Microsoft Server Mover Project

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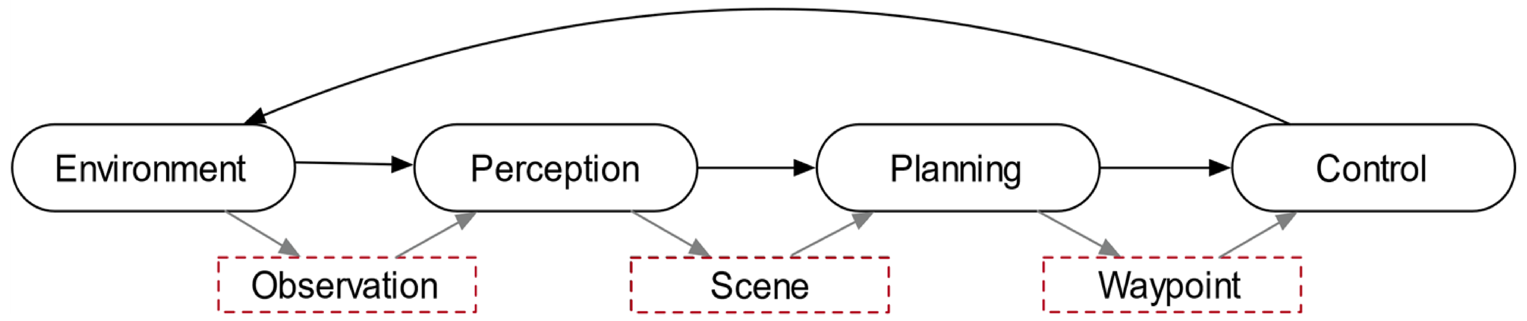
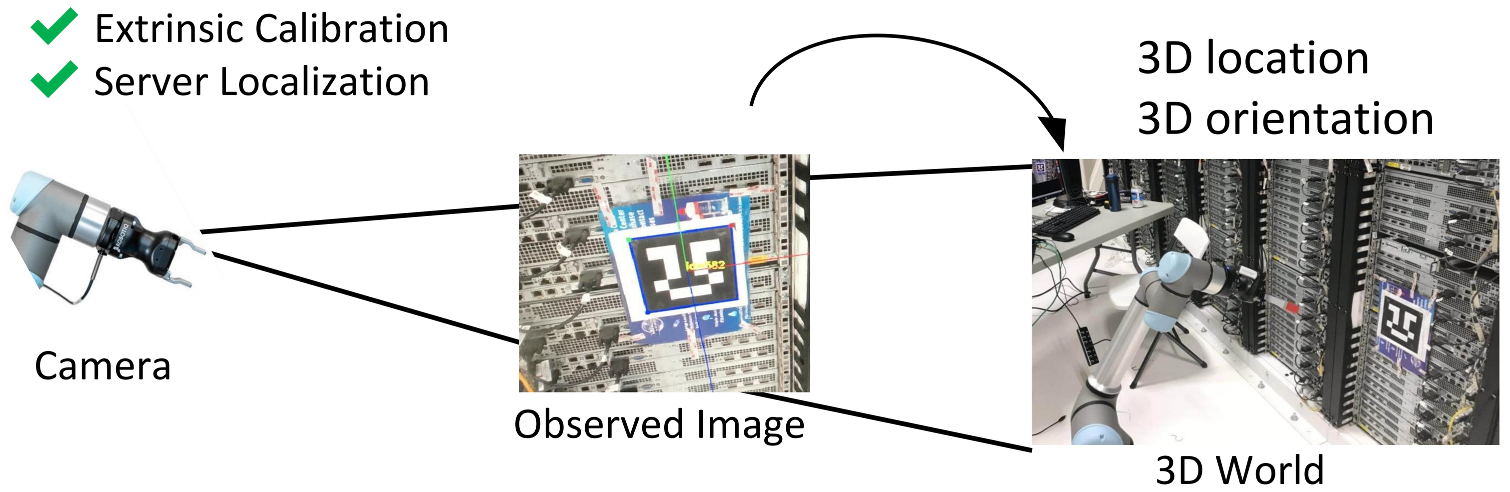
Overall System

- Collaborate with Microsoft to investigate a full-stack robot system composed of computer, electrical, and mechanical engineering, to automate the process of server replacement and server repairment.
- Build a mobile manipulator, shown on the left, that can detect and localize servers, pick and place servers, carry servers and navigate in the server room.
- A UR5 manipulator mounted on top of an autonomous grounded vehicle (AGV) equipped with LiDAR and conveyor.
- Our final system is capable of powering a conveyor, simulating a pick-place procedure, and successfully reaching the server rack in the real world.



