Testing a Point Distribution Model of the Head Designed From Healthy Subjects in Respect of Craniofacial Deformities

Matthias Schaufelberger, Instiute of Biomedical Engineering Karlsruhe Institute of Technology, Karlsruhe, Germany, matthias.schaufelberger@kit.edu
Werner Nahm, Instiute of Biomedical Engineering Karlsruhe Institute of Technology, Karlsruhe, Germany, werner.nahm@kit.edu
Reinald Kühle, Klinik und Poliklinik für Mund-, Kiefer- und Gesichtschirurgie Universitätsklinikum Heidelberg, Heidelberg, Germany, reinald.kuehle@med.uni-heidelberg.de
Frederic Weichel, Klinik und Poliklinik für Mund-, Kiefer- und Gesichtschirurgie Universitätsklinikum Heidelberg, Heidelberg, Germany, frederic.weichel@med.uni-heidelberg.de
Christian Freudlsperger, Klinik und Poliklinik für Mund-, Kiefer- und Gesichtschirurgie Universitätsklinikum Heidelberg, Heidelberg, Germany, christian.freudlsperger@med.uni-heidelberg.de

Introduction

This pre-study is part of a project on estimating classes of craniosynostosis from shape deformities. Craniosynostosis is characterized by the premature fusion of cranial sutures in infants, causing typical changes in the shape of the head. Point distribution models (PDMs) are an important class of statistical shape models. PDMs of the human head exist, but are often used to depict physiologically normal head shapes and are therefore composed of healthy subjects. We test if the principle components of a publicly available PDM composed of physiological subjects can be applied to pathologic deformities which were not present in the training set.

Methods

We use the Liverpool-York-Child-Model, which was composed of 133 subjects under the age of 15. The dataset is well balanced in gender (66 female and 67 male). The mean age is 8.9 years and the standard deviation is 3.3 years. Typical cases of craniosynostosis (trigonocephaly and anterior plagiocephaly) were manually modified from the mean shape using Blender regardless of the principle components of the source model. The resulting deformities were approved by an expert. We approximated the deformities on the target mesh using mean shape and principal components from the PDM. Point-to-point-distances from the target mesh to the approximated mesh served as an error metric.

Results

While the average point-to-point-distances for points on the deformity decreased, they increased for points outside the deformity. Local shape modifications were accompanied by undesired global changes in the model.

Conclusion

We conclude that the sole use of a PDM from healthy subjects cannot be expected to easily depict also pathological head deformities, most likely due to the absence of pathological deformities from the source dataset. Either subjects with the desired shape modifications should be included in the PDM, or a more general type of statistical shape models should be used.

3D printing of tissue-simulating fluorescence phantoms for diffuse optical imaging

Sandra Schädel-Ebner, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, sandra.schaedel-ebner@ptb.de
Thomas Gladytz, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, thomas.gladytz@ptb.de
Dirk Grosenick, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, dirk.grosenick@ptb.de

Introduction

Three-dimensional (3D) printing provides a method for fabricating physiologically realistic phantoms useful in developing biomedical optical devices and in validating and calibrating measured data. However, the preparation of fluorescent phantoms by this technology remains a challenging task. Up to date, fluorescence in 3D printed tissue-simulating phantoms is based on cavities filled with liquid fluorescent solutions. To realize solid fluorescent phantoms it is necessary to incorporate a fluorescent agent in the printing process.

Methods

We present a methodology to generate phantoms for diffuse optical imaging with fluorescence properties similar to those of the frequently applied near-infrared contrast agent indocyanine green (ICG) by a 3D digital light processing printer. Light scattering and absorption properties of the phantoms were adjusted by incorporating titanium dioxide powder and black ink into the clear methacrylate photopolymer base material of the printer. Fluorescence properties were obtained by adding the dye Lumogen IR 765. The optical properties of several series of printed disc phantoms with varied concentrations of the agents were characterized using time-resolved measurements, UV/VIS and fluorescence spectroscopy.

