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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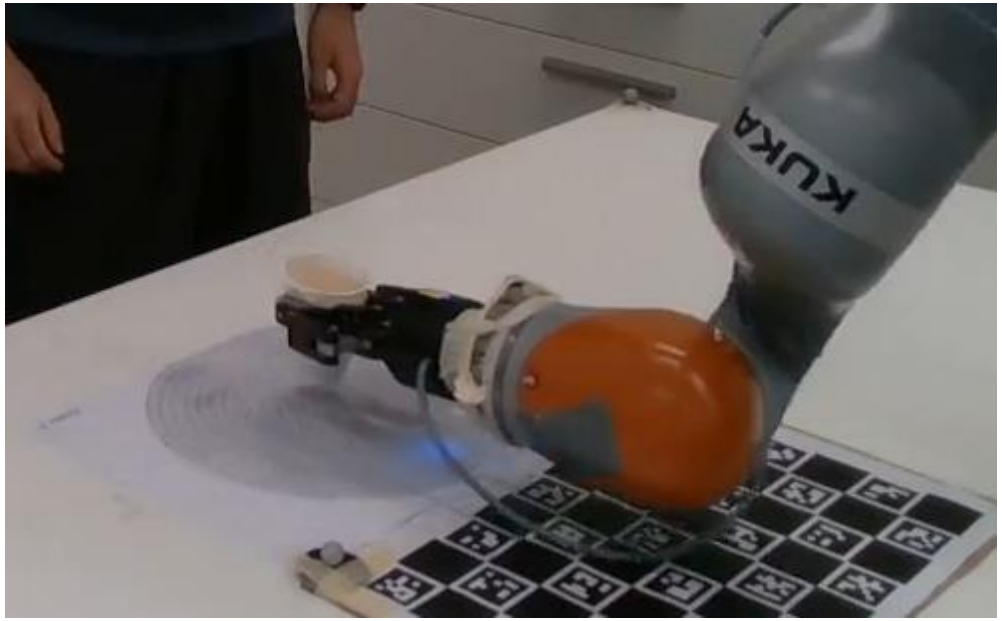
Human-robot interaction in the real world

Unsafe for human



Unsafe for the container

Benchmark for human-to-robot handovers of unseen containers with unknown filling
Sanchez-Matilla, Chatzilygeroudis, Modas, Duarte, Xompero, Frossard, Cavallaro
IEEE Robotics and Automation Letters (RA-L), vol. 5, no. 2, Apr. 2020

Addressing limitations of handover simulations

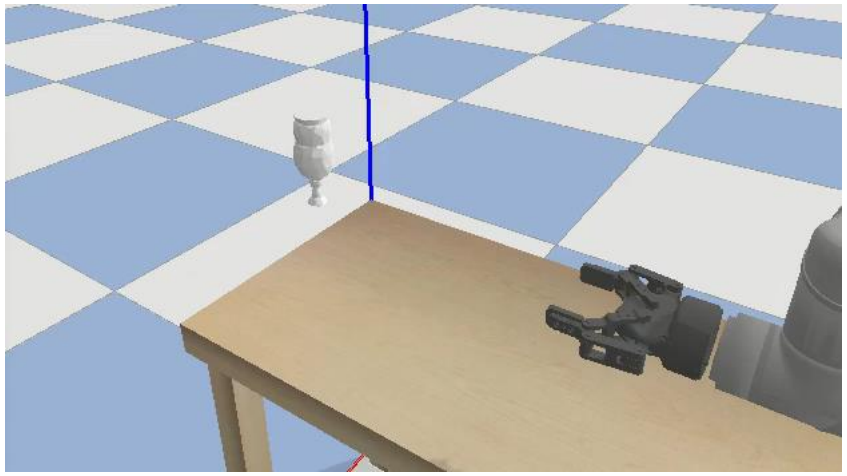
Limitations of existing simulators for handovers	Proposed real-to-simulation framework
✗ Visualization of trajectory only	✓ Simulation of contact forces
✗ Primitive shape objects or 3D scan required	✓ Vision based object reconstruction
✗ Static or limited dynamic setup	✓ Fully dynamic setup

