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中尾 恵（京都大学）, 田浦 康二朗（京都大学）, 松田 哲也（京都大学）

Hierarchical Simulation of Respiration Using Alveolus and Airway Models

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Abstract

Respiration is accomplished by expansion and contraction of lung and is essential to live. Therefore the mechanism of respiration has been studied in order to treat respiratory disease. To analyze the respiratory mechanism, the relationship between lung deformation and air flow in the lung must be clarified. This study aimed to reveal the respiratory mechanism considering the lung deformation and the air flow in the airway. Respiration was simulated hierarchically by the alveolus and airway models, as shown in Fig. In order to analyze the alveolus shape deformation and the air flow in the alveolus, the authors designed the alveolus model that consists of 3 models of the elastic model, the fluid model, and the coupled model. Firstly, the elastic model using Kelvin-Voigt model was applied to represent the lung deformation. Secondly, the fluid model using Navier-Stokes equation was applied to calculate the air flow velocity and pressure in the alveolus. Finally, in order to represent the mutual relations in the alveolus, the authors proposed the coupled model using the immersed boundary method. Further it is necessary to integrate the result of the alveolus simulations to calculate the respiratory volume occurred by the lung deformation. Therefore, the authors proposed the airway model for the integration of result of the alveolus simulations. In the airway model, the flow volume and the pressure loss in the airway were calculated on the assumption that the airway was comprised of the pipes and the junctions and that the air flow in the airway was regarded as Hagen-Poiseuille flow. In the evaluation experiments, the authors examined the distribution of pressure and flow velocity in the alveolus using the alveolus model. As the result of simulation, the distribution of pressure and flow velocity in alveolus changed according to lung deformation. Moreover the authors estimated respiratory volume of the simplified lung by the integration of result of the alveolus simulations, and confirmed that the respiratory volume was changed according to the distribution of the lung tissue elasticity.

Keywords: simulation, lung, deformation, airway, alveolus, immersed boundary.

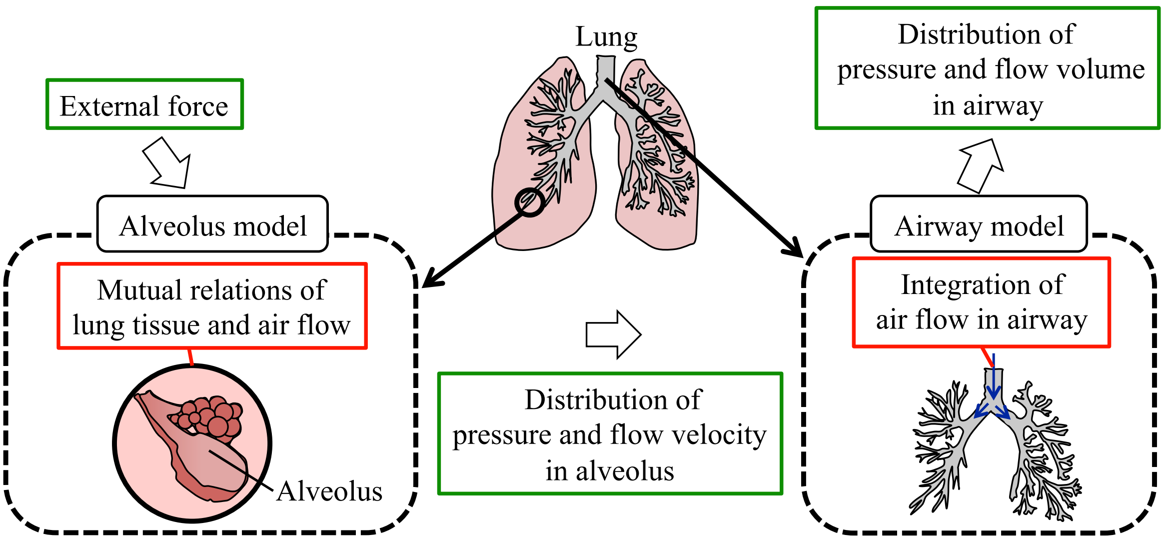

Fig. Overview of proposed hierarchical simulation of respiration

A rendering method based on local maximum intensity projection for *in vivo* cellular imaging

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Abstract

In recent years, the development of fluorescence microscopy have enabled us to observe the inside of biological tissues as 3D image data, and live imaging has become an essential technique to clarify biological mechanisms. Analyzing changes of cells in biological tissues is getting more important in biology and medicine, and how to analyze slice images acquired by live imaging is important problem.

