Markerless motion tracking and correction for PET, MRI, and simultaneous PET/MRI
We demonstrate and evaluate the first markerless motion tracker compatible with PET, MRI, and simultaneous PET/MRI systems for motion correction (MC) of brain imaging. PET and MRI compatibility is achieved by careful positioning of in-bore vision extenders and by placing all electronic components out-of-bore. The motion tracker is demonstrated in a clinical setup during a pediatric PET/MRI study including 94 pediatric patient scans. PET MC is presented for two of these scans using a customized version of the Multiple Acquisition Frame method. Prospective MC of MRI acquisition of two healthy subjects is demonstrated using a motion-aware MRI sequence. Real-time motion estimates are accompanied with a tracking validity parameter to improve tracking reliability. For both modalities, MC shows that motion induced artifacts are noticeably reduced and that motion estimates are sufficiently accurate to capture motion ranging from small respiratory motion to large intentional motion. In the PET/MRI study, a time-activity curve analysis shows image improvements for a patient performing head movements corresponding to a tumor motion of ±5-10 mm with a 19% maximal difference in standardized uptake value before and after MC. The first markerless motion tracker is successfully demonstrated for prospective MC in MRI and MC in PET with good tracking validity. As simultaneous PET/MRI systems have become available for clinical use, an increasing demand for accurate motion tracking and MC in PET/MRI scans has emerged. The presented markerless motion tracker facilitate this demand.
Statistical Shape Clustering of Left Atrial Appendages

Fifteen percent of all strokes are caused by emboli formed in the left atrium (LA) in case of atrial fibrillation (AF). The most common site of thrombus formation is inside the left atrial appendage (LAA). The LAA is accounting for 70% to 90% of the thrombi formed in the LA in patients with non-valvular AF. Studies have shown there is a correlation between the LAA morphology and risk of ischemic stroke; Chicken Wing and Cauliflower LAA shapes are associated with lower and higher risk, respectively. These two LAA shape categories come from a popular classification in the medical domain, but it is subjective and based on qualitative shape parameters. In this paper, we describe a full framework for shape analysis and clustering of the LAA. Initially, we build a point distribution model to quantitatively describe the LAA shape variation based on 103 LAA surfaces segmented and reconstructed from multidetector computed tomography volumes. We are successfully able to determine point correspondence between LAA surfaces, by non-rigid volumetric registration of signed distance fields. To validate if LAA shapes are clustered, we employ an unsupervised clustering on the shape models parameters to estimate the natural number of clusters in our training set, where the number of shape clusters is estimated by validating the test log-likelihood of several Gaussian mixture models using two level crossvalidation. We found that the LAAs surfaces basically formed two shape clusters broadly corresponding to the Chicken wing and non-Chicken Wing morphologies, which fits well with clinical knowledge.

General information
Publication status: Published
Organisations: Image Analysis & Computer Graphics, Department of Applied Mathematics and Computer Science, University of Copenhagen, Pompeu Fabra University
Pages: 32–39
Publication date: 2019

Host publication information
Title of host publication: Statistical Atlases and Computational Models of the Heart
Publisher: Springer
ISBN (Print): 978-3-030-12028-3
(Lecture Notes in Computer Science, Vol. 11395).
Keywords: Left atrial appendage, Point distribution models, Clustering, Gaussian mixture models
DOIs: 10.1007/978-3-030-12029-0_4
Source: PublicationPreSubmission
Source-ID: 170357586

Wind Turbine Surface Damage Detection by Deep Learning Aided Drone Inspection Analysis
Timely detection of surface damages on wind turbine blades is imperative for minimizing downtime and avoiding possible catastrophic structural failures. With recent advances in drone technology, a large number of high-resolution images of wind turbines are routinely acquired and subsequently analyzed by experts to identify imminent damages. Automated analysis of these inspection images with the help of machine learning algorithms can reduce the inspection cost. In this work, we develop a deep learning-based automated damage suggestion system for subsequent analysis of drone inspection images. Experimental results demonstrate that the proposed approach can achieve almost human-level precision in terms of suggested damage location and types on wind turbine blades. We further demonstrate that for relatively small training sets, advanced data augmentation during deep learning training can better generalize the trained
model, providing a significant gain in precision.

Can we train a single deep learning model to detect and segment nuclei images acquired with any microscope or staining modality?

Computer Aided Identification of Motion Disturbances Related to Parkinson’s Disease
We present a framework for assessing which types of simple movement tasks are most discriminative between healthy controls and Parkinson’s patients. We collected movement data in a game-like environment, where we used the Microsoft Kinect sensor for tracking the user’s joints. We recruited 63 individuals for the study, of whom 30 had been diagnosed with Parkinson’s disease. A physician evaluated all participants on movement-related rating scales, e.g., elbow rigidity. The participants also completed the game task, moving their arms through a specific pattern. We present an innovative approach for data acquisition in a game-like environment, and we propose a novel method, sparse ordinal regression, for predicting the severity of motion disorders from the data.
Computerized feedback during colonoscopy training leads to improved performance: a randomized trial

Background and Aims: Simulation-based training in colonoscopy is increasingly replacing the traditional apprenticeship method to avoid patient-related risk. Mentoring during simulation is necessary to provide feedback and to motivate, but expert supervisors are a scarce resource. We aimed to determine whether computerized feedback in simulated colonoscopy would improve performance, optimize time spent practicing, and optimize the pattern of training.

Methods: Forty-four participants were recruited and randomized to either a feedback group (FG) or a control group (CG). Participants were allowed 2 hours of self-practice where they could practice as they saw fit on 2 different cases: one easy and one difficult. The CG practiced without feedback but the FG was given a score of progression every time they reached the cecum. All participants were tested on a different case after end of training. The primary outcome was progression score in the final case and secondary outcomes were time spent practicing and training pattern.

Results: Regression analysis adjusting for sex was done due to an uneven sex distribution between groups (P = 0.026) and significantly higher performance scores by men (37.6, SD 25.9) compared with women (19.7, SD 18.7), P = 0.012. The FG outperformed the CG in the final case (FG scoring 14.4 points (95% CI, 1.2 - 27.6) more than the CG, P = 0.033) and spent more time practicing (FG practicing 25.8 minutes [95% CI, 11.6 - 39.9] more than the CG; P = 0.001). The FG practiced more on the easy case and reached the cecum 3.2 times more (95% CI, 2 - 4.5) during practice (P <0.001). Conclusions: Our findings of this study revealed that an automatic, computerized score of progression during simulated colonoscopy motivates the novices to improve performance, optimize time spent practicing, and optimize their pattern of training (Clinical trial registration number: NCT03248453).
FastSME: faster and smoother manifold extraction from 3D stack

Patient-specific estimation of detailed cochlear shape from clinical CT images
A personalized estimation of the cochlear shape can be used to create computational anatomical models to aid cochlear implant (CI) surgery and CI audio processor programming ultimately resulting in improved hearing restoration. The purpose of this work is to develop and test a method for estimation of the detailed patient-specific cochlear shape from CT images. From a collection of temporal bone CT images, we build a cochlear statistical deformation model (SDM), which is a description of how a human cochlea deforms to represent the observed anatomical variability. The model is used for regularization of a non-rigid image registration procedure between a patient CT scan and a [Formula: see text]CT image, allowing us to estimate the detailed patient-specific cochlear shape. We test the accuracy and precision of the predicted cochlear shape using both [Formula: see text]CT and CT images. The evaluation is based on classic generic metrics, where we achieve competitive accuracy with the state-of-the-art methods for the task. Additionally, we expand the evaluation with a few anatomically specific scores. The paper presents the process of building and using the SDM of the cochlea. Compared to current best practice, we demonstrate competitive performance and some useful properties of our method.

Perceptually motivated analysis of numerically simulated head-related transfer functions generated by various 3D surface scanning systems
Numerical simulations offer a feasible alternative to the direct acoustic measurement of individual head-related transfer functions (HRTFs). For the acquisition of high quality 3D surface scans, as required for these simulations, several approaches exist. In this paper, we systematically analyze the variations between different approaches and evaluate the influence of the accuracy of 3D scans on the resulting simulated HRTFs. To assess this effect, HRTFs were numerically simulated based on 3D scans of the head and pinna of the FABIAN dummy head generated with 6 different methods. These HRTFs were analyzed in terms of interaural time difference, interaural level difference, energetic error in auditory filters and by their modeled localization performance. From the results, it is found that a geometric precision of about 1 mm is needed to maintain accurate localization cues, while a precision of about 4 mm is sufficient to maintain the overall spectral shape.

General information
Publication status: Published
Contributors: Dinakaran, M., Brinkmann, F., Harder, S., Pelzer, R., Grosche, P., Paulsen, R. R., Weinzierl, S.
Number of pages: 1
Publication date: 2018
Peer-reviewed: Yes
Electronic versions:
PosterPresentations_ICASSP2018_Manoj_2107_0.pdf

Bibliographical note
https://sigport.org/documents/perceptually-motivated-analysis-numerically-simulated-head-related-transfer-functions
Source: PublicationPreSubmission
Source-ID: 151068080
Research output: Contribution to conference → Poster – Annual report year: 2018 → Research → peer-review

Creating Ultra Dense Point Correspondence Over the Entire Human Head
While the acquisition and analysis of 3D faces has been an active area of research for decades, it is still a complex and demanding task to accurately model the entire head and ears. Having accurate models would for example enable virtual design of hearing devices. In this paper, we describe a complete framework for surface registration of complete human heads where the result is point correspondence with a very high number of points. The method is based on a volumetric and multi-scale non-rigid registration of signed distance fields. The method is evaluated on a set of 30 human heads and the results are convincing. The output can for example be used to compute statistical shape models. The accuracy of predicted anatomical landmarks is on the level of experienced human operators.

General information
Publication status: Published
Organisations: Copenhagen Center for Health Technology, Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Technical University of Denmark, DGS Denmark A/S
Contributors: Paulsen, R. R., Marstal, K. K., Laugesen, S., Harder, S.
Pages: 438-447
Publication date: 2017

Host publication information
Title of host publication: Lecture Notes in Computer Science: Image Analysis
Volume: 10270
Publisher: Springer
ISBN (Print): 978-3-319-59128-5
ISBN (Electronic): 978-3-319-59129-2
Keywords: Surface registration, Signed distance field, Human head modelling
Electronic versions:
FullHeads_final.pdf. Embargo ended: 19/05/2018
DOIs:
10.1007/978-3-319-59129-2_37
Source: PublicationPreSubmission
Source-ID: 134203216
Research output: Chapter in Book/Report/Conference proceeding → Article in proceedings – Annual report year: 2017 → Research → peer-review
Data Descriptor: A multiscale imaging and modelling dataset of the human inner ear
Understanding the human inner ear anatomy and its internal structures is paramount to advance hearing implant technology. While the emergence of imaging devices allowed researchers to improve understanding of intracochlear structures, the difficulties to collect appropriate data has resulted in studies conducted with few samples. To assist the cochlear research community, a large collection of human temporal bone images is being made available. This data descriptor, therefore, describes a rich set of image volumes acquired using cone beam computed tomography and micro-CT modalities, accompanied by manual delineations of the cochlea and sub-compartment, a statistical shape model encoding its anatomical variability, and data for electrode insertion and electrical simulations. This data makes an important asset for future studies in need of high-resolution data and related statistical data objects of the cochlea used to leverage scientific hypotheses. It is of relevance to anatomists, audiologists, computer scientists in the different domains of image analysis, computer simulations, imaging formation, and for biomedical engineers designing new strategies for cochlear implantations, electrode design, and others.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Scientific Computing, University of Bern, Alma Medical Imaging, SCANCO Medical AG, MED-EL GmbH, Pompeu Fabra University, University Hospital of Bern, Catalan Institution for Research and Advanced Studies, Technical University of Munich
Number of pages: 12
Publication date: 2017
Peer-reviewed: Yes

Publication information
Journal: Scientific Data
Volume: 4
Article number: 170132
ISSN (Print): 2052-4463
Ratings:
Scopus rating (2017): CiteScore 6.08 SJR 3.026 SNIP 2.291
Web of Science (2017): Impact factor 5.305
Original language: English
Electronic versions:
sdata2017132.pdf
DOIs:
10.1038/sdata.2017.132
Source: FindIt
Source-ID: 2390770382
Research output: Contribution to journal › Journal article – Annual report year: 2017 › Research › peer-review

Foreign object detection in multispectral X-ray images of food items using sparse discriminant analysis
Non-invasive food inspection and quality assurance are becoming viable techniques in food production due to the introduction of fast and accessible multispectral X-ray scanners. However, the novel devices produce massive amount of data and there is a need for fast and accurate algorithms for processing it. We apply a sparse classifier for foreign object detection and segmentation in multispectral X-ray. Using sparse methods makes it possible to potentially use fewer variables than traditional methods and thereby reduce acquisition time, data volume and classification speed. We report our results on two datasets with foreign objects, one set with spring rolls and one with minced meat. Our results indicate that it is possible to limit the amount of data stored to 50% of the original size without affecting classification accuracy of materials used for training. The method has attractive computational properties, which allows for fast classification of items in new images.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Statistics and Data Analysis, Copenhagen Center for Health Technology, Danish Technological Institute
Pages: 350-361
Publication date: 2017

Host publication information
Title of host publication: SCIA 2017
Volume: 10269
Publisher: Springer
A framework for geometry acquisition, 3-D printing, simulation, and measurement of head-related transfer functions with a focus on hearing-assistive devices

