

Modeling Free-surface Solitary Waves with Smoothed Particle Hydrodynamics

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Abstract

A three-dimensional weakly compressible Smoothed Particle Hydrodynamics (SPH) solver is presented and applied to simulate free-surface solitary waves generated in a quasi two-dimensional dam-break experiment. Test cases are constructed based on the measurement layouts of a dam-break experiment. The simulated wave propagation speeds are compared to the exact solutions of the Korteweg-de Vries (KdV) equation as a first order theory, and to a second order iterative approximation investigated in the literature. Free surface shapes of different simulation cases are investigated as well. The results show good agreement with the free surface shapes of the KdV equation as well as with the second order approximation of solitary wave propagation speeds.

Keywords

soliton, solitary wave, free-surface flow, smoothed particle hydrodynamics

1 Introduction

The first known observation of a solitary wave was reported by Scott Russell in 1834 [1]. He studied the behaviour of the solitary waves in laboratory while the first theoretical model explaining them appeared in 1895 by Korteweg and de Vries [2]. The idea of the Korteweg-de Vries (KdV) theory is based on slightly dispersive shallow water waves whose dispersion is balanced by nonlinear effects so that the wave preserves its amplitude and shape during the propagation on arbitrary distances. The exact solution of the KdV equation describes the shape and propagation speed of a soliton.

Although the KdV theory can be considered a first order approximation and its solution describes real solitary waves well, higher order approximations can also be constituted. In [3] Halász introduced an iterative, successive approximation-model with arbitrarily order. The model reproduces the KdV theory in the first iteration step, nevertheless, higher order investigation requires a numerical approach.

SPH is a meshless Lagrangian numerical scheme firstly published by R.A. Gingold and J.J. Monaghan [4] and independently by L. Lucy [5] in 1977. In the beginning SPH was applied in the field of astrophysics, then the first attempts on modeling fluid flows motivated by coastal engineering problems was published by J.J. Monaghan in 1994 [6] and [7]. Later the investigation of the dynamics of Scott Russell's Solitary wave generator with SPH has been carried out by the same author in 2000 [8]. Different aspects of free-surface waves in SPH were rigorously investigated, like turbulence modeling of breaking waves by R.A. Dalrymple and B.D. Rogers [9]. Standing and regular waves were modelled by Antuono et al. in [10] and the damping of viscous gravity waves in SPH were validated to analytical solutions by M. Antuono and A. Colagrossi [11]. Solitary waves over non-uniform bottoms and wave-splitting mechanics were investigated by Li et al. [12] and S. De Chowdhury and S.A. Sannasiraj in [13].


During the past two decades, owing to its attractive properties and prominent capabilities in modeling free surface flows, SPH became one of the most popular particle based numerical schemes in many different areas of engineering applications, like modeling coastal waves or tsunamics.

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Modeling Water Waves With Smoothed Particle Hydrodynamics

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Risio, Daniele Celli, Davide Pasquali**



Modeling Water Waves With Smoothed Particle Hydrodynamics:

Advanced Numerical Modelling of Wave Structure Interaction David M Kelly, Angelos Dimakopoulos, Pablo Higuera Caubilla, 2021-04-06 This book will serve as a reference guide and state of the art review for the wide spectrum of numerical models and computational techniques available to solve some of the most challenging problems in coastal engineering. The topics covered in this book are explained fundamentally from a numerical perspective and also include practical examples applications. Important classic themes such as wave generation propagation and breaking turbulence modelling and sediment transport are complemented by hot topics such as fluid and structure interaction or multi body interaction to provide an integral overview on numerical techniques for coastal engineering. Through the vision of 10 high impact authors each an expert in one or more of the fields included in this work the chapters offer a broad perspective providing several different approaches which the readers can compare critically to select the most suitable for their needs. *Advanced Numerical Modelling of Wave Structure Interaction* will be useful for a wide audience including PhD students research scientists numerical model developers and coastal engineering consultants alike.

