PhD position

École doctorale EEA de Lyon

DESIGN OF A HAPTIC SIMULATOR TO TRAIN ON VENTRICULAR PUNCTURE

Enrollment Institution : INSA Lyon, Université de Lyon, France
Doctoral School: ED 160 EEA de Lyon
PhD Department: Automatic Control
Research unit: Ampère (UMR CNRS 5005) Within the Robotics Working Group of the Ampère laboratory (Automation Systems Engineering Department AIS) at INSA Lyon, France
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Key words: medical robotics, haptic simulator, augmented reality, external ventricular drainage

Expected Profile (prerequisite) :

- Robotic, automatic, mechanic
- With programming skills: Matlab / C / C++ et 3D

Possible external collaboration(s)/partnership(s):

CHU Lyon, Department of Pediatric Neurosurgery headed by Professor Federico Di Rocco.

Scientific field and context:
This subject is in the field of medical robotics, more precisely haptic simulation for learning medical gestures, and responds directly to the expectation of the High Authority of Health: "Never the first time on a patient".
Ventricular drainage is commonly performed in neurosurgery departments or in the emergency room. It consists of inserting a catheter into the brain, using a needle, until it reaches the frontal horn to drain cerebrospinal fluid for therapeutic or diagnostic purposes [1] (see figure 1). The clinical routine is to insert this needle blindly. The only indication of success is the sudden loss of resistance when the ventricle is reached [2].

Currently, it is fundamental that a neurosurgeon be able to perform this gesture "by hand".Indeed, the assistance systems (e.g. ROSA robot [7]) are unusual and expensive. However, the learning of this gesture is only performed by companionship: there is no effective simulator for training in this type of surgery (neither anatomical mannequins [3] nor current Virtual Reality simulators [4-6]). However, the risks of causing serious after-effects for the patient are high.

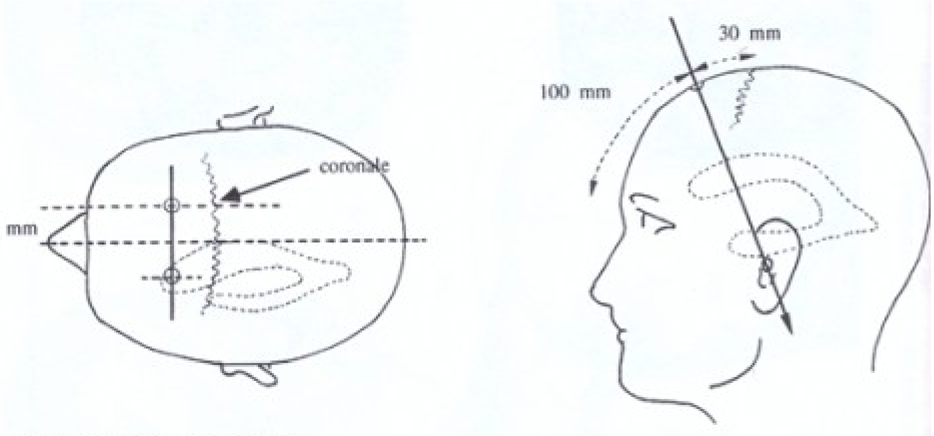

Figure 1: ventricular drainage axis

Objectives of the thesis:

The main objective consists in designing and prototyping a haptic simulator [8] for the training of the ventricular drainage gesture in neurosurgical operations. The haptic interface manipulated by the learner will be specific to this gesture in order to reproduce conditions close to reality.

The gestures performed during real operations will be analyzed and processed in order to propose a tool for a fast and objective evaluation of gestures during simulations.

The simulator will have to be able to customize the training sessions based on data specific to each patient (preoperative MRI images) to reduce the risk of errors during the surgical procedure.

Scientific problems:

- Analyze and model the interactions between the surgeon and the patient in order to be able to transcribe them on a haptic simulator [9].
- Determine the man/robot synergy allowing the most faithful reproduction of reality based on the principle of comanipulation [10].
- Virtual reproduction of the patient's anatomy from MRI images and integration of instrument trajectory information based on real-time robot sensors [11].

