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Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

Juliane Röscheisen, 15.12.2022

Reactive Human-to-Robot Handovers of Arbitrary Objects

Outline of the presentation

1. Introduction and motivation
2. Challenges and prior work
3. Introduced system
   - About the paper
   - Reactive handover strategy
   - Hand and object segmentation
   - grasp selection
4. Evaluation
5. Conclusion

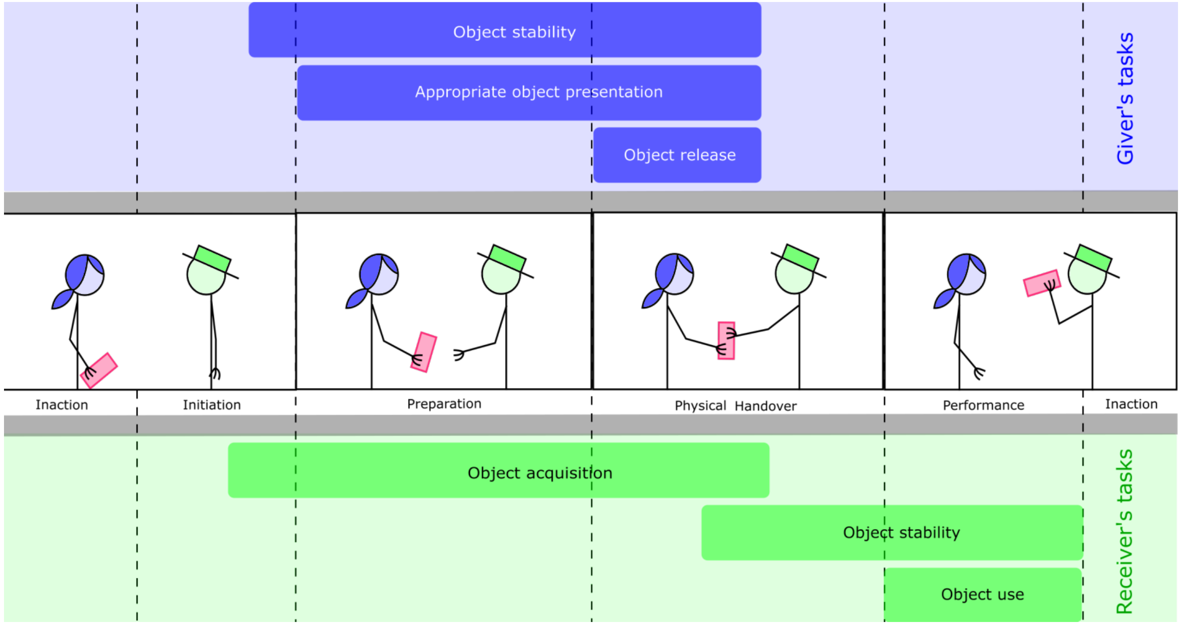
1. Introduction and motivation

Why do we need human-robot collaboration?

- Assist rather than replace human operators
- Bring independence to humans with limited mobility
- Provide services for humans in everyday life

Robot adaptation to human physical fatigue in human–robot co-manipulation, *Auton Robot*, 2018 [2]

Human-to-Robot vs Robot-to-Human Handovers



Object Handovers: a Review for Robotics, IEEE Transactions on Robotics , 2021 [3]

2. Challenges and prior work

Challenges

- Human hand is not easily identified
- Object may be partially occluded by fingers
- Unpredictable motions of human
- Approach directions constrained by human pose
- Robot movements must be intuitive and feel safe for humans
- A wide variety of objects used by humans every day

Limitations of prior work

- Restricted object and grasp poses [4, 5, 6]
- Wearable sensing needed on human to determine human pose [7]
- Limited object types [5]
- Open-loop: No adjustment during approach [6]