Individual head-related transfer functions (HRTFs) are essential in applications like fitting hearing-assistive devices (HADs) for providing accurate sound localization performance. Individual HRTFs are usually obtained through intricate acoustic measurements. This paper investigates the use of a three-dimensional (3D) head model for acquisition of individual HRTFs. Two aspects were investigated: whether a 3D-printed model can replace measurements on a human listener and whether numerical simulations can replace acoustic measurements. For this purpose, HRTFs were acoustically measured for four human listeners and for a 3D printed head model of one of these listeners. Further, HRTFs were simulated by applying the finite element method to the 3D head model. The monaural spectral features and spectral distortions were very similar between re-measurements and between human and printed measurements, however larger deviations were observed between measurement and simulation. The binaural cues were in agreement among all HRTFs of the same listener, indicating that the 3D model is able to provide localization cues potentially accessible to HAD users. Hence, the pipeline of geometry acquisition, printing, and acoustic measurements or simulations, seems to be a promising step forward towards in-silico design of HADs.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Copenhagen Center for Health Technology, Austrian Academy of Sciences, Oticon A/S, Eriksholm Research Centre
Contributors: Harder, S., Paulsen, R. R., Larsen, M., Laugesen, S., Mihocic, M., Majdak, P.
Pages: 39-46

Host publication information
Title of host publication: Skeletonization: Theory, Methods and Applications
Publisher: Elsevier
ISBN (Print): 978-0-08-101291-8
DOI: 10.1016/B978-0-08-101291-8.00013-4
Source: FindIt
Source-ID: 2392798601
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2017 › Research › peer-review
Automatic Model Generation Framework for Computational Simulation of Cochlear Implantation

Recent developments in computational modeling of cochlear implantation are promising to study in silico the performance of the implant before surgery. However, creating a complete computational model of the patient's anatomy while including an external device geometry remains challenging. To address such a challenge, we propose an automatic framework for the generation of patient-specific meshes for finite element modeling of the implanted cochlea. First, a statistical shape model is constructed from high-resolution anatomical μCT images. Then, by fitting the statistical model to a patient's CT image, an accurate model of the patient-specific cochlea anatomy is obtained. An algorithm based on the parallel transport frame is employed to perform the virtual insertion of the cochlear implant. Our automatic framework also incorporates the surrounding bone and nerve fibers and assigns constitutive parameters to all components of the finite element model. This model can then be used to study in silico the effects of the electrical stimulation of the cochlear implant. Results are shown on a total of 25 models of patients. In all cases, a final mesh suitable for finite element simulations was obtained, in an average time of 94 s. The framework has proven to be fast and robust, and is promising for a detailed prognosis of the cochlear implantation surgery.
Cochlear implant electrode localization in post-operative CT using a spherical measure

When implanting cochlear implants the positions of electrodes have a large impact on the quality of the restored hearing. Due to metal artifacts it is difficult to estimate the precise location in post-operative scans. In this paper we present a method for automatically locating and determining the ordering of electrode contacts on implanted electrode arrays from post-operative CT images. Our method applies a specialized filter chain to the images based on a threshold and spherical measure, and selects contact positions at local maxima in the filtered image. Two datasets of 13 temporal bone specimens scanned in CBCT are used to validate the method, which successfully locates the electrode array in every image.

Free-form image registration of human cochlear μCT data using skeleton similarity as anatomical prior

Better understanding of the anatomical variability of the human cochlear is important for the design and function of Cochlear Implants. Proper non-rigid alignment of high-resolution cochlear μCT data is a challenge for the typical cubic B-spline registration model. In this paper we study one way of incorporating skeleton-based similarity as an anatomical registration prior. We extract a centerline skeleton of the cochlear spiral, and generate corresponding parametric pseudo-landmarks between samples. These correspondences are included in the cost function of a typical cubic B-spline registration model to provide a more global guidance of the alignment. The resulting registrations are evaluated using different metrics for accuracy and model behavior, and compared to the results of a registration without the prior.
Monopolar Stimulation of the Implanted Cochlea: A Synthetic Population-Based Study

Cochlear implantation is carried out to recover the sense of hearing. However, its functional outcome varies highly between patients. In the current work, we present a study to assess the functional outcomes of cochlear implants considering the inter-variability found among a population of patients. In order to capture the cochlear anatomical details, a statistical shape model is created from high-resolution human μCT data. A population of virtual patients is automatically generated by sampling new anatomical instances from the statistical shape model. For each virtual patient, an implant insertion is simulated and a finite element model is generated to estimate the electrical field created into the cochlea. These simulations are defined according to the monopolar stimulation protocol of a cochlear implant and a prediction of the voltage spread over the population of virtual patients is evaluated.
Anatomically Correct Surface Recovery: A Statistical Approach

We present a method for 3D surface recovery in partial surface scans. The method is based on an Active Shape Model, which is used to predict missing data. The model is constructed using a bootstrap framework, where an initially small collection of hand-annotated samples is used to fit to and register unknown samples, resulting in an extensive statistical model. The statistical recovery uses a multivariate point prediction, where the distribution of the points is given by the Active Shape Model. We show how missing data in a partial scan, once point correspondence is achieved, can be predicted using the learned statistics. A quantitative evaluation is performed on a data set of 10 laser scans of ear canal impressions with minimal noise and artificial holes. We also present a qualitative evaluation on authentic partial scans from an actual direct in ear scanner prototype. Compared to a state-of-the-art surface reconstruction algorithm, the presented method gives matching prediction results for the synthetic evaluation samples and superior results for the direct scanner data.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics
Contributors: Jensen, R. R., Nielsen, J. B., Larsen, R., Paulsen, R. R.
Number of pages: 12
Pages: 216-227
Publication date: 2015

Assisting doctors on assessing movements in infants using motion tracking

In this work, we consider the possibilities of having an automatic computer-based system for tracking the movements of infants. An existing motion tracking system is used to process recorded video sequences containing both color and spatial information of the infant's body pose and movements. The system uses these sequences of data to estimate the underlying skeleton of the infant and parametrize the movements. Post-processing of these parameters can yield objective measurements of an infant's movement patterns. This could e.g. be quantification of (a)symmetry and recognition of certain gestures/actions such as kicking, crying, roll over and bringing hands together. Clinicians could benefit from such a system, as it would ease the task of diagnosing infants with motor disorders, and in some cases, this could initiate an intervention earlier than usual. It should be clear, that we do not seek to substitute the task of the clinicians, but the system should instead be considered as a tool for easy extraction of objective measurements describing the movements and as well as a screening tool for highlighting certain patterns in the movements.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics
Contributors: Olsen, M., Herskind, A., Nielsen, J. B., Paulsen, R. R.
Number of pages: 1
Pages: 55
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Developmental Medicine and Child Neurology
Volume: 57
Automatic Generation of a Computational Model for Monopolar Stimulation of Cochlear Implants

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Copenhagen Center for Health Technology, Pompeu Fabra University, INRIA Sophia Antipolis, Alma Medical Systems, MED-EL GmbH
Pages: S67-S68
Publication date: 2015
Peer-reviewed: Yes

Publication information
Volume: 10
Issue number: Supplement 1
ISSN (Print): 1861-6410
Ratings:
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.7 SJR 0.539 SNIP 1.065
Web of Science (2015): Indexed yes
Original language: English
Keywords: Cochlear implant, Finite element mesh, Automatic generation, Finite element model, Implant optimization
Source-ID: 118521623
Research output: Contribution to journal › Conference abstract in journal – Annual report year: 2016 › Research › peer-review

Cochlear Implant Planning, Selection and Simulation with Patient Specific Data

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Copenhagen Center for Health Technology, Alma Medical Imaging, MED-EL GmbH, UPF/ICREA
Contributors: Vera, S., Caro, R., Perez, F., Bordone, M., Herrero, J., Kjer, H. M., Fagertun, J., Paulsen, R. R., Dhanasingh, A., Ballester, M. G.
Pages: S43-S44
Publication date: 2015
Peer-reviewed: Yes

Publication information
Volume: 10
Issue number: Supplement 1
ISSN (Print): 1861-6410
Correction of Motion Artifacts for Real-Time Structured Light

While the problem of motion is often mentioned in conjunction with structured light imaging, few solutions have thus far been proposed. A method is demonstrated to correct for object or camera motion during structured light 3D scene acquisition. The method is based on the combination of a suitable pattern strategy with fast phase correlation image registration. The effectiveness of this approach is demonstrated on motion corrupted data of a real-time structured light system, and it is shown that it improves the quality of surface reconstructions visually and quantitively.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics
Contributors: Wilm, J., Olesen, O. V., Paulsen, R. R., Larsen, R.
Number of pages: 10
Pages: 149-158
Publication date: 2015

Host publication information
Title of host publication: Image Analysis: 19th Scandinavian Conference, SCIA 2015 Copenhagen, Denmark, June 15–17, 2015 Proceedings
Publisher: Springer Science+Business Media
ISBN (Print): 978-3-319-19664-0
ISBN (Electronic): 978-3-319-19665-7
(Lecture Notes in Computer Science).
DOIs:
10.1007/978-3-319-19665-7_12


The 19th Scandinavian Conference on Image Analysis was held at the IT University of Copenhagen in Denmark during June 15-17, 2015. The SCIA conference series has been an ongoing biannual event for more than 30 years and over the years it has nurtured a world-class regional research and development area within the four participating Nordic countries. It is a regional meeting of the International Association for Pattern Recognition (IAPR).

We would like to thank all authors who submitted works to this year’s SCIA, the invited speakers, and our Program Committee.

In total 67 papers were submitted to SCIA 2015 and were reviewed by members of the Program Committee and additional reviewers. Each paper was reviewed by at least two independent reviewers followed by a meta-review by the Program Committee. Finally, 26 papers were chosen for oral presentation and 19 papers for poster presentation. The topics of the accepted papers range from novel applications of vision systems, pattern recognition, machine learning, feature extraction, segmentation, 3D vision, to medical and biomedical image analysis. The papers originate from all the Scandinavian countries and several other European countries.

It is our sincere hope that the participants had an enjoyable and fruitful experience, both scientifically and socially, in Copenhagen.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Copenhagen
Number of pages: 544
Image Registration of Cochlear µCT Data Using Heat Distribution Similarity

Better understanding of the anatomical variability of the human cochlear is important for the design and function of Cochlear Implants. Good non-rigid alignment of high-resolution cochlear µCT data is a challenging task.

In this paper we study the use of heat distribution similarity between samples as an anatomical registration prior. We set-up and present our heat distribution model for the cochlea and utilize it in a typical cubic B-spline registration model. Evaluation and comparison is done against a corresponding normal registration of binary segmentations.

Predicting Detailed Inner Ear Anatomy from Pre-Oppreoperational CT for cochlear implant surgery

In this paper we study the use of heat distribution similarity between samples as an anatomical registration prior. We set-up and present our heat distribution model for the cochlea and utilize it in a typical cubic B-spline registration model. Evaluation and comparison is done against a corresponding normal registration of binary segmentations.
Predicting facial characteristics from complex polygenic variations

Research into the importance of the human genome in the context of facial appearance is receiving increasing attention and has led to the detection of several Single Nucleotide Polymorphisms (SNPs) of importance. In this work we attempt a holistic approach predicting facial characteristics from genetic principal components across a population of 1,266 individuals. For this we perform a genome-wide association analysis to select a large number of SNPs linked to specific facial traits, recode these to genetic principal components and then use these principal components as predictors for facial traits in a linear regression. We show in this proof-of-concept study for facial trait prediction from genome-wide SNP data that some facial characteristics can be modeled by genetic information: facial width, eyebrow width, distance between eyes, and features involving mouth shape are predicted with statistical significance (p < 0.03).
Using Motion Tracking to Detect Spontaneous Movements in Infants
We study the characteristics of infants’ spontaneous movements, based on data obtained from a markerless motion tracking system. From the pose data, the set of features are generated from the raw joint-angles of the infants and different classifiers are trained and evaluated using annotated data. Furthermore, we look at the importance of different features and outline the most significant features for detecting spontaneous movements of infants. Using these findings for further analysis of infants’ movements, this might be used to identify infants in risk of cerebral palsy.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Technical University of Denmark
Contributors: Olsen, M. D., Herskind, A., Nielsen, J. B., Paulsen, R. R.
Number of pages: 8
Pages: 410-417
Publication date: 2015

Host publication information
Title of host publication: Image Analysis : 19th Scandinavian Conference, SCIA 2015 Copenhagen, Denmark, June 15–17, 2015 Proceedings
Publisher: Springer Science+Business Media
ISBN (Print): 978-3-319-19664-0
ISBN (Electronic): 978-3-319-19665-7
(Lecture Notes in Computer Science).
DOIs:
10.1007/978-3-319-19665-7_34

VirtualTable: a projection augmented reality game
VirtualTable is a projection augmented reality installation where users are engaged in an interactive tower defense game. The installation runs continuously and is designed to attract people to a table, which the game is projected onto. Any number of players can join the game for an optional period of time. The goal is to prevent the virtual stylized soot balls, spawning on one side of the table, from reaching the cheese. To stop them, the players can place any kind of object on the table, that then will become part of the game. Depending on the object, it will become either a wall, an obstacle for the soot balls, or a tower, that eliminates them within a physical range. The number of enemies is dependent on the number of objects in the field, forcing the players to use strategy and collaboration and not the sheer number of objects to win the game.

