GMDS Submission

1. Title

Combining image processing libraries for patient-specific anatomical modelling

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5. Abstract (1000 words)

1. Introduction and Objectives

Medical simulation, as a component of medical training, may be seen as the creation of a realistic environment with standardized and reproducible scenarios without endangering patients. Simulators enable a level of competency to be obtained before skills of physicians are put into practice in a clinical environment [1].

Anatomical models are used in medical simulations to improve the diagnosis and assist the physician. Unlike generic anatomical modelling which cannot express the variability that exists among individuals and lead to different diagnosis and treatment, patient-specific modelling develops computational models of human pathophysiology that are individualized to patient-specific data [2].

Regional anaesthesia (RA) is a technique that demands training and assistance to successfully block the peripheral nerves through local injection of anaesthesia. Epidural blocks and spinal anaesthesia are the most frequently applied RA procedures, which all benefit from medical simulators of patient-specific regions [3-5].

The Regional Anaesthesia Simulator and Assistant (RASimAs) project combines image processing, physiological models, and virtual reality to support ultrasound-guided and electrical nerve stimulation-guided RA. RASimAs is used to train novice physicians and provides assistance during the clinical application of RA at later stages. The use of patient-specific data such as magnetic resonance image (MRI) and computed tomography (CT) to improve the quality of the virtual physiological human (VPH) model is one of the key innovations of the project.

The objective of this paper is to present the VPH model data, the patient image data collection, and the composition of a library of image processing algorithms.

2. Material and Methods

2.1. Model Data

The Virtual Physiological Human (VPH) initiative targets the whole human body as the system of interest, and it aims at understanding human physiology quantitatively, as a dynamic system and at all relevant levels between genes and the organism [6]. Generic commercial VPH models provide accurate models with high resolution and details to use as reference as well as for prototyping.

Two models are used for patient-specific data modelling, Anatomium (http://www.anatomium.com) and Zygote (http://www.zygote.com). They yield the human anatomy in 3D view and provide polygonal meshes with texture. Zygote was extended to fit the needs of the RASimAs project by (i) replacing the femoral nerve at a more common position in regards to blood system and the muscles and (ii) adding fascia, *i.e.*, flat bands of tissue below the skin that cover underlying tissue, separate different layers of tissue, or enclose muscles.

2.2. Patient Images

All necessary image data for the anatomical models include CT and MRI. They are archived into the web-based RASimAs Information Storage System (ISS) which includes: (i) Picture Archiving and Communication System (PACS) server for medical image storage and retrieval; and (ii) data server for 3D generic and registered models storage and retrieval.

The medical images are stored using the Digital Imaging and Communications in Medicine (DICOM) standards, which provide methods to ensure data privacy and security in the clinical environments of PACS.

2.3. Image Processing Library

Different technological platforms, interfaces, and algorithms are used for the development of the tools along the RASimAs project. In order to compose the image processing library, existing tools were considered: toolkits that provide task specific support with extensive adaptability; development environments, which are comprehensive applications; and extensible software packages that can be extended by customized code provided by the user.

The search focused on the following characteristics: support for specific image processing tasks, image format support, licensing restrictions; and software platform.

3. Results

Fifty eight sets of MRI, CT, and ultrasound of sane male and female subjects have been recorded at Uniklinik RWTH Aachen, Research Centre Jülich, Germany, Cochin Hospital, France, and Trondheim Hospital, Norway. The selected regions of interest are the pelvis, neck, and the lower extremities.

Several open source libraries and softwares have been identified and reused to process medical images, such as:

- Gilles Registration Plugin part of SOFA (Simulation Open Framework Architecture) is used for non-rigid registration of musculoskeletal system.
- 3DSlicer utilized for image processing, image segmentation, and 3D mesh generation.

- Meshlab is used for 3D mesh processing (smoothing, slicing, splitting, remeshing).
- OpenGL (Open Graphics Library) is used to implement the 3D rendering engine.
- Glew is used to access OpenGL extension hiding calls to the operative system.
- GLM (OpenGL Mathematics) is used to compute he tetrahedral mesh deformation and tissue deformation.
- Qt as a part of Qt Creator is used to implement the user interface and create the OpenGL context and window
- FreeImage is used in the user interface to load the VPH model textures.
- Assimp is utilized to import various well-known 3D models formats in a uniform manner.
- CGAL (Computational Geometry Algorithms Library) is used for the tetrahedral mesh building process.
- OpenMP (Open MultiProcessing) is used to speed up some parts of the pre-processor application (mesh loading, tissue mapping).

Some of these libraries are used for modelling the patient-specific anatomy. At the end of the complete process including image registration, the resulting X3D-files represent the skin, muscles and bones in patients' MRI. Other tissues as e.g. blood vessels or nerves are interpolated, based on the initial data in the VPH model and the transformations retrieved from the registration.

4. Discussion

RASimAs uses existing commercial VPH models and enhance them by incorporating patient data collected by MRI and CT utilizing existing libraries and algorithms for image processing to support image segmentation, registration and 3D mesh processing. The focus is the deployment of a VPH model enriched with patient-specific data into clinical environment.

Also, the VPH models are evaluated for (1) clinical training (RA simulator) by improving the practitioner's skills before performing the procedure to the subject, and (2) clinical guidance (RA assistant), by improving the success rate of RA procedures integrating predictive anatomic models.

Future works include a refined automatic elastic registration of skin, muscle, and skeleton on MRI and/or CT, building a database of 3D virtual patients and providing statistics on this database for use in RASimAs without patient-specific data.

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6. References

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