

Jaroslav Krivánek · Pascal Gautron

Practical Global Illumination with Irradiance Caching

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Pascal Gautron

Raffaela Di Napoli



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Practical Global Illumination with Irradiance Caching Jaroslav Krivanek, Pascal Gautron, 2009-07-08 Irradiance caching is a ray tracing based technique for computing global illumination on diffuse surfaces Specifically it addresses the computation of indirect illumination bouncing off one diffuse object onto another The sole purpose of irradiance caching is to make this computation reasonably fast The main idea is to perform the indirect illumination sampling only at a selected set of locations in the scene store the results in a cache and reuse the cached value at other points through fast interpolation This book is for anyone interested in making a production ready implementation of irradiance caching that reliably renders artifact free images Since its invention 20 years ago the irradiance caching algorithm has been successfully used to accelerate global illumination computation in the Radiance lighting simulation system Its widespread use had to wait until computers became fast enough to consider global illumination in film production rendering Since then its use is ubiquitous Virtually all commercial and open source rendering software base the global illumination computation upon irradiance caching Although elegant and powerful the algorithm in its basic form often fails to produce artifact free mages Unfortunately practical information on implementing the algorithm is scarce The main objective of this book is to show the irradiance caching algorithm along with all the details and tricks upon which the success of its practical implementation is dependent In addition we discuss some extensions of the basic algorithm such as a GPU implementation for interactive global illumination computation and temporal caching that exploits temporal coherence to suppress flickering in animations Our goal is to show the material without being overly theoretical However the reader should have some basic understanding of rendering concepts ray tracing in particular Familiarity with global illumination is useful but not necessary to read this book Table of Contents Introduction to Ray Tracing and Global Illumination Irradiance Caching Core Practical Rendering with Irradiance Caching Irradiance Caching in a Complete Global Illumination Irradiance Caching on Graphics Hardware Temporal Irradiance Caching

Practical Global Illumination with Irradiance Caching Jaroslav Krivanek, Pascal Gautron, 2022-05-31 Irradiance caching is a ray tracing based technique for computing global illumination on diffuse surfaces Specifically it addresses the computation of indirect illumination bouncing off one diffuse object onto another The sole purpose of irradiance caching is to make this computation reasonably fast The main idea is to perform the indirect illumination sampling only at a selected set of locations in the scene store the results in a cache and reuse the cached value at other points through fast interpolation This book is for anyone interested in making a production ready implementation of irradiance caching that reliably renders artifact free images Since its invention 20 years ago the irradiance caching algorithm has been successfully used to accelerate global illumination computation in the Radiance lighting simulation system Its widespread use had to wait until computers became fast enough to consider global illumination in film production rendering Since then its use is ubiquitous Virtually all commercial and open source rendering software base the global

illumination computation upon irradiance caching Although elegant and powerful the algorithm in its basic form often fails to produce artifact free images Unfortunately practical information on implementing the algorithm is scarce The main objective of this book is to show the irradiance caching algorithm along with all the details and tricks upon which the success of its practical implementation is dependent In addition we discuss some extensions of the basic algorithm such as a GPU implementation for interactive global illumination computation and temporal caching that exploits temporal coherence to suppress flickering in animations Our goal is to show the material without being overly theoretical However the reader should have some basic understanding of rendering concepts ray tracing in particular Familiarity with global illumination is useful but not necessary to read this book

Table of Contents Introduction to Ray Tracing and Global Illumination Irradiance Caching Core Practical Rendering with Irradiance Caching Irradiance Caching in a Complete Global Illumination Irradiance Caching on Graphics Hardware Temporal Irradiance Caching *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

Virtual Material Acquisition and Representation for Computer Graphics

Dar'ya Guarnera,Giuseppe Claudio Guarnera,2022-05-31 This book provides beginners in computer graphics and related fields a guide to the concepts models and technologies for realistic rendering of material appearance It provides a complete and thorough overview of reflectance models and acquisition setups along with providing a selection of the available tools to explore visualize and render the reflectance data Reflectance models are under continuous development since there is still no straightforward solution for general material representations Every reflectance model is specific to a class of materials Hence each has strengths and weaknesses which the book highlights in order to help the reader choose the most suitable model for any purpose The overview of the acquisition setups will provide guidance to a reader who needs to acquire virtual

materials and will help them to understand which measurement setup can be useful for a particular purpose while taking into account the performance and the expected cost derived from the required components. The book also describes several recent open source software solutions useful for visualizing and manipulating a wide variety of reflectance models and data. **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. **Introductory Tiling Theory for**

