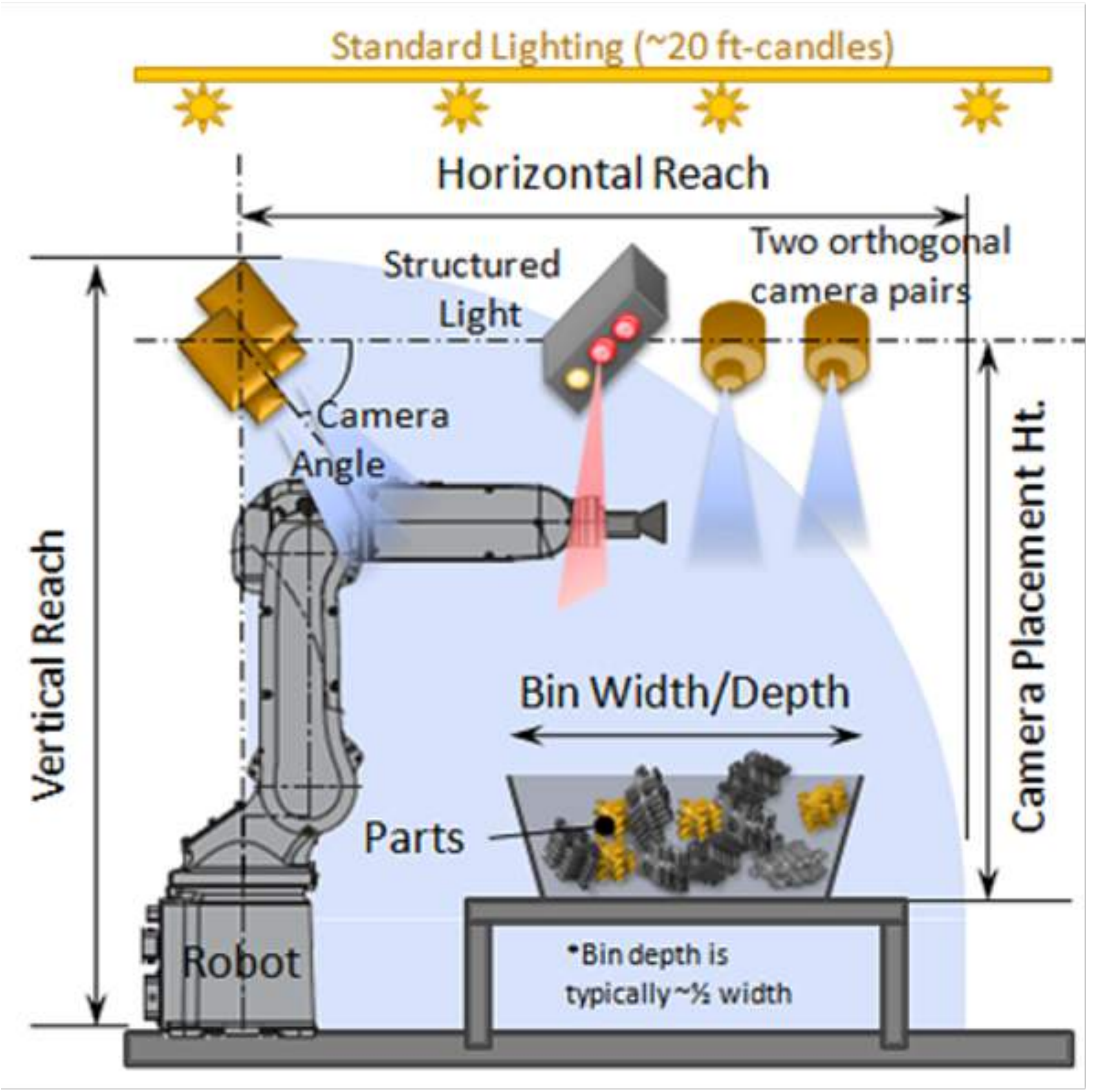
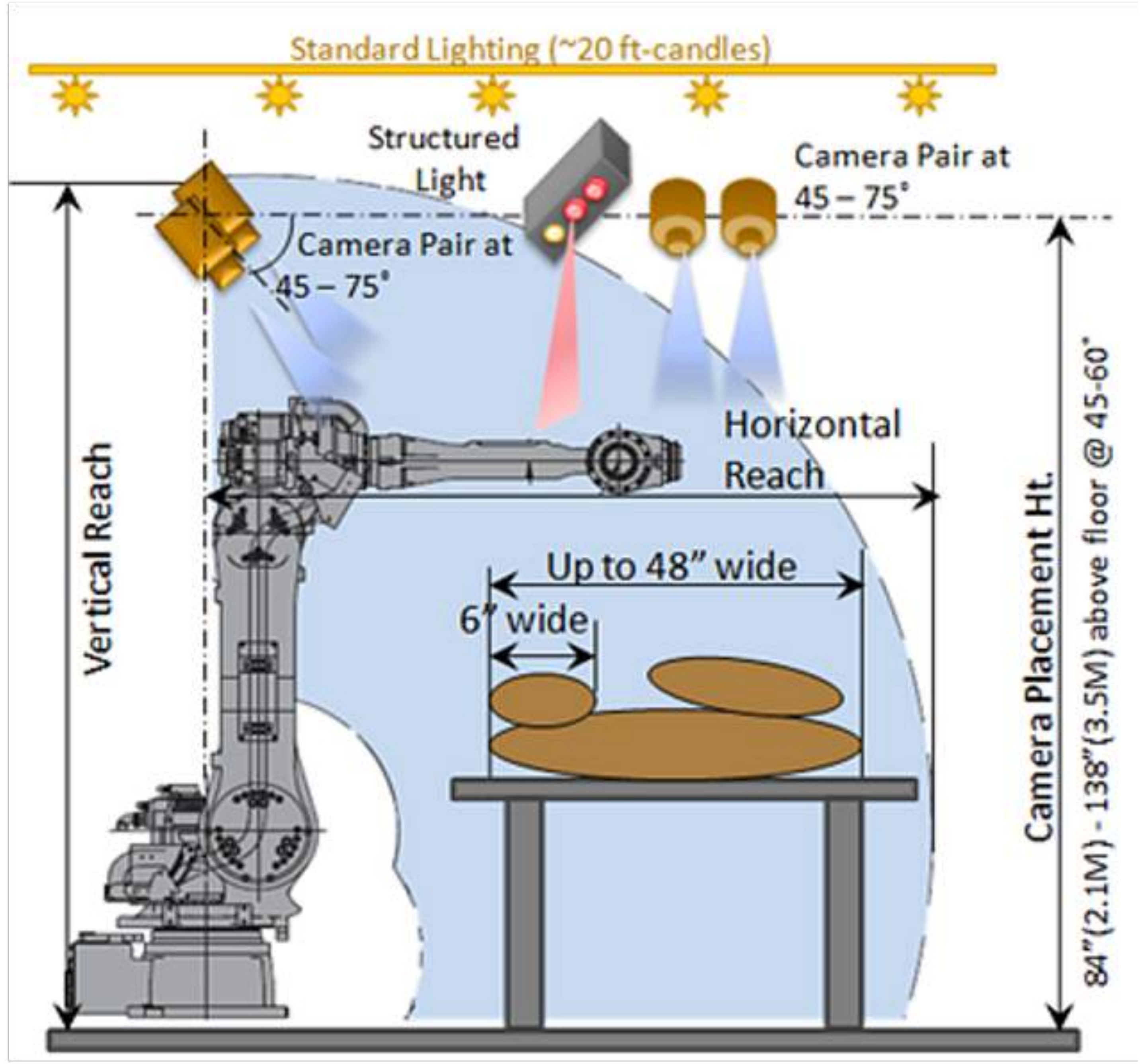