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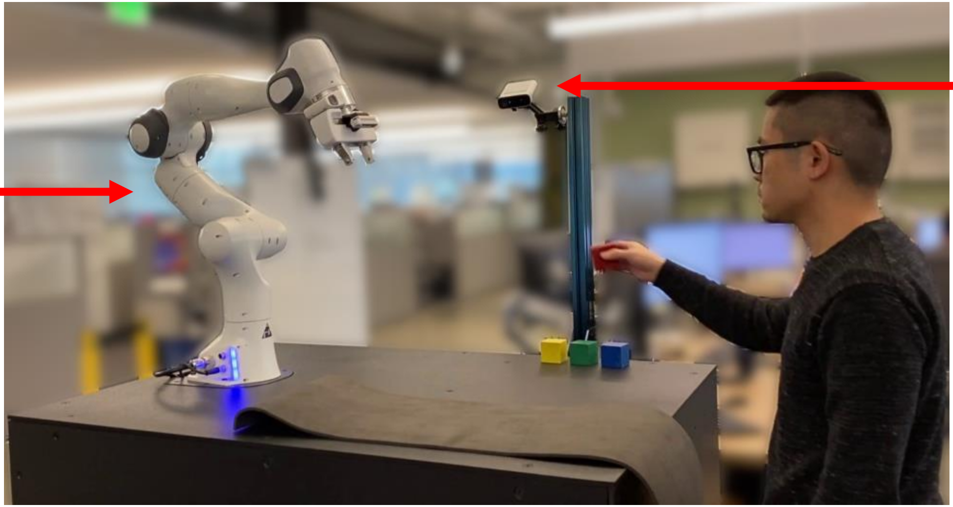
3. Introduced system

About the paper

- Wei Yang, Chris Paxton, Arsalan Mousavian, Yu-Wei Chao, Maya Cakmak and Dieter Fox
- NVIDIA Seattle Robotics Lab & University of Washington, USA
- 2021 IEEE ICRA Best Paper Award on Human-Robot Interaction (HRI)
- 26 citations

Setup

Franka-Emika Panda robot (6 DOF)



Azure Kinect RGBD camera

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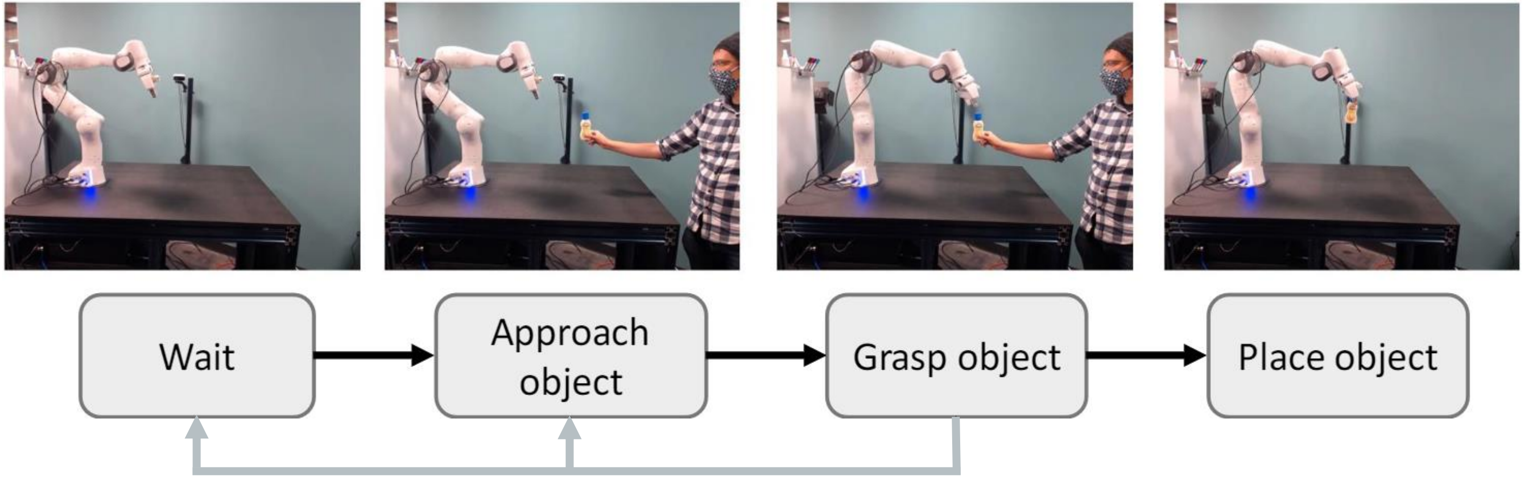
Reactive handover strategy