General information
Publication status: Published
Organisations: IT Service, Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Mathematics, Statistics and Data Analysis
Number of pages: 1
Publication date: 2015
3D facial landmarks: Inter-operator variability of manual annotation

Background
Manual annotation of landmarks is a known source of variance, which exist in all fields of medical imaging, influencing the accuracy and interpretation of the results. However, the variability of human facial landmarks is only sparsely addressed in the current literature as opposed to e.g. the research fields of orthodontics and cephalometrics. We present a full facial 3D annotation procedure and a sparse set of manually annotated landmarks, in effort to reduce operator time and minimize the variance.

Method
Facial scans from 36 voluntary unrelated blood donors from the Danish Blood Donor Study was randomly chosen. Six operators twice manually annotated 73 anatomical and pseudo-landmarks, using a three-step scheme producing a dense point correspondence map. We analyzed both the intra- and inter-operator variability, using mixed-model ANOVA. We then compared four sparse sets of landmarks in order to construct a dense correspondence map of the 3D scans with a minimum point variance.

Results
The anatomical landmarks of the eye were associated with the lowest variance, particularly the center of the pupils. Whereas points of the jaw and eyebrows have the highest variation. We see marginal variability in regards to intra-operator and portraits. Using a sparse set of landmarks (n=14), that capture the whole face, the dense point mean variance was reduced from 1.92 to 0.54 mm.

Conclusion
The inter-operator variability was primarily associated with particular landmarks, where more leniently landmarks had the highest variability. The variables embedded in the portray and the reliability of a trained operator did only have marginal influence on the variability. Further, using 14 of the annotated landmarks we were able to reduced the variability and create a dense correspondences mesh to capture all facial features.
Body-Part Tracking of Infants

Motion tracking is a widely used technique to analyze and measure adult human movement. However, these methods cannot be transferred directly to motion tracking of infants due to the big differences in the underlying human model. However, motion tracking of infants can be used for automatic analysis of infant development and might be able to tell something about possible motor disabilities such as cerebral palsy. In this paper, we address markerless 3D body part detection of infants using a widely available depth sensor and discuss some of the major challenges that arise. We present a method to detect and identify a set of the anatomical extremities and the results are evaluated based on manually annotated 3D positions.

DLP technology application: 3D head tracking and motion correction in medical brain imaging

In this paper we present a novel sensing system, robust Near-infrared Structured Light Scanning (NIRSL) for three-dimensional human model scanning application. Human model scanning due to its nature of various hair and dress appearance and body motion has long been a challenging task. Previous structured light scanning methods typically emitted visible coded light patterns onto static and opaque objects to establish correspondence between a projector and a camera for triangulation. In the success of these methods rely on scanning objects with proper reflective surface for visible light, such as plaster, light colored cloth. Whereas for human model scanning application, conventional methods suffer from low signal to noise ratio caused by low contrast of visible light over the human body. The proposed robust NIRSL, as implemented with the near infrared light, is capable of recovering those dark surfaces, such as hair, dark jeans and black shoes under visible illumination. Moreover, successful structured light scan relies on the assumption that the subject is static during scanning. Due to the nature of body motion, it is very time sensitive to keep this assumption in the case of human model scan. The proposed sensing system, by utilizing the near-infrared capable high speed LightCrafter DLP projector, is robust to motion, provides accurate and high resolution three-dimensional point cloud, making our system more efficient and robust for human model reconstruction. Experimental results demonstrate that our system is effective and efficient to scan real human models with various dark hair, jeans and shoes, robust to human body motion and produces accurate and high resolution 3D point cloud.
Genus zero graph segmentation: Estimation of intracranial volume

The intracranial volume (ICV) in children with premature fusion of one or more sutures in the calvaria is of interest due to the risk of increased intracranial pressure. Challenges for automatic estimation of ICV include holes in the skull e.g. the foramen magnum and fontanelles. In this paper, we present a fully automatic 3D graph-based method for segmentation of the ICV in non-contrast CT scans. We reformulate the ICV segmentation problem as an optimal genus 0 segmentation problem in a volumetric graph. The graph is the result of a volumetric spherical subsampling. The equidistantly sampled data points are connected using Delaunay tetrahedralisation creating a highly connected neighborhood. A Markov Random Field (MRF) is constructed on the graph with probabilities learned from an Expectation Maximisation algorithm matching a Mixture of Gaussians to the data. The result of the MRF segmentation is compared to manual segmentations performed by an expert. We have achieved very high Dice scores ranging from 98.14% to 99.00%, while volume deviation from the manual segmentation ranges from 0.7% to 3.7%. The Hausdorff distance, which shows the maximum error from automatic to manual segmentation, ranges from 4.73 to 9.81 mm. Since this is sensitive to single error, we have also found the 95% Hausdorff distance, which ranges from 1.10 to 3.65 mm. The segmentation is very consistent with the reference and differs only in difficult areas, where it seems that our method is much more slice-wise consistent than a manual segmentation. The proposed method is expected to perform well for other volumetric segmentations.
Model-Based Motion Tracking of Infants

Even though motion tracking is a widely used technique to analyze and measure human movements, only a few studies focus on motion tracking of infants. In recent years, a number of studies have emerged focusing on analyzing the motion pattern of infants, using computer vision. Most of these studies are based on 2D images, but few are based on 3D information. In this paper, we present a model-based approach for tracking infants in 3D. The study extends a novel study on graph-based motion tracking of infants and we show that the extension improves the tracking results. A 3D model is constructed that resembles the body surface of an infant, where the model is based on simple geometric shapes and a hierarchical skeleton model.

Patient Specific Simulation for Planning of Cochlear Implantation Surgery

Cochlear implantation is a surgical procedure that can restore the hearing capabilities to patients with severe or complete functional loss. However, the level of restoration varies highly between subjects and depends on patient-specific factors. This paper presents a software application for planning cochlear implantation procedures that includes patient-specific anatomy estimation using high resolution models, implant optimization for patient-specific implant selection, simulation of mechanical and electrical properties of the implant as well as clinical reporting.
Patient-Specific Simulation of Implant Placement and Function for Cochlear Implantation Surgery Planning

We present a framework for patient specific electrical stimulation of the cochlea, that allows to perform in-silico analysis of implant placement and function before surgery. A Statistical Shape Model (SSM) is created from high-resolution human μCT data to capture important anatomical details. A Finite Element Model (FEM) is built and adapted to the patient using the results of the SSM. Electrical simulations based on Maxwell’s equations for the electromagnetic field are performed on this personalized model. The model includes implanted electrodes and nerve fibers. We present the results for the bipolar stimulation protocol and predict the voltage spread and the locations of nerve excitation.

Rapid Generation of Personalized HRTFs

Numerical simulations offer a viable alternative to measurements for generating personalized head-related transfer functions (HRTFs). The fast multipole boundary element method (FM-BEM) is a popular method for simulating the HRTFs since it requires a surface mesh of the head (and torso) only. The FM-BEM simulation of the HRTF at a single frequency can be computed in a few minutes. Utilizing cloud computing, the entire audible frequency range can be simulated in less than an hour. A bottleneck in the fast acquisition of the personalized HRTFs has been the complexity of generating good quality head models for the simulation. We compare three photography based geometry acquisition methods, ranging from a system of 52 cameras to a method using a single mobile phone camera only.

Shape modelling of the inner ear from micro-CT data
The effect of gender on eye colour variation in European populations and an evaluation of the IrisPlex prediction model

In two recent studies of Spanish individuals [1,2], gender was suggested as a factor that contributes to human eye colour variation. However, gender did not improve the predictive accuracy on blue, intermediate and brown eye colours when gender was included in the IrisPlex model [3]. In this study, we investigate the role of gender as a factor that contributes to eye colour variation and suggest that the gender effect on eye colour is population specific. A total of 230 Italian individuals were typed for the six IrisPlex SNPs (rs12913832, rs1800407, rs12896399, rs1393350, rs16891982 and rs12203592). A quantitative eye colour score (Pixel Index of the Eye: PIE-score) was calculated based on digital eye images using the custom made DIAT software. The results were compared with those of Danish and Swedish population samples. As expected, we found HERC2 rs12913832 as the main predictor of human eye colour independently of ancestry. Furthermore, we found gender to be significantly associated with quantitative eye colour measurements in the Italian population sample. We found that the association was statistically significant only among Italian individuals typed as heterozygote GA for HERC2 rs12913832. Interestingly, we did not observe the same association in the Danish and Swedish population. This indicated that the gender effect on eye colour is population specific. We estimated the effect of gender on quantitative eye colour in the Italian population sample to be 4.9%. Among gender and the IrisPlex SNPs, gender ranked as the second most important predictor of human eye colour variation in Italians after HERC2 rs12913832. We, furthermore, tested the five lower ranked IrisPlex predictors, and evaluated all possible 36 (729) genotype combinations of the IrisPlex assay and their corresponding predictive values using the IrisPlex prediction model [4]. The results suggested that maximum three (rs12913832, rs1800407, rs16891982) of the six IrisPlex SNPs are useful in practical forensic genetic casework.
3D gender recognition using cognitive modeling
We use 3D scans of human faces and cognitive modeling to estimate the "gender strength". The "gender strength" is a continuous class variable of the gender, superseding the traditional binary class labeling. To visualize some of the visual trends humans use when performing gender classification, we use linear regression. In addition, we use the gender strength to construct a smaller but refined training set, by identifying and removing ill-defined training examples. We use this refined training set to improve the performance of known classification algorithms. Results are presented using a 5-fold cross-validation scheme and also reproduced using an unseen data set.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Cognitive Systems, Copenhagen University Hospital
Contributors: Fagertun, J., Andersen, T., Hansen, T., Paulsen, R. R.
Number of pages: 4
Publication date: 2013

Host publication information
Title of host publication: 2013 International Workshop on Biometrics and Forensics (IWBF)
Publisher: IEEE
ISBN (Print): 978-1-4673-4987-1
DOIs:
10.1109/IWBF.2013.6547324
Source: dtu
Source-ID: n:oai:DTIC-ART:iel/388558217::29760

3D Surface Realignment Tracking for Medical Imaging: A Phantom Study with PET Motion Correction
We present a complete system for motion correction in high resolution brain positron emission tomography (PET) imaging. The system is based on a compact structured light scanner mounted above the patient tunnel of the Siemens High Resolution Research Tomograph (HRRT) PET brain scanner. The structured light system is equipped with a near infrared diode and uses phase-shift interferometry (PSI) to compute 3D point clouds of the forehead of the patient. These 3D point clouds are progressively aligned to a reference surface, thereby giving the head pose changes. The estimated pose changes are used to reposition a sequence of reconstructed PET frames. To align the structured light system with the PET coordinate system, a novel registration algorithm based on the PET transmission scan and an initial surface has been developed. The performance of the complete setup has been evaluated using a custom-made phantom, based on a plastic mannequin head equipped with two positron-emitting line sources. Two experiments were performed. The first simulates rapid and short head movements, while the second simulates slow and continuous movements. In both cases, the system was able to produce PET scans with focused PET reconstructions. The system is nearly ready for clinical testing.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Siemens A/S, Copenhagen University Hospital
Pages: 11-19
Publication date: 2013

Host publication information
Title of host publication: Image-Based Geometric Modeling and Mesh Generation
Publisher: Springer
Editor: Zhang, Y. (.
ISBN (Print): 978-94-007-4254-3
ISBN (Electronic): 978-94-007-4255-0
(Lecture Notes in Computational Vision and Biomechanics, Vol. 3).
DOIs:
10.1007/978-94-007-4255-0_2
Source: RIS
Source-ID: urn:781772B67165092F9CE852BD3ED70E8
Apparatus and method for motion tracking in brain imaging

Disclosed is apparatus and method for motion tracking of a subject in medical brain imaging. The method comprises providing a light projector and a first camera; projecting a first pattern sequence (S1) onto a surface region of the subject with the light projector, wherein the subject is positioned in a scanner borehole of a medical scanner, the first pattern sequence comprising a first primary pattern (P1,1) and/or a first secondary pattern (P1,2); detecting the projected first pattern sequence (S1') with the first camera; determining a second pattern sequence (S2) comprising a second primary pattern (P2,1) based on the detected first pattern sequence (S1'); projecting the second pattern sequence (S2) onto a surface region of the subject with the light projector; detecting the projected second pattern sequence (S2') with the first camera; and determining motion tracking parameters based on the detected second pattern sequence (S2').

