NRI Large: Collaborative Research: Complementary Situational Awareness for Human-Robot Partnerships

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Motivation

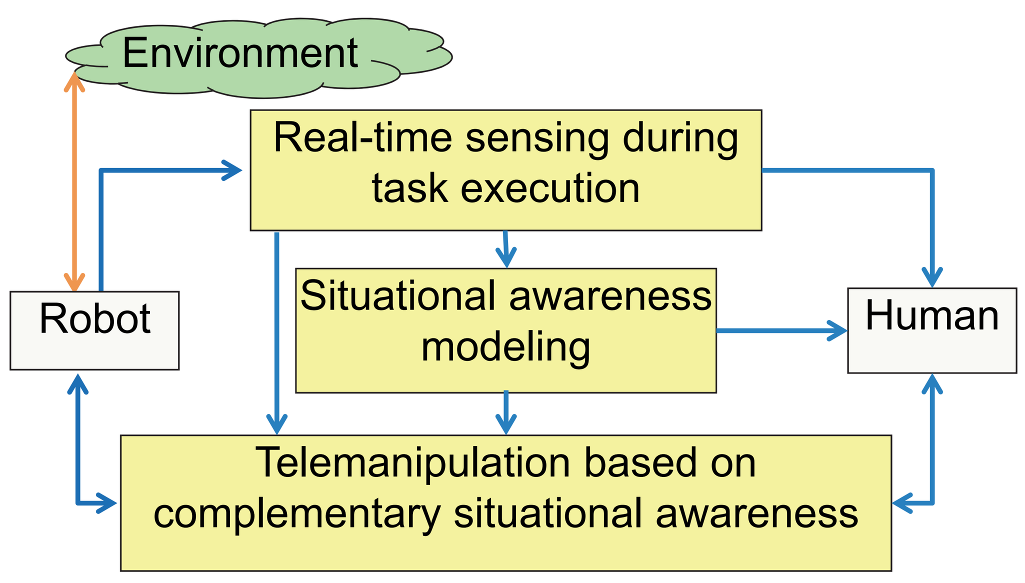
- Robots are currently used to extend the reach of humans and to augment their physiological skills during manipulation.
- This research aims to introduce a new paradigm of ***complementary situational awareness (CSA)***, which is the simultaneous perception and use of the environment and operational constraints for task execution.
- Using this new paradigm robots can act as our partners, not only in manipulation, but in perception and control.

Illustrative Examples

- A search and rescue telemanipulation robot that uses its own perception to form an understanding of task constraints. For example the robot could use LIDAR information to augment the perception of the user who typically sees only the video feed from a forward-looking camera.
- An intelligent excavator that uses sensory information about the ground and potentially hidden pipes to assist the user in safe excavation
- An intelligent surgical robot that uses in-vivo sensory information to characterize its operational constraints and to assist the surgeon in avoiding sensitive anatomy

