A comparison of reflectance properties on polymer micro-structured functional surface

In this study, a functional micro-structure surface [1] has been developed as a combination of arrays of micro ridges. The scope of the surface is to achieve specific directional optical properties: that is, under constrained lighting, maximizing the reflectance from a certain viewing direction, and minimizing it from the corresponding horizontally orthogonal position, i.e. maximize the contrast between two horizontally orthogonal view positions at the same inclination (Figure 1). The sample is composed of 12 different anisotropic surfaces, that are designed as a combination of ridges defined by their pitch distance and their angle in respect to the surface (Figure 2). The geometry was obtained by precision milling of a tool steel bar and replicated through silicone replica technology [2], and by hot embossing using Acrylonitrile Butadiene Styrene (ABS). A digital microscope has been used as a gonioreflectometer to determine the directional surface reflectance of each surface to varying light and camera positions. The presented results show that the replication processes and the polymeric material have a strong impact on the contrast under constrained lightening. More specifically, the reflectance properties are strongly influenced by the geometry of the structure and by the colour.

An Error Analysis of Structured Light Scanning of Biological Tissue

This paper presents an error analysis and correction model for four structured light methods applied to three common types of biological tissue; skin, fat and muscle. Despite its many advantages, structured light is based on the assumption of direct reflection at the object surface only. This assumption is violated by most biological material e.g. human skin, which exhibits subsurface scattering. In this study, we find that in general, structured light scans of biological tissue deviate significantly from the ground truth. We show that a large portion of this error can be predicted with a simple, statistical linear model based on the scan geometry. As such, scans can be corrected without introducing any specially designed pattern strategy or hardware. We can effectively reduce the error in a structured light scanner applied to biological tissue by as much as factor of two or three.
An image-based method for objectively assessing injection moulded plastic quality

In high volume productions based on casting processes, like high-pressure die casting (HPDC) or injection moulding, there is a wide range of variables that affect the end quality of produced parts. These variables include production parameters (temperature, pressure, mixture), and external factors (humidity, temperature, etc.). With this many variables it is a challenge to maintain a stable output quality, wherefore massive amounts of resources are spent on quality assurance (QA) of produced parts. Currently, this QA is done manually through visual inspection. We demonstrate how a multispectral imaging system can be used to automatically rate the quality of a produced part using an autocorrelation and a Fourier-based method. These methods are compared with human rankings and achieve good correlations on a variety of samples.

General information
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A performance assessment of a 2 axis scanning mirror galvanometer for powder bed fusion

Additive Manufacturing by powder bed fusion allows production of high strength parts with complex features, not possible through conventional manufacturing. To experiment and test current theory within laser processing of metal powder, an
open and customizable laser scanner platform is developed and constructed. The platform seeks to fully support and enable the laser driven process of selective consolidation metal powder, as most industrially available powder bed fusion machine tools are closed and proprietary systems. This allows the machine tool manufacturer to strictly control how the system is used and therefore maintain stability through limiting the operator to use proprietary software hardware and process materials but unfortunately limits to an equally wide extent how such machine tools can be applied for research purposes as it renders the scientist to become a mere operator of the machine tool. A galvanometer based laser scanning system is here presented. The system was designed to meet a theoretical resolution of 0.009 mm. From inspiration of the use of optomechanical hole plates as reference artefacts for coordinate metrology a test was conducted to verify the accuracy of the laser scanning system. The system was found to perform excellent for relative positioning. Absolute positioning of the laser beam did not conform with design specifications, as the test deviated by 0.12mm with respect to the nominal test value, yet this is expected in the future to be met from the implementation of a better galvanometer control system.

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**Applied 3D Vision: An Empirical Study**

**General information**

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Organisations: Department of Applied Mathematics and Computer Science
Authors: Jensen, S. H. N. (Intern), Aanæs, H. (Intern)
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**Augmented Reality Interfaces for Additive Manufacturing**

This paper explores potential use cases for using augmented reality (AR) as a tool to operate industrial machines. As a baseline we use an additive manufacturing system, more commonly known as a 3D printer. We implement novel augmented interfaces and controls using readily available open source frameworks and low cost hardware. Our results show that the technology enables richer and more intuitive printer control and performance monitoring than currently available on the market. Therefore, there is a great deal of potential for these types of technologies in future digital factories.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Department of Mechanical Engineering, Manufacturing Engineering, Technical University of Denmark, MIT Media Lab
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Pages: 515-525
A variational study on BRDF reconstruction in a structured light scanner

Time-efficient acquisition of reflectance behavior together with surface geometry is a challenging problem. In this study, we investigate the impact of system parameter uncertainties when incorporating a data-driven BRDF reconstruction approach into the standard pipeline of a structured light scanning system. The parameters investigated include geometric detail of scanned objects; vertex positions and normals; and position and intensity of light sources. To have full control of uncertainties, experiments are carried out in a simulated environment, mimicking an actual structured light scanning setup. Results show that while uncertainties in vertex positions and normals have a high impact on the quality of reconstructed BRDFs, object geometry and light source properties have very little influence on the reconstructed BRDFs. With this analysis, practitioners now have insight in the tolerances required for accurate BRDF acquisition to work.

Computer Vision for Additive Manufacturing.

Ever since the commercialization of additive manufacturing in the late 80's, it has been clear what enormous potential the technology could have, potentially disrupting several industries. However, we have yet to see the technology fully adopted by the manufacturing industry. One of the issues that has prevented widespread adoption of 3D printing for use within manufacturing is the apparent lack of quality control during and after the printing process. This thesis demonstrates how computer vision may be applied in beneficial ways within additive manufacturing. The main contributions aim at solving part of the challenges required for the technology to reach its full envisioned potential, and to reach widespread industry adoption as a de-facto manufacturing modality. Quality control has been a major milestone to overcome in this regard. As a result, a core part of the contributions revolves around this central topic. The work is separated into three main categories: The first two concerning process and quality control of appearance and geometry. The third category concerns machine interaction paradigms within additive manufacturing. Here, challenges are addressed within the 3D ecosystem, aiming towards facilitating a fluid integration of additive manufacturing within the factory of tomorrow.
Evaluation of optical functional surfaces on the injection moulding insert by micro milling process

This study presents the optimization of micro milling process for manufacturing injection moulding inserts with an optical functional surface. The objective is the optimal surface functionality. Micro ridges were used as the microstructures to realize the function to generate contrast between orthogonally textured areas by reflecting light in different directions. In order to maximize the contrast, a sample was machined with the same structures and dimensions, according to a Design of Experiments (DOEs) to optimize the milling parameters by considering the contrast as a response. The contrast was evaluated based on the image processing method. The proper cutting condition was selected in order to obtain machined surface with the highest contrast and the results presented by DOE analysis. The correlations between the cutting parameters, the burrs height, and the function were determined. The contrast was found to be proportional to the spindle speed and feed rate and “oil+air” was considered as the preferred cooling method.

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Optical functional surface, Micro milling, Optimization, DOE
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

In-line 3D print failure detection using computer vision

Here we present our findings on a novel real-time vision system that allows for automatic detection of failure conditions that are considered outside of nominal operation. These failure modes include warping, build plate delamination and extrusion failure. Our system consists of a calibrated camera whose position and orientation is known in the machine coordinate system. We simulate what the object under print should look like for any given moment in time. This is compared to a segmentation of the current print, and statistical detection of significant deviation. We demonstrate that this methodology precisely and unambiguously detects the time point of print failure.

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Modeling the Anisotropic Reflectance of a Surface with Microstructure Engineered to Obtain Visible Contrast after Rotation

Engineering of surface structure to obtain specific anisotropic reflectance properties has interesting applications in large scale production of plastic items. In recent work, surface structure has been engineered to obtain visible reflectance contrast when observing a surface before and after rotating it 90 degrees around its normal axis. We build an analytic anisotropic reflectance model based on the microstructure engineered to obtain such contrast. Using our model to render synthetic images, we predict the above mentioned contrasts and compare our predictions with the measurements reported in previous work. The benefit of an analytical model like the one we provide is its potential to be used in computer vision for estimating the quality of a surface sample. The quality of a sample is indicated by the resemblance of camera-based contrast measurements with contrasts predicted for an idealized surface structure. Our predictive model is also useful in optimization of the microstructure configuration, where the objective for example could be to maximize reflectance contrast.

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Photogrammetry for Repositioning in Additive Manufacturing

In this preliminary work, we present our current status on how to use single camera photogrammetry to determine the orientation of an additively manufactured partly finished object that has been repositioned in the printing chamber from a single image taken with a calibrated camera, and comparing this to the CAD model of the object. We describe how this knowledge can be used to update the machine code of the printer such that printing of the object can be resumed. This opens possibilities for embedding and assembling foreign parts into the additive manufacturing pipeline, adding another layer of flexibility to the process. However, due to various errors sources in estimating the orientation of the object, more work is needed before this update can be applied.

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PicPrint: Embedding pictures in additive manufacturing

Here we present PicPrint, a method and tool for producing an additively manufactured lithophane, enabling transferring and embedding 2D information into additively manufactured 3D objects. The method takes an input image and converts it to a corresponding height-map, indicating the material density required to achieve a brightness specified at any given location. Non-linear scattering properties are compensated for using predefined falloff profiles. Using the produced height-map, a watertight mesh is distorted to match the specified material densities, after which the mesh is ready for either direct print on an additive manufacturing system, or transfer to other geometries via Boolean mesh operations.

Process chain for fabrication of anisotropic optical functional surfaces on polymer components

This paper aims to introduce a process chain for fabrication of anisotropic optical functional surfaces on polymer products. The surface features under investigation are composed of micro serrated ridges. The scope was to maximize the visible contrast between orthogonally textured surfaces from a certain viewing angle. The process chain comprised three steps: tooling, replication and quality assurance. Tooling was achieved by precision micro milling. Replication processes such as injection moulding, hot embossing, blow moulding, etc. were employed according to the specific type of product. In order to implement the traceability of the manufacturing process, the geometry and dimension of the microstructure on the tool and the replica were assessed via metrological methods. The functionality of the anisotropic surfaces on the polymer replicas were evaluated by a gonioreflectometer and image processing. Eventually, according to the function evaluation of polymer products, the process chain steps will be optimized by tuning the tooling and moulding processes.

