RECENT RESULTS ON SEMI-LINEAR HYPERBOLIC PROBLEMS IN BOUNDED DOMAINS

A. HARAUX[*]

1. GENERALITIES

Let Ω be a bounded open domain in $\mathbb{R}^n$, $n \geq 1$ and f,g two <u>odd</u> functions: $\mathbb{R} \to \mathbb{R}$ such that,

(1.1) $\qquad f \in C^1(\mathbb{R})$, $f' \geq 0$

(1.2) $\qquad g$ is continuous and non-decreasing.

The partial differential equation

(1.3) $\qquad \begin{cases} \dfrac{\partial^2 u}{\partial t^2} - \Delta u + f(u) + g(\frac{\partial u}{\partial t}) = h(t,x), & (t,x) \in \mathbb{R}^+ \times \Omega \\[2mm] u(t,x) = 0 & (t,x) \in \mathbb{R}^+ \times \delta\Omega \end{cases}$

represents the small oscillations of an n-dimensional membrane with fixed edge $\{0\} \times \delta\Omega$ under the action of 4 forces

— The elastic (global, distributed) force represented by Δu.

— A non linear <u>restoring</u> <u>force</u> $-f(u)$, of local character.

— A <u>damping</u> <u>force</u> $-g(\frac{\partial u}{\partial t})$, possibly non linear, also of local character.

— An exterior time-dependent force density $h(t,x)$.

The physical interpretation of (1.3) suggests that the initial value problem must be well set in the function space $C(\mathbb{R}^+, H_0^1(\Omega)) \cap C^1(\mathbb{R}^+, L^2(\Omega))$ and that the <u>total energy</u> given by

(1.4) $\qquad E(t) = \displaystyle\int_\Omega \left\{ \frac{1}{2}(\frac{\partial u}{\partial t})^2 + \frac{1}{2}|\Delta u|^2 + \int_0^{u(t,x)} f(s)ds \right\} dx$

must play an important role in the definition of solutions to (1.3).

Equation (1.3) has been studied by a number of authors since 1953. More precisely, the initial-value problem has been studied successively

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Semilinear Hyperbolic Problems In Bounded Domains

Michael Reissig,Bert-Wolfgang Schulze

Semilinear Hyperbolic Problems In Bounded Domains:

Semi-Linear Hyperbolic Problems in Bounded Domains Alain Haraux,1987-01-01 The opening chapter provides background information on the basic functional setting semi groups and the abstract wave equation almost periodicity and the wave equation and technical tools Succeeding chapters cover the initial value problem asymptotics in autonomous cases non resonance in the purely dissipative case stability of periodic and almost periodic solutions oscillation properties in the conservative case and global properties of the full equation Includes bibliographic references and indexes by author and subject   ,   **From Finite to Infinite Dimensional Dynamical Systems** James Robinson,Paul Glendinning,2001-05-31 This volume contains six papers originally presented at a NATO Advanced Study Institute held in Cambridge U K in 1995 on the fundamental properties of partial differential equations and modeling processes involving spatial dynamics The contributors from academic institutions in Europe and the U S discuss such topics as lattice dynamical systems low dimensional models of turbulence and nonlinear dynamics of extended systems The volume is not indexed c Book News Inc

Mathematical Analysis of Deterministic and Stochastic Problems in Complex Media Electromagnetics G. F. Roach,I. G. Stratis,A. N. Yannacopoulos,2012-03-04 Electromagnetic complex media are artificial materials that affect the propagation of electromagnetic waves in surprising ways not usually seen in nature Because of their wide range of important applications these materials have been intensely studied over the past twenty five years mainly from the perspectives of physics and engineering But a body of rigorous mathematical theory has also gradually developed and this is the first book to present that theory Designed for researchers and advanced graduate students in applied mathematics electrical engineering and physics this book introduces the electromagnetics of complex media through a systematic state of the art account of their mathematical theory The book combines the study of well posedness homogenization and controllability of Maxwell equations complemented with constitutive relations describing complex media The book treats deterministic and stochastic problems both in the frequency and time domains It also covers computational aspects and scattering problems among other important topics Detailed appendices make the book self contained in terms of mathematical prerequisites and accessible to engineers and physicists as well as mathematicians   **Asymptotic Behavior of Dissipative Systems** Jack K. Hale,2010-01-04 This monograph reports the advances that have been made in the area by the author and many other mathematicians it is an important source of ideas for the researchers interested in the subject Zentralblatt MATH Although advanced this book is a very good introduction to the subject and the reading of the abstract part which is elegant is pleasant this monograph will be of valuable interest for those who aim to learn in the very rapidly growing subject of infinite dimensional dissipative dynamical systems Mathematical Reviews This book is directed at researchers in nonlinear ordinary and partial differential equations and at those who apply these topics to other fields of science About one third of the book focuses on the existence and properties of the flow on the global attractor for a discrete or continuous dynamical system The author presents a