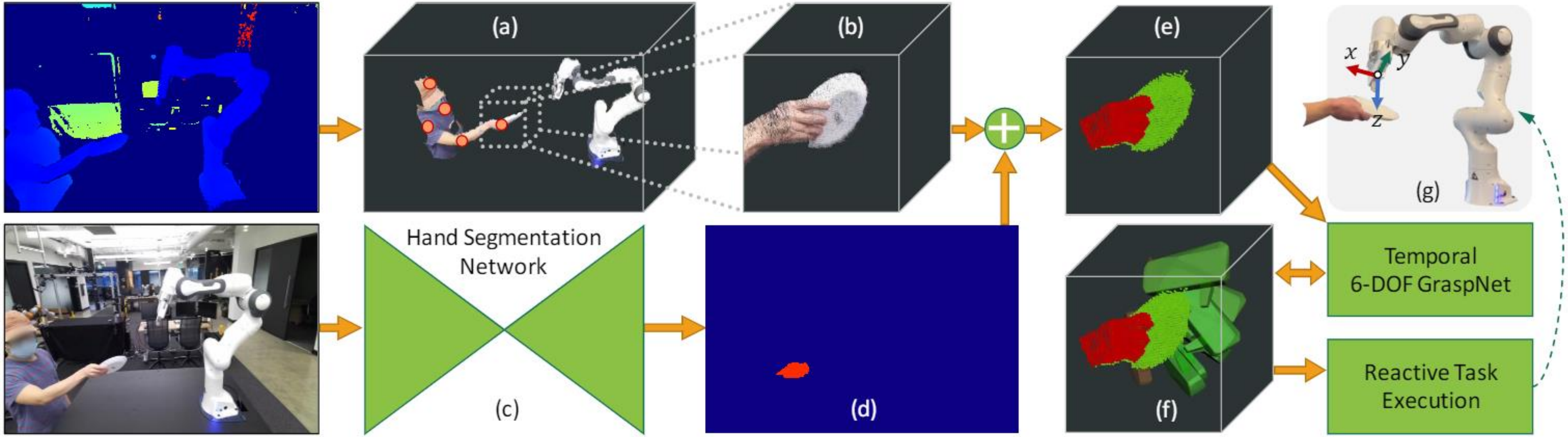


Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

Reactive handover strategy

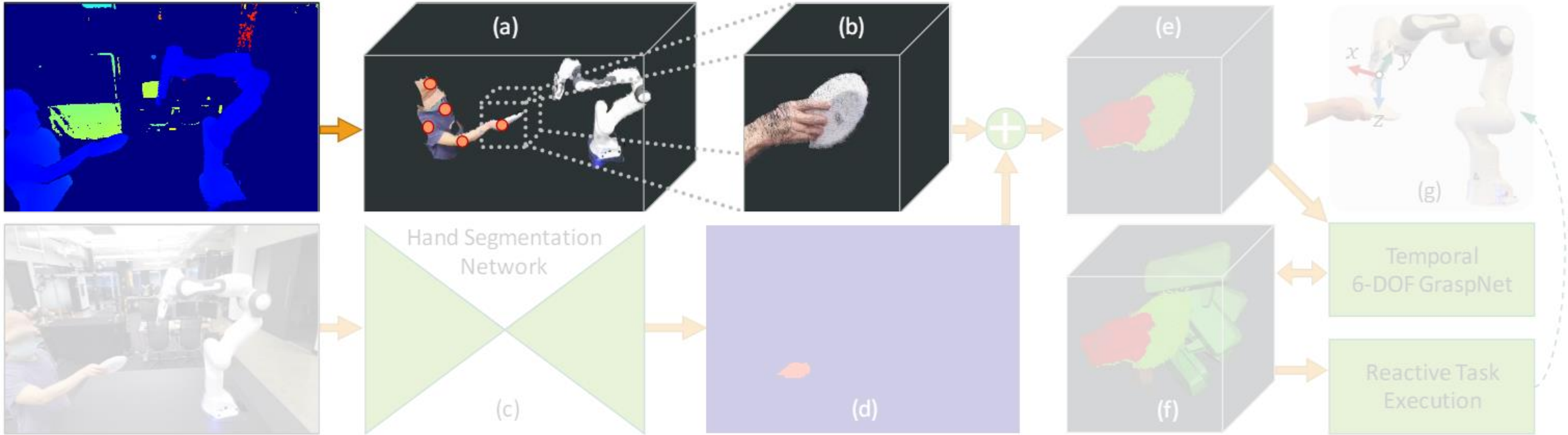
https://sites.google.com/nvidia.com/handovers-of-arbitrary-objects