A three dimensional children head database for acoustical research and development

Most computational-acoustic work within spatial hearing relies on head-related transfer functions from databases of measurements taken on adult humans or dummy heads. We aim to provide a set of 3D digital heads including children, from which head-related transfer functions can be computed instead of measured. However, current volumetric scanning techniques do not have sufficient resolution for accurately scanning the external ear, and computed tomography also involves radiation. In this paper we propose a framework for scanning, stitching and meshing complete human heads. The process starts by acquisition of multiple 3D surface scans of the same subject using a high-resolution photogrammetric scanner. Secondly, the scans are semi-automatically aligned and noise and incoherence is removed. This is followed by an iterative process where a volumetric implicit representation of the head is optimized. The process consists of a regularized surface reconstruction step followed by an alignment step. Finally, a surface representation of the entire head is extracted using a triangulation of the zero-level iso-surface of the implicit volume. The process has been used to reconstruct the heads of children aged 10 months to 9 years. The data and the associated reconstruction algorithms will be made publicly available for use in acoustical research and development.
Correlation of iris biometrics and DNA
The presented work concerns prediction of complex human phenotypes from genotypes. We were interested in correlating iris color and texture with DNA. Our data consist of 212 eye images along with DNA: 32 single-nucleotide polymorphisms (SNPs). We used two types of biometrics to describe the eye images: One for iris color and one for iris texture. Both biometrics were high dimensional and a sparse principle component analysis (SPCA) reduced the dimensions and resulted in a representation of data with good interpretability. The correlations between the sparse principal components (SPCs) and the 32 SNPs were found using a canonical correlation analysis (CCA). The result was a single significant canonical correlation (CC) for both biometrics. Each CC comprised two correlated canonical variables, consisting of a linear combination of SPCs and a linear combination of SNPs, respectively. The significant canonical variables for color and texture were primarily explained by the first SPC (SPC1). Therefore, we made a visual inspection of the first SPCs. The color based SPC1 explained a blue to brown variation in iris color and the texture based SPC1 gave a general explanation of iris texture. The SNPs (rs12896399, rs3733542, rs6475555, rs12913832) and (rs12896399, rs3733542, rs12913832) had the highest correlation to the canonical variable for color and texture, respectively. Three of the most contributing SNPs were the same for both biometrics, revealing a covariance between iris color and texture.

Genetic analyses of the human eye colours using a novel objective method for eye colour classification
In this study, we present a new objective method for measuring the eye colour on a continuous scale that allows researchers to associate genetic markers with different shades of eye colour.

With the use of the custom designed software Digital Iris Analysis Tool (DIAT), the iris was automatically identified and extracted from high resolution digital images. DIAT was made user friendly with a graphical user interface. The software counted the number of blue and brown pixels in the iris image and calculated a Pixel Index of the Eye (PIE-score) that described the eye colour quantitatively. The PIE-score ranged from −1 to 1 (brown to blue). The software eliminated the need for user based interpretation and qualitative eye colour categories. In 94% (570) of 605 analyzed eye images, the iris region was successfully extracted and a PIE-score was calculated. A very high correlation between the PIE-score and the human perception of eye colour was observed. The correlations between the PIE-scores and the six IrisPlex SNPs (HERC2 rs12913832, OCA2 rs1800407, SLC24A4 rs12896399, TYR rs1393350, SLC45A2 rs16891982 and IRF4 rs12203592) were analyzed in 570 individuals. Significant differences (p < 10−6) in the PIE-scores of the individuals typed as HERC2 rs12913832 G (PIE = 0.99) and rs12913832 GA (PIE = −0.71) or A (PIE = −0.87) were observed. We adjusted for the effect of HERC2 rs12913832 and showed that the quantitative PIE-scores were significantly associated with SNPs with minor effects (OCA2 rs1800407, SLC24A4 rs12896399 and TYR rs1393350) on the eye colour. We evaluated the two published prediction models for eye colour (IrisPlex [1] and Snipper[2]) and compared the predictions with the PIE-scores. We found good concordance with the prediction from individuals typed as HERC2 rs12913832 G. However, both methods had difficulties in categorizing individuals typed as HERC2 rs12913832 GA because of the large variation in eye colour in HERC2 rs12913832 GA individuals. With the use of the DIAT software and the PIE-score, it will be possible to automatically compare the iris colour of large numbers of iris images obtained by different studies and to perform large meta-studies that may reveal loci with small effects on the eye colour.
Genus Zero Graph Segmentation: Estimation of Intracranial Volume

The intracranial volume (ICV) in children with premature fusion of one or more sutures in the calvaria is of interest due to the risk of increased intracranial pressure. Challenges for automatic estimation of ICV include holes in the skull e.g. the foramen magnum and fontanellae. In this paper, we present a fully automatic 3D graph-based method for segmentation of the ICV in non-contrast CT scans. We reformulate the ICV segmentation problem as an optimal genus 0 segmentation problem in a volumetric graph. The graph is the result of a volumetric spherical subsample from the data connected using Delaunay tetrahedralisation. A Markov Random Field is constructed on the graph with probabilities learned from an Expectation Maximisation algorithm matching a Mixture of Gaussians to the data. Results are compared to manual segmentations performed by an expert. We have achieved very high Dice scores ranging from 98.14% to 99.00%, while volume deviation from the manual segmentation ranges from 0.7%-3.7%. The Hausdorff distance, which shows the maximum error from automatic to manual segmentation ranges, from 4.73-9.81mm. Since this is sensitive to single error, we have also found the 95% Hausdorff distance, which ranges from 1.10-3.65mm. The proposed method is expected to perform well for other volumetric segmentations.
List-Mode PET Motion Correction Using Markerless Head Tracking: Proof-of-Concept With Scans of Human Subject

A custom designed markerless tracking system was demonstrated to be applicable for positron emission tomography (PET) imaging. Precise head motion registration is crucial for accurate motion correction (MC) in PET imaging. State-of-the-art tracking systems applied with PET brain imaging rely on markers attached to the patient's head. The marker attachment is the main weakness of these systems. A healthy volunteer participating in a cigarette smoking study to image dopamine release was scanned twice for 2 h with $^{11}{\text{C}}$-raclopride on the high resolution research tomograph (HRRT) PET scanner. Head motion was independently measured, with a commercial marker-based device and the proposed vision-based system. A list-mode event-by-event reconstruction algorithm using the detected motion was applied. A phantom study with hand-controlled continuous random motion was obtained. Motion was time-varying with long drift motions of up to 18 mm and regular step-wise motion of 1–6 mm. The evaluated measures were significantly better for motion-corrected images compared to no MC. The demonstrated system agreed with a commercial integrated system. Motion-corrected images were improved in contrast recovery of small structures.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Yale University, Siemens A/S
Pages: 200-209
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: IEEE Transactions on Medical Imaging
Volume: 32
Issue number: 2
ISSN (Print): 0278-0062
Ratings:
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 5.55 SJR 2.161 SNIP 3.284
Web of Science (2013): Impact factor 3.799
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Original language: English
Keywords: Motion correction, Motion tracking, Positron emission tomography (PET), Vision system
DOIs:
10.1109/TMI.2012.2219693
Source: dtu
Source-ID: n:oai:DTIC-ART:iel/37605646::25814
Research output: Contribution to journal › Journal article – Annual report year: 2013 › Research › peer-review

The genetics of eye colours in an Italian population measured with an objective method for eye colour quantification

Brown and blue eye colours are primarily explained by the single nucleotide polymorphism (SNP) HERC2 rs12913832. However, the genetics of eye colours that appear to be neither blue nor brown are not well understood. In this study, 230 unrelated Italian individuals were typed for 32 SNP loci in pigmentary genes. High resolution digital images of the participants' eyes were taken and the iris region was successfully extracted with the use of the custom designed software Digital Iris Analysis Tool (DIAT) from 218 of the 230 (95%) images. The software counted the numbers of blue and brown pixels in the iris region and calculated a Pixel Index of the Eye (PIE-score) that described the eye colours quantitatively. The PIE-score ranged from -1 to 1 (brown to blue). We investigated the association of the PIE-scores extracted from the eye images with the genotypes of the 32 pigmentary SNPs. We observed a statistically significant association between the PIE-scores and the SNP loci rs12913832, rs4778241, rs7495174 in the HERC2/OCA2 region and the locus rs16891982 in SLC45A2.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Copenhagen
Contributors: Pietroni, C., Andersen, J., Johansen, P., Harder, S., Paulsen, R. R., Børsting, C., Morling, N.
Pages: e23–e24
What Genes Tell about Iris Appearance

Predicting phenotypes based on genotypes is generally hard, but has shown good results for prediction of iris color. We propose to correlate the appearance of iris with DNA. Six single-nucleotide polymorphisms (SNPs) have previously been shown to correlate with human iris color, and we demonstrate that especially one of the six SNPs are correlated with iris appearance. To perform this analysis we need a method to model the iris appearance, and we suggest an iris characterization based on a bag of visual words, which gives us a similarity measure between images of eyes. We have a dataset of 215 eye images with corresponding SNP types, where the image of the iris has been segmented. We perform two experiments based on the iris characterization. An agglomerative clustering is performed and the result is that one SNP - rs12913832 (HERC2) is highly correlated with the image clustering. Furthermore subspace projections are performed supporting that this SNP is very important for eye color expression. With the suggested image characterizations we are able to investigate the correlation between the phenotypic iris appearance and specific SNPs. This has potential for further investigation of the relation between DNA and iris appearance, especially with focus on iris texture. © 2013 Springer-Verlag.
Adaptive RT for Head-and-Neck Cancer: The Usefulness of Deformable Image Registration

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Copenhagen University Hospital
Contributors: Behrens, C., Eiland, R., Sjöström, D., Maare, C., Paulsen, R. R.
Pages: S775
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: International Journal of Radiation: Oncology - Biology - Physics
Volume: 84
Issue number: 3S
ISSN (Print): 0360-3016
Ratings:
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 4.27 SJR 2.623 SNIP 2.042
Web of Science (2012): Impact factor 4.524
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Original language: English
Source: dtu
Source-ID: u::5484
Research output: Contribution to journal › Conference abstract in journal – Annual report year: 2012 › Research › peer-review

Automatic quantification of iris color
An automatic algorithm to quantify the eye colour and structural information from standard hi-resolution photos of the human iris has been developed. Initially, the major structures in the eye region are identified including the pupil, iris, sclera, and eyelashes. Based on this segmentation, the iris is resampled into a standardized quadratic coordinate system, where occluded and invalid regions are masked out. Secondly, a pixel classification approach has been evaluated with good results. It is based on a so-called Markov Random Field spatial classification into dominantly brown and blue regions. The result is a blue-brown ratio for each eye.
Furthermore, an image clustering approach has been used with promising results. The approach is based on using a sparse dictionary of feature vectors learned from a training set of iris regions. The feature vectors contain both local structural information and colour information. For each iris an explanatory histogram is build, containing information about the weighted occurrence of each visual word. A hierarchical agglomerative clustering of the entire set of photos is performed using the distance between the explanatory histograms. The approach is completely data driven and it can divide a group of eye images into classes based on structure, colour or a combination of the two. The methods have been tested on a large set of photos with promising results.

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Technical University of Denmark, University of Copenhagen
Contributors: Christoffersen, S., Harder, S., Andersen, J. D., Johansen, P., Dahl, A. L., Morling, N., Paulsen, R. R.
Pages: 20
Publication date: 2012

Host publication information
Title of host publication: Meeting of the English Speaking Working Group (ESWG) of the International Society of Forensic Genetics (ISFG) : Programme
Dosimetric- and geometric evaluation of adaptive H&N IMRT using deformable image registration

Purpose/Objective: Anatomical changes can occur during RT treatment of H&N cancer patients. This can lead to a difference between planned- and delivered dose. Adaptive RT has the potential to overcome this, utilizing deformable image registration (DIR). The purpose of this study was to evaluate the performance of a DIR algorithm, using geometric and dosimetric measures.

Materials and Methods: Seven patients treated with IMRT were included in this study, each with a planning- and midterm CT (pCT, ReCT) as well as a CBCT, acquired on the same day as the ReCT. ReCT served as the ground truth for evaluation of the DIR. A deformed CT (dCT) with contours was created by deforming the pCT and associated manually drawn contours to the CBCT. A commercially software using the Demons DIR algorithm (SmartAdapt, Varian Medical Systems, v.11.0) was utilized. A geometrical comparison was based on the estimated volumes from the contours on the dCT, and the manually drawn contours on the ReCT. Center of mass shifts (CMS) and dice similarity coefficients (DSC) were found between contours on dCT and ReCT. In the treatment planning system (Eclipse, Varian Medical system, v.10.0) the initial treatment plan was copied to the dCT and ReCT and the dose recalculated. DVH points (D50 for parotid glands and Dmax for spinal cord) were evaluated. Conformity index (CI), lesion coverage fraction (LCF) and normal tissue overdose fraction (NTOF) was evaluated with regard to target coverage.

Results: The PTV volume was estimated larger for dCT than ReCT with a median of 4.4% (range -4.0; 69.3). In four of seven patients, the volume difference was <5%. Six patients had a median CMS for PTV of 0.28 cm (range 0.05; 0.43). The median DSC was 0.88 (range 0.60; 0.95). Similar results were obtained for GTV and CTV. The median relative volume deviation from ReCT was -11.2% (range -28.0; 16.7), -26.2% (range -42.1; 3.4) and -10.9% (range -33.3; 32.3) for parotid dxt, parotid sin and spinal cord, respectively. The median CMS was 0.51 cm (range 0.19; 2.22). DSC had a median of 0.47 (range 0.45; 0.85). The median relative deviation from ReCT in DVH points for parotid dxt, parotid sin and spinal cord was 8.3% (range -8.4; 25.3), -12.7% (range -28.6; 31.0), and 1.3% (range -5.4; 31.8), respectively. CI, LCF and NTOF are visualized in the figure. Ideal values of CI and LCF are unity and zero for NTOF.

