Development of the Carpal Wrist; a Symmetric, Parallel-Architecture Robotic Wrist

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Abstract

This dissertation summarizes the research effort to develop a novel, three degree-of-freedom device that is ideally suited as a robotic wrist or platform manipulator. Because of its similarity to the human wrist, this invention has been named the "Carpal Wrist." Much like its natural counterpart, the Carpal Wrist has eight primary links, corresponding to the eight carpal bones of the human wrist, a parallel actuation scheme, similar to the flexor and extensor carpi muscles along the forearm, and an open interior passage, which forms a protected tunnel for routing hoses and electrical cables, much like the well-known carpal tunnel. The Carpal Wrist also has the significant advantages of possessing closed-form forward and inverse kinematic solutions and a large, dexterous workspace that is free of interior singularities (either considered separately or as part of a manipulator arm). As a result of its symmetric parallel architecture, the Wrist can handle a large payload capacity and can easily be adapted to a variety of actuation schemes.

While parallel-architecture manipulators have long been recognized for their high-rigidity and large payload-to-weight capacity, few have been developed for application, primarily because of complications in kinematic and dynamic modeling. The mathematical model of any manipulator must be developed in order to allow the necessary motion control of the device. The mathematical model provides a mapping from the input space (called joint space) to the output space (called tool space) of the manipulator. Given a desired task in terms of motion of the robot tool, the mathematical model determines the required motor input parameters. Advanced manipulator performance through automatic control becomes possible when the model includes inertial or dynamic effects of the manipulator and tool. The research leading to the development of the Carpal Wrist is significant because it presents a complete kinematic and dynamic model of a parallel-architecture manipulator, and thus will provide significant improvement over current serial robot technology.

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Carpal Wrist Prototype Video

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