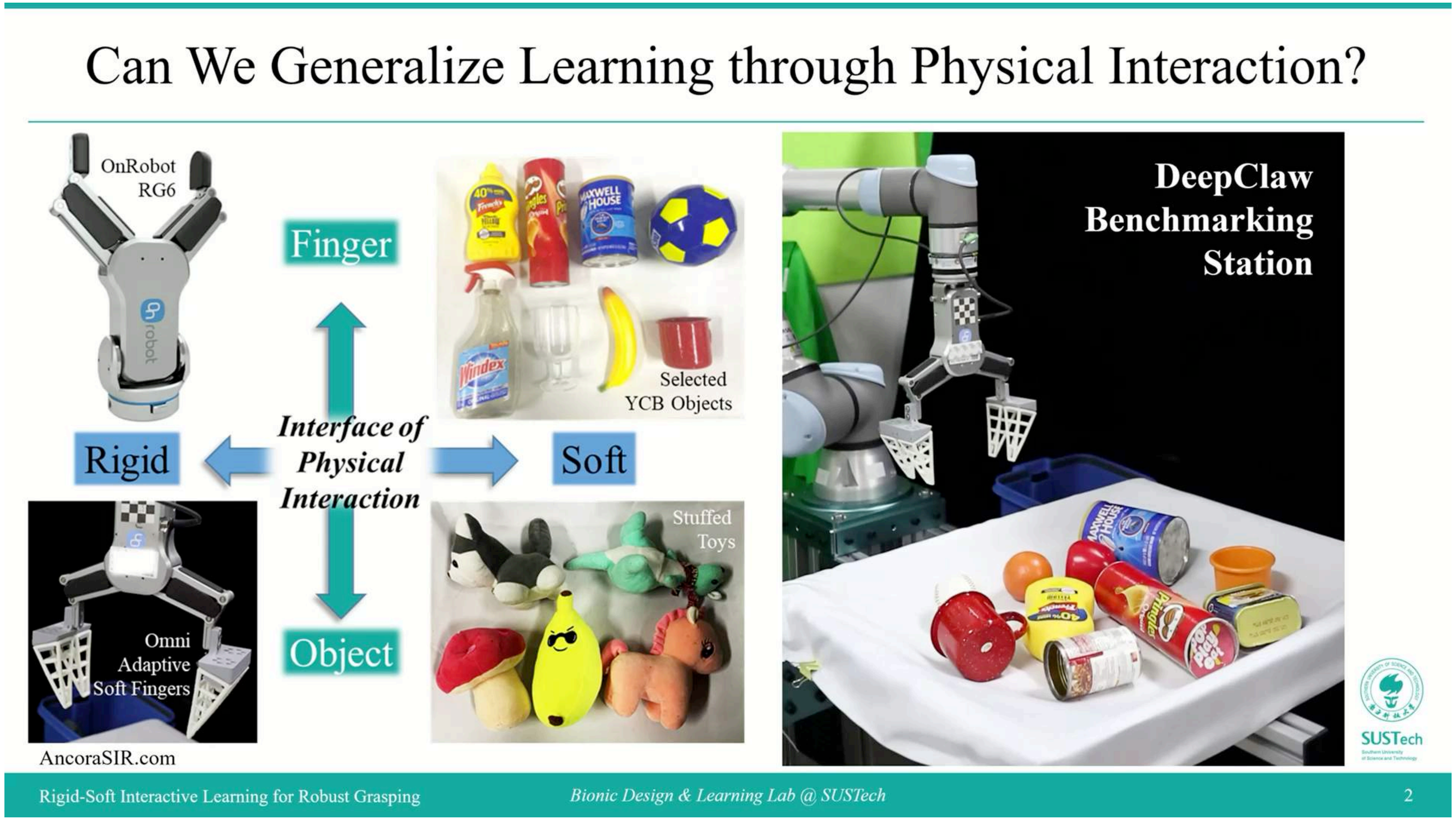






