An Anticipative Control Approach and Interactive GUI to Enhance the Rendering of the Distal Robot Interaction with its Environment during Robotized Tele-Echography: Interactive Platform for Robotized Tele-Echography

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1. INTRODUCTION

Robotized tele-echography, also referred to as robotized tele-ultrasound, was developed in the mid-nineties to compensate for the insufficient number of ultrasound (US) experts and their regrouping in large health care centers, resulting in a growing number of medically isolated areas. Ultrasound imaging is a low cost, reliable, non-invasive technique used routinely in hospitals. However, it is an expert-dependent technique, meaning that the experts can only make an accurate diagnosis when they are able to combine their anatomical knowledge with their skills in orienting and positioning the probe on the patient’s body in order to analyze the ultrasound images. In Arbeille (2008), Arbeille has shown that robotized tele-echography offers radiologists a solution to perform real time diagnoses for remotely located patients with results comparable to diagnoses using standard local echography. This robotized approach is more reliable than the basic tele-ultrasound modality presented in the 90’s (Kontaxakis, 2000; Chimiak, 1996). Several research teams (Fichtinger, 2008; Masuda, 2011; Vieyres, 2006; Bassit, 2003; Najafi, 2008; Neubach, 2010; Vilchis, 2003; Ito, 2010) have been developing tele-operated robotized tele-echography systems using portable ultrasound devices via standard communication networks such as internet and satellite links (e.g. ultrasound scan, needle insertion, prostate biopsy). During the robotized tele-echography procedure, a paramedical assistant positions the probe-holder serial robot on a pre-determined anatomical location and holds it on the patient’s body as shown in Figure 1a. The ultrasound expert, using a haptic probe developed by Essomba et al. (2012) and presented in Figure 1b, achieves an open-loop control position of the remotely located robot orientations. The role of the haptic probe is two-fold: firstly, it reproduces the contact force applied by the real ultrasound probe on the patient’s skin, and secondly, it records the ultrasound expert’s gestures which will be reproduced by the remote robot’s end effector. Using the available network, the patient’s ultrasound image is the sole information sent back to the health specialist who then analyzes it in real time and provides a diagnosis.

However, performing robotized tele-ultrasound via specific networks raises two issues. The first is transparency in order to enable the operator, that is, the ultrasound specialist, to safely and accurately perform bilateral tele-operation tasks despite the long time delays inherent to the communication link. To counter these effects, two strategies are combined to improve, at the operator site, the rendering of the interactions between the remote robotic systems with its environment (i.e. the patient), and the control of the robot’s orientation at the operator site. The first approach is the development of a new control architecture based on an internal model providing an anticipated value of the distant environment stiffness; it is complemented with a graphic user interface (GUI) which provides the expert with the real-time relative position of the haptic probe with the robot’s end-effector for better tele-operated control. These combined strategies provide the expert with an improved interactive tool for tele-diagnosis.

ABSTRACT

Performing a robotized telemedicine act via specific networks brings forth the issue of transparency in order to enable the operator, e.g. the medical ultrasound specialist, to safely and accurately perform bilateral tele-operation tasks despite the long time delays inherent to the communication link. To counter these effects, two strategies are combined to improve, at the operator site, the rendering of the interactions between the remote robotic systems with its environment (i.e. the patient), and the control of the robot’s orientation at the operator site. The first approach is the development of a new control architecture based on an internal model providing an anticipated value of the distant environment stiffness; it is complemented with a graphic user interface (GUI) which provides the expert with the real-time relative position of the haptic probe with the robot’s end-effector for better tele-operated control. These combined strategies provide the expert with an improved interactive tool for tele-diagnosis.

Keywords: Bilateral Architecture, Force Feedback, Graphic User Interface (GUI), Medical Robotics, Tele-Echography, Tele-Ultrasound
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