This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

SAND2019-15057C

Sandia National Laboratories

Model-Based Robust Mobile Manipulation

Jonathon E. Slightam, Carol C. Young, Matt V. Gallegos, Scott T. Gladwell, Stephen P. Buerger

Technical Challenge

Robotic manipulation of objects in unstructured environments, i.e., "the real world" is further complicated by introducing mobility. The greater uncertainty of reference frames, unknown constraints, and real-world phenomena such as objects being stuck or atypically constructed may result in unforeseen scenarios that are more difficult than classical structured and stationary robotic manipulation problems.

Classification and Perception

Objects to be manipulated can be trained with a neural net and then classified with YOLO (You Only Look Once) with a real-time video stream on a mobile robot.

For example, a door class with different subsets of information can be created that help identify necessary information to interact with it.

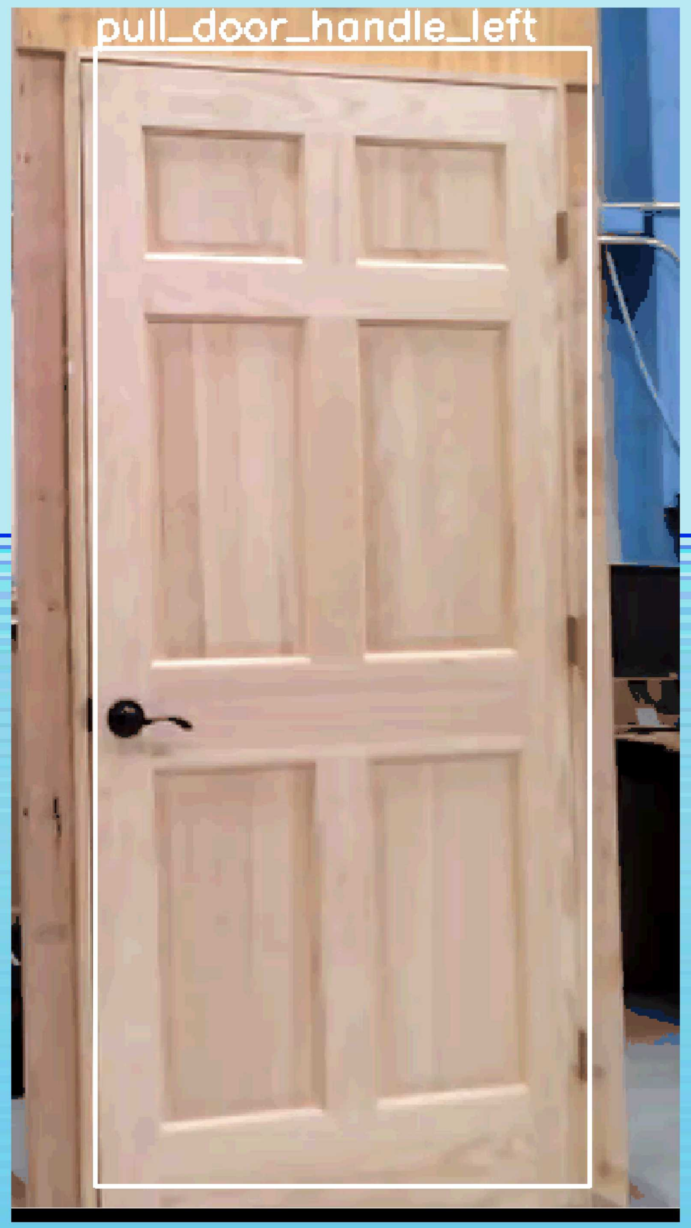

Figure 1. Door classified with YOLO.

Figure 1 shows the classified door that is a pull type with the handle on the left hand side of the door. This information helps predict how the door may move though space and allows for trajectory to be generated online to interact with the door.

Subcomponents, such as locations of interactions, like handles can also be identified.

Figure 2. Handle classified with YOLO.

Manipulation for High Uncertainty

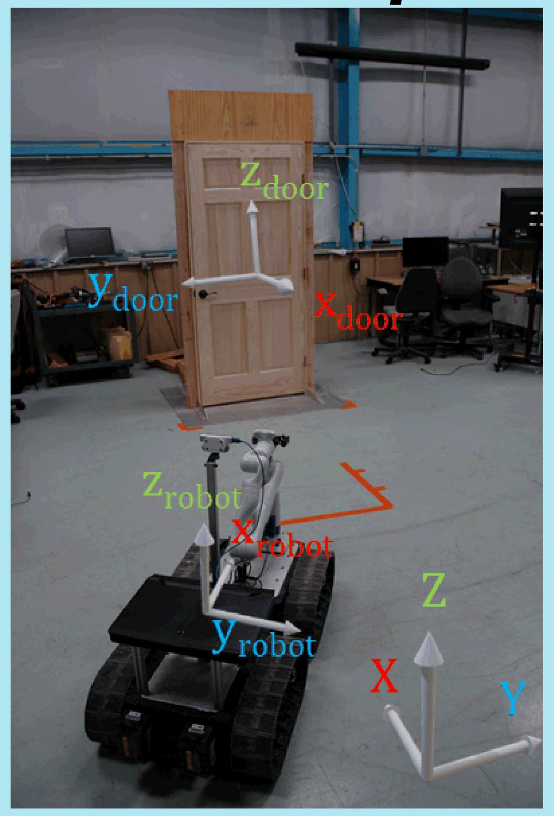

Figure 3. Gemini platform.

