Parallel Robot Projects at Ohio University

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The purpose of this white paper is just a bit of the old show-and-tell. The following parallel manipulators and haptic interfaces have been designed, built, programmed, controlled, and evaluated at Ohio University by the author along with the listed graduate students and visiting researcher. Feel free to contact the first author for further discussions on these or any other parallel robot projects.

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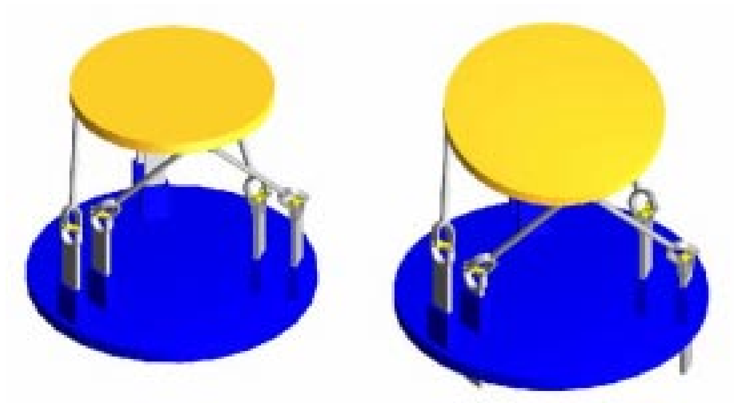
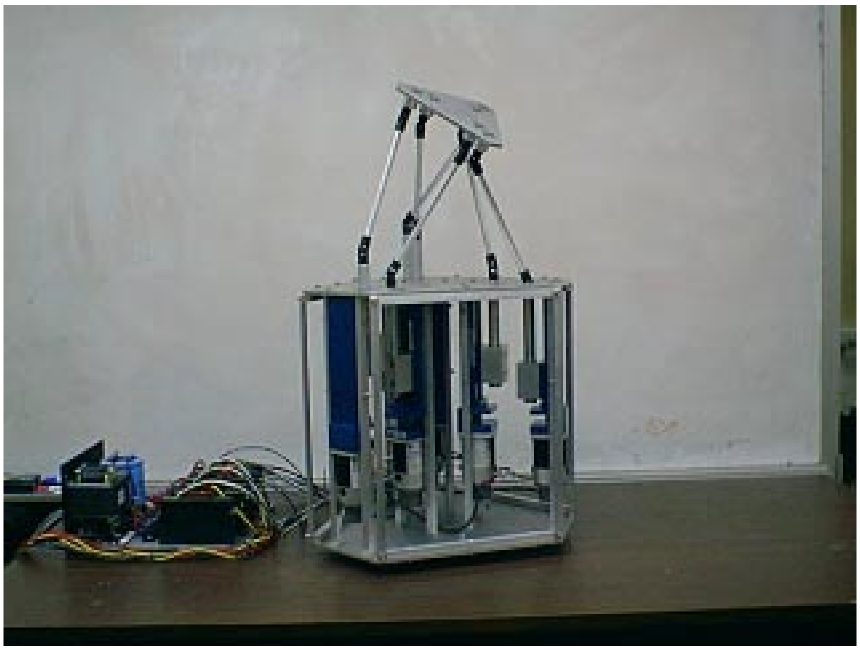
Parallel Robot Projects at Ohio University

1. GPS/IMU Calibration Platform

The Department of Mechanical Engineering and the Avionics Engineering Center at Ohio University have developed an electromechanical system for the calibration of an inertial measurement unit (IMU) using global positioning system (GPS) antennas. The GPS antennas and IMU are mounted to a common platform to be oriented in the angular roll, pitch, and yaw motions. Vertical motion is also included to test the systems in a vibrational manner. A four-dof system based on the parallel Carpal Wrist (from Virginia Tech, in turn from NASA Langley Research Center's double-octahedral variable geometry truss) is used; the carpal wrist has three linear actuators and the entire system rotates on a turntable. High-accuracy positioning is not required from the platform since the GPS technology provides absolute positioning for the IMU calibration process.

