Cache-mesh, a Dynamics Data Structure for Performance Optimization
This paper proposes the cache-mesh, a dynamic mesh data structure in 3D that allows modifications of stored topological relations effortlessly. The cache-mesh can adapt to arbitrary problems and provide fast retrieval to the most-referred-to topological relations. This adaptation requires trivial extra effort in implementation with the cache-mesh, whereas it may require tremendous effort using traditional meshes. The cache-mesh also gives a further boost to the performance with parallel mesh processing by caching the partition of the mesh into independent sets. This is an additional advantage of the cache-mesh, and the extra work for caching is also trivial. Though it appears that it takes effort for initial implementation, building the cache-mesh is comparable to a traditional mesh in terms of implementation.
Multi-phase Volume Segmentation with Tetrahedral Mesh

Volume segmentation is efficient for reconstructing material structure, which is important for several analyses, e.g. simulation with finite element method, measurement of quantitative information like surface area, surface curvature, volume, etc. We are concerned about the representations of the 3D volumes, which can be categorized into two groups: fixed voxel grids [1] and unstructured meshes [2]. Among these two representations, the voxel grids are more popular since manipulating a fixed grid is easier than an unstructured mesh, but they are less efficient for quantitative measurements. In many cases, the voxel grids are converted to explicit meshes, however the conversion may reduce the accuracy of the segmentations, and the effort for meshing is also not trivial. On the other side, methods using unstructured meshes have difficulty in handling topology changes. To reduce the complexity, previous methods only represent the surfaces, thus they only segment a single region without exterior or interior information (e.g. holes). Finally, yet importantly, previous methods of both representations have issues with multi-material segmentation, where vacuum and overlapping between surfaces occur. This paper proposes a method for volume segmentation using a tetrahedral mesh. The compelling advantages of our method include: natural multi-material support; output is tetrahedral mesh that can be utilized for simulation and analysis directly; and the ability to control the resolution for compact meshes. We are also experimenting to prove our advantages on high accuracy; and the potentiality to accompany shape prior information during segmentation.

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.
Cuttable Ruled Surface Strips for Milling

This paper proposes a novel pre-processing method for industrial robotic CNC-milling. The method targets a hybrid machining process, in which the main bulk of material is removed through robotic hot or abrasive wire cutting, after which regular CNC-machining is employed for removal of the remaining material volume. Hereby, the roughing process is significantly sped up, reducing overall machining time. We compare our method to the convex hull and remove between 5% and 75% more material; on most models we obtain a 50% improvement. Our method ensures that no overcutting happens and that the result is cuttable by wire cutting.

Designing for hot-blade cutting: Geometric Approaches for High-Speed Manufacturing of Doubly-Curved Architectural Surfaces

In this paper we present a novel method for the generation of doubly-curved, architectural design surfaces using swept Euler elastica and cubic splines. The method enables a direct design to production workflow with robotic hot-blade cutting, a novel robotic fabrication method under development by authors of the paper, which facilitates high-speed production of doubly-curved foam moulds. Complementary to design rationalisation, in which arbitrary surfaces are translated to hot-blade-cuttable geometries, the presented method enables architects and designers to design directly with the non-trivial constraints of blade-cutting in a bottom-up fashion, enabling an exploration of the unique architectural potential of this fabrication approach. The method is implemented as prototype design tools in MatLAB, C++, GhPython, and Python and demonstrated through cutting of expanded polystyrene foam design examples.
Hot Blade Cuttings for the Building Industries

The constructions of advanced architectural designs are presently very labour intensive, time consuming, and expensive. They are therefore only applied to a few prestige projects, and it is a major challenge for the building industry to bring the costs down and thereby offer the architects more variability in the (economically allowed) designs - i.e., to allow them to think out of the box. To address this challenge The Danish National Advanced Technology Foundation (now InnovationsFonden) is currently supporting the BladeRunner project that involves several Danish companies and public institutions. The project aims to reduce the amount of manual labour as well as production time by applying robots to cut expanded polystyrene (EPS) moulds for the concrete to form doubly curved surfaces. The scheme is based upon the so-called Hot Wire or Hot Blade technology where the surfaces are essentially swept out by driving an Euler elastica through a block of EPS. This paper will be centered around the mathematical challenges encountered in the implementation of this idea. Since the elastica themselves are well known and described in the works of Euler et al. already in eighteenth century, these new challenges are mainly concerned with the rationalization of the architects’ CAD drawings into surfaces that can be created via this particular sweeping and cutting technology.

Improving topology optimization intuition through games

This paper describes the educational game, TopOpt Game, which invites the player to solve various optimization challenges. The main purpose of gamifying topology optimization is to create a supplemental educational tool which can be used to introduce concepts of topology optimization to newcomers as well as to train human intuition of topology optimization. The players are challenged to solve the standard minimum compliance problem in 2D by distributing material in a design domain given a number of loads and supports with a material constraint. A statistical analysis of the gameplay data shows that players achieve higher scores the more they play the game. The game is freely available for the iOS.
platform at Apple's App Store and at http://www.topopt.dtu.dk/?q=node/909 for Windows and OSX.
Interactive Appearance Prediction for Cloudy Beverages

Juice appearance is important to consumers, so digital juice with a slider that varies a production parameter or changes juice content is useful. It is however challenging to render juice with scattering particles quickly and accurately. As a case study, we create an appearance model that provides the optical properties needed for rendering of unfiltered apple juice. This is a scattering medium that requires volume path tracing as the scattering is too much for single scattering techniques and too little for subsurface scattering techniques. We investigate techniques to provide a progressive interactive appearance prediction tool for this type of medium. Our renderings are validated by qualitative and quantitative comparison with photographs. Visual comparisons using our interactive tool enable us to estimate the apple particle concentration of a photographed apple juice.

Interactive directional subsurface scattering and transport of emergent light

Existing techniques for interactive rendering of deformable translucent objects can accurately compute diffuse but not directional subsurface scattering effects. It is currently a common practice to gain efficiency by storing maps of transmitted irradiance. This is, however, not efficient if we need to store elements of irradiance from specific directions. To include changes in subsurface scattering due to changes in the direction of the incident light, we instead sample incident radiance and store scattered radiosity. This enables us to accommodate not only the common distance-based analytical models for subsurface scattering but also directional models. In addition, our method enables easy extraction of virtual point lights for transporting emergent light to the rest of the scene. Our method requires neither preprocessing nor texture parameterization of the translucent objects. To build our maps of scattered radiosity, we progressively render the model from different directions using an importance sampling pattern based on the optical properties of the material. We obtain interactive frame rates, our subsurface scattering results are close to ground truth, and our technique is the first to include interactive transport of emergent light from deformable translucent objects.
Interactive Topology Optimization

Interactivity is the continuous interaction between the user and the application to solve a task. Topology optimization is the optimization of structures in order to improve stiffness or other objectives. The goal of the thesis is to explore how topology optimization can be used in applications in an interactive and intuitive way. By creating such applications with an intuitive and simple user interface we allow non-engineers like designers and architects to easily experiment with boundary conditions, design domains and other optimization settings. This is in contrast to commercial topology optimization software where the users are assumed to be well-educated both in the finite element method and topology optimization.
This dissertation describes how various topology optimization methods have been used for creating cross-platform applications with high performance. The user interface design is based on theory of from human-computer interaction which is described in Chapter 2. Followed by a description of the foundations of topology optimization in Chapter 3. Our applications for topology optimization in 2D and 3D are described in Chapter 4 and a game which trains the human intuition of topology optimization is presented in Chapter 5. Topology optimization can also be used as an interactive modeling tool with local control which is presented in Chapter 6. Finally, Chapter 7 contains a summary of the findings and concludes the dissertation.

Most of the presented applications of the thesis are available at: http://www.topopt.dtu.dk.
Robotic Hot-Blade Cutting: An Industrial Approach to Cost-Effective Production of Double Curved Concrete Structures

This paper presents a novel method for cost-effective, robotic production of double curved formwork in Expanded Polystyrene (EPS) for in situ and prefabricated concrete construction. A rationalization and segmentation procedure is developed, which allows for the transfinite bending of double curved NURBS surfaces to Euler elastica surface segments, while respecting various constraints of production. An 18 axis, tri-robot system approximates double curved NURBS surfaces by means of an elastically deformed and heated blade, mounted on the flanges of two manipulators. Re-orienting or translating either end of the blade dynamically deforms the blade’s curvature. The blade follows the contours of the rationalized surface by continuous change in position and orientation of the end-effectors. The concept’s potential is studied by a pilot production of a full-scale demonstrator panel assembly.