Discovering Novel Concepts and Structures

A structured hierarchy for learning structural skills



Course Overview

Welcome to [ME336]

Machine Intelligence Design & Learning Lab

Course Instructor

Course Advisor

仿生设计
与学习
实验室
Bionic Design
& Learning Lab
+
MIT TOY LAB

main DL
In Collaboration with MIT

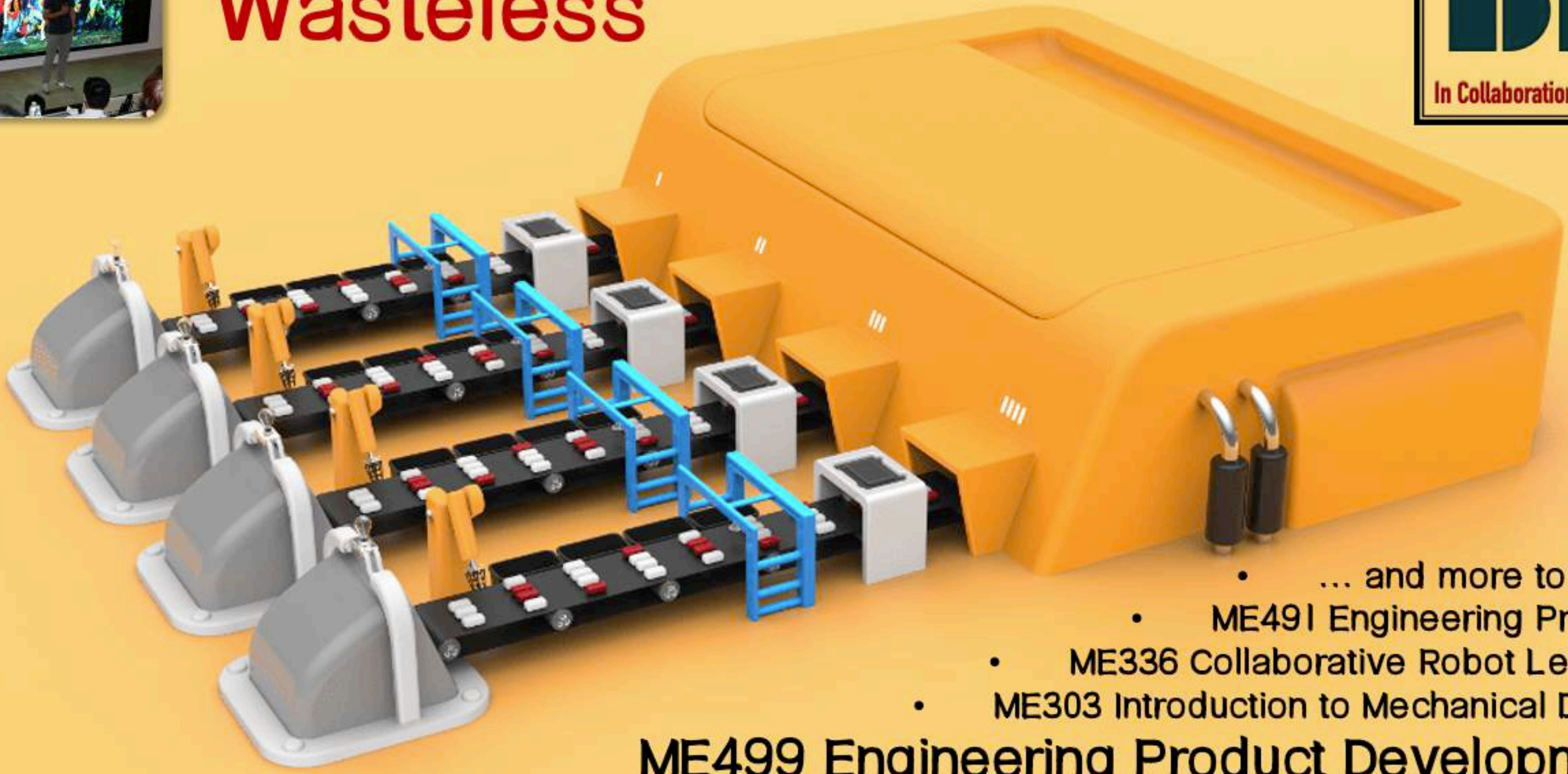
[ME303] Machine Design *(in Autumn)*

[ME336] Robot Learning *(in Spring)*

[ME491] Industrial Practice *(in Summer)*