Scene reassembly after multimodal digitization and pipeline evaluation using photorealistic rendering

Transparent objects require acquisition modalities that are very different from the ones used for objects with more diffuse reflectance properties. Digitizing a scene where objects must be acquired with different modalities requires scene reassembly after reconstruction of the object surfaces. This reassembly of a scene that was picked apart for scanning...
seems unexplored. We contribute with a multimodal digitization pipeline for scenes that require this step of reassembly. Our pipeline includes measurement of bidirectional reflectance distribution functions and high dynamic range imaging of the lighting environment. This enables pixelwise comparison of photographs of the real scene with renderings of the digital version of the scene. Such quantitative evaluation is useful for verifying acquired material appearance and reconstructed surface geometry, which is an important aspect of digital content creation. It is also useful for identifying and improving issues in the different steps of the pipeline. In this work, we use it to improve reconstruction, apply analysis by synthesis to estimate optical properties, and to develop our method for scene reassembly.

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ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
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Towards Plug-n-Play robot guidance: Advanced 3D estimation and pose estimation in Robotic applications

Robots are a key technology in the quest for higher productivity in Denmark and Europe. Robots have existed in many years as a part of production lines where they have solved monotonous and repetitive task in mass production industries. Typical the programming of these robots are handled by engineers with special knowledge who have often raised the price for using robots to a given production task. If robots have to be applicable for small and medium sized enterprises where production task often changes and batch sizes are below 50 products it is necessary that the staff is capable of re-programming the robot by themselves.

During the last five years a number of collaborative robots are introduced on the marked e.g. Universal Robot, which enables a production worker to program the robot to solve simple tasks. With the collaborative robot the production worker is able to make the robot grind, mill, weld and move objects, which are physical located at the same positions. In order to place objects in the same position each time, custom-made mechanical fixtures and aligners are constructed to ensure that objects are not moving. It is expensive to design and build these fixtures and it is difficult to quickly change to a novel task. In some cases where objects are placed in bins and boxes it is not possible to position the objects in the same location each time.

To avoid designing expensive mechanical solutions and to be able to pick objects from boxes and bins, a sensor is necessary to guide the robot. Today, primarily 2D vision systems are applied in industrial robotics, which are in-flexible and hard to program for the production workers. Smart cameras, which are easier to re-configure and program to detect objects exist. However, computing the correct position such that a robot can move to this position is still a challenge which requires calibration processes. Moreover, the ability to make the solution robust such that it is running 24/7 in a production is demanding and requires the right skills. Basically, the vision part of a flexible automation solution is difficult to manage for a production worker while the robot motion programming is easily handled with the new collaborative robots. This thesis deals with robot vision technologies and how these are made easier for production workers program in order to get robots to recognize and compute the position of objects in the industry.

This thesis investigates and discusses methods to encapsulate a 2D vision system into a framework in order to make changes in production task easier. The framework is presented in [Contribution B] and [Contribution C] and demonstrates how re-configuration of vision systems is made easier but in the same time reviles some of the fundamental problems that exist by observing a tree dimensional world through a two dimensional vision system. This requires a calibration procedure every time in order to convert 2D to 3D, which still is a cumbersome process for a production worker.

For this reason, the rest of the thesis investigates and discusses how 3D computer vision techniques can ease the problem of recognizing and computing the position of objects. In [Contribution D] a small lightweight 3D sensor is
presented. The 3D sensor has a size that makes it suitable for tool mounting at a collaborative robot. It is based on structured light principles and 3D estimation techniques, which enables fast and accurate acquisition of point clouds of low textured and reflective industrial objects.

In [Contribution E] a 3D vision system for easy learning of 3D models is presented. The system creates a 3D model of the object by scanning it from three views. Then the object acts as a reference model in the system when new instances of the object have to be located in the scene. With this approach fast re-configuration is possible. In [Contribution F] a new dataset for 3D object recognition and an evaluation of state-of-the-art local features for object recognition are presented. The contribution shows as expected that state-of-the-art 3D object recognition algorithms are not good enough to locate industrial objects with few local shape features on the surface.

General information
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Virtual reality inspection and painting with measured BRDFs

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Wearable Gaze Trackers: Mapping Visual Attention in 3D
The study of visual attention in humans relates to a wide range of areas such as: psychology, cognition, usability, and marketing. These studies have been limited to fixed setups with respondents sitting in front of a monitor mounted with a gaze tracking device. The introduction of wearable mobile gaze trackers allows respondents to move freely in any real world 3D environment, removing the previous restrictions. In this paper we propose a novel approach for processing visual attention of respondents using mobile wearable gaze trackers in a 3D environment. The pipeline consists of 3 steps: modeling the 3D area-of-interest, positioning the gaze tracker in 3D space, and 3D mapping of visual attention. The approach is general, but as a case study we created 3D heat maps of respondents visiting supermarket shelves as well as
finding their in-store movement relative to these shelves. The method allows for analysis across multiple respondents and to distinguish between phases of in-store orientation (far away) and product recognition/selection (up close) based on distance to shelves.

**A Large-Scale 3D Object Recognition dataset**

This paper presents a new large scale dataset targeting evaluation of local shape descriptors and 3d object recognition algorithms. The dataset consists of point clouds and triangulated meshes from 292 physical scenes taken from 11 different views; a total of approximately 3204 views. Each of the physical scenes contain 10 occluded objects resulting in a dataset with 32040 unique object poses and 45 different object models. The 45 object models are full 360 degree models which are scanned with a high precision structured light scanner and a turntable. All the included objects belong to different geometric groups; concave, convex, cylindrical and flat 3D object models. The object models have varying amount of local geometric features to challenge existing local shape feature descriptors in terms of descriptiveness and robustness. The dataset is validated in a benchmark which evaluates the matching performance of 7 different state-of-the-art local shape descriptors. Further, we validate the dataset in a 3D object recognition pipeline. Our benchmark shows as expected that local shape feature descriptors without any global point relation across the surface have a poor matching performance with flat and cylindrical objects. It is our objective that this dataset contributes to the future development of next generation of 3D object recognition algorithms. The dataset is public available at http://roboimagedata.compute.dtu.dk/.

**Designing for Color in Additive Manufacturing**

In this paper we present a color design pipeline for 3D printed or additively manufactured parts. We demonstrate how to characterize and calibrate a commercial printer and how to obtain its forward and backward color transformation models. We present results from our assistive color design tool, allowing for colorimetric accurate prints and visualization of the
In-Situ Monitoring in Additive Manufacturing Using Contact Image Sensors

Large-Scale Data for Multiple-View Stereopsis

The seminal multiple-view stereo benchmark evaluations from Middlebury and by Strecha et al. have played a major role in propelling the development of multi-view stereopsis (MVS) methodology. The somewhat small size and variability of these data sets, however, limit their scope and the conclusions that can be derived from them. To facilitate further development within MVS, we here present a new and varied data set consisting of 80 scenes, seen from 49 or 64 accurate camera positions. This is accompanied by accurate structured light scans for reference and evaluation. In addition all images are taken under seven different lighting conditions. As a benchmark and to validate the use of our data set for obtaining reasonable and statistically significant findings about MVS, we have applied the three state-of-the-art MVS algorithms by Campbell et al., Furukawa et al., and Tola et al. to the data set. To do this we have extended the evaluation protocol from the Middlebury evaluation, necessitated by the more complex geometry of some of our scenes. The data set and accompanying evaluation framework are made freely available online. Based on this evaluation, we are able to observe several characteristics of state-of-the-art MVS, e.g. that there is a tradeoff between the quality of the reconstructed 3D points (accuracy) and how much of an object’s surface is captured (completeness). Also, several issues that we hypothesized would challenge MVS, such as specularities and changing lighting conditions did not pose serious problems. Our study finds that the two most pressing issues for MVS are lack of texture and meshing (forming 3D points into closed triangulated surfaces).
On Practical Sampling of Bidirectional Reflectance

Accurate material models are a key part in producing convincing, photo-realistic, images in computer graphics. Elaborate analytical models exist, allowing graphics designers to manually design material appearance. However, given the complex nature and wide variability of material appearance, measuring this from the real world is an impractical and time-consuming process. Having a practical way of measuring material appearance will not only be of great value to the
In this thesis, the challenge of making material appearance measurements practical is addressed. Specifically, the Bidirectional Reflectance Distribution Function (BRDF), which is the quantity describing material appearance, is thoroughly analysed using both optimisation tools and multivariate statistics, in search of making BRDFs more accessible.

The work demonstrated includes an insight into the challenges of fitting analytical models to measured data and on the compromises one is bound to make when simplifying the real world with a parametric BRDF model. Specifically we identify what error measures work well for obtaining perceptually good results and how a simple BRDF model may be modified to better match real world data. With an offset in this, a linear, data-driven, BRDF model is proposed and a framework for reconstructing full and accurate BRDFs from only a few measurements is presented. It is here demonstrated that with as little as 20 point-samples, a BRDF can accurately be reconstructed. Furthermore utilising the field of view of a camera, this may be reduced to as little as two images. With this, the thesis demonstrates how BRDF measurements can be made practical, and it exemplifies this with a range of datasets intended for various purposes, each including high quality measured BRDFs.

Where the classical approach to BRDF capture may take weeks in measurement time, we here successfully demonstrate that is can in fact be reduced to no more than minutes or even seconds using our framework.
Real Time Structured Light and Applications

Structured light scanning is a versatile method for 3D shape acquisition. While much faster than most competing measurement techniques, most high-end structured light scans still take in the order of seconds to complete.

Low-cost sensors such as Microsoft Kinect and time of flight cameras have made 3D sensor ubiquitous and have resulted in a vast amount of new applications and methods. However, such low-cost sensors are generally limited in their accuracy and precision, making them unsuitable for e.g. accurate tracking and pose estimation.

With recent improvements in projector technology, increased processing power, and methods presented in this thesis, it is possible to perform structured light scans in real time with 20 depth measurements per second. This offers new opportunities for studying dynamic scenes, quality control, human-computer interaction and more.

This thesis discusses several aspects of real time structured light systems and presents contributions within calibration, scene coding and motion correction aspects. The problem of reliable and fast calibration of such systems is addressed with a novel calibration scheme utilising radial basis functions [Contribution B]. A high performance flexible open source software toolkit is presented [Contribution C], which makes real time scanning possible on commodity hardware. Further, an approach is presented to correct for motion artifacts in dynamic scenes [Contribution E].

An application for such systems is presented with a head tracking approach for medical motion correction [Contribution A, F]. This aims to solve the important problem of motion artifacts, which occur due to head movement during long acquisition times in MRI and PET scans. In contrast to existing methods, the one presented here is MRI compatible [Contribution D], not dependent on fiducial markers, and suitable for prospective correction.

Factors contributing to accuracy and precision of structured light systems are investigated with a study of performance factors [Contribution G]. This is also done in the context of biological tissue, which exhibit subsurface effects and other undesirable effects [Contribution H], and it is shown that this error is to a large extent deterministic and can be corrected.