Advances in Numerical Simulation of Nonlinear Water Waves Qingwei Ma, 2010

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Numerical Modeling Of Water Waves In Coastal And Ocean Engineering Pablo Higuera, Jinghua Wang, Jie Hu, Zhengtong Yang, 2023-03-16 This unique compendium introduces the field of numerical

modelling of water waves The topics included the most widely used water wave modelling approaches presented in increasing order of complexity and categorized into phase averaged and phase resolving at the highest level A comprehensive state of the art review is provided for each chapter comprising the historical development of the method the most relevant models and their practical applications A full description on the method s underlying assumptions and limitations are also provided The final chapter features coupling among different models outlining the different types of implementations highlighting their pros and cons and providing numerous relevant examples for full context The useful reference text benefits professionals researchers academics graduate and undergraduate students in wave mechanics in general and coastal and ocean engineering in particular Geo-disaster Modeling and Analysis: An SPH-based Approach Yu Huang,Zili Dai,Wei jie Zhang,2014-08-22 Through application of the Smoothed Particle Hydrodynamics SPH method this monograph mainly focuses on large deformations and flow failure simulations of geomaterials and movement behavior which are always involved in geo disasters The work covers the theoretical background numerical techniques code implementation issues and many novel and interesting applications Two dimensional and three dimensional SPH models in the framework of both hydrodynamics and solid mechanics are established with detailed descriptions The monograph also contains many appealing and practical examples of geo disaster modeling and analysis including the fluidized movement of flow like landslides lateral spread of liquefied soils and flow slides in landfills In the documented SPH simulations the propagation of geo disasters is effectively reproduced Dynamic behaviors of geomaterials during propagation are ascertained including sliding path flow velocity maximum distance reached and distribution of deposits In this way the monograph presents a means for mapping hazardous areas estimating hazard intensity and identifying and designing appropriate protective measures

Numerical Modeling of Water Waves Pengzhi Lin,2008-04-30 Modelling large scale wave fields and their interaction with coastal and offshore structures has become much more feasible over the last two decades with increases in computer speeds Wave modelling can be viewed as an extension of wave theory a mature and widely published field applied to practical engineering through the use of computer tools *Advances In Numerical Simulation Of Nonlinear Water Waves* Qingwei Ma,2010-04-15 Most of the Earth s surface is covered by water Many aspects of our everyday lives and activities may be affected by water waves in some way Sometimes the waves can cause disaster One of the examples was the tsunami that occurred in the Indian Ocean on 26 December 2004 This indicates how important it is for us to fully understand water waves in particular the very large ones One way to do so is to perform numerical simulation based on the nonlinear theory Considerable research advances have been made in this area over the past decade by developing various numerical methods and applying them to emerging problems however until now there has been no comprehensive book to reflect these advances This unique volume aims to bridge this gap This book contains 18 self contained chapters written by more than 50 authors from 12 different countries many of whom are world leading experts in the field Each chapter is based mainly on the

pioneering work of the authors and their research teams over the past decades The chapters altogether deal with almost all numerical methods that have been employed so far to simulate nonlinear water waves and cover many important and very interesting applications such as overturning waves breaking waves waves generated by landslides freak waves solitary waves tsunamis sloshing waves interaction of extreme waves with beaches interaction with fixed structures and interaction with free response floating structures Therefore this book provides a comprehensive overview of the state of the art research and key achievements in numerical modeling of nonlinear water waves and serves as a unique reference for postgraduates researchers and senior engineers working in industry

