Article

Solvability of nonlinear equations in case of branching solutions

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Abstract: The necessary and sufficient conditions of existence of the nonlinear operator equations' branches of solutions in the neighbourhood of branching points are derived. The approach is based on reduction of the nonlinear operator equations to finite–dimensional problems. Methods of nonlinear functional analysis, integral equations, spectral theory based on index of Kronecker–Poincaré, Morse–Conley index, power geometry and other methods are employed. Proposed methodology enables justification of the theorems on existence of bifurcation points and bifurcation sets in the nonstandard models. Formulated theorems are constructive. For a certain smoothness of the nonlinear operator, the asymptotic behaviour of the solutions is analysed in the neighbourhood of the branch points and uniformly converging iterative schemes with a choice of the uniformization parameter enables the comprehensive analysis of the problems details. General theorems are illustrated on the nonlinear integral equations.

Keywords: branch points; bifurcation points; Fredholm operator; uniformization; asymptotics; iterations; regularization

1. Introduction

The progress in the methods of analysis development and the new nonlinear problems of applied mathematics enable the nonlinear functional analysis novel concepts formulation. In the seminal paper of L.A. Lusternik [1] the main directions of this field paved the anevue for the branching theory of nolinear equations development. The classic works of A.M. Lyapunov, A.I. Nekrasov, J.H. Poincaré, M.A. Krasnoselsky [2], J. Toland and others contributed to this field. In their studies, reductions of the given nonlinear models to the finite-dimensional systems with parameters were used. The finite–dimensional equivalent system is now known as Lyapunov-Schmidt branching system and the corresponding method is known as Lyapunov-Schmidt (LS) method. In the review [3] and monograph of M.M. Vainberg and V.A. Trenogin [4] the basement of the analytical theory of branching solutions in Banach spaces with applications is given. These works contributed to the modern functional analysis development with many applications [5–22].

Studies of the integral equations in mechanics played the principal role not only in LS method development, but also iniciated the way for functional analysis new chapters construction. Studies of integral equations' bifurcation points are necessary in various mathematical models in the various fields. For example, for some parameter values there the loss of stability may occur and another series of solutions branches off from that bifurcation point.

Such problems include both classical problems of the critical load of the rod and the formation, the emergence of new forms of equilibrium of rotating fluids, a branch at a critical wind speed from

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Klaus Deimling

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Solvability and Bifurcations of Nonlinear Equations Pavel Drábek,1992 **Quasilinear Elliptic Equations with Degenerations and Singularities** Pavel Drábek,Alois Kufner,Francesco Nicolosi,2011-07-22 The series is devoted to the publication of high level monographs which cover the whole spectrum of current nonlinear analysis and applications in various fields such as optimization control theory systems theory mechanics engineering and other sciences One of its main objectives is to make available to the professional community expositions of results and foundations of methods that play an important role in both the theory and applications of nonlinear analysis Contributions which are on the borderline of nonlinear analysis and related fields and which stimulate further research at the crossroads of these areas are particularly welcome Please submit book proposals to J rgen Appell **Methods of Nonlinear Analysis** Pavel Drabek,Jaroslav Milota,2007-06-28 In this book the basic methods of nonlinear analysis are emphasized and illustrated in simple examples Every considered method is motivated explained in a general form but in the simplest possible abstract framework Its applications are shown particularly to boundary value problems for elementary ordinary or partial differential equations The text is organized in two levels a self contained basic and organized in appendices an advanced level for the more experienced reader Exercises are an organic part of the exposition and accompany the reader throughout the book **Nonlinear Partial Differential Equations** A Benkirane,J P Gossez,1996-04-11 This book presents a collection of selected contributions on recent results in nonlinear partial differential equations from participants to an international conference held in Fes Morocco in 1994 The emphasis is on nonlinear elliptic boundary value problems but there are also papers deveoted to related areas such as monotone operator theory calculus of variations Hamiltonian systems and periodic solutions Some of the papers are exhaustive surveys while others contain new results published here for the first time This book will be of particular interest to graduate or postgraduate students as well as to specialists in these areas **Progress in Variational Methods** Chungen Liu,Yiming Long,2010 In the last forty years nonlinear analysis has been broadly and rapidly developed Lectures presented in the International Conference on Variational Methods at the Chern Institute of Mathematics in Tianjin of May 2009 reflect this development from different angles This volume contains articles based on lectures in the following areas of nonlinear analysis critical point theory Hamiltonian dynamics partial differential equations and systems KAM theory bifurcation theory symplectic geometry geometrical analysis and celestial mechanics Combinations of topological analytical especially variational geometrical and algebraic methods in these researches play important roles In this proceedings introductory materials on new theories and surveys on traditional topics are also given Further perspectives and open problems on hopeful research topics in related areas are described and proposed Researchers graduate and postgraduate students from a wide range of areas in mathematics and physics will find contents in this proceedings are helpful Topological and Variational Methods for Nonlinear Boundary Value Problems Pavel Drabek,1997-04-17 In the rapidly developing area of

