



Biomechanical simulation of respiratory motion incorporating abdominal organs

Project Management and Software Development
for Medical Applications

General Info

Project Title: Biomechanical simulation of respiratory motion incorporating abdominal organs

Contact Person: Bernhard Fuerst

Contact Email: fuerst@in.tum.de

Project Abstract

Time-resolved imaging of the thorax or abdominal area is affected by respiratory motion. Nowadays, 1D respiratory surrogates are used to estimate the current state of the lung during its cycle, but with rather poor results. This project aims to improve the framework to predict the 3D lung motion based on a patient-specific finite element model of respiratory mechanics estimated from two CT images at end of inspiration (EI) and end of expiration (EE).

Background and Motivation

Respiratory motion is a source of artifacts in medical image acquisition, which is the basis for disease monitoring, therapy planning and intervention guidance. Currently, signals from devices such as spirometers, abdominal pressure belts or external markers are used as surrogates of respiratory motion. However, the 1D nature of these signals makes it difficult to estimate the 3D lung deformation accurately.

Two categories of methods for patient-specific estimation of respiratory movements can be distinguished: image-based and biomechanical

methods. On the one hand, image-based methods commonly estimate the lung deformations between two or more phases of the respiratory cycle using non-linear image registration. The idea is to create a lung-motion atlas, which is subsequently adapted to the patient. Recent results are promising, but image-based methods are usually restricted to normal breathing patterns, with lower predictive power and versatility in patients. On the other hand, biomechanical approaches compute lung biomechanics, often using finite element methods (FEM), to simulate the physiological deformations during respiration cycles. Often these approaches still rely on 4D image data, which makes it difficult to predict respiratory motion.

We have presented a first framework to estimate the patient's respiratory motion in [1]. The goal of this project is to improve and extend the framework to allow fast computation of the respiratory motion of the entire thorax and abdomen.

Student's Tasks Description

The student will be introduced to the SOFA framework and the novel modules introduced recently. As a first step towards improvement, the existing anatomical model needs to be improved to not only cover half the thorax and abdomen, but the entire abdomen and both lung. In a second step, the changes of the anatomical model must be validated in comparison to the existing solutions presented in [1, 2]. The project's task requiring most work is to reduce the computational effort during the estimation of the

Please send the completed document to us (Ralf.stauder@tum.de) before the project proposal deadline, September 30th. Please note that this proposal will be evaluated by the BMC coordinators and will be assigned to a student only in the case of acceptance.



driving forces of the biomechanical model. Currently, the NEWUOA optimization algorithm finds the most suitable values to drive the force, but perhaps initialization using machine learning techniques or the direct computation of the pressure forces could reduce the required optimization iterations.

Technical Prerequisites

All coding will be done in C++ and is therefore an important skill required. Matlab is used for evaluation of the model's quality during prediction.

Administrative Info

Working Time: 150 hours

Project Location: Garching

Required Equipment: The computer is set up and can be accessed using remote desktop.

Timeline and Milestones

The timeline and milestones are closely connected to the outline of the lecture. Therefore, kick-off, midterm and final presentations are required. Further details and milestones will be set to fit the student's skills.

References

- [1] B. Fuerst, T. Mansi, Parmeshwar Khurd, T. Zhang, J. Declerck, T. Boettger, N. Navab, J. Bayouth, A. Kamen, D. Comaniciu: A Personalized Biomechanical Model for Respiratory Motion Prediction, Proceedings of the 15th International Conference on Medical Image Computing and Computer Assisted Interventions (MICCAI), Nice, France, October 2012
- [2] B. Fuerst, T. Mansi, Parmeshwar Khurd, T. Zhang, J. Declerck, T. Boettger, N. Navab, J. Bayouth, A. Kamen. Patient-Specific Finite-Element Simulation of Respiratory Mechanics for Radiotherapy Guidance, A First Evaluation Study, IEEE International Symposium on Biomedical Imaging: From Nano to Macro (ISBI 2012), Barcelona, Spain, May 2 - 5, 2012

Please send the completed document to us (Ralf.stauder@tum.de) before the project proposal deadline, **September 30th**. Please note that this proposal will be evaluated by the BMC coordinators and will be assigned to a student only in the case of acceptance.