2. 6-PSU Platform Manipulator

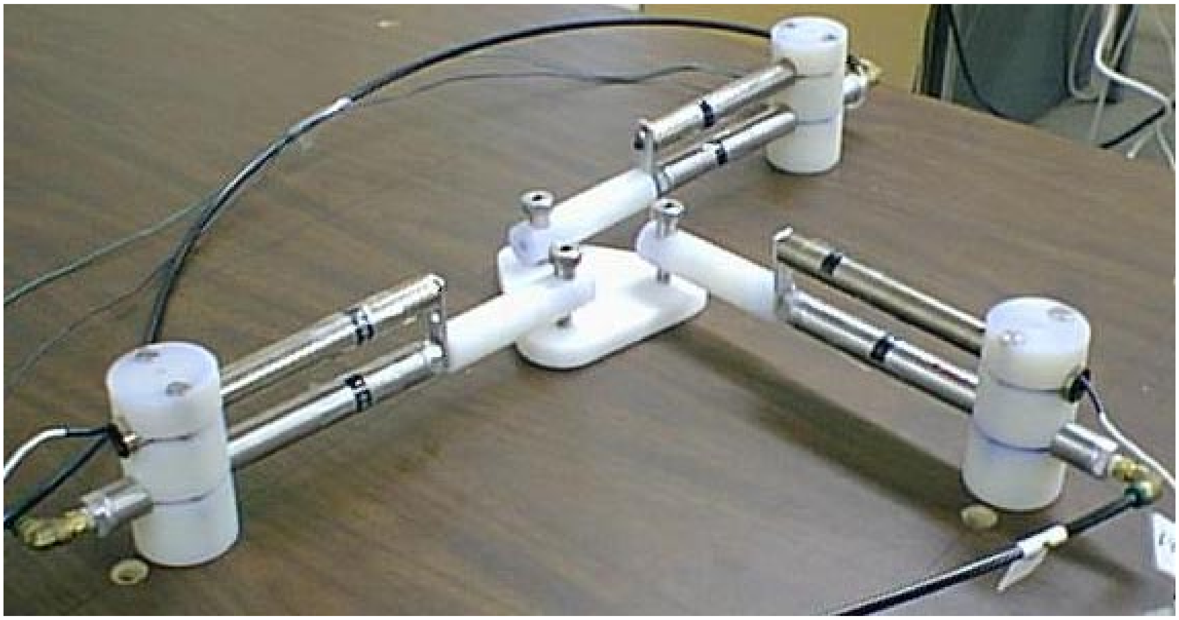


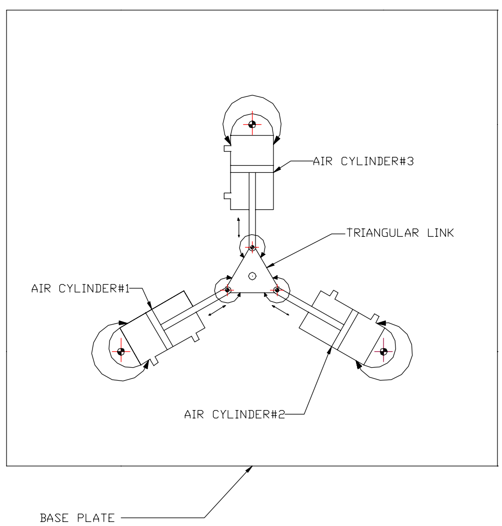


The Department of Mechanical Engineering at Ohio University has designed, constructed, and controlled a new 6-dof in-parallel-actuated platform, a combination and modification of existing designs. The 6-PSU platform consists of 6 legs with a prismatic joint, spherical joint, and universal joint connecting links in each leg which move the platform in the six Cartesian freedoms with respect to the base. The prismatic joint is actuated while the other two joints in each leg are passive. The six prismatic joints move vertically with respect to the base, which appears to be a big improvement over the standard Gough/Stewart platform. The base and moving platform joint locations are on concentric circles, which appears to have dexterity advantages over same-circle joint locations.

Our inspiration for this project comes from the Sandia Paradex, Merlet and Gosselin, Stoughton, Kozlowski, Wang et al., and Bonev and Ryu.

