Towards safe human-to-robot handovers of unknown containers
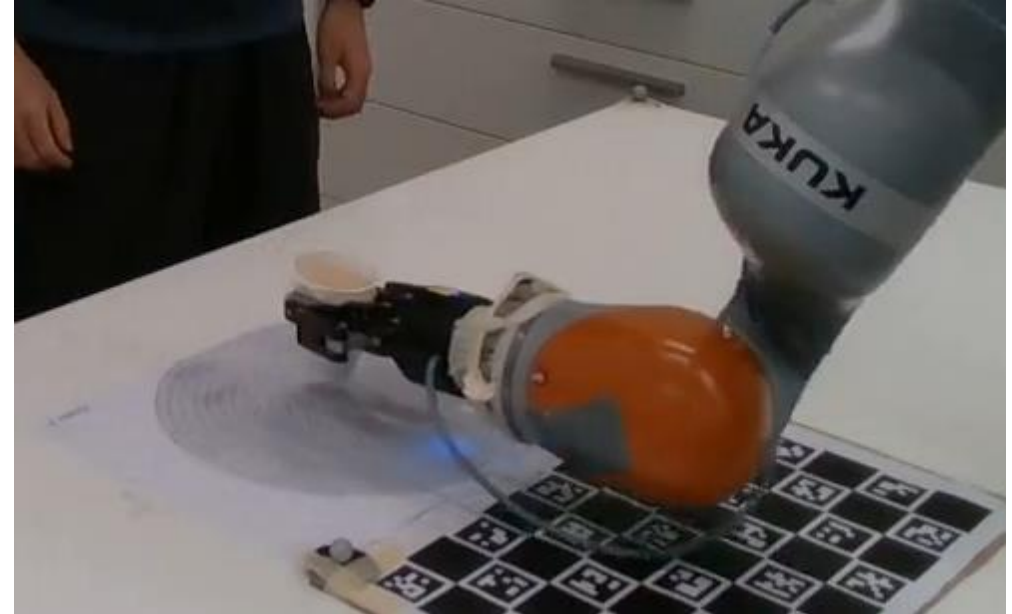
Yik Lung Pang, Alessio Xompero, Changjae Oh, Andrea Cavallaro

http://corsmal.eecs.qmul.ac.uk/safe_handover.html

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Human-robot interaction in the real world

Unsafe for human

Unsafe for the container

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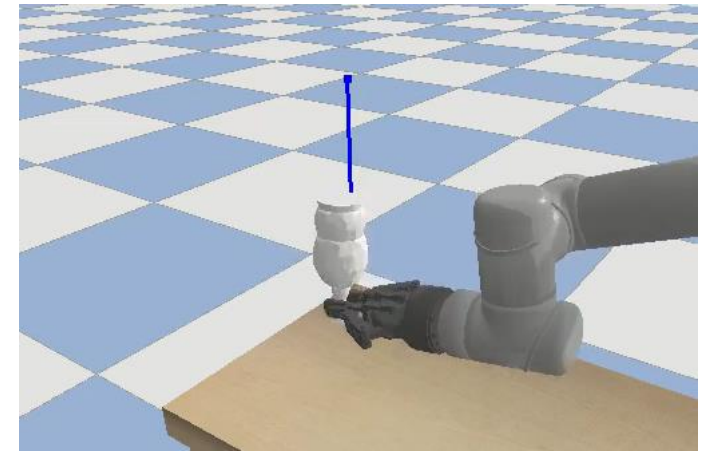
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Simulation of human-robot interaction
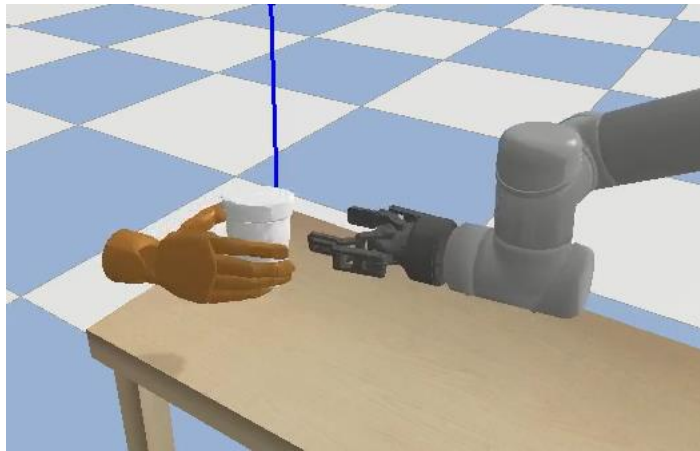
No safety concerns
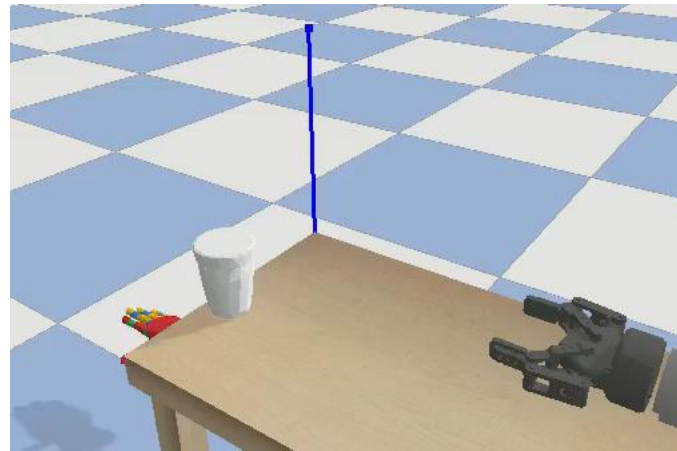
Faster than real time