System workflow



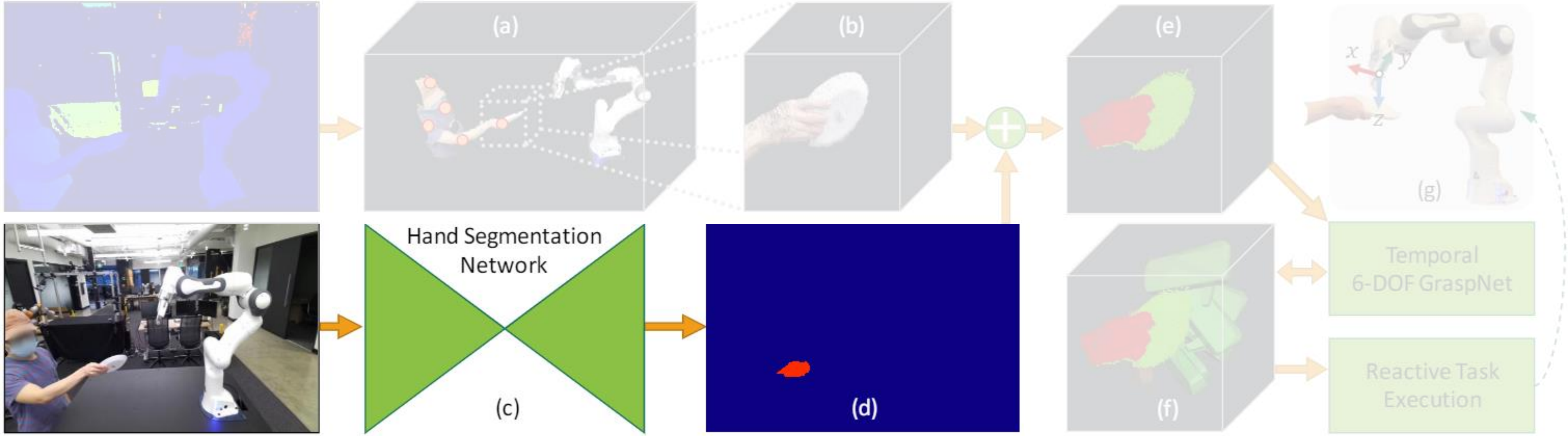
Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

Obtaining the hand-object point cloud



Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

Obtaining the hand mask



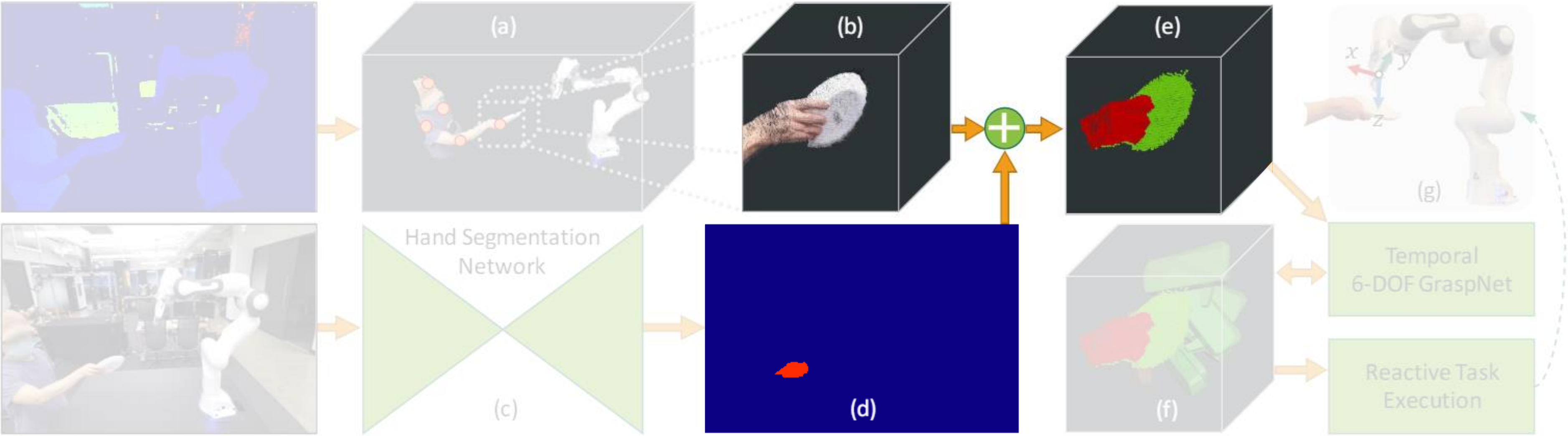
Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

Obtaining the hand mask

- Fully convolutional network generates feature map in original resolution
- Binary segmentation mask seperates hand from background pixelwise
- Pretrained Feature Pyramid Network[9] as Backbone, finetuning with data generated from point clouds