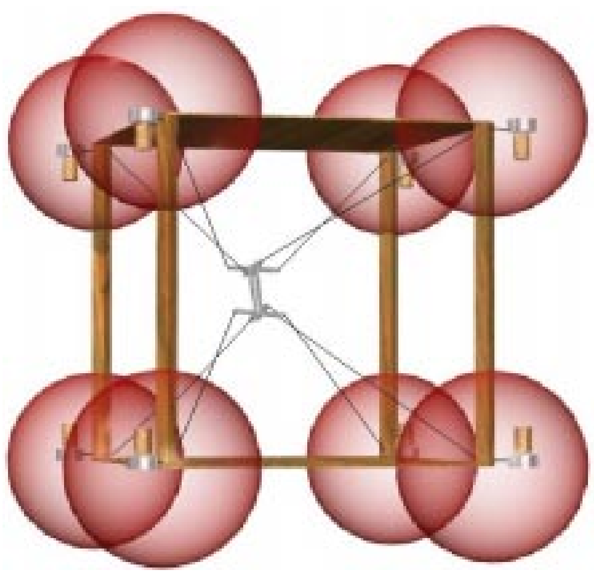
3. Pneumatic planar 3-RPR Robot





A planar three degree-of-freedom (dof) in-parallel-actuated manipulator has been designed, constructed, and controlled at Ohio University. The symmetric manipulator is composed of three identical legs connecting the fixed base to the end-effector triangle (see the figures). Each leg is of *RPR* design, with two passive revolute joints and an active prismatic joint in-between. Each prismatic joint is an actively controlled pneumatic cylinder. Using real-time closed-loop feedback control for each actuator length independently, we developed inverse pose and resolved-rate control for this manipulator. The objective of this work is to implement in hardware this 3-*RPR* manipulator design and to evaluate parallel manipulator control using pneumatics. This type of manipulator can be used for general tasks such as assembly and trajectory following. Since the workspace is smaller than an equivalent serial robot, we have considered workspace determination and design for this manipulator.

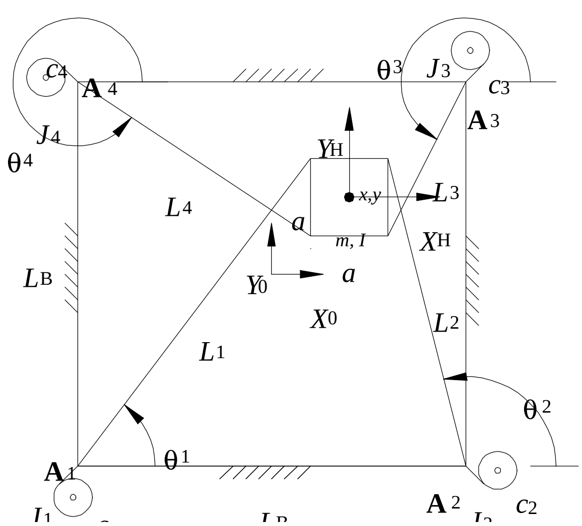
4. 8-dof spatial Cable-Suspended Haptic Interface (CSHI)



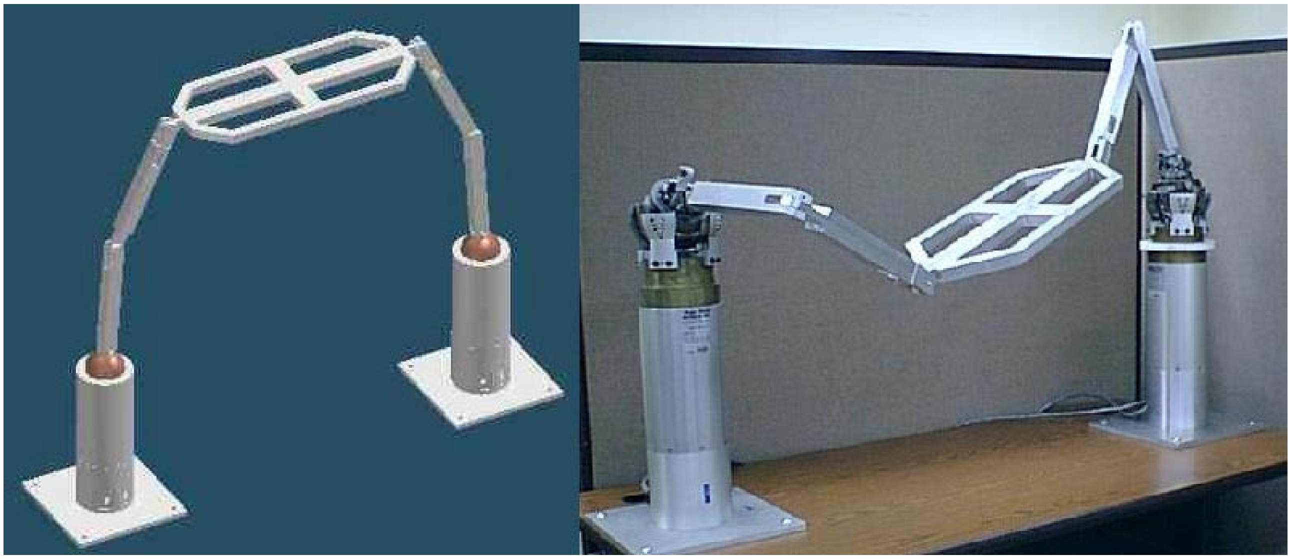
An 8-dof cable-suspended haptic interface (*CSHI*) has been designed and built at Ohio University. The goal is to create an input/output device to provide six-degree-of-freedom (dof) wrench (force and moment) feedback to a human operator in virtual reality or remote applications. Compared to commercially-available haptic interfaces for virtual reality applications, the present concept is striving for lighter, safer, crisper, more dexterous, and more economical operation. The first virtual environment programmed includes 8 one-eighth spheres with linear stiffness located at each corner of the frame, as shown above.

