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A one-DOF freehand haptic device for robotic tele-echography

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Abstract. Tele-echography may be an interesting alternative to conventional care when the medical expert is not close to the patient to be examined. In a system for tele-echography, medical expert proprioception and gesture feelings must be preserved to synchronize the ultrasound images with the motion made by the physician. It is why we develop a master-slave system for robotic tele-echography integrating force feedback. Because existing haptic devices are not fully adapted to this application – their workspace is often small and their basis is fixed, we have developed a one-dimensional free-hand force feedback device. In this paper, we describe the design and a first evaluation of this new haptic device for robotic tele-echography.

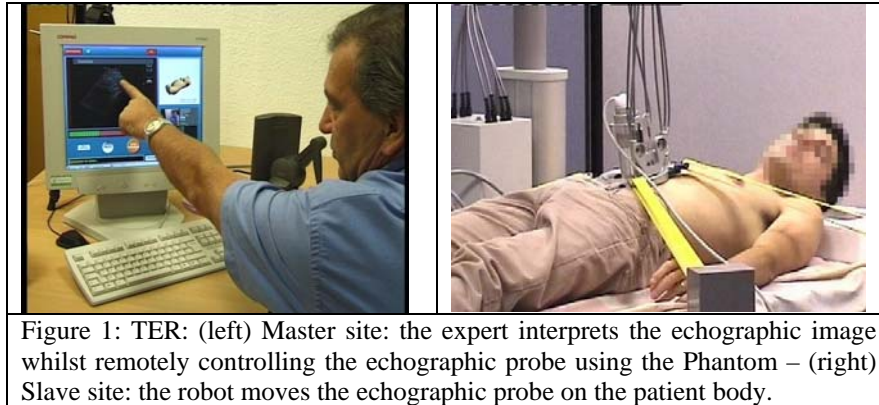
1. Introduction

Echography is a difficult examination based on specialized skills. Performing an ultrasound examination involves good eye-hand coordination and the ability to integrate the acquired information over time and space. The physician has to be able to build mentally 3D information from both the 2D images and the gesture information and to put a diagnosis from this information. Some of these specialized skills may lack in some healthcare centers or for emergency situations. Several systems are developed worldwide for tele-echography: some of them include a robot controlled remotely by the expert. The TER¹ project [1] developed by the TIMC laboratory in cooperation with clinical and industrial partners belongs to this category. TER is a master-slave system (see figure 1). The motion of a master manipulator carrying a virtual probe is controlled by the expert and remotely reproduced at the patient site by a slave robot carrying the echographic probe. The contact force between the probe and the patient is fed back to the operator allowing him to have a haptic virtual environment. The objective of this haptic control is to preserve medical expert proprioception and gesture feeling which are necessary to synchronize the ultrasound images with the motion made by the physician.

In the first two versions of TER, the virtual probe is attached to the PHANToM haptic device (Sensable Technologies Inc.) in order to facilitate the expert hand-eye coordination. It renders force information from local models and measurements from the slave site. Experiments have been successfully performed on phantoms and humans (see [3] for more details). However, this haptic system has several drawbacks for this application: it has a rather limited workspace and its basis is fixed whilst the natural gesture is free and

¹ TER is a french acronym for robotic tele-echography

takes place in a potentially large workspace. Moreover, during echography the crucial information for the control of the probe is the pressure exerted on the body of the patient. Very few haptic systems correspond to such needs; [Sato] is probably the closest one. Thus, we decided to develop a one degree of freedom (DOF) free-hand haptic device for the remote robot-based echographic examination. We name it “haptic probe”.



2. Description of the system

As already introduced, the aim of the haptic probe is to provide the interface to a robot which carries an echographic probe on a patient located afar. The probe offers the user two main functions:

- To transmit position and orientation parameters to the slave site. In particular, the two DOF corresponding to the position of the probe on the surface on which it moves, the DOF corresponding to the probe axial translation (in other words: the probe pressure onto the body), the 3 orientation DOF.
- To receive the information of the slave robot in order to realize the force feedback.

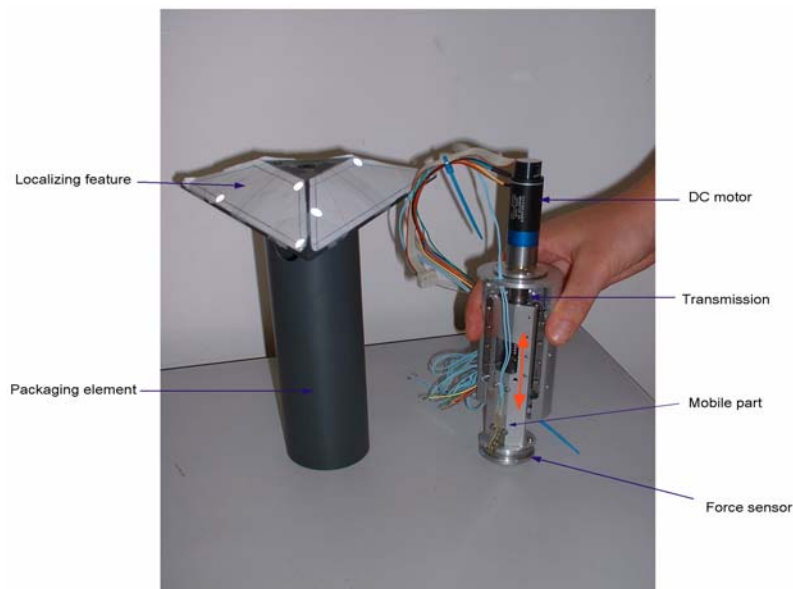


Figure 2: The haptic probe

The prototype has a cylindrical form and is composed of two parts (see Figure 2). The external part is held by the operator. Its position and orientation are tracked in real time using a localizer and positional information is sent to the robot. In the current version, we

use a passive optical localizer (Polaris from Northern Digital Inc.). A rigid body attached to the haptic probe is equipped with reflecting markers. Its design is such that it remains visible when the haptic probe is rotated by the operator during the examination. The rigid body is located at the top of the probe. This first packaging element is rigidly attached to a second part integrating a DC motor and a transmission. This second part, which contacts the working surface (a table or a manikin), moves relatively to the rest of the haptic probe to render force information to the operator. The motor transmits a torque to a ball-screw mechanism which transforms rotational motion of the motor into linear motion of the mobile part. A force sensor is placed at the extremity of the haptic probe to measure the applied force and to control the motor. The probe is connected to a PC which acquires and treats the data and realizes the force feedback.

3. Results and discussion

Current work deals with the fine tuning of the motor control parameters in order to provide a good haptic perception for the remote control of the robot.

The haptic probe has still to be integrated into the TER system but preliminary experiments are promising. Size and weight issues were not considered for this first prototype but the gesture can be very natural with the haptic probe which does not constrain the workspace and renders a relevant whilst limited (1D) force information. There are no equivalent devices dedicated to tele-echography. In similar projects of robotic tele-echography, few include force feedback while the gesture is very important for echographic image interpretation. Systems which include force feedback integrate complex devices have the same drawbacks than the Phantom.

4. Conclusion

In this paper, the design and first elements of evaluation of a new haptic probe dedicated to robotic tele-echography were presented. This new probe is really adapted to remote echographic examination. The probe enlarges the workspace of the physician, which can also accomplish actions with more precision and has an environment close to the one of a conventional echography. The force feedback adds the tactile perception to the visual perception and also improves the quality of the ultrasound examination.

References

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