Perception System

✔ Tag Pose Detection
✔ Extrinsic Calibration
✔ Server Localization



- Our camera hardware developments have included Logitech C270 (*usb_cam*), Asus xtion pro live (*openni2_camera*), Intel D435 (*realsense_ros*), and Robotiq wrist camera (*robotiq*).
- Camera Intrinsics Calibration: *camera_calibration* is used with a checkerboard. The lens distortions are verified empirically, and focal lengths are compared against product spec.
- Pose Detection: *aruco_ros* and *apriltags_*ros are applied for off-the-shelf pose detection. This results in cm accuracy for server localization.
- Camera Extrinsics Calibration: *easy_handeye* is used for calibrating the transform between the camera optical frame to the robot base. This calibration procedure requires the pose detection mechanism and motion system.

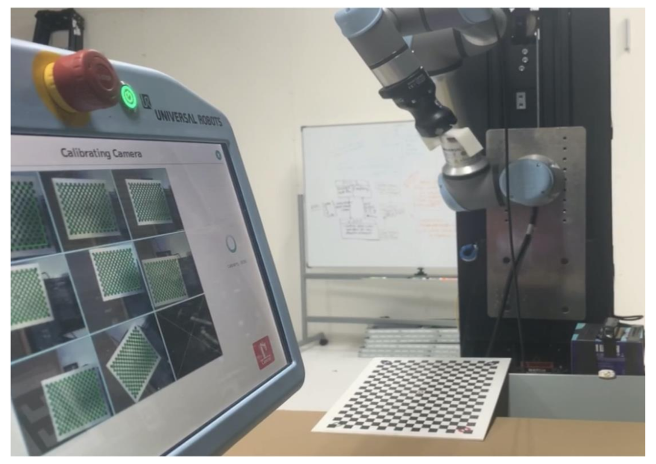
Note: *Italic font* denotes ROS package names.

Robotiq Wrist Camera:
- Compatible with UR5 as a URCAP for teach pendant
- Easily installable with the end effector
- Support off-the-shelf detection package.

Intel D435:
- RGB-D Camera
- Intrinsics Calibrated in factory
- Library supported for easy configuration
- ROS packages easy to use and stable

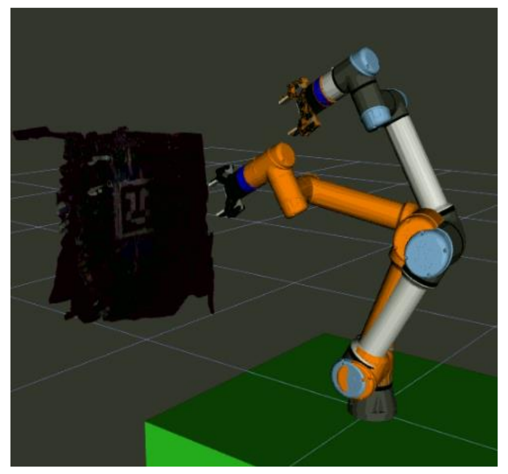
Teach Pendant System

- Independent from the ROS system, Teach Pendant can also be used for identifying the server, to change the orientation of the arm and to control the grippers.
- The wrist camera calibration procedure moves arm automatically and takes around 36 snapshots from different angles.
- Parametric Teach method is used with the wrist camera to identify the server. The input measurements of the object are processed to identify the object.