General Information

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Reliable Gait Recognition Using 3D Reconstructions and Random Forests - An Anthropometric Approach

Photogrammetric measurements of bodily dimensions and analysis of gait patterns in CCTV are important tools in forensic investigations but accurate extraction of the measurements are challenging. This study tested whether manual annotation of the joint centers on 3D reconstructions could provide reliable recognition. Sixteen participants performed normal walking where 3D reconstructions were obtained continually. Segment lengths and kinematics from the extremities were manually extracted by eight expert observers. The results showed that all the participants were recognized, assuming the same expert annotated the data. Recognition based on data annotated by different experts was less reliable achieving 72.6% correct recognitions as some parameters were heavily affected by interobserver variability. This study verified that 3D reconstructions are feasible for forensic gait analysis as an improved alternative to conventional CCTV. However, further studies are needed to account for the use of different clothing, field conditions, etc.

General information
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Scopus rating (2011): SJR 1.303 SNIP 1.257 CiteScore 1.48
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.03 SNIP 1.157
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.495 SNIP 1.177
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.053 SNIP 1.054
Scopus rating (2007): SJR 1.03 SNIP 0.877
Scopus rating (2006): SJR 0.897 SNIP 0.919
Scopus rating (2005): SJR 0.948 SNIP 1.015
Tangible 3D modeling of coherent and themed structures

We present CubeBuilder, a system for interactive, tangible 3D shape modeling. CubeBuilder allows the user to create a digital 3D model by placing physical, non-interlocking cubic blocks. These blocks may be placed in a completely arbitrary fashion and combined with other objects. In effect, this turns the task of 3D modeling into a playful activity that hardly requires any learning on the part of the user. The blocks are registered using a depth camera and entered into the cube graph where each block is a node and adjacent blocks are connected by edges. From the cube graph, we transform the initial cubes into coherent structures by generating smooth connection geometry for some edges of the graph. Based on an analysis of the cube graph, we identify subgraphs that match given graph templates. These subgraph templates map to predefined geometric refinements of the basic shape. This, in turn, allows the user to tangibly build structures of greater details than the blocks provide in and of themselves. We show a number of shapes that have been modeled by users and are indicative of the expressive power of the system. Furthermore, we demonstrate the scalability of the tangible interface which appears to be limited only by the number of blocks available.
In this paper we present a practical innovation concerning how to achieve high accuracy of camera positioning, when using a 6 axis industrial robots to generate high quality data sets for computer vision. This innovation is based on the realization that to a very large extent the robots positioning error is deterministic, and can as such be calibrated away. We have successfully used this innovation in our efforts for creating data sets for computer vision. Since the use of this innovation has a significant effect on the data set quality, we here present it in some detail, to better aid others in using robots for image data set generation.
Nanoparticles and nanoimaging for organic solar cells
Solar energy is one of the few energy sources with the potential to power humanity in a future scenario where fossil fuels are not attractive due to their effect on the global climate or fossil fuels have been depleted all together. Organic photovoltaics is a promising technology for solar harvesting due to its potential for scalable roll-to-roll production and low manufacturing cost. However, the technology is faced with several obstacles which have to be overcome such as low efficiency and stability. Some of the issues are related to nano structures and device morphology. This dissertation is devoted to studying organic photovoltaics on the micro to nanometer scale, in particular photoactive Landfester particles. The ultimate goal is to increase the performance of Landfester particle layers so they can become a viable alternative to photoactive layers cast from organic solvent. Transition to a water based ink would provide a production environment without toxic fumes from organic solvents and the nanoparticle structure would provide additional morphological control. The first part of the dissertation maps photodegradation in active layers cast from organic solvents. Reducion in degradation rates is quantified for mixed electron donor and acceptor material. The spatial distribution of photodegradation in an electron donor material is mapped and the degradation is found to be homogeneous at the sub-micron length scale. The second and third part is devoted to studying the nano structures in photoactive Landfester nanoparticles. The dispersed particles are characterized by size, internal structure and crystallinity. Crystal orientation and spatial distribution of materials are quantified for cast layers of Landfester particles. A layer of particles is also investigated in a tandem solar cell and compared to other layers in the structure using Tomographic 3D mapping. The fourth part presents a projection alignment algorithm for tomographic methods. It works by estimating projection movement through iterative logic using projection distance minimization. It is tested on simulated datasets and results in decreased angular displacements and increased resolution. Further development of the algorithm could therefore be used to increase spatial resolution for characterization of organic photovoltaics and computed tomography in general.

General information
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Organisations: Department of Energy Conversion and Storage, Imaging and Structural Analysis, Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics
Authors: Pedersen, E. B. L. (Intern), Andreasen, J. W. (Intern), Aanæs, H. (Intern)
Number of pages: 171
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Publisher: Department of Energy Conversion and Storage, Technical University of Denmark
Original language: English
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Main Research Area: Technical/natural sciences
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New equations to calculate 3D joint centres in the lower extremities
Biomechanical movement analysis in 3D requires estimation of joint centres in the lower extremities and this estimation is based on extrapolation from markers placed on anatomical landmarks. The purpose of the present study was to quantify the accuracy of three established set of equations and provide new improved equations to predict the joint centre locations. The 'true' joint centres of the knee and ankle joint were obtained in vivo by MRI scans on 10 male subjects whereas the 'true' hip joint centre was obtained in 10 male and 10 female cadavers by CT scans.

For the hip joint the errors ranged from 26.7 (8.9) to 29.6 (7.5) mm, for the knee joint 5.8 (3.1) to 22.6 (3.3) mm and for the ankle joint 14.4 (2.2) to 27.0 (4.6) mm. This differed significantly from the improved equations by which the error for the hip joint ranged from 8.2 (3.6) to 11.6 (5.6) mm, for the knee joint from 2.9 (2.1) to 4.7 (2.5) mm and for the ankle joint from 3.4 (1.3) to 4.1 (2.0) mm. The coefficients in the new hip joint equations differed significantly between sexes. This difference depends on anatomical differences of the male and female pelvis.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Copenhagen, Copenhagen University Hospital, Aalborg University
Authors: Sandau, M. (Ekstern), Heimbürger, R. V. (Ekstern), Villa, C. (Ekstern), Jensen, K. E. (Ekstern), Moeslund, T. B. (Ekstern), Aanæs, H. (Intern), Alkjær, T. (Ekstern), Simonsen, E. B. (Ekstern)
Pages: 948-955
Publication date: 2015
Main Research Area: Technical/natural sciences
Publication information
Journal: Medical Engineering & Physics
Volume: 37
Issue number: 10
Our 3D Vision Data-Sets in the Making

General information

State: Published

Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, IT Service, National Space Institute, Istituto Italiano di Tecnologia, Aston University

Predicting Color Output of Additive Manufactured Parts

In this paper we address the colorimetric performance of a multicolor additive manufacturing process. A method on how to measure and characterize color performance of said process is presented. Furthermore, a method on predicting the color output is demonstrated, allowing for previsualization of parts prior to print. Results show that color prediction can be achieved with an average color difference error of $\Delta E^{*} = 1.5$ and std.dev $\sigma = 0.75$, with similar order of magnitude as the literature defined threshold for „Just Noticeable Difference“ (JND).

Quality Assurance Based on Descriptive and Parsimonious Appearance Models

In this positional paper, we discuss the potential benefits of using appearance models in additive manufacturing, metal casting, wind turbine blade production, and 3D content acquisition. Current state of the art in acquisition and rendering of appearance cannot easily be used for quality assurance in these areas. The common denominator is the need for descriptive and parsimonious appearance models. By ‘parsimonious’ we mean with few parameters so that a model is useful both for fast acquisition, robust fitting, and fast rendering of appearance. The word ‘descriptive’ refers to the fact that a model should represent the main features of the acquired appearance data. The solution we propose is to reduce the degrees of freedom by greater use of multivariate statistics.
Structured Light Scanning of Skin, Muscle and Fat

We investigate the quality of structured light 3D scanning on pig skin, muscle and fat. These particular materials are interesting in a number of industrial and medical use-cases, and somewhat challenging because they exhibit subsurface light scattering. Our goal therefor is to quantify the amount of error that various encoding strategies show, and propose an error correcting model, which can bring down the measurement bias considerably. Samples of raw and unprocessed pig tissue were used with the number of sampled surface points $N_{meat} = 1.2 \times 10^6$, $N_{skin} = 4.0 \times 10^6$ and $N_{fat} = 2.1 \times 10^6$ from 8 different pieces of tissue. With the standard N-step phase shifting method, the bias and RMS errors were found to be $0.45 \pm 0.22 \text{mm}$ (muscle), $0.51 \pm 0.19 \text{mm}$ (skin) and $0.14 \pm 0.16 \text{mm}$ (fat). After applying a linear correction model containing view, light angles and point distances, the bias was almost completely removed on test data, and standard deviations slightly reduced. To our knowledge this is the first quantitative study of the measurement error of structured light with biological tissue.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics
Authors: Wilm, J. (Intern), Jensen, S. H. N. (Intern), Aanæs, H. (Intern)
Number of pages: 9
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Teach it Yourself - Fast Modeling of Industrial Objects for 6D Pose Estimation

In this paper, we present a vision system that allows a human to create new 3D models of novel industrial parts by placing the part in two different positions in the scene. The two shot modeling framework generates models with a precision that allows the model to be used for 6D pose estimation without loss in pose accuracy. We quantitatively show that our modeling framework reconstructs noisy but adequate object models with a mean RMS error at 2.7 mm, a mean standard deviation at 0.025 mm and a completeness of 70.3 % over all 14 reconstructed models, compared to the ground truth CAD models. In addition, the models are applied in a pose estimation application, evaluated with 37 different scenes with 61 unique object poses. The pose estimation results show a mean translation error on 4.97 mm and a mean rotation error on 3.38 degrees.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Southern Denmark, Danish Technological Institute
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Pages: 289-302
Publication date: 2015
A Structured Light Scanner for Hyper Flexible Industrial Automation

A current trend in industrial automation implies a need for doing automatic scene understanding, from optical 3D sensors, which in turn imposes a need for a lightweight and reliable 3D optical sensor to be mounted on a collaborative robot e.g., Universal Robot UR5 or Kuka LWR. Here, we empirically evaluate the feasibility of structured light scanners for this purpose, by presenting a system optimized for this task. The system incorporates several recent advances in structured light scanning, such as Large-Gap Gray encoding for dealing with defocusing, automatic creation of illumination masks for noise removal, as well as employing a multi exposure approach dealing with different surface reflectance properties. In addition to this, we investigate expanding the traditional structured light setup to using three cameras, instead of one or two. Also, a novel method for fusing multiple exposures and camera pairs is given. We present an in-depth evaluation, that lead us to conclude, that this setup performs well on tasks relevant for an industrial environment, where many metallic and other surfaces with difficult reflectance properties are in abundance. We demonstrate, that the added components contribute to the robustness of the system. Hereby, we demonstrate that structured light scanning is a technology well suited for hyper flexible industrial automation, by proposing an appropriate system.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Southern Denmark, Danish Technological Institute
Authors: Hansen, K. (Ekstern), Pedersen, J. (Ekstern), Sølund, T. (Intern), Aanæs, H. (Intern), Kraft, D. (Ekstern)
Pages: 401-408
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Erratum to: Interesting Interest Points

