Mesh generation of anatomical structures: application in biomechanical simulation

Internship proposal supported by the LABEX CAMI, http://www.cami-labex.fr/

Internship location: LaTIM INSERM UMR1101 (Brest) Lab.

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Collaboration:

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1. The CAMI context

Medical Interventions (surgery, interventional radiology, radiotherapy) can provide a significant boost for progress in terms of patient-specific optimal planning and performance. To fulfill patient's demand for Quality, Senior Operators demand to see beyond the immediately visible, to be assisted in their real-time vital decisions and to accede to enhanced dexterity, while junior operators request to "learn to fly" before being left alone, and Public Health Authorities and companies require demonstration of the Medical Benefit of innovations.

The Computer Assisted Medical Interventions LABEX (CAMI LABEX) strategic vision is that an integrated approach of medical interventions will result in a breakthrough in terms of quality of medical interventions, demonstrated in terms of medical benefits and degree of penetration of CAMI technology in routine clinical practice.

Among the different actions undertaken in the scope of the CAMI LABEX, about 10 internships are to be financed yearly. The following internship proposal deals with themes within LABEX's scientific field.

2. Background

Biomedical engineering is a vast field of research with applications aiming to improve modern medicine and optimize the operation process with the introduction of computer assisted surgery systems in the clinical environment. Many medical applications required biomedical modeling based on finite element. Such operation process needs to mesh anatomical structure from patient images (CT, MRI, etc). However in order to establish an accurate biomechanical model several limitations are arising. These limitations concern the initial and basic step of the biomechanical model development, that of the geometric representation of the area of interest. The anatomical area to be modeled must be represented with a discretized geometry assembly of finite elements were the mathematical formulation of the model can be applied and provide accurate realistic results. For example in the case of prostate brachytherapy we need to represent a complex geometry of the prostate gland and the organs in close proximity to consider interactions of the prostate with its environment and additionally we need to be able to model fine structures inside the volume of the prostate such as needles and radioactive seeds which are the primary tools of the brachytherapy operation. Moreover the different organs and structure inside the geometric representation have to be differentiable in order to apply different constitutive laws for the description of the different domains acquiring a more realistic model. Finally this geometric representation has to represent the specific anatomy under consideration with the maximum detail possible.

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3. Detailed subject

The aim of this subject is to develop an advance and user-friendly software with graphical interface able to generate automatically multi-domain high quality tetrahedral meshes from segmented medical images for biomechanical modeling applications.

A. An engine will be developed with QT framework and CGAL library (Computational Geometry Algorithms Library) in order to propose a toolkit for generation of qualitative tetrahedral meshes. The developed engine should automatically mesh anatomical structures from segmented medical images. This toolkit must resolve two main issues: meshing two neighbor structures by considering interface and meshing structures with different and/or with adaptive accuracies.

B. To ensure user-friendly software that includes visualization of the medical image and the resulted meshed object, the proposed toolkit will be integrated in the CamiTK toolkit. The aim is to propose new tools for meshing anatomical structure within the field of CAMI.

C. The proposed tools will be evaluated in a context of prostate biomedical modeling for brachytherapy applications. Based on patient images (MRI), prostates will be segmented by a clinician. The proposed methods will be used to mesh the different organs (prostate, rectum and pelvic bones). The resulted meshes will be used to simulate by finite element, the edema of the prostate occurring during the intervention of brachytherapy intervention.

4. Required knowledge

- Computer science, applied mathematics, optimization methods, mesh triangulation
- C/C++, GNU/Linux

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