# Training robots how to learn, make decisions on the fly

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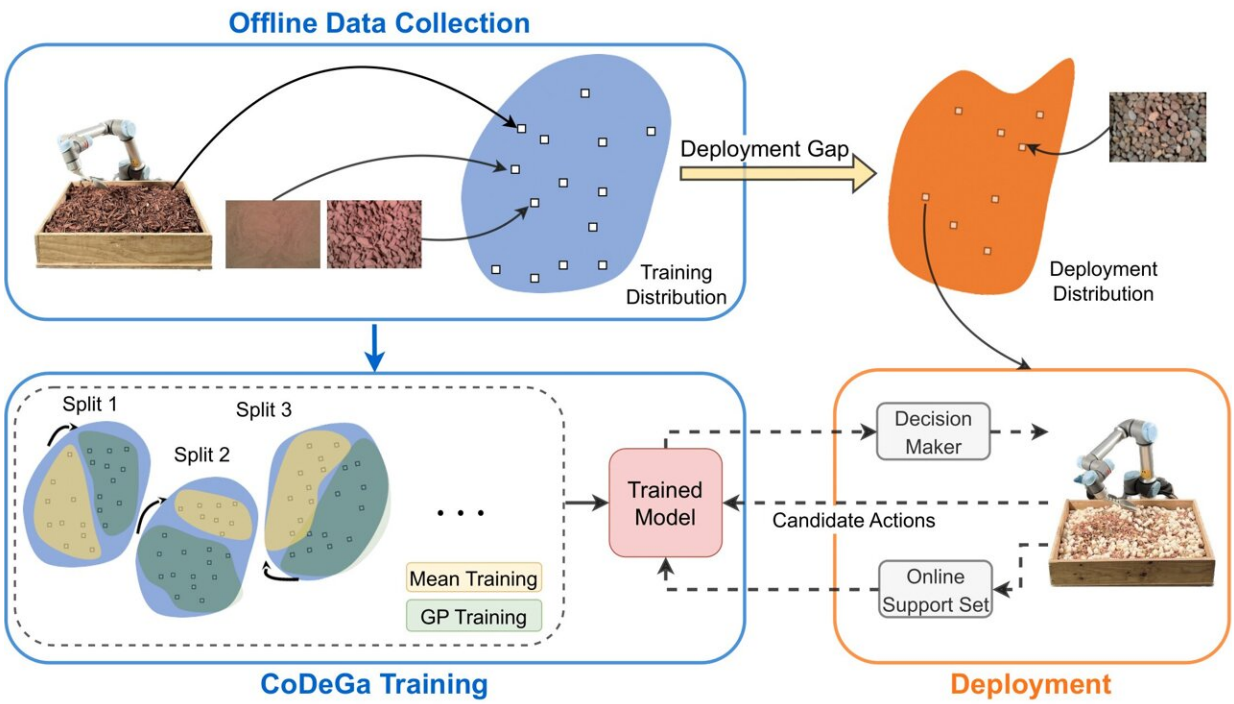


The proposed deep Gaussian process model is trained on the offline database with deep meta-learning with controlled deployment gaps, which repeatedly splits the training set into mean-training and kernel-training and learns kernel parameters to minimize the residuals from the mean models. In deployment, the decision-maker uses the trained model and adapts it to the data acquired online. Credit: University of Illinois Dept. of Aerospace Engineering

Mars rovers have teams of human experts on Earth telling them what to do. But robots on lander missions to moons orbiting Saturn or Jupiter are too far away to receive timely commands from Earth.

Researchers in the Departments of Aerospace Engineering and Computer Science at the University of Illinois Urbana-Champaign developed a novel learning-based method so robots on extraterrestrial bodies can make decisions on their own about where and how to scoop up terrain samples.

"Rather than simulating how to scoop every possible type of rock or granular material, we created a new way for autonomous landers to learn how to learn to scoop quickly on a new material it encounters," said Pranay Thangeda, a Ph.D. student in the Department of Aerospace Engineering.

"It also learns how to adapt to changing landscapes and their properties, such as the topology and the composition of the materials," he said.

Using this method, Thangeda said a robot can learn how to scoop a new material with very few attempts. "If it makes several bad attempts, it learns it shouldn't scoop in that area and it will try somewhere else."

One of the challenges for this research is the lack of knowledge about ocean worlds like Europa.

"Before we sent the recent rovers to Mars, orbiters gave us pretty good information about the terrain features," Thangeda said. "But the best image we have of Europa has a resolution of 256 to 340 meters per pixel, which is not clear enough to ascertain features."

Thangeda's adviser Melkior Ornik said, "All we know is that Europa's surface is ice, but it could be big blocks of ice or much finer like snow.

We also don't know what's underneath the ice."

For some trials, the team hid material under a layer of something else. The robot only sees the top material and thinks it might be good to scoop. "When it actually scoops and hits the bottom layer, it learns it is unscoopable and moves to a different area," Thangeda said.

From these 12 materials and terrains made of a unique composition of one or more materials, a database of 6,700 was created. Credit: University of Illinois Dept. of Aerospace Engineering

NASA wants to send battery-powered rovers rather than nuclear to Europa because, among other mission-specific considerations, it is critical to minimize the risk of contaminating ocean worlds with potentially hazardous materials.

"Although nuclear power supplies have a lifespan of months, batteries have about a 20-day lifespan. We can't afford to waste a few hours a day to send messages back and forth. This provides another reason why the robot's autonomy to make decisions on its own is vital," Thangeda said.

This method of learning to learn is also unique because it allows the robot to use vision and very little on-line experience to achieve high-quality scooping actions on unfamiliar terrains—significantly outperforming non-adaptive methods and other state-of-the-art meta-learning methods.

The team used a robot in the Department of Computer Science at Illinois. It is modeled after the arm of a lander with sensors to collect scooping data on a variety of materials, from 1-millimeter grains of sand to 8-centimeter rocks, as well as different volume materials such as shredded cardboard and packing peanuts. The resulting database in the simulation contains 100 points of knowledge for each of 67 different terrains, or 6,700 total points.

"To our knowledge, we are the first to open source a large-scale dataset on granular media," Thangeda said. "We also provided code to easily access the dataset so others can start using it in their applications."

The model the team created will be deployed at NASA's Jet Propulsion Laboratory's Ocean World Lander Autonomy Testbed.

"We're interested in developing autonomous robotic capabilities on extraterrestrial surfaces, and in particular challenging extraterrestrial surfaces," Ornik said. "This unique method will help inform NASA's continuing interest in exploring ocean worlds."

"The value of this work is in adaptability and transferability of knowledge or methods from Earth to an extraterrestrial body, because it is clear that we will not have a lot of information before the lander gets there. And because of the short battery lifespan, we won't have a long time for the learning process. The lander might last for just a few days, then die, so learning and making decisions autonomously is extremely beneficial."

**More information:** Yifan Zhu et al, Few-shot Adaptation for Manipulating Granular Materials Under Domain Shift, *Robotics: Science and Systems XIX* (2023). DOI: 10.15607/RSS.2023.XIX.048 www.roboticsproceedings.org/rss19/p048.html

Open-source dataset: drillaway.github.io/scooping-dataset.html.

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