Real recordings to simulated human-to-robot handovers

RGB video

Perceptual estimations + Annotations

Simulation

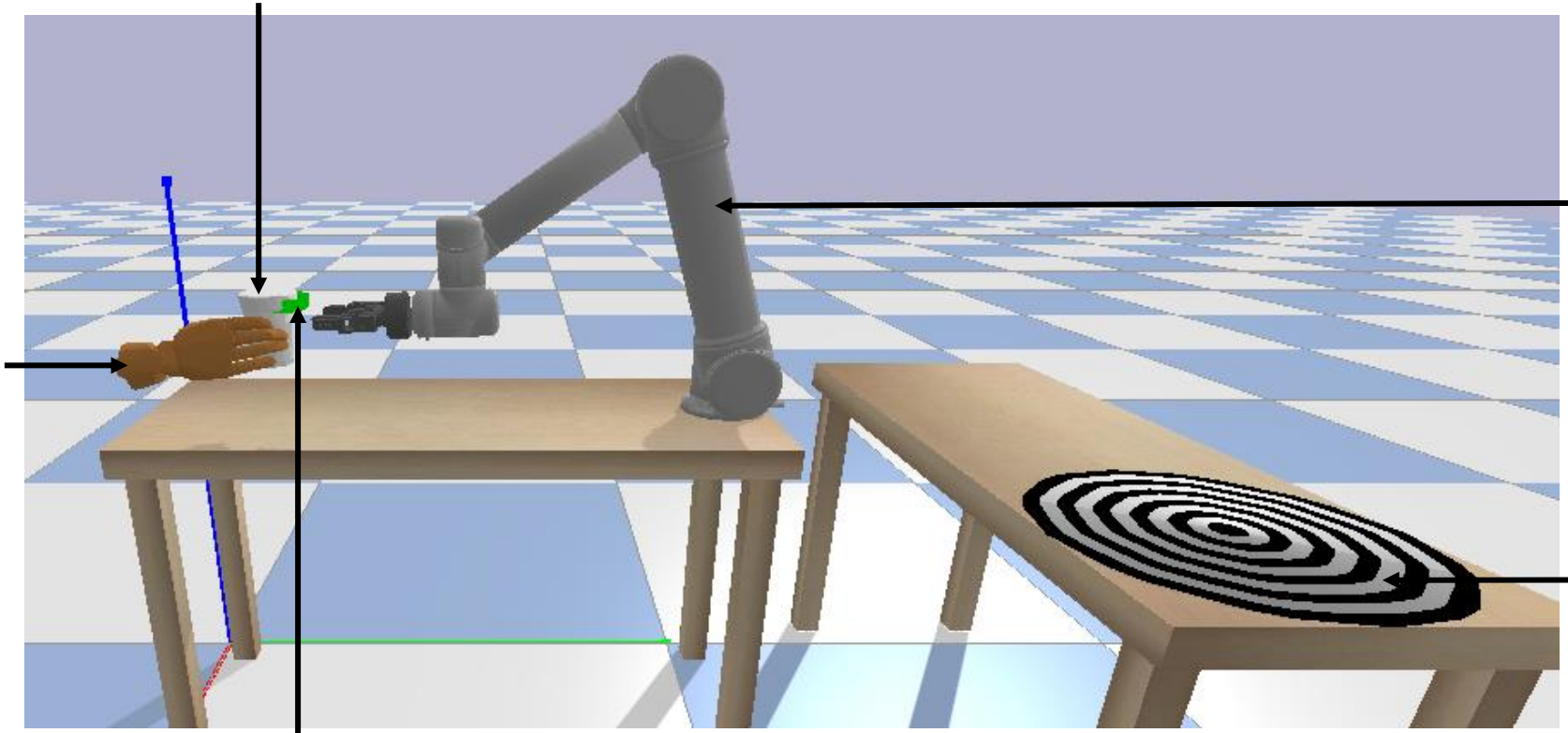


Human maneuvering

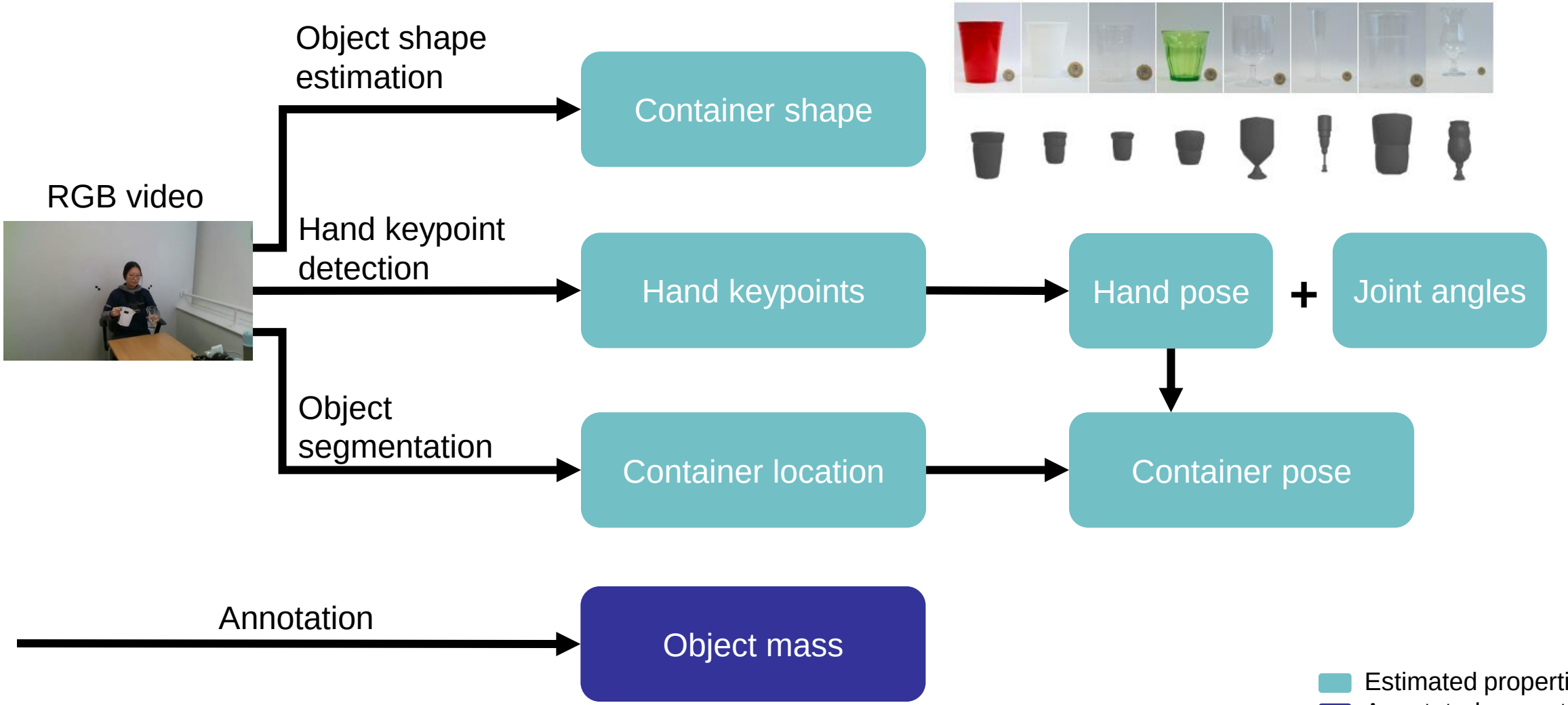
Robot maneuvering