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.
3D interactive topology optimization on hand-held devices

This educational paper describes the implementation aspects, user interface design considerations and workflow potential of the recently published TopOpt 3D App. The app solves the standard minimum compliance problem in 3D and allows the user to change design settings interactively at any point in time during the optimization. Apart from its educational nature, the app may point towards future ways of performing industrial design. Instead of the usual geometrize, then model and optimize approach, the geometry now automatically adapts to the varying boundary and loading conditions. The app is freely available for iOS at Apple’s App Store and at http://www.topopt.dtu.dk/TopOpt3D for Windows and OSX.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Department of Mechanical Engineering, Solid Mechanics, University of Tokyo
Authors: Nobel-Jørgensen, M. (Intern), Aage, N. (Intern), Christiansen, A. N. (Intern), Igarashi, T. (Ekstern), Bærentzen, J. A. (Intern), Sigmund, O. (Intern)
Number of pages: 7
Pages: 1385-1391
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Structural and Multidisciplinary Optimization
Volume: 51
Issue number: 6
ISSN (Print): 1615-147X
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.14
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.42
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.86
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.08
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.85
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Web of Science (2008): Indexed yes
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Web of Science (2005): Indexed yes
Web of Science (2004): Indexed yes
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Web of Science (2001): Indexed yes
Web of Science (2000): Indexed yes
Original language: English
Interactive, Smartphones, Tablets, Topology optimization, Product design, Regulatory compliance, Shape optimization, Topology, User interfaces, Educational papers, Hand-held devices, Implementation aspects, Loading condition, Minimum compliance, User interface designs, Loading
Combined Shape and Topology Optimization

Shape and topology optimization seeks to compute the optimal shape and topology of a structure such that one or more properties, for example stiffness, balance or volume, are improved. The goal of the thesis is to develop a method for shape and topology optimization which uses the Deformable Simplicial Complex (DSC) method. Consequently, we present a novel method which combines current shape and topology optimization methods. This method represents the surface of the structure explicitly and discretizes the structure into non-overlapping elements, i.e. a simplicial complex. An explicit surface representation usually limits the optimization to minor shape changes. However, the DSC method uses a single explicit representation and still allows for large shape and topology changes. It does so by constantly applying a set of mesh operations during deformations of the structure. Using an explicit instead of an implicit representation gives rise to several advantages including straightforward modeling of the surface, improved scalability and ability to optimize multiple materials.

This dissertation describes the essential parts of the novel method for combined shape and topology optimization. This includes the structural analysis in Chapter 2, the optimization in Chapter 3 and the Deformable Simplicial Complex method in Chapter 4. Finally, four applications of the developed method are presented in the included papers and summarized in Chapter 5.
Interactive Global Illumination Effects Using Deterministically Directed Layered Depth Maps

A layered depth map is an extension of the well-known depth map used in rasterization. Multiple layered depth maps can be used as a coarse scene representation. We develop two global illumination methods which use said scene representation. The first is an interactive ambient occlusion method. The second is an interactive single-bounce indirect lighting method based on photon differentials. All of this is implemented in a rasterization-based pipeline.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Technical University of Denmark
Authors: Aalund, F. P. (Ekstern), Frisvad, J. R. (Intern), Bærentzen, J. A. (Intern)
Number of pages: 12
Publication date: 2015

Host publication information
Title of host publication: Proceedings of the 26th Eurographics Symposium on Rendering - Experimental Ideas and Implementations (EGSR-EI&I 2015)
Publisher: Eurographics Association
Editors: Lehtinen, J., Nowrouzezahrai, D.
Main Research Area: Technical/natural sciences
Conference: 26th Eurographics Symposium on Rendering - Experimental Ideas and Implementations (EGSR-EI&I 2015), Darmstadt, Germany, 24/06/2015 - 24/06/2015
Electronic versions: DeterministicallyDirectedLDMs.pdf
DOIs: 10.2312/sre.20151170

Bibliographical note
http://dx.doi.org/10.2312/sre.20151170<br/>As required by the Eurographics Exclusive License Form, a note has been inserted in the attached pdf (bottom left corner of the first page) so that it can be posted in "employer's website/repository".
Source: PublicationPreSubmission
Source-ID: 112535610
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Advising students in technical projects - recognizing problem scenarios
In this paper, we consider the advisor’s role during the technical work and the thesis preparation for a student in the final phase of a course of study in an engineering education. We initially claim that there is a marked difference between the learning that takes place in regular course work and the learning ensuing from project work. Concrete differences include that
• unlike the a-priori fixed curriculum of regular courses, an important aspect of a project is to define and scientifically formulate the problem itself, in which the student is to be engaged.
• projects are carried out individually or in very small groups. For an interesting project, the precise outcome cannot be known in advance.
• The flexible and individual nature of each project requires that time must be carefully divided and managed between defining the problem, seeking information, implementing solutions and presenting results.
While students work hard during projects and advisors will do their best to support the students’ activities, it is not uncommon that a student fails to meet either his or her own expectations and/or those of the advisor. Occasionally, this is true also of students who perform brilliantly in regular courses. The goal of this paper is to relate the authors’ experiences and investigations into the project advisory process and to provide recommendations for other engineering educators.
After an initial discussion of a typical engineering project advisory process, we review a number of representative projects (abstracted and anonymized) and analyze conditions under which a failure to meet or match expectations is likely to arise. This leads us to a small number of scenarios, where a student is likely to under-perform. Common to these scenarios is a lack of balance between the necessary activities in an engineering project. As our main contribution, we investigate and categorize these imbalances leading to the aforementioned scenarios. Finally, we distill suggestions for best project advisory practices.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Toronto
Authors: Bærentzen, J. A. (Intern), Singh, K. (Ekstern)
Number of pages: 10
Publication date: 2014
Automatic balancing of 3D models

3D printing technologies allow for more diverse shapes than are possible with molds and the cost of making just one single object is negligible compared to traditional production methods. However, not all shapes are suitable for 3D print. One of the remaining costs is therefore human time spent on analyzing and editing a shape in order to ensure that it is fit for production. In this paper, we seek to automate one of these analysis and editing tasks, namely improving the balance of a model to ensure that it stands. The presented method is based on solving an optimization problem. This problem is solved by creating cavities of air and distributing dense materials inside the model. Consequently, the surface is not deformed. However, printing materials with significantly different densities is often not possible and adding cavities of air is often not enough to make the model balance. Consequently, in these cases, we will apply a rotation of the object which only deforms the shape a little near the base. No user input is required but it is possible to specify manufacturing constraints related to specific 3D print technologies. Several models have successfully been balanced and printed using both polyjet and fused deposition modeling printers.
Interactive Shape Modeling using a Skeleton-Mesh Co-Representation

We introduce the Polar-Annular Mesh representation (PAM). A PAM is a mesh-skeleton co-representation designed for the modeling of 3D organic, articulated shapes. A PAM represents a manifold mesh as a partition of polar (triangle fans) and annular (rings of quads) regions. The skeletal topology of a shape is uniquely embedded in the mesh connectivity of a PAM, enabling both surface and skeletal modeling operations, interchangeably and directly on the mesh itself. We develop an algorithm to convert arbitrary triangle meshes into PAMs as well as techniques to simplify PAMs and a method to convert a PAM to a quad-only mesh. We further present a PAM-based multi-touch sculpting application in order to demonstrate its utility as a shape representation for the interactive modeling of organic, articulated figures as well as for editing and posing of pre-existing models.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Toronto
Authors: Bærentzen, J. A. (Intern), Abdrashitov, R. (Ekstern), Singh, K. (Ekstern)
Number of pages: 10
Publication date: 2014
BFI conference series: International Conference on Computer Graphics and Interactive Techniques (5000583)
Main Research Area: Technical/natural sciences

Publication information
Journal: ACM Transactions on Graphics
Volume: 33
Issue number: 4
Article number: 132
ISSN (Print): 0730-0301
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.69 SJR 2.45 SNIP 2.496
Web of Science (2016): Indexed Yes
BFI (2015): BFI-level 2
Multiphase Image Segmentation Using the Deformable Simplicial Complex Method

The deformable simplicial complex method is a generic method for tracking deformable interfaces. It provides explicit interface representation, topological adaptivity, and multiphase support. As such, the deformable simplicial complex method can readily be used for representing active contours in image segmentation based on deformable models. We show the benefits of using the deformable simplicial complex method for image segmentation by segmenting an image into a known number of segments characterized by distinct mean pixel intensities.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Statistics and Data Analysis, Image Analysis & Computer Graphics
Authors: Dahl, V. A. (Intern), Christiansen, A. N. (Intern), Bærentzen, J. A. (Intern)
Pages: 1002-1007
Publication date: 2014
On the Benefits of Stereo Graphics in Virtual Obstacle Avoidance Tasks

In virtual reality, stereo graphics is a very common way of increasing the level of perceptual realism in the visual part of the experience. However, stereo graphics comes at cost, both in technical terms and from a user perspective. In this paper, we present the preliminary results of an experiment to see if stereo makes any quantifiable, statistically significant difference in the ability to avoid collisions with virtual obstacles while navigating a 3-D space under constant acceleration. Our results indicate that for this particular application scenario, stereo does provide a significant benefit in terms of the amount of time that participants were able to avoid obstacles.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Aalborg University
Authors: Bærentzen, J. A. (Intern), Stenholt, R. (Ekstern)
Number of pages: 2
Pages: 231-232
Publication date: 2014

