

Realistic Eye Motion Using Procedural Geometric Methods

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Figure 1: (a) Model, (b) primitives, coordinate system, quadrants, (c) gray-scale render, (d) spherical coordinate skinning, (e) vertex gate weights.

For late-breaking R&D on the upcoming Disney film *King of the Hearts*, we have embarked upon an adventure called the Realistic Eye Initiative; to investigate realistic procedural methods for one of the most important aspects of a digital character's face – the eyes. We will leap beyond the simple spheres of previous Disney films, into realistic, wrinking realism. Using an anatomically motivated approach, our method to produce realistic convincing deformations of the skin and flesh surrounding the eye is unique, not only due to the novel approaches employed, but also because our method is entirely procedural, based on geometric analysis and packaged into a production friendly, compact, efficient mathematical apparatus in the form of a single block-box deformer that can be easily applied onto any digital creature's face.

1 Spherical Coordinate Lid Skinning

The movement of the lid skin over the eye ball is the most significant motion that occurs during a blink. To simulate this skin deformation, we use *transformation-propagation*. The deformation basis function is given by internally computed spline patches. The patches are defined by a curvature-continuous blend between key shapes that include a neutral shape (obtained by least-squares fitting of spline patches into the original eye opening) and user-defined closed, warped, and intermediate shapes.

Once the patches are in place, we define a smooth vector field of displacements $D(x)$ on the eye-lid skin as follows. First, attachment weights are set on the skin region directly driven by the patches. Next, vertex weights are computed to define a pulling area that smoothly follows the attachment. Finally, $D(x)$ is set to non-occlude of the pulling and attachment regions.

In the pulling regions of $D(x)$ we require nearly perfect harmonic behavior (i.e. $\Delta D(x) = 0$); in addition our resulting surface should maintain the curvature defined by the sum of the eye ball radius and thickness of the skin. This requires solving a differential equation that defines $D(x)$ for the pulled vertices. Instead of solving Poisson's equation with special conditions, which would make computations too expensive for interactive use, we introduce a novel, fast relaxation scheme. The essence of this scheme is Laplacian smoothing based on spherical coordinates. The system of spherical coordinates is defined by the location and orientation of the eye ball E ; constructing the map function $S(x, E)$ converts x to local spherical coordinates. We define the Laplacian operator as

$$\Delta D(S(x, E)) = \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial D}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial}{\partial \theta} \left(\sin^2 \theta \frac{\partial D}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial}{\partial \phi} \left(\sin^2 \theta \frac{\partial D}{\partial \phi} \right)$$

We are guaranteed convergence of the smoothing iterations to a surface with vertices equilibrated from the eye's center while direct manipulation of the radius component gives us exact control over curvature.

2 Procedurally Unfolding Skin Wrinkles

Another blink-driven deformation is the unfolding of wrinkles between the lower lower and the lids. To make this appear natural, we allow the pace of the unfolding to be independent from the gaze motion of the blink. The actual unfold is done using anisotropic relaxation along the blink's primary direction.

3 Driven Wrinkles and Lid Pressure

As the lids blink, the skin uncompresses and unfolds into a smooth, relaxed spherical coordinate space. Thus, we interpolate new wrinkles and bulging that occur when the eye closes. When the spline surfaces meet at blink, a pressure value activates a bulge force perpendicular to blink direction. The blink also activates normal displaced wrinkles around the eye. Wrinkles and bulges have vertex weights, allowing subtle control over shape of wrinkle or flesh as it bulges or creases.

4 Shape Shifting based on Gaze Angle

A blink is only a portion of eye motion; flesh and skin are and the eye must as look direction changes due to underlying anatomy. To mimic this effect we implement three additional layers to cause skin reaction to the eye's gaze angle: a flesh layer, a driven lid progression layer and a shape shifting layer.

First, the coordinate system of the eye is stored and a bend is computed. The inverse parent matrix causes deformation only occurs from changes in local eye space. The eye coordinate system is then decomposed and quaternions are used to extract rotations, initially removing twist from the eye matrix. Spline diffuse weighting is computed, radiating from the eye center. Weighted skinning is then applied for a smooth fleshy effect when the eye looks around.

Next, to apply driven lid progression, we extract side looking rotation and build a matrix that only represents upward and downward motion. The signed lid motion is set by alignment of the bend Y-axis and run-time Z-axis (the look vector). An additive weighted blending is applied, and the transition seamlessly blends when the eye is neutral and also fades off entirely as the blink occurs.