Computer Graphics Craig Kaplan, 2022-06-01 Tiling theory is an elegant branch of mathematics that has applications in several areas of computer science. The most immediate application area is graphics, where tiling theory has been used in the contexts of texture generation, sampling theory, remeshing, and of course the generation of decorative patterns. The combination of a solid theoretical base, complete with tantalizing open problems, practical algorithmic techniques, and exciting applications, make tiling theory a worthwhile area of study for practitioners and students in computer science. This synthesis lecture introduces the mathematical and algorithmic foundations of tiling theory to a computer graphics audience. The goal is primarily to introduce concepts and terminology, clear up common misconceptions, and state and apply important results. The book also describes some of the algorithms and data structures that allow several aspects of tiling theory to be used in practice. Table of Contents: Introduction, Tiling Basics, Symmetry, Tilings by Polygons, Isohedral Tilings, Nonperiodic and Aperiodic Tilings, Survey. 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 Mubbasir Kapadia,Nuria Pelechano,Jan Allbeck,Norm Badler,2022-05-31 This volume presents novel computational models for representing digital humans and their interactions with other virtual characters and meaningful environments In this context we describe efficient algorithms to animate control and author human like agents having their own set of unique capabilities personalities and desires We begin with the lowest level of footstep determination to steer agents in collision free paths Steering choices are controlled by navigation in complex environments including multi domain planning with dynamically changing situations Virtual agents are given perceptual capabilities analogous to those of real people including sound perception multi sense attention and understanding of environment semantics which affect their behavior choices The roles and impacts of individual attributes such as memory and personality are explored The animation challenges of integrating a number of simultaneous behavior and movement demands on an agent are addressed through an open source software system Finally the creation of stories and narratives with groups of agents subject to planning and environmental constraints culminates the presentation

Mathematical Basics of Motion and Deformation in Computer Graphics Ken Anjyo,Hiroyuki Ochiai,2014-10-22 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 Table of Contents Preface Symbols and Notations Introduction Rigid Transformation Affine Transformation

Exponential and Logarithm of Matrices 2D Affine Transformation between Two Triangles Global 2D Shape Interpolation
 Parametrizing 3D Positive Affine Transformations Further Readings Bibliography Authors Biographies **Design, Representations, and Processing for Additive Manufacturing** Marco Attene,Marco Livesu,Sylvain Lefebvre,Stefano Ellero,Szymon Rusinkiewicz,Thomas Funkhouser,2022-06-01 The wide diffusion of 3D printing technologies continuously calls for effective solutions for designing and fabricating objects of increasing complexity The so called computational fabrication pipeline comprises all the steps necessary to turn a design idea into a physical object and this book describes the most recent advancements in the two fundamental phases along this pipeline design and process planning We examine recent systems in the computer graphics community that allow us to take a design idea from conception to a digital model and classify algorithms that are necessary to turn such a digital model into an appropriate sequence of machining instructions Information Theory Tools for Computer Graphics Mateu Sbert,Miquel Feixas,Jaume Rigau,Miguel Chover,Ivan Viola,2022-06-01 Information theory IT tools widely used in scientific fields such as engineering physics genetics neuroscience and many others are also emerging as useful transversal tools in computer graphics In this book we present the basic concepts of IT and how they have been applied to the graphics areas of radiosity adaptive ray tracing shape descriptors viewpoint selection and saliency scientific visualization and geometry simplification Some of the approaches presented such as the viewpoint techniques are now the state of the art in visualization Almost all of the techniques presented in this book have been previously published in peer reviewed conference proceedings or international journals Here we have stressed their common aspects and presented them in an unified way so the reader can clearly see which problems IT tools can help solve which specific tools to use and how to apply them A basic level of knowledge in computer graphics is required but basic concepts in IT are presented The intended audiences are both students and practitioners of the fields above and related areas in computer graphics In addition IT practitioners will learn about these applications Table of Contents Information Theory Basics Scene Complexity and Refinement Criteria for Radiosity Shape Descriptors Refinement Criteria for Ray Tracing Viewpoint Selection and Mesh Saliency View Selection in Scientific Visualization Viewpoint based Geometry Simplification **Mathematical Tools for Shape Analysis and Description** Silvia Biasotti,Bianca Falcidieno,Daniela Giorgi,Michela Spagnuolo,2022-06-01 This book is a guide for researchers and practitioners to the new frontiers of 3D shape analysis and the complex mathematical tools most methods rely on The target reader includes students researchers and professionals with an undergraduate mathematics background who wish to understand the mathematics behind shape analysis The authors begin with a quick review of basic concepts in geometry topology differential geometry and proceed to advanced notions of algebraic topology always keeping an eye on the application of the theory through examples of shape analysis methods such as 3D segmentation correspondence and retrieval A number of research solutions in the field come from advances in pure and applied mathematics as well as from the re reading of classical theories and their adaptation to

