

Dynamic Simulation of Splashing Fluids

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Abstract: *In this paper we describe a method for modeling the dynamic behavior of splashing fluids. The model simulates the behavior of a fluid when objects impact or float on its surface. The forces generated by the objects create waves and splashes on the surface of the fluid. To demonstrate the realism and limitations of the model, images from a computer-generated animation are presented and compared with video frames of actual splashes occurring under similar initial conditions.*

1 Introduction

The world is filled with natural phenomena that are remarkable in their form and movements: a tree blowing in the wind, lightning arcing across the sky and the simple elegance of ripples in a pool of water. We, along with others in the computer graphics community, are attempting to emulate nature's splendor in our computer animations. Our approach to this problem is to add realism to computer-generated images and animations through the use of models and simulations that approximate the physical laws of nature.

While many natural phenomena appear simple, the true complexity of these behaviors is considerable. For example, a rock falling into a pool of water involves complex interactions between the rock and the water. The rock strikes the pool's surface, displacing water and creating a disturbance that travels outward from the impact as it forms waves on the surface. Fluid that is displaced with sufficient force breaks free of the pool and flies through the air as spray. Cohesion between water molecules causes the formation of sheets of water, and air forced beneath the surface generates foam and bubbles.

Computer animations have been produced by skilled animators manipulating models of a computer-generated world using their intuition about the real or

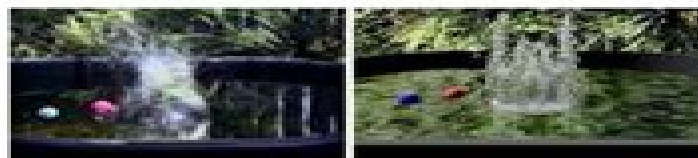


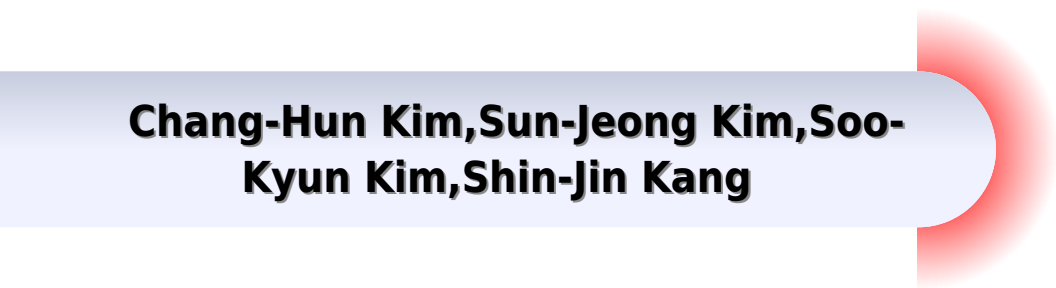
Figure 1: Comparison between a video image of a physical splash and a synthetic image generated using dynamic models of the fluid and the impacting object.

imaginary physical laws of the animated universe. To provide the animator with higher level tools for producing realistic computer animations of natural phenomena, researchers have investigated the use of dynamically based simulations. By modeling the physical effects of natural forces, the modeled systems can display realistic behavior without explicit specification of the movement for each object. Unfortunately, physically correct simulations of complex natural phenomena are often computationally expensive, requiring many hours of computation time to generate only a few seconds of motion.

In the following sections, we describe a method for modeling the dynamic behavior of a fluid. The simulation method allows animation of impacts to the surface of the fluid, splashes, and the waves that arise as a result of an impact. The simulation also models the behavior and effects of objects floating on the surface of a fluid. Because our goal is to provide a method suitable for computer animation, we have compromised accuracy for reduced computation time. Nonetheless, these methods model many of the visual effects seen in the real world, as demonstrated by the images in Figures 1 and 7.

Dynamic Simulation Of Splashing Fluids Computer Graphics

Chang-Hun Kim, Sun-Jeong Kim, Soo-Kyun Kim, Shin-Jin Kang



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Fluid Simulation for Computer Graphics Robert Bridson, 2015-09-25 A practical introduction the second edition of Fluid Simulation for Computer Graphics shows you how to animate fully three dimensional incompressible flow It covers all the aspects of fluid simulation from the mathematics and algorithms to implementation while making revisions and updates to reflect changes in the field since the first edition Highlights of the Second Edition New chapters on level sets and vortex methods Emphasizes hybrid particle voxel methods now the industry standard approach Covers the latest algorithms and techniques including fluid surface reconstruction from particles accurate viscous free surfaces for buckling coiling and rotating liquids and enhanced turbulence for smoke animation Adds new discussions on meshing particles and vortex methods The book changes the order of topics as they appeared in the first edition to make more sense when reading the first time through It also contains several updates by distilling author Robert Bridson s experience in the visual effects industry to highlight the most important points in fluid simulation It gives you an understanding of how the components of fluid simulation work as well as the tools for creating your own animations