Design Theme of the Year

Wasteless

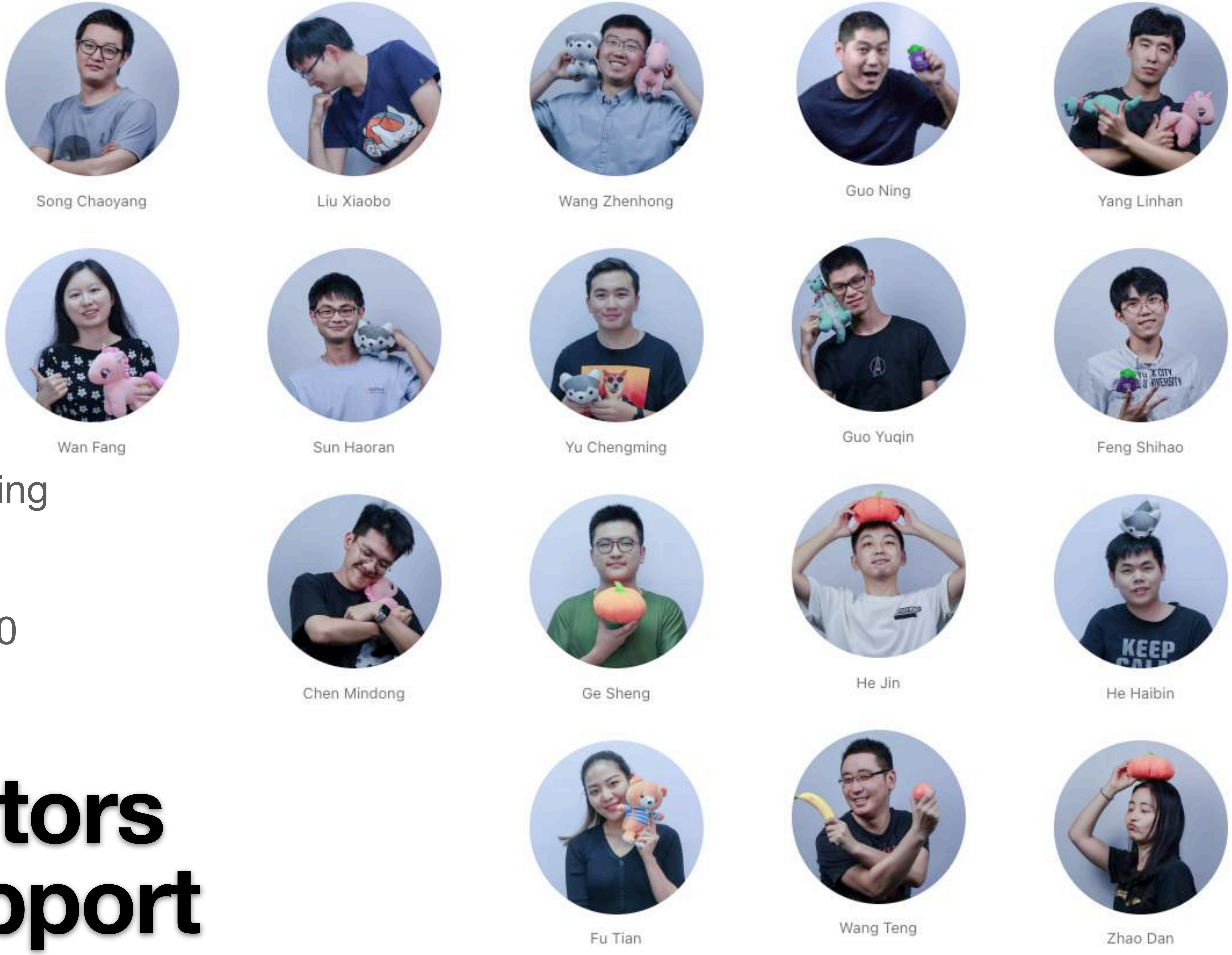


In Collaboration with MIT

- ... and more to come
- ME491 Engineering Practice
- ME336 Collaborative Robot Learning
- ME303 Introduction to Mechanical Design

ME499 Engineering Product Development

Course Instructors & Teaching Support



Location:

- Room 235, New Engineering Building

Time:

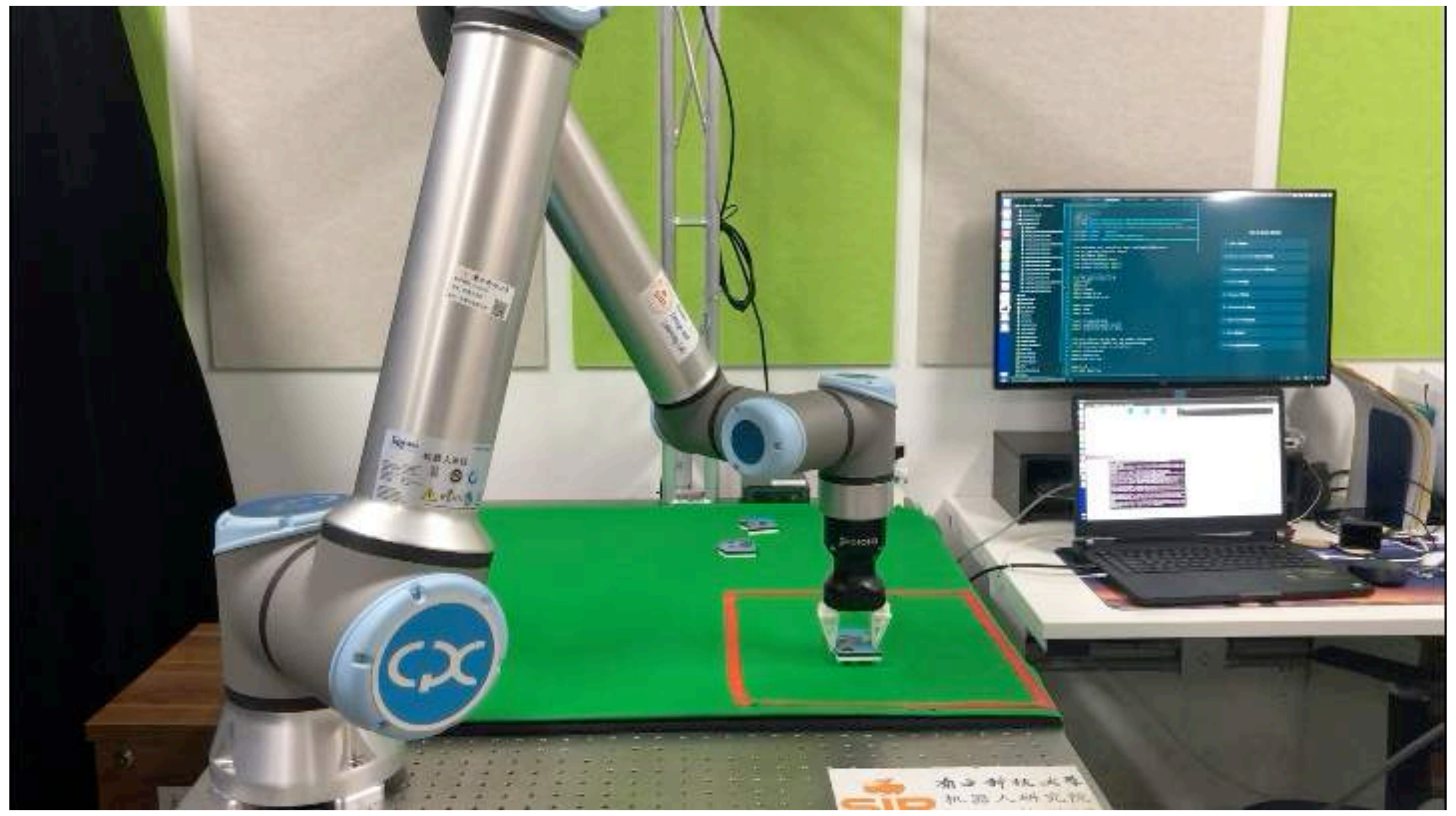
- Lecture on Wednesday: 1400~1550
- Lab on Friday: 0800-0950