Results

The dye Lumogen IR 765 showed stable fluorescence after UV curing of the phantoms. Its absorption maximum in the printed phantom is at about 760 nm, and fluorescence emission occurs around 810 nm. Hence, the phantoms are well suited to simulate the fluorescence properties of ICG. By adding different amounts of the titanium oxide powder, scattering coefficents could easily be adjusted in the physiologically relevant range from 5 cm^{-1} to 15 cm^{-1}. Similar, absorption by ink could be realized up to about 0.1 cm^{-1}. Above 850 nm the base polymer starts to show intrinsic absorption. The distribution of the agents in the phantoms was homogeneous, and the agents did not have any negative effects on the UV curing process.

Conclusion

We have successfully demonstrated 3D printing of phantoms for diffuse optical imaging with fluorescence properties similar to those of the near-infrared contrast agent ICG. Our results open the way to fabricate stable, tissue-simulating phantoms with different geometries and multiple tissue optical parameters for development, characterization and evaluation of biomedical imaging methods in order to ensure accurate measurements of optical properties in biological tissue.

Optical Coherence Microscopy using Visible Light with Small Bandwidth

Yilun Su, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany, yilun.su@kit.edu
Werner Nahm, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany, werner.nahm@kit.edu

Introduction

Optical coherence microscopy (OCM) combines optical coherence tomography (OCT) with high numerical aperture (NA) objectives to achieve high-resolution in-vivo label-free tissue imaging. Typical light sources for OCT systems are in the near-infrared range. In order to obtain a high axial resolution, light sources of choice need to have very broad spectral bandwidth, which could increase system complexity. By employing a low-coherence light source in the visible range, a high axial resolution can be obtained with a narrower bandwidth. This will also simplify the components' requirements in terms of supporting broadband applications. Meanwhile, the shorter wavelength will further enhance the lateral resolution of the system.

Methods

We propose an OCM system deploying a narrow bandwidth in the visible spectral range of a supercontinuum laser (SCL). A bandwidth of approx. 23 nm centered around 554 nm of the spectrum was selected. An electro-optical modulator (EOM) was used to generate the heterodyne signal. A 40x microscope objective was integrated for a high lateral resolution. We used a balanced photodetector to detect the signal.

Results

System characterization of our OCM system was performed. The system permits an axial resolution of approx. 5.5 micrometers and a lateral resolution below 1 micrometer. We used a self-made resolution test target to further test the system performance.

Conclusion

We demonstrated an OCM system using visible light with a narrow spectral bandwidth. By using light with shorter wavelengths, the lateral resolution is almost halved compared to systems using light sources in the NIR range. Comparable axial resolution can be achieved with narrower spectral bandwidth. However, for fiber-based systems, optical power attenuation in fibers and other components is greater than in the NIR range, which requires light sources with higher outpower.

Combined fluorescence imaging and angle-resolved light scattering detection in laser flow cytometry

Alexander Hoppe, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, alexander.hoppe@ptb.de
Martin Hussels, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, martin.hussels@ptb.de
Jonas Gienger, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, jonas.gienger@ptb.de
Dirk Grosenick, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, dirk.grosenick@ptb.de

Introduction

The measurement of cell concentrations by conventional laser flow cytometry is limited by coincidences of two or more cells in the observation volume, by the occurrence of cell agglomerates and by changes of the cell shape due to hydrodynamic focusing. Angle-resolved measurements of the scattered light offer a way to gain additional information on the shape of the scattering particles, on their internal structures, and on their indices of refraction. However, the scattering patterns are difficult to interpret when affected by the above mentioned events.

Methods

We have extended a home-made laser flow cytometer with two cameras for spatially-resolved detection of the light scattered by particles in forward and sideward direction and for imaging of fluorescence. The scattered light is recorded as a function of the scattering angle by guiding the parallel beams of the infinity-corrected microscope objectives directly to the cameras. For imaging of particles, tube lenses can be integrated in front of the cameras to obtain fringe-resolved images. Additionally, bandpass filters are used to record images of the fluorescence of stained particles.