Topology optimization using an explicit interface representation

We introduce the Deformable Simplicial Complex method to topology optimization as a way to represent the interface explicitly yet being able to handle topology changes. Topology changes are handled by a series of mesh operations, which also ensures a well-formed mesh. The same mesh is therefore used for both finite element calculations and shape representation. In addition, the approach unifies shape and topology optimization in a complementary optimization strategy. The shape is optimized on the basis of the gradient-based optimization algorithm MMA whereas holes are introduced using topological derivatives. The presented method is tested on two standard minimum compliance problems which demonstrates that it is both simple to apply, robust and efficient.
General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Department of Mechanical Engineering, Solid Mechanics
Authors: Christiansen, A. N. (Intern), Nobel-Jørgensen, M. (Intern), Aage, N. (Intern), Sigmund, O. (Intern), Bærentzen, J. A. (Intern)
Pages: 387-399
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Journal: Structural and Multidisciplinary Optimization
Volume: 49
Issue number: 3
ISSN (Print): 1615-147X
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.14
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.42
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.86
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.08
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.85
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Web of Science (2008): Indexed yes
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Web of Science (2005): Indexed yes
Web of Science (2004): Indexed yes
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Web of Science (2001): Indexed yes
Web of Science (2000): Indexed yes
Original language: English

Topology optimization, Topological derivative, Non-parametric shape optimization, Explicit interface representation, Deformable simplicial complex method
Improving Topology Optimization using Games

Topology optimization has had, and still has, a great impact on the design of structures and mechanical elements. Even though computers and topology optimization algorithms are able to find good solutions to most problems, it is also important for users of such programs to have a good intuition for whether a structure is optimal. We hypothesize that human intuition regarding topology optimization is often led astray. Our goal is to collect data in order to test this hypothesis and at the same time to actively train users (in particular students of mechanical engineering) in designing optimal structures. Consequently, we have created a game, the TopOptGame, which improves the player's topology optimization intuition in a fun and engaging way while collecting data about the users performance.

Technically, the TopOptGame builds on the TopOptApp [1] - an interactive topology optimization application designed for hand-held devices. The TopOptApp solves the 2D minimum compliance problem with interactive control of loads, supports and volume fraction, and thus the TopOptApp allows the user to change the problem on the y and watch the design evolve to a new optimum in real time. TopOptApp is available free of charge on iOS and Android devices.

The TopOptGame is inspired by puzzle-games (a genre of computer games), which constantly challenges the players and gives rewards when progress is made. This engagement loop will take the player on a journey starting with simple problems with few supports and a single load and gradually increase the difficulty by adding more loads, restrictions on the design domain, distributed loads and multiple load cases. The goal is to distribute material in a discretized design domain, under some volume and time constraints, while searching for a good solution (minimum compliance). A visualization of the strain energy density will help the player finding a feasible solution.

Besides training the player in topology optimization, the game also tracks the progress of each player and sends this progress in anonymized form to a database. When enough data has been collected, this will allow us to analyze the data to measure human performance of topology optimization and more importantly, in which cases people's intuition succeed or fail.

The game is currently a working prototype and is scheduled for final release on both iOS and Android before WCSMO-10.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Department of Mechanical Engineering, Solid Mechanics
Authors: Nobel-Jørgensen, M. (Intern), Christiansen, A. N. (Intern), Bærentzen, J. A. (Intern), Aage, N. (Intern), Sigmund, O. (Intern)
Number of pages: 2
Publication date: 2013
Event: Abstract from 10th World Congress on Structural and Multidisciplinary Optimization, Orlando, FL, United States.
Main Research Area: Technical/natural sciences
Electronic versions: 5106.pdf
Source: dtu
Source-ID: u::8565
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2013

Multiphase Flow of Immiscible Fluids on Unstructured Moving Meshes

In this paper, we present a method for animating multiphase flow of immiscible fluids using unstructured moving meshes. Our underlying discretization is an unstructured tetrahedral mesh, the deformable simplicial complex (DSC), that moves with the flow in a Lagrangian manner. Mesh optimization operations improve element quality and avoid element inversion. In the context of multiphase flow, we guarantee that every element is occupied by a single fluid and, consequently, the interface between fluids is represented by a set of faces in the simplicial complex. This approach ensures that the underlying discretization matches the physics and avoids the additional book-keeping required in grid-based methods where multiple fluids may occupy the same cell. Our Lagrangian approach naturally leads us to adopt a finite element approach to simulation, in contrast to the finite volume approaches adopted by a majority of fluid simulation techniques that use tetrahedral meshes. We characterize fluid simulation as an optimization problem allowing for full coupling of the pressure and velocity fields and the incorporation of a second-order surface energy. We introduce a preconditioner based on the diagonal Schur complement and solve our optimization on the GPU. We provide the results of parameter studies as well as a performance analysis of our method, together with suggestions for performance optimization.
Pond of Illusion: Interacting through Mixed Reality

Pond of Illusion is a mixed reality installation where a virtual space (the pond) is injected between two real spaces. The users are in either of the real spaces, and they can see each other through windows in the virtual space as illustrated in Figure 1(left). The installation attracts people to a large display in either of the real spaces by allowing them to feed virtual fish swimming in the pond. Figure 1(middle) shows how a Microsoft Kinect mounted on top of the display is used for detecting throw motions, which triggers virtual breadcrumbs to be thrown into the pond for feeding the nearby fish. Of course, the fish may not be available because they are busy eating what people have thrown into the pond from the other side.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics
Authors: Nobel-Jørgensen, M. (Intern), Nielsen, J. B. (Intern), Larsen, A. B. L. (Intern), Olsen, M. D. (Intern), Frisvad, J. R. (Intern), Bærentzen, J. A. (Intern)
Number of pages: 1
Publication date: 2013

Host publication information
Title of host publication: Proceedings of SIGGRAPH Asia 2013 Posters
Publisher: Association for Computing Machinery
Article number: 26
ISBN (Print): 978-1-4503-2634-6
BFI conference series: International Conference on Computer Graphics and Interactive Techniques (5000583)
Main Research Area: Technical/natural sciences
DOIs: 10.1145/2542302.2542334

Bibliographical note
Poster abstract.
Source: dtu
Source-ID: n:oai:DTIC-ART:acm/426516734::34909
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2013

PorkCAD: Case study of the design of a pork product prototyper

With the help of industry experts we developed porkCAD, an application intended to aid in the communication process between producer and retailer when developing new meat products for a constantly evolving market. The application interface allows the user to make planar cuts to a virtual pig formed from CT-scans of a real-world pig carcass. We present a case study of the design process from conceptualization to intended introduction into the work flow of a meat production company. We discuss critical design decisions during development and present perspectives for future development.

To determine the usability of porkCAD, we tested it with personnel from the pork industry, using two different controller interfaces, one being a traditional mouse and keyboard input, and the other a six degrees of freedom haptic feedback device. The accurate depiction of pig anatomy guided trained professionals to re-create standardized pig products using porkCAD. The quantitative results of the usability test with sales personnel did not lean significantly in favor of either interface.

Since one interface was extremely well known and the other highly unfamiliar, the fact that users did not express a clear preference for the known input modality is deemed important. We report on the observed user experience regarding the two interfaces.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Cognitive Systems, Statistics and Data Analysis, University of Tokyo, Danish Technological Institute
Authors: Laursen, L. F. (Intern), Bærentzen, J. A. (Intern), Igarashi, T. (Ekstern), Petersen, M. K. (Intern), Clemmensen, L. K. H. (Intern), Erbsløb, B. K. (Intern), Christensen, L. B. (Ekstern)
Number of pages: 12
Pages: 1134-1
Publication date: 2013

Host publication information
Title of host publication: Proceedings of IASDR 2013
Topology Optimization using an Explicit Interface Representation

Current methods for topology optimization primarily represent the interface between solid and void implicitly on fixed grids. In contrast, shape optimization methods represent the interface explicitly, but do not allow for any topological changes to the structure. Using an explicit interface representation has a number of advantages as described below. Consequently, we propose to use the Deformable Simplicial Complex (DSC) method [1] which represents the interface explicitly as one or more closed piecewise linear curves in 2D.

As opposed to pure shape optimization methods, the DSC method is able to handle topology changes. It does so by discretizing the entire design domain into an irregular adaptive triangle mesh and thereby explicitly representing both the structure and the embedding space. In other words, the entire design domain is divided into triangles, where the interface is represented as piecewise linear curves between void and non-void triangles.

Another advantage of the DSC method is that we can exploit the triangle mesh for the FEM computations used in the optimization procedure. The non-void elements define the structure and their deformation is described by second order shape functions. To increase performance, degrees of freedom associated with void triangles are eliminated from the FE equation. Using the triangle mesh for computations is possible since the DSC method ensures a mesh with no degenerate elements. If the mesh contained degenerate or close to degenerate elements the FEM computations would break down and the results would no longer be valid. The DSC method solves this issue by a series of mesh operations which keeps the mesh ever well-formed. Put another way, the consequence of using a well-formed adaptive mesh is that the representation for the FEM calculations and the shape of the structure can be one and the same.

In addition to unifying calculations and representation of the structure, the approach also unifies shape and topology optimization into a single framework. Furthermore, it combines the two in a simultaneous optimization strategy. Here, the shape is optimized on the basis of the gradient based optimization algorithm Method of Moving Asymptotes whereas holes are introduced using topological derivatives. Since we combine these methods, and since FEM calculations are performed only on non-void triangles and gradients are calculated only for the interface nodes, the presented approach is efficient.