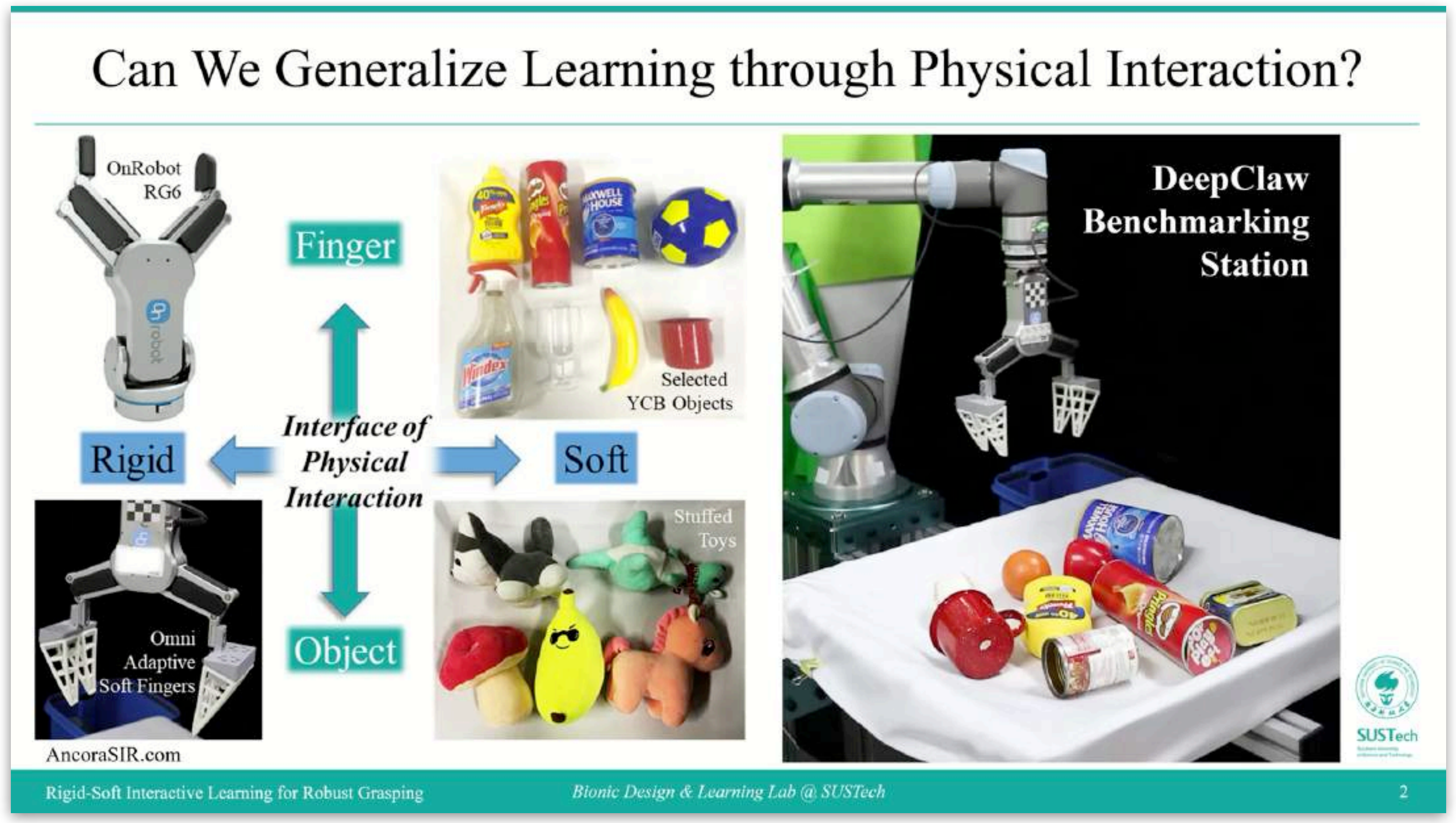
3 Mini Courses + 2 Lab Assignments + 1 Themed Project