Conclusions: The DIR produced geometrical results similar to the ReCT in four of seven patients with regard to the target. Larger geometrical variations were observed for organs at risk (OAR). OAR contours obtained with the DIR were for nearly all patients estimated smaller than in the ReCT whereas target contours were estimated larger. The dosimetric results for OAR showed some variation between dCT and ReCT, especially for the parotid glands. The LCF were similar for dCT and ReCT, whereas NTOF were larger for ReCT than for dCT. Despite variation in volume and dose, between dCT and ReCT, the differences were within acceptable limits for most of the patients.
Gender Recognition Using Cognitive Modeling
In this work, we use cognitive modeling to estimate the "gender strength" of frontal faces, a continuous class variable, superseding the traditional binary class labeling. To incorporate this continuous variable we suggest a novel linear gender classification algorithm, the Gender Strength Regression. In addition, we use the gender strength to construct a smaller but refined training set, by identifying and removing ill-defined training examples. We use this refined training set to improve the performance of known classification algorithms. Also the human performance of known data sets is reported, and surprisingly it seems to be quite a hard task for humans. Finally our results are reproduced on a data set of above 40,000 public Danish LinkedIn profile pictures.

General information
Publication status: Published
Contributors: Fagertun, J., Andersen, T., Paulsen, R. R.
Pages: 300-308
Publication date: 2012

Host publication information
Title of host publication: Computer Vision – ECCV 2012: Workshops and Demonstrations, Part II
Publisher: Springer
ISBN (Print): 978-3-642-33867-0
ISBN (Electronic): 978-3-642-33868-7
(Lecture Notes in Computer Science, Vol. 7584).
Keywords: Gender recognition, Linear Discriminant Analysis, Support Vector Machines, Cognitive Modeling, Linear Regression
DOIs:
10.1007/978-3-642-33868-7_30
Source: dtu
Source-ID: n:oai:DTIC-ART:inspec/371485512::20368
Research output: Chapter in Book/Report/Conference proceeding > Article in proceedings – Annual report year: 2012 > Research > peer-review

Mesh Processing in Medical Image Analysis: MeshMed 2012 Proceedings
The following topics are dealt with: mesh processing; medical image analysis; interactive freeform modeling; statistical shape analysis; clinical CT images; statistical surface recovery; automated segmentation; cerebral aneurysms; and real-time particle-based representation.

General information
Publication status: Published
Publication date: 2012

Publication information
Publisher: Springer
ISBN (Print): 978-3-642-33462-7
ISBN (Electronic): 978-3-642-33463-4
Original language: English
(Lecture Notes in Computer Science, Vol. 7599).
DOIs:
10.1007/978-3-642-33463-4
Mesh Processing in Medical-Image Analysis—a Tutorial

Medical-image analysis requires an understanding of sophisticated scanning modalities, constructing geometric models, building meshes to represent domains, and downstream biological applications. These four steps form an image-to-mesh pipeline. For research in this field to progress, the imaging, modeling, and simulation communities will need to work together more closely.

General information
Publication status: Published
Contributors: Levine, J. A., Paulsen, R. R., Zhang, Y.
Pages: 22-28
Publication date: 2012
Peer-reviewed: Yes

Publication information
Volume: 32
Issue number: 5
ISSN (Print): 0272-1716
Ratings:
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 1.46 SJR 0.466 SNIP 1.911
Web of Science (2012): Impact factor 1.228
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Original language: English
DOIs: 10.1109/MCG.2012.91
Source: dtu
Source-ID: n::oai:DTIC-ART:isi/369690166::19456

Motion Tracking for Medical Imaging: A Non-Visible Structured Light Tracking Approach

We present a system for head motion tracking in 3D brain imaging. The system is based on facial surface reconstruction and tracking using a structured light (SL) scanning principle. The system is designed to fit into narrow 3D medical scanner geometries limiting the field of view. It is tested in a clinical setting on the high resolution research tomograph (HRRT), Siemens PET scanner with a head phantom and volunteers. The SL system is compared to a commercial optical tracking system, the Polaris Vicra system, from NDI based on translatory and rotary ground truth motions of the head phantom. The accuracy of the systems was similar, with root-mean-square (RMS) errors of 0.09° for 20° axial rotations, and RMS errors of 0.24 mm for 25 mm translations. Tests were made using 1) a light emitting diode (LED) based miniaturized video projector, the Pico projector from Texas Instruments, and 2) a customized version of this projector replacing a visible light LED with an 850 nm near infrared LED. The latter system does not provide additional discomfort by visible light projection into the patient's eyes. The main advantage over existing head motion tracking devices, including the Polaris Vicra system, is that it is not necessary to place markers on the patient. This provides a simpler workflow and eliminates uncertainties related to marker attachment and stability. We show proof of concept of a marker less tracking system especially designed for clinical use with promising results.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Siemens A/S
Contributors: Olesen, O. V., Paulsen, R. R., Højgaard, L., Roed, B., Larsen, R.
Pages: 79-87
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: IEEE Transactions on Medical Imaging
Volume: 31
Issue number: 1
Optimized Acquisition Parameters for MRI Only RT Using Ultrashort Echo Times

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Copenhagen University Hospital
Contributors: Kjer, H. M., Hansen, R. H., Paulsen, R. R., Edmund, J. M.
Number of pages: 1
Pages: S866
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: International Journal of Radiation: Oncology - Biology - Physics
Volume: 84
Issue number: 3, Supplement
ISSN (Print): 0360-3016
Ratings:
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 4.27 SJR 2.623 SNIP 2.042
Web of Science (2012): Impact factor 4.524
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Original language: English
DOIs:
10.1016/j.ijrobp.2012.07.2317

Bibliographical note
Proceedings of the American Society for Radiation Oncology 54th Annual Meeting.
Source: dtu
Source-ID: u:5659
Research output: Contribution to journal › Conference abstract in journal – Annual report year: 2012 › Research › peer-review

Statistical analysis of MRI-only based dose planning
Purpose/Objective: Multimodality imaging is increasingly combined for better tumour delineation. MRI provides additional softtissue contrast to CT, but registration of MRI and CT introduce a systematic error. Further, adaptive RT introduces an increase in scans and additional systematic errors. MRIonly based RT eliminates these errors and reduce the time and costs of a CT scan. The aim of this study is to investigate the dosimetric differences of a treatment plan when the dose calculation is based on MRI as compared to CT.

Materials and Methods: Four diagnostic groups are investigated; 12 Head and Neck (HN) patients treated with static IMRT, 5 sarcoma (extremities only) patients treated with APPA, 21 prostate and 5 pelvic (not prostate) patients treated with VMAT. Data for each patient contains a CT scan (Phillips Big Bore CT) and a T2 weighted MRI scan (1T Panorama Phillips) as well as a clinically approved treatment plan. The treatment planning software is Eclipse v.10.0 (Varian Medical Systems). The dose calculation based on MRI data is evaluated in two different ways; a homogeneous density assigned MRI (MRI unit), where the entire body is assigned an HU equal to water and a heterogeneous density assigned MRI (MRI bulk) where in addition the CT segmented bone is transferred to the MRI and
assigned an age dependent HU based on ICRU report 46. The CT based clinical treatment plan and structure set are registered to the corresponding MRI unit and MRI bulk. The body is outlined on both the MRI and the CT. The differences in dose distributions of the MRI bulk, MRI unit and CT data are quantified using DVH points. The reported DVH points for the PTV and CTV are Dmedian, D98% and D2% in accordance with ICRU report 83. The DVH points for the organs at risk are based on clinically guidelines used at our hospital and QUANTEC. Oneway twotailed ANOVA and paired ttest are used to investigate the differences in dose, based on MRI bulk, MRI unit and CT. The assumptions of ANOVA are found to be fulfilled, since data is normal distributed with constant variances.

**Results:** The results of differences in DVH points are displayed in the table. MRIonly based RT requires bulk density correction for prostate patients. For the remaining diagnostic groups both the unit and bulk density corrected MRI show nonsignificant deviation for the selected DVH points. The mean differences are in the order of 2 %.

**Conclusions:** The investigated DVH points show that MRIonly based RT seems to be a feasible alternative to CT based RT. However, the analysis only describes similarities in DVH points and not in the shape of the DVH. Even though the mean differences are nonsignificant there might be unacceptable differences for the individual patient. In addition, significant differences may not be detected due to a large variance within a diagnostic group. The obtained results are consistent with those previous reported.
Statistical Surface Recovery: A Study on Ear Canals

We present a method for surface recovery in partial surface scans based on a statistical model. The framework is based on multivariate point prediction, where the distribution of the points are learned from an annotated data set. The training set consist of surfaces with dense correspondence that are Procrustes aligned. The average shape and point covariances can be estimated from this set. It is shown how missing data in a new given shape can be predicted using the learned statistics. The method is evaluated on a data set of 29 scans of ear canal impressions. By using a leave-one-out approach we reconstruct every scan and compute the point-wise prediction error. The evaluation is done for every point on the surface and for varying hole sizes. Compared to state-of-the art surface reconstruction algorithm, the presented methods gives very good prediction results.

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, 3Shape
Contributors: Jensen, R. R., Olesen, O. V., Paulsen, R. R., van der Poel, M., Larsen, R.
Pages: 49-58
Publication date: 2012

Host publication information
Title of host publication: Mesh Processing in Medical Image Analysis : MeshMed 2012 Proceedings
Publisher: Springer
ISBN (Print): 978-3-642-33462-7
ISBN (Electronic): 978-3-642-33463-4
(Lecture Notes in Computer Science, Vol. 7599).
DOIs: 10.1007/978-3-642-33463-4_6
Research output: Chapter in Book/Report/Conference proceeding → Article in proceedings – Annual report year: 2012 → Research → peer-review

3D Surface Realignment Tracking for Medical Imaging: A Phantom Study with PET Motion Correction

We present a complete system for motion correction in high resolution brain positron emission tomography (PET) imaging. It is based on a compact structured light scanner mounted above the patient tunnel of the Siemens High Resolution Research Tomograph PET brain scanner. The structured light system is equipped with a near infrared diode and uses phase-shift interferometry to compute 3D representations of the forehead of the patient. These 3D point clouds are progressively aligned to a reference surface and thereby giving the head pose changes. The estimated pose changes are used to reposition a sequence of reconstructed PET frames. To align the structured light system with the PET coordinate system a novel registration algorithm based on the PET transmission scan and an initial surface has been developed. The performance of the complete setup has been evaluated using a custom made phantom based on a plastic mannequin head equipped with two positron emitting line sources. Two experiments were performed. The rst simulates rapid and short head movements, while the second simulates slow and continuous movements. In both cases, the system was able to produce PET scans with focus the PET reconstructions. The system is near ready for clinical testing.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Siemens A/S, Copenhagen University Hospital
Publication date: 2011

Host publication information
Title of host publication: Proceedings of the MICCAI workshop on Mesh Processing in Medical Image Analysis (MeshMed)
URLs: http://www2.imm.dtu.dk/projects/MeshMed/program.html
Source: orbit
Source-ID: 312560
Research output: Chapter in Book/Report/Conference proceeding → Article in proceedings – Annual report year: 2011 → Research → peer-review

Comparison of external motion tracking systems for PET list-mode reconstruction

The present improvement that we see III 3D medical scanner technology including increasing spatio-temporal resolution and increasing signal-to-noise ratio underlines the need for reliable motion correction. Many motion correction schemes assume that the motions are known [1-3]. However, a reliable markerless tracking system is not trivial to provide and to our knowledge not presently existent. The Polaris Vicra optical tracking system (Northern Digital Inc.) is generally used with PET brain imaging and has been demonstrated to work very well on phantoms [4]. However, it suffers from the necessary attachment of markers to the subject introducing image artifacts on human scans. We have previously designed a camera-based structured light (SL) system for 3D head tracking used with the high resolution research
tomograph (HRRT, Siemens, Knoxville, USA) [5]. The system was modified to use invisible light and the accuracy was demonstrated similar to a commercial system [6]. Presently, we show the SL system integrated with the HRRT PET scanner ready for PET motion correction. We show a comparison study with the Polaris Vicra based on list-mode motion corrected [7].

**General information**
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Olesen, O. V., Paulsen, R. R., Keller, S. H., Højgaard, L., Roed, B., Larsen, R.
Pages: 3414-3416
Publication date: 2011

**Host publication information**
Title of host publication: Proceedings of the 2011 IEEE Nuclear Science Symposium and Medical Imaging Conference
URLs:
Source: orbit
Source-ID: 313140
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2011 › Research › peer-review

**Geometric calibration between PET scanner and structured light scanner**
Head movements degrade the image quality of high resolution Positron Emission Tomography (PET) brain studies through blurring and artifacts. Many image reconstruction methods allow for motion correction if the head position is tracked continuously during the study. Our method for motion tracking is a structured light scanner placed just above the patient tunnel on the High Resolution Research Tomograph (HRRT, Siemens). It continuously registers point clouds of a part of the patient's face. The relative motion is estimated as the rigid transformation between frames. A geometric calibration between the HRRT scanner and the tracking system is needed in order to reposition the PET listmode data or image frames in the HRRT scanner coordinate system. This paper presents a method where obtained transmission scan data is segmented in order to create a point cloud of the patient's head. The point clouds from both systems can then be aligned to each other using the Iterative Closest Point (ICP) algorithm.

