Towards a novel man-machine interface to speed up training on robot-assisted surgery

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New robotically-assisted minimally invasive surgery (RAMIS) systems make surgeries safer and reduce hospitalization time. Nevertheless, mastering the use of different surgical robotic tools requires demanding training and continuous practice as for an athlete. The final aim of our research is to shorten the training time for robotic surgery by developing a virtual mentor to provide haptic feedback. This paper presents a partial validation of a novel haptics device, designed to provide hand guidance (i.e., the device transmits commands to the user in order to direct his/her hand in the space).

1 Introduction

In comparison with open surgery, RAMIS systems can provide significant advantages. Current systems, like Da Vinci® robots, have been shown to reduce hospital stay [1-3], while avoiding large scars like laparoscopic surgery. Additionally, in certain type of surgeries, this technology enabled less blood losses [2], [4], and post-operative reduction in dose of analgesic and anti-inflammatory drugs [5].

The counterpart of this is that the new generations of surgeons must add an extensive training in robot teleoperation to their medical knowledge and skill set. The recommended training curricula progress from manipulation tasks to simulated surgical tasks [6-8], followed by often limited clinical exercises on cadavers [9]. Regrettably, trainees may not be ready for surgical independence at the end [10], [11].

To address these problems, we propose to integrate virtual reality together with haptic feedback in the surgical training sessions. In this paper we propose a portable haptic device that offers hand guidance while the user performs surgical gestures. The user will feel “as if” a force was directing his/her hand through of the surgical gesture. After a complete validation of our device, we plan to use the wearable haptic device with surgeon trainees to determine whether haptic guidance shortens the training time.

2 Definitions

Illustration of jargon for the actuation zones (Fig. 1).

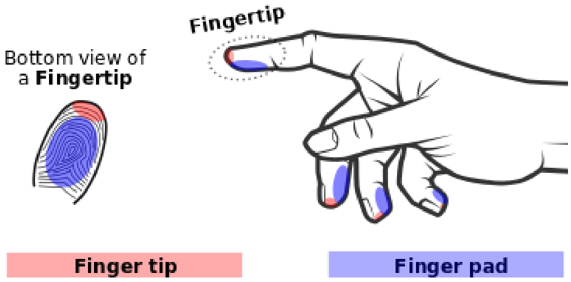

Figure 1: *The colors show the location terms of each zone.*

3 Materials

The device consists of a pair of servomotors mounted in a 3D printed handle, which has a similar design to the haptic device presented in [12]. Different views of the device are presented in Fig. 2. Each motor has a lever arm to stimulate the user’s finger pad (Fig. 1) of the thumb/index distal phalanges by rotating through a semicircular arc (see schema in Fig. 2). The working principle of the device is to employ the lever arms to stretches the skin on the finger pads, giving the sensation that user's hand is being pulled.

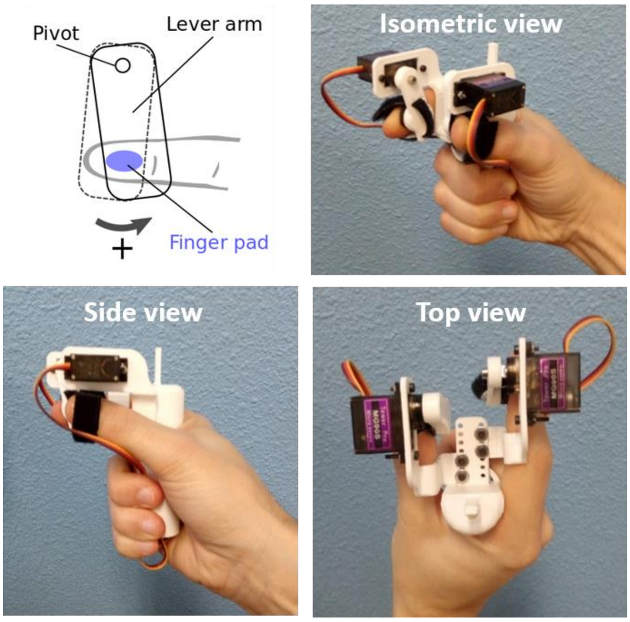

Figure 2: *Scheme for one actuator of the haptic device (working principle) and different views of the entire mechanism.*

The device has a range of motion of ± 20º for each finger. The contact of the fingers was ensured by fastening the distal phalange with Velcro® strips, similarly to those in the Da Vinci® master console.

4 Methods

The test method seeks to determine two key aspects: (1) if there is a common perception of tactile cues among different users; and (2) cues strength, which is related to stimulus-cue repeatability by user and intra-users. Thus, the haptic device stimulates user's finger pads and then, the user answered in which direction they felt a directing force. In essence, we execute a system identification procedure for the tactile sense of the user, aiming to identifying commands in 4 different directions or 2 degrees of freedom (DoF).

The experiment involved 6 right-handed users in a 2 trial tests on different days. 72 different stimuli were applied in a pseudorandom sequence of 360 stimuli per trial, totalizing 720 stimuli (each stimulus 10 times). In addition, the participant's visual and auditory sense were masked to capture the perceived commands only from the sense of touch.

For each stimulus, participants chose from five options: Left, Right, Twist Left, Twist Right, and Unclear. Therefore, if each user identifies a stimulus as the same direction many times, it means that this cue feels strongly (is clear) for a certain combination of servomotors actuation.

5 Results

The multidimensional nature of the results is expressed by marks in a two-dimensional map. In this map (Fig. 3), the colors encode the type of directional cue (e.g., Twist Left, Twist Right, Left, and Right), the X-Y location of each mark corresponds to an angular displacement for each servomotor (stimulus), and the mark size represents the saliency of this cue (big circle = intuitive cue). Examples of cue saliency cases are: (1) biggest circles = 100% stimulus-cue repeatability; (2) different color circles overlaid = intra-users cue mismatch; and (3) medium and small circles = not relevant stimulus for this application.

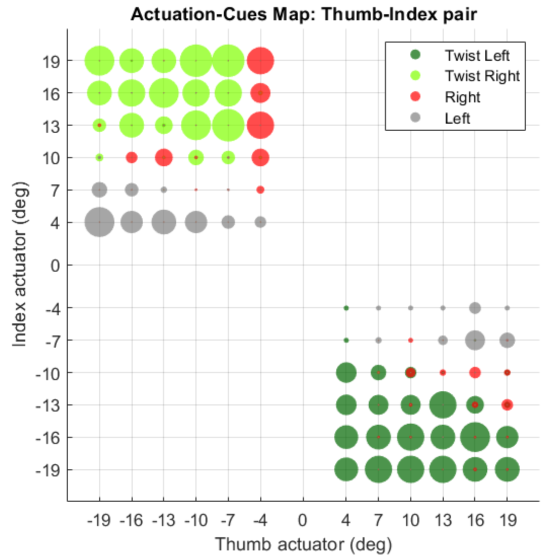

Figure 3: *Results of the partial haptics identification experiment (2nd and 4th quadrants). Marks diameter relates to directional cue saliency, color to cue type, and X-Y location in the map to a stimulus (motor movements).*

The results validate the possibility of delivering a strong feedback to the user in one DoF (Twist Left and Twist Right) because of several stimuli possibilities. These results also point out the feasibility to induce an additional DoF (translational Right and Left mouvements) by a reduced number of stimuli belonging to the 2nd quadrant.

The test is limited because of the low number of participants. The time required to conduct each trial was about 80 minutes. However, these results contain key information about an extensive variety of relevant stimuli. This data enable us to narrow the exploration space of additional commands that evoke hand movements (i.e., more DoFs), while shortening experiments time.

Acknowledgements

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