Research Goals

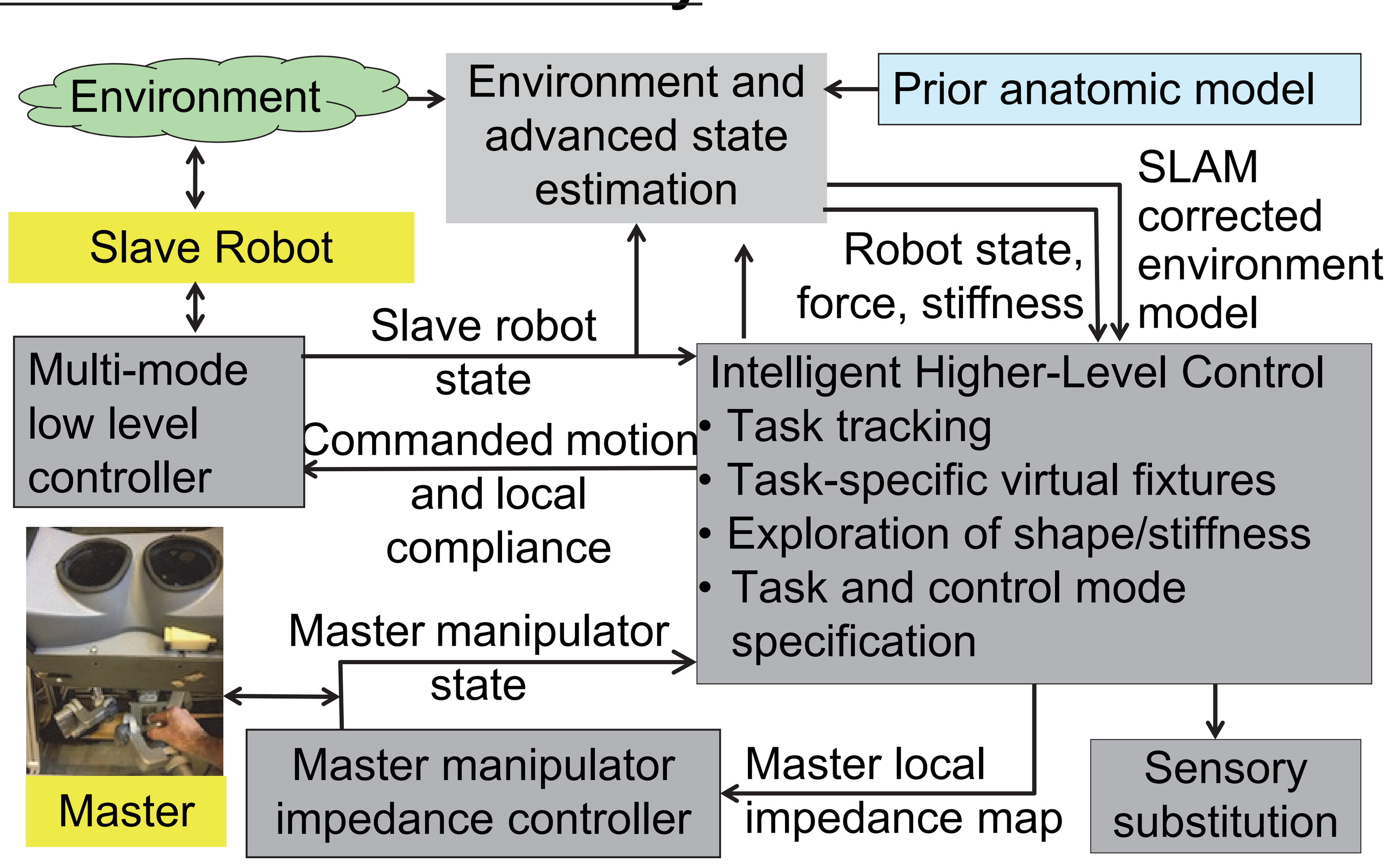
Real-time Sensing during Task Execution: Design algorithms for acquisition of *in-vivo* sensory information including methods for assessing the interaction with the environment.



Situational Awareness Modeling: extend simultaneous localization and mapping (SLAM) to develop algorithms that synthesize *in-vivo*, intraoperative and pre-operative data to augment human situational awareness.

Telemanipulation based on CSA: Create a telemanipulation framework that uses CSA to enable the use of assistive *virtual fixtures* based on the updated understanding of environmental characteristics to semi-automate surgical tasks.