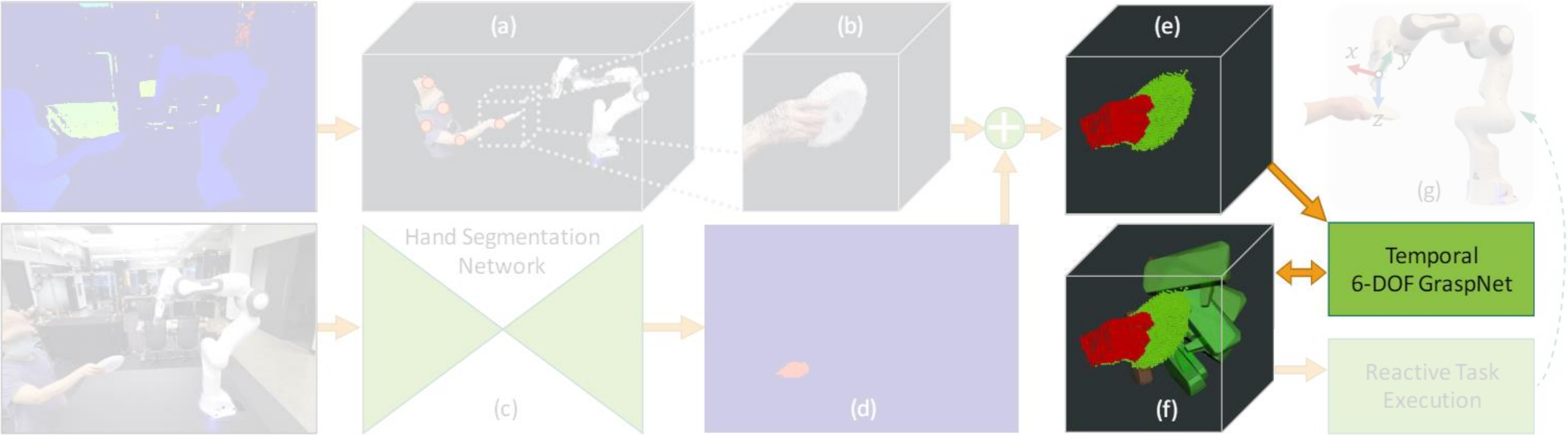
https://sites.google.com/nvidia.com/handovers-of-arbitrary-objects

Separating the object point cloud



Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

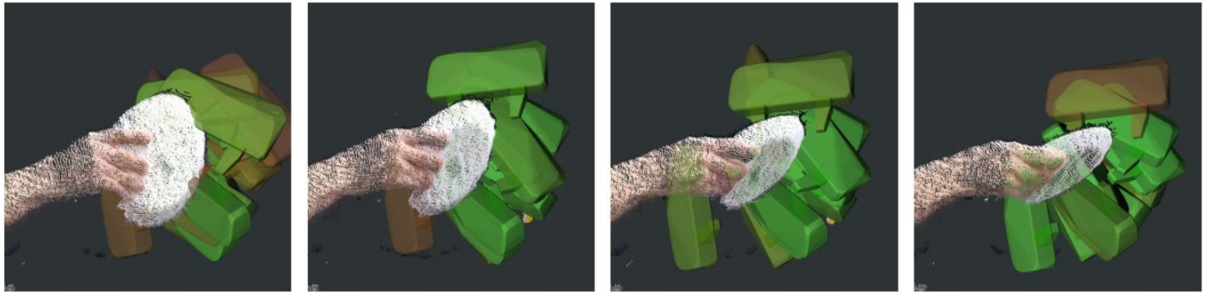
Point cloud based grasp sampling



Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

Point cloud based grasp sampling

- 6-DOF GraspNet[8] for sampling and quality estimation
- Metropolis-Hasting sampling to ensure temporal consistency
- Remove grasps colliding with the hand point cloud