Automated environment reset

Addressing limitations of handover simulations

Limitations of existing simulators for handovers	Proposed real-to-simulation framework
✖ Visualization of trajectory only	✔ Simulation of contact forces
✖ Primitive shape objects or 3D scan required	✔ Vision based object reconstruction
✖ Static or limited dynamic setup	✔ Fully dynamic setup

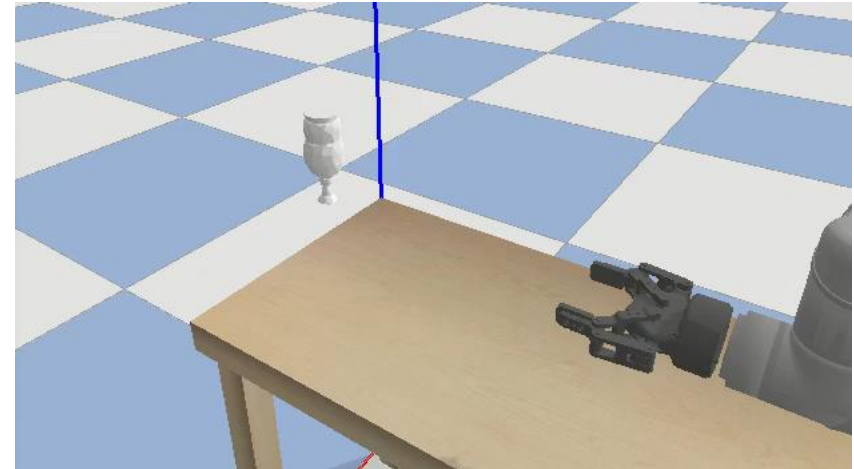# Real recordings to simulated human-to-robot handovers