Planned research activity



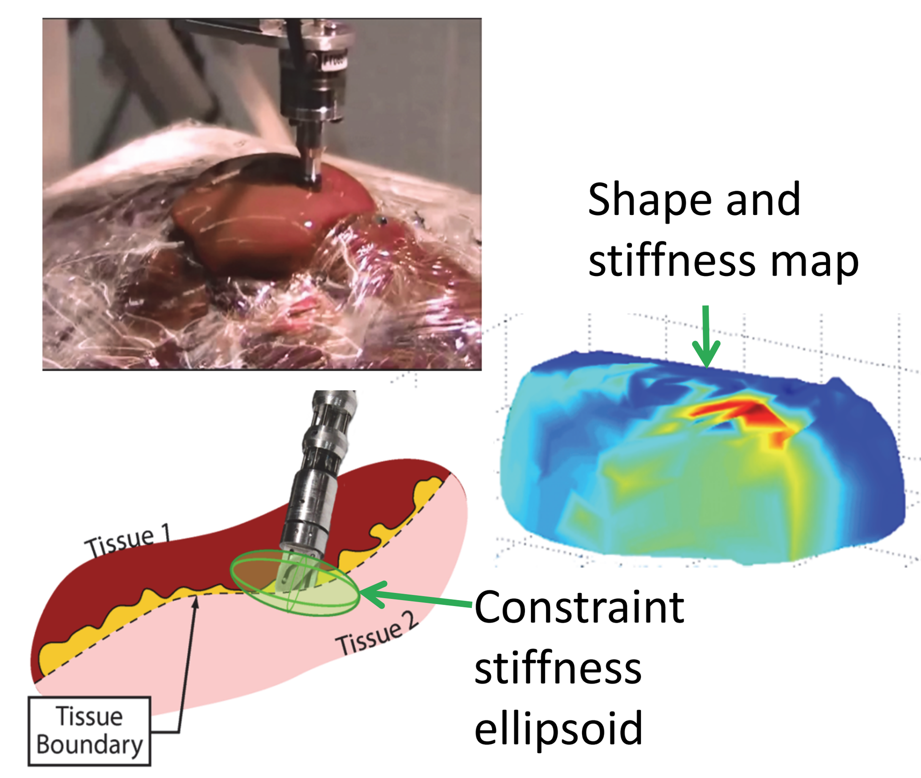
Telemanipulation based on CSA includes the intelligent *high level controller* (HLC), the *low level controller* (LLC) of the master robot, LLC of the slave robot, and SLAM-based modeling block to correct the environment model.

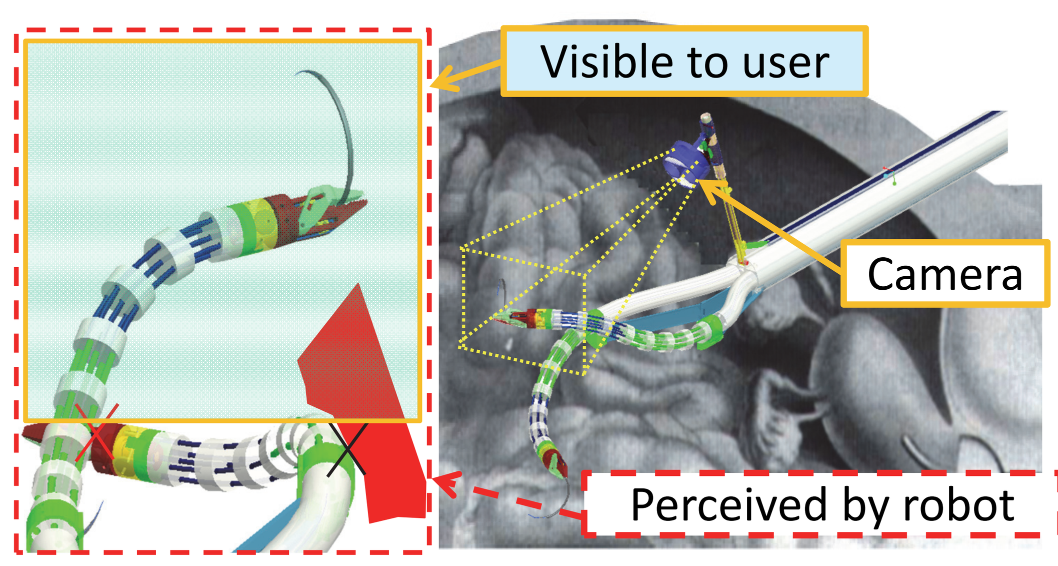
Key Challenges		
In-vivo Sensing	Situational Awareness Modeling	Control and Telemanipulation
Calculate robot state, estimate wrench and contact, estimate tool constraints, stiffness, and cancel flexibility and friction effects	Update pre-operative environmental models by fusing visual feature estimates with tracker data. Annotate surface models with stiffness features. Register a tool to a flexible environment.	Hybrid force/motion control, telemanipulation with force feedback, Adapt virtual fixtures in real-time based on annotated surface models from situational awareness modeling

Preliminary results

Automated force-guided tissue exploration has allowed for the generation of stiffness maps. This data may be used to identify tissue abnormalities such as tumors.

