AMBOTS

Cooperative 3D Printing

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Introduction

The manufacturing industry is limited by the specialization of machines in factories. AMBOTS is working to use swarm 3D printing and assembly to move towards a general-purpose factory. One step in this process is using different third-party robotic arms, but they all have their own native languages. Our goal is to design and implement a communication protocol for different third-party robotic arms to communicate with each other to cooperatively complete a task.

Kinova Gen3 6DoF

The Knova Gen3 Six Degrees of Freedom (6DOF) robotic arm is a 6-axis robotic arm. It is ROS compatible and can be simulated in both RViz and Gazebo.

UR10

The Universal Robots UR10 is the largest robot in the Universal Robots collaborative series. It has a payload up to 10 kg. It is very easy to set up and provides an accuracy of about 0.1mm. It is ROS compatible and can be simulated in both RViz and Gazebo.
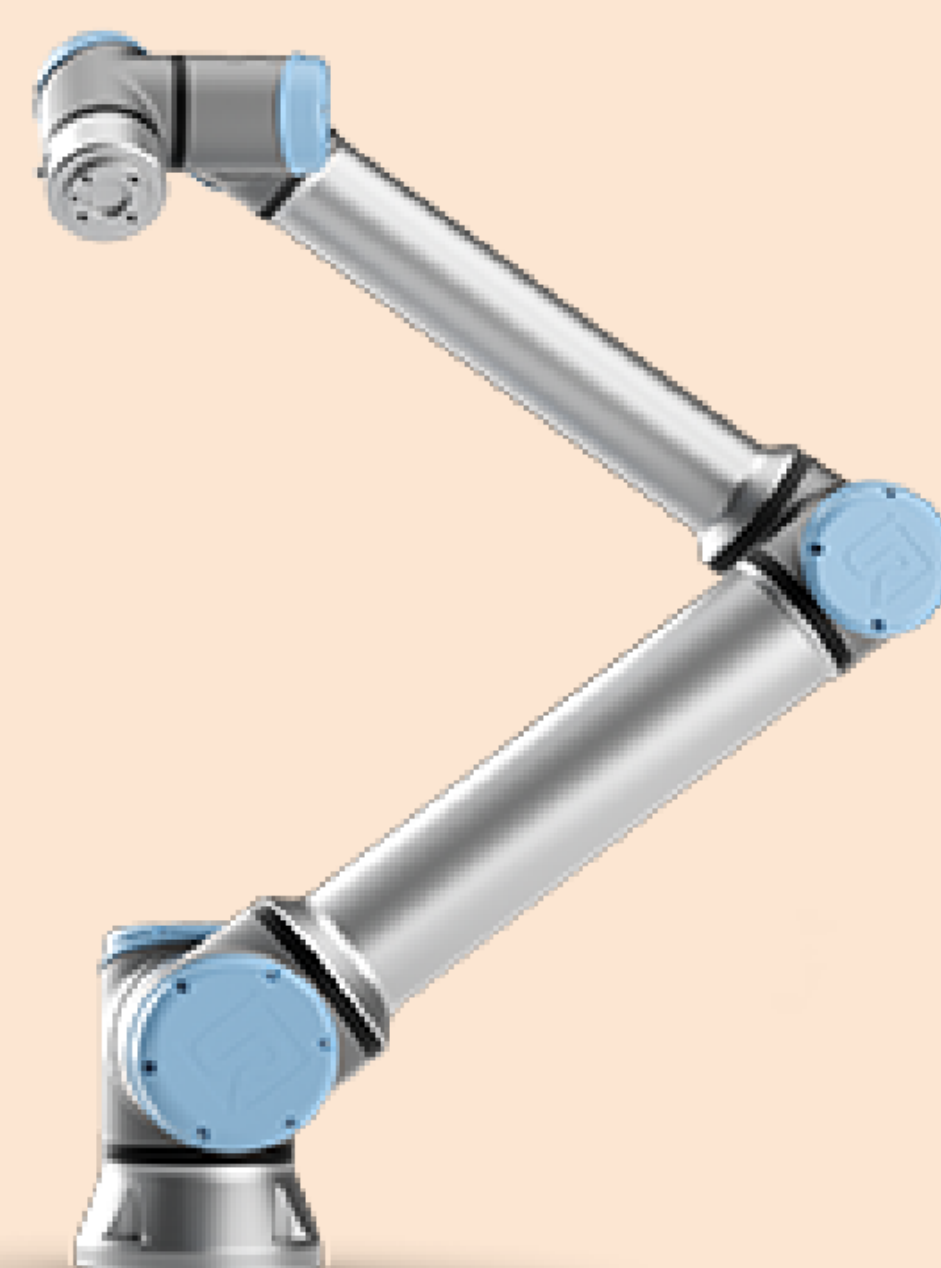
Architecture

Frontend - The front end receives the initial CAD (STL) file, which is divided into two files for each robotic arm using PyMesh. The two resulting STL files are converted into G-code using PrusaSlicer's CLI, and a bash file automates this process. The G-code files are sent to the Communication Hub. A GUI may be added if time permits.

Communication Hub - The communication hub receives the G-code from the front end and inserts any necessary pause or resume commands to avoid any collisions between the robots. Then it sends the commands to the firmware of the robots. Also, the hub handles communication between robots since direct communication is not possible between robots of different brands.