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

Overview of the handover simulation environment

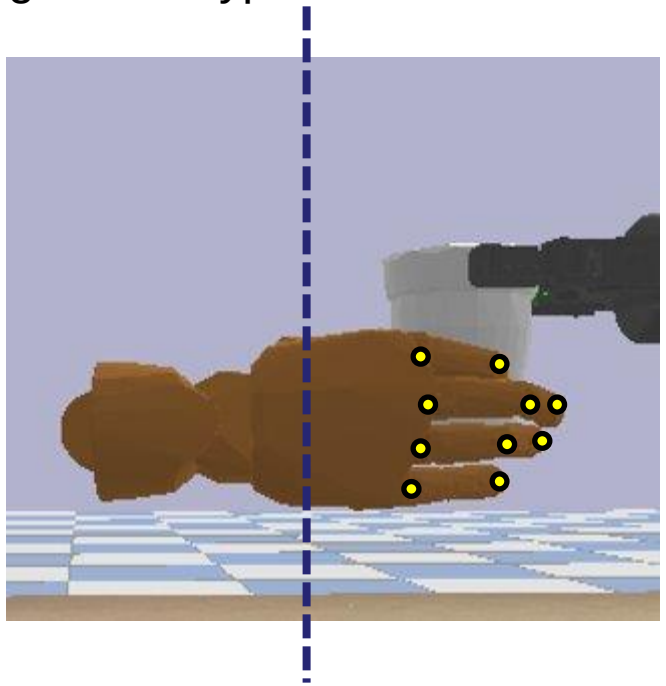


Perception pipeline



Safe grasping region estimation

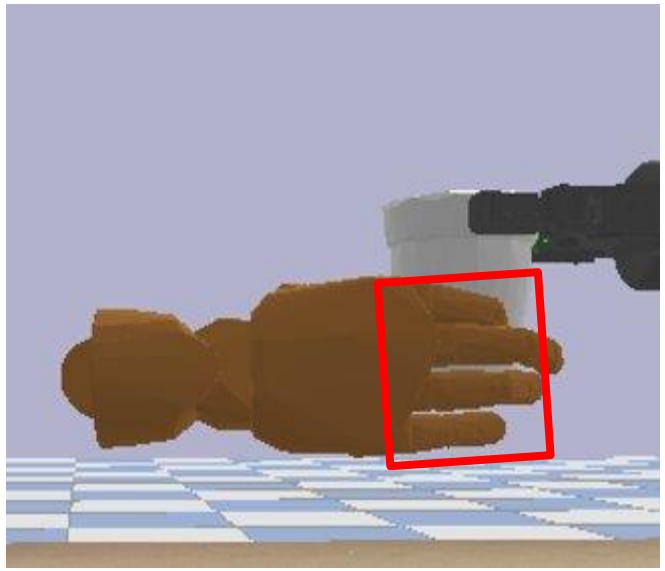
Extracting hand keypoints close to container



Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

Safe grasping region estimation

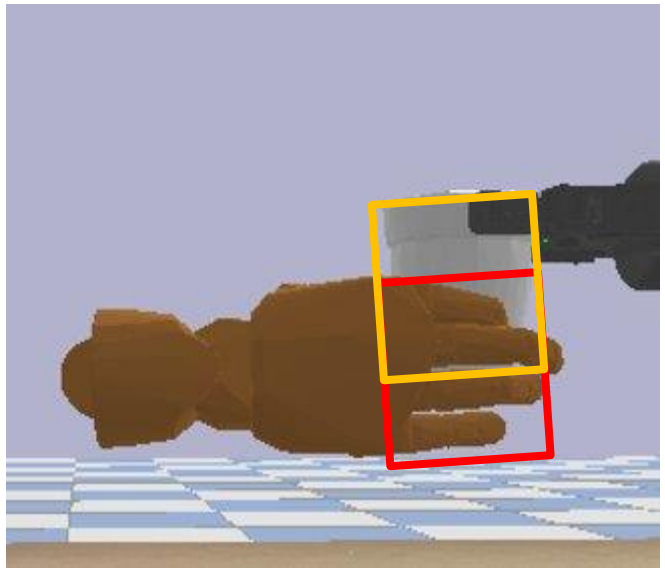
Obtain unsafe region



Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

Safe grasping region estimation

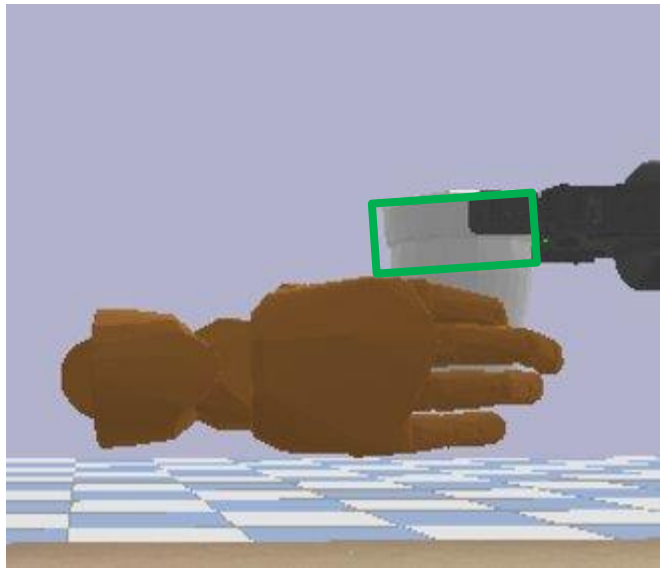
Initialize safe region



Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

Safe grasping region estimation

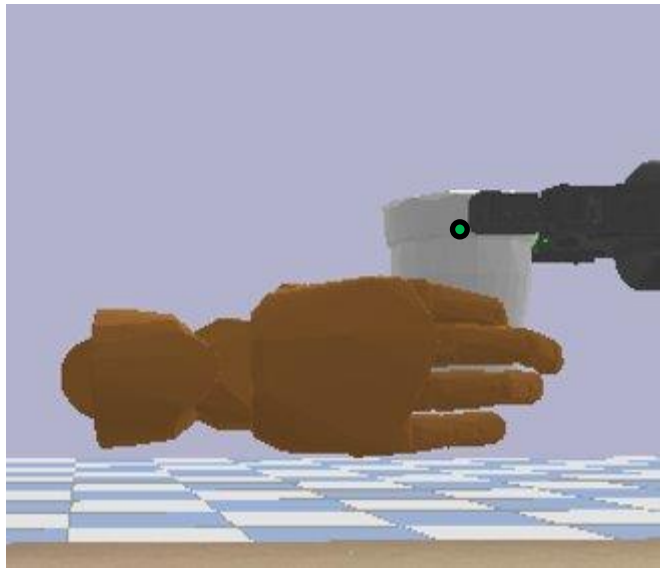
Remove unsafe region from safe region



Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

Safe grasping region estimation

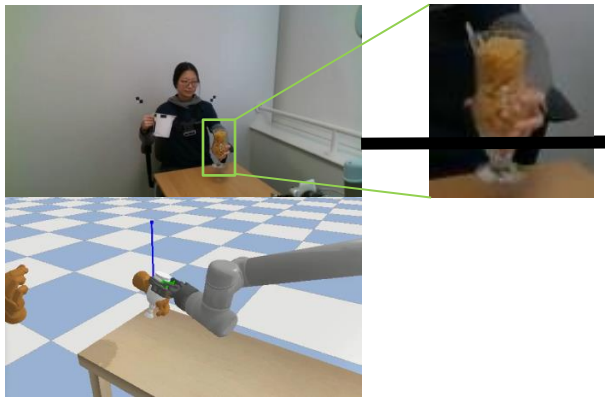
Obtain final grasping location



Initialized safe grasping region
Unsafe grasping region
Final safe grasping region