Expected contributions:

- There is currently no such simulator.
- Realize this simulator by simultaneously integrating: 1/ specific robotic interface, 2/ real time MRI image simulation and 3/ augmented reality, is unprecedented in this context.
- Integrate patient-specific exercises adds a strong constraint on the models used.

Research program and proposed scientific approach:

During the drainage, the surgeon will use the shape of the skull and in particular the position of the patient's nose and ears as anatomical landmarks. The first part of the project will focus on the design of a realistic skull/ear/nose combination. Indeed, during each ventricular puncture, the position of the hole through which the surgeon will insert the needle plays a major role in the success of the procedure. In practice, the surgeon relies on the positioning of the ears and nose to choose the location of the cranial drilling. These organs also serve as a reference point when the needle is inserted. Finally, he uses the patient's skull as a support point during the procedure. For all these reasons, it seems necessary to design physical cranial reproductions allowing the simulator to gain in realism. Different sizes of skulls can be developed for pediatric surgery. It will also be necessary to use tools similar to those used in the operating room in order to accentuate the immersion of the simulator. A needle substitute will have to be mounted on the robot and allow the same movements as the real needle.

It will be necessary to develop control laws on a Haption robot in order to realistically reproduce the sensation of needle penetration [12] through the brain and the ventricle. One can refer to the work of Ma. de los Angeles ALAMILLA-DANIEL on joint puncture [13] and to the various tests already carried out on the laboratory's test platform. This stage will require, among other things, a bibliographical study of the mechanical properties of the brain in order to be able to reproduce them with adapted and innovative control laws, always with the aim of pushing the realism of the haptic simulator to its paroxysm.

The third theme will deal with training and feedback. It will be necessary to work on the creation of an augmented universe allowing to navigate in the brain and to see the ventricle from the MRI images of the patients in which it will be necessary to be able to locate the trajectory of the needle [14]. This step is crucial in addressing the challenges of training new surgeons in this surgical procedure. Indeed, the creation of an augmented environment allowing the observation of the brain following different MRI slices and showing the needle trajectory during ventricular puncture training will facilitate the feedback of the expert surgeon accompanying the novice. It will also allow the learner to contextualize and visualize his mistakes or success in a learning process.

Finally, it will be necessary to work on the feedback given to the learner following his training. To do this, it will be necessary to classify the operations of novices and experts in order to better identify the difficulties of the gesture and personalize the training of each novice. This theme could be based on some of the laboratory work that has already addressed this subject. Indeed, in the context of the PhD work of M. SENAC [15], different machine learning methods have been implemented to analyze the gestures of novices and experts. The objective was to determine the characteristics of the gestures performed in order to highlight the differences between experts and novices and thus offer novices personalized training with dedicated exercises. Thus supervised and unsupervised methods were implemented and compared in order to find the most appropriate methods in our case. This work already followed on from the work carried out in the laboratory as part of Mrs CIFUENTES' doctoral thesis [16], which focused on the determination of objective criteria for the analysis of medical procedures. Based on previous work, this approach will allow us to optimize the learning curves of learners with personalized and targeted feedback.

Funding of the thesis: Doctoral contract from the institution of registration

Objectives for the valorization of research work:

Submission of papers to major international conferences in the field (IROS, ICRA, EMBC) and to international journals dealing with medical robotics (IEEE Trans on Robotics, ...) and medical robotics (IEEE Transactions on Medical Robotics, ...).
Given the strong applicative component of the subject, transfer activities to the industrial community for the medical sector will also be targeted, via the development and distribution of mechatronic solutions. The partnership with the University Hospital of Lyon motivates the interest of this simulator for the training of its staff and more generally of neurosurgeons..
The conception and validation of a field-tested prototype (TRL level 5) will pave the way for industrial valorization.
No research has yet been carried out. However the perfect knowledge of the simulator suppliers by the partner surgeons will foster the advertising of the device.

Competencies that will be developed during the PhD:
Robotic, haptic, co-manipulation, synchronized real-time 3D image.
Work methods related to any research work (bibliographical research, simulation, experimentation, writing scientific articles, ...).

Post-Doctoral Career Perspectives:
Career:

- in the academic field (post-doc followed by a position as a researcher)
  or
- in the industrial sector (e.g. R&D department)

References:

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