Firmware - The firmware handles the translation of the G-code commands into the robot's native language. It must map any movement distances into the robots' working space since each robot may be a different size and have different maximum reaches. The firmware nodes are where direct communication with each robot takes place.

Rviz - Rviz is the visualization software we use to simulate the movement of the arms. In a real use-case, this would be the actual robotic arms themselves.

High-Level Design
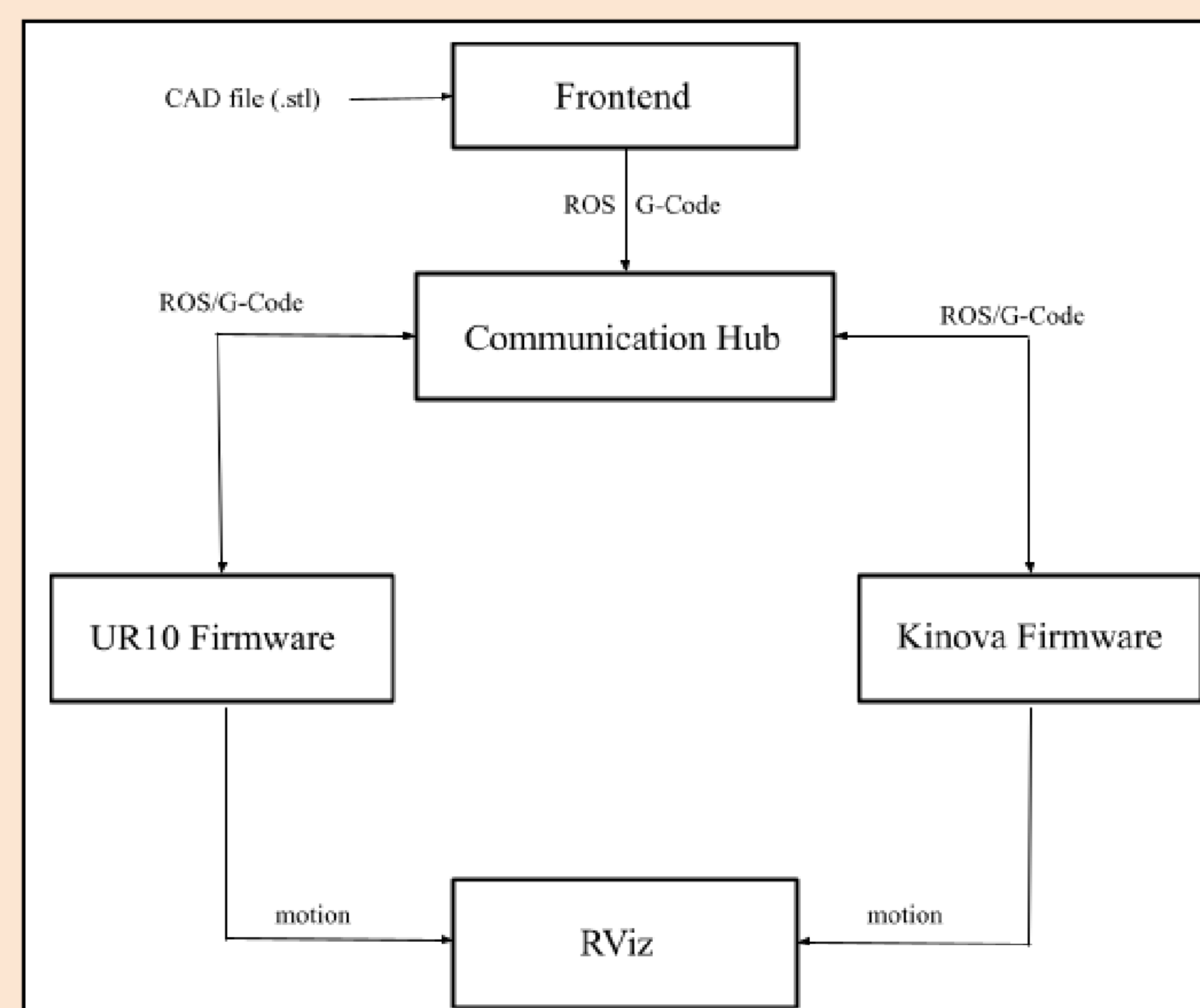
Potential Impact

This project's potential impact is for AMBOTS to use multiple different robotic arms from different brands in their research and products. Allowing cooperative 3D printing without having to develop a whole network of new robotic arms, which would be impractical and inefficient.

Future Work

While we are proud of what we have achieved, there are a few items that we were unable to get to. These include:

• Adding collision detection for the arms. Currently, our simulation does not check for collisions between arms.

• The ability to automatically compute alignment offsets. In our implementation, these values are hard-coded for the various arms.

• Switch to using Gazebo and M3DP-Sim. Rviz is great for visualization however it lacks the superior physics simulation of the Gazebo and M3DP-Sim simulation environments.

• Add a graphical user interface. A command line interface adds a level of complexity that inhibits non-technical workers from using the system. A GUI would make the system more accessible to more users.

Results

Overall, we were able to achieve the 3D printing of an object using multiple robotic arms of different brands. Starting with a single STL file all the way to a completed print in Rviz.