RGB video

Simulation

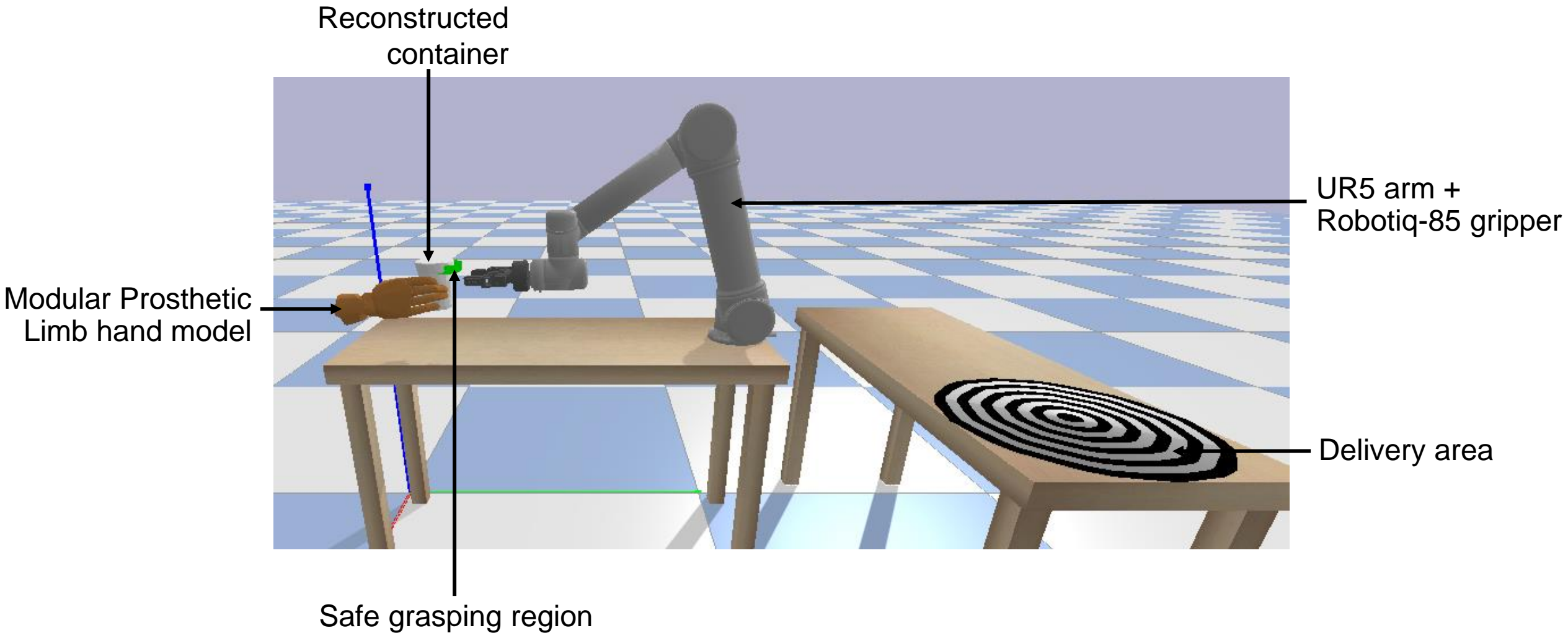Perceptual
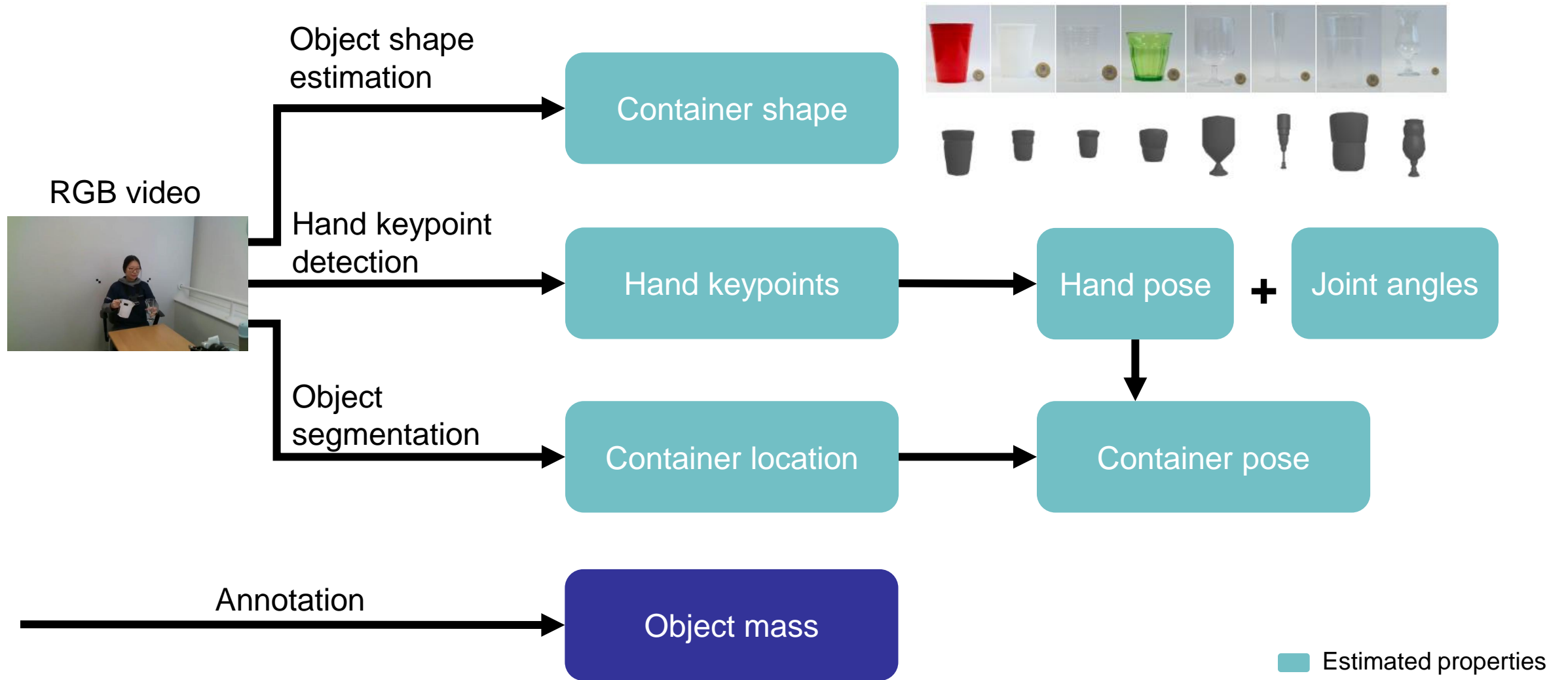estimations
+
Annotations

Human maneuvering

Robot maneuvering

http://corsmal.eecs.qmul.ac.uk/containersmanip.html

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Overview of the handover simulation environment

Reconstructed container

UR5 arm + Robotiq-85 gripper

Modular Prosthetic Limb hand model

Delivery area

Safe grasping region

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Perception pipeline

RGB video

Object shape estimation → Container shape

Hand keypoint detection → Hand keypoints → Hand pose **+** Joint angles

Object segmentation → Container location → Container pose

Annotation → Object mass

Estimated properties
Annotated properties

Robot control

Safe grasping region estimation

Extracting hand keypoints close to container

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Safe grasping region estimation

Obtain unsafe region

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Safe grasping region estimation

