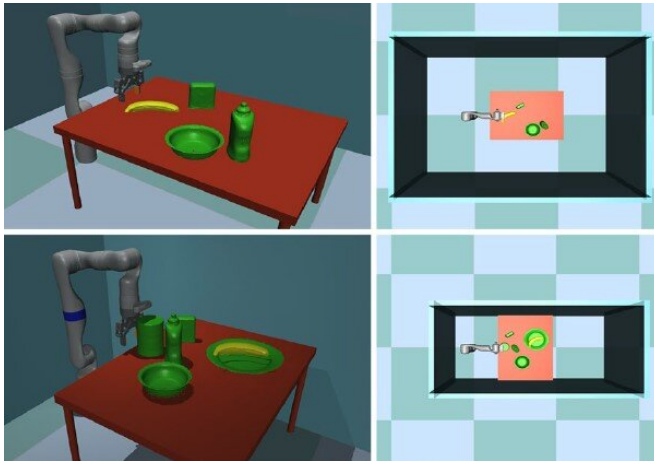


The path to more human-like robot object manipulation skills

26 May 2021



Top left) A Kinova GEN3robot is trying to grasp a banana (the target object is the yellow banana; background objects are in green and red colors). (Top right) Top-down view of the scene on the left. (Bottom left) Externally, background objects are altered: Objects' configurations are changed, new objects are introduced (cylindrical can, plate), the banana is placed on the plate, and the table is rotated by 90°; an environmental property is also changed: The light now comes from a different direction and casts shadows. Internally and dynamically, the robot's third joint (marked in blue) becomes jammed while it is moving. (Bottom right) Top-down view of the scene on the left. The whole setup has been moved to a smaller room. Credit: Jinda Cui and Jeff Trinkle, Lehigh University

What if a robot could organize your closet or chop your vegetables? A sous chef in every home could someday be a reality.

Still, while advances in artificial intelligence and machine learning have made better robotics possible, there is still quite a wide gap between what humans and robots can do. Closing that gap will require overcoming a number of obstacles in [robot](#) manipulation, or the ability of robots to manipulate environments and adapt to changing

stimuli.

Ph.D. candidate Jinda Cui and Jeff Trinkle, Professor and Chair of the Department of Computer Science and Engineering at Lehigh University, are interested in those challenges. They work in an area called learned robot manipulation, in which robots are "trained" through machine learning to manipulate objects and environments like humans do.

"I've always felt that for robots to be really useful they have to pick stuff up, they have to be able to manipulate it and put things together and fix things, to help you off the floor and all that," says Trinkle who has conducted decades of research in robot manipulation and is well known for his pioneering work in simulating multibody systems under contact constraints. "It takes so many technical areas together to look at a problem like that."

"In robot manipulation, learning is a promising alternative to traditional engineering methods and has demonstrated great success, especially in pick-and-place tasks," says Cui, whose work has been focused on the intersection of robot manipulation and [machine learning](#). "Although many research questions still need to be answered, learned robot manipulation could potentially bring robot manipulators into our homes and businesses. Maybe we will see robots mopping our tables or organizing closets in the near future."

In a review article in *Science Robotics* called "Toward next-generation learned robot manipulation," Cui and Trinkle summarize, compare and contrast research in learned robot manipulation through the lens of adaptability and outline promising research directions for the future.



In their research, Jinda Cui and his advisor Jeff Tinkle train robots through machine learning to perform manipulation tasks. Credit: Ryan Hulvat/Meris

Cui and Trinkle emphasize the usefulness of modularity in learning design and point to the need for appropriate representations for manipulation tasks. They also note that modularity enables customization.

Cui says that those in traditional engineering may doubt the reliability of learned skills for robot manipulation because they are usually 'black-box' solutions, which means that researchers may not know when and why a learned skill fails.

"As our paper points out, appropriate modularization of learned manipulation skills may open up 'black-boxes' and make them more explainable," says Cui.

The nine areas that Cui and Trinkle propose as particularly promising for advancing the capacity and adaptability of learned robot manipulation are:

- 1) Representation learning with more sensing modalities such as tactile, auditory, and temperature signals.
- 2) Advanced simulators for manipulation so they are able to be as fast and as realistic as possible.
- 3) Task/skill customization.
- 4) "Portable" task representations.
- 5) Informed exploration for manipulation in which active learning methods can find new skills efficiently by exploiting contact information.
- 6) Continual exploration, or a way for a learned skill to improve continually after

- 7) Massively distributed/parallel active learning.
- 8) Hardware innovations that simplify more challenging manipulations such as in-hand dexterous manipulation.
- 9) Real-time performance since, eventually, learned manipulation skills will be tested in the real world.

Following some of these directions, Cui and Trinkle are currently working on tactile-based sensorimotor skills to make robot manipulators more dexterous and robust.

For Cui, among the most exciting discoveries he made while exploring the current research is that learned robot manipulation is still in its infancy.

"That leaves many opportunities for the research community to explore and thrive on," says Cui. "The promising future and the vast space for exploration will make learned robot manipulation an exciting area of research for decades to come."

More information: J. Cui et al., "Toward next-generation learned robot manipulation," *Science Robotics* (2021). robotics.sciencemag.org/lookup.../scirobotics.abd9461

Provided by Lehigh University

APA citation: The path to more human-like robot object manipulation skills (2021, May 26) retrieved 21 January 2022 from <https://techxplore.com/news/2021-05-path-human-like-robot-skills.html>

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