Synthesis Lectures on Computer
Graphics and Animation

SYNTHESIS
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Miguel A. Otaduy · Ming C. Lin

High Fidelity Haptic Rendering

Springer

High Fidelity Haptic Rendering Ming C Lin

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High Fidelity Haptic Rendering Miguel A. Otaduy,Ming C. Lin,2022-05-31 The human haptic system among all senses provides unique and bidirectional communication between humans and their physical environment Yet to date most human computer interactive systems have focused primarily on the graphical rendering of visual information and to a lesser extent on the display of auditory information Extending the frontier of visual computing haptic interfaces or force feedback devices have the potential to increase the quality of human computer interaction by accommodating the sense of touch They provide an attractive augmentation to visual display and enhance the level of understanding of complex data sets They have been effectively used for a number of applications including molecular docking manipulation of nano materials surgical training virtual prototyping and digital sculpting Compared with visual and auditory display haptic rendering has extremely demanding computational requirements In order to maintain a stable system while displaying smooth and realistic forces and torques high haptic update rates in the range of 500 1000 Hz or more are typically used Haptics present many new challenges to researchers and developers in computer graphics and interactive techniques Some of the critical issues include the development of novel data structures to encode shape and material properties as well as new techniques for geometry processing data analysis physical modeling and haptic visualization This synthesis examines some of the latest developments on haptic rendering while looking forward to exciting future research in this area It presents novel haptic rendering algorithms that take advantage of the human haptic sensory modality Specifically it discusses different rendering techniques for various geometric representations e g point based polygonal multiresolution distance fields etc as well as textured surfaces It also shows how psychophysics of touch can provide the foundational design guidelines for developing perceptually driven force models and concludes with possible applications and issues to consider in future algorithmic design validating rendering techniques and evaluating haptic interfaces Haptic Rendering Ming C. Lin,Miguel Otaduy,2008-07-25 For a long time human beings have dreamed of a virtual world where it is possible to interact with synthetic entities as if they were real It has been shown that the ability to touch virtual objects increases the sense of presence in virtual environments This book provides an authoritative overview of state of theart haptic rendering algorithms **Sound Synthesis, Propagation, and Rendering** Shiguang Liu,Dinesh Manocha,2022-03-24 This book gives a broad overview of research on sound simulation driven by a variety of applications Vibrating objects produce sound which then propagates through a medium such as air or water before finally being heard by a listener As a crucial sensory channel sound plays a vital role in many applications There is a well established research community in acoustics that has studied the problems related to sound simulation for six decades Some of the earliest work was motivated by the design of concert halls theaters or lecture rooms with good acoustic characteristics These problems also have been investigated in other applications including noise control and sound design for urban planning building construction and automotive applications Moreover plausible or realistic sound effects can improve the sense of presence in a virtual environment or a game In these applications sound can provide important clues such as source directionality and spatial size The book first surveys various sound synthesis methods including harmonic synthesis texture synthesis spectral analysis and physics based synthesis Next it provides an overview of sound propagation techniques including wave based methods geometric based methods and hybrid methods The book also summarizes various techniques for sound rendering Finally it surveys some recent trends including the use of machine learning methods to accelerate sound simulation and the use of sound simulation techniques for other applications such as speech recognition source localization and computer aided design **Real-Time Massive Model Rendering** Sung-eui Yoon,Enrico Gobbetti,David Kasik,Dinesh Manocha,2022-06-01 Interactive display and visualization of large geometric and textured models is becoming a fundamental capability There are numerous application areas including games movies CAD virtual prototyping and scientific visualization One of observations about geometric models used in interactive applications is that their model complexity continues to increase because of fundamental advances in 3D modeling simulation and data capture technologies As computing power increases users take advantage of the algorithmic advances and generate even more complex models and data sets Therefore there are many cases where we are required to visualize massive models that consist of