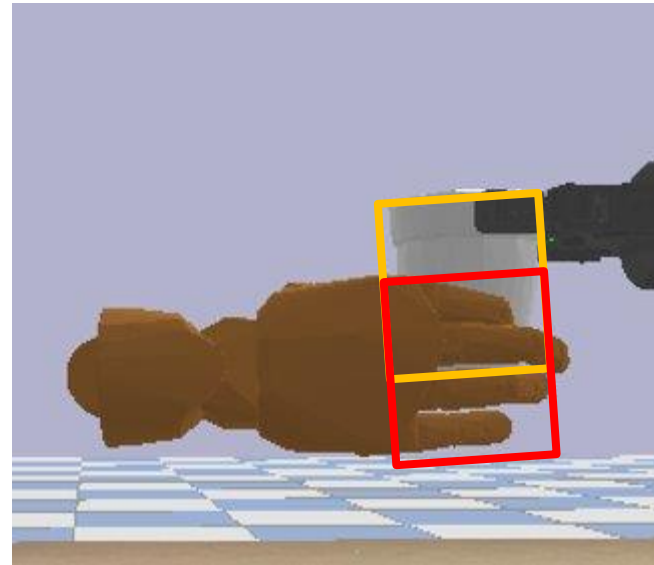Initialize safe region
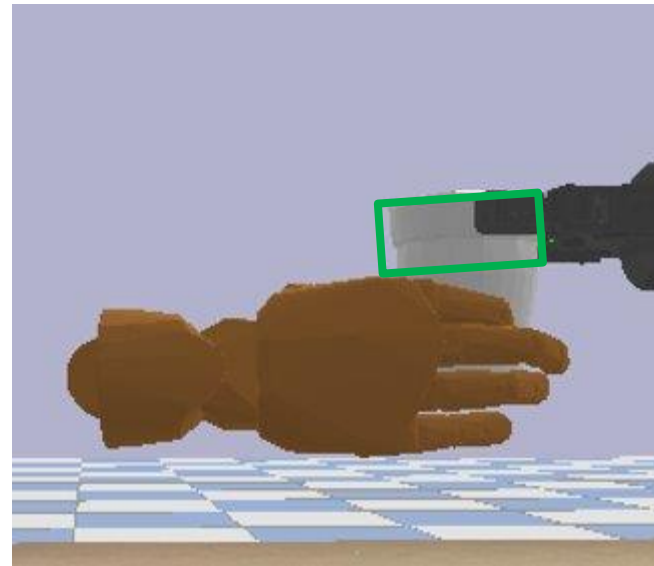

Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

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Safe grasping region estimation

Remove unsafe region from safe region

Initialized safe grasping region
Unsafe grasping region
Final safe grasping region
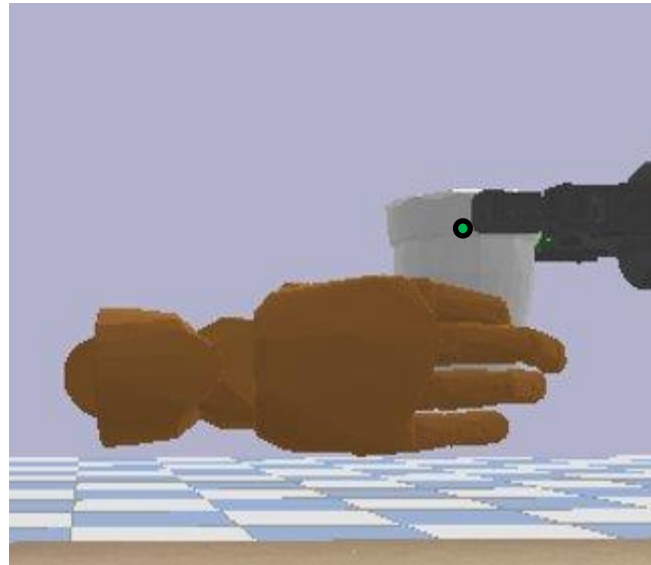
Safe grasping region estimation

