Ecole Centrale de Lyon - INSA de Lyon - Université Claude Bernard Lyon 1

Ampère

Unité Mixte de Recherche du CNRS - UMR 5005

Génie Electrique, Electromagnétisme, Automatique,
Microbiologie environnementale et Applications

Laboratory :
Ampère, UMR CNRS 5005 – Scientific Research Center in Engineering (CRSI) Liban

PhD thematic:
Medical Robotics

PhD topic :
SPARTE: Simulator of Puncture for ARTiculations under Echography

Scientific field and context :

Medical Robotics

Most medical specialties require experience when performing gestures. One of the main difficulties while learning is due to that most of the gestures are learned directly in the operating room. Indeed, it is not easy to learn under these conditions, especially when gestures are rare and carried out urgently. The development of simulators for initial and continuing training makes it possible to acquire (or maintain) an experience of the kinematics of the gesture and the forces involved. It is therefore necessary to offer physicians adequate tools to reproduce human behaviors.

Keywords :
Control Engineering, Mechatronics, Medical Robotics, Haptics

Thesis objectives, scientific locks and expected original contribution:

The Medical robotics team of Ampère laboratory is involved in the development of medical simulators for training (with, among others, the BirthSIM simulator for the training of obstetricians and midwives [2], the ARCHI simulator for endovascular procedures [3] or the PeriSIM simulator for training in epidural procedures [4]). This activity takes advantage of the skills in haptic interfaces and in the control of pneumatic laboratory systems, illustrated in [5] through a pneumatic haptic interface designed, manufactured and validated by the team. Bilateral [6] and multilateral [7] control laws are also developed and implemented in the laboratory. Some studies have also been carried out with the aim of proposing new tools for the objective evaluation of gestures [8]
The PhD student will be in charge of developing tools to reproduce human tissues behaviors during medical procedures. It will thus be necessary to develop control laws to control stiffness and damping for both electric and pneumatic actuators. An essential and innovative part of these tools is to obtain a haptic rendering as close as possible to the reality.
In the framework of medical simulators, it is often difficult to obtain numerical values of some physical parameters in order to define a precise book of specifications. It is often necessary to instrument surgeons' tools which is not always feasible. Another solution is to rely on numerical models. There is a very active collaboration between laboratories Ampère and LIRIS (CNRS UMR 5205). The Robotics group of Ampère laboratory develops prototypes to reproduce haptic of human behaviors. The ORIGAMI team of LIRIS laboratory develops numerical models of different organs of the human body [9-11]. Coupling these different systems is necessary to achieve realistic behavior. Generally, this coupling is based on a virtual interface which calculates the desired force to be reproduced by the haptic interface on the basis of the difference in position between the haptic interface and the numerical model [12, 13]. However, another solution can be based on the fact that user applies a force which leads to the displacement of the interface. Some researchers indicate that a compliant mechanism can suit to take into account the rate differences between simulation and control [14]. One of the research tracks is therefore to integrate this coupling into the control law of the haptic interface.
The objective of the thesis is to propose haptic interfaces which are able to reproduce forces in order

to improve user's immersion. The medical application is the puncture of articulations applied by rhumatologists. During this procedure, rhumatologists use a needle and an ultrasound probe. The aim is to reach the pathological area located around a joint which is usually a shoulder, a hip, a knee or an ankle. The main difficulty of this kind of gestures is to manipulate both tools in order to place correctly the needle in order to relieve the patient pain. With the ultrasound probe they have to follow the needle during its progression in the human body. The ORIGAMI team is able to generate ultrasonic images from a 3D model [15]. The novelty of our proposal is to offer haptic interfaces to allow physicians to navigate through the 3D model with haptic feedback. These feedbacks have to be reproduced not only on the needle but also on the ultrasound probe. A first prototype has been developed but it only concerns the needle [16]. It needs improvements to reach more realistic haptic feedback on different joints. Another axis to develop is the haptic feedback on the mock ultrasound probe. We would like to investigate the use of pneumatic actuator as a haptic interface inside the volume of an ultrasound probe.

Research program and scientific approach

- A bibliography of the control laws in stiffness and damping for haptic interfaces whatever the nature of the actuation will have to be updated. This study will be complemented by research of solutions on the coupling between numerical models and haptic interfaces.
- Control laws will be implemented on electric and pneumatic actuators. These haptic interfaces should be able to be used to reproduce any joints behaviors.
- The coupling between numerical models developed by our partner and our haptic interfaces will have to be implemented in order to propose more complete and realistic simulators.
- Finally, trials will be conducted with physicians (junior and senior) using our hospital partners (CHU Lyon, INSERM) in order to set up evaluation methods to be developed within the framework of the thesis.

Scientific supervision

Supervisor, PhD PHAM Minh Tu– minh-tu.pham@insa-lyon.fr – (20%)
Co-Supervisor, PhD MOREAU Richard – richard.moreau@insa-lyon.fr – *(80%)*

Collaboration – Cosupervision

The project is in Collaboration with the Lebanese University
Supervisor, Professor FRANCIS Clovis - cfrancis@ul.edu.lb
Co-Supervisor, PhD KOMATI Bilal – bilal.komati@ul.edu.lb

Research department

AIS department(100%)

Scientific publications:

Papers in the robotic fields have to be done (2 or 3 journals: IEEE TBME, IEEE TCST, IEEE TMRB ; 2 or 4 conferences (IEEE ICRA and IEEE IROS).

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