Teach Pendant Camera Calibration

Manipulation System



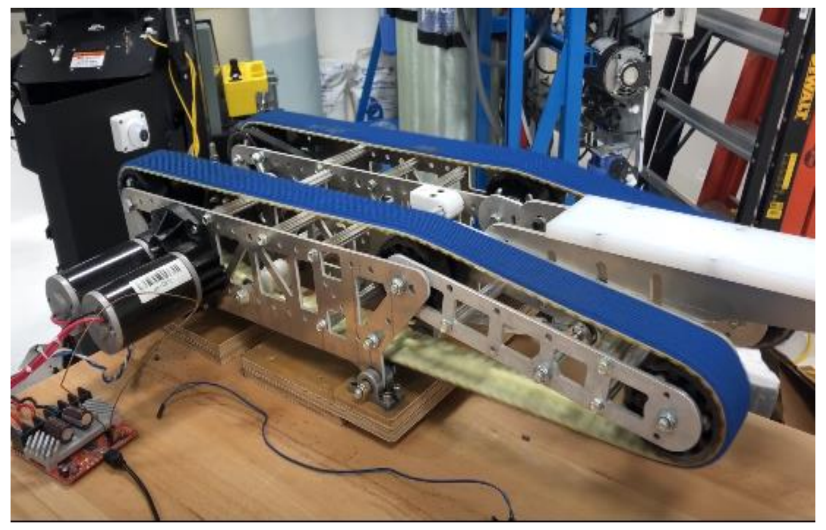
Manipulation Simulation

✔ Scene Simulation
✔ Arm & Gripper Control
✔ Collision-Free Motion Plan

- UR5 arm is integrated with Robotiq gripper and wrist camera in the rviz simulation. The green blocks denote the mounted base and the colored point clouds shows the camera observation.
- Moveit! is used as our planning framework to generate a smooth, collision-free trajectory in the configuration space.
- RRT-Connect implemented by the OMPL library is used to generate a trajectory for the controller to follow.
- After the vision system localizes the server, a grasp pose is computed as the input for our manipulation system. The generated trajectory and simulated motion can be visualized in rviz before real-world execution.
- Optimized parameters and features such as customized collision check, postprocessing trajectory optimizer, and coordination with the navigation system are left for future works.

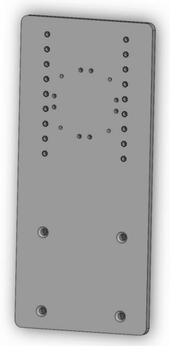
Mechanical System

LiDAR Mount Design



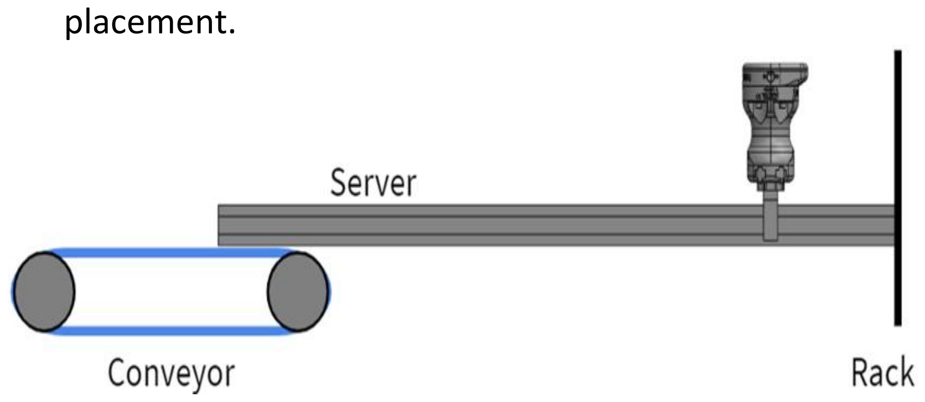
Conveyor

- Machined UR-5e Mount for AGV.
- Designed LiDAR camera mounts, 3D printed LiDAR mount prototype.
- Designed end-effector and 3-D printed functioning prototype and final design.
- Wired, configured, and programmed conveyor for server removal and placement.