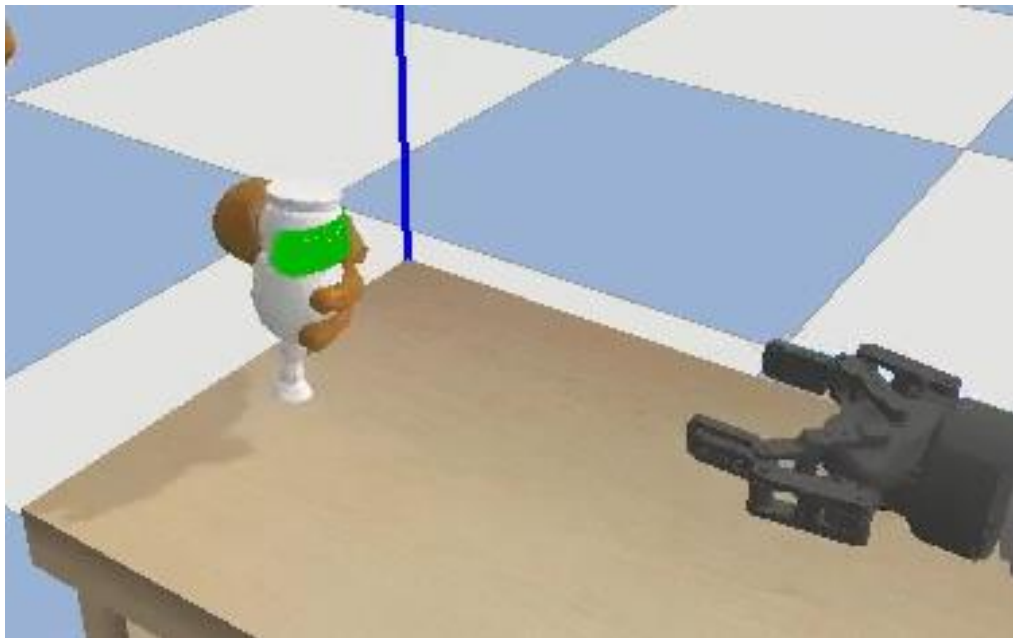Obtain final grasping location

Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

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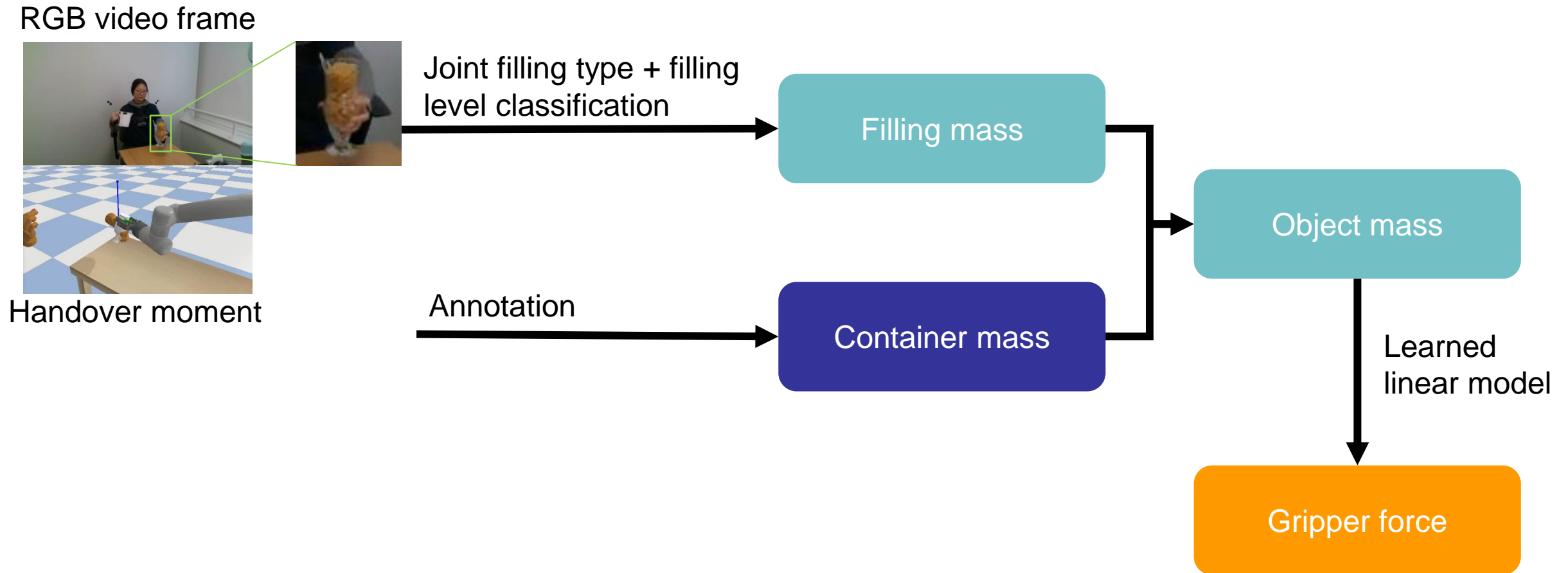shared manipulation and learning

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Safe grasping region estimation

Safe grasping region available

Safe grasping region unavailable
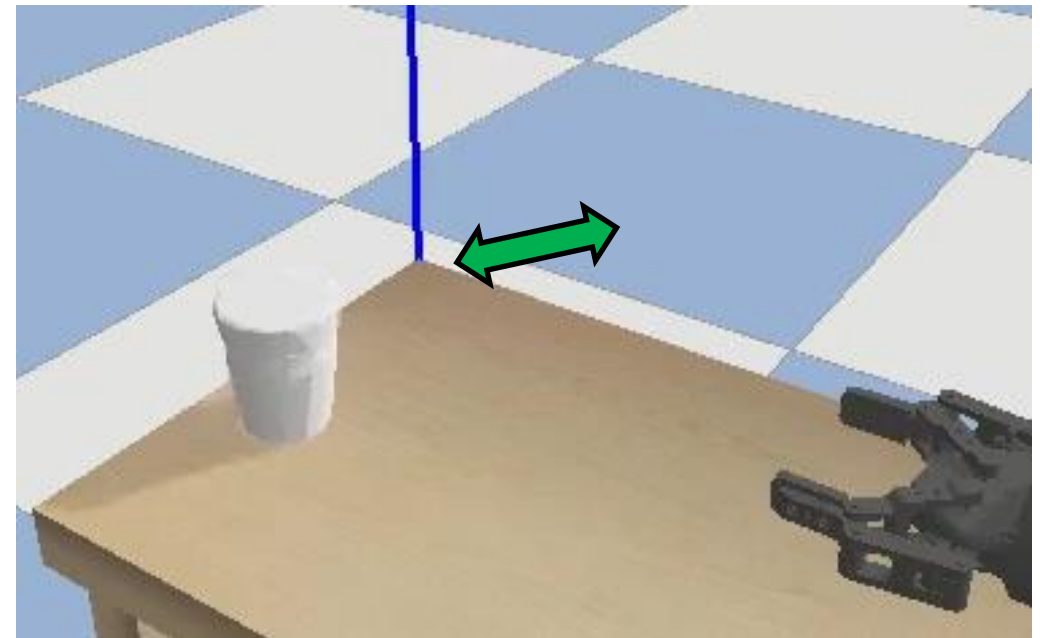
Filling mass estimation and gripper force