the discrete setting In a world where disciplines fortunately have blurred boundaries the authors believe that this guide will help to bridge the distance between theory and practice Table of Contents Acknowledgments Figure Credits About this Book 3D Shape Analysis in a Nutshell Geometry Topology and Shape Representation Differential Geometry and Shape Analysis Spectral Methods for Shape Analysis Maps and Distances between Spaces Algebraic Topology and Topology Invariants Differential Topology and Shape Analysis Reeb Graphs Morse and Morse Smale Complexes Topological Persistence Beyond Geometry and Topology Resources Bibliography Authors Biographies

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

Finite Element Method Simulation of 3D Deformable Solids Eftychios Sifakis, Jernej Barbič, 2022-06-01 This book serves as a practical guide to simulation of 3D deformable solids using the Finite Element Method FEM It reviews a number of topics related to the theory and implementation of FEM approaches measures of deformation constitutive laws of nonlinear materials tetrahedral discretizations and model reduction techniques for real time simulation Simulations of deformable solids are important in many applications in computer graphics including film special effects computer games and virtual surgery The Finite Element Method has become a popular tool in many such applications Variants of FEM catering to both offline and real time simulation have had a mature presence in computer graphics literature This book is designed for readers familiar with numerical simulation in computer graphics who would like to obtain a cohesive picture of the various FEM simulation methods available their strengths and weaknesses and their applicability in various simulation scenarios The book is also a practical implementation guide for the visual effects developer offering a lean yet adequate synopsis of the underlying mathematical theory Chapter 1 introduces the quantitative descriptions used to capture the deformation of elastic solids the concept of strain energy and discusses how force and stress result as a response

to deformation Chapter 2 reviews a number of constitutive models i.e analytical laws linking deformation to the resulting force that has successfully been used in various graphics oriented simulation tasks Chapter 3 summarizes how deformation and force can be computed discretely on a tetrahedral mesh and how an implicit integrator can be structured around this discretization Finally chapter 4 presents the state of the art in model reduction techniques for real time FEM solid simulation and discusses which techniques are suitable for which applications Topics discussed in this chapter include linear modal analysis modal warping subspace simulation and domain decomposition

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

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

Geometric Continuity of Curves and Surfaces Przemysław Kiciak, 2022-05-31 This book is written for students CAD system users and software developers who are interested in geometric continuity a notion needed in everyday practice of Computer Aided Design and also a hot subject of research It

contains a description of the classical geometric spline curves and a solid theoretical basis for various constructions of smooth surfaces Textbooks on computer graphics usually cover the most basic and necessary information about spline curves and surfaces in order to explain simple algorithms In textbooks on geometric design one can find more details more algorithms and more theory This book teaches how various parts of the theory can be gathered together and turned into constructions of smooth curves and smooth surfaces of arbitrary topology The mathematical background needed to understand this book is similar to what is necessary to read other textbooks on geometric design most of it is basic linear algebra and analysis More advanced mathematical material is introduced using elementary explanations Reading Geometric Continuity of Curves and Surfaces provides an excellent opportunity to recall and exercise necessary mathematical notions and it may be your next step towards better practice and higher understanding of design principles

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

Cloth Simulation for Computer Graphics Tuur Stuyck, 2022-06-01 Physics based animation is commonplace in animated feature films and even special effects for live action movies Think about a recent movie and there will be some sort of special effects such as explosions or virtual worlds Cloth simulation is no different and is ubiquitous because most virtual characters hopefully wear some sort of clothing The focus of this book is physics based cloth simulation We start by providing background information and discuss a range of applications

This book provides explanations of multiple cloth simulation techniques. More specifically, we start with the most simple explicitly integrated mass spring model and gradually work our way up to more complex and commonly used implicitly integrated continuum techniques in state of the art implementations. We give an intuitive explanation of the techniques and give additional information on how to efficiently implement them on a computer. This book discusses explicit and implicit integration schemes for cloth simulation modeled with mass spring systems. In addition to this simple model, we explain the more advanced continuum inspired cloth model introduced in the seminal work of Baraff and Witkin 1998. This method is commonly used in industry. We also explain recent work by Liu et al 2013 that provides a technique to obtain fast simulations. In addition to these simulation approaches, we discuss how cloth simulations can be art directed for stylized animations based on the work of Wojan et al 2016. Controllability is an essential component of a feature animation film production pipeline. We conclude by pointing the reader to more advanced techniques.

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.

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Practical Global Illumination With Irradiance Caching Pascal Gautron Introduction

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