hundreds of millions of triangles and even billions of triangles However interactive visualization and handling of such massive models still remains a challenge in computer graphics and visualization In this monograph we discuss various techniques that enable interactive visualization of massive models These techniques include visibility computation simplification levels of detail and cache coherent data management We believe that the combinations of these techniques can make it possible to interactively visualize massive models in commodity hardware Table of Contents Introduction Visibility Simplification and Levels of Detail Alternative Representations Cache Coherent Data Management Conclusions Bibliography **High Dynamic Range Video** Karol Myszkowski,Rafal Mantiuk,Grzegorz Krawczyk,2022-05-31 As new displays and cameras offer enhanced color capabilities there is a need to extend the precision of digital content High Dynamic Range HDR imaging encodes images and video with higher than normal 8 bit per color channel precision enabling representation of the complete color gamut and the full visible range of luminance However to realize transition from the traditional toHDRimaging it is necessary to develop imaging algorithms that work with the high precision data Tomake such algorithms effective and feasible in practice it is necessary to take advantage of the limitations of the human visual system by aligning the data shortcomings to those of the human eye thus limiting storage and processing precision Therefore human visual perception is the key component of the solutions we discuss in this book This book presents a complete pipeline forHDR image and video processing fromacquisition through compression and quality evaluation to display At the HDR image and video acquisition stage specialized HDR sensors or multi exposure techniques suitable for traditional cameras are discussed Then we present a practical solution for pixel values calibration in terms of photometric or radiometric quantities which are required in some technically oriented applications

Also we cover the problem of efficient image and video compression and encoding either for storage or transmission purposes including the aspect of backward compatibility with existing formats Finally we review existing HDR display technologies and the associated problems of image contrast and brightness adjustment For this purpose tone mapping is employed to accommodate HDR content to LDR devices Conversely the so called inverse tone mapping is required to upgrade LDR content for displaying on HDR devices We overview HDR enabled image and video quality metrics which are needed to verify algorithms at all stages of the pipeline Additionally we cover successful examples of the HDR technology applications in particular in computer graphics and computer vision The goal of this book is to present all discussed components of the HDR pipeline with the main focus on video For some pipeline stages HDR video solutions are either not well established or do not exist at all in which case we describe techniques for single HDR images In such cases we attempt to select the techniques which can be extended into temporal domain Whenever needed relevant background information on human perception is given which enables better understanding of the design choices behind the discussed algorithms and HDR equipment Table of Contents Introduction Representation of an HDR Image HDR Image and Video Acquisition HDR Image Quality HDR Image Video and Texture Compression Tone Reproduction HDR Display Devices LDR2HDR Recovering Dynamic Range in Legacy Content HDRI in Computer Graphics Software *High Dynamic Range Image Reconstruction* Asla M. Sa,Paulo Cezar Carvalho,Luiz Velho,2022-05-31 High dynamic range imaging HDRI is an emerging field that has the potential to cause a great scientific and technological impact in the near future Although new this field is large and complex with non trivial relations to many different areas such as image synthesis computer vision video and image processing digital photography special effects among others For the above reasons HDRI has been extensively researched over the past years and consequently the related scientific literature is vast As an indication that the field is reaching maturity tutorials and books on HDRI appeared Moreover this new resource has already reached interested practitioners in various application areas In this book we do not aim at covering the whole field of high dynamic range imaging and its applications since it is a broad subject that is still evolving Instead our intent is to cover the basic principles behind HDRI and focus on one of the currently most important problems both theoretically and practically That is the reconstruction of high dynamic range images from regular low dynamic range pictures Table of Contents Introduction Digital Image Imaging Devices and Calibration HDR Reconstruction HDRI Acquisition and Visualization Tone Enhancement References Biography

