Robot and surgeon - towards understanding of surgeon motor control in robotic surgery

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Teleoperated robotic minimally invasive surgery is a complex sensorimotor task in which surgeons use robotic manipulators to control instruments that are inserted into the body of the patient via small incisions. While being widely adopted for many procedures, robotic surgery has not realized its full potential to date. Prior studies have shown that robotic outcomes are correlated with the case experience of the surgeon, but the relative contribution of cognitive versus motor skill is not well understood.

As a first step towards modeling of surgeons’ movements in robotic surgery, we quantified the effects of master manipulator dynamics on simple reach movements of experienced surgeons and novice users. We hypothesized that, during teleoperation, the dynamics of the master manipulators impose challenges on the motor system of the user and may impact performance and learning. Using kinematic analysis of freehand and teleoperated movements, we found significant direction-dependent effects of teleoperation, user experience, and learning in several aspects of motion, including target acquisition error, movement speed, and movement smoothness. Using the Uncontrolled Manifold framework, we found that experienced surgeons coordinate the variability of their joint angles to stabilize hand movements more than novices, and that the effect of teleoperation depends on experience – experts increase teleoperated stabilization relative to freehand, whereas novices decrease it.

As a second step, we are studying the effects of master manipulator dynamics and teleoperation on needle driving of experienced surgeons and novice users. Preliminary kinematic analysis showed that teleoperation increases trial time but reduces path length, and that the trial times and path lengths of experienced surgeons are smaller than those of novices. In addition, there are significant differences in learning between experienced surgeons and novice users.
Computational modeling of surgeons’ movements combined with theories of motor coordination and learning could lead to the development of improved training curricula, optimization of robot design, and the development of novel controllers that will expand the current capabilities of robotic surgery. In addition, robotic surgery provides an excellent opportunity to develop and test novel hypotheses about the control of movement and about acquisition of skill in complex, real-life tasks.

About the Lecturer

Ilana Nisky received the B.Sc (summa cum laude), M.Sc. (summa cum laude), and Ph.D. in Biomedical Engineering from the Department of Biomedical Engineering, Ben-Gurion University of the Negev, Israel, in 2006, 2009, and 2011, respectively. She is currently a senior lecturer in the Department of Biomedical Engineering, Ben-Gurion University of the Negev, where she is the head of the Biomedical Robotics Lab. She was previously a postdoctoral research fellow in the Department of Mechanical Engineering, Stanford University. Her research interests include human motor control, haptics, robotics, human and machine learning, teleoperation, and robot-assisted surgery. She is a member of IEEE, the Society for the Neural Control of Movement, the Society for Neuroscience, Technical Committee on Haptics, and an Executive Committee member of the Eurohaptics Society.