Projection that makes 3D data to 2D image, especially Maximum Intensity Projection (MIP) is widely used in interpreting PET or MRI studies. MIP is a projection method that projects maximum intensity in the way to the plane of projection. MIP has the advantages of computationally low cost and unique result of projection without any parameter settings. In addition, for *in vivo* fluorescence cellular imaging data, MIP is also used in order to enhance contrast and reduce noise by projecting image stack into a single plane (fig.1). However, in the case that some cells overlap on projection direction, they are showed as one big cell and indistinguishable.

In this study, we proposed to use Local Maximum Intensity Projection (LMIP [1]) for *in vivo* cellular imaging data, and we also proposed a modified LMIP (fig.2) to improve the precision of distinguishability between overlapping cells on the projected plane. As a result, we confirmed that improvement of distinguishability was achieved, by applying some automatic segmentation methods to the images projected by MIP and our method.

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Keywords: live imaging, fluorescence microscope, MIP (maximum intensity projection), LMIP

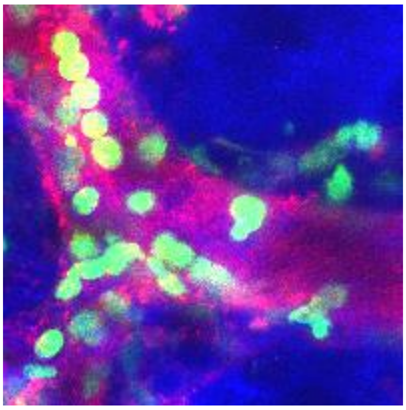

Fig.1 projected image by MIP

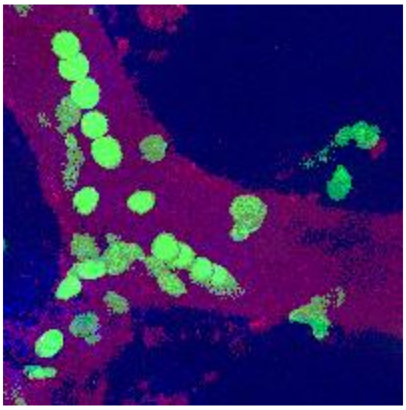

Fig.2 projected image by LMIP

[1] Sato, Y., et al. "Local Maximum Intensity Projection (LMIP): A New Rendering Method for Vascular Visualization." *Journal of computer assisted tomography* 22.6 (1998): 912-917.

Estimation of External Forces Using Local Displacement of Elastic Body

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Abstract

Endoscopic and robotic surgery has enabled minimally invasive procedures and allowed surgeons to perform delicate operation. However, because careful tool operation is required during surgery and current robotic surgery system cannot transfer forces, surgeons operate organs while estimating contact forces from only visual information. If intraoperative measurement and physical estimation of the deformed organs are possible during surgery, the state of organs will be recognized physically and quantitatively, which will make the recent surgery more safe and reliable. Although contact forces on the forceps has been investigated, the physical state of organs is not studied well.

This study proposes a new method for estimating external forces based on local displacement observation of elastic bodies. We assume that the external forces are sparse in manipulating organs that partially connected to other tissues. Local displacement of organs can be measured or estimated from multiple endoscopic cameras or from ultrasound systems. By applying L1-norm minimization to finite element method, the proposed method computes external forces applied to the mesh model from local displacements of the partially observed vertices. Some simulation studies are conducted to confirm the effectiveness of the method. The experiments showed that the external forces are successfully estimated by partial observation of the deformed shape.

Keywords: Force estimation, L1-norm minimization, Intraoperative support.