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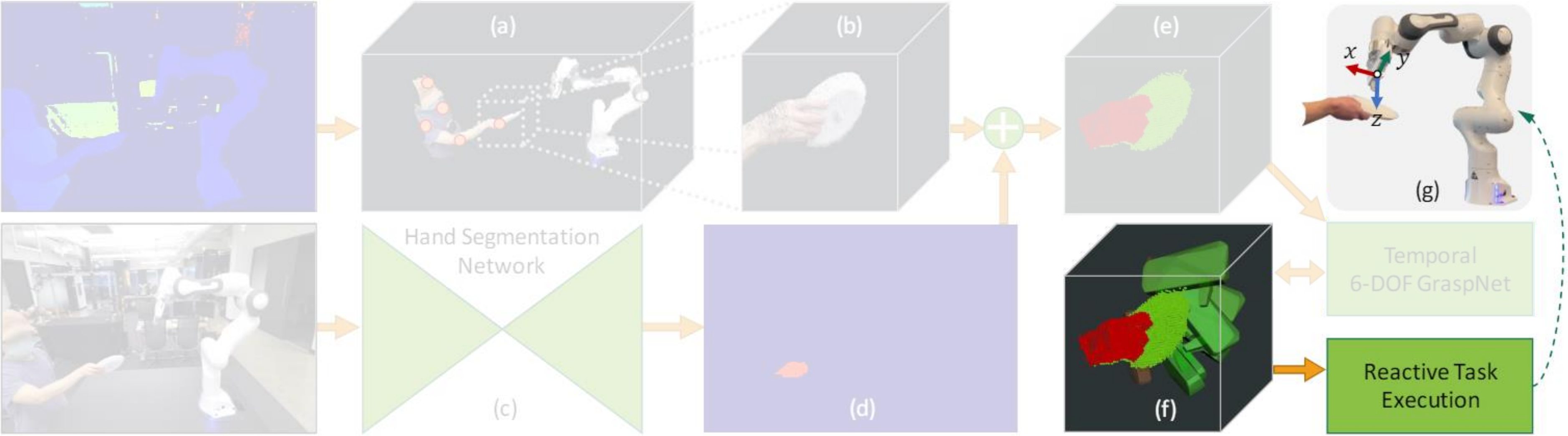
Reactive grasp selection



Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

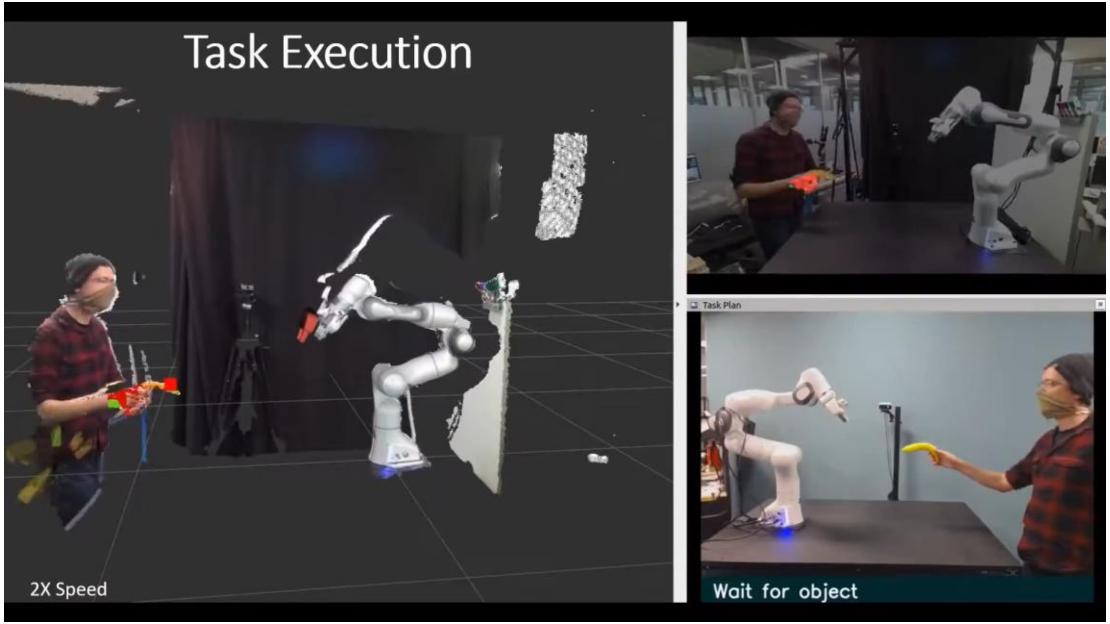
Reactive grasp selection

- Cost function:

$$C = w_s \min(s - s_{min}, 0) + w_{prev}\, d(x_{appr}, x_{prev}) + w_{home}\, d(x_{appr}, x_{home})$$

- Riemannian Motion Policies [11] for motion planning
- Trac-IK [10] for inverse kinematics
- Check for collisions in joint space and cartesian space
- Attempt grasp after reaching approach position

