Kinematics based Safety Operation Mechanism for Robotic Surgery extending the JHU SAW Framework

Anand Malpani, Balazs Vagvolgyi, and Rajesh Kumar
Computer Science, Johns Hopkins University

As robotic surgery gains popularity [1, 2, 3], methods for improving situational awareness during teleoperation have become an active area of research. Literature has attempted to incorporate haptic feedback displays to enhance and improve user performance. For example, Massimino *et al.* [4] showed that a combination of vibrotactile and auditory substitutions lead to task performance (peg-in hole task) comparable to that using a force feedback. Kitagawa *et al.* [5] extended this approach by using visual force displays and and auditory cues, in experiments showing comparable performance in surgical tasks (knot-tying). Reiley *et al.* [6] used a visual force display in a teleoperated knot-tying task to demonstrate lower forces and reduced suture breakage by trainees.

The above art demonstrates the need for information overlays in telerobotic surgical tasks. However, this literature also used prototype software and tools intended only for the specific experiments. By contrast, we use the Surgical Assistant Workstation (SAW) [7, 8] in development at Johns Hopkins University to create a general information overlay, and demonstrate its utility by creating a visual warning display for telerobotic surgery that detects instruments being operated outside of the field of view of the endoscopic camera. SAW is a modular framework for rapid prototyping of new tools and methods for robotic surgery. It includes methods for image guidance, registration with pre-operative and intra-operative images, and ability to interact with the graphical objects rendered within the display with the master or slave manipulators in a teleoperation environment.

The common telesurgical system in use is the da Vinci Surgical System (Intuitive Surgical Inc.). It consists of a surgeon's console containing the two master manipulators, a patient side cart with up to four robotic arms - three for the slave instrument manipulators which can be equipped with the removable instruments and an endoscope camera manipulator connected to a high-performance stereo vision system. The da Vinci also provides a research and development application programming interface (DiMaio, *et al.*, [9]) that streams kinematics data and system events at configurable rates of up to 100Hz. The SAW/cisst framework also contains an interface to the da Vinci API.

We present an overlay architecture (Figure 1) implemented using the *cisst*/SAW libraries to integrate contextual procedure and system information for improving safety, and situational awareness during these delicate and complex manipulations. While the presented methods can be modified for use with any robotic system, we used our da Vinci S Surgical System (Intuitive Surgical Inc.) for the validation experiments (Figure 2) here. Results from validation experiments with 17 users and a total of 50 training sessions totaling 214350 image frames are presented.

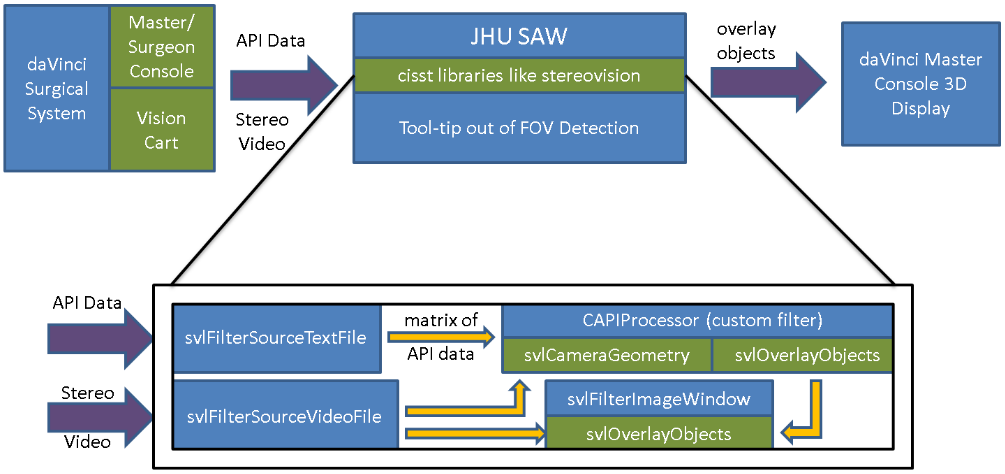

Figure 1: Data Flow in the instrument out of field of view detection architecture.