detailed discussion of abstract properties and examples of asymptotically smooth maps and semigroups He also covers some of the continuity properties of the global attractor under perturbation its capacity and Hausdorff dimension and the stability of the flow on the global attractor under perturbation The remainder of the book deals with particular equations occurring in applications and especially emphasizes delay equations reaction diffusion equations and the damped wave equations In each of the examples presented the author shows how to verify the existence of a global attractor and for several examples he discusses some properties of the flow on the global attractor   Exact Controllability and Stabilization of the Wave Equation Enrique Zuazua,2024-08-23 This comprehensive monograph illustrates the intricate realm of controllability and stabilization of wave phenomena Authored by an expert in the field this book integrates J L Lion s renowned HUM method multiplier techniques and the construction of Lyapunov functionals Through meticulous analysis and practical applications this book provides invaluable insights for researchers seeking to navigate the expansive domain of wave like equations and their control Whether you are a seasoned mathematician or a newcomer to the field this book serves as an indispensable guide offering a thorough introduction and essential tools for understanding and controlling wave phenomena   Long-Time Behavior of Second Order Evolution Equations with Nonlinear Damping Igor Chueshov,Irena Lasiecka,2008 The authors consider abstract nonlinear second order evolution equations with a nonlinear damping Questions related to long time behavior existence and structure of global attractors are studied Particular emphasis is put on dynamics which in addition to nonlinear dissipation have noncompact semilinear terms and whose energy may not be necessarily decreasing For such systems the authors first develop a general theory at the abstract level They then apply the general theoryto nonlinear wave and plate equations exhibiting the aforementioned characteristics and are able to provide new results pertaining to several open problems in the area of structure and properties of global attractors arising in this class of PDE dynamics   Equadiff-91 - International Conference On Differential Equations (In 2 Volumes) C Perello,C Simo,Morales J De Sola,1993-05-25 Equadiff 91 stems from the series of conferences initiated by the late Professor Vogel The first conference Equadiff 70 which was held in Marseille Since then similar conferences had been held in Brussels Florence Wurzburg as well as Xanthi The purpose of the Equadiff series of conferences is to present the latest development in the field of differential equations both ordinary and partial including their numerical treatment and applications to the mathematics community These conferences had attracted renowned mathematicians from all over the world to present their studies and findings The latest conference under the series was Equadiff 91 held in Barcelona It attracted some 30 renowned mathematicians Researchers and graduate students of pure and applied mathematics will find this compilation of conference proceedings up to date relevant and insightful   Delay Differential Evolutions Subjected to Nonlocal Initial Conditions Monica-Dana Burlică,Mihai Necula,Daniela Roșu,Ioan I. Vrabie,2018-09-03 Filling a gap in the literature Delay Differential Evolutions Subjected to Nonlocal Initial Conditions reveals important results on ordinary differential equations ODEs and partial