Results

Angle-resolved scatter patterns and fluorescence images were recorded for particles of different size and shape with high signal-to-noise ratio. Measured angular distributions were compared to simulations based on Mie theory (spherical particles) and on the discrete dipole approximation (non-spherical particles) to estimate the particle size and shape. The information from the fluorescence images was successfully exploited to support and evaluate the interpretation of the scatter patterns by distinguishing single particles from coincidences and agglomerates.

Conclusion

The extension of laser flow cytometry by fluorescence imaging and angle-resolved light scattering detection offers a viable way to gain additional information about single cells and to recognize coincidences and agglomerates. This information could be exploited to increase the accuracy in cell counting and to improve the detetion of rare cells.

A Survey: Specular Reflection Removal Methods on Single Endoscopic Image

Lu Guo, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany, lu.guo@kit.edu
Werner Nahm, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany, Werner.Nahm@kit.edu

Introduction

Specular reflection of the light source (Specularity) in endoscopic images can cause difficulty for visualizing the underlying tissues, and errorneous results for many post-analysis methods, for instance, 3D reconstruction of the surgical scene. Besides, crucial information of the tissues (texture details, colors) contained in the specular areas may be lost. Thus, removing specularity while preserving the original information is significant for improving effective endoscopic images analysis.

Methods

Currently, the specularity removal methods on single endoscopic image can be roughly divided into histogram analysis, dichromatic reflection model-based methods, image inpainting, learning-based methods, and low-rank and sparse decomposition methods. Representatives are tested using endoscopic images with presence of (at least one) following factors: large specular areas, texture details in specular areas, tissues with bright color, and smoke. Their performances are compared and evaluated in terms of accuracy and robustness by using forced-choice questionnaires for green hands and experienced surgeons, and applying to stereo reconstruction.

Results

In general, learning-based methods could obtain accurate and robust results. However, they suffer from ungeneralizable training and test data sets, which limit the range of applications. For the other methods, large amount of data sets is not required. However, for dichromatic reflection model-based methods, it's hard to retain original colour information in specular areas. And image inpainting methods always lose texture details. Comparatively speaking, low-rank and sparse decomposition methods work better on endoscopic images, but only when the specular area is small.

Conclusion

To develop a more general specularity removal method, if enough data sets are available, it's worth training a learning network with generalizable data sets. Otherwise, improving low-rank and sparse decomposition methods directing at large specular areas worth a trial.

Abstracts – BMT 2020 – Leipzig, September 29 – October 1 • DOI 10.1515/bmt-2020-6@@@
Biomed. Eng.-Biomed. Tech. 2020; 65(s1): S@@@–S@@@ • © by Walter de Gruyter • Berlin • Boston

Investigation of the Potential of CycleGANs for Generating Artificial Photorealistic Images of Patients Outcome after Surgery

Andreas Wachter, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany, publications@ibt.kit.edu
Robin Andlauer, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany
Werner Nahm, Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany

Introduction

Deformities of the jaw, so-called dysgnathia, are widespread in the population with a prevalence of up to 70%. Ultimately only 5% of those affected need orthodontic or surgical treatment. Due to the correction of the underlying bone structure, this surgery often affects the aesthetics of the face which implies an additional burden for the patient to decide whether or not to undergo surgery. Today, physicians can provide the patient with 2D or 3D predictions of the post-operative face to guide the patient's decision-making. These predictions are derived by hand-crafted algorithms that leverage laser- and tomography scans of the patient's face and a virtual simulation of craniofacial surgery. Unfortunately, the current tools for generating postsurgical 2D images provide only unrealistic and not very vivid images.
To overcome this gap of unrealistic images, generative adversarial networks (GANs) might be suitable. GANs have shown their potential to generate or modify highly realistic images of faces. In this work, we studied whether GANs can generate realistic images of faces with a simulated face modification. Ultimately, the motivation of this work was that GANs can be used to partially or even completely replace current rule-based algorithms for predicting the postoperative face.