**General information**
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Siemens A/S, Copenhagen University Hospital
Contributors: Kjer, H. M., Olesen, O. V., Paulsen, R. R., Højgaard, L., Roed, B., Larsen, R.
Publication date: 2011

**Host publication information**
Title of host publication: Proceedings of the MICCAI workshop on Mesh Processing in Medical Image Analysis (MeshMed)
Electronic versions:
paper_HMK.pdf
URLs:
http://www2.imm.dtu.dk/projects/MeshMed/
Source: orbit
Source-ID: 312550
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2011 › Research › peer-review

**Introduction to Medical Image Analysis**
This book is a result of a collaboration between DTU Informatics at the Technical University of Denmark and the Laboratory of Computer Vision and Media Technology at Aalborg University. It is partly based on the book "Image and Video Processing", second edition by Thomas Moeslund. The aim of the book is to present the fascinating world of medical image analysis in an easy and interesting way. Compared to many standard books on image analysis, the approach we have chosen is less mathematical and more casual. Some of the key algorithms are exemplified in C-code. Please note that the code is neither optimal nor complete and merely serves as an additional input for comprehending the algorithms. It is no secret that this book is written by two authors. The keen reader will therefore note changes in style and language throughout the text.

**General information**
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Aalborg University
Project Supervision - An Engineering Approach

For more than twenty years, a group based supervision strategy has been used when supervising engineering bachelor- and master thesis students at our research group. In recent years, we have formalised the approach and used our industry experience to create a very successful framework for project supervision. This paper is a best practice guide aiming at research groups that would like to try to implement our supervision approach or parts of it. The approach is based on the belief that engineering students should be prepared for their new role as development engineers or PhD students as part of their master thesis writing. The supervision principles are: Ownership: The student should feel that their project is their own. Ideally, they should formulate the project themselves. Write early: We strongly encourage the students to write and generate figures and images already from the first week of the project period. Management: The student is considered project manager of his own project. The supervisor is a guide or coach (or a project owner) Plans: The student is asked to write a project plan during the first week of the project together with a risk-analysis. Group Meetings: A group of students and supervisors meet every week on a fixed weekday. In our team, it is normal that one supervisor supervises three to five projects simultaneously. The core of the supervision is the weekly meetings where the students present what they have been doing and what they plan to do. By default, all students are present at all meetings. Weekly meetings are scheduled to be at a specific day at a specific place for the entire process.
Real Time Surface Registration for PET Motion Tracking

Head movement during high resolution Positron Emission Tomography brain studies causes blur and artifacts in the images. Therefore, attempts are being made to continuously monitor the pose of the head and correct for this movement. Specifically, our method uses a structured light scanner system to create point clouds representing parts of the patient's face. The movement is estimated by a rigid registration of the point clouds. The registration should be done using a robust algorithm that can handle partial overlap and ideally operate in real time. We present an optimized Iterative Closest Point algorithm that operates at 10 frames per second on partial human face surfaces. © 2011 Springer-Verlag.

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Siemens A/S, Copenhagen University Hospital
Contributors: Wilm, J., Olesen, O. V., Paulsen, R. R., Højgaard, L., Roed, B., Larsen, R.
Pages: 166-175
Publication date: 2011

Host publication information
Publisher: Springer
ISBN (Print): 978-3-642-21226-0
ISBN (Electronic): 978-3-642-21227-7
(Lecture Notes in Computer Science). Keywords: Registration, ICP, Motion tracking

Sparse Similarity-Based Fisherfaces

In this work, the effect of introducing Sparse Principal Component Analysis within the Similarity-based Fisherfaces algorithm is examined. The technique aims at mimicking the human ability to discriminate faces by projecting the faces in a highly discriminative and easy interpretative way. Pixel intensities are used by Sparse Principal Component Analysis and Fisher Linear Discriminant Analysis to assign a one dimensional subspace projection to each person belonging to a reference data set. Experimental results performed in the AR dataset show that Similarity-based Fisherfaces in a sparse version can obtain the same recognition results as the technique in a dense version using only a fraction of the input data. Furthermore, the presented results suggest that using SPCA in the technique offers robustness to occlusions.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Fagertun, J., Gomez, D. D., Hansen, M. F., Paulsen, R. R.
Pages: 69-78
Publication date: 2011

Host publication information
Publisher: Springer
ISBN (Print): 978-3-642-21226-0
(Lecture Notes in Computer Science; No. 6688). Keywords: Face recognition, Fisher Linear Discriminant Analysis, Biometrics, Sparse Principal Component Analysis, Multi-Subspace Method
Ultra Fast Optical Sectioning: Signal preserving filtering and surface reconstruction

In 3D surface scanning it is desirable to filter away bad data without altering the quality of the remaining good data. Filtering of raw scanner data before surface reconstruction can minimize the induced error and improve the probability of reconstructing the true surface. If outliers consist of actual data such as hair, and not just evenly distributed noise, these outliers tend to err smoothing algorithms away from the wanted result. We present a novel algorithm based on a Markov Random Field that uses a distance constraint to robustly classify a 3D scan volume. Through this classification a signal preserving filtering of the data set is done. The remaining data are used for a smooth surface reconstruction creating very plausible surfaces. The data used in our work comes from a newly developed hand held 3D scanner. The scanner is an Ultra Fast Optical Sectioning scanner, which is able to extract high quality 3D surface points from 2D images recorded at over 3000 fps. The scanner has been developed for digital impression taking in the dental area. Our work relates to future in-ear scanning for fitting custom hearing aids without impression taking.

Anatomically Plausible Surface Alignment and Reconstruction

With the increasing clinical use of 3D surface scanners, there is a need for accurate and reliable algorithms that can produce anatomically plausible surfaces. In this paper, a combined method for surface alignment and reconstruction is proposed. It is based on an implicit surface representation combined with a Markov Random Field regularisation method. Conceptually, the method maintains an implicit ideal description of the sought surface. This implicit surface is iteratively updated by realigning the input point sets and Markov Random Field regularisation. The regularisation is based on a prior energy that has earlier proved to be particularly well suited for human surface scans. The method has been tested on full cranial scans of ten test subjects and on several scans of the outer human ear.
Dealing with difficult deformations: Construction of a knowledge-based deformation atlas
Twenty-three Taiwanese infants with unilateral cleft lip and palate (UCLP) were CT-scanned before lip repair at the age of 3 months, and again after lip repair at the age of 12 months. In order to evaluate the surgical result, detailed point correspondence between pre- and post-surgical images was needed. We have previously demonstrated that non-rigid registration using B-splines is able to provide automated determination of point correspondences in populations of infants without cleft lip. However, this type of registration fails when applied to the task of determining the complex deformation from before to after lip closure in infants with UCLP. The purpose of the present work was to show that use of prior information about typical deformations due to lip closure, through the construction of a knowledge-based atlas of deformations, could overcome the problem. Initially, mean volumes (atlases) for the pre- and post-surgical populations, respectively, were automatically constructed by non-rigid registration. An expert placed corresponding landmarks in the cleft area in the two atlases; this provided prior information used to build a knowledge-based deformation atlas. We model the change from pre- to post-surgery using thin-plate spline warping. The registration results are convincing and represent a first move towards an automatic registration method for dealing with difficult deformations due to this type of surgery. New or breakthrough work to be presented: The method provides a simple way of dealing with complex morphological changes using knowledge of typical deformations.

External motion tracking for brain imaging: structured light tracking with invisible light
The importance of motion correction in 3D medical imaging increases with increasing scanner resolution. It is necessary for scanners with long image acquisition and low contrast images to correct for patient motion in order to optimize image quality. We present a near infrared structured light stereo depth map system for head motion estimation inside 3D medical scanners with limited space.
Markov Random Field Surface Reconstruction
A method for implicit surface reconstruction is proposed. The novelty in this paper is the adaption of Markov Random Field regularization of a distance field. The Markov Random Field formulation allows us to integrate both knowledge about the type of surface we wish to reconstruct (the prior) and knowledge about data (the observation model) in an orthogonal fashion. Local models that account for both scene-specific knowledge and physical properties of the scanning device are described. Furthermore, how the optimal distance field can be computed is demonstrated using conjugate gradients, sparse Cholesky factorization, and a multiscale iterative optimization scheme. The method is demonstrated on a set of scanned human heads and, both in terms of accuracy and the ability to close holes, the proposed method is shown to have similar or superior performance when compared to current state-of-the-art algorithms.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Paulsen, R. R., Bærentzen, J. A., Larsen, R.
Pages: 636-646
Publication date: 2010
Peer-reviewed: Yes

Publication information
Volume: 16
Issue number: 4
ISSN (Print): 1077-2626
Ratings:
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.602 SNIP 2.622
Web of Science (2010): Impact factor 1.922
Web of Science (2010): Indexed yes
Original language: English
Keywords: Mesh Generation, Markov Random Field, Bayesian Approach, Surface Reconstruction, Implicit Surface
Electronic versions:
Rasmus.pdf
DOIs:
10.1109/TVCG.2009.208

Bibliographical note
Copyright 2010 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.
Source: orbit
Source-ID: 252510
Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review

Motion tracking in narrow spaces: A structured light approach
We present a novel tracking system for patient head motion inside 3D medical scanners. Currently, the system is targeted at the Siemens High Resolution Research Tomograph (HRRT) PET scanner. Partial face surfaces are reconstructed using a miniaturized structured light system. The reconstructed 3D point clouds are matched to a reference surface using a robust iterative closest point algorithm. A main challenge is the narrow geometry requiring a compact structured light system and an oblique angle of observation. The system is validated using a mannequin head mounted on a rotary stage. We compare the system to a standard optical motion tracker based on a rigid tracking tool. Our system achieves an angular RMSE of 0.11 degrees demonstrating its relevance for motion compensated 3D scan image reconstructions as well as its competitiveness against the standard optical system with an RMSE of 0.08 degrees. Finally, we demonstrate qualitative result on real face motion estimation.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Siemens A/S, Copenhagen University Hospital
Contributors: Olesen, O. V., Paulsen, R. R., Højgaard, L., Roed, B., Larsen, R.
Pages: 253-260
Publication date: 2010
Peer-reviewed: Yes
Multivariate Analysis of Variance: Finding significant growth in mice with craniofacial dysmorphology caused by the Crouzon mutation

Crouzon syndrome is characterized by growth disturbances caused by premature fusion of the cranial growth zones. A mouse model with mutation Fgfr2C342Y, equivalent to the most common Crouzon syndrome mutation (henceforth called the Crouzon mouse model), has a phenotype showing many parallels to the human counterpart. Quantifying growth in the Crouzon mouse model could test hypotheses of the relationship between craniosynostosis and dysmorphology, leading to better understanding of the causes of Crouzon syndrome as well as providing knowledge relevant for surgery planning. In the present study we used micro-CT scans of 4-week-old mice (N=5) and 6-week-old mice (N=10) with Crouzon syndrome (Fgfr2 C342Y/) were compared to control groups of 4-week-old wild-type mice (N=5) and 6-week-old wild-type mice (N=10), respectively.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, University of Copenhagen
Publication date: 2010

Host publication information
Title of host publication: The Eighth French-Danish Workshop on Spatial Statistics and Image Analysis in Biology : Book of Abstracts
Editors: Erbsøll, B. K., Guillot, G.
Electronic versions:
SSIAB.pdf
Source: orbit
Source-ID: 264316
Research output: Chapter in Book/Report/Conference proceeding » Conference abstract in proceedings – Annual report year: 2010 » Research » peer-review

Project supervision - an engineering approach

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Paulsen, R. R.
Publication date: 2010

Publication information
Original language: English
Keywords: project supervision
Electronic versions:
SuperVisionGuide.pdf
Semi-automated tracking of behaviour of Betta splendens
In this paper, a novel software system for animal behaviour tracking is described. It is used for tracking fish filmed in aquariums using a low quality acquisition system. The tracking is based on a multiscale template matching technique that finds both the position and the orientation of the tracked fish. The template is matched in the background subtracted frames, where the background is estimated using a median based approach. The system is very stable and has been used in a large behavioural study design to the use of the behavioural pattern known as mate choice copying in Betta splendens.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, University of Copenhagen
Contributors: Durey, M., Paulsen, R. R., Matessi, G., Dabelsteen, T.
Publication date: 2010

Structured light 3D tracking system for measuring motions in PET brain imaging
Patient motion during scanning deteriorates image quality, especially for high resolution PET scanners. A new proposal for a 3D head tracking system for motion correction in high resolution PET brain imaging is set up and demonstrated. A prototype tracking system based on structured light with a DLP projector and a CCD camera is set up on a model of the High Resolution Research Tomograph (HRRT). Methods to reconstruct 3D point clouds of simple surfaces based on phase-shifting interferometry (PSI) are demonstrated. The projector and camera are calibrated using a simple stereo vision procedure where the projector is treated as a camera. Additionally, the surface reconstructions are corrected for the non-linear projector output prior to image capture. The results are convincing and a first step toward a fully automated tracking system for measuring head motions in PET imaging.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Technical University of Denmark, Siemens A/S, Copenhagen University Hospital
Number of pages: 11
Pages: 76250X
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Proceedings of SPIE, the International Society for Optical Engineering
Volume: 7625
ISSN (Print): 0277-786X
Ratings:
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.208 SNIP 0.225
Web of Science (2010): Indexed yes
Original language: English
DOI: 10.1117/12.845060
4D Lung Reconstruction with Phase Optimization
This paper investigates and demonstrates a 4D lung CT reconstruction/registration method which results in a complete volumetric model of the lung that deforms according to a respiratory motion field. The motion field is estimated iteratively between all available slice samples and a reference volume which is updated on the fly. The method is two part and the second part of the method aims to correct wrong phase information by employing another iterative optimizer. This two part iterative optimization allows for complete reconstruction at any phase and it will be demonstrated that it is better than using an optimization which does not correct for phase errors. Knowing how the lung and any tumors located within the lung deforms is relevant in planning the treatment of lung cancer.