General information
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Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Copenhagen
Authors: Aanæs, H. (Intern), Dahl, A. L. (Intern), Kim, S. P. (Ekstern)
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- BFI (2015): BFI-level 2
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- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 2.834 SNIP 4.735 CiteScore 6
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 3.767 SNIP 5.083 CiteScore 7.59
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- Scopus rating (2012): SJR 2.315 SNIP 5.445 CiteScore 5.92
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 2.67 SNIP 5.37 CiteScore 7.45
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 3.055 SNIP 5.827
- BFI (2009): BFI-level 2
- BFI (2008): BFI-level 1
- Scopus rating (2008): SJR 2.751 SNIP 6.056
Large Scale Multi-view Stereopsis Evaluation

The seminal multiple view stereo benchmark evaluations from Middlebury and by Strecha et al. have played a major role in propelling the development of multi-view stereopsis methodology. Although seminal, these benchmark datasets are limited in scope with few reference scenes. Here, we try to take these works a step further by proposing a new multi-view stereo dataset, which is an order of magnitude larger in number of scenes and with a significant increase in diversity. Specifically, we propose a dataset containing 80 scenes of large variability. Each scene consists of 49 or 64 accurate camera positions and reference structured light scans, all acquired by a 6-axis industrial robot. To apply this dataset we propose an extension of the evaluation protocol from the Middlebury evaluation, reflecting the more complex geometry of some of our scenes. The proposed dataset is used to evaluate the state of the art multiview stereo algorithms of Tola et al., Campbell et al. and Furukawa et al. Hereby we demonstrate the usability of the dataset as well as gain insight into the workings and challenges of multi-view stereopsis. Through these experiments we empirically validate some of the central hypotheses of multi-view stereopsis, as well as determining and reaffirming some of the central challenges.

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Markerless motion capture can provide reliable 3D gait kinematics in the sagittal and frontal plane

Estimating 3D joint rotations in the lower extremities accurately and reliably remains unresolved in markerless motion capture, despite extensive studies in the past decades. The main problems have been ascribed to the limited accuracy of the 3D reconstructions. Accordingly, the purpose of the present study was to develop a new approach based on highly detailed 3D reconstructions in combination with a translational and rotational unconstrained articulated model. The highly detailed 3D reconstructions were synthesized from an eight camera setup using a stereo vision approach. The subject specific articulated model was generated with three rotational and three translational degrees of freedom for each limb segment and without any constraints to the range of motion. This approach was tested on 3D gait analysis and compared to a marker based method. The experiment included ten healthy subjects in whom hip, knee and ankle joint were analysed. Flexion/extension angles as well as hip abduction/adduction closely resembled those obtained from the marker based system. However, the internal/external rotations, knee abduction/adduction and ankle inversion/eversion were less
Classification of Pansharpened Urban Satellite Images

The classification of high resolution urban remote sensing imagery is addressed with the focus on classification of imagery that has been pansharpened by a number of different pansharpening methods. The pansharpening process introduces some spectral and spatial distortions in the resulting fused multispectral image, the amount of which highly varies depending on which pansharpening technique is used. In the majority of the pansharpening techniques that have been proposed, there is a compromise between the spatial enhancement and the spectral consistency. Here we study the effects of the spectral and spatial distortions on the accuracy in classification of pansharpened imagery. We also study the performance in terms of accuracy of the various pansharpening techniques during classification with spatial information, obtained using mathematical morphology (MM). MM is used to derive local spatial information from the panchromatic data. Random Forests (RF) and Support Vector Machines (SVM) will be used as classifiers. Experiments are done for three different datasets that have been obtained by two different imaging sensors, IKONOS and QuickBird. These sensors deliver multispectral images that have four bands, R, G, B and near infrared (NIR). To further study the contribution of the NIR band, experiments are done using both the RGB bands and all four bands, respectively.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, University of Iceland
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Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 1.548 SNIP 2.008 CiteScore 3.26
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.682 SNIP 2.462 CiteScore 3.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.664 SNIP 2.165 CiteScore 3.33
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.319 SNIP 2.084 CiteScore 2.97
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1

Optical scanning is rapidly becoming ubiquitous. From industrial laser scanners to medical CT, MR and 3D ultrasound scanners, numerous organizations now have easy access to optical acquisition devices that provide huge volumes of image data. However, the raw geometry data acquired must first be processed before it is useful.

This Guide to Computational Geometry Processing reviews the algorithms for processing geometric data, with a practical focus on important techniques not covered by traditional courses on computer vision and computer graphics. This is balanced with an introduction to the theoretical and mathematical underpinnings of each technique, enabling the reader to not only implement a given method, but also to understand the ideas behind it, its limitations and its advantages.

Topics and features:

- Presents an overview of the underlying mathematical theory, covering vector spaces, metric space, affine spaces, differential geometry, and finite difference methods for derivatives and differential equations
- Reviews geometry representations, including polygonal meshes, splines, and subdivision surfaces
- Examines techniques for computing curvature from polygonal meshes
- Describes algorithms for mesh smoothing, mesh parametrization, and mesh optimization and simplification
- Discusses point location databases and convex hulls of point sets
- Investigates the reconstruction of triangle meshes from point clouds, including methods for registration of point clouds and surface reconstruction
- Provides additional material at a supplementary website
- Includes self-study exercises throughout the text

Graduate students will find this text a valuable, hands-on guide to developing key skills in geometry processing. The book will also serve as a useful reference for professionals wishing to improve their competency in this area.

General information

State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Department of Mathematics, Geometry
Authors: Bærentzen, J. A. (Intern), Gravesen, J. (Intern), Anton, F. (Intern), Aanæs, H. (Intern)
Number of pages: 325
Publication date: 2012
Interesting Interest Points: A Comparative Study of Interest Point Performance on a Unique Data Set

Not all interest points are equally interesting. The most valuable interest points lead to optimal performance of the computer vision method in which they are employed. But a measure of this kind will be dependent on the chosen vision application. We propose a more general performance measure based on spatial invariance of interest points under changing acquisition parameters by measuring the spatial recall rate. The scope of this paper is to investigate the performance of a number of existing well-established interest point detection methods. Automatic performance evaluation of interest points is hard because the true correspondence is generally unknown. We overcome this by providing an extensive data set with known spatial correspondence. The data is acquired with a camera mounted on a 6-axis industrial robot providing very accurate camera positioning. Furthermore the scene is scanned with a structured light scanner resulting in precise 3D surface information. In total 60 scenes are depicted ranging from model houses, building material, fruit and vegetables, fabric, printed media and more. Each scene is depicted from 119 camera positions and 19 individual LED illuminations are used for each position. The LED illumination provides the option for artificially relighting the scene from a range of light directions. This data set has given us the ability to systematically evaluate the performance of a number of interest point detectors. The highlights of the conclusions are that the fixed scale Harris corner detector performs overall best followed by the Hessian based detectors and the difference of Gaussian (DoG). The methods based on scale space features have an overall better performance than other methods especially when varying the distance to the scene, where especially FAST corner detector, Edge Based Regions (EBR) and Intensity Based Regions (IBR) have a poor performance. The performance of Maximally Stable Extremal Regions (MSER) is moderate. We observe a relatively large decline in performance with both changes in viewpoint and light direction. Some of our observations support previous findings while others contradict these findings.

General information
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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, University of Copenhagen
Authors: Aanæs, H. (Intern), Dahl, A. L. (Intern), Pedersen, K. S. (Ekstern)
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BFI (2015): BFI-level 2
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.834 SNIP 4.735 CiteScore 6
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ISI indexed (2013): ISI indexed yes
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Scopus rating (2012): SJR 2.315 SNIP 5.445 CiteScore 5.92
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.67 SNIP 5.37 CiteScore 7.45
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 3.055 SNIP 5.827
Multiple View Stereo by Reflectance Modeling

Multiple view stereo is typically formulated as an optimization problem over a data term and a prior term. The data term is based on the consistency of images projected on a hypothesized surface. This consistency is based on a measure denoted a visual metric, e.g. normalized cross correlation. Here we argue that a visual metric based on a surface reflectance model should be founded on more observations than the degrees of freedom (dof) of the reflectance model. If (partly) specular surfaces are to be handled, this implies a model with at least two dof. In this paper, we propose to construct visual metrics of more than one dof using the DAISY methodology, which compares favorably to the state of the art in the experiments carried out. These experiments are based on a novel data set of eight scenes with diffuse and specular surfaces and accompanying ground truth. The performance of six different visual metrics based on the DAISY framework is investigated experimentally, addressing whether a visual metric should be aggregated from a set of minimal images, which dof is best, or whether a combination of one and two dof should be used. Which metric performs best is dependent on the viewed scene, although there are clear tendencies for the two dof minimal metric to be the preferred one.
3D Shape Modeling Using High Level Descriptors

The goal of this Ph.D. project is to investigate and improve the methods for describing the surface of 3D objects, with focus on modeling geometric texture on surfaces. Surface modeling being a large field of research, the work done during this project concentrated around a few smaller areas corresponding to the research papers presented here. One of those areas is formulating surface priors by utilizing local surface properties. A well defined prior can, in a Bayesian framework, assist many common task in geometry processing, like denoising, object recovery, object matching and classification. Some of the priors described here are defined on the main entities of the triangular mesh, vertices, edges and faces. Other priors are defined on small planar patches, denoted surfels. Another area of research deals with textures which cannot be described by height fields, for example biological features like thorns, bark and scales. Presented here is a simple method for easy modeling, transferring and editing that kind of texture. The method is an extension of the height-field texture, but incorporates an additional tilt of the height field. Related to modeling non-heightfield textures, a part of my work involved developing feature-aware resizing of models with complex surfaces consisting of underlying shape and a distinctive texture detail. The aim was to deform an object while preserving the shape and size of the features.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Andersen, V. (Intern), Aanaes, H. (Intern), Bærentzen, J. A. (Intern)
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3D Surface Scanner Using Structured Light & Industrial Robot

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Authors: Stets, J. D. (Intern), Dahl, A. L. (Intern), Aanaes, H. (Intern)
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13107d01.pdf
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Descriptor Based Classification of Shapes in Terms of Style and Function