An explicit representation is not just useful when considering simplicity and performance. In many cases, the explicitly represented interface is necessary to be able to model a problem. For example for ow or electromagnetic problems with localized boundary effects. Furthermore, control of boundary smoothness is simple to implement and can e.g. be used to control fillet radius at corners. The method also opens up for the opportunity to apply other local constraints, such as min/max length scale of the structure. Finally, the explicit interface is in all cases necessary when interpreting the final design. The status of the work is that the method has been developed and is showing promising results. For instance, the cantilever beam problem has been solved to a high precision using a fine discretization by evaluating the objective function approximately 500 times. This took around 100 seconds on an ordinary laptop utilizing a single thread. In addition, a coarse solution to the same problem has been obtained in approximately 10 seconds.
synthesis has been a relatively unexplored topic. In effect, this makes texture synthesis supervised rather than fully automatic.

In this technical paper, we propose automatic parameter optimization methods for example based texture synthesis. We cover research to directly estimate specific texture synthesis parameters, such as patch size and iteration convergence, based on input textures. We also examine various similarity measures and evaluate their effectiveness. The goal for each measure is to properly evaluate how well the resulting synthesis compares to the original input.

A good similarity measure will enable the search for the optimal texture synthesis parameters by maximizing the quality of the synthesis as a function of parameters.

We apply presented methods to a state of the art texture synthesis algorithm, namely the one proposed by Kopf et al [14]. It is easy to find a set of exemplars for which there is no single optimal set of settings. The results show a promising foundation for further research in establishing an automated optimal synthesis for a multitude of textures.

**General information**

State: Published
Organisations: Department of Informatics and Mathematical Modeling, DTU Data Analysis, Image Analysis and Computer Graphics
Authors: Laursen, L. F. (Intern), Clemmensen, L. K. H. (Intern), Bærentzen, J. A. (Intern), Igarashi, T. (Ekstern), Ersbøll, B. K. (Intern)
Number of pages: 31
Publication date: 2012

**Publication information**

Place of publication: Kongens Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English

Number: 2012-07
ISSN: 1601-2321
Main Research Area: Technical/natural sciences
Publication: Research › Report – Annual report year: 2012

**Converting skeletal structures to quad dominant meshes**

We propose the Skeleton to Quad-dominant polygonal Mesh algorithm (SQM), which converts skeletal structures to meshes composed entirely of polar and annular regions. Both types of regions have a regular structure where all faces are quads except for a single ring of triangles at the center of each polar region. The algorithm produces high quality meshes which contain irregular vertices only at the poles or where several regions join. It is trivial to produce a stripe parametrization for the output meshes which also lend themselves well to polar subdivision. After an initial description of SQM, we analyze its properties, and present two extensions to the basic algorithm: the first ensures that mirror symmetry is preserved by the algorithm, and the second allows for objects of non-spherical topology.

**General information**

State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Misztal, M. K. (Intern), Welnicka, K. (Intern)
Pages: 555-561
Publication date: 2012
Conference: Shape Modeling International Conference, SMI 2012, College Station, TX, United States, 22/05/2012 - 22/05/2012
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Computers & Graphics
Volume: 36
Issue number: 5
ISSN (Print): 0097-8493
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.476 SNIP 1.113 CiteScore 1.63
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Methods for procedural modelling tend to be designed either for organic objects, which are described well by skeletal structures, or for man-made objects, which are described well by surface primitives. Procedural methods, which allow for modelling of both kinds of objects, are few and usually of greater complexity. Consequently, there is a need for a simple, general method which is capable of generating both types of objects. Generic Graph Grammar has been developed to address this need. The production rules consist of a small set of basic productions which are applied directly onto primitives in a directed cyclic graph. Furthermore, the basic productions are chosen such that Generic Graph Grammar seamlessly combines the capabilities of L-systems to imitate biological growth (to model trees, animals, etc.) and those of split grammars to design structured objects (chairs, houses, etc.). This results in a highly expressive grammar capable of generating a wide range of types of models. Models which consist of skeletal structures or surfaces or any combination of these. Besides generic modelling capabilities, the focus has also been on usability, especially userfriendliness and efficiency. Therefore several steps have been taken to simplify the workflow as well as to make the modelling scheme interactive. As proof of concept, a generic procedural modelling tool based on Generic Graph Grammar has been developed.
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.
Multiphase flow of immiscible fluids on unstructured moving meshes

In this paper, we present a method for animating multiphase flow of immiscible fluids using unstructured moving meshes. Our underlying discretization is an unstructured tetrahedral mesh, the deformable simplicial complex (DSC), that moves with the flow in a Lagrangian manner. Mesh optimization operations improve element quality and avoid element inversion. In the context of multiphase flow, we guarantee that every element is occupied by a single fluid and, consequently, the interface between fluids is represented by a set of faces in the simplicial complex. This approach ensures that the underlying discretization matches the physics and avoids the additional book-keeping required in grid-based methods where multiple fluids may occupy the same cell. Our Lagrangian approach naturally leads us to adopt a finite element approach to simulation, in contrast to the finite volume approaches adopted by a majority of fluid simulation techniques that use tetrahedral meshes. We characterize fluid simulation as an optimization problem allowing for full coupling of the pressure and velocity fields and the incorporation of a second-order surface energy. We introduce a preconditioner based on the diagonal Schur complement and solve our optimization on the GPU. We provide the results of parameter studies as well as a performance analysis of our method.

Realistic Virtual Cuts

Pigs and pig meat are major sources of income for Denmark. As one of the country's primary exports, it is no wonder that Denmark strives to maintain its competitive edge in the meat market. As part of an on-going effort to lower costs and maintain high standards, X-ray computed tomography (CT), along with image analysis, is being deployed in Danish abattoirs. The data made available from scanning pig carcasses paves the way for new means to optimize the production process.

This thesis is concerned with the development of a communication tool intended to make use of the aforementioned technology in the product prototyping process. In broad terms, the focus can be divided into two areas of focus: visualization and interaction.

Visualizing volume data, obtained via CT-scanning, is a common area of research within other areas of research, e.g. for medical applications. The availability of graphics processing units, and the subsequent programmability of the unit, has allowed for computationally heavy visualization algorithms to execute in real-time. Despite the flexibility of modern GPUs, their architecture still poses problems that require further study. The thesis presents research within the area of texture synthesis and data interpolation in an effort to create even more realistic volume data visualization.

The potential advantages provided by volume data, is exponentially expanded when we are free to interact with it. The food industry sees a significant benefit in volume interaction when concerned with product development. Product earnings projection, product specifications, and interactive training are just a few of the applicable areas. In this thesis we present an interaction method intended for the commercial development of meat product prototypes. The interaction method is evaluated in a thorough usability study with eight volunteer participants from the target user group.

This thesis presents technology and research which, combined with the advent of using CT in the abattoir, paves the way for new possibilities and advantages when designing meat product prototypes. I have no doubt that this is just the tip of the iceberg in regards to modernizing and optimizing the way animal carcasses are processed and handled before becoming consumer goods.
Real-Time Rendering of Teeth with No Preprocessing

We present a technique for real-time rendering of teeth with no need for computational or artistic preprocessing. Teeth constitute a translucent material consisting of several layers: a highly scattering material (dentine) beneath a semitransparent layer (enamel) with a transparent coating (saliva). In this study we examine how light interacts with this multilayered structure. In the past, rendering of teeth has mostly been done using image-based texturing or volumetric scans. We work with surface scans and have therefore developed a simple way of estimating layer thicknesses. We use scattering properties based on measurements reported in the optics literature, and we compare rendered results qualitatively to images of ceramic teeth created by denturists.

Registration-based Interpolation Real-Time Volume visualization

We present a technique for real-time interpolation of volumetric data with no need for preprocessing. Volumetric data consists of a 3D grid of values, and in this study we examine how light interacts with this structure. In the past, interpolation of volumetric data has mostly been done using image-based texturing or volumetric scans. We work with surface scans and have therefore developed a simple way of estimating layer thicknesses. We use scattering properties based on measurements reported in the optics literature, and we compare rendered results qualitatively to images of ceramic teeth created by denturists.
We present a novel, topology-adaptive method for deformable interface tracking, called the Deformable Simplicial Complex (DSC). In the DSC method, the interface is represented explicitly as a piecewise linear curve (in 2D) or surface (in 3D) which is a part of a discretization (triangulation/tetrahedralization) of the space, such that the interface can be retrieved as a set of faces separating triangles/tetrahedra marked as inside from the ones marked as outside (so it is also given implicitly). This representation allows robust topological adaptivity and, thanks to the explicit representation of the interface, it suffers only slightly from numerical diffusion. Furthermore, the use of an unstructured grid yields robust adaptive resolution. Also, topology control is simple in this setting. We present the strengths of the method in several examples: simple geometric flows, fluid simulation, point cloud reconstruction, and cut locus construction.
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), Aanæs, H. (Intern), Bærentzen, J. A. (Intern)
Number of pages: 139
Publication date: 2011

Publication information
Place of publication: Kgs. Lyngby, Denmark
Publisher: Technical University of Denmark, DTU Informatics, Building 321
Original language: English

Series: IMM-PHD-2011
Number: 233
ISSN: 0909-3192
Main Research Area: Technical/natural sciences
Electronic versions: phd233_va-m.pdf
Source: orbit
Anisotropic 3D texture synthesis with application to volume rendering

We present a novel approach to improving volume rendering by using synthesized textures in combination with a custom transfer function. First, we use existing knowledge to synthesize anisotropic solid textures to fit our volumetric data. As input to the synthesis method, we acquire high quality images using a 12.1 megapixel camera. Next, we extend the volume rendering pipeline by creating a transfer function which yields not only color and opacity from the input intensity, but also texture coordinates for our synthesized 3D texture. Thus, we add texture to the volume rendered images. This method is applied to a high quality visualization of a pig carcass, where samples of meat, bone, and fat have been used to produce the anisotropic 3D textures.