Finally, the shape shifting effect is applied. In order to achieve subtle almost shaped deformations, the eye coordinate system is partitioned into six gaze quadrants: up, down, and diagonally 45° on left/right, up/down sides. As the eye's look vector aligns with a gaze quadrant, a weighted transformation causes the skin to change shape.

5 Cornea / Sclera Collision Primitives

The anatomical domed like nature of the cornea requires skin-to-eye-ball collision and sliding interaction. This is achieved using fast sphere primitives fitted to the dome of the cornea's mesh, instead of complex polygons. A fast radius test detects lid intersection, and a smooth non-dynamic weighted collision is applied, pushing the lid back onto the limit of the primitive with control over magnitude and attenuation, resulting in a smooth, convincing sclera/corneal bulge sliding beneath the lids.

6 Future and Planned Work

We're currently extending this procedural deformation system with a layered compression based wrinkle algorithm, skin and flesh simulation to resolve self collisions, and better automatic weight generation using heat diffusion. Future R&D is also slated for rendering areas: research here are novel eye reflectance models, corneal refraction-distortion texture unwarping, and procedural iris generation using texture synthesis and Markov Random Fields.

Geometric Methods In Biomedical Image Processing

**Nico Karssemeijer, Boudewijn
Lelieveldt**



Geometric Methods In Biomedical Image Processing:

Geometric Methods in Bio-Medical Image Processing Ravikanth Malladi,2012-12-06 The genesis of this book goes back to the conference held at the University of Bologna June 1999 on collaborative work between the University of California at Berkeley and the University of Bologna The book in its present form is a compilation of some of the recent work using geometric partial differential equations and the level set methodology in medical and biomedical image analysis The book not only gives a good overview on some of the traditional applications in medical imagery such as CT MR Ultrasound but also shows some new and exciting applications in the area of Life Sciences such as confocal microscope image understanding

Deformable Models Aly Farag,2007-08-02 This book covers the complete spectrum of deformable models its evolution as an imagery field and its use in many biomedical engineering and clinical application disciplines The book focuses on the core image processing techniques theory and biomaterials useful to research and industry Contributors are all pioneers in the field

Handbook of Biomedical Image Analysis David Wilson,Swamy Laxminarayan,2006-10-28 Handbook of Biomedical Image Analysis Segmentation Models Volume I is dedicated to the segmentation of complex shapes from the field of imaging sciences using different mathematical techniques This volume is aimed at researchers and educators in imaging sciences radiological imaging clinical and diagnostic imaging physicists covering different medical imaging modalities as well as researchers in biomedical engineering applied mathematics algorithmic development computer vision signal processing computer graphics and multimedia in general both in academia and industry Key Features Principles of intra vascular ultrasound IVUS Principles of positron emission tomography PET Physical principles of magnetic resonance angiography MRA Basic and advanced level set methods Shape for shading method for medical image analysis Wavelet transforms and other multi scale analysis functions Three dimensional deformable surfaces Level Set application for CT lungs brain MRI and MRA volume segmentation Segmentation of incomplete tomographic medical data sets Subjective level sets for missing boundaries for segmentation

Hybrid Image Processing Methods for Medical Image Examination Venkatesan Rajinikanth,E Priya,Hong Lin,Fuhua Lin,2021-01-29 In view of better results expected from examination of medical datasets images with hybrid integration of thresholding and segmentation image processing methods this work focuses on implementation of possible hybrid image examination techniques for medical images It describes various image thresholding and segmentation methods which are essential for the development of such a hybrid processing tool Further this book presents the essential details such as test image preparation implementation of a chosen thresholding operation evaluation of threshold image and implementation of segmentation procedure and its evaluation supported by pertinent case studies Aimed at researchers graduate students in the medical image processing domain image processing and computer engineering this book Provides broad background on various image thresholding and segmentation techniques Discusses information on various assessment metrics and the confusion matrix Proposes integration of the thresholding technique with

the bio inspired algorithms Explores case studies including MRI CT dermoscopy and ultrasound images Includes separate chapters on machine learning and deep learning for medical image processing