differential equations PDEs It presents very recent results relating to the existence boundedness regularity and asymptotic behavior of global solutions for differential equations and inclusions with or without delay subjected to nonlocal implicit initial conditions After preliminaries on nonlinear evolution equations governed by dissipative operators the book gives a thorough study of the existence uniqueness and asymptotic behavior of global bounded solutions for differential equations with delay and local initial conditions It then focuses on two important nonlocal cases autonomous and quasi autonomous The authors next discuss sufficient conditions for the existence of almost periodic solutions describe evolution systems with delay and nonlocal initial conditions examine delay evolution inclusions and extend some results to the multivalued case of reaction diffusion systems The book concludes with results on viability for nonlocal evolution inclusions   Free and Moving Boundaries Roland Glowinski,Jean-Paul Zolesio,2007-06-06 Addressing algebraic problems found in biomathematics and energy Free and Moving Boundaries Analysis Simulation and Control discusses moving boundary and boundary control in systems described by partial differential equations PDEs With contributions from international experts the book emphasizes numerical and theoretical control of mo   **Control and Estimation of Distributed Parameter Systems** Wolfgang Desch,F. Kappel,Karl Kunisch,1994 A semigroup formulation of a nonlinear size structured distributed rate population model Damage detection and characterization in smart material structures Optimality conditions for non qualified parabolic control problems Convergence of trajectories for a controlled viscous Burgers equation Optimality conditions for boundary control problems of parabolic type Pontryagin s principle for optimal control problems governed by semilinear elliptic equations Invariance of the Hamiltonian in control problems for semilinear parabolic distributed parameter systems Rate distribution modeling for structured heterogeneous populations A model for a two layered plate with interfacial slip Numerical solution of a constrained control problem for a phase field model Uniform stabilizability of nonlinearly coupled Kirchhoff plate equations Boundary temperature control for thermally coupled Navier Stokes equations Adaptive estimation of nonlinear distributed parameter systems Decay estimates for the wave equation with internal damping On the controllability of the rotation of a flexible arm Modeling and controllability of interconnected elastic membranes On feedback controls for dynamic networks of strings and beams and their numerical simulation Various relaxations in optimal control of distributed parameter systems Convergence of an SQP method for a class of nonlinear parabolic boundary control problems Conditional stability in determination of densities of heat sources in a bounded domain Boundary stabilization of the Korteweg de Vries equation Controllability of the linear system of thermoelasticity Dirichlet Neumann boundary conditions   *Von Karman Evolution Equations* Igor Chueshov,Irena Lasiecka,2010-04-08 In the study of mathematical models that arise in the context of concrete plications the following two questions are of fundamental importance i we posedness of the model including existence and uniqueness of solutions and ii qualitative properties of solutions A positive answer to the rst question ing of prime interest on purely mathematical grounds also provides an important test of the viability of the model as a description of a given physical

phenomenon An answer or insight to the second question provides a wealth of information about the model hence about the process it describes Of particular interest are questions related to long time behavior of solutions Such an evolution property cannot be v i ed empirically thus any in a priori information about the long time asymptotics can be used in predicting an ultimate long time response and dynamical behavior of solutions In recent years this set of investigations has attracted a great deal of attention Consequent efforts have then resulted in the creation and infusion of new methods and new tools that have been responsible for carrying out a successful an ysis of long time behavior of several classes of nonlinear PDEs

Energy Methods in Continuum Mechanics S.N. Antontsev,J.I. Díaz,S.I. Shmarev,2012-12-06 This volume contains the proceedings of the Workshop Energy Methods for Free Boundary Problems in Continuum Mechanics held in Oviedo Spain from March 21 to March 23 1994 It is well known that the conservation laws and the constitutive equations of Continuum Mechanics lead to complicated coupled systems of partial differential equations to which as a rule one fails to apply the techniques usually employed in the studies of scalar uncoupled equations such as for instance the maximum principle The study of the qualitative behaviour of solutions of the systems re quires different techniques among others the so called Energy Methods where the properties of some integral of a nonnegative function of one or several unknowns allow one to arrive at important conclusions on the envolved unknowns This vol ume presents the state of the art in such a technique A special attention is paid to the class of Free Boundary Problems The organizers are pleased to thank the European Science Foundation Pro gram on Mathematical treatment of free boundary problems the DGICYT Spain the FICYT Principado de Asturias Spain and the Universities of Oviedo and Complutense de Madrid for their generous financial support Finally we wish to thank Kluwer Academic Publishers for the facilities received for the publication of these Proceedings **Attractors Under Autonomous and Non-autonomous Perturbations** Matheus C. Bortolan,Alexandre N. Carvalho,José A. Langa,2020-05-29 This book provides a comprehensive study of how attractors behave under perturbations for both autonomous and non autonomous problems Furthermore the forward asymptotics of non autonomous dynamical systems is presented here for the first time in a unified manner When modelling real world phenomena imprecisions are unavoidable On the other hand it is paramount that mathematical models reflect the modelled phenomenon in spite of unimportant neglectable influences discounted by simplifications small errors introduced by empirical laws or measurements among others The authors deal with this issue by investigating the permanence of dynamical structures and continuity properties of the attractor This is done in both the autonomous time independent and non autonomous time dependent framework in four distinct levels of approximation the upper semicontinuity lower semicontinuity topological structural stability and geometrical structural stability This book is aimed at graduate students and researchers interested in dissipative dynamical systems and stability theory and requires only a basic background in metric spaces functional analysis and for the applications techniques of ordinary and partial differential equations **Partial Differential Equations arising from**