RGB video frame

Handover moment

Joint filling type + filling level classification

Annotation

Filling mass

Container mass

Object mass

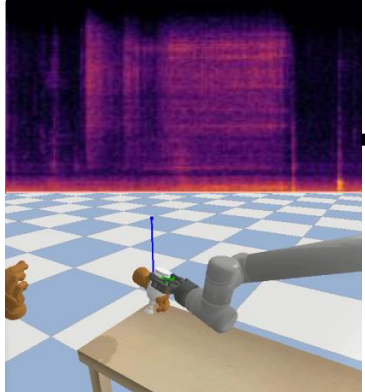Learned linear model

Gripper force

Audio classification of the content of food containers and drinking glasses
Donaher, Xompero, Cavallaro
European Signal Processing Conference (EUSIPCO), 2021

Estimated properties
Annotated properties
Robot control parameters

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Filling mass estimation and gripper force

Audio spectrogram[1]

Handover moment

Joint filling type + filling level classification →
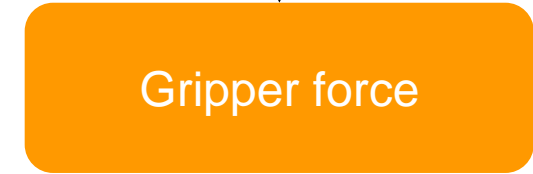
Annotation →

Filling mass

Container mass

Object mass

Learned linear model ↓

Gripper force

Audio classification of the content of food containers and drinking glasses
Donaher, Xompero, Cavallaro
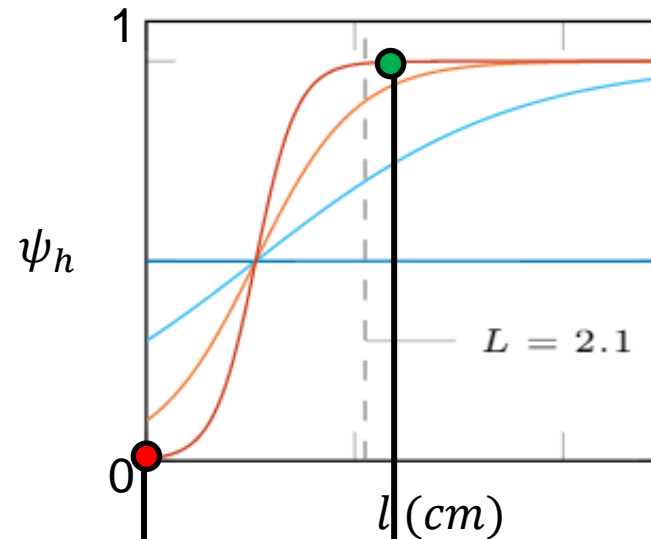European Signal Processing Conference (EUSIPCO), 2021

- Estimated properties
- Annotated properties
- Robot control parameters

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Modelling human safety for handovers
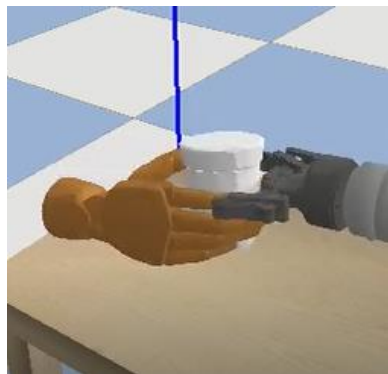
Human safety (sigmoid) $\psi_h = \dfrac{1}{1+e^{\left(\frac{2l}{L}-1\right)\ln\left(\frac{1-c}{c}\right)}}$

l: Minimum distance between hand model and robot
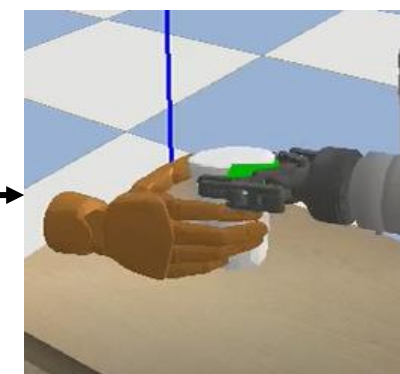L: Minimum safety distance
c: Sensitivity parameter
— : $c = 0.5$
— : $c = 0.7$
— : $c = 0.9$
— : $c = 0.995$