Medical Image Computing and Computer-Assisted Intervention -- MICCAI 2004 Christian Barillot, David R. Haynor, Joao Falcao e Cunha, Pierre Hellier, 2004-09-17 The 7th International Conference on Medical Imaging and Computer Assisted Intervention MICCAI 2004 was held in Saint Malo Brittany France at the Palais du Grand Large conference center September 26 29 2004 The purpose to host MICCAI 2004 was strongly encouraged and supported by IRISA Rennes IRISA is a publicly funded national research laboratory with a staff of 370 including 150 full time research scientists or teaching research scientists and 115 postgraduate students INRIA the CNRS and the University of Rennes 1 are all partners in this mixed research unit and all three organizations were helpful in supporting MICCAI MICCAI has become a premier international conference with in depth perspectives on the multidisciplinary fields of medical image computing computer assisted intervention and medical robotics The conference brings together clinicians biological scientists computer scientists engineers physicists and other researchers and offers them a forum to exchange ideas in these exciting and rapidly growing fields The impact of MICCAI increases each year and the quality and quantity of submitted papers this year was very impressive We received a record 516 full submissions 8 pages in length and 101 short communications 2 pages from 36 different countries and 5 continents see figures below All submissions were reviewed by up to 4 external reviewers from the Scientific Review Committee and a primary reviewer from the Program Committee All reviews were then considered by the MICCAI 2004 Program Committee resulting in the acceptance of 235 full papers and 33 short communications

Handbook of Biomedical Image Analysis Jasjit S. Suri, David Wilson, David Lynn Wilson, Swamy Laxminarayan, 2005-06-09 With rapid advancements in technology body imaging or components thereof have become ubiquitous in medicine While the biomedical devices such as the MRI CT X rays Ultrasound PET SPECT and Microscopy etc provide us with high resolution images the challenges that have continued to confront us with lie in the interpretation of the vast amounts of data generated by these devices Biomedical applications are the bottom line essentials in the diagnostic world It is this diagnostic interpretation feature that forms the core niche for these books and will serve the needs of a broad spectrum of audience including researchers research clinicians and students Together the three volumes will illustrate the role of the fusion of registration and segmentation systems for complete biomedical applications therapy delivery benefiting the biomedical doctors clinical researchers radiologists and others

Biomedical Image Registration Bernd Fischer, 2010 Welcome to the proceedings of the 4th Workshop on Biomedical Image Registration WBIR Previous WBIRs took place in Bled Slovenia 1999 at the University of Pennsylvania USA 2003 and in Utrecht The Netherlands 2006 This year WBIR was hosted by the Institute Mathematics and Image Processing and the Fraunhofer Project Group on Image Registration and it was held in Lubbeck Germany It provided the opportunity to bring together researchers from all over the world to discuss some of the most recent advances in image registration and its applications We

had an excellent collection of papers that were reviewed by at least three reviewers each from a 35 member Program Committee assembled from a world wide community of registration experts This year 17 papers were accepted for oral presentation while another 7 papers were accepted as poster papers We believe all of the conference papers were of excellent quality Registration is a fundamental task in image processing used to match two or more pictures taken for example at different times from different sensors or from different viewpoints Establishing the correspondence of structures within medical images is fundamental to diagnosis treatment planning and surgical guidance The conference papers address state of the art techniques for providing reliable and efficient registration techniques thereby imposing relationships between specific application areas and appropriate registration schemes We are grateful to all those who contributed to the success of WBIR 2010

Riemannian Geometric Statistics in Medical Image Analysis Xavier Pennec, Stefan Sommer, Tom Fletcher, 2019-09-02 Over the past 15 years there has been a growing need in the medical image computing community for principled methods to process nonlinear geometric data Riemannian geometry has emerged as one of the most powerful mathematical and computational frameworks for analyzing such data Riemannian Geometric Statistics in Medical Image Analysis is a complete reference on statistics on Riemannian manifolds and more general nonlinear spaces with applications in medical image analysis It provides an introduction to the core methodology followed by a presentation of state of the art methods Beyond medical image computing the methods described in this book may also apply to other domains such as signal processing computer vision geometric deep learning and other domains where statistics on geometric features appear As such the presented core methodology takes its place in the field of geometric statistics the statistical analysis of data being elements of nonlinear geometric spaces The foundational material and the advanced techniques presented in the later parts of the book can be useful in domains outside medical imaging and present important applications of geometric statistics methodology Content includes The foundations of Riemannian geometric methods for statistics on manifolds with emphasis on concepts rather than on proofs Applications of statistics on manifolds and shape spaces in medical image computing Diffeomorphic deformations and their applications As the methods described apply to domains such as signal processing radar signal processing and brain computer interaction computer vision object and face recognition and other domains where statistics of geometric features appear this book is suitable for researchers and graduate students in medical imaging engineering and computer science A complete reference covering both the foundations and state of the art methods Edited and authored by leading researchers in the field Contains theory examples applications and algorithms Gives an overview of current research challenges and future applications