The uncertainty of a mobile robot location relative to objects in the environment is exacerbated by the larger global map that is significantly larger than the workspace of a traditional stationary robot. Sensor noise, odometry of skid-steer robots, make this uncertainty more problematic.

This technical challenge can be address by moving from a global frame to the local robot frame for interacting with objects in the environment.

Globalized perception of objects can help build primitive models how they can be plausibly manipulated. Figure 4. illustrates the construction of a 2 DOF mechanical model constructed from a classified door of type *pull_door_handle_right*.

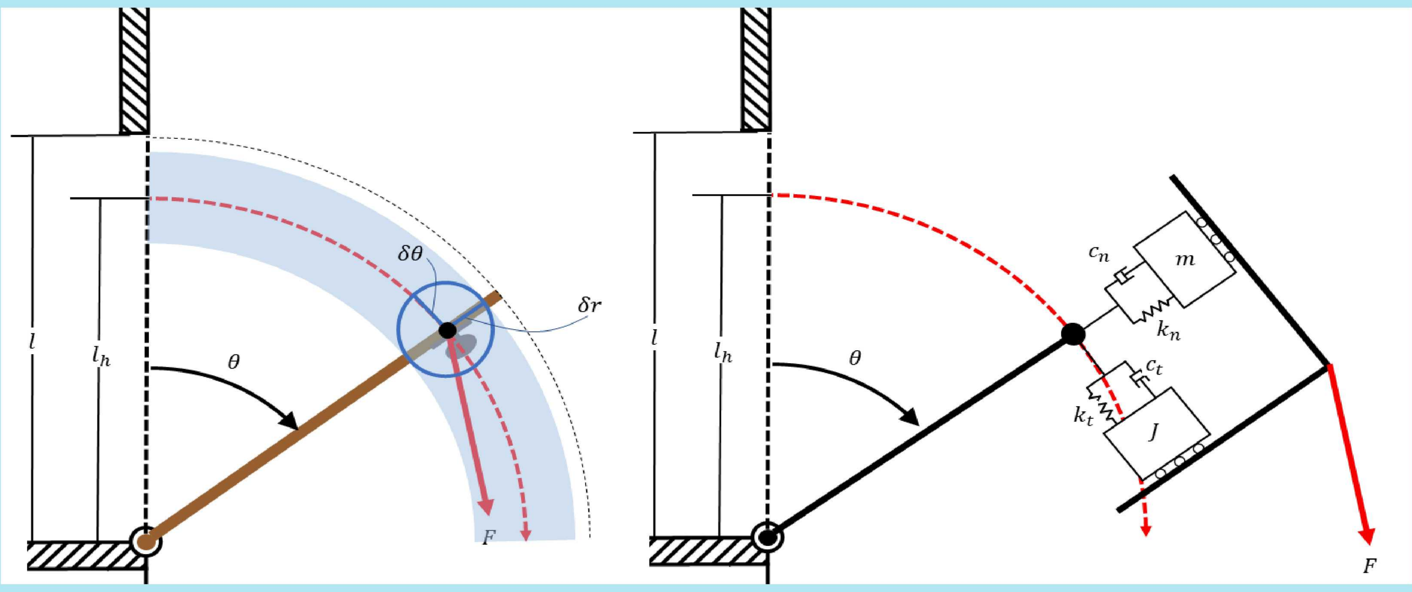

Figure 4. Mechanical model generated by perception toolchain.

The global model of an object can be translated to the local frame, where existing uncertainties can be addressed by utilizing impedance control of the robot arm, allowing for discrepancies between generated trajectories and what's physically encountered. Figure 5 illustrates the concept of the impedance controller that emulates a spring-damper behavior when subjected to an external force.

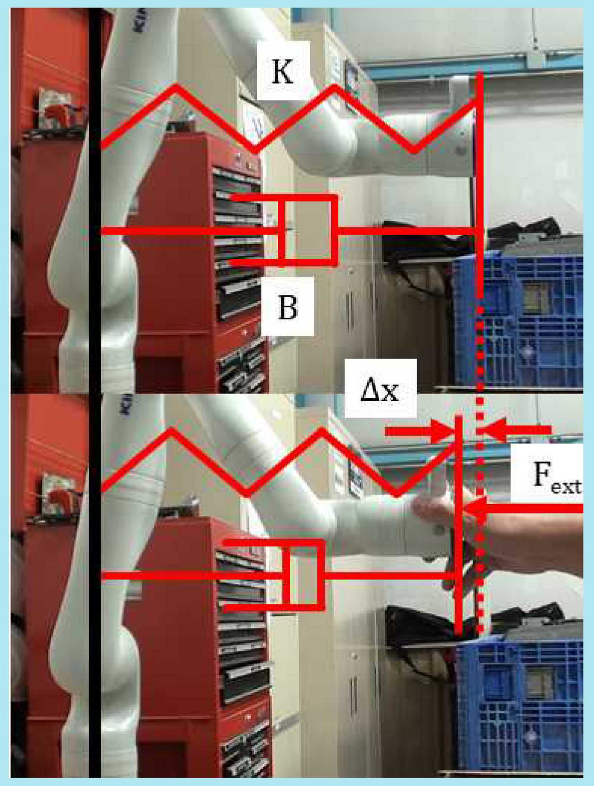

Figure 5. Robot arm impedance control.