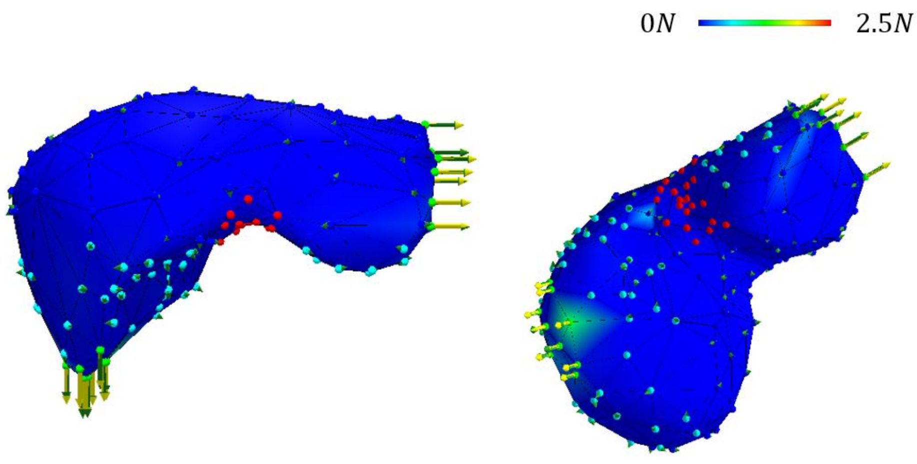

Figure 1. Force estimation result and error between the estimated force and the target force. Yellow arrows are the estimation target. The estimated results (green arrows) are computed from displacement of the observed vertices (light blue).

Three-dimensional Measurement of Muscle Fiber Direction in Hip and Thigh Muscles: Toward Multidisciplinary Computational Anatomy Approach to Musculoskeletal Analysis

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Abstract

This paper outlines our efforts on the modeling of muscle fiber direction. Our approach is twofold: 1) estimation of the fiber direction of the hip and thigh muscles by texture analysis of a series of high-resolution cryosection photographs (Visible Korean Dataset), and 2) its experimental validation via 3D tracing of the fiber direction in cadaver specimens. The preliminary results demonstrated a reasonable agreement between the model and the cadaveric evaluation. This fiber modeling in combination with a CT-derived patient-specific model of the muscle's outer structure would offer a new avenue for the patient-specific muscle dynamics analysis toward multidisciplinary computational anatomy.

Keywords: muscle fiber modeling, cadaveric evaluation, multidisciplinary computational anatomy.

Graph-based unsupervised and semi-supervised learning for prostate extraction in MRI images

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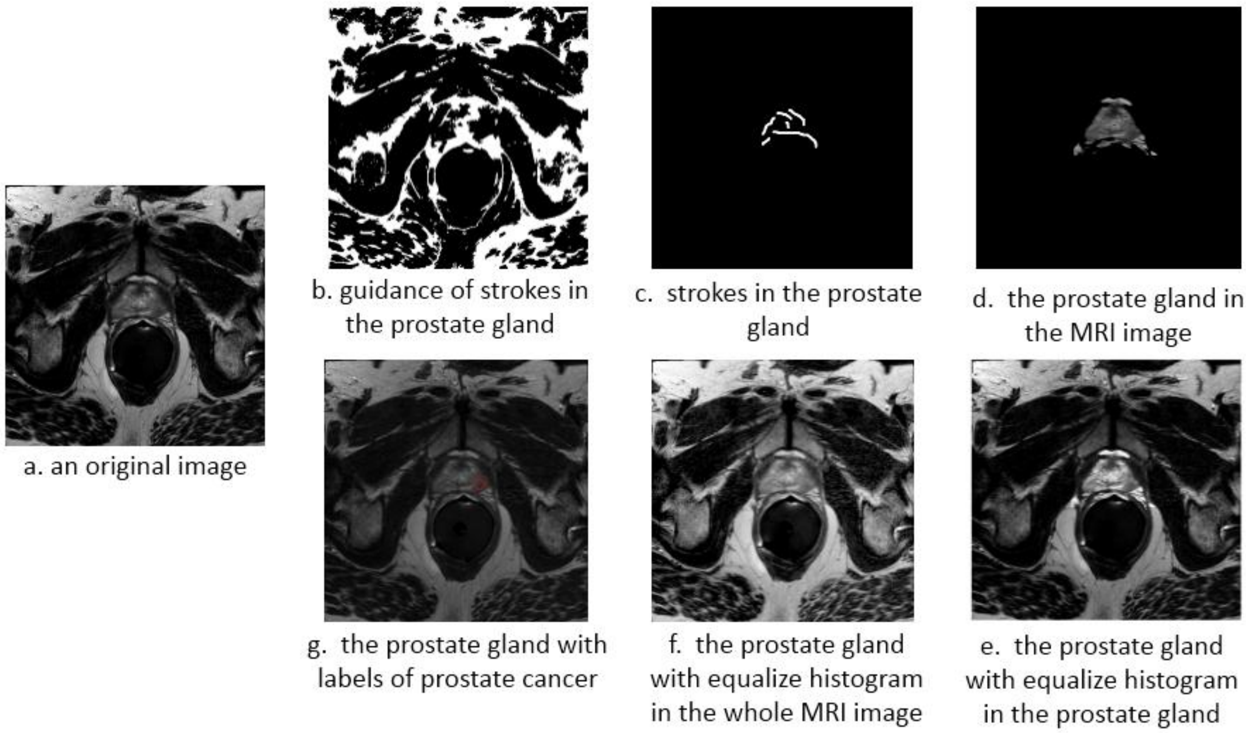
Abstract