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Odense University Hospital
Contributors: Lyksborg, M., Paulsen, R., Brink, C., Larsen, R.
Pages: 2227-2230
Publication date: 2009

Analysis of gait using a treadmill and a Time-of-flight camera
We present a system that analyzes human gait using a treadmill and a Time-of-flight camera. The camera provides spatial data with local intensity measures of the scene, and data are collected over several gait cycles. These data are then used to model and analyze the gait. For each frame the spatial data and the intensity image are used to fit an articulated model to the data using a Markov random field. To solve occlusion issues the model movement is smothened providing the missing data for the occluded parts. The created model is then cut into cycles, which are matched and through Fourier fitting a cyclic model is created. The output data are: Speed, Cadence, Step length and Range-of-motion. The described output parameters are computed with no user interaction using a setup with no requirements to neither background nor subject clothing.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Jensen, R. R., Paulsen, R. R., Larsen, R.
Pages: 154-166
Publication date: 2009

Analyzing Gait Using a Time-Of-Flight Camera
An algorithm is created, which performs human gait analysis using spatial data and amplitude images from a Time-of-flight camera. For each frame in a sequence the camera supplies cartesian coordinates in space for every pixel. By using an articulated model the subject pose is estimated in the depth map in each frame. The pose estimation is based on likelihood, contrast in the amplitude image, smoothness and a shape prior used to solve a Markov random field. Based on the pose estimates, and the prior that movement is locally smooth, a sequential model is created, and a gait analysis is
done on this model. The output data are: Speed, Cadence (steps per minute), Step length, Stride length (stride being two consecutive steps also known as a gait cycle), and Range of motion (angles of joints). The created system produces good output data of the described output parameters and requires no user interaction.

Apparatus and method for representing a scanned surface
Disclosed is a method for generating a digital representation of a surface of an object from point data indicative of coordinates of points on the surface. The method comprises receiving a point data item indicative of coordinates of a point in a first one of a plurality of sub-volumes of a volume to be scanned; determining whether a first predetermined trigger condition is fulfilled for the first sub-volume; and if the first trigger condition is fulfilled, computing a local surface representation associated with the first sub-volume from received point data items associated with at least the first sub-volume; determining whether a second predetermined trigger condition is fulfilled; and if the second trigger condition is fulfilled, computing a surface representation of the surface of the object from a set of computed local surface representations associated with respective sub-volumes.

Automatic Assessment of Craniofacial Growth in a Mouse Model of Crouzon Syndrome
BACKGROUND & PURPOSE: Crouzon syndrome is characterized by growth disturbances caused by premature craniosynostosis. A mouse model with mutation Fgfr2C342Y, equivalent to the most common Crouzon syndrome mutation (henceforth called the Crouzon mouse model), has a phenotype showing many parallels to the human counterpart. Quantifying growth in the Crouzon mouse model could test hypotheses of the relationship between craniosynostosis and dysmorphology, leading to better understanding of the causes of Crouzon syndrome as well as providing knowledge relevant for surgery planning. METHODS: Automatic non-rigid volumetric image registration was applied to micro-CT scans of ten 4-week and twenty 6-week euthanized mice for growth modeling. Each age group consisted of 50% normal and 50% Crouzon mice. Four 3D mean shapes, one for each mouse-type and age group were created. Extracting a dense field of growth vectors for each mouse-type; growth models were created using linear interpolation and visualized as 3D animations. Spatial regions of significantly different growth were identified using the local False Discovery Rate method, estimating the expected percentage of false predictions in a set of predictions. For all image registrations, the Image Registration Toolkit was used under Licence from Ixico Ltd. RESULTS: Investigation proved growth in the Crouzon group to be inhibited, especially in the nasal and posterior regions of the skull compared to the growth in the normal group, and showed an expansion vertically and laterally in the middle and anterior part of the calvaria. Image registration was used to automatically obtain landmarks, thus, different skull measures could be performed e.g. length, width, height. The registrations were quantitatively validated using expert-placed landmarks. CONCLUSIONS: Image registrations made it possible to automatically quantify and visualize average craniofacial growth in normal and Crouzon mouse models, and
significantly different growth patterns were found between the two. The methodology generalizes to quantification of shape and growth in other mouse models, and provides a tool for spatially detailed automatic phenotyping. **MAIN OBJECTIVES OF PRESENTATION:** We will present a 3D growth model of normal and Crouzon mice, and differences will be statistically and visually compared.

**General information**
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Washington University St. Louis, University of Copenhagen
Pages: 74-75
Publication date: 2009

**Host publication information**
Title of host publication: American Cleft Palate-Craniofacial Association : 66th Annual Meeting
Source: orbit
Source-ID: 233429
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2009 › Research

**Hierarchical Markov Random Fields Applied to Model Soft Tissue Deformations on Graphic Hardware**

**General information**
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, University of Bern
Contributors: Seiler, C., Büchler, P., Noite, L., Reyes, M., Paulsen, R. R.
Pages: 133-148
Publication date: 2009

**Host publication information**
Title of host publication: Recent Advances in the 3D Physiological Human
Publisher: Springer
Editor: Magenat-Thalmann, N.
ISBN (Print): 978-1-84882-564-2
DOIs: 10.1007/978-1-84882-565-9_9
Source: orbit
Source-ID: 253295
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2009 › Research › peer-review

**Regularisation of 3D Signed Distance Fields**
Signed 3D distance fields are used a in a variety of domains. From shape modelling to surface registration. They are typically computed based on sampled point sets. If the input point set contains holes, the behaviour of the zero-level surface of the distance field is not well defined. In this paper, a novel regularisation approach is described. It is based on energy formulation, where both local smoothness and data fidelity are included. The minimisation of the global energy is shown to be the solution of a large set of linear equations. The solution to the linear system is found by sparse Cholesky factorisation. It is demonstrated that the zero-level surface will act as a membrane after the proposed regularisation. This effectively closes holes in a predictable way. Finally, the performance of the method is tested with a set of synthetic point clouds of increasing complexity.

**General information**
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Paulsen, R. R., Bærentzen, J. A., Larsen, R.
Pages: 513-519
Publication date: 2009

**Host publication information**
Title of host publication: Proceedings of the 16th Scandinavian Conference on Image Analysis
Publisher: Springer
ISBN (Print): 978-3-642-02229-6
Analysis of Surfaces Using Constrained Regression Models

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Computer Science and Artificial Intelligence Laboratory
Contributors: Darkner, S., Sabuncu, M. R., Golland, P., Paulsen, R. R., Larsen, R.
Pages: 842-849
Publication date: 2008

Host publication information
Title of host publication: Lecture Notes in Computer Science: Medical Image Computing and Computer-assisted Intervention
Volume: 5241-I
Publisher: Springer
Keywords: hearing aid, image registration, ear canal
Source: orbit
Source-ID: 223720

Analysis of Deformation of the Human Ear and Canal Caused by Mandibular Movement

Many hearing aid users experience physical discomfort when wearing their device. The main contributor to this problem is believed to be deformation of the ear and ear canal caused by movement of the mandible. Physical discomfort results from added pressure on soft tissue areas in the ear. Identifying features that can predict potential deformation is therefore important for identifying problematic cases in advance. A study on the physical deformation of the human ear and canal due to movement of the mandible is presented. The study is based on laser scannings of 30 pairs of ear impressions from 9 female and 21 male subjects. Two impressions have been taken from each subject, one with open mouth, and one with the mouth closed. All impressions are registered using non-rigid surface registration and a shape model is built. From each pair of impressions a deformation field is generated and propagated to the shape model, enabling the building of a deformation model in the reference frame of the shape model. A relationship between the two models is established, showing that the shape variation can explain approximately 50% of the variation in the deformation model. An hypothesis test for significance of the deformations for each deformation field reveals that all subjects have significant deformation at Tragus and in the canal. Furthermore, a relation between the magnitude of the deformation and the gender of the subject is demonstrated. The results are successfully validated by comparing the outcome to the anatomy by using a single set of high resolution histological sectionings of the region of interest.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Darkner, S., Paulsen, R. R., Larsen, R.
Pages: 801-808
Publication date: 2007

Host publication information
Title of host publication: Lecture Notes in Computer Science: Medical Image Computing and Computer-Assisted Intervention – MICCAI 2007
Volume: Volume 4792
Place of publication: Berlin / Heidelberg
Publisher: Springer
ISBN (Print): 978-3-540-75758-0
DOIs:
10.1007/978-3-540-75759-7
Source: orbit
Source-ID: 208976
Automated 3D Rigid Registration of Open 2D Manifolds

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Darkner, S., Vester-Christensen, M., Larsen, R., Nielsen, C., Paulsen, R. R.
Pages: 19-22
Publication date: 2006

Host publication information
Title of host publication: MICCAI 2006 Workshop "From Statistical Atlases to Personalized Models"
ISBN (Print): 978-86-7611-156-4
URLs:
http://www2.imm.dtu.dk/pubdb/views/publication_details.php?id=4879
Source: orbit
Source-ID: 192793
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2006 › Research › peer-review

Statistical Shape Analysis of the Human Ear Canal with Application to In-the-Ear Hearing Aid Design
This thesis is about the statistical shape analysis of the human ear canal with application to the mechanical design of in-the-ear hearing aids. Initially, it is described how a statistical shape model of the human ear canal is built based on a training set of laser-scanned ear impressions. A thin plate spline based approach creates a dense correspondence between the shapes in training set. In addition, a new flexible, non-rigid registration framework is proposed and used to optimise the correspondence field. The framework is based on Markov Random Field regularisation and is motivated by prior work on image restoration. It is shown how the method significantly improves the shape model. In the second part of the thesis, the shape model is used in software tools that mimic the skills of the expert hearing aid makers. The first result is that it is possible to learn an algorithm to cut an ear canal in order to produce an optimal in-the-ear hearing aid. Secondly, a framework for component placement using a coupling of stochastic optimisation and the results from the shape model is proposed. It is successfully, used to place the so-called faceplate with associated component on in-the-ear hearing aids. In addition, the idea of one-size-fits-most shells is explored.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Paulsen, R. R.
Number of pages: 197
Publication date: Nov 2004

Publication information
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English
Electronic versions:
imm3196.pdf
URLs:
Source: orbit
Source-ID: 154834

Markov Random Field Restoration of Point Correspondences for Active Shape Modelling
In this paper it is described how to build a statistical shape model using a training set with a sparse of landmarks. A well defined model mesh is selected and fitted to all shapes in the training set using thin plate spline warping. This is followed by a projection of the points of the warped model mesh to the target shapes. When this is done by a nearest neighbour projection it can result in folds and inhomogeneities in the correspondence vector field. The novelty in this paper is the use and extension of a Markov Random field regularisation of the correspondence field. The correspondence field is regarded as a collection of random variables, and using the Hammersley-Clifford theorem it is proved that it can be treated as a Markov Random Field. The problem of finding the optimal correspondence field is cast into a Bayesian framework for Markov Random Field restoration, where the prior distribution is a smoothness term and the observation model is the curvature of the shapes. The Markov Random Field is optimised using a combination of Gibbs sampling and the Metropolis-Hasting algorithm. The parameters of the model is found using a leave-one-out approach. The method leads to
a generative model that produces highly homogeneous polygonised shapes with improved reconstruction capabilities of the training data. Furthermore, the method leads to an overall reduction in the total variance of the resulting point distribution model. The method is demonstrated on a set of human ear canals extracted from 3D-laser scans.

**General information**
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics
Contributors: Hilger, K. B., Paulsen, R. R., Larsen, R.
Publication date: 2004

**Host publication information**
Title of host publication: SPIE - Medical Imaging
URLs:
Source: orbit
Source-ID: 154623

**Using a Shape Model in the Design of Hearing Aids**
Today the design of custom completely-in-the-canal hearing aids is a manual process and therefore there is a variation in the quality of the finished hearing aids. Especially the placement of the so-called faceplate on the hearing aid strongly influences the size and shape of the hearing aid. Since the future hearing aid production will be less manual there is a need for algorithms that mimic the craftsmanship of skilled operators. In this paper it is described how a statistical shape model of the ear canal can be used to predict the placement of the faceplate on a hearing aid made for a given ear canal.

The shape model is a point distribution model built using a training set of shapes with manually placed landmarks. An interpolation method is used to generate dense landmark correspondence over the training set prior to building the shape model. Faceplates have also been placed on the training shapes by a skilled operator. These faceplate planes are aligned to the average shape from the shape model and an average faceplate plane is calculated. Given a surface representation of a new ear canal, the shape model is fitted using a combination of the iterative closest point algorithm and the active shape model approach. The average faceplate from the training set can now be placed on the new ear canal using the position of the fitted shape model. A leave-one-out study shows that the algorithm is able to produce results comparable to a human operator.

**General information**
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Oticon A/S
Contributors: Paulsen, R. R., Nielsen, C., Laugesen, S., Larsen, R.
Publication date: 2004

**Host publication information**
Title of host publication: SPIE - Medical Imaging
URLs:
Source: orbit
Source-ID: 154656

**Shape Modelling Using Markov Random Field Restoration of Point Correspondences**
A method for building statistical point distribution models is proposed. The novelty in this paper is the adaption of Markov random field regularization of the correspondence field over the set of shapes. The new approach leads to a generative model that produces highly homogeneous polygonized shapes and improves the capability of reconstruction of the training data. Furthermore, the method leads to an overall reduction in the total variance of the point distribution model. Thus, it finds correspondence between semilandmarks that are highly correlated in the shape tangent space. The method is demonstrated on a set of human ear canals extracted from 3D-laser scans.