Room 235, New Engineering Building

Subject to Change

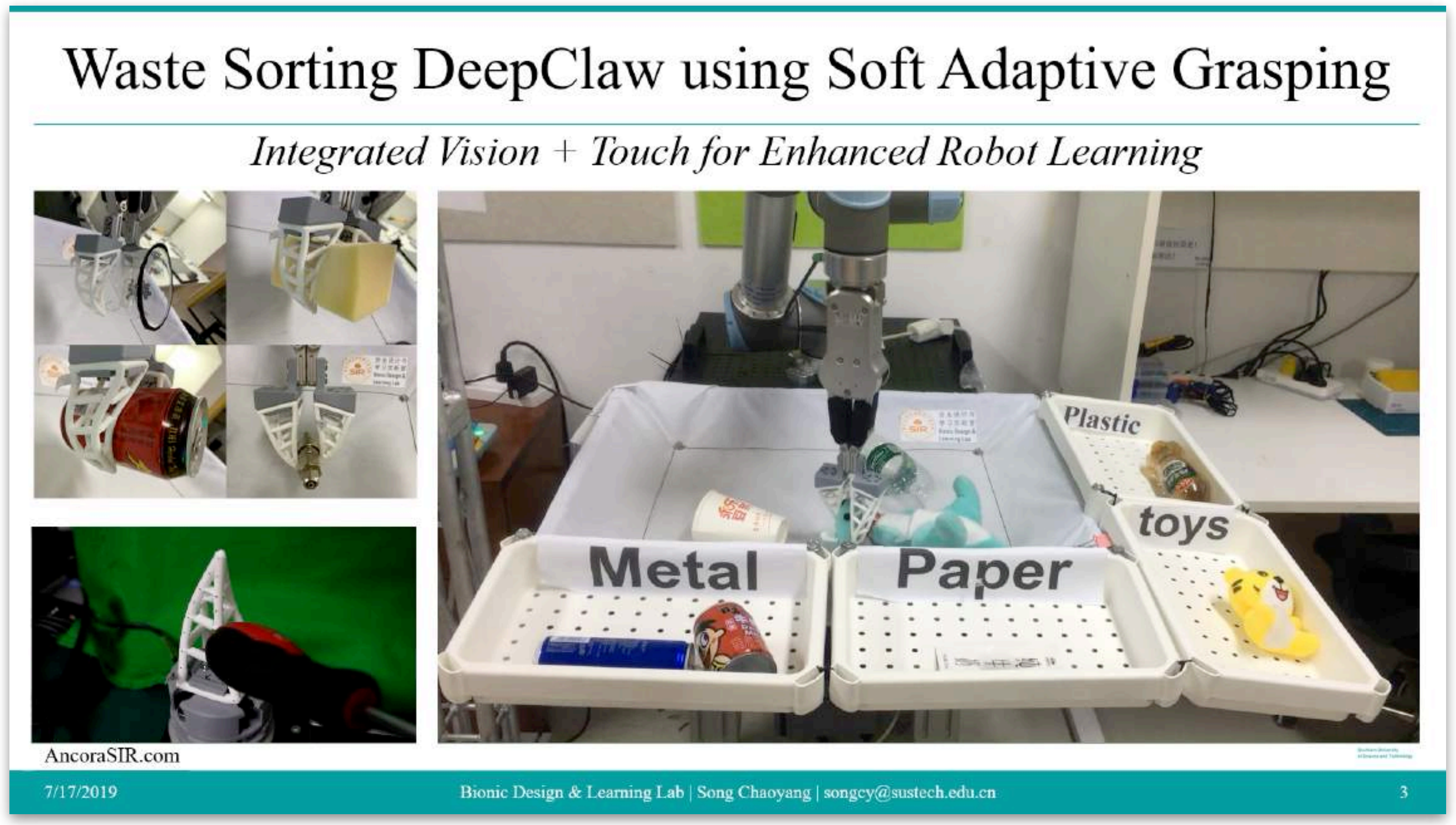
- **Human-Centered Robot Games (5 weeks)**
  - Introduction to the human-centered design of learning systems for competitive gaming with a robot player.





- **Dive Deep with Robot Learning (5 weeks)**
  - Advanced topics focusing on the system integration and algorithm implementation of robot learning.

- **Wasteless Robot Learning Challenge (5 weeks)**
  - A themed challenge among student teams to design and develop a learning system for a competitive picking for waste sorting




ME303 INTRO TO MECH DESIGN
仿生设计
与学习
实验室
Bionic Design
& Learning Lab
main
DL
In Collaboration with MIT
Team Red
Team Green
Team Blue
Team Yellow

Machine Intelligence Design & Learning Lab

“Wasteless” Themed Lab Project, Space, and Equipment

- Designed by SUSTech Students
- Used by SUSTech Students
- Learned by SUSTech Students