Autonomous Interaction with the real-world

Combining the manipulation approach, complaint control, and perception toolchain, a mobile system can successfully interact with objects in the world, as shown by Gemini autonomously opening a door in 6a-6h.

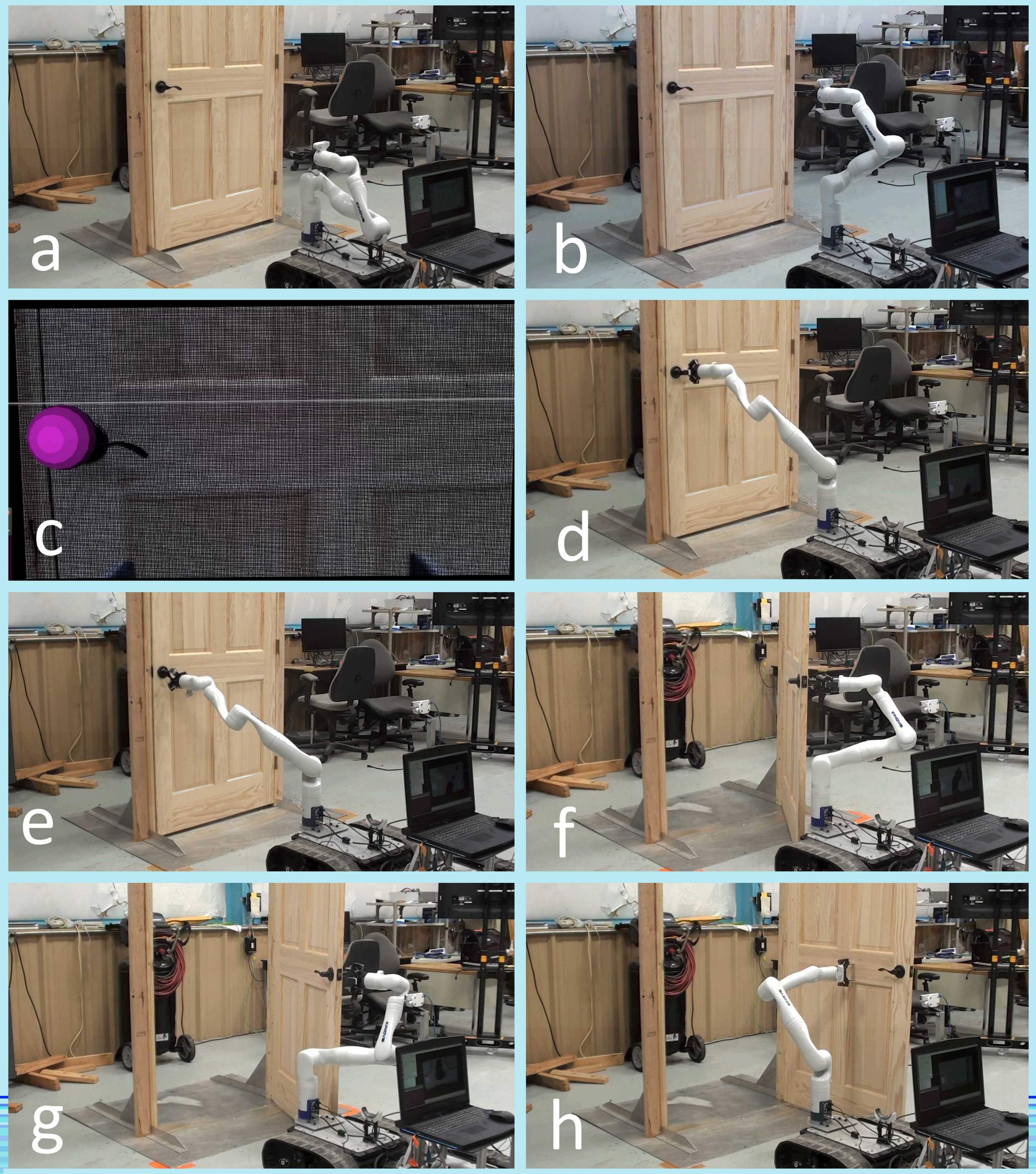

Figure 6. Autonomous door opening with Gemini platform.

Experiments have shown that desired tasks can still be achieved with the using impedance control approaches on a mobile platform.

Further improvements can likely be afforded adapting trajectories real-time to minimize forces and the robot end-effector and eliminate the possibility of significant forces that may result in a failed manipulation task.

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology &Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. ____________

Sandia National Laboratories