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Nuria Pelechano · Jan M. Allbeck · Norman I. Badler

Virtual Crowds: Methods, Simulation, and Control

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Virtual Crowds Methods Simulation And Control Norman Badler

Marie-Paule Cani,Takeo Igarashi,Geoff Wyvill

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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

Simulating Heterogeneous Crowds with Interactive Behaviors Nuria Pelechano,Jan M. Allbeck,Mubbasir Kapadia,Norman I. Badler,2016-10-26 This book provides a deep understanding of state of art methods for simulation of heterogeneous crowds in computer graphics It will cover different aspects that are necessary to achieve plausible crowd

behaviors The book will be a review of the most recent literature in this field that can help professionals and graduate students interested in this field to get up to date with the latest contributions and open problems for their possible future research The chapter contributors are well known researchers and practitioners in the field and they include their latest contributions in the different topics required to achieve believable heterogeneous crowd simulation Provides crowd simulation methodology to populate virtual environments for video games or any kind of applications that requires believable multi agent behavior Presents the latest contributions on crowd simulation animation planning rendering and evaluation with detailed algorithms for implementation purposes Includes perspectives of both academic researchers and industrial practitioners with reference to open source solutions and commercial applications where appropriate **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 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 **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 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 fromthe 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 **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 **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

An Introduction to Verification of Visualization Techniques Tiago Etiene,Robert M. Kirby,Cláudio T. Silva,2022-06-01 As we increase our reliance on computer generated information often using it as part of our decision making process we must devise tools to assess the correctness of that information Consider for example software embedded on vehicles used for simulating aircraft performance or used in medical imaging In those cases software correctness is of paramount importance as there s little room for error Software verification is one of the tools available to attain such goals Verification is a well known and widely studied subfield of computer science and computational science and the goal is to help us increase confidence in the software implementation by verifying that the software does what it is supposed to do The goal of this book

is to introduce the reader to software verification in the context of visualization In the same way we became more dependent on commercial software we have also increased our reliance on visualization software The reason is simple visualization is the lens through which users can understand complex data and as such it must be verified The explosion in our ability to amass data requires tools not only to store and analyze data but also to visualize it This book is comprised of six chapters After an introduction to the goals of the book we present a brief description of both worlds of visualization Chapter 2 and verification Chapter 3 We then proceed to illustrate the main steps of the verification pipeline for visualization algorithms We focus on two classic volume visualization techniques namely Isosurface Extraction Chapter 4 and Direct Volume Rendering Chapter 5 We explain how to verify implementations of those techniques and report the latest results in the field of verification of visualization techniques The last chapter concludes the book and highlights new research topics for the future

Simulating Crowds in Egress Scenarios Vinícius J. Cassol,Soraia R. Musse,Cláudio R. Jung,Norman I Badler,2017-12-08 This book describes from a computer science viewpoint the software methods of simulating and analysing crowds with a particular focus on the effects of panic in emergency situations The power of modern technology impacts on modern life in multiple ways every day A variety of scientific models and computational tools have been developed to improve human safety and comfort in built environments In particular understanding pedestrian behaviours during egress situations is of considerable importance in such contexts Moreover some places are built for large numbers of people such as train stations and airports and high volume special activities such as sporting events Simulating Crowds in Egress Scenarios discusses the use of computational crowd simulation to reproduce and evaluate egress performance in specific scenarios Several case studies are included evaluating the work and different analyses and comparisons of simulation data versus data obtained from real life experiments are given **GPU Ray Tracing in Non-Euclidean Spaces** Tiago Novello,Vinícius da Silva,Luiz Velho,2022-05-31 This book explores the visualization of three dimensional non Euclidean spaces using ray tracing 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 *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   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   *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

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 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 **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

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 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

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