Advanced Computational Methods and Geomechanics

Shenghong Chen,2023-01-01 The aim of this book is intended through parallel expounding to help readers comprehensively grasp the intrinsic features of typical advanced computational methods These methods are created in recent three decades for the understanding of the post failure of geo materials accompanied with discontinuous and finite deformation dislocation as well as the violent fluid structure interaction accompanied with strong distortion of water surface The strong points and weak points of the formalisms for governing equations the discretization schemes the nodal interpolation approximation of field variables and their connectivity via support domains covers or enrichments the basic algorithms etc are clarified Being aware of that the differences in these methods are not so large as at the first glance this book will help readers to select appropriate methods to improve the methods for their specific purpose and to evaluate the reliability applicability of the outcomes in the hazard evaluation of geotechnical hydraulic structures beyond extreme work situation This book may be looked at as an advanced continuation of Computational Geomechanics and Hydraulic Structures by the author 2018 Springer Verlag ISBN 978 981 10 8134 7 which elaborates the fundamental computational methods in geomechanics for the routine design of geotechnical hydraulic engineering

Advanced Numerical Models for Simulating Tsunami Waves

and Runup Philip L. F. Liu,2008 Provides a brief review of the theoretical background for depth integrated wave equations which are employed to simulate tsunami runup This work also describes high resolution finite volume methods for solving the nonlinear shallow water equations It focuses on the applications of these methods to tsunami runup

Advances in Hydraulics and Hydroinformatics Jianguo Zhou,Jianmin Zhang,Yong Peng,Alistair Borthwick,2020-12-29 This Special Issue reports on recent research trends in hydraulics hydrodynamics and hydroinformatics and their novel applications in practical engineering The Issue covers a wide range of topics including open channel flows sediment transport dynamics two phase flows flow induced vibration and water quality The collected papers provide insight into new developments in physical mathematical and numerical modelling of important problems in hydraulics and hydroinformatics and include demonstrations of the application of such models in water resources engineering

Impact of Ocean Forcing on the Coastal Hydrology, Environment and Freshwater Resources Tianyuan Zheng,Chengji Shen,Xiuyu Liang ,Olaf Kolditz,Guangquan

Chen,2024-10-24 Groundwater is a valuable source of freshwater in coastal areas The groundwater flux in coastal aquifers

generally occurs in two processes seawater intrusion SWI and submarine groundwater discharge SGD SWI the subsurface movement of seawater into freshwater aquifers is a natural phenomenon in coastal areas As a result of SWI the salinity of groundwater in the aquifer increases thereby reducing the availability of freshwater in coastal areas The total efflux including fresh groundwater and circulating seawater to the sea is commonly referred to as SGD SGD is an important source of freshwater nutrients metals and carbon to the ocean thereby affecting coastal water quality and ecosystems The study of the hydrological behaviors of these two processes in coastal aquifers is beneficial for the sustainable management of marine and groundwater resources in coastal areas

Geophysics and Ocean Waves Studies Khalid S. Essa, Marcello Di Risio, Daniele Celli, Davide Pasquali, 2021-03-17 The book Geophysics and Ocean Waves Studies presents the collected chapters in two sections named Geophysics and Ocean Waves Studies The first section Geophysics provides a thorough overview of using different geophysical methods including gravity self potential and EM in exploration Moreover it shows the significance of rock physics properties and enhanced oil recovery phases during oil reservoir production The second section Ocean Waves Studies is intended to provide the reader with a strong description of the latest developments in the physical and numerical description of wind generated and long waves including some new features discovered in the last few years The section is organized with the aim to introduce the reader from offshore to nearshore phenomena including a description of wave dissipation and large scale phenomena i e storm surges and landslide induced tsunamis This book shall be of great interest to students scientists geologists geophysicists and the investment community

Selected Topics of Computational and Experimental Fluid Mechanics Jaime Klapp, Gerardo Ruíz Chavarría, Abraham Medina Ovando, Abel López Villa, Leonardo Di G. Sigalotti, 2015-03-05 This book contains invited lectures and selected contributions presented at the Enzo Levi and XIX Annual Meeting of the Fluid Dynamic Division of the Mexican Physical Society in 2013 It is aimed at fourth year undergraduate and graduate students and scientists in the fields of physics engineering and chemistry who are interested in fluid dynamics from an experimental and theoretical point of view The invited lectures are introductory and avoid the use of complicated mathematics The fluid dynamics applications include multiphase flow convection diffusion heat transfer rheology granular material viscous flow porous media flow geophysics and astrophysics The material contained in the book includes recent advances in experimental and theoretical fluid dynamics and is suitable for both teaching and research

Mathematical Modeling of Fluid Flow and Heat Transfer in Petroleum Industries and Geothermal Applications Mehrdad Massoudi, 2020-04-16 Geothermal energy is the thermal energy generated and stored in the Earth's core mantle and crust Geothermal technologies are used to generate electricity and to heat and cool buildings To develop accurate models for heat and mass transfer applications involving fluid flow in geothermal applications or reservoir engineering and petroleum industries a basic knowledge of the rheological and transport properties of the materials involved drilling fluid rock properties etc especially in high temperature and high pressure environments are needed This Special Issue considers

all aspects of fluid flow and heat transfer in geothermal applications including the ground heat exchanger conduction and convection in porous media The emphasis here is on mathematical and computational aspects of fluid flow in conventional and unconventional reservoirs geothermal engineering fluid flow and heat transfer in drilling engineering and enhanced oil recovery hydraulic fracturing CO2 injection etc applications Design and Modeling of Mechanical Systems—III Mohamed Haddar,Fakher Chaari,Abdelmajid Benamara,Mnaouar Chouchane,Chafik Karra,Nizar Aifaoui,2017-11-25 This book offers a collection of original peer reviewed contributions presented at the 7th International Congress on Design and Modeling of Mechanical Systems CMSM 2017 held in Hammamet Tunisia from the 27th to the 29th of March 2017 It reports on both research findings innovative industrial applications and case studies concerning mechanical systems and related to modeling and analysis of materials and structures multiphysics methods nonlinear dynamics fluid structure interaction and vibroacoustics design and manufacturing engineering Continuing on the tradition of the previous editions this proceedings offers a broad overview on the state of the art in the field and a useful resource for academic and industry specialists active in the field of design and modeling of mechanical systems CMSM 2017 was jointly organized by two leading Tunisian research laboratories the Mechanical Modeling and Manufacturing Laboratory of the National Engineering School of Sfax and the Mechanical Engineering Laboratory of the National Engineering School of Monastir **Computational and Experimental Simulations in Engineering** Kun Zhou,2024-12-02 This book gathers the latest advances innovations and applications in the field of computational engineering as presented by leading international researchers and engineers at the 30th International Conference on Computational bioengineering geotechnical engineering offshore multi scale structural integrity materials design and computer modeling methods in engineering The contributions which were selected by means of a rigorous international peer review process highlight numerous exciting ideas that will spur novel research directions and foster multidisciplinary collaborations Coastal Engineering 2004 - Proceedings Of The 29th International Conference (In 4 Vols) Jane Mckee Smith,2005-04-08 This comprehensive and up to date volume contains 367 papers presented at the 29th International Conference on Coastal Engineering held in Lisbon Portugal 19 24 September 2004 It is divided into five parts waves long waves nearshore currents and swash sediment transport and morphology coastal management beach nourishment and dredging coastal structures The contributions cover a broad range of topics including theory numerical and physical modeling field measurements case studies design and management Coastal Engineering 2004 provides engineers scientists and planners state of the art information on coastal engineering and coastal processes The proceedings have been selected for coverage in **Trends in Renewable Energies Offshore** C. Guedes Soares,2022-11-02 Renewable energy resources offshore are a growing contributor to the total energy production in a growing number of countries As a result the interest in the topic is increasing Trends in Renewable Energies Offshore includes the papers presented at the 5th International Conference on Renewable Energies Offshore RENEW 2022 Lisbon Portugal 8 10 November 2022 and covers

