Viability of Low-Fidelity Platforms for Autonomous Robotic Construction. J. Martin[1], A. Quartaro[1], and E. Komendera[2],
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Introduction: For robotic construction to be a viable solution for commercial applications, low cost and easily acquired components must be available. Additionally, for in-space assembly (ISA) problems, where teleoperation is often not feasible due to the large distances between operators and the assembly sites, robotic systems must be autonomous [1]. The Field and Space Experimental Robotics (FASER) Laboratory has investigated the use of a COTS components built autonomous robotic platform, capable of interacting over an autonomous network with other robots and passive manipulation objects. As such, the Mobile Assembly Robotic Collaborator (MARC), a low-fidelity system, has been proven capable of basic assembly and construction tasks, both with teleoperation and goal-oriented autonomy.

Collaboration Implementation: The MARC robot is a medium-scale manipulator, divided into two main components: a wheelbase and a robotic arm. The wheel-base uses mecanum wheels to provide vectorized motion in any direction on the floor plane. The arm consists of a Gearwurx arm [2], with additional wrist joints to increase the degrees of freedom (DOF) to a 6 DOF arm, and customized end effectors (EE).

The EE used is based on electro-permanent magnet (EPM) technology, developed by Altius Space Machines [3] and integrated into the MARC to make an in-house robotic interface, and allows for a toggleable magnetic gripping force with minimal power requirements. The EPM interface is beneficial because it expands the capture volume for planar and rotational tolerances while not introducing additional moving components.

Given the nature of the commercial, low-cost MARC system, the precision of robot operations is tied to the limits of hardware constraints. However, implementing the autonomy structure and using the EPM interface enables the MARC to be a viable infrastructure for heterogeneous robotic collaboration, allowing for collaborating MARCs or a singular MARC paired with a dexterous manipulator (Stewart-Gogh Platform) to complete higher precision tasks.

Autonomous Integration: Because autonomous systems are vital to construction in harsh environments, the MARC is constructed such that it is capable of autonomous and teleoperation commands. The autonomy structure utilized involves an HTTP server with high level controls and visualization done through a web browser, sending joint commands at a frequency of 8Hz to every robot in the current scenario.

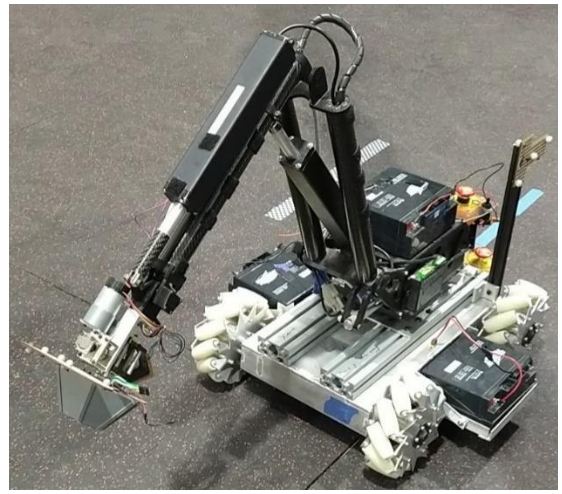

Figure 1: MARC Hardware System

State estimation of the robot joints is achieved by applied an Ensemble Kalman Filter with measurements taken from two metrology marker sets on each MARC, placed on the base and EE as shown in Fig. 1. Furthermore, screw theory forward and inverse kinematics are used to determine output joint values and velocities. The MARC system does not send encoder joint values back to the autonomy controller, which acts as an example of manipulation without perfect information, or how a non-invasive autonomy system can be integrated into a system.

Experiment: To demonstrate the MARCs in a collaborative construction application, two MARCs are controlled by the central autonomy computer to execute a sequential set of tasks based on feedback from the external metrology system and the ON/OFF status of each MARC's EE.

References: [1] Komendera E. et al (2017), *IEEE/RSJ IROS*, 4672-4679. [2] Gearwurx, https://gearwurx.com/, Accessed: 2022-3-01.
[3] Altius Space Machines, https://altius-space.com/technologies.html