It seems that great shifts in how human beings use technology often create a push for changes to the way we divide work between human beings and technology. Chemical film has all but disappeared and almost everybody takes digital photos which they proceed to put online for easy sharing with friends and family. Together with a number of other trends which have contributed to the vast amount of online and locally stored digital photos, this has made automatic recognition of people in images an important research topic - in spite of the fact that recognition is one of the tasks generally left to human beings, since we excel at recognition. We believe that recognition of the style of a 3D object is something that is also likely to be increasingly useful in the foreseeable future. Optical scanning methodologies make the generation of 3D content more feasible than previously, and it is easy to envision digital artists wanting to compile content for a 3D scene or
composite object being in need of a method for searching for an object not just of a specific function but also a specific style. The scope broadens further if we look beyond man made objects. It seems clear that, say, the various limbs of a specific human being have some commonality that separate them from those of another person. Thus, one could argue that an individual represents a style. Style in the context of biological variation is something that we explore in the work presented here. Specifically, we investigate whether we can define a style class for the teeth of a person. Unfortunately, style is subtle and we do not hope to be able to automatically extract a description of style from 3D objects. Furthermore, we avoid using explicit ways of describing style. Recognizing the style of an object based on some textual or otherwise encoded information might be a feasible approach in some cases such as, for instance, recognizing to which order a given classical greek column belongs. But, relying on explicit information about a given style would require us either to solve the above problem of automatically extracting style information from shapes or to rely on human beings to encode style - a task that we believe would be both tedious and difficult. Instead, we rely on examples in the work presented here. This requires that we have example (training) objects for each style. It also requires that we have an orthogonal class of functions, since, as we discuss below, the function of the object (what it is) clearly also has a profound impact on shape. Thus, our work can be summed up as example based classification of digital 3D shapes in both style and function categories.

Example based style classification
We address the problem of analysis of families of shapes which can be classified according to two categories: the main one corresponding usually to the coarse shape which we call the function and the more subtle one which we call the style. The style and the function both contribute to the overall shape which makes the general analysis and retrieval of such shapes more challenging. Also there is no single way of defining the style as this depends much on the context of the family of shapes used for the analysis. That is why the definition needs to be given through the examples. The straightforward way of finding the shape descriptors ‘responsible’ for a given category would be to use well known statistical methods and find through them such descriptors with which we are able to classify shapes according to a given category. When a function is dominating this approach might not suffice - we might be unable to find a set descriptors which are independent of a given function. We show how to decouple the effect of the style from that of the function by considering the shapes of the same function but different styles. We also propose a metric coanalysis approach: if two styles are similar this similarity should be reflected across different functions. We show the usability of our methods first on the example of a number of chess sets which our method helps sort. Next, we investigate the problem of finding a replacement for a missing tooth given a database of teeth.
Finding the Best Feature Detector-Descriptor Combination

Addressing the image correspondence problem by feature matching is a central part of computer vision and 3D inference from images. Consequently, there is a substantial amount of work on evaluating feature detection and feature description methodology. However, the performance of the feature matching is an interplay of both detector and descriptor methodology. Our main contribution is to evaluate the performance of some of the most popular descriptor and detector combinations on the DTU Robot dataset, which is a very large dataset with massive amounts of systematic data aimed at two view matching. The size of the dataset implies that we can also reasonably make deductions about the statistical significance of our results. We conclude, that the MSER and Difference of Gaussian (DoG) detectors with a SIFT or DAISY descriptor are the top performers. This performance is, however, not statistically significantly better than some other methods. As a byproduct of this investigation, we have also tested various DAISY type descriptors, and found that the difference among their performance is statistically insignificant using this dataset. Furthermore, we have not been able to produce results collaborating that using affine invariant feature detectors carries a statistical significant advantage on general scene types.

In Depth Analysis of Food Structures: Hyperspectral Subsurface Laser Scattering

In this paper we describe a computer vision system based on SLS (Subsurface Laser Scattering) for industrial food inspection. To obtain high and uniform quality, in for example dairy products like yoghurt and cheese, it is important to monitor the change in size and shape of microscopic particles over time. In this paper we demonstrate the usefulness of our SLS system for characterizing food items. We use a laser source that can be tuned to any wavelength in the range of 455 nm - 1020 nm by applying an AOTF (Acousto-Optical Tunable Filter) to an optical beam generated by a SuperK (supercontinuum) laser system. In our experiments we show how the system can be used for discriminating dairy products with different structure and how the structural change of a foam can be monitored over time. Time stability of the system is essential for measurements over several hours, and we demonstrate the time stability by measuring the reflectance profile of an inorganic phantom. The SLS technique is a very promising technique for non-intrusive food inspection, especially for homogenous products where particle size and shape are important parameters.
Practical indoor mobile robot navigation using hybrid maps

This paper presents a practical navigation scheme for indoor mobile robots using hybrid maps. The method makes use of metric maps for local navigation and a topological map for global path planning. Metric maps are generated as 2D occupancy grids by a range sensor to represent local information about partial areas. The global topological map is used to indicate the connectivity of the 'places-of-interests' in the environment and the interconnectivity of the local maps. Visual tags on the ceiling to be detected by the robot provide valuable information and contribute to reliable localization. The navigation scheme based on the hybrid metric-topological maps is scalable and adaptable since new local maps can be easily added to the global topology, and the method can be deployed with minimum amount of modification if new areas are to be explored. The method is implemented successfully on a physical robot and evaluated in a hospital environment.

General information
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Organisations: Department of Mechanical Engineering, Engineering Design and Product Development, Department of Management Engineering, Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, City College of New York, FORCE Technology
Authors: Özkil, A. G. (Intern), Fan, Z. (Intern), Xiao, J. (Ekstern), Kristensen, J. K. (Ekstern), Dawids, S. (Intern), Christensen, K. H. (Ekstern), Aanæs, H. (Intern)
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Main Research Area: Technical/natural sciences
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Supercontinuum Light Sources for Hyperspectral Subsurface Laser Scattering: Applications for Food Inspection

A materials structural and chemical composition influences its optical scattering properties. In this paper we investigate the use of subsurface laser scattering (SLS) for inferring structural and chemical information of food products. We have constructed a computer vision system based on a supercontinuum laser light source and an Acousto-Optic Tunable Filter (AOTF) to provide a collimated light source, which can be tuned to any wavelength in the range from 480 to 900 nm. We present the newly developed hyperspectral vision system together with a proof-of-principle study of its ability to discriminate between dairy products with either similar chemical or structural composition. The combined vision system is a new way for industrial food inspection allowing non-intrusive online process inspection of parameters that is hard with existing technology.

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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Department of Photonics Engineering, NKT Photonics A/S
Pages: 327-337
Publication date: 2011
Empirical evaluation of a practical indoor mobile robot navigation method using hybrid maps

This video presents a practical navigation scheme for indoor mobile robots using hybrid maps. The method makes use of metric maps for local navigation and a topological map for global path planning. Metric maps are generated as occupancy grids by a laser range finder to represent local information about partial areas. The global topological map is used to indicate the connectivity of the ‘places-of-interests’ in the environment and the interconnectivity of the local maps. Visual tags on the ceiling to be detected by the robot provide valuable information and contribute to reliable localization. The navigation scheme based on the hybrid metric-topological maps saves memory space and is also scalable and adaptable since new local maps can be easily added to the global topology, and the method can be deployed with minimum amount of modification if new areas are to be explored. The video demonstrated that the method is implemented successfully on physical robot in a hospital environment, which provides a practical solution for indoor navigation.

GPU-Boosted Camera-Only Indoor Localization

Localization can be defined as the process of estimating the pose of an agent, given a representation of the environment and sensor input. In this work, we use Topo-metric Appearance Maps to represent the environment, and introduce a new method for localization using only a camera. The method relies on local image features detection, description and matching; by parallelizing these computationally intensive tasks on the graphical processing unit (GPU), it is possible to do online localization using a Topometric Appearance Map. The method is developed as an integral part of a mobile service robot system [1], and empirically evaluated using a real robot in a typical indoor environment.
Image Fusion for Classification of High Resolution Images Based on Mathematical Morphology

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

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Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 271533
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Improved 3D reconstruction in smart-room environments using ToF imaging
This paper presents the use of Time-of-Flight (ToF) cameras in smart-rooms and how this leads to improved results in segmenting the people in the room from the background and consequently better 3D reconstruction of foreground objects. A calibrated rig consisting of one Swissranger SR3100 Time-of-Flight range camera and a high resolution standard CCD camera is set in a smart-room containing five other standard cameras. A probabilistic background model is used to segment each view and a shape from silhouette volume is reconstructed. It is shown that the presence of the range camera gives ways of eliminating regional artifacts and therefore creating a more robust input for higher level applications such as people tracking or human motion analysis.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Polytechnic University of Catalonia, University of Iceland
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Pages: 1376-1384
Publication date: 2010
Main Research Area: Technical/natural sciences
Markov Random Fields on Triangle Meshes
In this paper we propose a novel anisotropic smoothing scheme based on Markov Random Fields (MRF). Our scheme is formulated as two coupled processes. A vertex process is used to smooth the mesh by displacing the vertices according to a MRF smoothness prior, while an independent edge process labels mesh edges according to a feature detecting prior. Since we should not smooth across a sharp feature, we use edge labels to control the vertex process. In a Bayesian framework, MRF priors are combined with the likelihood function related to the mesh formation method. The output of our algorithm is a piecewise smooth mesh with explicit labelling of edges belonging to the sharp features.

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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, University of Copenhagen
Authors: Andersen, V. (Intern), Aanaes, H. (Intern), Bærentzen, J. A. (Intern), Nielsen, M. (Ekstern)
Pages: 265-270
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ISBN (Print): 978-80-86943-87-9
Main Research Area: Technical/natural sciences
On Recall Rate of Interest Point Detectors

In this paper we provide a method for evaluating interest point detectors independently of image descriptors. This is possible because we have compiled a unique data set enabling us to determine if common interest points are found. The data contains 60 scenes of a wide range of object types, and for each scene we have 119 precisely located camera positions obtained from a camera mounted on an industrial robot arm. The scene surfaces have been scanned using structured light, providing precise 3D ground truth. We have investigated a number of the most popular interest point detectors. This is done in relation to the number of interest points, the recall rate as a function of camera position and light variation, and the sensitivity relative to model parameter change. The overall conclusion is that the Harris corner detector has a very high recall rate, but is sensitive to change in scale. The Hessian corners perform overall well followed by MSER (Maximally Stable Extremal Regions), whereas the FAST corner detector, IBR (Intensity Based Regions) and EBR (Edge Based Regions) performs poorly. Furthermore, the repeatability of the corner detectors is quite unaffected by the parameter setting, and only the number of interest points change.