Physics and Geometry Mohamed Ben Ayed,Mohamed Ali Jendoubi,Yomna Rébaï,Hasna Riahi,Hatem Zaag,2019-05-02 Presents the state of the art in PDEs including the latest research and short courses accessible to graduate students   New Trends in the Theory of Hyperbolic Equations Michael Reissig,Bert-Wolfgang Schulze,2006-03-21 Presenting several developments in the theory of hyperbolic equations this book s contributions deal with questions of low regularity critical growth ill posedness decay estimates for solutions of different non linear hyperbolic models and introduce new approaches based on microlocal methods   **Partial Differential Operators** Fernando A. Cardoso,Djairo G. de Figueiredo,Rafael Iorio,Orlando Lopes,2006-12-08 The Latin American School of Mathematics ELAM is one of the most important mathematical events in Latin America It has been held every other year since 1968 in a different country of the region and its theme varies according to the areas of interest of local research groups The subject of the 1986 school was Partial Differential Equations with emphasis on Microlocal Analysis Scattering Theory and the applications of Nonlinear Analysis to Elliptic Equations and Hamiltonian Systems   *Control Methods in PDE-Dynamical Systems* Fabio Ancona,2007 While rooted in controlled PDE systems this 2005 AMS IMS SIAM Summer Research Conference sought to reach out to a rather distinct yet scientifically related research community in mathematics interested in PDE based dynamical systems Indeed this community is also involved in the study of dynamical properties and asymptotic long time behavior in particular stability of PDE mixed problems It was the editors conviction that the time had become ripe and the circumstances propitious for these two mathematical communities that of PDE control and optimization theorists and that of dynamical specialists to come together in order to share recent advances and breakthroughs in their respective disciplines This conviction was further buttressed by recent discoveries that certain energy methods initially devised for control theoretic a priori estimates once combined with dynamical systems techniques yield wholly new asymptotic results on well established nonlinear PDE systems particularly hyperb These expectations are now particularly well reflected in the contributions to this volume which involve nonlinear parabolic as well as hyperbolic equations and their attractors aero elasticity elastic systems Euler Korteweg models thin film equations Schrodinger equations beam equations etc in addition the static topics of Helmholtz and Morrey potentials are also prominently featured A special component of the present volume focuses on hyperbolic conservation laws to take advantage of recent theoretical advances with significant implications also on applied problems in all these areas the reader will find state of the art accounts as stimulating starting points for further research   Control and Estimation in Distributed Parameter Systems H. T. Banks,1992-01-01 Research in control and estimation of distributed parameter systems encompasses a wide range of applications including both fundamental science and emerging technologies The latter include smart materials piezoceramics shape memory alloys magnetostrictives electrorheological fluids fabrication and testing design of high pressure chemical vapor deposition CVD reactors for production of microelectronic surfaces e g semiconductors while the former include groundwater contamination cleanup and other environmental modeling questions

climatology flow control and fluid structure interactions as well as more traditional topics in biology mechanics and acoustics These expository papers provide substantial stimulus to both young researchers and experienced investigators in control theory Includes a comprehensive and lucid presentation that relates frequency domain techniques to state space or time domain approaches for infinite dimensional systems including design of robust stabilizing and finite dimensional controllers for infinite dimensional systems It focuses on these two approaches to control design in an integrated system theoretic framework This is excellent reading for researchers in both the frequency domain and time domain control communities In other articles topics considered include pointwise control of distributed parameter systems bounded and unbounded sensors and actuators stabilization issues for large flexible structures and an overview discussion of damping models for flexible structures *Boletim da Sociedade Paranaense de Matemática* ,2004

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