nonlinear theory of differential equations many important results have been obtained by the use of nonlinear functional analysis based on topological and variational methods The survey papers presented in this volume represent the current state of the art in the subject The methods outlined in this book can be used to obtain new results concerning the existence uniqueness multiplicity and bifurcation of the solutions of nonlinear boundary value problems for ordinary and partial differential equations The contributions to this volume are from well known mathematicians and every paper contained in this book can serve both as a source of reference for researchers working in differential equations and as a starting point for those wishing to pursue research in this direction With research reports in the field typically scattered in many papers within various journals this book provides the reader with recent results in an accessible form   Global Bifurcation in Variational Inequalities Vy Khoi Le,Klaus Schmitt,2013-12-01 Bifurcation Problems for Variational Inequalities presents an up to date and unified treatment of bifurcation theory for variational inequalities in reflexive spaces and the use of the theory in a variety of applications such as obstacle problems from elasticity theory unilateral problems torsion problems equations from fluid mechanics and quasilinear elliptic partial differential equations The tools employed are the tools of modern nonlinear analysis This book is accessible to graduate students and researchers who work in nonlinear analysis nonlinear partial differential equations and additional research disciplines that use nonlinear mathematics   *Handbook of Differential Equations: Ordinary Differential Equations* A. Canada,P. Drabek,A. Fonda,2004-09-09 The book contains seven survey papers about ordinary differential equations The common feature of all papers consists in the fact that nonlinear equations are focused on This reflects the situation in modern mathematical modelling nonlinear mathematical models are more realistic and describe the real world problems more accurately The implications are that new methods and approaches have to be looked for developed and adopted in order to understand and solve nonlinear ordinary differential equations The purpose of this volume is to inform the mathematical community and also other scientists interested in and using the mathematical apparatus of ordinary differential equations about some of these methods and possible applications   Progress in Partial Differential Equations Herbert Amann,C Bandle,Michel Chipot,F Conrad,I Shafrir,1998-04-01 The numerous applications of partial differential equations to problems in physics mechanics and engineering keep the subject an extremely active and vital area of research With the number of researchers working in the field advances large and small come frequently Therefore it is essential that mathematicians working in partial differential equations and applied mathematics keep abreast of new developments Progress in Partial Differential Equations presents some of the latest research in this important field Both volumes contain the lectures and papers of top international researchers contributed at the Third European Conference on Elliptic and Parabolic Problems In addition to the general theory of elliptic and parabolic problems the topics covered at the conference include applications free boundary problems fluid mechanics general evolution problems ocalculus of variations homogenization modeling numerical analysis The research notes in these volumes offer a valuable update on the