Full system running



https://sites.google.com/nvidia.com/handovers-of-arbitrary-objects

4. Evaluation

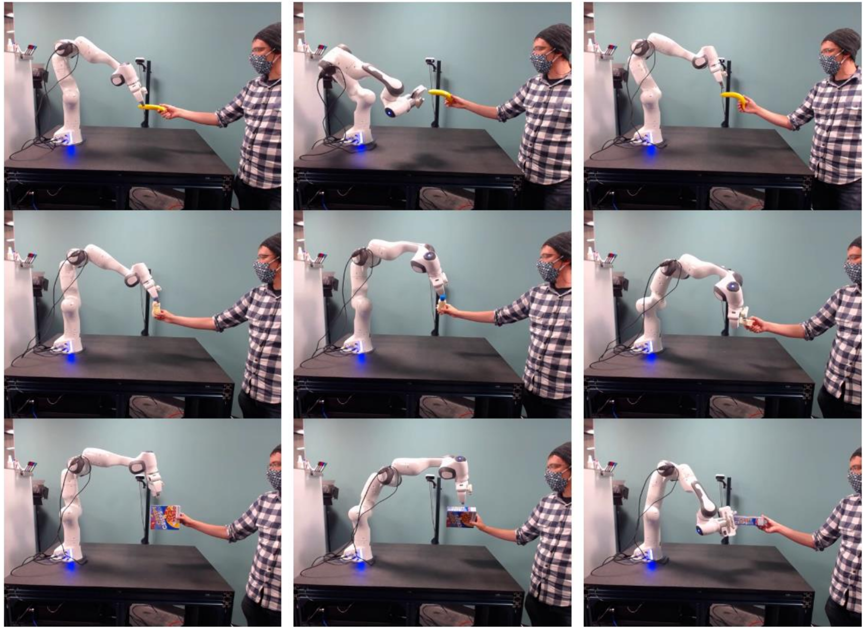
Handover variations

flat | 45° | 90°

Banana

Bottle

Cereal box



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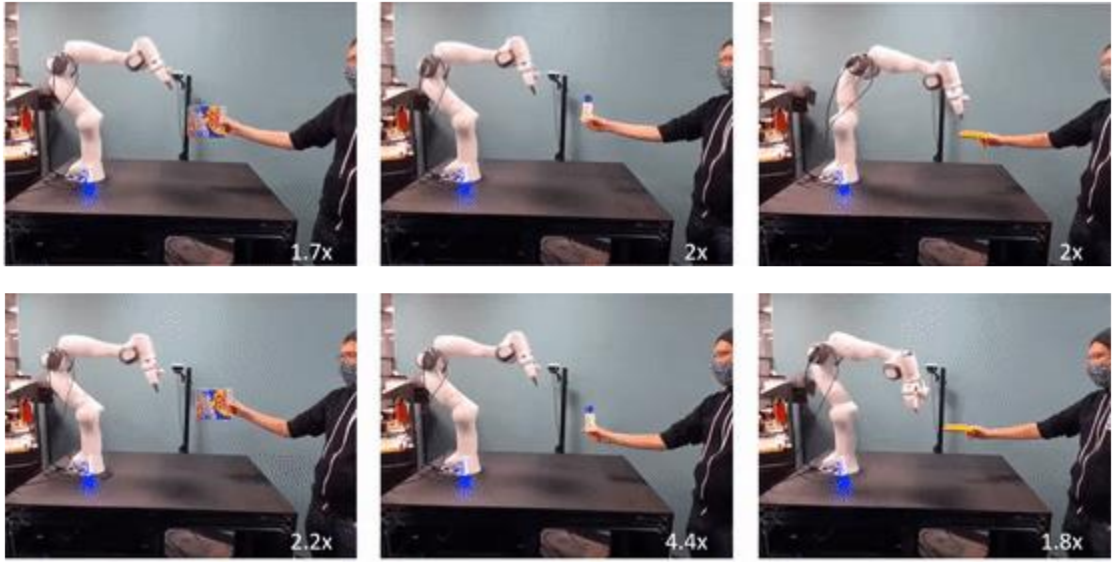
Handover variations

Cereal box | Bottle | Banana

0-45°

0-90°



https://sites.google.com/nvidia.com/handovers-of-arbitrary-objects

Handover variations

Static orientation

	Banana		Bottle		Cereal Box		Overall	
Grasp Type	Time (s)	Success (%)	Time (s)	Success (%)	Time (s)	Success (%)	Time (s)	Success (%)
Flat	11.87 ± 0.33	100%	8.46 ± 0.30	100%	10.42 ± 1.50	75%	10.27 ± 1.65	90%
45 degrees	7.81 ± 1.53	100%	11.02 ± 1.39	75%	10.99 ± 3.83	75%	10.05 ± 2.84	82%
90 degrees	7.94 ± 0.58	100%	18.59 ± 5.77	100%	15.89 ± 3.73	100%	14.14 ± 6.02	100%
Overall	9.21 ± 2.12	100%	12.53 ± 5.26	90%	12.23 ± 3.91	82%	11.39 ± 4.29	90%