Heterogeneous Spatial Data Giuseppe Patanè,Michela Spagnuolo,2022-05-31 New data acquisition techniques are emerging and are providing fast and efficient means for multidimensional spatial data collection Airborne LIDAR surveys SAR satellites stereo photogrammetry and mobile mapping systems are increasingly used for the digital reconstruction of the environment All these systems provide extremely high volumes of raw data often enriched with other sensor data e g beam intensity Improving methods to process and visually analyze this massive amount of geospatial and user generated data is crucial to increase the efficiency of organizations and to better manage societal challenges Within this context this book proposes an up to date view of computational methods and tools for spatio temporal data fusion multivariate surface generation and feature extraction along with their main applications for surface approximation and rainfall analysis The book is intended to attract interest from different fields such as computer vision computer graphics geomatics and remote sensing working on the common goal of processing 3D data To this end it presents and compares methods that process and analyze the massive amount of geospatial data in order to support better management of societal challenges through more timely and better decision making independent of a specific data modeling paradigm e g 2D vector data regular grids or 3D point clouds We also show how current research is developing from the traditional layered approach adopted by most GIS softwares to intelligent methods for integrating existing data sets that might contain important information on a geographical area and environmental phenomenon These services combine traditional map oriented visualization with fully 3D visual decision support methods and exploit semantics oriented information e g a priori knowledge annotations segmentations when processing merging and integrating big pre existing data sets **Efficient Quadrature Rules for Illumination Integrals** Ricardo Marques,Christian Bouville,Luís Paulo Santos,Kadi Bouatouch,2022-06-01 Rendering photorealistic images is a costly process which can take up to several days in the case of high quality images In most cases the task of sampling the incident radiance function to evaluate the illumination integral is responsible for an important share of the computation time Therefore to reach acceptable rendering times the illumination integral must be evaluated using a limited set of samples Such a restriction raises the question of how to obtain the most accurate approximation possible with such a limited set of samples One must thus ensure that sampling produces the highest amount of information possible by carefully placing and weighting the limited set of samples Furthermore the integral evaluation should take into account not only the information brought by sampling but also possible information available prior to sampling such as the integrand smoothness This idea of sparse information and the need to fully exploit the little information available is present throughout this book The presented methods correspond to the state of the art solutions in computer graphics and take into account information which had so far been underexploited or even neglected by the previous approaches The intended audiences are Ph D students and researchers in the field of realistic image synthesis or global illumination algorithms or any person with a solid background in graphics and numerical techniques **An Introduction to Laplacian Spectral Distances and Kernels** Giuseppe Patanè,2022-05-31 In geometry processing and shape analysis several applications have been addressed through the properties of the Laplacian spectral kernels and distances such as commute time biharmonic diffusion and wave distances Within this context this book is intended to provide a common background on the definition and computation of the Laplacian spectral kernels and distances for geometry processing and shape analysis To this end we define a unified representation of the isotropic and anisotropic discrete Laplacian operator on surfaces and volumes then we introduce the associated differential equations i e the harmonic equation the Laplacian eigenproblem and the heat equation Filtering the Laplacian spectrum we introduce the Laplacian spectral distances which generalize the commute time biharmonic diffusion and wave distances and their discretization in terms of the Laplacian spectrum As main applications we discuss the design of smooth functions and the Laplacian smoothing of noisy scalar functions All the reviewed numerical schemes are discussed and compared in terms of robustness approximation accuracy and computational cost thus supporting the reader in the selection of the most appropriate with respect to shape representation computational resources and target application Numerical Methods for Linear Complementarity Problems in Physics-Based Animation Sarah Niebe,Kenny Erleben,2022-05-31 Linear complementarity problems LCPs have for many years been used in physics based animation to model contact forces between rigid bodies in contact More recently LCPs have found their way into the realm of fluid dynamics Here LCPs are used to model boundary conditions with fluid wall contacts LCPs have also started to appear in deformable models and granular simulations There is an increasing need for numerical methods to solve the resulting LCPs with all these new applications This book provides a numerical foundation for such methods especially suited for use in computer graphics This book is mainly intended for