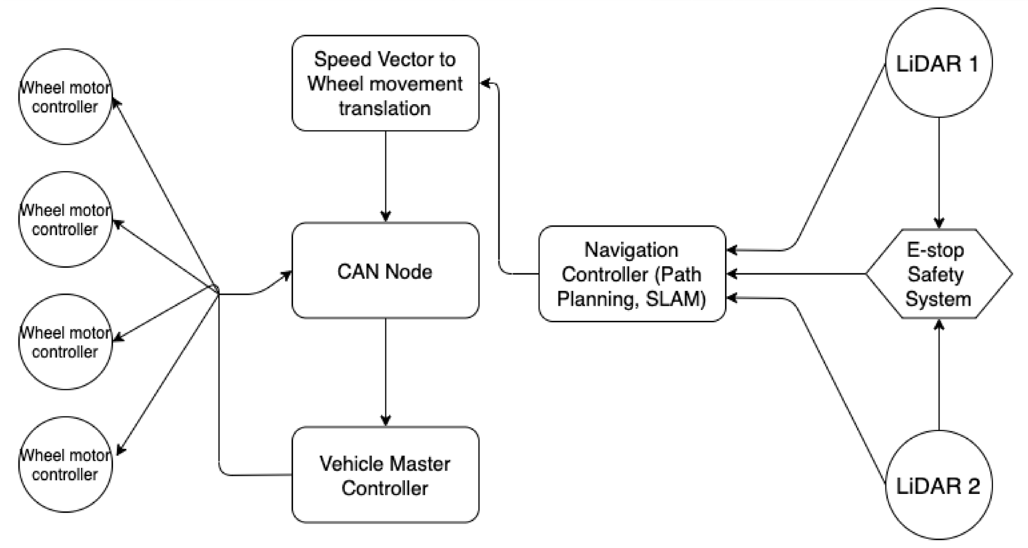
UR-5e Mount

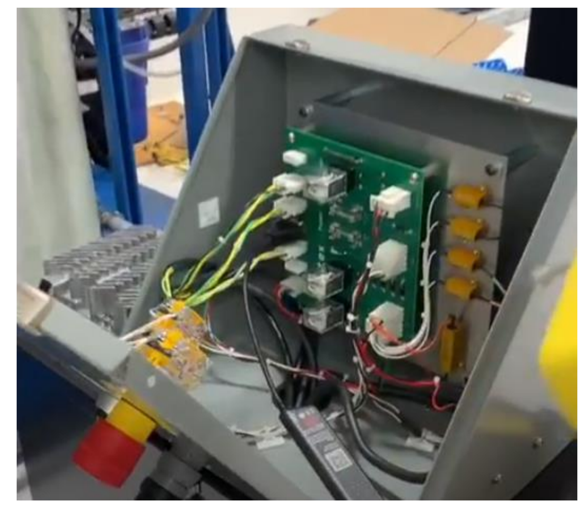
End Effector Design



System Overview:
- UR5e with end effector pulls out and guides server to conveyor.
- Conveyor pulls server onto AGV.
- Process repeats in reverse order for server loading.

Navigation System





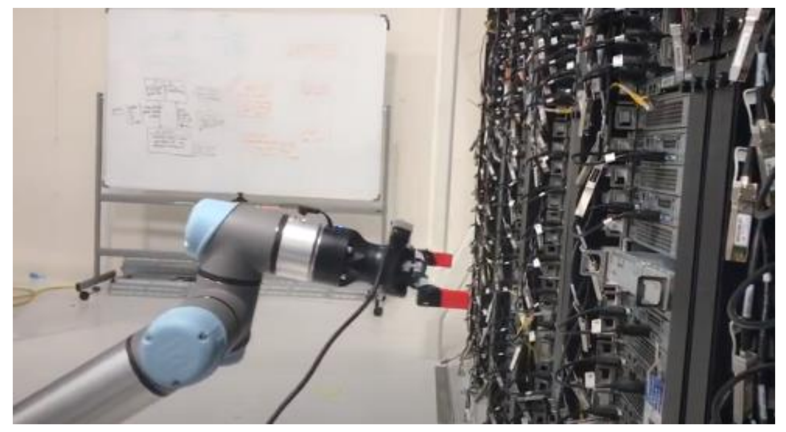
CAN Node and VMC

- The ANT Lite+ software is the high-level navigation controller that is responsible for path planning.
- The Speed vector commands outputted from ANT Lite are converted to omnidirectional wheel movements.
- Our CAN node can use the CAN Open communication protocol for controlling the vehicle.
- The VMC(vehicle master controller) receives CAN commands and controls the movement of the vehicle.
- The speed feedback from the wheels is communicated in real time with ANT Lite

