Background:

Humans' use of the 4th and 5th digits as well as the lower forearm and wrist for anchoring, during tasks such as writing, surgery, sewing, soldering, etc., allows both positional feedback and increased stability, which aids in task completion. **I propose a research path to develop similar localized adaptive anchoring at the site of interaction in robotic systems (Figure 1).** The use of such remote anchoring points (RAPs) would allow for robots to effectively perform everyday tasks as well as specialized high precision tasks. The use of RAPs could also allow robotic systems to conserve energy by resting limbs on surfaces as well as leading to further research on how robots can use RAPs to improve overall postural stability.

In general, to interact with their environments in a more human-friendly and flexible fashion, a class of robotic arms is moving from highly rigid, internally precise robotic arms, to much more flexible, compliant and lower precision arms. At the same time, robotic systems are being used for more complicated and varied tasks than ever before. To rectify this, additional sensor modalities are needed to refine a system's positioning and interaction as well as to stabilize the system during precise world interactions. Research has focused on model based predictive techniques, haptic based end of arm sensing [1], vision based eye in hand servoing, and vision based overhead servoing [2]. All of these systems aid in improving task completion, however they are not ideal for fine tasks at distance from the primary arm anchor point or when the task space is in motion. RAPs could be an important tool in such situations.

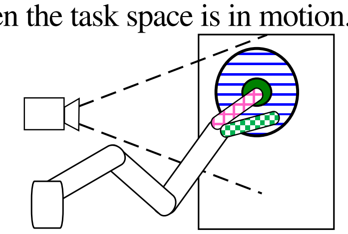

Figure 1: Robot system using a RAP to improve stability and precision. The solid dark green circle represents a task goal, which is to be acted on by the hashed pink primary effector. The lined blue circle represents an area around the target which could be used by the checkered green anchor for attachment. Such a system would allow increased precision of the primary effector with relation to the goal.

Aims:

I Develop a more robust understanding of how and when humans use RAPs

II Develop a methodology to determine when, where, and how a robotic manipulator should use RAPs

III Develop and test a framework for implementing the use of RAPs

Proposed Methodology, Expected Results, and Impacts:

The research and development will proceed in three phases, corresponding to the three aims.

Phase I: Understanding (8-12 months):

Methodology: There has been study on human hand use for grasping objects in general [3], as well as human use of RAPs for general postural stability [4]. Study is needed on how humans use RAPs for fine motor tasks. A variety of human subjects will be asked to perform tasks which require various levels of precision within various task spaces, which necessitate super fine motor skills. A specific subset of the tasks and human subjects will be surgical tasks and surgeons due to the critical nature of their work, and the recognized potential of robotics in the surgical field. Subjects will be fitted with a sleeve and glove which will not impede their motion, but will capture force along the fingers, hands, forearm and elbow. Similar instruments have been used in the past for capturing data from the hand and fingertips. The test apparatus will also include tags to enable positional tracking via a vision system. With force and position data, a model will be developed to describe human use of RAPs.

Expected Results: It is expected that human subjects will use RAPs with increased frequency as the required precision of a task increases and as the location of the task places more load on the proximal motor systems. It is further expected that as the task space size increases, the anchor point will shift further from the hand to the wrist, forearm and then the elbow.

Impact: The results of Phase I will directly feed into Phase II. Further, the results could help to improve prosthesis design, human friendly workspace design, and human augmentation.

Phase II: The Methodology (8-12 months):

Methodology:A methodology will be developed to determine when and where to use remote anchor points for robotic manipulation tasks. It will be developed by using the data from Phase I to inform the development of a space of simulated robotic interactions with the environment which can be searched computationally. The methodology design will leverage modern machine learning techniques, allowing for generalization across a series of different robotic configurations.

Expected Results:It is expected that Phase II will lead to a theoretical understanding of how robots can effectively use RAPs to improve their performance.

Impact:An understanding of how a robot can use RAPs will drive the development in Phase III. In addition, it will provide a foundation for further research into alternative uses of RAPs, for example, postural stability.

Phase III: Implementation and Testing (18-24 months):

Methodology:In order to test and prove the feasibility of using RAPs, a robotic arm will be outfitted with a custom designed tool to enable anchoring to surfaces. This tool will comprise a soft end effector, with sensors to detect force and slip along a surface, similarly to human touch [5]. A vision system will be used to identify targets and regions for anchoring (Figure 1). The methodology from Phase II will be used to drive the hardware. Testing will be done using the end effector with and without the stabilizing anchor in a number of different scenarios which necessitate fine precision, to determine the quantifiable impact of a robotic system using RAPs.

Expected Results:It is expected that Phase III will result in a clear positive indication as to the benefit of using RAPs, as evidenced by improved task performance when using RAPs.

Impact:A proof of the value and feasibility of RAPs in robotic applications will serve as a first step towards enabling robotic systems to leverage RAPs for improved system performance. The designs (mechanical, electrical, and computational) will be published in an open source forum for further research to expand on. Technology maturation will lead to robots which can interact more effectively in human environments as well as perform specialized tasks (surgery, marking, sewing, writing, etc.) more precisely. On whole these advancements will improve lives.

Enablers for Success:

A number of enabling technologies are coming together in the spaces of soft robotics (for attaching to RAPs), haptics (for receiving data on pose shift relative to RAPs), vision (for locating suitable RAPs), and machine learning (for selecting appropriate RAPs). Personally, I have a broad background spanning mechanical design, computer vision, computer science, physiology, machine design, and fabrication. I have spent time in industry developing novel technologies and have spent time academically developing an understanding of the theory behind both man and machine function.

References

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