Handbook of Biomedical Imaging Nikos Paragios, James Duncan, Nicholas Ayache, 2015-03-24 This book offers a unique guide to the entire chain of biomedical imaging explaining how image formation is done and how the most appropriate algorithms are used to address demands and diagnoses It is an exceptional tool for radiologists research scientists senior undergraduate and graduate students in health sciences and

engineering and university professors Multi-Sensor Image Fusion and Its Applications Rick S. Blum,Zheng Liu,2018-10-03 Taking another lesson from nature the latest advances in image processing technology seek to combine image data from several diverse types of sensors in order to obtain a more accurate view of the scene very much the same as we rely on our five senses Multi Sensor Image Fusion and Its Applications is the first text dedicated to the theory and practice of the registration and fusion of image data covering such approaches as statistical methods color related techniques model based methods and visual information display strategies After a review of state of the art image fusion techniques the book provides an overview of fusion algorithms and fusion performance evaluation The following chapters explore recent progress and practical applications of the proposed techniques to solving problems in such areas as medical diagnosis surveillance and biometric systems remote sensing nondestructive evaluation blurred image restoration and image quality assessment Recognized leaders from industry and academia contribute the chapters reflecting the latest research trends and providing useful algorithms to aid implementation Supplying a 28 page full color insert Multi Sensor Image Fusion and Its Applications clearly demonstrates the benefits and possibilities of this revolutionary development It provides a solid knowledge base for applying these cutting edge techniques to new challenges and creating future advances

Geometric Methods in Signal and Image Analysis Hamid Krim,Abdessamad Ben Hamza,2015-06-18 This comprehensive guide offers a new approach for developing and implementing robust computational methodologies that uncover the key geometric and topological information from signals and images With the help of detailed real world examples and applications readers will learn how to solve complex signal and image processing problems in fields ranging from remote sensing to medical imaging bioinformatics robotics security and defence With an emphasis on intuitive and application driven arguments this text covers not only a range of methods in use today but also introduces promising new developments for the future bringing the reader up to date with the state of the art in signal and image analysis Covering basic principles as well as advanced concepts and applications and with examples and homework exercises this is an invaluable resource for graduate students researchers and industry practitioners in a range of fields including signal and image processing biomedical engineering and computer graphics *Biomedical Image Analysis* Aly A. Farag,2014-10-30 Ideal for classroom use and self study this book explains the implementation of the most effective modern methods in image analysis covering segmentation registration and visualisation and focusing on the key theories algorithms and applications that have emerged from recent progress in computer vision imaging and computational biomedical science Structured around five core building blocks signals systems image formation and modality stochastic models computational geometry level set methods and tools and CAD models it provides a solid overview of the field Mathematical and statistical topics are presented in a straightforward manner enabling the reader to gain a deep understanding of the subject without becoming entangled in mathematical complexities Theory is connected to practical examples in x ray ultrasound nuclear medicine MRI and CT

imaging removing the abstract nature of the models and assisting reader understanding

Medical Computer Vision: Recognition Techniques and Applications in Medical Imaging Bjoern Menze, Georg Langs, Le Lu, Albert Montillo, Zhuowen Tu, Antonio Criminisi, 2013-03-14 This book constitutes the thoroughly refereed workshop proceedings of the Second International Workshop on Medical Computer Vision MCV 2012 held in Nice France October 2012 in conjunction with the 15th International Conference on Medical Image Computing and Computer Assisted Intervention MICCAI 2012 The 24 papers have been selected out of 42 submissions At MCV 2012 12 papers were presented as a poster and 12 as a poster together with a plenary talk The book also features four selected papers which were presented at the previous CVPR Medical Computer Vision workshop held in conjunction with the International Conference on Computer Vision and Pattern Recognition on June 21 2012 in Providence Rhode Island USA The papers explore the use of modern computer vision technology in tasks such as automatic segmentation and registration localization of anatomical features and detection of anomalies as well as 3D reconstruction and biophysical model personalization

Handbook of Medical Image Computing and Computer Assisted Intervention S. Kevin Zhou, Daniel Rueckert, Gabor Fichtinger, 2019-10-18 Handbook of Medical Image Computing and Computer Assisted Intervention presents important advanced methods and state of the art research in medical image computing and computer assisted intervention providing a comprehensive reference on current technical approaches and solutions while also offering proven algorithms for a variety of essential medical imaging applications This book is written primarily for university researchers graduate students and professional practitioners assuming an elementary level of linear algebra probability and statistics and signal processing working on medical image computing and computer assisted intervention Presents the key research challenges in medical image computing and computer assisted intervention Written by leading authorities of the Medical Image Computing and Computer Assisted Intervention MICCAI Society Contains state of the art technical approaches to key challenges Demonstrates proven algorithms for a whole range of essential medical imaging applications Includes source codes for use in a plug and play manner Embraces future directions in the fields of medical image computing and computer assisted intervention