Changing orientation

Rotation	Time (s)	Success (%)	Time (s)	Success (%)	Time (s)	Success (%)	Time (s)	Success (%)
0-45 degrees	16.34 ± 2.92	100%	10.86 ± 1.55	100%	8.23 ± 1.11	100%	11.81 ± 3.93	100%
0-90 degrees	16.47 ± 8.49	100%	18.40 ± 6.89	75%	12.89 ± 6.15	50%	15.41 ± 7.39	69%

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User study

Reactive Human-to-Robot Handovers of Arbitrary Objects, *ICRA*, 2021 [1]

User study

	Medicine Box	Newspaper	Plate	Mug	Remote	Toothpaste	Scissors	Towel	Pen	Spoon	Average
Approach Time (s)	9.1 ± 3.5	13.7 ± 4.7	10.2 ± 2.1	9.1 ± 3.5	9.7 ± 0.7	9.1 ± 1.9	11.2 ± 3.0	13.8 ± 3.8	11.2 ± 4.8	10.4 ± 1.9	10.7 ± 3.6
Number of Attempts	1.3 ± 0.5	1.0	1.0	1.8 ± 1.8	1.0	1.2 ± 1.2	1.2 ± 1.2	1.0	2.0 ± 2.0	1.5 ± 0.8	1.3 ± 0.3
Success Rate	75.0%	100%	100%	54.5%	100%	85.7%	85.7%	100%	50.0%	66.7%	81.8%

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Failure cases

- Missing depth information on dark surfaces
- Object recognized as hand due to failure of hand segmentation network
- Noise in object point cloud due to nearby objects

5. Conclusion

Conclusion

- System is generalizable to diverse unknown objects
- Reactive temporally consistent grasp generation
- No hard constraints on object presentation

Outlook

- Update segmentation network with wider user data
- Add more cameras for more detailed object point cloud generation
- Speed up inverse kinematics through parallelism
- Improve point cloud cropping and noise reduction

Questions and Feedback

References

[1] W. Yang, C. Paxton, A. Mousavian, Y. -W. Chao, M. Cakmak and D. Fox, “Reactive Human-to-Robot Handovers of Arbitrary Objects,” 2021 IEEE International Conference on Robotics and Automation (ICRA), pp. 3118-3124, 2021.

[2] L. Peternel, N. Tsagarakis, D. Caldwell et al., “Robot adaptation to human physical fatigue in human–robot co-manipulation,” Auton Robot, vol. 42, pp. 1011–1021, 2018.

[3] V. Ortenzi, A. Cosgun, T. Pardi, W. Chan, E. Croft, and D. Kulic, “Object handovers: a review for robotics,” IEEE Transactions on Robotics, 2021.

[4] A. Edsinger and C. C. Kemp, “Human-robot interaction for cooperative manipulation: Handing objects to one another,” in RO-MAN. IEEE, 2007

[5] W. Yang, C. Paxton, M. Cakmak, and D. Fox, “Human grasp classification for reactive human-to-robot handovers,” IROS, 2020.

References

[6] P. Rosenberger, A. Cosgun, R. Newbury, J. Kwan, V. Ortenzi, P. Corke, and M. Grafinger, "Object-independent human-to-robot handovers using real time robotic vision," IEEE Robotics and Automation Letters, vol. 6, no. 1, pp. 17–23, 2021.

[7] W. Wang, R. Li, Z. M. Diekel, Y. Chen, Z. Zhang, and Y. Jia, "Controlling object hand-over in human–robot collaboration via natural wearable sensing," IEEE Transactions on Human-Machine Systems, 2018.

[8] A. Mousavian, C. Eppner, and D. Fox, "6-dof graspnet: Variational grasp generation for object manipulation," in ICCV, 2019

[9] T.-Y. Lin, P. Dollar, R. Girshick, K. He, B. Hariharan, and S. Belongie, "Feature pyramid networks for object detection," in CVPR, 2017.

[10] P. Beeson and B. Ames, "Trac-ik: An open-source library for improved solving of generic inverse kinematics," in Humanoids. IEEE, 2015.

References

[11] N. D. Ratliff, J. Issac, D. Kappler, S. Birchfield, and D. Fox, “Riemannian motion policies,” arXiv preprint arXiv:1801.02854, 2018.