Cut Locus Construction using Deformable Simplicial Complexes

In this paper we present a method for approximating cut loci for a given point $p$ on Riemannian 2D manifolds, closely related to the notion of Voronoi diagrams. Our method finds the cut locus by advecting a front of points equally distant from $p$ along the geodesics originating at $p$ and finding the lines of self-intersections of the front in the parametric space. This becomes possible by using the deformable simplicial complexes (DSC, [1]) method for deformable interface tracking. DSC provide a simple collision detection mechanism, allows for interface topology control, and does not require the domain to have disk topology. We test our method for tori of revolution and compare our results to the benchmark ones from [2]. The method, however, is generic and can be easily adapted to construct cut loci for other manifolds of genera other than 1.
Descriptor Based Analysis of Digital 3D Shapes

Analysis and processing of 3D digital shapes is a significant research area with numerous medical, industrial, and entertainment applications which has gained enormously in importance as optical scanning modalities have started to make acquired 3D geometry commonplace. The area holds many challenges. One such challenge, which is addressed in this thesis, is to develop computational methods for classifying shapes which are in agreement with the human way of understanding and classifying shapes. In this dissertation we first present a shape descriptor based on the process of diffusion on the surface of the shape – the auto diffusion function. When all heat is inserted at a single point, the function describes how much of that heat will remain at the same point after a period of time. This method allows for finding shape features at different scales related to time parameter. For instance, in conjunction with the method of Reeb graphs for skeletonization, it is an effective tool for generating scale dependent skeletons of shapes represented as 3D triangle meshes. The second part of the thesis aims at capturing the style phenomenon. The style of an object is easily recognized by humans but a computational method for finding the style of an object is elusive. Instead of codifying the style explicitly, which can be only done within a specific context, we develop a general method for dealing with both style and function which uses the supervision provided by a set of training examples and can be evaluated using any shape descriptor, that produces dissimilarity measures between different shapes. Our methods decouple the effect of style from the effect of function and assess how suitable a descriptor is to a specific problem.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics
Authors: Welnicka, K. (Intern), Bærentzen, J. A. (Intern)
Number of pages: 157
Publication date: 2011

Publication information
Place of publication: Kgs. Lyngby, Denmark
Publisher: Technical University of Denmark (DTU)
Original language: English

Series: IMM-PHD-2011
Number: 262
ISSN: 0909-3192
Main Research Area: Technical/natural sciences
Electronic versions:
phd262_katg-net.pdf
Source: orbit
Source-ID: 284720
Publication: Research › Ph.D. thesis – Annual report year: 2012

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.
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.

Grammar for general purpose procedural modeling

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Christiansen, A. N. (Intern), Bærentzen, J. A. (Intern)
Publication date: 2011
Event: Poster session presented at Visionday : Graphical, Lyngby, Denmark,
Mathematical foundation of the optimization-based fluid animation method
We present the mathematical foundation of a fluid animation method for unstructured meshes. Key contributions not previously treated are the extension to include diffusion forces and higher order terms of non-linear force approximations. In our discretization we apply a fractional step method to be able to handle advection in a numerically simple Lagrangian approach. Following this a finite element method is used for the remaining terms of the fractional step method. The key to deriving a discretization for the diffusion forces lies in restating the momentum equations in terms of a Newtonian stress tensor. Rather than applying a straightforward temporal finite difference method followed by a projection method to enforce incompressibility as done in the stable fluids method, the last step of the fractional step method is rewritten as an optimization problem to make it easy to incorporate non-linear force terms such as surface tension.

Real time ray tracing of skeletal implicit surfaces
Modeling and rendering in real time is usually done via rasterization of polygonal meshes. We present a method to model with skeletal implicit surfaces and an algorithm to ray trace these surfaces in real time in the GPU. Our skeletal representation of the surfaces allows to create smooth models easily that can be seamlessly animated and textured. The ray tracing is performed at interactive frame rate thanks to an acceleration data structure based on a BVH and a kd-tree.
Deformable Simplicial Complexes
In this dissertation we present a novel method for deformable interface tracking in 2D and 3D deformable simplicial complexes (DSC). Deformable interfaces are used in several applications, such as fluid simulation, image analysis, reconstruction or structural optimization. In the DSC method, the interface (curve in 2D; surface in 3D) is represented explicitly as a piecewise linear curve or surface. However, the domain is also subject to discretization: triangulation in 2D; tetrahedralization in 3D. This way, the interface can be alternatively represented as a set of edges/triangles separating triangles/tetrahedra marked as outside from those marked as inside. Such an approach allows for robust topological adaptivity. Among other advantages of the deformable simplicial complexes there are: space adaptivity, ability to handle and preserve sharp features, possibility for topology control. We demonstrate those strengths in several applications. In particular, a novel, DSC-based fluid dynamics solver has been developed during the PhD project. A special feature of this solver is that due to the fact that DSC maintains an explicit interface representation, surface tension is more easily dealt with. One particular advantage of DSC is the fact that as an alternative to topology adaptivity, topology control is also possible. This is exploited in the construction of cut loci on tori where a front expands from a single point on a torus and stops when it self-intersects.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Misztal, M. K. (Intern), Anton, F. (Intern), Bærentzen, J. A. (Intern)
Publication date: 2010

Generating quality tetrahedral meshes from binary volumes
This paper presents two new quality measures for tetrahedra which are smooth and well-suited for gradient based optimization. Both measures are formulated as a distance from the regular tetrahedron and utilize the fact that the covariance of the vertices of a regular tetrahedron is isotropic. We use these measures to generate high quality meshes from signed distance maps. This paper also describes an approach for computing (smooth) signed distance maps from binary volumes as volumetric data in many cases originate from segmentation of objects from imaging techniques such as CT, MRI, etc. The mesh generation is split into two stages; a candidate mesh generation stage and a compression stage, where the surface of the candidate mesh is moved to the zero iso-surface of the signed distance maps, while one of the quality measures ensures that the quality remains high. We apply the mesh generation algorithm on four examples (torus, Stanford dragon, brain mask, and pig back) and report the dihedral angle, aspect ratio and radius-edge ratio. Even though, the algorithm incorporates none of the mentioned quality measures in the compression stage it receives a good score for all these measures. The minimum dihedral angle is in none of the examples smaller than $15^\circ$.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Hansen, M. F. (Intern), Bærentzen, J. A. (Intern), Larsen, R. (Intern)
Number of pages: 372
Publication date: 2010

Host publication information
Title of host publication: Proceedings of the VISAPP
Publisher: Springer
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.

Markov Random Field Surface Reconstruction

A method for implicit surface reconstruction is proposed. The novelty in this paper is the adaption of Markov Random Field regularization of a distance field. The Markov Random Field formulation allows us to integrate both knowledge about the type of surface we wish to reconstruct (the prior) and knowledge about data (the observation model) in an orthogonal fashion. Local models that account for both scene-specific knowledge and physical properties of the scanning device are described. Furthermore, how the optimal distance field can be computed is demonstrated using conjugate gradients, sparse Cholesky factorization, and a multiscale iterative optimization scheme. The method is demonstrated on a set of scanned human heads and, both in terms of accuracy and the ability to close holes, the proposed method is shown to have similar or superior performance when compared to current state-of-the-art algorithms.
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
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.