Nye metoder til geobranchen

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Geodesy, National Space Institute
Authors: Aanæs, H. (Intern), Nielsen, A. A. (Intern)
Pages: 14-16
Publication date: 2010
Main Research Area: Technical/natural sciences
Surfel Based Geometry Reconstruction

We propose a method for retrieving a piecewise smooth surface from noisy data. In data acquired by a scanning process sampled points are almost never on the discontinuities making reconstruction of surfaces with sharp features difficult. Our method is based on a Markov Random Field (MRF) formulation of a surface prior, with the surface represented as a collection of small planar patches, the surfels, associated with each data point. The main advantage of using surfels is that we avoid treating data points as vertices. MRF formulation of the surface prior allows us to separately model the likelihood (related to the mesh formation process) and the local surface properties. We chose to model the smoothness by considering two terms: the parallelism between neighboring surfels, and their overlap. We have demonstrated the feasibility of this approach on both synthetical and scanned data. In both cases sharp features were precisely located and planar regions smoothed.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Andersen, V. (Intern), Aanæs, H. (Intern), Bærentzen, J. A. (Intern)
Pages: 39-44
Publication date: 2010

Computer Vision for Timber Harvesting

The goal of this thesis is to investigate computer vision methods for timber harvesting operations. The background for developing computer vision for timber harvesting is to document origin of timber and to collect qualitative and quantitative parameters concerning the timber for efficient harvest planning. The investigations in this thesis is done as initial work on a planning and logistic system for timber harvesting called logTracker. In this thesis we have focused on three methods for the logTracker project, which includes image segmentation, image classification, and image retrieval. Segmentation is to partition an image based on image characteristics and in our study we have focused on image texture. Our segmentation method is inspired by iterative function systems and contractive maps, which makes the basis for both our texture characterization and our method for obtaining the image segments. The purpose of image segmentation is to make the basis for more advanced computer vision methods like object recognition and classification. Our second method concerns image classification and we present a method where we classify small timber samples to tree species based on Active Appearance Models and texture characteristics. The last method is image retrieval based on the so called "bag of visual words" procedure. An image is characterized as a distribution of local image descriptors, which is the basis for effective image search. These methods are described and discussed in relation to the logTracker project and ideas for further development of the system is provided. Building a complete logTracker system is a very demanding task and the conclusion is that it is important to focus on the elements that can bring most value to timber harvest planning. Besides contributing to the development of the logTracker system the described methods have a general applicability making them useful for many other computer vision problems.

General information
Camera Resectioning from a Box

Efficient Incorporation of Markov Random Fields in Change Detection

Many change detection algorithms work by calculating the probability of change on a pixel-wise basis. This is a disadvantage since one is usually looking for regions of change, and such information is not used in pixel-wise classification - per definition. This issue becomes apparent in the face of noise, implying that the pixel-wise classifier is also noisy. There is thus a need for incorporating local homogeneity constraints into such a change detection framework. For this modelling task Markov Random Fields are suitable. Markov Random Fields have, however, previously been plagued by lack of efficient optimization methods or numerical solvers. We here address the issue of efficient incorporation of local homogeneity constraints into change detection algorithms. We do this by exploiting recent advances in graph based algorithms for Markov Random Fields. This is combined with an IR-MAD change detector, and demonstrated on real data with good results.

General information

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Publication date: 2009

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Height and Tilt Geometric Texture

We propose a new intrinsic representation of geometric texture over triangle meshes. Our approach extends the conventional height field texture representation by incorporating displacements in the tangential plane in the form of a normal tilt. This texture representation offers a good practical compromise between functionality and simplicity: it can efficiently handle and process geometric texture too complex to be represented as a height field, without having recourse to full blown mesh editing algorithms. The height-and-tilt representation proposed here is fully intrinsic to the mesh, making texture editing and animation (such as bending or waving) intuitively controllable over arbitrary base mesh. We also provide simple methods for texture extraction and transfer using our height-and-field representation.

Mobile Robot Navigation Using Visual Tags: A Review

In this paper, the need for automated transportation systems for hospitals is investigated. Among other alternatives, mobile robots stand out as the most prominent means of automation of transportation tasks in hospitals. Existing transportation routines of a hospital are analyzed in order to verify the need for automation and identify possible areas of
improvement. The analysis shows that most of the existing transportation is carried out manually, and hospitals can greatly benefit from automated transportation. Based on the results of the analysis, three alternatives are derived for implementing mobile service robots for transportation tasks in hospitals.

**Shape Analysis Using the Auto Diffusion Function**

Scalar functions defined on manifold triangle meshes is a starting point for many geometry processing algorithms such as mesh parametrization, skeletonization, and segmentation. In this paper, we propose the Auto Diffusion Function (ADF) which is a linear combination of the eigenfunctions of the Laplace-Beltrami operator in a way that has a simple physical interpretation. The ADF of a given 3D object has a number of further desirable properties: Its extrema are generally at the tips of features of a given object, its gradients and level sets follow or encircle features, respectively, it is controlled by a single parameter which can be interpreted as feature scale, and, finally, the ADF is invariant to rigid and isometric deformations. We describe the ADF and its properties in detail and compare it to other choices of scalar functions on manifolds. As an example of an application, we present a pose invariant, hierarchical skeletonization and segmentation algorithm which makes direct use of the ADF.
Effective Image Database Search via Dimensionality Reduction

Image search using the bag-of-words image representation is investigated further in this paper. This approach has shown promising results for large scale image collections making it relevant for Internet applications. The steps involved in the bag-of-words approach are feature extraction, vocabulary building, and searching with a query image. It is important to keep the computational cost low through all steps. In this paper we focus on the efficiency of the technique. To do that we substantially reduce the dimensionality of the features by the use of PCA and addition of color. Building of the visual vocabulary is typically done using k-means. We investigate a clustering algorithm based on the leader follower principle (LF-clustering), in which the number of clusters is not fixed. The adaptive nature of LF-clustering is shown to improve the quality of the visual vocabulary using this. In the query step, features from the query image are assigned to the visual vocabulary. The dimensionality reduction enables us to do exact feature labeling using kD-tree, instead of approximate approaches normally used. Despite the dimensionality reduction to between 6 and 15 dimensions we obtain improved results compared to the traditional bag-of-words approach based on 128 dimensional SIFT feature and k-means clustering.

General information
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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Dahl, A. B. (Intern), Aanæs, H. (Intern)
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Main Research Area: Technical/natural sciences
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Bibliographical note
Fusion of stereo vision and Time-Of-Flight imaging for improved 3D estimation

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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Guðmundsson, S. Á. (Intern), Aanæs, H. (Intern), Larsen, R. (Intern)
Pages: 425 - 433
Publication date: 2008
Main Research Area: Technical/natural sciences

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Source-ID: 222805
Publication: Research › Conference article – Annual report year: 2007

Markov Random Fields on 3D Polygonal Meshes

General information
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Organisations: Department of Informatics and Mathematical Modeling, University of Copenhagen
Authors: Andersen, V. (Intern), Aanæs, H. (Intern), Bærentzen, J. A. (Intern), Nielsen, M. (Ekstern)
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Publication date: 2008

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MeshesMRF.pdf
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http://www.diku.dk/publikationer/tekniske.rapporter/rapporter/08-10.pdf
Source: orbit
Source-ID: 227901
Publication: Research › Conference abstract in proceedings – Annual report year: 2008

Model-based satellite image fusion
A method is proposed for pixel-level satellite image fusion derived directly from a model of the imaging sensor. By design, the proposed method is spectrally consistent. It is argued that the proposed method needs regularization, as is the case for any method for this problem. A framework for pixel neighborhood regularization is presented. This framework enables the formulation of the regularization in a way that corresponds well with our prior assumptions of the image data. The proposed method is validated and compared with other approaches on several data sets. Lastly, the intensity-hue-saturation method is revisited in order to gain additional insight of what implications the spectral consistency has for an image fusion method.
In this Paper we present the use of Time-of-Flight (TOF) cameras in Smart rooms and how this leads to improved results in segmenting the people in the room from the background and consequently better 3D reconstruction of the people. A calibrated rig of one Swissranger SR3100 Time-of-flight range camera and a high resolution standard camera is set in a smart-room consisting of 5 other standard cameras. A probabilistic background model is used to segment each view and a shape from silhouette 3D volume is constructed. It is shown that the presence of the range camera gives ways of eliminating regional artifacts and therefore a more robust input for higher level applications such people tracking or human motion analysis.
Classification of Biological Objects Using Active Appearance Modelling and Color Cooccurrence Matrices

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Dahl, A. B. (Intern), Aanæs, H. (Intern), Larsen, R. (Intern), Ersbøll, B. K. (Intern)
Pages: 938-947
Publication date: 2007

Environmental Effects on Measurement Uncertainties of Time-of-Flight Cameras
In this paper the effect the environment has on the SwissRanger SR3000 Time-Of-Flight camera is investigated. The accuracy of this camera is highly affected by the scene it is pointed at: such as the reflective properties, color and gloss. Also the complexity of the scene has considerable effects on the accuracy. To mention a few: the angle of the objects to the emitted light and the scattering effects of near objects. In this paper a general overview of known such inaccuracy factors are described, followed by experiments illustrating the additional uncertainty factors. Specifically we give a better description of how a surface color intensity influences the depth measurement, and illustrate how multiple reflections influence the resulting depth measurement.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Gudmundsson, S. A. (Intern), Aanæs, H. (Intern), Larsen, R. (Intern)
Publication date: 2007

On Spatial Priors for Satellite Image Fusion

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Sveinsson, J. R. (Ekstern), Bøvith, T. (Intern), Benediktsson, J. A. (Ekstern), Nielsen, A. A. (Intern), Gudmundsson, S. A. (Intern)
Publication date: 2007
Smoothing of Fused Spectral Consistent Satellite Images with TV-based Edge Detection

Several widely used methods have been proposed for fusing high resolution panchromatic data and lower resolution multi-channel data. However, many of these methods fail to maintain the spectral consistency of the fused high resolution image, which is of high importance to many of the applications based on satellite data. Additionally, most conventional methods are loosely connected to the image forming physics of the satellite image, giving these methods an ad hoc feel. Vesteinsson et al. [1] proposed a method of fusion of satellite images that is based on the properties of imaging physics in a statistically meaningful way and was called spectral consistent panshapping (SCP). In this paper we improve this framework for satellite image fusion by introducing a better image prior, via data-dependent image smoothing. The dependency is obtained via total variation edge detection method.

Variational Surface Interpolation from Sparse Point and Normal Data.

