

# Adaptive Methods for Contact Problems

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**Abstract** This contribution is concerned with the adaptive finite-element-formulation of contact problems. For this, first the theoretical background of continuum mechanics and contact kinematics is given. Next the basic finite element formulation for large deformation contact processes is presented for two-dimensional problems. The development of the discretization of contact contributions follows. Here standard approaches are discussed for the case of frictional and frictionless contact. Finally different adaptive strategies involving as well residual based error estimators as error indicators based on superconvergence patch recovery are derived and formulated to include the contributions due to contact. Also error estimators based on dual principles are discussed. Examples show the performance of the different formulations and adaptive strategies.

## 1 Introduction

Boundary value problems involving contact are of great importance in industrial applications in mechanical and civil engineering. The range of application starts with relatively simple problems like foundations or bearings and includes metal forming processes, rubber sealings, drilling problems, crash analysis of cars, rolling contact between car tires and the road. Other applications are related to biomechanics where human joints, implantats or teeth are of consideration. Due to this variety contact problems are today combined either with large elastic or inelastic deformations including time dependent responses. Thermal coupling might have to be considered, see cooling of electronic devices, heat removal within nuclear power plant vessels or thermal insulation of astronautic vehicles. For most industrial applications numerical methods have to be applied since the contacting bodies have complex geometries or undergo large deformations. Due to that the appropriate meshing for a problem can often not be found a priori to the computation. Hence there is a need to develop adaptive methods for contact problems.

The main idea of adaptive mesh refinement is depicted in Fig. 1. It shows the basic ingredients of an adaptive method for contact problems. Part 1 is the determination of the contact, part 2 a solution of the problem with a given mesh and finally the adaptive process in part 3 leads to an automatic mesh refinement of the discretization.

Adaptive methods rely on a posteriori error estimators which estimate e.g. the difference between the exact solution  $\mathbf{u}$  and the approximate solution  $\mathbf{u}_h$  of the displacement field. For an elliptic variational problem of order  $m$  with complete interpolation polynomials of order  $k$  in a norm containing derivatives of degree  $s$ , see Straug and Fix (1973), one

# New Developments In Contact Problems

**Shasha Hu**



## **New Developments In Contact Problems:**

**New Developments in Contact Problems** Peter Wriggers, Panagiotis Panatiotopoulos, 2014-05-04 The book gives an overview on formulation mathematical analysis and numerical solution procedures of contact problems In this respect the book should be of value to applied mathematicians and engineers who are concerned with contact mechanics

**Mechatronic Modeling of Real-Time Wheel-Rail Contact** Nicola Bosso, Maksym Spiryagin, Antonio Gugliotta, Aurelio Somà, 2013-03-15 Real time simulations of the behaviour of a rail vehicle require realistic solutions of the wheel rail contact problem which can work in a real time mode Examples of such solutions for the online mode have been well known and are implemented within standard and commercial tools for the simulation codes for rail vehicle dynamics This book is the result of the research activities carried out by the Railway Technology Lab of the Department of Mechanical and Aerospace Engineering at Politecnico di Torino This book presents work on the project for the development of a real time wheel rail contact model and provides the simulation results obtained with dSpace real time hardware Besides this the implementation of the contact model for the development of a real time model for the complex mechatronic system of a scaled test rig is presented in this book and may be useful for the further validation of the real time contact model with experiments on a full scale test rig

**Advances in Theory and Practice of Computational Mechanics** Lakhmi C. Jain, Margarita N. Favorskaya, Ilia S. Nikitin, Dmitry L. Reviznikov, 2020-03-31 This book discusses physical and mathematical models numerical methods computational algorithms and software complexes which allow high precision mathematical modeling in fluid gas and plasma mechanics general mechanics deformable solid mechanics and strength destruction and safety of structures These proceedings focus on smart technologies and software systems that provide effective solutions to real world problems in applied mechanics at various multi scale levels Highlighting the training of specialists for the aviation and space industry it is a valuable resource for experts in the field of applied mathematics and mechanics mathematical modeling and information technologies as well as developers of smart applied software systems

**Novel Approaches in Civil Engineering** Michel Fremond, Franco Maceri, 2003-11-19 In this edited book various novel approaches to problems of current interest in civil engineering are demonstrated The topics range from dynamic band seismic problems to the analysis of long span structures and ancient buildings Experts associated within the Lagrange Laboratory present recent research results on functionally graded or composite materials granular materials geotechnics as well as frictional or adhesive contact problems

**Modern Practice in Stress and Vibration Analysis** J. E. Mottershead, 2016-06-23 Modern Practice in Stress and Vibration Analysis documents the proceedings of the conference on Modern Practice in Stress and Vibration Analysis organized by the Stress Analysis Group of the Institute of Physics at the University of Liverpool 3 5 April 1989 The Group has been known in the UK for its contribution in providing meetings with an emphasis on application covering topics which range widely to include modern numerical techniques and advanced experimentation The volume contains 34 papers presented by researchers at the

conference covering a wide range of topics such as the application of the sensitivity analysis method to structural dynamics passive and active vibration control for use in vibration suppression in spacecraft analysis of an ultrasonically excited thick cylinder and the prediction of vibrational power transmission through a system of jointed beams carrying longitudinal and flexural waves It is hoped that the contributions published in this book will be of value to the broad community of practitioners in stress and vibration analysis whom the Stress Analysis Group exists to serve