Regularisation of 3D Signed Distance Fields

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

Regularisation of 3D Signed Distance Fields

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

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Gebal, K. (Intern), Bærentzen, J. A. (Intern), Aanæs, H. (Intern), Larsen, R. (Intern)
Pages: 1405-1413
Publication date: 2009
Conference: Symposium on Geometry Processing, Berlin, 01/01/2009
Main Research Area: Technical/natural sciences

Publication information
Journal: Computer Graphics Forum
Volume: 28
Issue number: 5
ISSN (Print): 0167-7055
Ratings:
  - Web of Science (2017): Indexed Yes
  - Scopus rating (2016): CiteScore 2.33
  - Scopus rating (2015): CiteScore 2.34
  - Scopus rating (2014): CiteScore 2.35
  - Web of Science (2014): Indexed yes
  - Scopus rating (2013): CiteScore 2.68
  - Scopus rating (2012): CiteScore 2.28
  - BFI (2011): BFI-level 1
  - Scopus rating (2011): CiteScore 2.2
  - ISI indexed (2011): ISI indexed yes
  - Web of Science (2011): Indexed yes
  - BFI (2010): BFI-level 1
  - Web of Science (2010): Indexed yes
  - BFI (2009): BFI-level 1
  - Web of Science (2009): Indexed yes
  - BFI (2008): BFI-level 1
Original language: English

eigensolutions, Reeb graphs, diffusion kernel, shape descriptor, Laplace-Beltrami operator, Auto Diffusion function

Electronic versions:
paper1085_final.pdf

Links:
Source: orbit
Source-ID: 248437
Publication: Research - peer-review › Conference article – Annual report year: 2009
Shader-Based Wireframe Drawing

In this paper, we first argue that drawing lines on polygons is harder than it may appear. We then propose two novel and robust techniques for a special case of this problem, namely wireframe drawing. Neither method suffers from the well-known artifacts associated with the standard two pass, offset based techniques for wireframe drawing. Both methods draw prefiltered lines and produce high-quality antialiased results without super-sampling. The first method is a single pass technique well suited for convex N-gons for small N (in particular quadrilaterals or triangles). It is demonstrated that this method is more efficient than the standard techniques and ideally suited for implementation using geometry shaders. The second method is completely general and suited for arbitrary N-gons which need not be convex. Lastly, it is described how our methods can easily be extended to support various line styles.
Two Methods for Antialiased Wireframe Drawing with Hidden Line Removal

Two novel and robust techniques for wireframe drawing are proposed. Neither suffer from the well-known artifacts associated with the standard two pass, offset based techniques for wireframe drawing. Both methods draw prefiltered lines and produce high-quality antialiased results without super-sampling. The first method is a single pass technique well suited for convex N-gons for small N (in particular quadrilaterals or triangles). It is demonstrated that this method is more efficient than the standard techniques and ideally suited for implementation using geometry shaders. The second method is completely general and suited for arbitrary N-gons which need not be convex. Lastly, it is described how our methods can easily be extended to support various line styles.

Boneless Pose Editing and Animation

In this paper, we propose a pose editing and animation method for triangulated surfaces based on a user controlled partitioning of the model into deformable parts and rigid parts which are denoted handles. In our pose editing system, the user can sculpt a set of poses simply by transforming the handles for each pose. Using Laplacian editing, the deformable parts are deformed to match the handles. In our animation system the user can constrain one or several handles in order to define a new pose. New poses are interpolated from the examples poses, by solving a small non-linear optimization problem in order to obtain the interpolation weights. While the system can be used simply for building poses, it is also an animation system. The user can specify a path for a given constraint and the model is animated correspondingly.
Variational Volumetric Surface Reconstruction from Points

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics
Authors: Jakobsen, B. (Intern), Bærentzen, J. A. (Intern), Christensen, N. J. (Intern)
Publication date: 2007

Host publication information
Title of host publication: IEEE/EG International Symposium on Volume Graphics
Main Research Area: Technical/natural sciences
Links:
http://www2.imm.dtu.dk/pubdb/views/publication_details.php?id=5516
Source: orbit
Source-ID: 205558
Publication: Research - peer-review › Article in proceedings – Annual report year: 2007

3D Distance Fields: A Survey of Techniques and Applications
A distance field is a representation where at each point within the field we know the distance from that point to the closest point on any object within the domain. In addition to distance, other properties may be derived from the distance field, such as the direction to the surface, and when the distance field is signed, we may also determine if the point is internal or external to objects within the domain. The distance field has been found to be a useful construction within the areas of Computer Vision, Physics and Computer Graphics. This paper serves as a timely exposition of methods for the production of distance fields, and a review of alternative representations and applications of distance fields. In the course of this paper we present various methods from all three of the above areas, and we answer pertinent questions such as: - How accurate are these methods compared to each other? - How simple are they to implement? - What is the complexity and run-time of such methods?

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Jones, M. (Ekstern), Bærentzen, J. A. (Intern), Sramek, M. (Ekstern)
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Transactions on Visualization and Computer Graphics
Volume: 12
Issue number: 4
ISSN (Print): 1077-2626
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.94 SJR 1.365 SNIP 2.356
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.82 SNIP 2.08 CiteScore 2.91
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.208 SNIP 2.591 CiteScore 3.37
BFI (2013): BFI-level 2
Optimizing 3D Triangulations to Recapture Sharp Edges

In this report, a technique for optimizing 3D triangulations is proposed. The method seeks to minimize an energy defined as a sum of energy terms for each edge in a triangle mesh. The main contribution is a novel per edge energy which strikes a balance between penalizing dihedral angle yet allowing sharp edges. The energy is minimized using edge swapping, and this can be done either in a greedy fashion or using simulated annealing. The latter is more costly, but effectively avoids local minima. The method has been used on a number of models. Particularly good results have been obtained on digital terrain models. It is demonstrated how the method has been able to recapture sharp edges which are clearly present in the data but not reflected by the original triangulation of the elevation points.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern)
Publication date: 2006

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: imm4689.pdf
Links:
http://www2.imm.dtu.dk/pubdb/p.php?4689

Bibliographical note
Single-pass Wireframe Rendering
This sketch outlines a method for wireframe drawing which is fast, highly tweakable and gives better results than the traditional methods.

From Points to Smooth Surfaces

Hardware-accelerated Point Generation and Rendering of Point-based Impostors
This paper presents a novel scheme for generating points from triangle models. The method is fast and lends itself well to implementation using graphics hardware. The triangle to point conversion is done by rendering the models, and the rendering may be performed procedurally or by a black box API. I describe the technique in detail and discuss how the generated point sets can easily be used as impostors for the original triangle models used to create the points. Since the points reside solely in GPU memory, these impostors are fairly efficient. Source code is available online.
Robust Generation of Signed Distance Fields from Triangle Meshes

**General information**
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics
Authors: Bærentzen, J. A. (Intern)
Pages: 167-239
Publication date: 2005

**Host publication information**
Main Research Area: Technical/natural sciences
Conference: Fourth International Workshop on Volume Graphics, 2005., 01/01/2005
Source: orbit
Source-ID: 185592
Publication: Research - peer-review › Journal article – Annual report year: 2005

**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 $C^1$ 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.

**General information**
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Aanæs, H. (Intern)
Pages: 243 - 253
Publication date: 2005
Signed Distance Computation using the Angle Weighted Pseudo-normal

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Aanæs, H. (Intern)
Pages: 243-253
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Volume: 11
Issue number: 3
ISSN (Print): 1077-2626
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.94 SJR 1.365 SNIP 2.356
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.82 SNIP 2.08 CiteScore 2.91
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.208 SNIP 2.591 CiteScore 3.37
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.166 SNIP 2.605 CiteScore 3.39
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.853 SNIP 2.505 CiteScore 2.96
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.115 SNIP 2.774 CiteScore 3.39
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.268 SNIP 2.399
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.201 SNIP 2.773
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.968 SNIP 2.76
Scopus rating (2007): SJR 0.779 SNIP 2.629
Scopus rating (2006): SJR 0.714 SNIP 3.125
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.559 SNIP 3.189
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.486 SNIP 3.413
Scopus rating (2003): SJR 0.906 SNIP 3.6
Scopus rating (2002): SJR 2.469 SNIP 4.019
Scopus rating (2001): SJR 2.122 SNIP 4.256
Scopus rating (2000): SJR 1.902 SNIP 2.784
Scopus rating (1999): SJR 0.842 SNIP 1.884
Original language: English
Hardware Accelerated Point Rendering of Isosurfaces
Interactive volume sculpting and volume editing often employ surface, based visualization techniques, and interactive applications require fast generation and rendering of surface primitives. In this paper, we revisit point primitives as an alternative to triangle primitives.

We propose an approximate technique for point scaling using distance attenuation which makes it possible to render points stored in display lists or vertex arrays. This enables us to render points quickly using OpenGL. Our comparisons show that point generation is significantly faster than triangle generation and that the advantage of rendering points as opposed to triangles increases with the size and complexity of the volumes. To gauge the visual quality of future hardware accelerated point rendering schemes, we have implemented a software based point rendering method and compare the quality to both MC and our OpenGL based technique.

PDE Based Surface Estimation for Structure from Motion.

PDE Based Surface Estimation for Structure from Motion.
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.
Interactive Modelling of Shapes Using the Level-Set Method

In this paper, we propose a technique for intuitive, interactive modelling of {3D} shapes. The technique is based on the Level-Set Method which has the virtue of easily handling changes to the topology of the represented solid. Furthermore, this method also leads to sculpting operations that are very simple and intuitive from a user perspective. A nal virtue is that the (LSM) makes it easy to maintain a distance eld representation of the represented solid. This has a number of bene ts such as simpli cation of the rendering scheme and the curvature computation. A number of (LSM) speed functions which are suitable for shape modelling are proposed. However, normally these would result in tools that would a ect the entire model. To facilitate local changes to the model, we introduce a windowing scheme which constrains the (LSM) to a ect only a small part of the model. The (LSM) based sculpting tools have been incorporated in our sculpting system which also includes facilities for volumetric (CSG) and several techniques for visualization.