ψ_h

$L = 2.1$

$l\,(cm)$

Unsafe for human

Safe for human
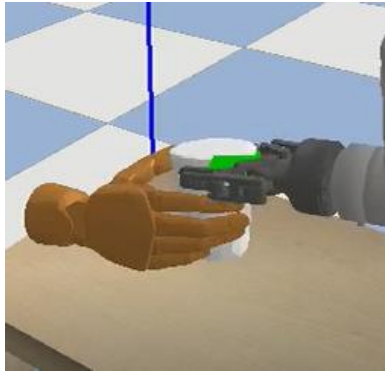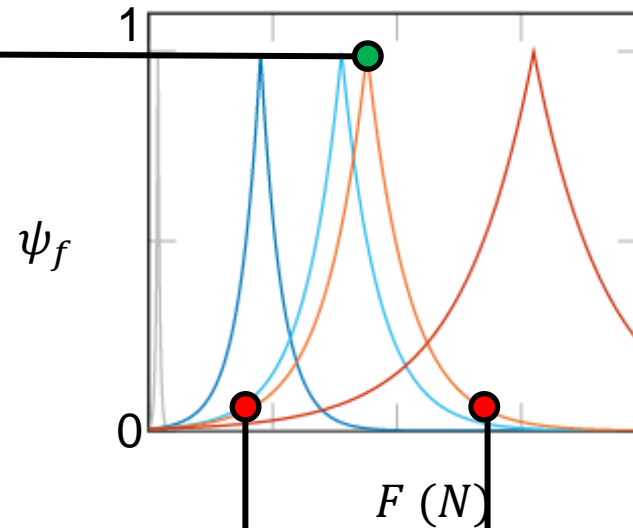
Pinching the hand

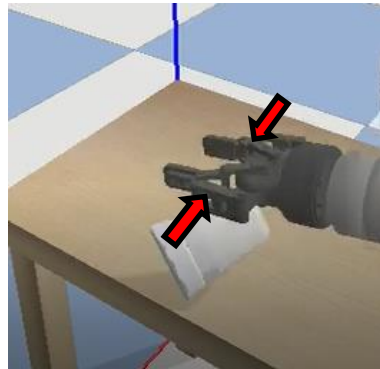# Modelling object safety for handovers

Safe for object

Object safety (exponential) $\psi_f = e^{\frac{|\tilde{F} - \hat{F}|}{\hat{F}} \ln(1-c)}$

$\tilde{F}$: Normal force predicted to be applied by the robot
$\hat{F}$: Normal force required to hold and deliver the object
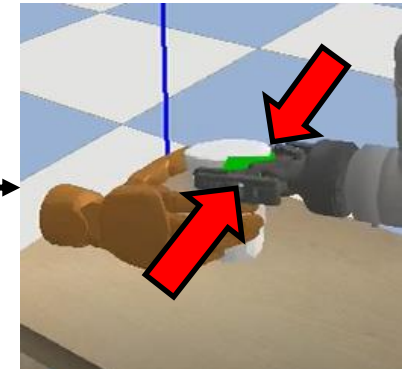c: Sensitivity parameter

—: Empty
—: 50% pasta
—: 90% pasta
—: 50% rice
—: 90% rice

ψ_f

$F\ (N)$

Unsafe for object

Insufficient force

Unsafe for object

Excessive force

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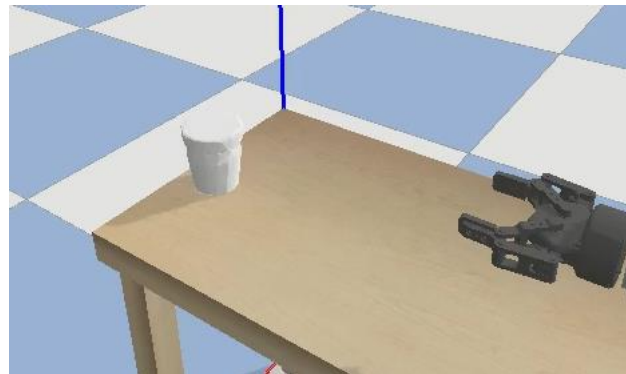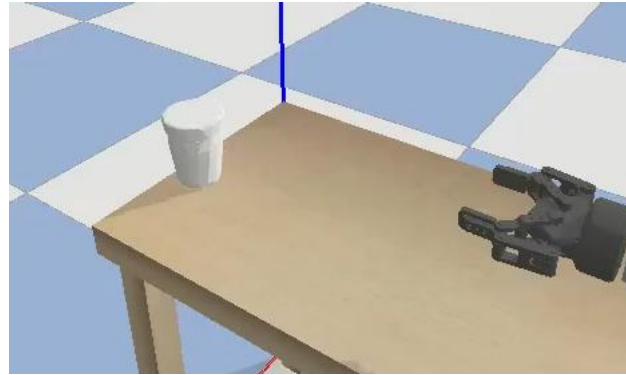shared manipulation and learning