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

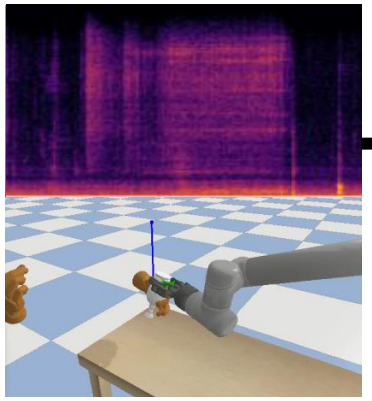
Gripper force

Estimated properties
Annotated properties
Robot control parameters

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

Filling mass estimation and gripper force

Audio spectrogram[1]



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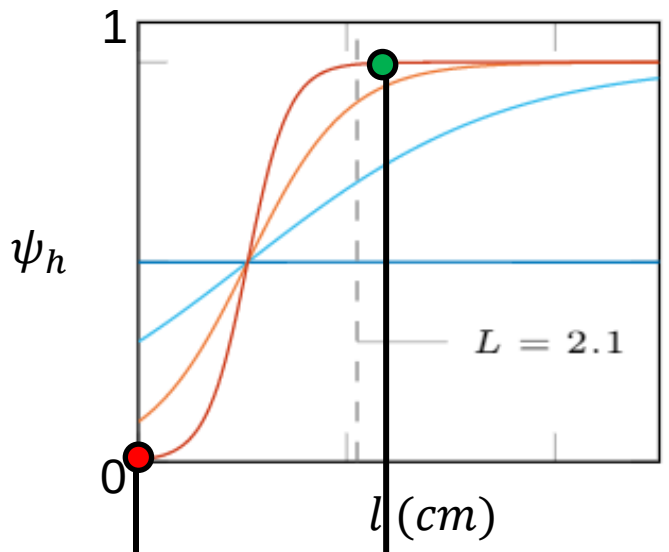
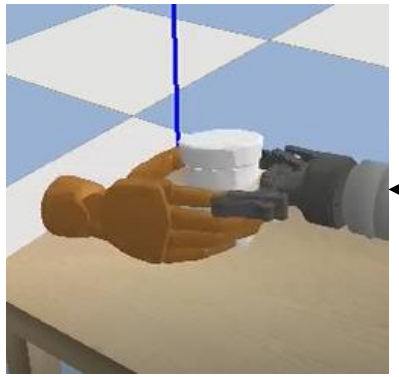
Modelling human safety for handovers

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



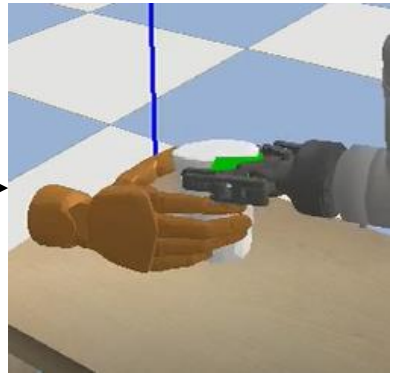
l: Minimum distance between hand model and robot
L: Minimum safety distance
c: Sensitivity parameter
— : $c = 0.5$
— : $c = 0.7$
— : $c = 0.9$
— : $c = 0.995$