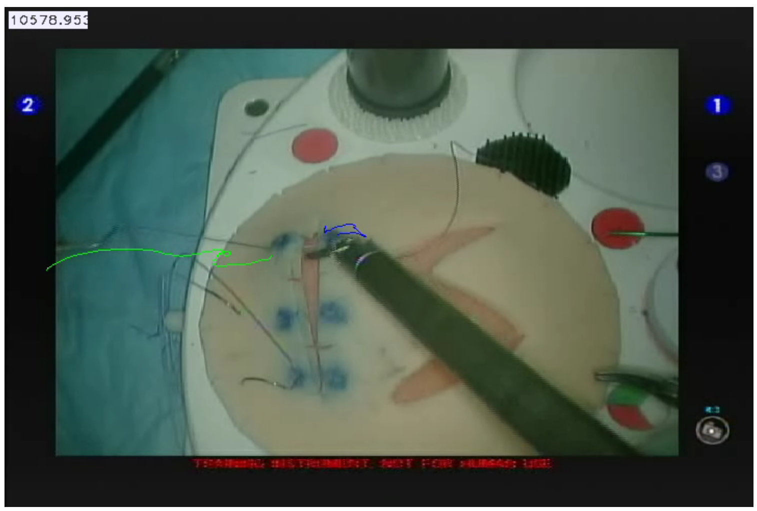

Figure 2: A sample image from a suturing training task with the left instrument having just gone out of the field of view. The green trajectory history (100 frames) indicates path of the left instrument, while the blue trajectory indicates the corresponding path of the right instrument.

References

[1] J.F. Boggess. Robotic surgery in gynecologic oncology: evolution of a new surgical paradigm. *Journal of Robotic Surgery*, 1(1):31–37, 2007.

[2] W.R. Chitwood Jr. Current status of endoscopic and robotic mitral valve surgery. *The Annals of thoracic surgery*, 79(6):2248–2253, 2005.

[3] KK Badani, S. Kaul, and M. Menon. Evolution of robotic radical prostatectomy: assessment after 2766 procedures. *Cancer*, 110(9):1951–1958, 2007.

[4] M.J. Massimino. Sensory substitution for force feedback in space teleoperation. 1992.

[5] M. Kitagawa, D. Dokko, A.M. Okamura, and D.D. Yuh. Effect of sensory substitution on suture-manipulation forces for robotic surgical systems. *Journal of Thoracic and Cardiovascular Surgery*, 129(1):151–158, 2005.

[6] C.E. Reiley, T. Akinbiyi, D. Burschka, D.C. Chang, A.M. Okamura, and D.D. Yuh. Effects of visual force feedback on robot-assisted surgical task performance. *The Journal of thoracic and cardiovascular surgery*, 135(1):196–202, 2008.

[7] Anton Deguet, Rajesh Kumar, Russell Taylor, and Peter Kazanzides. The *cisst* libraries for computer assisted intervention systems. In *MICCAI Workshop on Systems and Arch. for Computer Assisted Interventions*, Midas Journal: http://hdl.handle.net/10380/1465, Sep 2008.

[8] Balazs Vagvolgyi, Simon DiMaio, Anton Deguet, Peter Kazanzides, Rajesh Kumar, Chris Hasser, and Russell Taylor. The Surgical Assistant Workstation: a software framework for telesurgical robotics research. In *MICCAI Workshop on Systems and Arch. for Computer Assisted Interventions*, Midas Journal: http://hdl.handle.net/10380/1466, Sep 2008.

[9] Simon DiMaio and Christopher Hasser. The da vinci research interface. In *MICCAI Workshop on Systems and Arch. for Computer Assisted Interventions*, Midas Journal: http://hdl.handle.net/10380/1464, Sep 2008.