The purpose of this study is to present an algorithm of graph –based unsupervised and semi-supervised learning for extracting prostate from MRI images. And then we only adjust the grayscales of the prostate in order to let radiologists more easily detect the cancer regions. The unsupervised scheme can detect entire inhomogeneous regions which are showed in (b). This detectability of inhomogeneous regions is useful for guiding the placement of stokes in a semi-supervised learning. Placements with (b) are stoked by users and showed in (c). The prostate with (d) is extracted by the semi-supervised learning. Only the prostate is enhanced with equalize histogram method. (e) is the result of the prostate enhancement. While the whole MRI image with (f) is enhanced with equalize histogram method.

Keywords: Graph-based unsupervised learning, Graph-based semi-supervised learning, Prostate extraction, MRI image



a. an original image
b. guidance of strokes in the prostate gland
c. strokes in the prostate gland
d. the prostate gland in the MRI image
g. the prostate gland with labels of prostate cancer
f. the prostate gland with equalize histogram in the whole MRI image
e. the prostate gland with equalize histogram in the prostate gland

A Bone Marrow Recognition Method for Bone Tissue Images using Wavelet Transform

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Abstract

We introduce a method for the analysis of a sequence of bone tissue images taken by a two-photon microscope. Because of the difficulty in inspecting the inside of in-vivo bone tissue covered with hard calcium, the behavior of cells inside bone tissue has not been fully understood. On the other hand, application of two-photon microscopy to bone tissue has enabled in-vivo imaging more locally and deeply, which visualizes how blood flows inside the bone. These images contain many clues to unveil mechanism of osteoclasts, which absorb bone tissue. It is also expected to cure disease such as osteoporosis.

In previous work, we have proposed methods to segment the images based on spatial or temporal continuity. These methods require a time-series of images, optimization of parameters, or manual seed input by a user. In this work, we propose a method to recognize bone marrow regions inside the images by extracting feature values of each pixel and classifying them using Support Vector Machine. Features are mainly retrieved based on wavelet transform, which recognizes the texture pattern of the images. We prepared 4 time-series of images taken by the microscope and compared them with ground truth images. We confirm that our method properly extracts bone marrow regions with optimized wavelet parameters, and better understood important wavelets and parameters for our method.

Keywords: wavelet transform, two-photon excitation microscopy image

A Study on Semi-automatic Fibular Transfer Planning in Mandibular Reconstruction

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Abstract

In preoperative planning of mandibular reconstruction with fibular segments, it is necessary to determine the osteotomy lines and the proper placement of the segments. Interactive planning software [1, 2] is recently utilized in preoperative decision making, and surgeons are able to objectively analyze the surgical plan based on quantitative indicators. However, a time-consuming trial-and-error process is needed to obtain a better reconstruction pattern because manual 3D operation is required for adjustment of the fibular segments.

This study aims to develop a semi-automatic fibular transfer planning system based on both interactive operation and automatic placement of fibular segments. We formulate the placement process as an optimization problem that minimizes the shape error [2] between the surfaces of the patient's original mandible and of the fibular segments. The position of the connecting points of each segment is explored under the local shape constraint using a gradient-based search algorithm (Figure 1). In this presentation, we report some automatic placement results in 2-segment and 3-segment case and discuss applicability to practical preoperative planning.