Unsafe for human



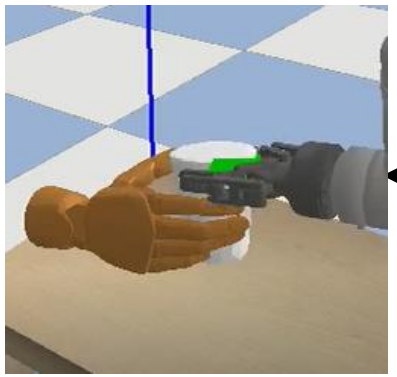
Pinching the hand

Safe for human

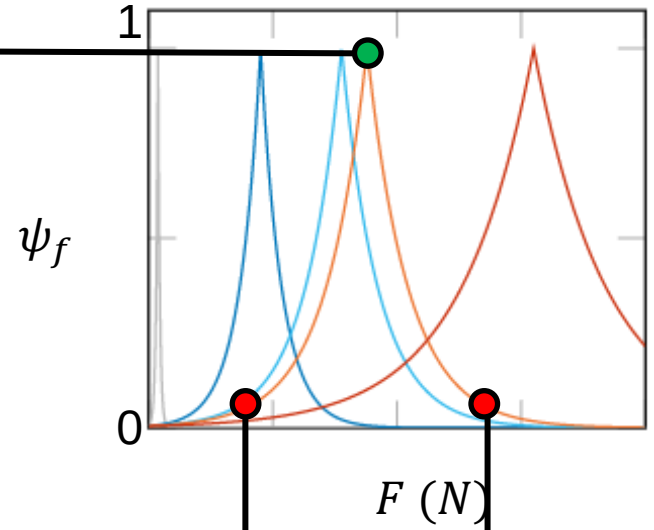


Modelling object safety for handovers

Safe for object



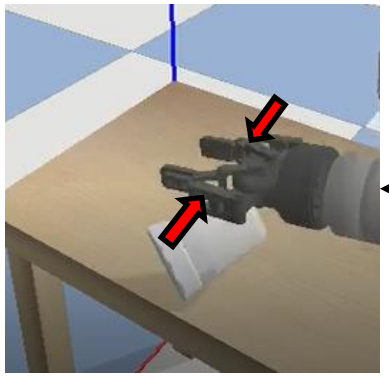
Object safety (exponential) $\psi_f = e^{\frac{|\tilde{F}-\hat{F}|}{\hat{F}}\ln(1-c)}$



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

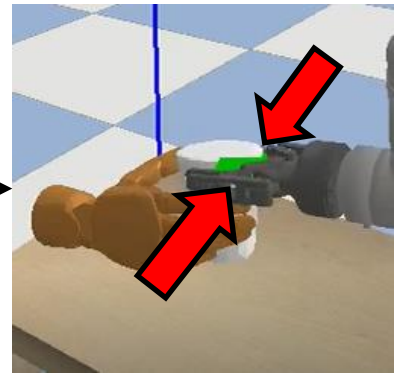
— : Empty
— : 50% pasta
— : 90% pasta
— : 50% rice
— : 90% rice

Unsafe for object



Insufficient force

Unsafe for object



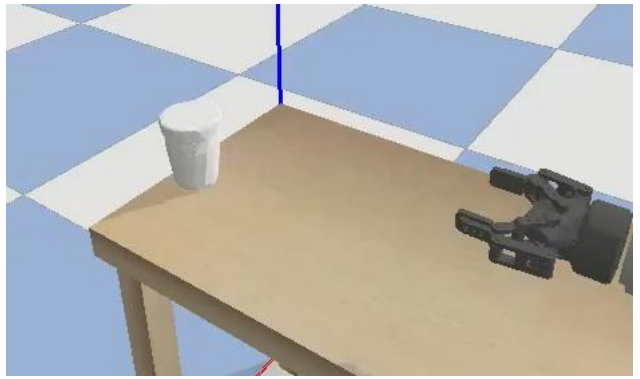
Excessive force

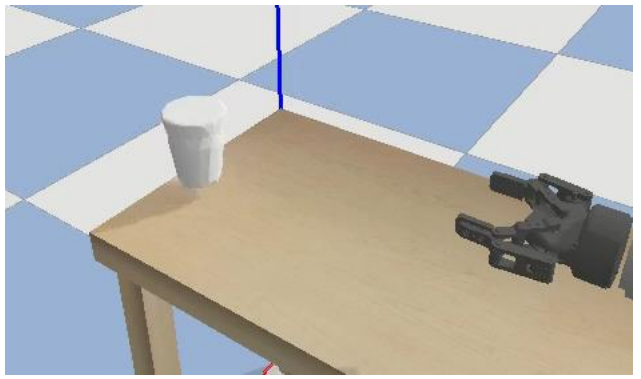
Estimating safe grasping region for handover