Experimental Outcome

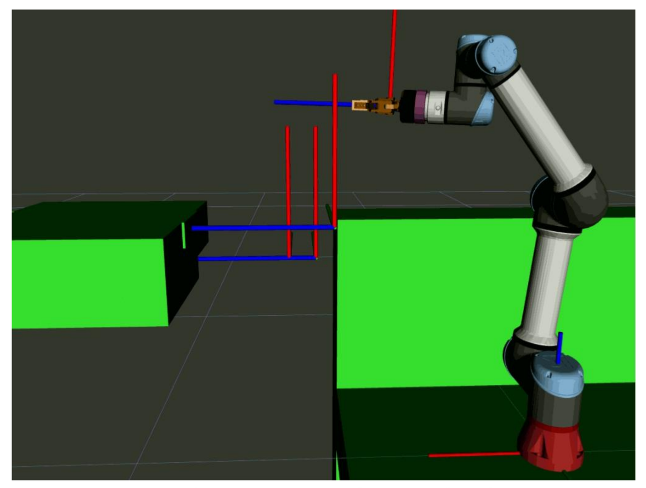
Real World

- This demo shows a UR5 server reaching task in the real world.
- The mounted vision system detects the tag on the server rack and the manipulation system plans and controls the motion to grasp a server on the top.



Real World Reaching

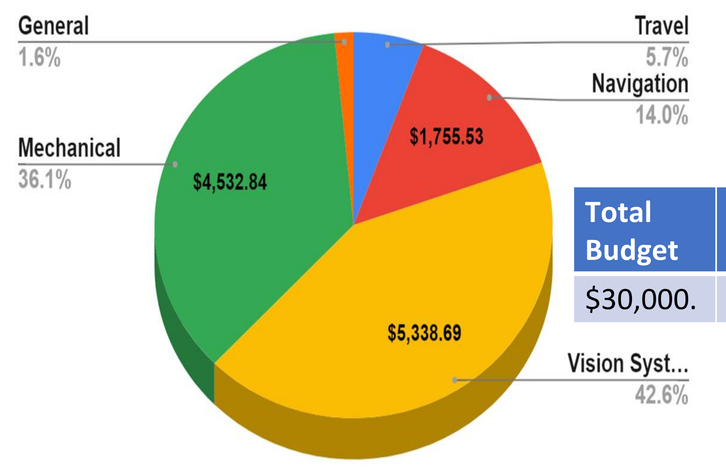
Simulation



Simulation Pick and Place

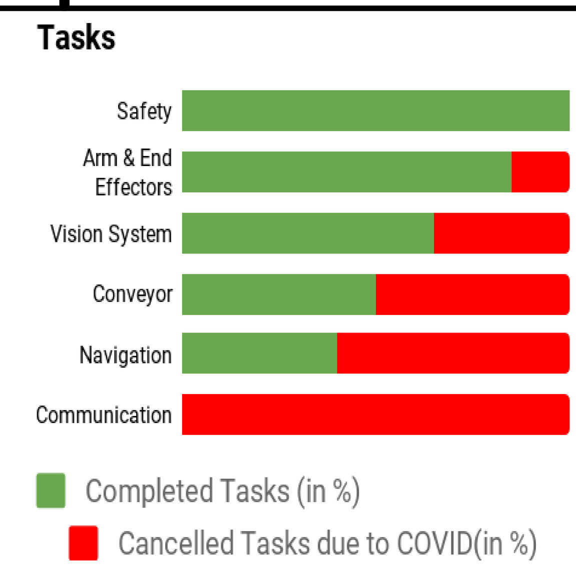
- This simulation demo shows how UR5 would grasp a server and place it in the server rack.
- The axes represent the coordinate systems on base, end effector, and server standoff pose.
- The green blocks to the right simulate servers on the server rack and the green blocks near the robot denote virtual obstacles.
- The planning system generates smooth trajectory for controller execution.

Budget



Total Budget	Total Spent
$30,000.	$12,542.

Requirement



Future Work

- Integrate ROS and Teach Pendant System to one system.
- Integrate marker detection system to increase accuracy of server identification.
- Full test for accurate and robust pick-and-place in the real world.
- Implement autonomous navigation and test in the real world.
- Complete communication protocol with Server Repair work cell and be able to carry servers back and to the work cell.