Twentieth Conference for African American Researchers in the Mathematical Sciences
CAARMS20 – Princeton University, June 11th -14th , 2014

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Surgical Motion Characterization for Robotic Device Design and Surgical Performance Assessment

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The efficacy of surgical robots can be improved significantly if their designs are based upon knowledge of effective manual surgery practices and relevant technical skills. This research focuses on empirical characterization of manual microsurgical motion for the purpose of (1) developing performance specifications for a microsurgery robot designed to enhance the technical skills of surgeons and (2) establishing correlations between quantitative measures of surgical motion and qualitative surgical performance evaluations so that performance assessment can be standardized and automated.

Manual microsurgical motion is characterized by attaching small electromagnetic trackers to surgical instruments to record instrument motions as surgeons perform procedures. Instrument motion data acquired over several procedures are statistically analyzed to determine attributes such as workspace boundaries, spatial and angular motion ranges, distribution and frequency of specific motions types, and motion bandwidth. These data are used to define the kinematic structure, mechanism design, and control capabilities required of a robotic device to enhance surgical micromanipulation capabilities. A novel dexterous robotic wrist mechanism was designed specifically to meet these kinematic requirements.

This experimentally acquired surgical motion data was also compared against qualitative, subjective measures of surgical performance to establish a mapping between kinematic tendencies and what experts perceive as high surgical proficiency. Results show a clear correlation between motion data and perceived proficiency, where path length and task time (quantitative measures) decrease with qualitative scoring of surgical skill and amount experience. The degree of this correlation, however, tends to decrease as surgeons become more expert.