Biomedical Engineering Systems and Technologies Ana Fred, Joaquim Filipe, Hugo Gamboa, 2008-11-27 This book contains the best papers of the First International Joint Conference on Biomedical Engineering Systems and Technologies BIOSTEC 2008 organized by the Institute for Systems and Technologies of Information Control and Communication INSTICC technically co sponsored by the IEEE Engineering in Medicine and Biology Society EMB ACM SIGART and the Workflow Management Coalition WfMC in cooperation with AAAI The purpose of the International Joint Conference on Biomedical Engineering Systems and Technologies is to bring together researchers and practitioners including engineers biologists health professionals and informatics computer scientists interested in both theoretical advances and applications of information systems artificial intelligence signal processing electronics and other engineering tools in knowledge areas related to biology and medicine BIOSTEC is composed of three co located

conferences each specializes in one of the aforementioned main knowledge areas namely BIODEVICES International Conference on Biomedical Electronics and vices focuses on aspects related to electronics and mechanical engineering specially equipment and materials inspired from biological systems and or dressing biological requirements Monitoring devices instrumentation sensors and systems biorobotics micro nanotechnologies and biomaterials are some of the technologies addressed at this conference

Modern Methods in Scientific Computing and Applications Anne Bourlioux, Martin Gander, 2012-12-06 When we first heard in the spring of 2000 that the Seminaire de matMmatiques superieures SMS was interested in devoting its session of the summer of 2001 its 40th to scientific computing the idea of taking on the organizational work seemed to us somewhat remote More immediate things were on our minds one of us was about to go on leave to the Courant Institute the other preparing for a research summer in Paris But the more we learned about the possibilities of such a seminar the support for the organization and also the great history of the SMS the more we grew attached to the project The topics we planned to cover were intended to span a wide range of theoretical and practical tools for solving problems in image processing thin films mathematical finance electrical engineering moving interfaces and combustion These applications alone show how wide the influence of scientific computing has become over the last two decades almost any area of science and engineering is greatly influenced by simulations and the SMS workshop in this field came very timely We decided to organize the workshop in pairs of speakers for each of the eight topics we had chosen and we invited the leading experts worldwide in these fields We were very fortunate that every speaker we invited accepted to come so the program could be realized as planned

Information Processing in Medical Imaging Nico Karssemeijer, Boudewijn Lelieveldt, 2007-07-14 This book constitutes the refereed proceedings of the 20th International Conference on Information Processing in Medical Imaging IPMI 2007 held in Kerkrade The Netherlands in July 2007 It covers segmentation cardiovascular imaging detection and labeling diffusion tensor imaging registration image reconstruction functional brain imaging as well as shape models and registration

Medical Image Analysis Methods Lena Costaridou, 2005-07-13 To successfully detect and diagnose disease it is vital for medical diagnosticians to properly apply the latest medical imaging technologies It is a worrisome reality that due to either the nature or volume of some of the images provided early or obscured signs of disease can go undetected or be misdiagnosed To combat these inaccuracies diagno

Proceedings of the IEEE Workshop on Mathematical Methods in Biomedical Image Analysis, 2001

Hierarchical and Geometrical Methods in Scientific Visualization Gerald Farin, Bernd Hamann, Hans Hagen, 2012-12-06 The nature of the physical Universe has been increasingly better understood in recent years and cosmological concepts have undergone a rapid evolution see e g 11 2 or 5 Although there are alternate theories it is generally believed that the large scale relationships and homogeneities that we see can only be explained by having the universe expand suddenly in a very early stationary period Subsequent evolution of the Universe is described by the Hubble

expansion the observation that the galaxies are flying away from each other We can attribute different rates of this expansion to domination of different cosmological processes beginning with radiation evolving to matter domination and relatively recently to vacuum domination the Cosmological Constant term ⁴ We assume throughout that we will be relying as much as possible on observational data with simulations used only for limited purposes e g the appearance of the Milky Way from nearby intergalactic viewpoints The visualization of large scale astronomical data sets using fixed non interactive animations has a long history Several books and films exist ranging from Cosmic View The Universe in Forty Jumps ³ by Kees Boeke to Powers of 10 ^{6 13} by Charles and Ray Eames and the recent Imax film Cosmic Voyage ¹⁵ We have added our own contribution ⁹ Cosmic Clock which is an animation based entirely on the concepts and implementation described in this paper

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