In Situ Augmentation of Force and Torque Perception Using Patient-Based Forces

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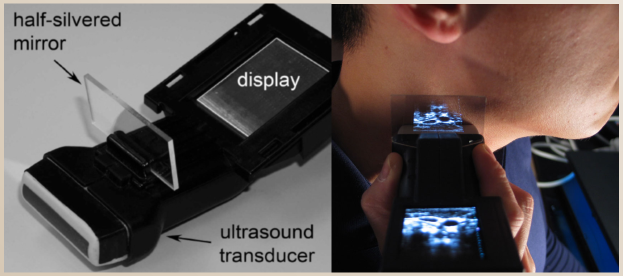
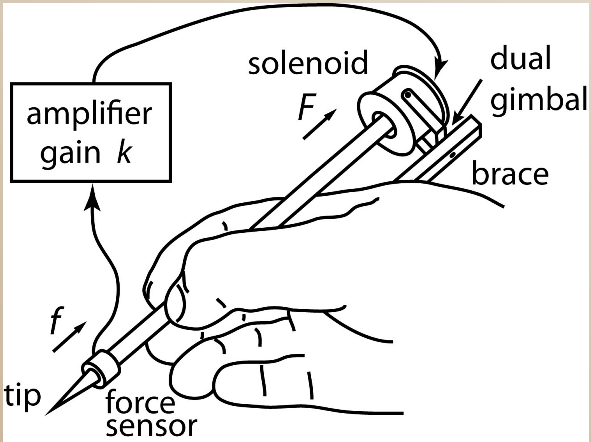
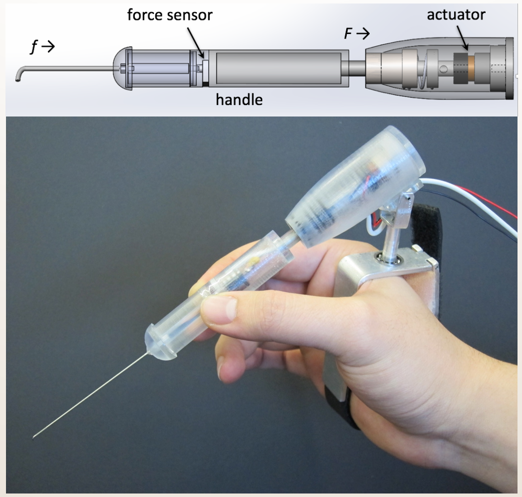
HAND-HELD FORCE MAGNIFIER

We have previously developed technology to provide in-situ augmentation of the clinician's vision by superimposing a virtual image of real-time ultrasound using a semi-transparent mirror, the Sonic Flashlight (see below).

In the same spirit, we are now augmenting the clinician's sense of touch using a cooperative robot that holds the tool along with the clinician, providing forces that augment those detected at the tip of the tool. As shown below and to the right, in the Hand-Held Force Magnifier (HHFM), a force *F* is added by an actuator to the force *f* detected at the tip of the tool. Others have used robot arms mounted on the table-top or floor to accomplish this (Hopkins Steady-Hand Robot), but ours uses a hand-held platform, freeing the surgeon's hand to move freely relative to the patient [1,2].







We now propose an improvement to the HHFM by grounding the augmenting forces relative to the surface of the patient rather than the hand, leading to a number of advantages outlined to the right. We call this the Patient-Based Force Magnifier (PBFM). Variable-compliance linkages are used in place of actuators, adding stiffness to the tissue when needed to provide enhanced sensory feedback and protect particular structures from undue strain.

We describe an initial embodiment aimed at aiding in Difficult Venous Access, a critical problem in many patients, including children, whose veins are delicate and tend to roll. With the proposed system, the surgeon is provided with haptic feedback that naturally guides the needle into a moving vein and prevents puncture of the far wall, using ultrasound to sense deformation in identified targets rather than measuring force directly. The in-situ display of the Sonic Flashlight is included in the prosed device (see right).

REFERENCES

[1] Stetten G, (2015) U.S. Patent no. 8,981,914, Portable Haptic Force Magnifier, filed September 27, 2011, issued March 17, 2015.

[2] R. Lee, R. L. Klatzky, and G. Stetten, In-Situ Force Augmentation Improves Surface Contact and Force Control, IEEE Transactions on Haptics, Volume: 10, Issue: 4, Oct.-Dec. 2017.

PATIENT-BASED FORCE MAGNIFIER

Advantages of generating the forces relative to the patient in the PBFM include:

- (1) Augmenting forces exist outside the hand, informing upper arm and shoulder.
- (2) Platform resting on the patient can be heavier, permitting larger forces.
- (3) Forces now generated nearer distal end of the tool, avoiding leverage problems with non-axial forces and torques.
- (4) Since augmenting force and torques are never greater than those applied by surgeon, we may use variable-compliance linkages instead of actuators, providing multiple degrees of freedom from a single linkage.
- (5) Eliminating the brace frees surgeon to shift grasp on tool and switch tools more easily.

In addition, replacing embedded force sensors by real-time imaging (ultrasound) to detect tissue motion and deformation, permits use of standard surgical instruments, and allows these instruments to be switched easily.