a researcher Ph D student post doc professor who wants to study the algorithms and do more work research in this area Programmers might have to invest some time brushing up on math skills for this we refer to Appendices A and B The reader should be familiar with linear algebra and differential calculus We provide pseudo code for all the numerical methods which should be comprehensible by any computer scientist with rudimentary programming skills The reader can find an online supplementary code repository containing Matlab implementations of many of the core methods covered in these notes as well as a few Python implementations Erleben 2011 Table of Contents Introduction Numerical Methods Guide for Software and Selecting Methods Bibliography Authors Biographies **Rethinking Quaternions** Ron Goldman,2022-05-31 Quaternion multiplication can be used to rotate vectors in three dimensions Therefore in computer graphics quaternions have three principal applications to increase speed and reduce storage for calculations involving rotations to avoid distortions arising from numerical inaccuracies caused by floating point computations with rotations and to interpolate between two rotations for key frame animation Yet while the formal algebra of quaternions is well known in the graphics community the derivations of the formulas for this algebra and the geometric principles underlying this algebra are not well understood The goals of this monograph are to provide a fresh geometric interpretation for quaternions appropriate for contemporary computer graphics based on mass points to present better ways to visualize quaternions and the effect of quaternion multiplication on points and vectors in three dimensions using insights from the algebra and geometry of multiplication in the complex plane to derive the formula for quaternion multiplication from first principles to develop simple intuitive proofs of the sandwiching formulas for rotation and reflection to show how to apply sandwiching to compute perspective projections In addition to these theoretical issues we also address some computational questions We develop straightforward formulas for converting back and forth between quaternion and matrix representations for rotations reflections and perspective projections and we discuss the relative advantages and disadvantages of the quaternion and matrix representations for these transformations Moreover we show how to avoid distortions due to floating point computations with rotations by using unit quaternions to represent rotations We also derive the formula for spherical linear interpolation and we explain how to apply this formula to interpolate between two rotations for key frame animation Finally we explain the role of quaternions in low dimensional Clifford algebras and we show how to apply the Clifford algebra for R3 to model rotations reflections and perspective projections To help the reader understand the concepts and formulas presented here we have incorporated many exercises in order to clarify and elaborate some of the key points in the text Table of Contents Preface Theory Computation Rethinking Quaternions and Clif ford Algebras References Further Reading Author Biography **Stochastic Partial Differential Equations for Computer Vision with Uncertain Data** Tobias Preusser,Robert M. Kirby,Torben Pätz,2022-06-01 In image processing and computer vision applications such as medical or scientific image data analysis as well as in industrial scenarios images are used as input measurement data It is good scientific practice that proper measurements must be equipped with error and uncertainty estimates For many applications not only the measured values but also their errors and uncertainties should be and more and more frequently are taken into account for further processing This error and uncertainty propagation must be done for every processing step such that the final result comes with a reliable precision estimate The goal of this book is to introduce the reader to the recent advances from the field of uncertainty quantification and error propagation for computer vision image processing and image analysis that are based on partial differential equations PDEs It presents a concept with which error propagation and sensitivity analysis can be formulated with a set of basic operations The approach discussed in this book has the potential for application in all areas of quantitative computer vision image processing and image analysis In particular it might help medical imaging finally become a scientific discipline that is characterized by the classical paradigms of observation measurement and error awareness This book is comprised of eight chapters After an introduction to the goals of the book Chapter 1 we present a brief review of PDEs and their numerical treatment Chapter 2 PDE based image processing Chapter 3 and the numerics of stochastic PDEs Chapter 4 We then proceed to define the concept of stochastic images Chapter 5 describe how to accomplish image processing and computer vision with stochastic images Chapter 6 and demonstrate the use of these principles for accomplishing sensitivity analysis Chapter 7 Chapter 8 concludes the book and highlights new research topics for the future **Virtual Crowds** Nuria Palechano,Norman Badler,Jan Allbeck,2022-05-31 