Variational Surface Interpolation from Sparse Point and Normal Data.
Smoothing of Fused Spectral Consistent Satellite Images.

Several widely used methods have been proposed for fusing high resolution panchromatic data and lower resolution multi-channel data. However, many of these methods fail to maintain spectral consistency of the fused high resolution image, which is of high importance to many of the applications based on satellite data. Additionally, most conventional methods are loosely connected to the image forming physics of the satellite image, giving these methods an ad hoc feel. Vesteinsson et al. (2005) proposed a method of fusion of satellite images that is based on the properties of imaging physics in a statistically meaningful way. The fusion method was called spectral consistent pansharpening (SC) and it was shown that spectral consistency was a direct consequence of imaging physics and hence guaranteed by the SCP. In this paper we exploit this framework and investigate two smoothing methods of the fused image obtained by SCP. The first smoothing method is based on Markov random field (MRF) model, while the second method uses wavelet domain hidden Markov models (HMM) for smoothing of the SCP fused image.

General information

State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Sveinsson, J. (Ekstern), Aanæs, H. (Intern), Benediktsson, J. A. (Ekstern)
Publication date: 2006

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Publisher: IEEE
ISBN (Print): 0-7803-9510-7
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Spectrally consistent satellite image fusion

General information
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Publication date: 2006

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Source: orbit
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2006

Spectrally Consistent Satellite Image Fusion with Improved Image Priors
Here an improvement to our previous framework for satellite image fusion is presented. A framework purely based on the sensor physics and on prior assumptions on the fused image. The contributions of this paper are two fold. Firstly, a method for ensuring 100% spectrally consistency is proposed, even when more sophisticated image priors are applied. Secondly, a better image prior is introduced, via data-dependent image smoothing.

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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Nielsen, A. A. (Intern), Aanæs, H. (Intern), Jensen, T. B. (Intern), Sveinsson, J. (Ekstern), Benediktsson, J. (Ekstern)
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Bibliographical note
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Overlapping Constraint for Variational Surface

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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Overlapping constraint for variational surface reconstruction

In this paper a counter example, illustrating a shortcoming in most variational formulations for 3D surface estimation, is presented. The nature of this shortcoming is a lack of an overlapping constraint. A remedy for this shortcoming is presented in the form of a penalty function with an analysis of the effects of this function on surface motion. For practical purposes, this will only have minor influence on current methods. However, the insight provided in the analysis is likely to influence future developments in the field of variational surface reconstruction.

Signed distance computation using the angle weighted pseudonormal

The normals of closed, smooth surfaces have long been used to determine whether a point is inside or outside such a surface. It is tempting to also use this method for polyhedra represented as triangle meshes. Unfortunately, this is not possible since, at the vertices and edges of a triangle mesh, the surface is not C^0 continuous, hence, the normal is undefined at these loci. In this paper, we undertake to show that the angle weighted pseudonormal (originally proposed by Thurmer and Wuthrich and independently by Sequin) has the important property that it allows us to discriminate between points that are inside and points that are outside a mesh, regardless of whether a mesh vertex, edge, or face is the closest feature. This inside-outside information is usually represented as the sign in the signed distance to the mesh. In effect, our result shows that this sign can be computed as an integral part of the distance computation. Moreover, it provides an additional argument in favor of the angle weighted pseudonormals being the natural extension of the face normals. Apart from the theoretical results, we also propose a simple and efficient algorithm for computing the signed distance to a closed C^0 mesh. Experiments indicate that the sign computation overhead when running this algorithm is almost negligible.
Signed Distance Computation using the Angle Weighted Pseudo-normal

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Spectral Consistent Satellite Image Fusion: Using a High

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Authors: Vesteinsson, A. (Ekstern), Aanæs, H. (Intern), Sveinsson, J. (Ekstern), Benediktsson, J. A. (Ekstern)
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Host publication information
Title of host publication: IGARSS 05
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 185761
Publication: Research - peer-review › Article in proceedings – Annual report year: 2005

A Variational Analysis of Shape from Specularities using Sparse Data

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Solem, J. E. (Ekstern), Aanæs, H. (Intern), Heyden, A. (Ekstern)
Publication date: 2004

Host publication information
Title of host publication: 3D Data Processing, Visualization & Transmission, 3DPVT
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 154667
Publication: Research - peer-review › Article in proceedings – Annual report year: 2004

Methods for Structure from Motion
Structure from motion, the problem of estimating 3D structure from 2D images hereof, is one of the most popular and well studied problems within computer vision. In part because it is academically interesting, but also because it holds a wealth of commercially very interesting prospects, e.g. within entertainment, reverse engineering and architecture. This thesis is a study within this area of structure from motion. The result of the work, which this thesis represents is the development of new methods for addressing some of the problems within the field. Mainly in robustifying the factorization approach, relaxing the rigidity constrains, and in considering alternative ways of solving the surface estimation problem.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Larsen, R. (Intern)
Publication date: Nov 2003

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: imm2822.pdf
PDE Based Shape from Specularities

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Solem, J. E. (Ekstern), Aanæs, H. (Intern), Heyden, A. (Ekstern)
Publication date: 2003

Host publication information
Title of host publication: Scale Space 2003
Main Research Area: Technical/natural sciences
Conference: Scale Space 2003, 01/01/2003
Source: orbit
Source-ID: 200381
Publication: Research - peer-review › Article in proceedings – Annual report year: 2003

PDE Based Surface Estimation for Structure from Motion.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Larsen, R. (Intern), Bærentzen, J. A. (Intern), Bigün et al., J. (ed.) (Ekstern)
Pages: 632-639
Publication date: 2003

Host publication information
Title of host publication: 13th Scandinavian Conference on Image Analysis, Gothenburg, Sweden
Publisher: Springer
Main Research Area: Technical/natural sciences
Conference: 13th Scandinavian Conference in Image Analysis, Gothenburg, Sweden, 29/06/2003 - 29/06/2003
Source: orbit
Source-ID: 58493
Publication: Research - peer-review › Article in proceedings – Annual report year: 2003

Pseudo-Normals for Signed Distance Computation

The face normals of triangular meshes have long been used to determine whether a point is in- or outside of a given mesh. However, since normals are a differential entity they are not defined at the vertices and edges of a mesh. The latter causes problems in general algorithms for determining the relation of a point to a mesh. At the vertices and edges of a triangle mesh, the surface is not $C^1$ continuous. Hence, the normal is undefined at these loci. Thürmer and Wüthrich proposed the angle weighted pseudo-normal as a way to deal with this problem. In this paper, we undertake showing that the angle weighted pseudo-normal has an important property, namely that it allows us to discriminate between points that are inside and points that are outside the mesh. This result is used for proposing a simple and efficient algorithm for computing the signed distance field from a mesh. Moreover, our result is an additional argument for the angle weighted pseudo-normals being the natural extension of the face normals.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Bærentzen, J. A. (Intern)
Publication date: 2003

Host publication information
Title of host publication: Vision, modeling, and visualization 2003, Munich, Germany
Main Research Area: Technical/natural sciences
Conference: Vision, modeling, and visualization 2003, Munich, Germany, 01/01/2003
Structure Estimation and Surface Triangulation of Deformable Objects

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Svensson, C. (Ekstern), Aanæs, H. (Intern), Kahl, F. (Ekstern)
Publication date: 2003

Host publication information
Title of host publication: Scandinavian Conference on Image Analysis
Main Research Area: Technical/natural sciences
Links:

A Factorization Approach for deformable Structure from Motion

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Kahl, F. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: Proceedings of SSAB
Main Research Area: Technical/natural sciences
Links:

Computing discrete signed distance fields from triangle meshes

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Aanæs, H. (Intern)
Publication date: 2002

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
imm1289.pdf
Links:

Estimation of Deformable Structure and Motion

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Factorization with Contaminated Data

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Fisker, R. (Intern), Åström, K. (Ekstern), Carstensen, J. M. (Intern)
Publication date: 2002

Host publication information
Title of host publication: Presentation and abstract at Eleventh International Workshop on Matrices and Statistics, EIWMS-2002, Lyngby, August 29-31
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 58234
Publication: Research › Article in proceedings – Annual report year: 2002

Factorization with Erroneous Data

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Fisker, R. (Intern), Åström, K. (Ekstern), Carstensen, J. M. (Intern)
Number of pages: 8
Publication date: 2002

Host publication information
Title of host publication: Proceedings of Photogrammetric Computer Vision, PCV02, Graz, Austria
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 58145
Publication: Research › Article in proceedings – Annual report year: 2002

Generating Signed Distance Fields From Triangle Meshes

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Aanæs, H. (Intern)
Publication date: 2002

Publication information
Publisher: Informatics and Mathematical Modelling
Original language: English
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Robust factorization

Factorization algorithms for recovering structure and motion from an image stream have many advantages, but they usually require a set of well-tracked features. Such a set is in generally not available in practical applications. There is thus a need for making factorization algorithms deal effectively with errors in the tracked features. We propose a new and computationally efficient algorithm for applying an arbitrary error function in the factorization scheme. This algorithm enables the use of robust statistical techniques and arbitrary noise models for the individual features. These techniques and models enable the factorization scheme to deal effectively with mismatched features, missing features, and noise on the individual features. The proposed approach further includes a new method for Euclidean reconstruction that significantly improves convergence of the factorization algorithms. The proposed algorithm has been implemented as a modification of the Christy-Horaud factorization scheme, which yields a perspective reconstruction. Based on this implementation, a considerable increase in error tolerance is demonstrated on real and synthetic data. The proposed scheme can, however, be applied to most other factorization algorithms.

General information

State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Fisker, R. (Intern), Åström, K. (Ekstern), Carstensen, J. M. (Intern)
Pages: 1215-1225
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information

Journal: IEEE Transactions on Pattern Analysis and Machine Intelligence
Volume: 24
Issue number: 9
ISSN (Print): 0162-8828
Ratings:
  BFI (2018): BFI-level 2
  Web of Science (2018): Indexed yes
  BFI (2017): BFI-level 2
  Web of Science (2017): Indexed Yes
  BFI (2016): BFI-level 2
  Scopus rating (2016): CiteScore 13.59 SJR 6.298 SNIP 6.317
  Web of Science (2016): Indexed yes
  BFI (2015): BFI-level 2
  Scopus rating (2015): SJR 5.357 SNIP 7.658 CiteScore 12.66
  Web of Science (2015): Indexed yes
  BFI (2014): BFI-level 2
  Scopus rating (2014): SJR 4.024 SNIP 7.97 CiteScore 11.05
  BFI (2013): BFI-level 2
  Scopus rating (2013): SJR 4.715 SNIP 8.721 CiteScore 11.8
  ISI indexed (2013): ISI indexed yes
  BFI (2012): BFI-level 2
  Scopus rating (2012): SJR 3.327 SNIP 9.043 CiteScore 10.09
  ISI indexed (2012): ISI indexed yes
  BFI (2011): BFI-level 2
  Scopus rating (2011): SJR 3.207 SNIP 7.189 CiteScore 8.89
  ISI indexed (2011): ISI indexed yes
  BFI (2010): BFI-level 2
  Scopus rating (2010): SJR 3.513 SNIP 7.095
  BFI (2009): BFI-level 2
  BFI (2008): BFI-level 2
  Scopus rating (2008): SJR 3.435 SNIP 7.286
Integrating prior knowledge and structure from motion

A new approach for formulating prior knowledge in structure form motion is presented, where the structure is viewed as a 3D stochastic variable, hereby priors are more naturally expressed. It is demonstrated that this formulation is efficient for regularizing structure reconstruction via prior knowledge. Specifically algorithms for imposing priors in the proposed formulation are presented.