Methods

We trained a GAN that received two inputs: An image of a face and a virtual 3D model e.g. with a chin or nose modification to describe the post-surgical outcome. Based on this input the GAN was tasked to predict a realistic but modified image of a face. For simplification, the provided virtual 3D model was expressed by a 3D statistical model of facial shape. To overcome the lack of ground-truth pairs between two modified faces of the same person, we adapted a CycleGAN approach to train our framework without supervision. Hereby, we penalized only the statistics of the prediction and the reconstruction loss after back- and forth translation between the image domain and the domain of the virtual 3D model. Then, we conducted a user study with 10 participants to evaluate whether the generated images were realistic and if the desired modification could be recognized.

Results

The result of the study was that on average 54.41% of the participants judged the generated modified images of our GAN to be realistic. The best case with 80% was the modification of a larger chin and the worst case with 34% was the modification of a smaller nose. However, only 18.0% of all generated images were without the presence of any artifacts according to the participants.

Conclusion

We showed that a CycleGAN can generate realistic modified images of faces with fine details based on an unmodified image of a face and a given 3D modification. However, the robustness of the proposed framework must be improved and addressed in future work, yet this work highlighted the potential of GANs for predicting postoperative faces after craniofacial surgery.

Surgical Audio Guidance: Feasibility Check for Robotic Surgery Procedures

Anna Schaufler, Otto-von-Guericke Universität, Magdeburg, Germany, anna.schaufler@st.ovgu.de
Alfredo Illanes, Otto-von-Guericke Universität, Magdeburg, Germany, alferdo.illanes@ovgu.de
Ivan Maldonado, Otto-von-Guericke Universität, Magdeburg, Germany, ivan.maldonado@ovgu.de
Axel Boese, Otto-von-Guericke Universität, Magdeburg, Germany, axel.boese@ovgu.de
Roland Croner, Otto-von-Guericke Universität, Magdeburg, Germany, roland.croner@med.ovgu.de
Michael Friebe, Otto-von-Guericke Universität, Magdeburg, Germany, michael.friebe@ovgu.de

Introduction

The lack of haptic feedback during robotic-assisted procedures poses a performance limitation for the surgeon in terms of the assessment of diseased tissue, the recognition of hidden structures and controlled force application to tissue. Interactions between the robotic instruments and tissue cause vibrations that travel through the robotic system, are emitted as acoustic emissions (AE) on surfaces and can be recorded as acoustic signals by an audio sensor attached to the system. The information on haptic instrument/tissue interactions contained in these audio signals could be used to provide the surgeon with guidance information during robotic surgery. However, the feasibility of this concept for a realistic scenario depends on whether valuable audio signals can be acquired from a measuring location outside the sterile surgical field. The aim of this work is to demonstrate that the acquisition of meaningful AE signals can be achieved by measurements in the non-sterile field.

Metheods

An experimental setup was prepared to simulate interactions of a da Vinci Surgical System instrument with three different tissues. The instrument tip was moved across the tissues, while the emitted AE were recorded using a MEMS microphone. The experiments were performed for three different microphone mounting locations. Subsequently, the audio signals were analyzed in the time domain and the time-frequency domain.

Results

The three tissue types led to different time domain signal behaviour in the three tested locations, with location-dependent damping effects being reflected in the signal intensity. Also in the time-frequency domain examination a characteristic trace for each tissue could be observed.

Conclusion

The results showed that tissue-specific information was contained in the signals recorded at realistic locations. The ability to obtain relevant signals in the non-sterile area is an essential aspect to meet clinical requirements and thus for the applicability of surgical audio guidance in robotic procedures.