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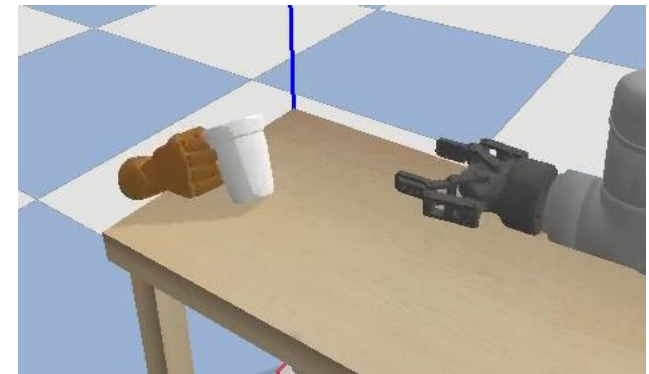University of London
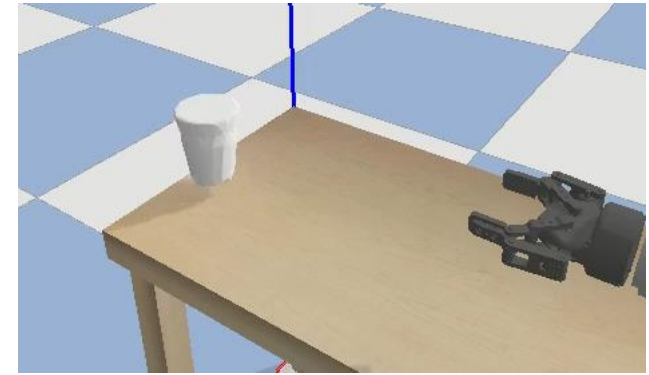
Estimating safe grasping region for handover

RGB input
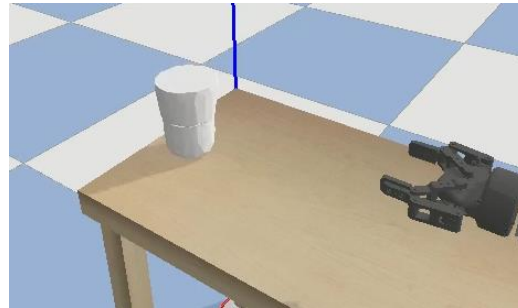
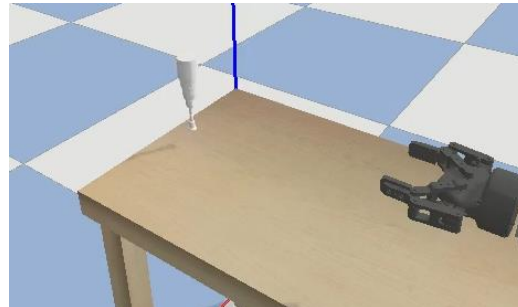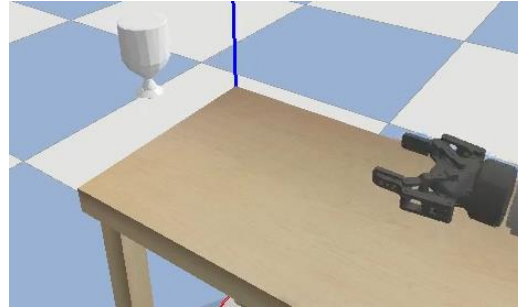With safe grasping region

Without safe grasping region

Handovers of various containers and fillings
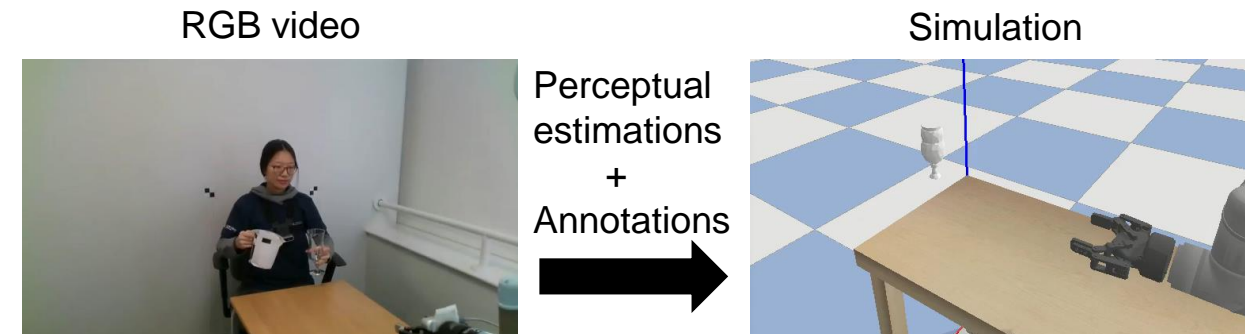
RGB input

Simulated handover

Simulated delivery

Summary

- Novel modular real-to-simulation framework for human-to-robot handovers
  - Handover simulation when *a real robot is not accessible*
  - Real estimation of the *physical properties of an object* **manipulated by a person** (no markers, no MOCAPs, no scanned 3D models)
  - Safe grasping region estimation
  - Quantify the **handover safeness**: human safety and object safety

- Future work
  - Validation with a real setup
  - Improving simulation detail: deformable objects, content dynamics

RGB video

Perceptual estimations + Annotations

Simulation

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