Robust structure and motion

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Aanæs, H. (Intern), Fisker, R. (Intern), Carstensen, J. M. (Intern)
Pages: 1-9
Publication date: 2000
Projects:

**Estimation of Surface Radiometry**
Department of Applied Mathematics and Computer Science
Period: 15/08/2017 → 14/08/2020
Number of participants: 4
Phd Student: Doest, Mads Emil Brix (Intern)
Supervisor: Aanæs, Henrik (Intern)

**Image Synthesis and Analysis of Engineered Surface Microstructure**
Department of Applied Mathematics and Computer Science
Period: 01/05/2017 → 30/04/2020
Number of participants: 4
Phd Student: Falster, Viggo (Intern)
Supervisor: Aanæs, Henrik (Intern)

**The Statistics of Estimated Surfaces**
Department of Applied Mathematics and Computer Science
Period: 01/01/2017 → 31/12/2019
Number of participants: 4
Phd Student: Jensen, Janus Nørtoft (Intern)
Supervisor: Bærentzen, Jakob Andreas (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD
Data analysis methods for process understanding and improvement in injection moulding production

Department of Applied Mathematics and Computer Science
Period: 01/10/2016 → 30/09/2019
Number of participants: 4
Phd Student:
Frumosu, Flavia Dalia (Intern)
Supervisor:
Aanaes, Henrik (Intern)
Tosello, Guido (Intern)
Main Supervisor:
Kulahci, Murat (Intern)

Financing sources
Source: Internal funding (public)

Material Appearance Prediction

Department of Applied Mathematics and Computer Science
Period: 15/12/2015 → 14/12/2018
Number of participants: 3
Phd Student:
Luongo, Andrea (Intern)
Supervisor:
Aanaes, Henrik (Intern)
Main Supervisor:
Frisvad, Jeppe Revall (Intern)

Financing sources
Source: Internal funding (public)

Verification of large scale surface geometry including shape and texture variation of injection molded surfaces

Department of Applied Mathematics and Computer Science
Period: 15/01/2015 → 15/07/2018
Number of participants: 4
Phd Student:
Lyngby, Rasmus Ahrenkiel (Intern)
Supervisor:
Aanaes, Henrik (Intern)
Nielsen, Ewa (Ekstern)
Main Supervisor:
Dahl, Anders Bjorholm (Intern)

Financing sources
Source: Internal funding (public)

Real-time Detection of Deformable Objects

Department of Applied Mathematics and Computer Science
Period: 01/12/2014 → 30/11/2017
Number of participants: 3
Phd Student:
Jensen, Sebastian Hoppe Nesgaard (Intern)
Supervisor:
Kruger, Norbert (Ekstern)
Main Supervisor:
Aanæs, Henrik (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

**Image Base Tracking and 3D Content Generation**
Department of Applied Mathematics and Computer Science
Period: 01/11/2014 → 30/01/2018
Number of participants: 3
Phd Student:
Stets, Jonathan Dyssel (Intern)
Supervisor:
Larsen, Rasmus (Intern)
Main Supervisor:
Aanæs, Henrik (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

**Computer Vision based geometrical and textural control for 3D print and injection moulding processes**
Department of Applied Mathematics and Computer Science
Period: 01/12/2013 → 29/09/2017
Number of participants: 6
Phd Student:
Eiríksson, Eyþór Rúnar (Intern)
Supervisor:
Pedersen, David Bue (Intern)
Main Supervisor:
Aanæs, Henrik (Intern)
Examiner:
Carstensen, Jens Michael (Intern)
Krüger, Norbert (Ekstern)
Taylor, John (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Offentlig finansiering

**Relations**
Publications:
Computer Vision for Additive Manufacturing.
Project: PhD

**A statistical Take on Computer Graphics - Automatic Radiometric Modelling of Real World Objects**
Department of Applied Mathematics and Computer Science
Period: 01/07/2013 → 18/01/2017
Number of participants: 7
Phd Student:
Nielsen, Jannik Boll (Intern)
Supervisor:
Computer Vision Assisted Motion Correction in Medical Imaging
Department of Applied Mathematics and Computer Science
Period: 01/09/2012 → 31/03/2016
Number of participants: 7
Phd Student:
Wilm, Jakob (Intern)
Supervisor:
Højgaard, Liselotte (Intern)
Pausen, Rasmus Reinhold (Intern)
Main Supervisor:
Aanæs, Henrik (Intern)
Examiner:
Carstensen, Jens Michael (Intern)
Vogiatzis, George (Ekstern)
Åström, Kalle (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.

Miljøvenlige, organiske solceller med kontrolleret nanostruktur, baseret på partikler i vandig dispersion
Department of Energy Conversion and Storage
Period: 01/06/2012 → 30/09/2015
Number of participants: 6
Phd Student:
Pedersen, Emil Bøje Lind (Intern)
Supervisor:
Aanæs, Henrik (Intern)
Main Supervisor:
Andreasen, Jens Wenzel (Intern)
Examiner:
Poulsen, Henning Friis (Intern)
Müller, Christian (Ekstern)
Stingelin-Stutzmann, Natalie (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD
Towards Plug-n-Play robot guidance: Advanced 3D sensors and pose estimation in Robotic applications

Department of Applied Mathematics and Computer Science
Period: 01/04/2012 → 12/12/2016
Number of participants: 7
Phd Student:
Sølund, Thomas (Intern)
Supervisor:
Beck, Anders Billesø (Intern)
Kruger, Norbert (Ekstern)
Main Supervisor:
Aanæs, Henrik (Intern)
Examiner:
Carstensen, Jens Michael (Intern)
Gramkow, Claus (Intern)
Kämäräinen, Joni-Kristian (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU

Relations
Publications:
Towards Plug-n-Play robot guidance: Advanced 3D estimation and pose estimation in Robotic applications
Project: PhD

Decoupled visual control for robots based on structured light and weld seam tracking

Engineering Design and Product Development
Department of Management Engineering
Period: 10/03/2010 → 10/03/2011
Number of participants: 4
Project ID: 95-4248-81082
Project participant:
Li, Yuan (Ekstern)
Ravn, Ole (Intern)
Aanæs, Henrik (Intern)
Project Manager, organisational:
Fan, Zhun (Intern)

Financing sources
Source: Forsk. Private danske - Fonde
Name of research programme: Forsk. Private danske - Fonde
Amount: 500,000.00 Danish Kroner
Project

Oprational Shape Desribtors

Department of Informatics and Mathematical Modeling
Period: 01/10/2008 → 21/12/2011
Number of participants: 7
Phd Student:
Welnicka, Katarzyna (Intern)
Supervisor:
Aanæs, Henrik (Intern)
Larsen, Rasmus (Intern)
Main Supervisor:
Bærentzen, Jakob Andreas (Intern)
Examiner:
Conradsen, Knut (Intern)
P. Kobbelt, Leif (Ekstern)
Østergaard, Lasse Riis (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

New AI and its Application in Hospital Service Robotics
Department of Management Engineering
Period: 15/02/2008 → 31/08/2011
Number of participants: 6
Phd Student:
Özkil, Ali Gürcan (Intern)
Supervisor:
Aanæs, Henrik (Intern)
Klaæstrup Kristensen, Jens (Intern)
Main Supervisor:
Fan, Zhun (Intern)
Examiner:
Ravn, Ole (Intern)
Hallqvist, Claes Brylle (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD

3D Shape Modelling using High Level Descriptors
Department of Informatics and Mathematical Modeling
Period: 01/06/2007 → 22/06/2011
Number of participants: 6
Phd Student:
Dahl, Vedrana Andersen (Intern)
Supervisor:
Bærentzen, Jakob Andreas (Intern)
Main Supervisor:
Aanaes, Henrik (Intern)
Examiner:
Paulsen, Rasmus Reinhold (Intern)
Solem, Jan Erik (Ekstern)
Sporring, Jon (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

A Systems Approach to Structure form Motion
Department of Informatics and Mathematical Modeling
Period: 01/06/2007 → 31/07/2009
Number of participants: 3
Phd Student:
Perfanov, Vesselin Kirilov (Intern)
Supervisor:
Aanaes, Henrik (Intern)
Main Supervisor:
Larsen, Rasmus (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

**Godkendelse og sporing af tømmerstokke ved 3D-billedbehandling**
Department of Informatics and Mathematical Modeling
Period: 15/10/2005 → 27/05/2009
Number of participants: 7
Phd Student:
Dahl, Anders Bjorholm (Intern)
Supervisor:
Aanæs, Henrik (Intern)
Tarp-Johansen, Mads Jeppe (Ekstern)
Main Supervisor:
Ersbøll, Bjarne Kjær (Intern)
Examiner:
Hansen, Lars Kai (Intern)
Demirci, M. Fatih (Ekstern)
Sauter, Udo Hans (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD

**Modellering af biologisk diversitet hos grise**
Department of Informatics and Mathematical Modeling
Period: 01/02/2005 → 02/02/2009
Number of participants: 6
Phd Student:
Erbou, Søren Gylling Hemmingsen (Intern)
Supervisor:
Christensen, Lars Bager (Intern)
Main Supervisor:
Ersbøll, Bjarne Kjær (Intern)
Examiner:
Aanæs, Henrik (Intern)
Darvann, Tron Andre (Intern)
Vangen, Odd (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: DTU, Samfinansiering
Project: PhD

**3D/4D image anaysis**
Department of Informatics and Mathematical Modeling
Period: 01/07/2000 → 11/12/2003
Number of participants: 5
Phd Student:
Aanæs, Henrik (Intern)
Main Supervisor:
Larsen, Rasmus (Intern)
Examiner:
Ersbøll, Bjarne Kjær (Intern)
Pollefeys, Marc (Ekstern)
Zhu, Song-Chun (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD