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Virtual Crowds

Methods, Simulation, and Control

Nuria Pelechano
Jan Allbeck
Norman Badler

SYNTHESIS LECTURES ON COMPUTER GRAPHICS AND ANIMATION

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Virtual Crowds Methods Simulation And Control Norman Badler

Tobias Preusser,Robert M. Kirby,Torben Pätz

Virtual Crowds Methods Simulation And Control Norman Badler:

Virtual Crowds Nuria Palechano,Norman Badler,Jan Allbeck,2008-11-08 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

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

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 Wang Tiles in Computer Graphics Ares Lagae,2022-06-01 Many complex signals in computer graphics such as point distributions and textures cannot be efficiently synthesized and stored This book presents tile based methods based on Wang tiles and corner tiles to solve both these problems Instead of synthesizing a complex signal when needed the signal is synthesized beforehand over a small set of Wang tiles or corner tiles Arbitrary large amounts of that signal can then efficiently be generated when needed by generating a stochastic tiling and storing only a small set of tiles reduces storage requirements A tile based method for generating a complex signal consists of a method for synthesizing the signal over a set of Wang tiles or corner tiles and a method for generating a stochastic tiling using the set of tiles The method for generating a stochastic tiling using the set of tiles is independent of the signal This book covers scanline stochastic tiling algorithms and direct stochastic tiling algorithms for Wang tiles and corner tiles The method for synthesizing the signal over a set of tiles is dependent on the signal This book covers tile based methods for texture synthesis and for generating Poisson disk distributions This book also explores several applications such as tile based texture mapping and procedural modeling and texturing Although the methods for constructing a complex signal over a set of Wang tiles or corner tiles are dependent on the signal the general idea behind these methods generalizes to other kinds of signals The methods presented in this book therefore have the potential to make the generation and storage of almost any complex signal efficient Table of Contents Introduction Wang Tiles and Corner Tiles Tiling Algorithms for Wang Tiles and Corner Tiles Tile Based Methods for Texture Synthesis Tile Based Methods Generating Poisson Disk Distributions Applications of Poisson Disk Distributions **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 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 **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

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 **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 **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 *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 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 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 *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

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 *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 **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 **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 **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 **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 Eleven Exercises in the Art of Architectural Drawing Marco Frascari,2011-03-08 This text offers 11 servings of slow food for the architectural imagination as opposed to the tasteless fast food that dominates many drawing tables or digital tablets

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Virtual Crowds Methods Simulation And Control Norman Badler Introduction

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