Stiffness information allows for constrained motion between tissue clefts.



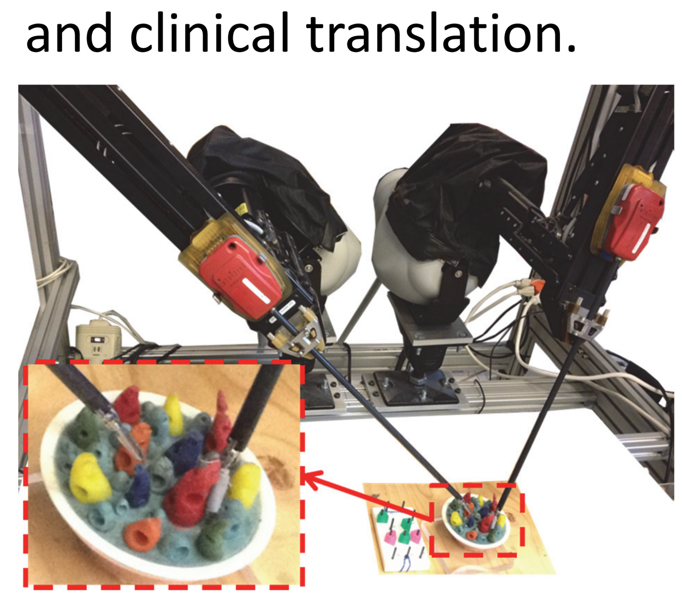


Intrinsic force sensing allows for the detection of contact in continuum robots. The robot can restrict movement to avoid collisions outside the surgeon's view.

A combination of contact detection and constrained filtering has demonstrated the ability to register the robotic system to an unknown, flexible environment.

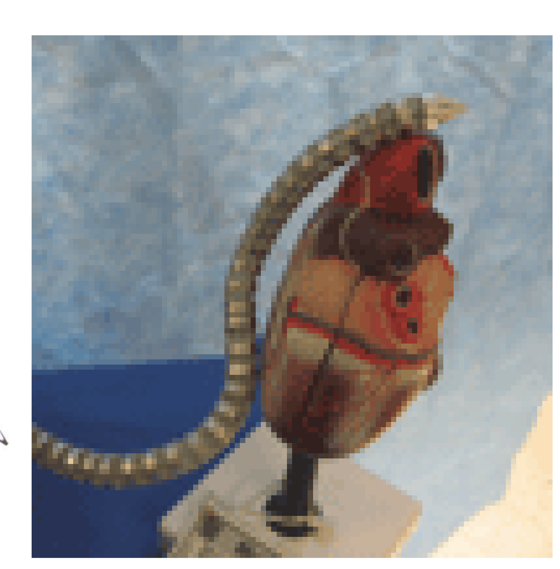
Broader Impact

To demonstrate the flexibility of our approach, we will use both standard and prototype high degree-of-freedom (DoF) robots for experimental validation. The DaVinci Classic platform is present across all collaborating institutions as a standard platform for benchmarking and clinical translation.



Intuitive Surgical *DaVinci Classic*

VU *IREP surgical robot*



CMU *surgical robot*

Preliminary Results Publications:

1. Bajo A. & Simaan, N., "Kinematics-Based Detection and Localization of Contacts Along Multisegment Continuum Robots", IEEE Transactions on Robotics, Vol 28, No. 2, pp. 291-302
2. S. Tully, A. Bajo, G. Kantor, H. Choset, and N. Simaan, "Constrained filtering with contact detection data for the localization and registration of continuum robots in flexible environments," in *2012 IEEE International Conference on Robotics and Automation*, 2012, pp. 3388–3394.
3. S. Tully, A. Bajo, N. Simaan and H. Choset, and, "A Filtering Approach for Surgical Registration with Unknown Stiffness", in 2013 proceedings of the Hamlyn Symposium on Medical Robotics.