The Boundary Integral Approach to Static and Dynamic Contact Problems H. Antes, P.D. Panagiotopoulos, 2013-03-07 The fields of boundary integral equations and of inequality problems or more generally of nonsmooth mechanics have seen in a remarkably short time a considerable development in mathematics and in theoretical and applied mechanics The engineering sciences have also benefited from these developments in that open problems have been attacked successfully and entirely new methodologies have been developed The contact problems of elasticity is a class of problems which has offered many open questions to deal with both to the research workers working on the theory of boundary integral equations and to those working on the theory of inequality problems Indeed the area of static and dynamic contact problems could be considered as the testing workbench of the new developments in both the inequality problems and in the boundary integral equations This book is a first attempt to formulate and study the boundary integral equations arising in inequality contact problems The present book is a result of more than two decades of research and teaching activity of the first author on boundary integral equations and of the second author on inequality problems as well as the outgrowth of seminars and courses for a variety of audiences in the Technical University of Aachen the Aristotle University of Thessa Ioniki the Universities of Bochum of Hamburg and Braunschweig the Pontificia Univ Catolica in Rio de Janeiro etc

New Developments in Behavior Therapy Cyril M. Franks, 1984 Leading experts in the field of behavior therapy review developments in the field and highlight implications for clinical practice Following a comprehensive overview of behavior therapy by Editor Cyril Franks each chapter provides an in depth review of the pertinent literature and a translation of the findings into ramifications for clinical practice and concludes with an overview of the major indicators and contra indicators for direct application The practicing clinician will find practical relevant chapters on obesity smoking alcohol abuse anxiety depression insomnia and sexual dysfunction

New Developments on Fundamental Problems in Quantum Physics M. Ferrero, Alwyn van der Merwe, 2012-12-06 Quantum theory is one of the most fascinating and successful constructs in the intellectual history of mankind Nonetheless the theory has very shaky philosophical foundations This book contains thoughtful discussions by eminent researchers of a spate of experimental techniques newly developed to test some of the stranger predictions of quantum physics The advances considered include recent experiments in quantum optics electron and ion interferometry photon down conversion in nonlinear crystals single trapped ions interacting with laser beams atom field coupling in micromaser cavities quantum computation quantum cryptography decoherence and macroscopic quantum effects the quantum state diffusion model

quantum gravity the quantum mechanics of cosmology and quantum non locality along with the continuing debate surrounding the interpretation of quantum mechanics Audience The book is intended for physicists philosophers of science mathematicians graduate students and those interested in the foundations of quantum theory *New Developments of Newton-Type Iterations for Solving Nonlinear Problems* Tugal Zhanlav,Ochbadrakh Chuluunbaatar,2024-08-06 This comprehensive book delves into the intricacies of Newton type methods for nonlinear equations offering insights into their convergence accelerations and extensions Divided into three parts the book explores higher order iterations for nonlinear equations and their systems and their applications in linear algebra and some nonlinear problems of theoretical physics Emphasizing the pivotal role of iteration parameters in shaping convergence and expanding the domain the authors draw from their extensive collaborative research to systematically compile and elucidate these findings Catering to readers graduate students and researchers in applied mathematics numerical analysis and related disciplines this book serves as a valuable resource synthesizing decades of research to advance understanding and practical application in the field

*Occupational Compensation Survey--pay Only* ,1992 **Signal Processing Techniques for Communication** K.C. Raveendranathan,2024-10-30 The reference text discusses signal processing tools and techniques used for the design testing and deployment of communication systems It further explores software simulation and modeling tools like MATLAB GNU Octave Mathematica and Python for modeling simulation and detailed analysis leading to comprehensive insights into communication systems The book explains topics such as source coding pulse demodulation systems and the principle of sampling and aliasing This book Discusses modern techniques including analog and digital filter design and modulation principles including quadrature amplitude modulation and differential phase shift keying Covers filter design using MATLAB system simulation using Simulink signal processing toolbox linear time invariant systems and non linear time variant systems Explains important pulse keying techniques including Gaussian minimum shift keying and quadrature phase shift keying Presents signal processing tools and techniques for communication systems design modeling simulation and deployment Illustrates topics such as software defined radio SDR systems spectrum sensing and automated modulation sensing The text is primarily written for senior undergraduates graduate students and academic researchers in the fields of electrical engineering electronics and communication engineering computer science and engineering Evaluating Communication for Development June Lennie,Jo Tacchi,2013-02-11 Evaluating Communication for Development presents a comprehensive framework for evaluating communication for development C4D This framework combines the latest thinking from a number of fields in new ways It critiques dominant instrumental accountability based approaches to development and evaluation and offers an alternative holistic participatory mixed methods approach based on systems and complexity thinking and other key concepts It maintains a focus on power gender and other differences and social norms The authors have designed the framework as a way to focus on achieving sustainable social change and to continually improve and develop C4D initiatives

The benefits and rigour of this approach are supported by examples and case studies from a number of action research and evaluation capacity development projects undertaken by the authors over the past fifteen years Building on current arguments within the fields of C4D and development the authors reinforce the case for effective communication being a central and vital component of participatory forms of development something that needs to be appreciated by decision makers They also consider ways of increasing the effectiveness of evaluation capacity development from grassroots to management level in the development context an issue of growing importance to improving the quality effectiveness and utilisation of monitoring and evaluation studies in this field The book includes a critical review of the key approaches methodologies and methods that are considered effective for planning evaluation assessing the outcomes of C4D and engaging in continuous learning This rigorous book is of immense theoretical and practical value to students scholars and professionals researching or working in development communication and media applied anthropology and evaluation and program planning

**Occupational Compensation Survey--pay and Benefits** ,1996 *Leading and Managing in Canadian Nursing E-Book* Patricia S. Yoder-Wise,2019-08-08

UNIQUE Two NEW chapters help build your leadership skills within your academic program one of which is authored by an undergraduate student and an early career alumnus NEW UNIQUE Chapter on nursing leadership in Indigenous health explains the leadership role and is also integrated into relevant topics throughout the text NEW Expanded and updated coverage of topics includes workplace violence and incivility strength based nursing and the role of nurses as change agents visioning shaping culture leading change NEW Expanded discussion on the interdependence of leadership and management roles and competencies clearly fosters leadership ideas for effective and responsive health care environments NEW Additional examples of real life practice cases and examples help you to examine and apply theoretical concepts

**Advances in Automation II** Andrey A. Radionov,Vadim R. Gasiyarov,2021-03-19

This book reports on innovative research and developments in automation Spanning a wide range of disciplines including communication engineering power engineering control engineering instrumentation signal processing and cybersecurity it focuses on methods and findings aimed at improving the control and monitoring of industrial and manufacturing processes as well as safety Based on the International Russian Automation Conference held on September 6 12 2020 in Sochi Russia the book provides academics and professionals with a timely overview of and extensive information on the state of the art in the field of automation and control systems and fosters new ideas and collaborations between groups in different countries

*Analogies In Physics And Life: A Scientific Autobiography* Richard M Weiner,2008-04-22

Analogies play a fundamental role in science To understand how and why at a given moment a certain analogy was used one has to know the specific historical circumstances under which the new idea was developed This historical background is never presented in scientific articles and quite rarely in books For the general reader the undergraduate or graduate student who learns the subject for the first time but also for the practitioner who looks for inspiration or who wants to understand what his colleague working in

another field does these historical circumstances can be fascinating and useful This book discusses a series of analogy effects in subatomic physics the prediction and theory of which the author has contributed to in the last 50 years These phenomena are presented at a level accessible to the non specialist without formulae but with emphasis on the personal and historical background memoirs of meetings discussions and correspondence with collaborators and colleagues As such besides its scientific aspects the book constitutes an absorbing witness account of a holocaust survivor who subsequently illegally crossed the Iron Curtain to escape communist persecution

**Army Research and Development** ,1965 Public Works for Water and Power Development and Energy Research Appropriations for Fiscal Year 1977 United States. Congress.

Senate. Committee on Appropriations. Subcommittee on Public Works,1976 *Education In Cybernetic Age* B C

Mahapatra,2006 **Clinical Applications of Microcomputers in Communication Disorders** James L. Fitch,2014-05-10

Clinical Applications of Microcomputers in Communication Disorders is a comprehensive reference for the utilization of microcomputers in the field of communication disorders The human machine interface is discussed along with word processing and data processing The use of the microcomputer in the diagnosis and treatment of speech language pathology is also reviewed Comprised of 13 chapters this book begins with a historical perspective of the computer in society and its role in the field of communication disorders The reader is then introduced to computer hardware and software and computer languages are described with examples written in BASIC Subsequent chapters focus on the challenge that society faces in learning to live with technology word processing and data management and specific applications of the computer in the fields of speech language pathology and audiology Programs that are either commercially available or are in the public domain are reviewed The final chapter paints a picture of the clinic of the future and the role that will be played by the computer This monograph will be a useful resource for clinicians and other practicing professionals in the fields of speech pathology and audiology including those who have an interest in or need to stay current with developments in the clinical management of communication disorders

## **New Developments In Contact Problems** Book Review: Unveiling the Magic of Language

In an electronic era where connections and knowledge reign supreme, the enchanting power of language has become more apparent than ever. Its power to stir emotions, provoke thought, and instigate transformation is really remarkable. This extraordinary book, aptly titled "**New Developments In Contact Problems**," written by a very acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound effect on our existence. Throughout this critique, we will delve into the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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