recent developments and experiences gained in concept development design and operation of such devices The scope of the contributions is broad covering all aspects of renewable energies offshore activities including Resource assessment Tidal Energy Wave Energy Wind Energy Solar Energy Renewable Energy Devices Multiuse Platforms Maintenance planning Materials and structural design Trends in Renewable Energies Offshore will be of interest to academics and professionals involved or interested in applications of renewable energy resources offshore The Proceedings in Marine Technology and Ocean Engineering series is dedicated to the publication of proceedings of peer reviewed international conferences dealing with various aspects of Marine Technology and Ocean Engineering The Series includes the proceedings of the following conferences the International Maritime Association of the Mediterranean IMAM conferences the Marine Structures MARSTRUCT conferences the Renewable Energies Offshore RENEW conferences and the Maritime Technology MARTECH conferences The Marine Technology and Ocean Engineering series is also open to new conferences that cover topics on the sustainable exploration and exploitation of marine resources in various fields such as maritime transport and ports usage of the ocean including coastal areas nautical activities the exploration and exploitation of mineral resources the protection of the marine environment and its resources and risk analysis safety and reliability The aim of the series is to stimulate advanced education and training through the wide dissemination of the results of scientific research

Modelling in Engineering 2020: Applied Mechanics Arkadiusz Mężyk, Sławomir Kciuk, Roman Szewczyk, Sławomir Duda, 2021-02-12 This book includes the outcomes of the 59th Symposium Modelowanie w Mechanice Engineering Modelling in Mechanics held in Ustro from 22 February to 26 February 2020 The International Conference has an over 58 year old history and is organized by the Department of Theoretical and Applied Mechanics of Silesian University of Technology under the patronage of the Polish Society of Theoretical and Applied Mechanics Gliwice Branch Subjects of the conference are modelling of mechatronic systems machinery dynamics control systems sensitivity analysis and optimization numerical modelling and experimental methods in mechanics biomechanics heat flow analysis fluid mechanics etc The papers are dealing with interdisciplinary problems in which mechanical phenomena are of decisive importance The potential reader of this book will find their set of papers concentrated on the use of computer aided design virtual modelling numerical simulations fast prototyping and experimental tests of mechanical systems It is an area of versatile and interdisciplinary research trends with one of the mainstreams focusing on applied mechanics

Renewable Energy in Marine Environment Eugen Rusu, 2020-03-25 The effects of human caused global warming are obvious requiring new strategies and approaches The concept of business as usual is now no longer beneficial Extraction of renewable energy in marine environments represents a viable solution and an important path for the future These huge renewable energy resources in seas and oceans can be harvested including wind tide and waves Despite the initial difficulties related mostly to the elevated operational risks in the harsh marine environment newly developed technologies are economically effective or promising Simultaneously many challenges remain to be faced

These are the main issues targeted by the present book which is associated with the Special Issue of Energies Journal entitled Renewable Energy in Marine Environment Papers on innovative technical developments reviews case studies and analytics as well as assessments and papers from different disciplines that are relevant to the topic are included From this perspective we hope that the results presented are of interest to for scientists and those in related fields such as energy and marine environments as well as for a wider audience

Numerical Modeling of Coupled Phenomena in Science and Engineering Mario César Suárez Arriaga, Jochen Bundschuh, Francisco Javier Dominguez-Mota, 2008-12-01 Mathematics is a universal language Differential equations mathematical modeling numerical methods and computation form the underlying infrastructure of engineering and the sciences In this context mathematical modeling is a very powerful tool for studying engineering problems natural systems and human society This interdisciplinary book cont

This book delves into Modeling Water Waves With Smoothed Particle Hydrodynamics. Modeling Water Waves With Smoothed Particle Hydrodynamics is a vital topic that must be grasped by everyone, ranging from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Modeling Water Waves With Smoothed Particle Hydrodynamics, encompassing both the fundamentals and more intricate discussions.

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- The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. This book is highly recommended for anyone seeking to gain a comprehensive understanding of Modeling Water Waves With Smoothed Particle Hydrodynamics.

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