PhD proposal: Training simulator for ultrasound-guided puncture of large articulations.

Keywords:

Computer graphics, augmented reality, bio-mechanical simulation, GPU, haptic, medical simulators.

Project background and objectives:

Thanks to technological advances, the gesture of the puncture of large articulations has greatly evolved over the past decade with the use of an ultrasound probe. Thus, guided by the ultrasound image (which is plotted on a screen) and the tactile feeling, the operator adjusts his gesture during the insertion of the needle to reach the articulation. The main difficulty thus lies in the simultaneous handling of two instruments: a hand is used for the ultrasound probe and the other for the needle with possible changes from one hand to the other during the gesture.

In this context, our project aims to create a training simulator for the gesture of the puncture of large articulations guided by ultrasound, whose objective is to facilitate the learning of this gesture without risk to the patient. This simulator will combine a numerical simulation and a haptic device. For the design of this simulator, a study of the targeted activity will be conducted upstream to analyze and understand the learning of real gesture, and thus define the necessary elements of the simulator according to the numerical simulation and the haptic device. It will also offer various relevant scenarios for training and will assess the level of realism required for learning.

This innovative simulator will thus permit to treat indifferently several types of articulation and various pathologies. It may also allow ultimately the search for an optimal mechanical solution of "conduct" of the puncture needle. This will avoid so the use of anthropomorphic manikins, thanks to an immersive augmented reality environment.

Development of the numerical simulation:

The topic of the proposed PhD thesis is more especially the realization of the numerical aspect of the simulator that will allow feedback of the tissues' behavior during the needle insertion and will offer the learner a realistic visualization of the medical act. Its implementation will require the development of:

- **Geometric and bio-mechanical modeling of articulations and soft tissues** from medical imaging data. It concerns the simulation of the deformation induced when inserting the needle and of displacements due to the movement of the probe on soft tissues, and an ultrasound-like visualization of the results of the numerical simulation.
- **Coupling between the numerical simulation and the haptic device.** This includes tracking the operator movements (position and orientation of the needle and the ultrasound probe) and the calculation of the efforts returned by the virtual patient that should be reproduced by the haptic interface.

The work will be carried out within a numeric simulation platform available at LIRIS. The issue here clearly relates to the optimization of calculating the deformation with the introduction of new generic algorithms in simulation and collision on parallel architecture (GPU). Optimization aspects of the model (adaptation of geometry or space of the mesh along the needle, without the prior knowledge of the trajectory) and possible use of meshless models, will be particularly studied.

The coupling with the haptic device will be done in close collaboration with the Ampère laboratory, the partner responsible of the mechatronic part of the simulator, engaged in the design of the physical device.

The thesis also concerns the study of the contribution of augmented reality and immersive environments (force feedback devices, augmented reality helmet) in simulators for learning medical procedures. It will well be to study the gestures made by the apprentice and the educational benefit of the simulator. This study and the more comprehensive validation of the simulator will be particularly conducted in collaboration with our medical partner (Rheumatology Service, Lyon-Sud Hospital).

According to the progress of the thesis, this work could eventually integrate the "patient-specific" aspects of the pre-interventional planning (best path calculation). The extension to other similar medical applications will also be considered.

Required skills:

Master or equivalent degree with research experience in the field of computer graphics or related to the themes of the project. Good C++ programming skills. Knowledge in parallel CPU/GPU programming, augmented reality, haptic devices or mechanics, will also be appreciated.

Environment of the PhD

The thesis will be funded by the IDEFI-SAMSEI program (Learning Strategies in Health Carriers in Immersive Environment), and will take place at the University Lyon 1 within the SAARA team of the LIRIS Lab. (building Nautibus, scientific domain of la Doua, Villeurbanne, France).

Duration 3 years, beginning in October 2016. Teaching possibilities.

Partners: Ampere laboratory, LIBM Laboratory and Lyon-Sud Hospital.

To apply, send detailed CV, motivation letter, Master's report cards, and coordinates of potential referees to Fabrice JAILLET and Florence ZARA.