Keywords: Surgical process modeling, automated planning, mandibular reconstruction

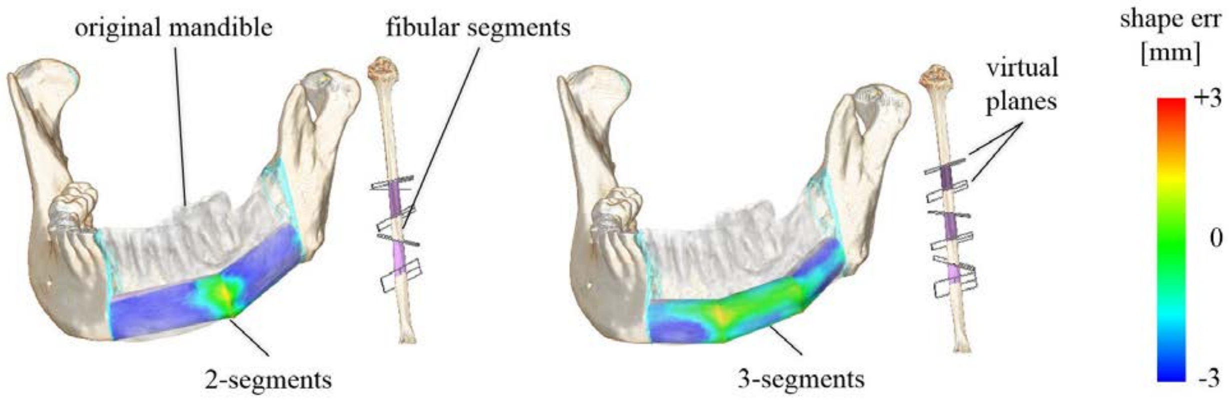

Figure 1. Automatic placement results with a gradient-based search algorithm

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Resection Process Modeling Based on 3D Images

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Abstract

Virtual planning software using CT/MR images allows preoperative planning of a patient-specific resection path by considering three-dimensional (3D) vascular structures as guiding anatomical reference points. A time-series simulation of the resection process is also desirable to provide a preview of the locally visible anatomical structures in the intraoperative deformed state. In the conventional modeling of incisions, tetrahedral elements of the organ model are divided or replaced, and their surfaces are rendered to visualize deformation [1]. However, the computation time is prohibitively expensive due to the large number of vertices needed to adequately represent the physical behavior.

In this study, we introduce resection process modeling methods to create cutting simulations with deformations based on 3D CT/MR images (Figure 1). A sparse tetrahedral mesh is first constructed to enclose the organ region. For a given cutting point, the vertices are relocated to satisfy the geometrical constraints of the resection path. The mesh deformation is computed using the finite element method and rendered volumetrically by slicing the tetrahedral mesh [2, 3]. This approach models smooth resection paths and produces a high-quality visual simulation of the resection process. Real-time animation at greater than 10 frames/s is possible because vertex addition is not required. Moreover, the only manual step in the setup process is the segmentation of the target organ. In this presentation we demonstrate some simulation results in liver resection.

Keywords: Surgical process modeling, cutting simulation, volume deformation and liver resection

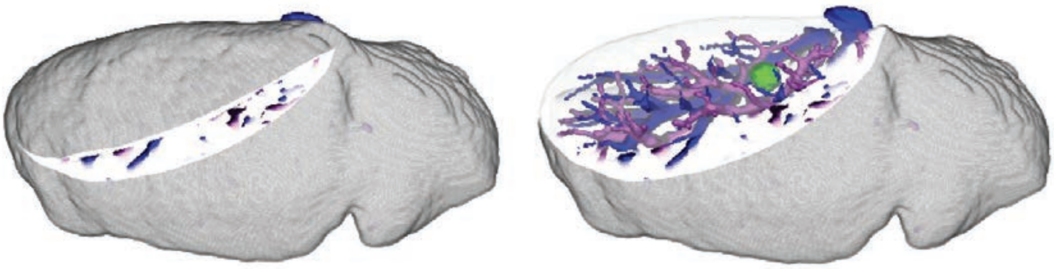

Figure 1. Visualizing liver resection process with volume deformation

Acknowledgements
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