Developments toward a hybrid actuated cable-driven parallel manipulator

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ABSTRACT

A hybrid cable-driven parallel manipulator (CDPM) is being developed that expands the capabilities of conventional CDPMs by replacing one of the cables with a high packing ratio linear actuator that can be spooled and extended. This actuator uses three curved leaf springs connected using magnetic strips to provide compressive or tensile forces while being very compactly stored, and is kinematically similar to a cable that can push. Conventional CDPMs are useful because they can be lightweight, efficient, have workspaces of hundreds of metres across, and have had accelerations greater than 40G. They are limited in that each of the cables can only produce a tensile force, meaning that in order to function they must have limited forces and accelerations or be configured so that the cables pull against one another antagonistically. By incorporating the extensible linear actuator into the design of a CDPM, the resultant hybrid-actuated manipulator can maintain many of the benefits of standard CDPMs and help overcome their unique challenges. This is being implemented into a 4-actuator pick-and-place manipulator with each of the actuators placed above the workspace in order to help avoid cable interference and ensure that this manipulator could be used in similar spaces as other pick-and-place manipulators like the popular Flexpicker robot created by the ABB (ASEA Brown Boveri) robotics company.

For the linear actuator to be used as a replacement for a cable it must be capable of similar motions. CDPMs treat each cable kinematically as a UPS kinematic chain, where U represents a universal joint, P is an actuated prismatic joint, and S represents a spherical joint, more simply described as a straight line from an anchor point on the frame to one on the end-effector. The designed linear actuator must be capable of these same pointing motions, with a universal joint fixed to the frame and a spherical attachment to the end-effector. The universal attachment to the frame is a complicated mechanical design problem for an actuator that is created from three coiled rolls, must have low weight and inertia to allow pointing motions, and support each coiled leaf spring before they are combined into a rigid rod, as they can easily buckle before that. This design is presented in the context of the spatial manipulator, along with the potential uses of the pick-and-place manipulator.