Design and Control of a Three-DoF Ball Joint With Applications in Robotic COVID-19 Swabbing and Surgery

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This paper presents the mechanical design and control of a three degree of freedom (DoF) ball joint module suitable for use in COVID swabbing robots and surgical robots. A prototype iteration was constructed to verify the mechanism, and a final iteration was designed in CAD. The final iteration features a more compact, robust structure and significantly larger range of motion than the prototype. Configurations of the modules with various medical and surgical tools were demonstrated as well. To create three DoF motion and overcome limitations of current medical robots, the modules incorporate two spherical gears, the cross spherical gear (CS-gear) and monopole gear (MP-gear). Each MP-gear transmits motion in up to two DoF, pitch and roll, to the CS-gear. With an MP-gear placed on both sides of the CS-gear, which is constrained by a spherical housing, three DoF motion is achieved. Custom differential mechanisms were manufactured to drive each MP-gear in two DoF. To evaluate performance, mathematical simulations of the system's inverse kinematics were conducted, and the control algorithm was implemented on the prototype assembly. Comparisons to existing medical robot actuation and range of motion capabilities confirm this mechanism's potential for extensive performance improvements in COVID swabbing robots and surgical robots.

Awards Won:
Third Award of $1,000