5. 4-dof planar Cable-Direct-Driven Robot (CDDR)

We have simulated the dynamics and control of a planar, translational cable-direct-driven robot (CDDR). The motivation behind this work is to improve the serious cable interference problem with existing CDDRs and to avoid configurations where negative cable tensions are required to exert general forces on the environment and during dynamic motions. Generally for CDDRs the commanded rotations are more demanding than commanded translations in terms of slack cable conditions. Therefore we provide a translational CDDR whose end-effector may be fitted with a traditional serial wrist mechanism to provide the rotational freedoms (assuming proper design to resist the rotational moments). We have simulated examples to demonstrate control including feedback linearization of the 4-cable CDDR (with one degree of actuation redundancy) performing a Cartesian task. An on-line dynamic minimum torque estimation algorithm has been developed to ensure all cable tensions remain positive for all motion; otherwise slack cables can result from CDDR dynamics and control is lost. We have built a planar 4-dof CDDR for experimental verification of our theoretical and simulation results.

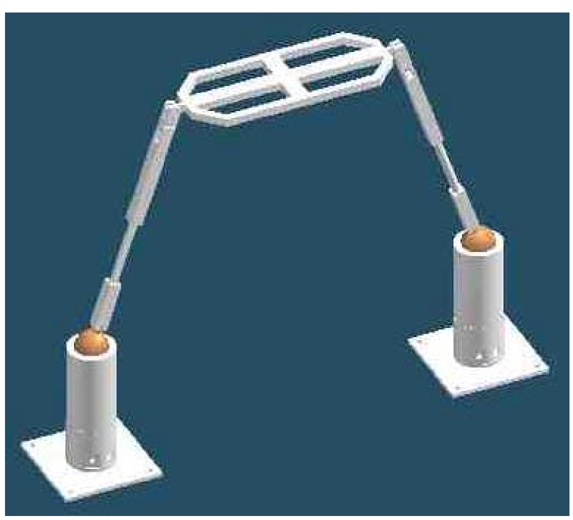


6. Spherically-Actuated platform Manipulators (SAM)



A novel 6-dof platform manipulator has been developed at Ohio University, actuated by two base-mounted spherical actuators. The moving platform is connected to the fixed base by two identical *SRU* serial chain legs. The *S*-joint is active, and the remaining two joints in each chain are passive. An analytical solution has been developed for the inverse pose kinematics problem, a semi-analytical solution is used for the rate kinematics problems, and the numerical Newton-Raphson technique has been employed to solve the forward pose problem. Unfortunately, the passive joint variables cannot be ignored in the kinematics solutions as they can for the Gough/Stewart platform. Experimental hardware has been built, using two Rosheim Omni-Wrists from NASA Langley Research Center as the spherical actuators.

An improved SAM is currently under development, wherein the serial chains are two identical *SPU* serial chain legs; that is, the passive revolute (*R*) joints will be replaced with passive prismatic (*P*) joints, see the CAD concept below. This change allows better singularity avoidance and better workspace.



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