**General information**
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Contributors: Paulsen, R. R., Hilger, K. B.
Pages: 1-12
Publication date: 2003
Some Issues of Biological Shape Modelling with Applications
This paper illustrates current research at Informatics and Mathematical Modelling at the Technical University of Denmark within biological shape modelling. We illustrate a series of generalizations to, modifications to, and applications of the elements of constructing models of shape or appearance. These elements are correspondence analysis, analysis and decomposition of variability, alignment, and visualisation.

Building and Testing a Statistical Shape Model of the Human Ear Canal
This work deals with the analysis of the shape of the human ear canal. It is described how a dense surface point distribution model of the human ear canal is built based on a training set of laser scanned ear impressions and a sparse set of anatomical landmarks placed by an expert. The dense surface models are built by using the anatomical landmarks to warp a template mesh onto all shapes in the training set. Testing the gender related differences is done by initially reducing the dimensionality using principal component analysis of the vertices of the warped meshes. The number of
components to retain is chosen using Horn's parallel analysis. Finally a multivariate analysis of variance is performed on these components.

General information
Publication status: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Technical University of Denmark
Contributors: Paulsen, R. R., Larsen, R., Ersbøll, B. K., Nielsen, C., Laugesen, S., Conradsen, K. (ed.)
Publication date: 2002

Host publication information
Title of host publication: Eleventh International Workshop on Matrices and Statistics
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
URLs:
Source: orbit
Source-ID: 58216
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2002 › Research › peer-review

Projects:

Deep learning methods for otoscopy and wideband tympanometry for the diagnosis of otitis media with effusion and acute otitis media
Sundgaard, J. V., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Christensen, A. N., Supervisor
Harte, J., Supervisor
01/05/2019 → 30/04/2022
Project: PhD

IMOS: Intelligent Motion Sensing during neuro imaging using machine learning
Slipsager, J. M., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Olesen, O. V., Supervisor
Heijgaard, L., Supervisor
01/09/2018 → 31/08/2021
Project: PhD

Deep Learning Methods for Cardiac CT analysis
Juhl, K. A., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Camara, O., Supervisor
De Backer, O., Supervisor
Kofoed, K. F., Supervisor
Technical University of Denmark
01/08/2018 → 31/07/2021
Award relations: Deep Learning Methods for Cardiac CT analysis
Project: PhD

Formanalyse af ørekanaler
Paulsen, R. R., PhD Student, Department of Informatics and Mathematical Modeling
Larsen, R., Main Supervisor
Conradsen, K., Supervisor
Delingette, H., Supervisor
Laugesen, S., Supervisor
Carstensen, J. M., Examiner
Thodberg, H. H., Examiner
Cootes, T. F., Examiner
Innovationsfonden
01/06/2001 → 26/11/2004
Award relations: Formanalyse af ørekanaler
**Project: PhD**

**Image Base Tracking and 3D Content Generation**
Stets, J. D., PhD Student, Department of Mathematics
Aabøeas, H., Main Supervisor
Larsen, R., Supervisor
Paulsen, R. R., Examiner
Hansen, D. W., Examiner
Lensch, H. P. A., Examiner
Forskningsrådsfinansiering
01/11/2014 → 15/08/2018
Award relations: Image Base Tracking and 3D Content Generation

**Computerised Quantification of Motions Associated with Psychiatric Disorders**
Einarsson, G., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Clemmensen, L. K. H., Supervisor
Fink-Jensen, A., Supervisor
Pagsberg, A. K., Supervisor
Nielsen, A. A., Examiner
Gudmundsson, S., Examiner
Moeslund, T. B., Examiner
Samfinansieret - Andet
15/08/2014 → 16/05/2018
Award relations: Computerised Quantification of Motions Associated with Psychiatric Disorders

**Motion Correction on High resolution Brain PET Imaging**
Olesen, O. V., PhD Student, Department of Informatics and Mathematical Modeling
Larsen, R., Main Supervisor
Paulsen, R. R., Supervisor
Roed, B., Supervisor
Conradsen, K., Examiner
Bentzen, S. M., Examiner
Reyes, M., Examiner
Holgaard, L., Supervisor
ErhvervsPhD-ordningen VTU
15/11/2008 → 20/01/2012
Award relations: Motion Correction on High resolution Brain PET Imaging

**Shape Analysis of the Dynamics of the Human Ear Canal**
Darkner, S., PhD Student, Department of Informatics and Mathematical Modeling
Larsen, R., Main Supervisor
Olsen, O. F., Supervisor
Paulsen, R. R., Supervisor
Carstensen, J. M., Examiner
Ahlberg, J., Examiner
Lorenz, C., Examiner
ErhvervsPhD-ordningen VTU
01/07/2005 → 30/01/2009
Award relations: Shape Analysis of the Dynamics of the Human Ear Canal

**Statistical Shape Modelling of the Human Cochlear with Application to Cochlear Implant Surgical Procedures**
Kjær, H. M., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Dahl, A. B., Examiner
Darvann, T. A., Examiner
Delingette, H., Examiner
EU-finansieret
01/09/2012 → 30/09/2015
Award relations: Statistical Shape Modelling of the Human Cochlear with Application to Cochlear Implant Surgical Procedures
Project: PhD

Motion Tracking of Children in Risk of Cerebral Palsy
Olsen, M. D., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Nielsen, J. B., Supervisor
Van Leemput, K., Examiner
Adde, L., Examiner
Lorenz, C., Examiner
1/3 FUU, 1/3 inst 1/3 Andet
15/09/2012 → 24/02/2016
Award relations: Motion Tracking of Children in Risk of Cerebral Palsy
Project: PhD

Advanced Methods for Biological Shape Analysis
Hansen, M. S., PhD Student, Department of Informatics and Mathematical Modeling
Lar森, R., Main Supervisor
Ersbøll, B. K., Supervisor
Paulsen, R. R., Examiner
Rueckert, D., Examiner
Van Leemput, K., Examiner
DTU-lønnet stipendie
01/07/2006 → 25/11/2009
Award relations: Advanced Methods for Biological Shape Analysis
Project: PhD

3D Shape Modelling using High Level Descriptors
Dahl, V. A., PhD Student, Department of Informatics and Mathematical Modeling
Aanaes, H., Main Supervisor
Bærentzen, J. A., Supervisor
Paulsen, R. R., Examiner
Solem, J. E., Examiner
Sporring, J., Examiner
DTU-lønnet stipendie
01/06/2007 → 22/06/2011
Award relations: 3D Shape Modelling using High Level Descriptors
Project: PhD

Computing pseudo-CT from MR: Towards MR-only based radiation therapy
Andreasen, D., PhD Student, Department of Mathematics
Van Leemput, K., Main Supervisor
Edmund, J. M., Supervisor
Lar森, R., Supervisor
Paulsen, R. R., Examiner
Nyholm, T., Examiner
Cardoso, J., Examiner
Technical University of Denmark
01/08/2013 → 12/12/2016
Award relations: Computing pseudo-CT from MR: Towards MR-only based radiation therapy
Project: PhD

Computer Vision Assisted Motion Correction in Medical Imaging
Wilm, J., PhD Student, Department of Mathematics
Aanaes, H., Main Supervisor
Paulsen, R. R., Supervisor
Carstensen, J. M., Examiner
Åström, K., Examiner
Vogiatzis, G., Examiner
Højgaard, L., Supervisor
**Individualized directional microphone optimization in hearing aids based on reconstructing 3D geometry of the head and ear from 2D photos**

Harder, S., PhD Student, Department of Mathematics
Paulsen, R. R., Main Supervisor
Laugesen, S., Supervisor
Bærentzen, J. A., Examiner
Ballester, M. A. G., Examiner
Juhl, P. M., Examiner
Eksternt finansieret virksomhed
15/03/2012 → 19/06/2015
Award relations: Individualized directional microphone optimization in hearing aids based on reconstructing 3D geometry of the head and ear from 2D photos
Project: PhD

**Facial recognition**

Fagertun, J., PhD Student, Department of Informatics and Mathematical Modeling
Paulsen, R. R., Main Supervisor
Clemmensen, L. K. H., Examiner
Hansen, D. W., Examiner
Cootes, T. F., Examiner
Technical University of Denmark
01/09/2010 → 26/02/2014
Award relations: Facial recognition
Project: PhD

**Planning and evaluation of radio-therapeutic treatment of head-and-neck cancer using PET/CT scanning**

Hollensen, C., PhD Student, Department of Informatics and Mathematical Modeling
Larsen, R., Main Supervisor
Paulsen, R. R., Examiner
Ballester, M. A. G., Examiner
Visvikis, D., Examiner
Højgaard, L., Supervisor
Specht, L., Supervisor
1/3 DTU-stip, 2/3 PUR/andet
01/08/2009 → 19/12/2012
Award relations: Planning and evaluation of radio-therapeutic treatment of head-and-neck cancer using PET/CT scanning
Project: PhD

**Determination of magnetic resonance imaging biomarkers for multiple sclerosis treatment effects**

Lyksborg, M., PhD Student, Department of Informatics and Mathematical Modeling
Larsen, R., Main Supervisor
Dyrby, T. B., Supervisor
Paulsen, R. R., Examiner
Jones, D. K., Examiner
Westin, C., Examiner
Siebner, H. R., Supervisor
Institut, samfinansiering
01/04/2010 → 17/06/2013
Award relations: Determination of magnetic resonance imaging biomarkers for multiple sclerosis treatment effects
Project: PhD

**Cranio-facial growth modelling**

Thorup, S. S., PhD Student, Department of Informatics and Mathematical Modeling
Larsen, R., Main Supervisor
Darvann, T. A., Supervisor
Hermann, N., Supervisor
Paulsen, R. R., Supervisor
A Neuroimaging study: Consequences of physical exercise on regional brain structure and connectivity in AD
Larsen, C. T., PhD Student, Department of Mathematics
Van Leemput, K., Main Supervisor
Garde, E., Supervisor
Paulsen, R. R., Examiner
Hendrikse, J., Examiner
Menze, B. H., Examiner
Institut samfinansiering
01/12/2011 → 21/01/2016
Award relations: A Neuroimaging study: Consequences of physical exercise on regional brain structure and connectivity in AD
Project: PhD

Computational Analysis of Brain Images: Towards a Useful Tool in Clinical Practice
Puonti, O., PhD Student, Department of Mathematics
Van Leemput, K., Main Supervisor
Larsen, R., Supervisor
Paulsen, R. R., Examiner
Ashburner, J., Examiner
Maes, F., Examiner
Technical University of Denmark
01/11/2012 → 24/02/2016
Award relations: Computational Analysis of Brain Images: Towards a Useful Tool in Clinical Practice
Project: PhD

Anatomical surface reconstruction and optimization
Jensen, R. R., PhD Student, Department of Informatics and Mathematical Modeling
Paulsen, R. R., Main Supervisor
Poel, M. V. D., Supervisor
Bærentzen, J. A., Examiner
Olsen, O. F., Examiner
Reyes, M., Examiner
Institut samfinansiering
15/04/2010 → 30/08/2013
Award relations: Anatomical surface reconstruction and optimization
Project: PhD

Image Analysis for X-ray Imaging of Food
Einarsdottir, H., PhD Student, Department of Mathematics
Ersbøll, B. K., Main Supervisor
Larsen, R., Supervisor
Paulsen, R. R., Examiner
Heyden, A., Examiner
Andersen, K., Examiner
Institut samfinansiering
01/06/2012 → 30/09/2016
Award relations: Image Analysis for X-ray Imaging of Food
Project: PhD

Neuro-morphological Interpretation of Clinical Outcome
Jensen, B. V., PhD Student, Department of Mathematics
Larsen, R., Main Supervisor
Paulsen, R. R., Examiner
OpenHATS: An open database of 3D scans of the human head, ear, and torso
The aim of this project is to generate a database of high-resolution 3D scans of the head and torso of humans. The data will be presented on a web-portal where software to view, manipulate and process the data is also available. The intended users of the data and tools are students and researches working with acoustical modelling. Specifically, the data can for example be used to optimise spatial perception in hearing aids, boom design for headsets, and simulating individual head related transfer functions.

Mathematical modelling of the sound field surrounding the head is an emerging discipline that has shown promise to alleviate some of the difficulties in for example designing and testing the performance of new hearing aid designs. However, current state-of-the arts methods are mostly based on synthetic data and the results are therefore somewhat misleading. The lack of data is mainly due to the difficulty in acquiring real 3D data of the human head and torso. Especially, the 3D geometry of the human ear is very difficult to obtain using traditional 3D acquisition techniques like CT, MR, and laser scanning. Recently, the 3D Laboratory at the school of dentistry at the University of Copenhagen obtained a 3dMD cranial scanner by a donation from the Oticon Foundation. This scanner can be used to capture high quality 3D scans of the head, ear (pinna and part of concha), and torso of humans. The aim of this project is to use the scanner at the 3D laboratory to capture the torso and head geometry of a group of test persons. Furthermore, ear impressions should be taken and scanned so the final and merged data is a precise 3D presentation of torso, head, and the ear canal.

Paulsen, R. R., Project Manager
Forsk. Private danske - Fonde: DKK1,000,000.00
01/02/2008 → 01/03/2011
Collaborators: Technical University of Denmark
Award relations: An open database of 3D scans of the human head, ear, and torso
Project: Research