main
DL
In Collaboration with MIT
Team
Red

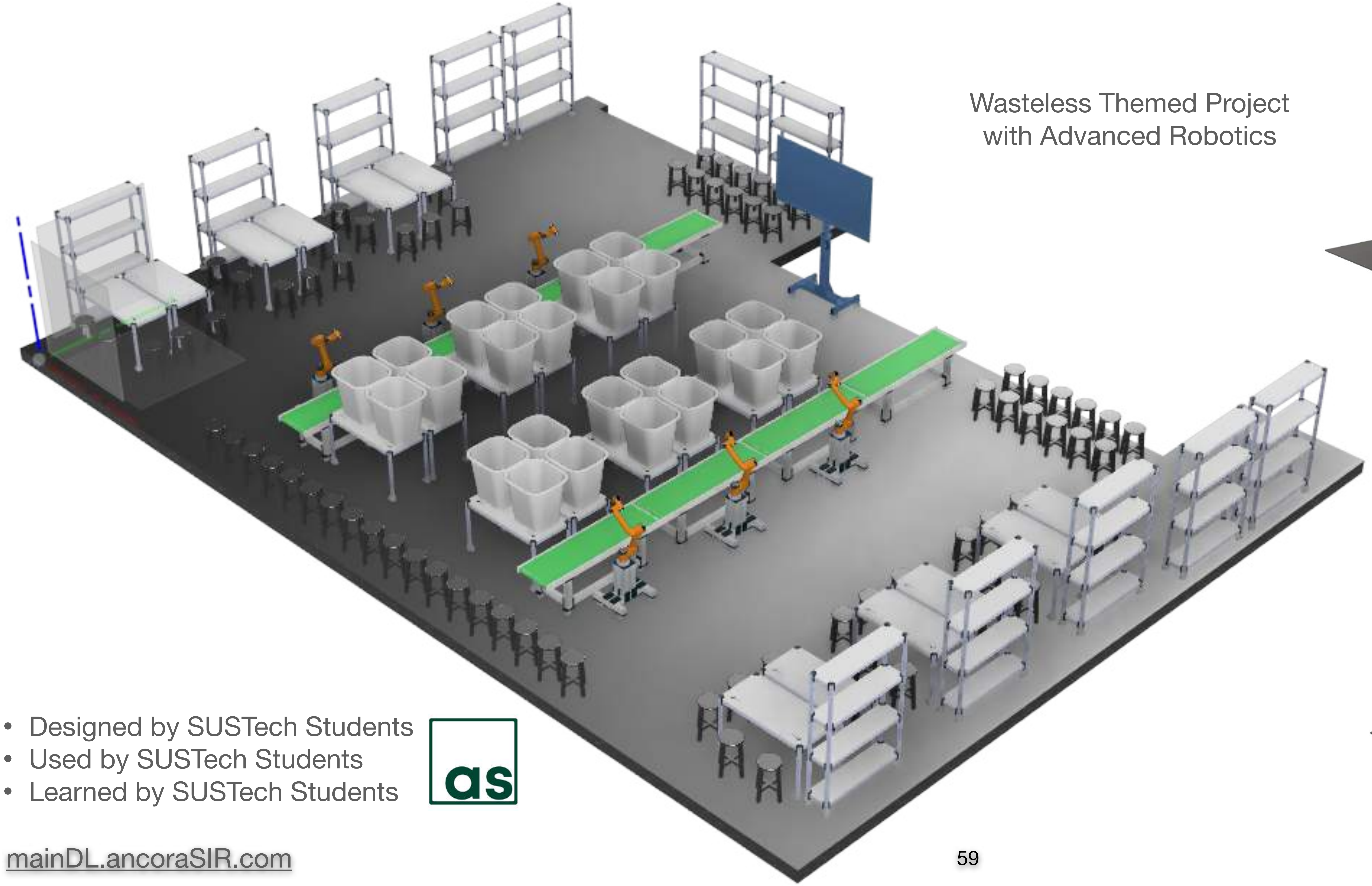

main
DL
In Collaboration with MIT
Team
Green


main
DL
In Collaboration with MIT
Team
Blue

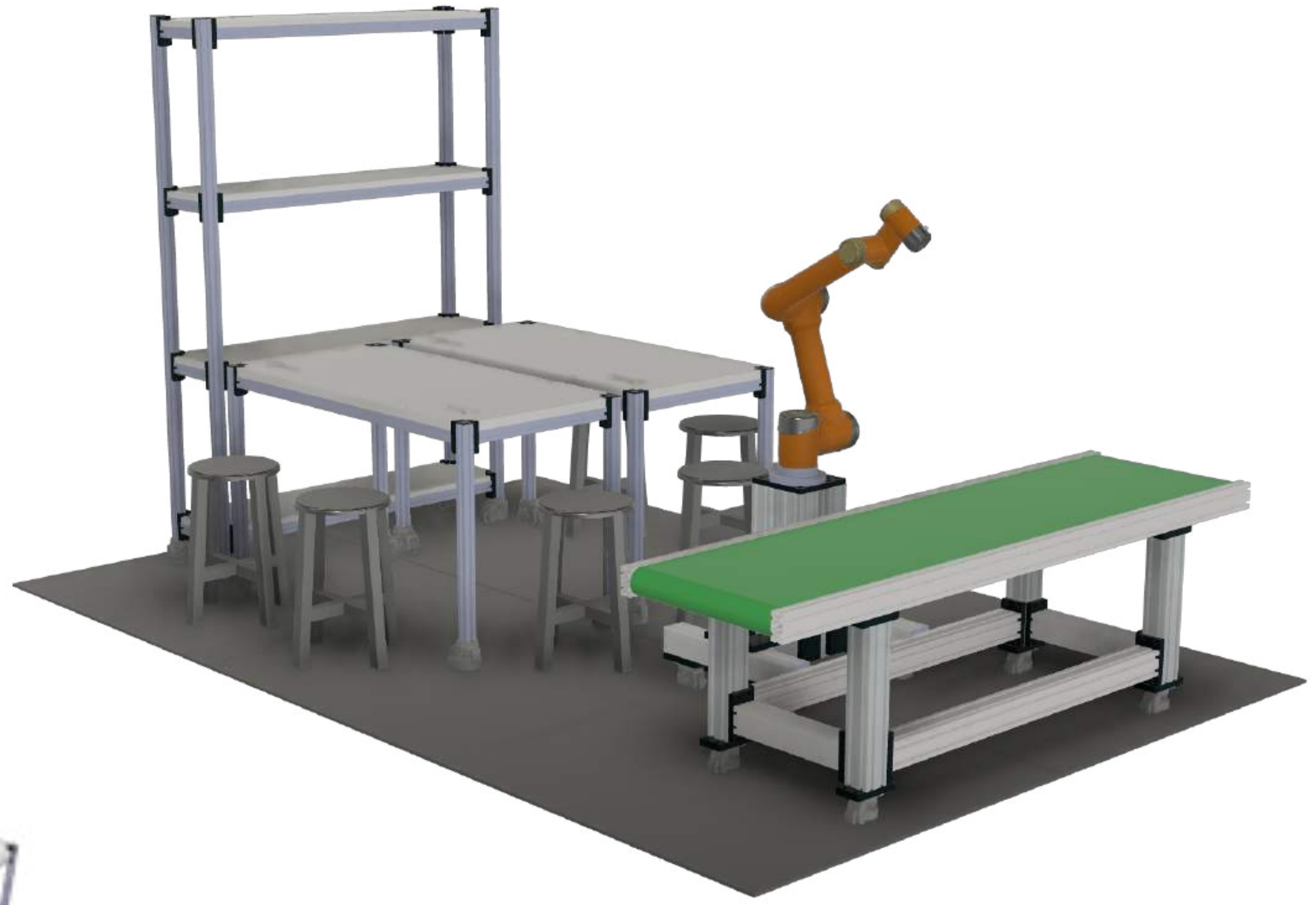

main
DL
In Collaboration with MIT
Team
Yellow

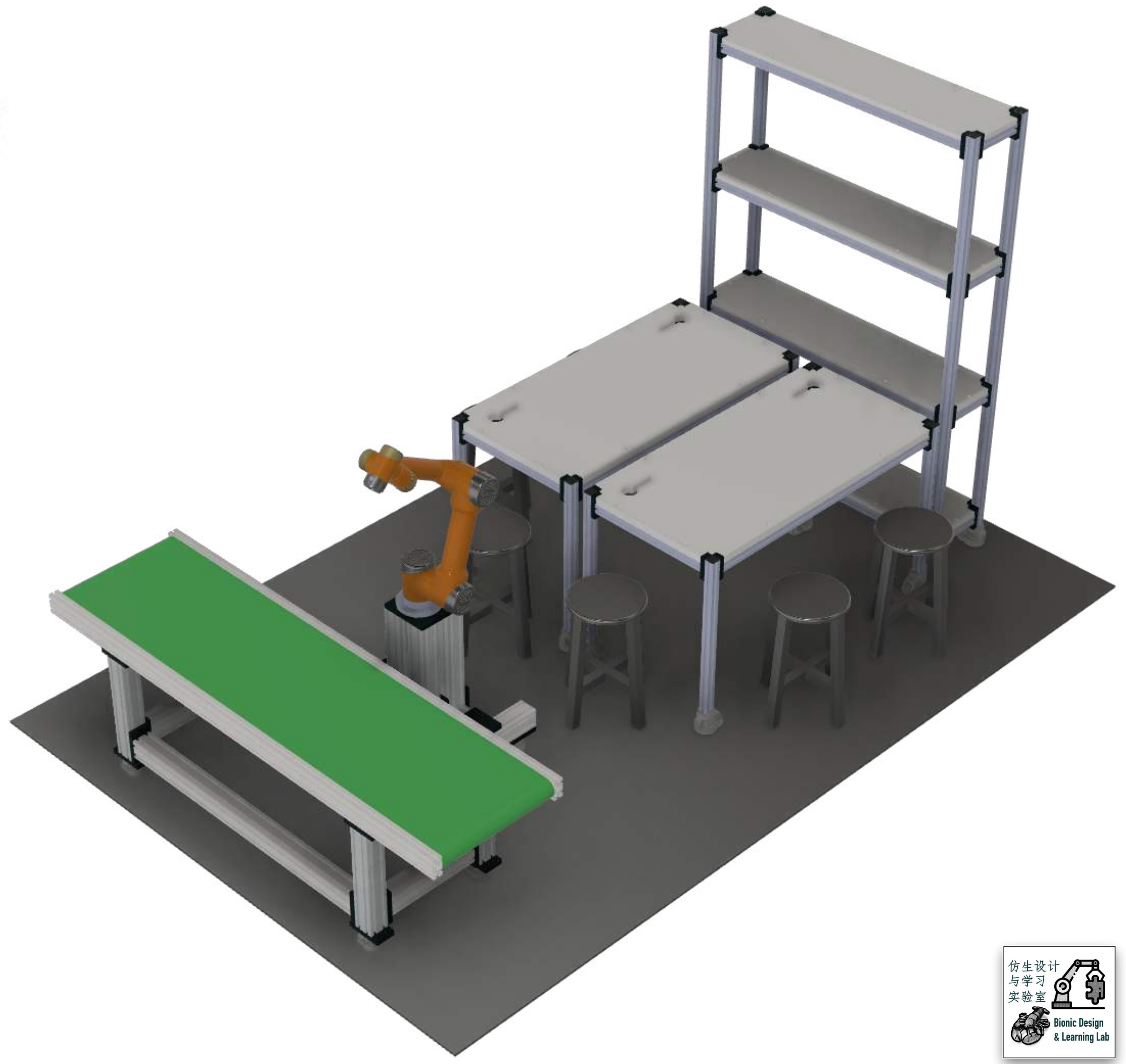
For ME336, From ME303

Reconfigurable Automation SYSTEM for Higher Education



Wasteless Themed Project
with Advanced Robotics





- Designed by SUSTech Students
- Used by SUSTech Students
- Learned by SUSTech Students

as

All Students of the Class
(~30 per class)

2 Teams of Student Designer
(~15 per team)

Team Red

Team Green

3 Task Forces of Student Designers
(7~8 per task force)

Task Force [Arnold]

Task Force [Bernard]

8 Team Roles
per team

System Integrator
Financial Officer
Tool Officer
Information Officer
Team Site Master
Safety Officer
Yoda Officer
Video Log Officer

5 Task Roles
per task force

Design Engineer
Algorithm Engineer
System Engineer
Software Engineer
Data Engineer

ME336

Teams & Task Forces

ME336
Collaborative Robot Learning

For more information, please visit mainDL.ancoraSIR.com

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Thank you

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