General information

State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Christensen, N. J. (Intern)
Pages: 79-97
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information

Journal: International Journal of Shaping Modeling
Volume: 8
Issue number: 2
ISSN (Print): 0218-6543
Ratings:

Scopus rating (2013): SJR 0.103 SNIP 0.087
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.108 SNIP 0.395
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.154 SNIP 0.268
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.21 SNIP 0.241
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.362 SNIP 0.719
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.425 SNIP 1.338
Scopus rating (2007): SJR 0.489 SNIP 0.719
Scopus rating (2006): SJR 0.226 SNIP 0.245
Scopus rating (2005): SJR 0.201 SNIP 0.469
Scopus rating (2004): SJR 0.278 SNIP 0.774
Scopus rating (2003): SJR 0.139 SNIP 0.396
Scopus rating (2002): SJR 0.298 SNIP 0.099
Original language: English
Links:

http://www.worldscinet.com/cgi-bin/details.cgi?id=jsname:ijsm&type=all

Bibliographical note
Manipulation of volumetric solids with applications to sculpting

The topic of this thesis is volume graphics, and in particular techniques which are applicable to volume sculpting. A volume sculpting system is an interactive computer program for shape modelling where the shape is represented volumetrically in a 3D lattice of so-called voxels. It is argued that it is reasonable to classify the tools in a sculpting system according to whether the tools tend to deform the sculpted object or work according to the paradigm of Constructive Solid Geometry (CSG). Existing volume sculpting systems are surveyed, and it is found that almost all systems provide sculpting tools belonging exclusively to either or both categories. It is also found that existing systems have a number of important deficiencies. For instance, none of the systems provide a generic methodology for deformation. Rather they provide specific solutions for concrete deformation tasks, e.g. smoothing or the creation of small protrusions or dents. Moreover, most of the existing systems are based on a volume representation where the value of a voxel is construed as a pseudo-density with no precise meaning. More precisely, we can tell from a voxel whether it is on the inside or the outside of a represented solid, but nothing more. In this thesis it is argued, that it is useful to be able to give a voxel a more precise meaning. This leads to a cleaner volume representation, and if we choose (as the precise meaning of a voxel) the shortest distance from the voxel position to the closest surface point, we reap additional benefits: It becomes trivial to find surface points, and it becomes much easier to find offset surfaces and to compute various geometric properties such as curvature. Generic techniques for constructive (CSG based) and deformative tools have been implemented. Both sets of tools maintain a volume representation where the meaning of a voxel is shortest distance. The deformative tools are based on a specialization of the Level Set Method. The main advantage of using the Level Set Method is that it is a very generic technique as opposed to methods previously proposed. The main task here has been to restrict the effect of the Level Set Method to a local region of influence and to ensure a smooth transition between the affected region and the unaffected. The theoretical problem of what shapes that are suitable for volume representation has been considered. I reach the conclusion that a shape is suitable if we can roll a ball on either side of the surface in such a way that no point on (either side of) the surface is untouched. Here, the size of the ball depends on the scale of the voxel lattice. The intuitive quality that the ball can roll on either side of the surface of the solid has been formulated more precisely using concepts from mathematical morphology. Essentially, if the solid is unchanged by a morphological opening using the ball as structuring element, then the ball rolls on the interior side. Likewise, invariance with respect to closing implies that the ball can roll on the exterior. These results are, of course, of theoretical interest, but not exclusively: A technique for constructive manipulation which maintains the properties of openness and closedness has been developed. A technique for fast volume visualization is an essential part of a sculpting system. Two techniques for interactive visualization have been implemented: A novel technique based on point rendering and the well-known Marching Cubes Method. The point rendering technique is compared to marching cubes and to texture based visualization. A ray casting method has also been implemented for the generation of high quality images. The most important disadvantage of the volume representation is its lack of support for features at different scales. By choosing a volume representation, we implicitly choose a scale, and features that are very small with respect to that scale are essentially un-representable. As a solution, I propose an adaptive framework, where voxels are no longer stored in a regular grid but in adaptive grid. This allows for higher concentrations of voxels in some parts of the volume than others, and this, in turn, allows for features at vastly differing scales.
Volume Sculpting Using the Level-Set Method

In this paper, we propose the use of the Level–Set Method as the underlying technology of a volume sculpting system. The main motivation is that this leads to a very generic technique for deformation of volumetric solids. In addition, our method preserves a distance field volume representation. A scaling window is used to adapt the Level–Set Method to local deformations and to allow the user to control the intensity of the tool. Level–Set based tools have been implemented in an interactive sculpting system, and we show sculptures created using the system.

A Technique for Volumetric CSG Based on Morphology

In this paper, a new technique for volumetric CSG is presented. The technique requires the input volumes to correspond to solids which fulfill a voxelization suitability criterion. Assume the CSG operation is union. The volumetric union of two such volumes is defined in terms of the voxelization of the union of the two original solids. The theory behind the new technique is discussed, the algorithm and implementation are presented. Finally, we present images and timings.
On the implementation of fast marching methods for 3D lattices
This technical report discusses Sethian’s Fast Marching Method and its higher accuracy variant. Both methods may be used to compute the arrival times at the points of a discrete lattice of a front which is monotonously expanding. Applications of the method include arrival time computation and the construction of distance fields for 2D or 3D objects. The main aim of this report is to supplement the available papers with a practical guide to the implementation of the method. Through a simple example the Fast Marching Method and its high accuracy variant are compared with regard to speed and precision.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern)
Publication date: 2001

Volume Sculpting: Intuitive, Interactive 3D Shape Modelling
A system for interactive modelling of 3D shapes on a computer is presented. The system is intuitive and has a flat learning curve. It is especially well suited to the creation of organic shapes and shapes of complex topology. The interaction is simple; the user can either add new shape features or smooth and deform existing features.

A Morphological Approach to the Voxelization of Solids
In this paper we present a new, morphological criterion for determining whether a geometric solid is suitable for voxelization at a given resolution. The criterion embodies two conditions, namely that the curvature of the solid must be bounded and the critical points of the distance field must be at a certain distance from the boundary of the solid. For solids that fulfill this criterion, we present an analytic and an empirical bound for the trilinear reconstruction error. Additionally, we give a theoretical argument as to why the distance field approach to voxelization is more sound than the prefiltering technique. The essence of the argument is that while sampling and interpolation must always introduce some error, the latter method (but not the former) introduces an error in the surface position independently of the sampling.

General information
State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern), Sramek, M. (Ekstern), Christensen, N. J. (Intern)
Pages: 44-51
Publication date: 2000

Host publication information
Octree-based Volume Sculpting

A volume sculpting system is presented. The system provides tools for interactive editing of a voxel raster that is stored in an octree data structure. Two different modes of sculpting are supported: Sculpting by adding and subtracting solids, and sculpting with tools that are based on a spray can metaphor. The possibility of extending the method to support multiresolution sculpting is discussed.

General information

State: Published
Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling
Authors: Bærentzen, J. A. (Intern)
Publication date: 1998

Host publication information

Title of host publication: Proceedings Visualization '98
Place of publication: New York
Publisher: ACM Press
Main Research Area: Technical/natural sciences
Electronic versions:
imm707.pdf
Source: orbit
Source-ID: 200003
Publication: Research - peer-review › Article in proceedings – Annual report year: 1998

Projects:

Smart Manufacturing Frameworks

Department of Applied Mathematics and Computer Science
Period: 01/09/2017 → 01/12/2020
Number of participants: 3
Phd Student:
Maier, Dana (Intern)
Supervisor:
Larsen, Jakob Eg (Intern)
Main Supervisor:
Bærentzen, Jakob Andreas (Intern)

Financing sources

Source: Internal funding (public)
Name of research programme: Industrial PhD
Project: PhD

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:
A Traceable 3D Scanning and Reconstruction Pipeline
Department of Applied Mathematics and Computer Science
Period: 15/11/2016 → 14/11/2019
Number of participants: 3
Phd Student:
Gawrilowicz, Florian (Intern)
Supervisor:
Dahl, Anders Bjorholm (Intern)
Main Supervisor:
Bærentzen, Jakob Andreas (Intern)

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

Surface Design and Rationalization for Robotic Hotwire and Hotblade Cutting Techniques
Department of Applied Mathematics and Computer Science
Period: 15/12/2015 → 14/12/2018
Number of participants: 4
Phd Student:
Fisker, Ann-Sofie (Intern)
Supervisor:
Bærentzen, Jakob Andreas (Intern)
Gravesen, Jens (Intern)
Main Supervisor:
Brander, David (Intern)

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

Digital Factory
Collaboration with Odico APS and GXN. Constraint based design and rationalization for robotic hot-wire and hot-blade production of architectural formwork. Supported by Innovation Fund Denmark
Department of Applied Mathematics and Computer Science
Mathematics
Image Analysis & Computer Graphics
Period: 01/03/2015 → 15/12/2018
Number of participants: 4
Project participant:
Gravesen, Jens (Intern)
Bærentzen, Jakob Andreas (Intern)
Project Manager, organisational:
Brander, David (Intern)
Phd Student:
Segmentation and Reconstruction of Multi-Phase Structures using the Deformable Simplicial Complex Method