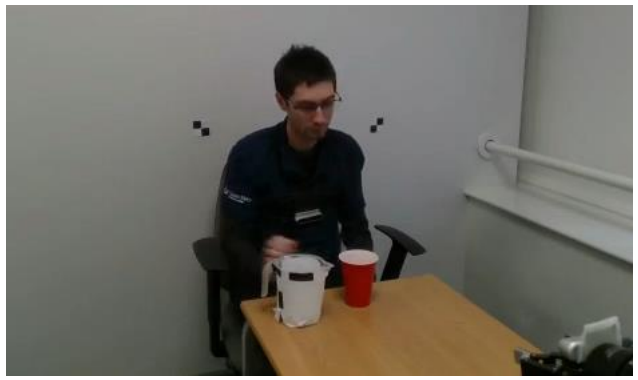
RGB input

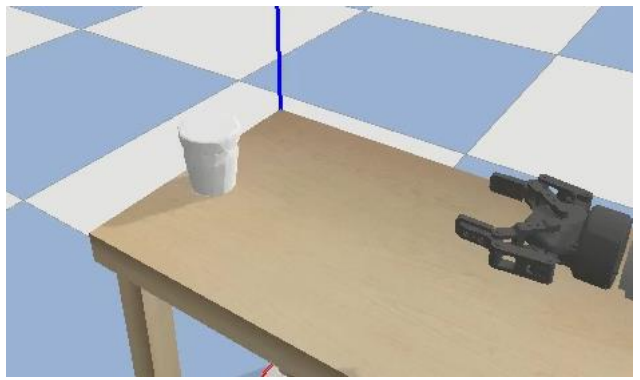
With safe grasping region

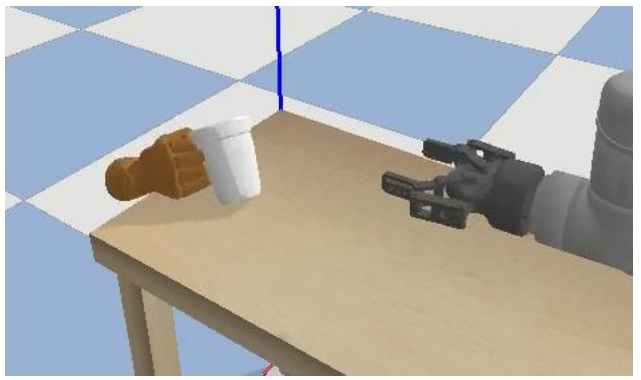
Without safe grasping region





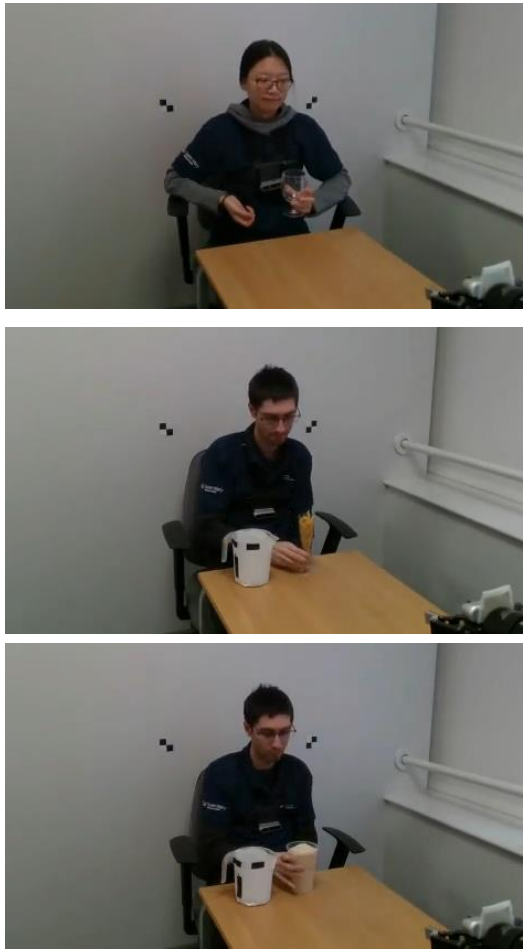




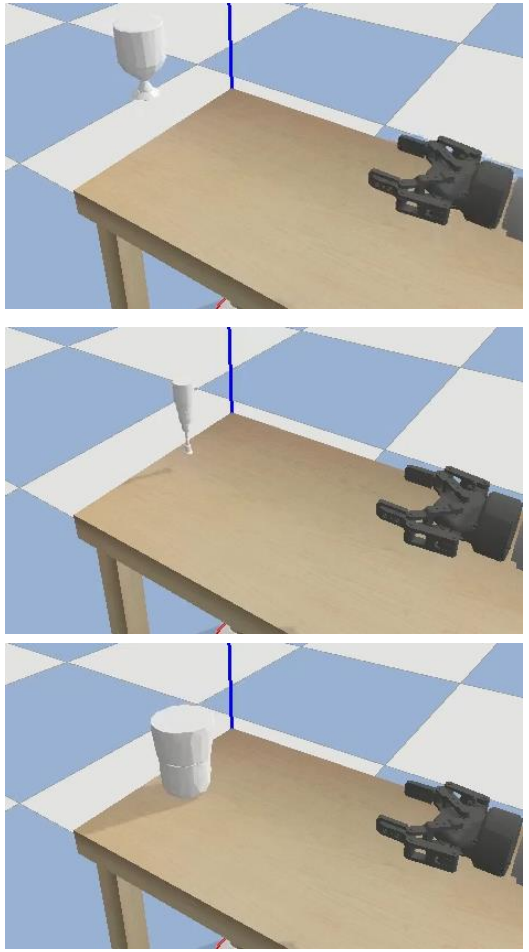


Handovers of various containers and fillings

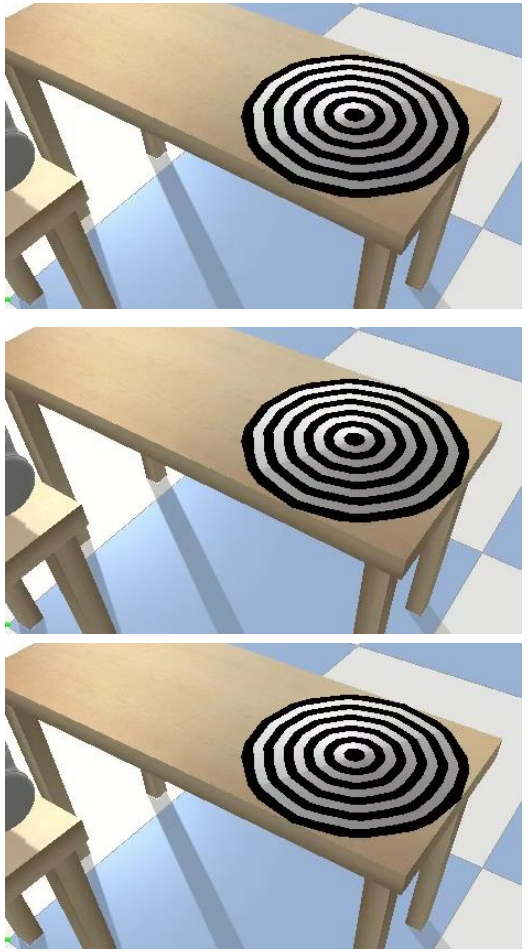
RGB input



Simulated handover



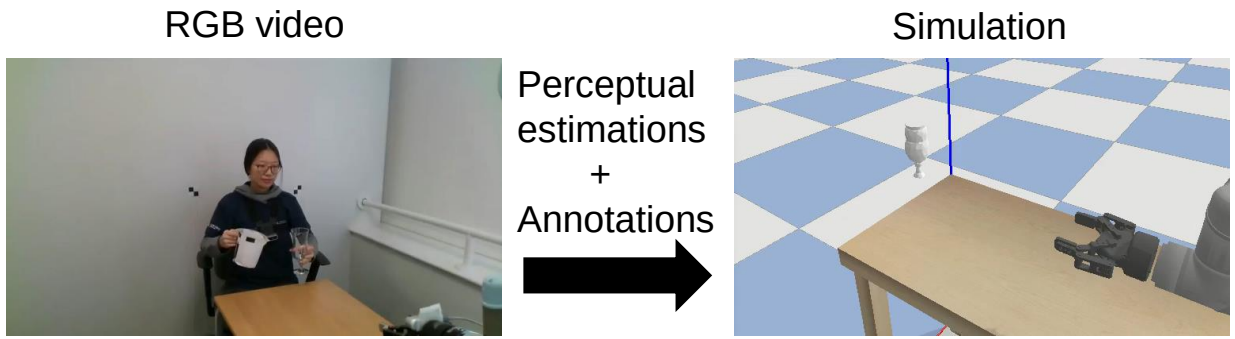
Simulated delivery



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



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