Computer Vision, Imaging and Computer Graphics: Theory and Applications Sebastiano Battiato, Sabine Coquillart, Robert S. Laramée, Andreas Kerren, José Braz, 2014-09-29 This book constitutes the refereed proceedings of the 8th International Conference VISIGRAPP 2013 consisting of the Joint Conferences on Computer Vision VISAPP the International Conference on Computer Graphics GRAPP 2013 and the International Conference on Information Visualization IVAPP 2013 held in Barcelona Spain in February 2013 The 15 revised full papers presented were carefully reviewed and selected from 445 submissions The papers are organized in topical sections on theory and applications in computer vision image analysis computer graphics and information visualization

Computer Vision and Graphics Leonard Bolc, Ryszard Tadeusiewicz, Leszek J. Chmielewski, Konrad Wojciechowski, 2010-09-14 Annotation This book is part I of a two volume work that contains the refereed proceedings of the International Conference on Computer Vision and Graphics ICCVG 2010 held in Warsaw Poland in September 2010 The 95 revised full papers presented were carefully reviewed and selected from numerous submissions The papers are organized in three topical sections advances in pattern recognition machine vision and image understanding human motion analysis and synthesis and computer vision and graphics

Frontiers of Discontinuous Numerical Methods and Practical Simulations in Engineering and Disaster Prevention Guangqi Chen, Yuzo Ohnishi, Lu Zheng, Takeshi Sasaki, 2013-08-12 Analysis of large deformation rigid body movement and strain or stress for discontinuous materials is often required for project designs and plans in the fields of engineering and disaster prevention Many numerical simulation and analysis methods have been developed for the requirement from science and technology people since 1970s Among them D

Computer Graphics Jeffrey J. McConnell, 2005 Computer Graphics Graphics Applications

Computational Science — ICCS 2002 Peter M.A. Sloot, C.J. Kenneth Tan, Jack J. Dongarra, Alfons G. Hoekstra, 2003-08-01 Computational Science is the scientific discipline that

aims at the development and understanding of new computational methods and techniques to model and simulate complex systems. The area of application includes natural systems such as biology, environmental and geo sciences, physics and chemistry, and synthetic systems such as electronics and financial and economic systems. The discipline is a bridge between classical computer science, logic, complexity, architecture, algorithms, mathematics, and the use of computers in the aforementioned areas. The relevance for society stems from the numerous challenges that exist in the various science and engineering disciplines which can be tackled by advances made in this field. For instance, new models and methods to study environmental issues like the quality of air, water and soil, and weather and climate predictions through simulations, as well as the simulation supported development of cars, airplanes, and medical and transport systems, etc. Paraphrasing R. Kenway (R. D. Kenway, Contemporary Physics, 1994): There is an important message to scientists, politicians, and industrialists in the future: science, the best industrial design and manufacture, the greatest medical progress, and the most accurate environmental monitoring and forecasting will be done by countries that most rapidly exploit the full potential of computational science. Nowadays we have access to high end computer architectures and a large range of computing environments, mainly as a consequence of the enormous stimulus from the various international programs on advanced computing, e.g.

Encyclopedia of Computer Graphics and Games Newton Lee, 2024-01-10. Encyclopedia of Computer Graphics and Games. ECGG is a unique reference resource tailored to meet the needs of research and applications for industry professionals and academic communities worldwide. The ECGG covers the history, technologies, and trends of computer graphics and games. Editor: Newton Lee, Institute for Education Research and Scholarships, Los Angeles, CA, USA. Academic Co-Chairs: Shlomo Dubnov, Department of Music and Computer Science and Engineering, University of California, San Diego, San Diego, CA, USA; Patrick C. K. Hung, University of Ontario Institute of Technology, Oshawa, ON, Canada; Jaci Lee Lederman, Vincennes University, Vincennes, IN, USA. Industry Co-Chairs: Shuichi Kurabayashi, Cygames Inc., FORTH ICS, Heraklion, Greece; University of Crete, Heraklion, Greece; Florian Richoux, Nantes Atlantic Computer Science Laboratory, LINA, Universit de Nantes, Nantes, France; Andrea Sanna, Dipartimento di Automatica e Informatica, Politecnico di Torino, Turin, Italy; Yann Savoye, Institut fur Informatik, Innsbruck University, Innsbruck, Austria; Sercan Engin, Wonsook Kim, School of Art, Illinois State University, Normal, IL, USA; Ruck Thawonmas, Ritsumeikan University, Shiga, Japan; Vinesh Thiruchelvam, Asia Pacific University of Technology Innovation, Kuala Lumpur, Malaysia; Rojin Vishkaie, Amazon, Seattle, WA, USA; Duncan A. H. Williams, Digital Creativity Labs, Department of Computer Science, University of York, York, UK; Sai Keung Wong, National Chiao Tung University, Hsinchu, Taiwan. Editorial Board: Intern Sam Romershausen, Vincennes University, Vincennes, IN, USA. **Advances in Swarm Intelligence** Ying Tan, Yuhui Shi, Carlos A. Coello Coello, 2014-09-03. This book and its companion volume LNCS vol 8794 and 8795 constitute the proceedings of the 5th International Conference on Swarm Intelligence (ICSI 2014) held in Hefei, China, in October 2014. The 107 revised full papers presented were carefully reviewed and selected from 198 submissions. The

papers are organized in 18 cohesive sections 3 special sessions and one competitive session covering all major topics of swarm intelligence research and development such as novel swarm based search methods novel optimization algorithm particle swarm optimization ant colony optimization for travelling salesman problem artificial bee colony algorithms artificial immune system evolutionary algorithms neural networks and fuzzy methods hybrid methods multi objective optimization multi agent systems evolutionary clustering algorithms classification methods GPU based methods scheduling and path planning wireless sensor networks power system optimization swarm intelligence in image and video processing applications of swarm intelligence to management problems swarm intelligence for real world application

Medicine Meets Virtual Reality 02/10 James D. Westwood, Helene M. Hoffman, Richard A. Robb, D. Stredney, 2006-01-15 The book offers papers on many aspects of electronic technology in healthcare Core areas are imaging simulation visualization data networks sensors robotics and displays Medical applications include information guided surgery education and procedural training telemedicine immersive environments stereoscopic projection diagnostic tools rehabilitation and augmented reality The papers describe both completed projects and recent developments in ongoing research The book is a the collection of papers of the 10th annual Medicine Meets Virtual Reality conference January 2002 This volume is a resource for computer scientists working in medical context and for creators of data focused products for clinical care medical education and procedural training

Medical Image Computing and Computer-Assisted Intervention - MICCAI 2011 Gabor Fichtinger, Anne Martel, Terry Peters, 2011-09-02 The three volume set LNCS 6891 6892 and 6893 constitutes the refereed proceedings of the 14th International Conference on Medical Image Computing and Computer Assisted Intervention MICCAI 2011 held in Toronto Canada in September 2011 Based on rigorous peer reviews the program committee carefully selected 251 revised papers from 819 submissions for presentation in three volumes The first volume includes 86 papers organized in topical sections on robotics localization and tracking and visualization planning and image guidance physical modeling and simulation motion modeling and compensation and segmentation and tracking in biological images

Advances in Modelling, Animation and Rendering John Vince, Rae Earnshaw, 2012-12-06 Advances in computer technology and developments such as the Internet provide a constant momentum to design new techniques and algorithms to support computer graphics Modelling animation and rendering remain principal topics in the field of computer graphics and continue to attract researchers around the world This volume contains the papers presented at Computer Graphics International 2002 in July at the University of Bradford UK These papers represent original research in computer graphics from around the world and cover areas such as Real time computer animation Image based rendering Non photo realistic rendering Virtual reality Avatars Geometric and solid modelling Computational geometry Physically based modelling Graphics hardware architecture Data visualisation Data compression The focus is on the commercial application and industrial use of computer graphics and digital media systems

ACM SIGGRAPH Symposium on Computer Animation ,2005 Practical Rendering

and Computation with Direct3D 11 Jason Zink, Matt Pettineo, Jack Hoxley, 2016-04-19 Direct3D 11 offers such a wealth of capabilities that users can sometimes get lost in the details of specific APIs and their implementation While there is a great deal of low level information available about how each API function should be used there is little documentation that shows how best to leverage these capabilities Written by active me Fluid Animation from Simulation on Tetrahedral Meshes Bryan Eric Feldman, 2007 **Technologies for E-Learning and Digital Entertainment** Zhigeng Pan, Ruth Aylett, Holger Diener, Xiaogang Jin, Stefan Göbel, Li Li, 2006-03-22 This book constitutes the refereed proceedings of the First International Conference on E learning and Games Edutainment 2006 held in Hangzhou China in April 2006 The 121 revised full papers and 52 short papers presented together with the abstracts of 3 invited papers and those of the keynote speeches cover a wide range of topics including e learning platforms and tools learning resource management practice and experience sharing e learning standards and more **Medicine Meets Virtual Reality** James D. Westwood, Helene M. Hoffman, Richard A. Robb, D. Stredney, 2006-12-15 MMVR offers solutions for problems in clinical care through the phenomenally expanding potential of computer technology Computer based tools promise to improve healthcare while reducing cost a vital requirement in today s economic environment This seventh annual MMVR focuses on the healthcare needs of women Women every where demand more attention to breast cancer cervical cancer ageing related conditions Electronic tools provide the means to revolutionise diagnosis treatment and education The book demonstrates what new tools can improve the care of their female patients As minimally invasive procedures are mainstreamed advanced imaging and robotics tools become indispensable The internet and other networks establish new venues for communication and research Medical education as well as clinical care is enhanced by systems allowing instruction and professional interaction in ways never before possible and with efficiency never before achieved Telemedicine networks now permit providers to meet patients needs where previously impossible MMVR strengthens the link between healthcare providers and their patients The volume contains selected papers authored by presenters at the conference Areas of focus include Computer Assisted Surgery Data Fusion Informatics Diagnostic Tools Education Training Mental Health Modelling Net Architecture Robotics Simulation Telemedicine Telepresence and Visualisation *Real-Time Visual Effects for Game Programming* Chang-Hun Kim, Sun-Jeong Kim, Soo-Kyun Kim, Shin-Jin Kang, 2015-04-30 This book introduces the latest visual effects VFX techniques that can be applied to game programming The usefulness of the physicality based VFX techniques such as water fire smoke and wind has been proven through active involvement and utilization in movies and images However they have yet to be extensively applied in the game industry due to the high technical barriers Readers of this book can learn not only the theories about the latest VFX techniques but also the methodology of game programming step by step The practical VFX processing techniques introduced in this book will provide very helpful information to game programmers Due to the lack of instructional books about VFX related game programming the demand for knowledge regarding these high tech VFXs might be very high

Dynamic Simulation of Splashing Fluids James F. O'Brien, Jessica K. Hodgins, Georgia Institute of Technology. Graphics, Visualization and Usability Center, 1994 Advances in Computer Graphics Hans-Peter Seidel, Tomoyuki Nishita, Qunsheng Peng, 2006-09-29 This is the refereed proceedings of the 24th Computer Graphics International Conference CGI 2006 The 38 revised full papers and 37 revised short papers presented were carefully reviewed The papers are organized in topical sections on rendering and texture efficient modeling and deformation digital geometry processing shape matching and shape analysis face virtual reality motion and image as well as CAGD *Deep Learning for Fluid Simulation and Animation* Gilson Antonio Giraldo, Liliane Rodrigues de Almeida, Antonio Lopes Apolinário Jr., Leandro Tavares da Silva, 2023-11-24 This book is an introduction to the use of machine learning and data driven approaches in fluid simulation and animation as an alternative to traditional modeling techniques based on partial differential equations and numerical methods and at a lower computational cost This work starts with a brief review of computability theory aimed to convince the reader more specifically researchers of more traditional areas of mathematical modeling about the power of neural computing in fluid animations In these initial chapters fluid modeling through Navier Stokes equations and numerical methods are also discussed The following chapters explore the advantages of the neural networks approach and show the building blocks of neural networks for fluid simulation They cover aspects related to training data data augmentation and testing The volume completes with two case studies one involving Lagrangian simulation of fluids using convolutional neural networks and the other using Generative Adversarial Networks GANs approaches

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Table of Contents Dynamic Simulation Of Splashing Fluids Computer Graphics

1. Understanding the eBook Dynamic Simulation Of Splashing Fluids Computer Graphics
 - The Rise of Digital Reading Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Advantages of eBooks Over Traditional Books
2. Identifying Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Dynamic Simulation Of Splashing Fluids Computer Graphics
 - User-Friendly Interface
4. Exploring eBook Recommendations from Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Personalized Recommendations
 - Dynamic Simulation Of Splashing Fluids Computer Graphics User Reviews and Ratings
 - Dynamic Simulation Of Splashing Fluids Computer Graphics and Bestseller Lists
5. Accessing Dynamic Simulation Of Splashing Fluids Computer Graphics Free and Paid eBooks
 - Dynamic Simulation Of Splashing Fluids Computer Graphics Public Domain eBooks
 - Dynamic Simulation Of Splashing Fluids Computer Graphics eBook Subscription Services
 - Dynamic Simulation Of Splashing Fluids Computer Graphics Budget-Friendly Options
6. Navigating Dynamic Simulation Of Splashing Fluids Computer Graphics eBook Formats
 - ePub, PDF, MOBI, and More
 - Dynamic Simulation Of Splashing Fluids Computer Graphics Compatibility with Devices
 - Dynamic Simulation Of Splashing Fluids Computer Graphics Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Highlighting and Note-Taking Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Interactive Elements Dynamic Simulation Of Splashing Fluids Computer Graphics

8. Staying Engaged with Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Dynamic Simulation Of Splashing Fluids Computer Graphics
9. Balancing eBooks and Physical Books Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Dynamic Simulation Of Splashing Fluids Computer Graphics
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Setting Reading Goals Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Fact-Checking eBook Content of Dynamic Simulation Of Splashing Fluids Computer Graphics
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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