state of the art in this important field of mathematics   <u>Nonlinear Elliptic Partial Differential Equations</u> J. P. Gossez,Denis Bonheure,2011 This volume contains papers on semi linear and quasi linear elliptic equations from the workshop on Nonlinear Elliptic Partial Differential Equations in honor of Jean Pierre Gossez s 65th birthday held September 2 4 2009 at the Universite Libre de Bruxelles Belgium The workshop reflected Gossez s contributions in nonlinear elliptic PDEs and provided an opening to new directions in this very active research area Presentations covered recent progress in Gossez s favorite topics namely various problems related to the p Laplacian operator the antimaximum principle the Fucik Spectrum and other related subjects This volume will be of principle interest to researchers in nonlinear analysis especially in partial differential equations of elliptic type   **Variational Methods: Open Problems, Recent Progress, and Numerical Algorithms** John Neuberger,John M. Neuberger,2004 This volume contains the proceedings of the conference on Variational Methods Open Problems Recent Progress and Numerical Algorithms It presents current research in variational methods as applied to nonlinear elliptic PDE although several articles concern nonlinear PDE that are nonvariational and or nonelliptic The book contains both survey and research papers discussing important open questions and offering suggestions on analytical and numerical techniques for solving those open problems It is suitable for graduate students and research mathematicians interested in elliptic partial differential equations   *Handbook of Differential Equations: Stationary Partial Differential Equations* Michel Chipot,Pavol Quittner,2004-07-06 The book could be a good companion for any graduate student in partial differential equations or in applied mathematics Each chapter brings indeed new ideas and new techniques which can be used in these fields The differents chapters can be read independently and are of great pedagogical value The advanced researcher will find along the book the most recent achievements in various fields Independent chapters Most recent advances in each fields Hight didactic quality Self contained Excellence of the contributors Wide range of topics   **Morse Theoretic Aspects of p-Laplacian Type Operators** Kanishka Perera,Ravi P. Agarwal,Donal O'Regan,2010 Presents a Morse theoretic study of a very general class of homogeneous operators that includes the p Laplacian as a special case The p Laplacian operator is a quasilinear differential operator that arises in many applications such as non Newtonian fluid flows Working with a new sequence of eigenvalues that uses the cohomological index the authors systematically develop alternative tools such as nonlinear linking and local splitting theories in order to effectively apply Morse theory to quasilinear problems   *Topics in Critical Point Theory* Kanishka Perera,Martin Schechter,2012-11-01 This book introduces the reader to powerful methods of critical point theory and details successful contemporary approaches to many problems some of which had proved resistant to attack by older methods Topics covered include Morse theory critical groups the minimax principle various notions of linking jumping nonlinearities and the Fu k spectrum in an abstract setting sandwich pairs and the cohomological index Applications to semilinear elliptic boundary value problems p Laplacian problems and anisotropic systems are given Written for graduate students and research scientists the book includes numerous examples and presents

more recent developments in the subject to bring the reader up to date with the latest research **Approximation And Regularisation Methods For Operator-functional Equations** Nikolay Sidorov,Denis Sidorov,Edixon M Rojas,Alexander V Sinitsyn,2025-03-05 This book presents an overview of the most recent research and findings in the field of approximation and regularisation methods for operator functional equations and explores their applications in electrical and power engineering It presents the state of the art in building operator theory regularised numerical methods and the verification of mathematical models for dynamical models based on integral and differential equations Special attention is paid to Volterra models a powerful tool for modelling hereditary dynamics This book begins by exploring the solvability of singular integral equations and moves on to study approximation methods for linear operator equations and nonlinear integral equations Following this it examines loaded equations and bifurcation analysis before concluding with an investigation of the applications of the contents of the book in electrical engineering and automation Each chapter provides an overview and analysis of the relevant problem statements outlines current methods within the field and identifies future directions for research With an interdisciplinary approach this book is essential reading for anyone interested in operator functional equations Graduate students and professors in the fields of applied mathematics physics materials science and numerical analysis will find this work insightful and valuable as will industry professionals in related fields *Theory and Applications of Nonlinear Operators of Accretive and Monotone Type* Athanass Kartsatos,1996-03-14 This work is based upon a Special Session on the Theory and Applications of Nonlinear Operators of Accretive and Monotone Type held during the recent meeting of the American Mathematical Society in San Francisco It examines current developments in non linear analysis emphasizing accretive and monotone operator theory The book presents a major survey research article on partial functional differential equations with delay and an important survey research article on approximation solvability Fixed Point Theory E. Fadell,G. Fournier,2006-11-14 **Methods for Analysis of Nonlinear Elliptic Boundary Value Problems** I. V. Skrypnik,1994-01-01 The theory of nonlinear elliptic equations is currently one of the most actively developing branches of the theory of partial differential equations This book investigates boundary value problems for nonlinear elliptic equations of arbitrary order In addition to monotone operator methods a broad range of applications of topological methods to nonlinear differential equations is presented solvability estimation of the number of solutions and the branching of solutions of nonlinear equations Skrypnik establishes by various procedures a priori estimates and the regularity of solutions of nonlinear elliptic equations of arbitrary order Also covered are methods of homogenization of nonlinear elliptic problems in perforated domains The book is suitable for use in graduate courses in differential equations and nonlinear functional analysis Generalized Topological Degree and Semilinear Equations Wolodymyr V. Petryshyn,1995-09-29 This book describes many new results and extensions of the theory of generalized topological degree for densely defined A proper operators and presents important applications particularly to boundary value problems of nonlinear ordinary and partial differential