Department of Applied Mathematics and Computer Science
Period: 01/11/2014 → 13/02/2018
Number of participants: 3
Phd Student:
Nguyen Trung, Tuan (Intern)
Supervisor:
Dahl, Vedrana Andersen (Intern)
Main Supervisor:
Bærentzen, Jakob Andreas (Intern)

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

Hybrid Techniques for Interactive Photorealistic Rendering

Department of Applied Mathematics and Computer Science
Period: 01/10/2014 → 01/04/2018
Number of participants: 3
Phd Student:
Dal Corso, Alessandro (Intern)
Supervisor:
Bærentzen, Jakob Andreas (Intern)
Main Supervisor:
Frisvad, Jeppe Revall (Intern)

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

Rationalization with ruled surfaces in architecture

Department of Applied Mathematics and Computer Science
Period: 01/05/2013 → 25/08/2016
Number of participants: 6
Phd Student:
Steenstrup, Kasper Hornbak ( Intern)
Supervisor:
Bærentzen, Jakob Andreas ( Intern)
Main Supervisor:
Gravesen, Jens ( Intern)
Examiner:
Christensen, Niels Jørgen ( Intern)
Lauze, Francois Bernard ( Ekstern)
Singh, Karan Sher ( Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 FUU, 1/3 inst 1/3 Andet

Relations
Publications:
Rationalization with ruled surfaces in architecture
Project: PhD
Statistical Priors in Variational Reconstruction Methods
Department of Applied Mathematics and Computer Science
Period: 01/11/2012 → 24/02/2016
Number of participants: 6
Phd Student:
Romanov, Mikhail (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Main Supervisor:
Dahl, Anders Bjorholm (Intern)
Examiner:
Bærentzen, Jakob Andreas (Intern)
Batenburg, Kees Jost (Ekstern)
Lauze, Francois Bernard (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Anden EU-finansiering
Project: PhD

Interactive Topology Optimization
Department of Applied Mathematics and Computer Science
Period: 01/04/2012 → 21/09/2015
Number of participants: 7
Phd Student:
Nobel-Jørgensen, Morten (Intern)
Supervisor:
Aage, Niels (Intern)
Sigmund, Ole (Intern)
Main Supervisor:
Bærentzen, Jakob Andreas (Intern)
Examiner:
Rose, Michael (Intern)
Singh, Karan Sher (Ekstern)
van Keulen, Alfred (Ekstern)

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

Individualized directional microphone optimization in hearing aids based on reconstructing 3D geometry of the head and ear from 2D photos
Department of Applied Mathematics and Computer Science
Period: 15/03/2012 → 19/06/2015
Number of participants: 6
Phd Student:
Harder, Stine (Intern)
Supervisor:
Laugesen, Søren (Intern)
Main Supervisor:
Paulsen, Rasmus Reinhold (Intern)
Examiner:
Bærentzen, Jakob Andreas (Intern)
Ballester, Miguel A. G. (Ekstern)
Juhl, Peter Møller (Intern)
Financing sources
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed
Project: PhD

Geometrical Design Representations for Topology Optimization
Department of Applied Mathematics and Computer Science
Period: 01/11/2011 → 23/01/2015
Number of participants: 7
Phd Student:
Christiansen, Asger Nyman (Intern)
Supervisor:
Krzysztof Misztal, Marek (Ekstern)
Sigmund, Ole (Intern)
Main Supervisor:
Bærentzen, Jakob Andreas (Intern)
Examiner:
Dahl, Anders Bjarholm (Ekstern)
Maute, Kurt (Ekstern)
Wojtan, Chris (Ekstern)

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

Anatomical surface reconstruction and optimization
Department of Informatics and Mathematical Modeling
Period: 15/04/2010 → 30/08/2013
Number of participants: 6
Phd Student:
Jensen, Rasmus Ramsbøl (Intern)
Supervisor:
Poel, Mike van der (Intern)
Main Supervisor:
Paulsen, Rasmus Reinhold (Intern)
Examiner:
Bærentzen, Jakob Andreas (Intern)
Olsen, Ole Fogh (Ekstern)
Reyes, Mauricio (Ekstern)

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

Surface Reconstruction of Coherent Deformable 3D Scans with Topological Recovery
Department of Informatics and Mathematical Modeling
Period: 01/05/2009 → 31/10/2010
Number of participants: 4
Phd Student:
Giotis, Nikolaos (Intern)
Supervisor:
Bærentzen, Jakob Andreas (Intern)
Paulsen, Rasmus Reinhold (Intern)
Main Supervisor:
Antón Castro, Francesc/François (Intern)
Towards the Interactive ESS-Food Catalogue

Department of Informatics and Mathematical Modeling
Period: 01/05/2009 → 24/08/2012
Number of participants: 7
Phd Student:
Laursen, Lasse Farnung (Intern)
Supervisor:
Bærentzen, Jakob Andreas (Intern)
Christensen, Lars Bager (Intern)
Main Supervisor:
Ersbøll, Bjarne Kjær (Intern)
Examiner:
Carstensen, Jens Michael (Intern)
Madsen, Claus Brøndsgaard (Ekstern)
Sramek, Milos (Ekstern)

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:
Aanæs, 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

Automatic Quantitative Image Analysis of 3D Micrographs
Department of Informatics and Mathematical Modeling
Department of Energy Conversion and Storage
Imaging and Structural Analysis
Period: 01/03/2007 → 22/09/2010
Number of participants: 7
Phd Student:
Jørgensen, Peter Stanley (Intern)
Supervisor:
Bowen, Jacob R. (Intern)
Hansen, Karin Vels (Intern)
Main Supervisor:
Larsen, Rasmus (Intern)
Examiner:
Bærentzen, Jakob Andreas (Intern)
Barnet, Scott (Intern)
Østergaard, Lasse Riis (Ekstern)

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

Lighting Design and Real-time Global Illumination
Department of Informatics and Mathematical Modeling
Period: 01/02/2006 → 30/03/2011
Number of participants: 5
Phd Student:
Kristensen, Anders Wang (Intern)
Main Supervisor:
Christensen, Niels Jørgen (Intern)
Examiner:
Bærentzen, Jakob Andreas (Intern)
Henriksen, Knud (Ekstern)
Myszkowski, Karol (Ekstern)

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

Virtuel reality - Volume sculpting
Department of Informatics and Mathematical Modeling
Period: 01/03/1998 → 06/03/2003
Number of participants: 5
Phd Student:
Bærentzen, Jakob Andreas (Intern)
Main Supervisor:
Christensen, Niels Jørgen (Intern)
Examiner:
Henriksen, Knud (Ekstern)
Chen, Min (Ekstern)
Takala, Tapio (Ekstern)

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

Computer Graphics and CAD
The overall purpose of this longterm project is to contribute to development of CAD systems and other 3D graphics systems such as Virtual Reality, computer animation, multimedia and scientific visualization systems. During the years the focus has been on visualization, modelling and the user interface part and the main application areas has been technical communication and CAD systems used in the early design stages of a project. At present the focus is on visualization and volume modelling. Many student project has contributed to the project of Global Illumination - the creation of realistic looking synthetic images. The focus of the project has been on rendering complex models containing procedural objects such as fractals without tesselating these objects. For this purpose Monte Carlo based ray tracing techniques have been used. Since pure Monte Carlo ray tracing is very inefficient the Photon Map was invented as a useful technique for optimizing the evaluation of the rendering equation. The Photon Map can be used to render caustics, used to optimize the rendering of indirect illumination and direct illumination. The photon map uses statistical techniques on a 3d-point set to compute information such as the incoming flux and the reflected radiance. This 3d-point set is stored using a balanced kd-tree which is completely independent of the geometry in the model. This has the advantage that the storage and computation of the global illumination is possible even in very large models containing millions of triangles (which can be instantiated). This is more costly using the popular radiosity method since it stores irradiance information with every patch in the model. The second part of the project is focusing on Virtual Reality (visualization and Volume models)

Department of Planning
Period: 01/02/1988 → …
Number of participants: 5
Project participant:
Nielsen, Hans Peter (Intern)
Jensen, Henrik Wann (Intern)
Bormann, Karsten (Intern)
Bærentzen, Jakob Andreas (Intern)
Project Manager, organisational:
Christensen, Niels Jørgen (Intern)
Project

Activities:

Symposium on Geometry Processing 2017
Period: 1 Jul 2017 → 5 Jul 2017
Jakob Andreas Bærentzen (Organizer)
Department of Applied Mathematics and Computer Science
Image Analysis & Computer Graphics

Description
Papers co-chair
Degree of recognition: International

Related event

Symposium on Geometry Processing 2017
01/07/2017 → 05/07/2017
London, United Kingdom
Activity: Attending an event › Participating in or organising a conference
Computer Graphics Forum (Journal)
Period: 1 May 2017 → 1 May 2020
Jakob Andreas Bærentzen (Reviewer)
Department of Applied Mathematics and Computer Science
Image Analysis & Computer Graphics

Description
Associate Editor
Degree of recognition: International

Related journal

Computer Graphics Forum
0167-7055
Local database
Activity: Research › Journal editor