There are many applications of computer animation and simulation where it is necessary to model virtual crowds of autonomous agents Some of these applications include site planning education entertainment training and human factors analysis for building evacuation Other applications include simulations of scenarios where masses of people gather flow and disperse such as transportation centers sporting events and concerts Most crowd simulations include only basic locomotive behaviors possibly coupled with a few stochastic actions Our goal in this survey is to establish a baseline of techniques and requirements for simulating large scale virtual human populations Sometimes these populations might be mutually engaged in a common activity such as evacuation from a building or area other times they may be going about their individual and personal agenda of work play leisure travel or spectator Computational methods to model one set of requirements may not mesh well with good approaches to another By including both crowd and individual goals and constraints into a comprehensive computational model we expect to simulate the visual texture and contextual behaviors of groups of seemingly sentient beings Table of Contents Introduction Crowd Simulation Methodology Survey Individual Differences in Crowds Framework HiDAC MACES CAROSA HiDAC Local Motion MACES Wayfinding with Communication and Roles CAROSA Functional Crowds Initializing a Scenario Evaluating Crowds **Geometric and Discrete Path Planning for Interactive Virtual Worlds** Marcelo Kallmann,Mubbasir Kapadia,2022-05-31 Path planning and navigation are indispensable components for controlling autonomous agents in interactive virtual worlds Given the growing demands on the size and complexity of modern virtual worlds a number of new techniques have been developed for achieving intelligent navigation for the next generation of interactive multi agent simulations This book reviews the evolution of several related techniques starting from classical planning and computational geometry techniques and then gradually moving toward more advanced topics with focus on recent developments from the work of the authors The covered topics range from discrete search and geometric representations to planning under different types of constraints and harnessing the power of graphics hardware in order to address Euclidean shortest paths and discrete search for multiple agents under limited time budgets The use of planning algorithms beyond path planning is also discussed in the areas of crowd animation and whole body motion planning for virtual characters **GPU Ray Tracing in Non-Euclidean Spaces** Tiago Novello,Vinícius da Silva,Luiz Velho,2022-03-21 This book explores the visualization of three dimensional non Euclidean spaces using raytracing techniques in Graphics Processing Unit GPU This is a trending topic in mathematical visualization that combines the mathematics areas of geometry and topology with visualization concepts of computer graphics Several conditions made this a special moment for such topic On one hand the development of mathematical research computer graphics and algorithms have provided the necessary theoretical framework On the other hand the evolution of the technologies and media allows us to be immersed in three dimensional spaces using Virtual Reality The content of this book serves both experts in the areas and students Although this is a short book it is self contained since it considers all the ideas motivations references and intuitive explanations of the required fundamental concepts *Digital Heritage Reconstruction Using Super-resolution and Inpainting* Milind G. Padalkar,Manjunath V. Joshi,Nilay L. Khatri,2022-06-01 Heritage sites across the world have witnessed a number of natural calamities sabotage and damage from visitors resulting in their present ruined condition Many sites are now restricted to reduce the risk of further damage Yet these masterpieces are significant cultural icons and critical markers of past civilizations that future generations need to see A digitally reconstructed heritage site could diminish further harm by using immersive navigation or walkthrough systems for virtual environments An exciting key element for the viewer is observing fine details of the historic work and viewing monuments in their undamaged form This book presents image super resolution methods and techniques for automatically detecting and inpainting damaged regions in heritage monuments in order to provide an enhanced visual experience The book presents techniques to obtain higher resolution photographs of the digitally reconstructed monuments and the resulting images can serve as input to immersive walkthrough systems It begins with the discussion of two novel techniques for image super resolution and an approach for inpainting a user supplied region in the given image followed by a technique to simultaneously perform super resolution and inpainting of given missing regions It then introduces a method for automatically detecting and repairing the damage to dominant facial regions in statues followed by a few approaches for automatic crack repair in images of heritage scenes This book is a giant step toward ensuring that the iconic sites of our past are always available and will never be truly lost **Interactive Shape Design** Marie-Paule Cani,Takeo Igarashi,Geoff Wyvill,2022-05-31 Providing an intuitive modeling system which would enable us to communicate about any free form shape we have in mind at least as quickly as with real world tools is one of the main challenges of digital shape design The user should ideally be able to create deform and progressively add details to a shape without being aware of the underlying mathematical representation nor being tied by any constraint on the geometrical or topological nature of the model This book presents the field of interactive shape design from this perspective Since interactively creating a shape builds on the humans ability of modeling by gesture we note that the recent advances in interactive shape design can be classified as those that rely on sculpting as opposed to sketching metaphors Our synthetic presentation of these strategies enables us to compare the different families of solutions discuss open issues and identify directions for future research Table of Contents Introduction Sculpting Metaphors Sketching Systems Future Directions Modeling by Gesture **Gazing at Games** Veronica Sundstedt,2022-05-31 Eye tracking is a process that identifies a specific point in both space and time that is being looked at by the observer This information can also be used in real time to control applications using the eyes Recent innovations in the video game industry include alternative input modalities to provide an enhanced more immersive user experience In particular eye gaze control has recently been explored as an input modality in video games This book is an introduction for those interested in using eye tracking to control or analyze video games and virtual environments Key concepts are illustrated through three case studies in which gaze control and voice recognition have been used in combination to control virtual characters and applications The lessons learned in the case studies are presented and issues relating to incorporating eye tracking in interactive applications are discussed The reader will be given an introduction to human visual attention eye movements and eye tracking technologies Previous work in the field of studying fixation behavior in games and using eye tracking for video game interaction will also be presented The final chapter discusses ideas for how this field can be developed further to create richer interaction for characters and crowds in virtual environments Alternative means of interaction in video games are especially important for disabled users for whom traditional techniques such as mouse and keyboard may be far from ideal This book is also relevant for those wishing to use gaze control in applications other than games Table of Contents Introduction The Human Visual System Eye Tracking Eye Tracking in Video Games Gaze and Voice Controlled Video Games Case Study I and II Gaze and Voice Controlled Drawing Case Study III Conclusion

Information Theory Tools for Image Processing Miquel Feixas,Anton Bardera,Jaume Rigau,Qing Xu,2022-06-01 Information Theory IT tools widely used in many scientific fields such as engineering physics genetics neuroscience and many others are also useful transversal tools in image processing In this book we present the basic concepts of IT and how they have been used in the image processing areas of registration segmentation video processing and computational aesthetics Some of the approaches presented such as the application of mutual information to registration are the state of the art in the field All techniques presented in this book have been previously published in peer reviewed conference proceedings or international journals We have stressed here their common aspects and presented them in an unified way so to make clear to the reader which problems IT tools can help to solve which specific tools to use and how to apply them The IT basics are presented so as to be self contained in the book The intended audiences are students and practitioners of image processing and related areas such as computer graphics and visualization In addition students and practitioners of IT will be interested in knowing about these applications Table of Contents Preface Acknowledgments Information Theory Basics Image Registration Image Segmentation Video Key Frame Selection Informational Aesthetics Measures Bibliography Authors Biographies *Mathematical Basics of Motion and Deformation in Computer Graphics, Second Edition* Ken Anjyo,Hiroyuki Ochiai,2022-06-01 This synthesis lecture presents an intuitive introduction to the mathematics of motion and deformation in computer graphics Starting with familiar concepts in graphics such as Euler angles quaternions and affine transformations we illustrate that a mathematical theory behind these concepts enables us to develop the techniques for efficient effective creation of computer animation This book therefore serves as a good guidepost to mathematics differential geometry and Lie theory for students of geometric modeling and animation in computer graphics Experienced developers and researchers will also benefit from this book since it gives a comprehensive overview of mathematical approaches that are particularly useful in character modeling deformation and animation

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