equations that are intractable under any other existing theory A proper mappings arise naturally in the solution to an equation in infinite dimensional space via the finite dimensional approximation The theory subsumes classical theory involving compact vector fields as well as the more recent theories of condensing vector fields strongly monotone and strongly accretive maps Researchers and graduate students in mathematics applied mathematics and physics who make use of nonlinear analysis will find this an important resource for new techniques **Nonlinear Functional Analysis** Klaus Deimling,2013-11-11 topics However only a modest preliminary knowledge is needed In the first chapter where we introduce an important topological concept the so called topological degree for continuous maps from subsets ofRn into Rn you need not know anything about functional analysis Starting with Chapter 2 where infinite dimensions first appear one should be familiar with the essential step of consider ing a sequence or a function of some sort as a point in the corresponding vector space of all such sequences or functions whenever this abstraction is worthwhile One should also work out the things which are proved in 7 and accept certain basic principles of linear functional analysis quoted there for easier references until they are applied in later chapters In other words even the completely linear sections which we have included for your convenience serve only as a vehicle for progress in nonlinearity Another point that makes the text introductory is the use of an essentially uniform mathematical language and way of thinking one which is no doubt familiar from elementary lectures in analysis that did not worry much about its connections with algebra and topology Of course we shall use some elementary topological concepts which may be new but in fact only a few remarks here and there pertain to algebraic or differential topological concepts and methods

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Table of Contents Solvability And Bifurcations Of Nonlinear Equations

1. Understanding the eBook Solvability And Bifurcations Of Nonlinear Equations
    - The Rise of Digital Reading Solvability And Bifurcations Of Nonlinear Equations
    - Advantages of eBooks Over Traditional Books
2. Identifying Solvability And Bifurcations Of Nonlinear Equations
    - 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 Solvability And Bifurcations Of Nonlinear Equations
    - User-Friendly Interface
4. Exploring eBook Recommendations from Solvability And Bifurcations Of Nonlinear Equations
    - Personalized Recommendations
    - Solvability And Bifurcations Of Nonlinear Equations User Reviews and Ratings
    - Solvability And Bifurcations Of Nonlinear Equations and Bestseller Lists
5. Accessing Solvability And Bifurcations Of Nonlinear Equations Free and Paid eBooks
    - Solvability And Bifurcations Of Nonlinear Equations Public Domain eBooks
    - Solvability And Bifurcations Of Nonlinear Equations eBook Subscription Services
    - Solvability And Bifurcations Of Nonlinear Equations Budget-Friendly Options

6. Navigating Solvability And Bifurcations Of Nonlinear Equations eBook Formats
     - ePub, PDF, MOBI, and More
     - Solvability And Bifurcations Of Nonlinear Equations Compatibility with Devices
     - Solvability And Bifurcations Of Nonlinear Equations Enhanced eBook Features
7. Enhancing Your Reading Experience
     - Adjustable Fonts and Text Sizes of Solvability And Bifurcations Of Nonlinear Equations
     - Highlighting and Note-Taking Solvability And Bifurcations Of Nonlinear Equations
     - Interactive Elements Solvability And Bifurcations Of Nonlinear Equations
8. Staying Engaged with Solvability And Bifurcations Of Nonlinear Equations
     - Joining Online Reading Communities
     - Participating in Virtual Book Clubs
     - Following Authors and Publishers Solvability And Bifurcations Of Nonlinear Equations
9. Balancing eBooks and Physical Books Solvability And Bifurcations Of Nonlinear Equations
     - Benefits of a Digital Library
     - Creating a Diverse Reading Collection Solvability And Bifurcations Of Nonlinear Equations
10. Overcoming Reading Challenges
     - Dealing with Digital Eye Strain
     - Minimizing Distractions
     - Managing Screen Time
11. Cultivating a Reading Routine Solvability And Bifurcations Of Nonlinear Equations
     - Setting Reading Goals Solvability And Bifurcations Of Nonlinear Equations
     - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Solvability And Bifurcations Of Nonlinear Equations
     - Fact-Checking eBook Content of Solvability And Bifurcations Of Nonlinear Equations
     - Distinguishing Credible Sources
13. Promoting Lifelong Learning
     - Utilizing eBooks for Skill Development
     - Exploring Educational eBooks
14. Embracing eBook Trends
     - Integration of Multimedia Elements

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