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BOOK REVIEWS

Control and estimation of distributed parameter systems edited by W. Desch, F. Kappel and K. Kunisch, Birkhauser Verlag AG, Klosterberg 23, CH-4010 Basel, Switzerland, 1998, pp. 320, sFr. 128.

This volume represents the proceedings of an international conference held in Austria during July 1996. The main theme of the conference is control theory of systems governed by partial differential equations. There are 23 articles by experts in the field which deal with different aspects of control theory. In order to be able to appreciate the contents of the book, we briefly recall the aim and scope of control problems.

Let us assume that we have a dynamical system. The class of systems dealt with in this volume has infinite degrees of freedom, e.g. flexible mechanical structures in engineering. In fact, their evolution in time is modelled by partial differential equations (linear or nonlinear) with appropriate boundary and initial conditions. The solution $y(t)$ which describes the state of the system at various instants of time may also be restricted to satisfy certain additional pointwise (or) integral constraints. Though PDEs occurring in a majority of the articles of the volume are of classical type (e.g. heat and wave equations) there are also some novel models describing specific systems, e.g. elastomers, elastic shells coupled with piezoceramic actuators, etc.

The second ingredient in a control system is the set of admissible controls. These may occur in PDE or in boundary condition. The control u may depend on the state of the system $u(t) = u(y(t))$ in which case it is called the feedback control. The chief aim of the control problem is to choose controls (according to some criteria) such that we can influence the system and change it to have a desired behaviour. This change may be big. Thus we seem to have a diametrically opposite emphasis in control theory from the classical notion of well-posedness in PDEs. Traditionally, engineers are interested in bounded controls. However, many articles in this volume emphasize the need of unbounded/nonsmooth controls to induce large effects and to treat bad systems.

The third object involved is a criterion to choose controls. It may be that we wish to carry the system from one initial state to another arbitrary final state within a time interval T (exact controllability), or that we wish to kill all vibrations and stabilize the system around an equilibrium for large times (stabilizability) or that we choose the control that optimizes a cost functional J which is defined in terms of state of the system and of course the control (optimal control problem). The functional J has also to incorporate the desired behaviour of the system in some way or the other. Almost all the articles of this book are devoted to the study of one or the other of the above criteria. In parameter estimation problems, the aim is to choose parameter values in the state equation such that the state of the system fits best with experimentally observed state. Obviously, this class of problems is an example of optimal control problems and investigated by a couple of articles of this volume.

Having described the objects involved in control problems, we must now define objectives of the control theory. The main tasks are:

(i) to prove that the state equation uniquely defines a solution $y(u)$ associated with each control u.
(ii) to study the properties of exactly controllable and stabilizable systems.
(iii) to prove that a control serving our purpose exists and to obtain necessary (and sufficient) conditions on it.
(iv) to study the structure and properties of the equations expressing these conditions.
(v) to suggest constructive algorithms amenable to numerical computations for the approximation of the state equation and the control.
(vi) to show that the error in the approximation indeed tends to zero as discretization parameter goes to zero.

All the works appearing in the present volume are devoted to one or the other of the objectives stated above. Regarding the point (v) above which may be the main and interesting point for engineers, let me mention the following techniques used here: A generalized augmented Lagrangian method is applied to treat non-smooth constraints. A novel approach called Reduced Basis Method is applied to some control problems in fluid flows. Suitable preconditioners for treating ill-conditioned matrix systems which often result from the discretization of optimal control problems are suggested.

There are singular situations (e.g. the state equation being nonlinear) where it is not clear how one can meet the objective (i) because there may be no solution or there could be more than one solution to the state equation. Under these circumstances, a fruitful idea is to regard the state equations as a constraint on the couples (y, u) and optimize the cost functional J under this constraint. Penalization technique may be used for this purpose. This idea has been exploited in a couple of articles.

There also exist contributions towards objectives (iii) and (iv). Indeed, a number of papers are devoted to Pontriagin Maximum Principle and Bellman's Dynamic Programming Principle, their generalization to nonlinear state equations and in the presence of unbounded non-smooth controls and finally their application to numerical approximation.

With regard to the aim (ii), there are some presentations making use of the Hilbert Uniqueness Method which is one of the poweful methods of recent times.

In the previous paragraphs, I have tried to highlight the main issues in control theory and at the same time have tried to place the present volume in the overall development of the subject. Even though this book is only a proceedings, the articles found in it are seen to be 'self-contained' in the sense that full details of proofs are mostly given except of course, for preliminaries. Further, the articles are 'uniformized' in the sense that their presentations follow a uniform pattern. The editors deserve credit for this.

The importance of the subject matter dealt with in this proceedings cannot be over emphasized. It is obviously a challenging and active area in applied mathematics at the present and in the future. It has potential applications in many areas: space, defence and aviation industries to name a few. This conference is seventh in the series on this subject and I am sure many more will follow. Such conferences ought to present the current sceanario of activities in the area and the present volume fulfils this task wonderfully. It will be without doubt useful to researchers interested in control aspects of dynamical systems. Finally, I must mention that the approach followed here is only analytical. Other approaches (geometrical and algebraic) do not find a place here.

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Analysis of divergence edited by William O. Bray and C. V. Stanojevic, Birkhauser Verlag AG, Klosterberg 23, CH-4010 Basel, Switzerland, 1998, pp. 592, sFr. 138.

This volume represents the proceedings of the Seventh International Workshop in Analysis and its Applications (IWAA). The principal theme of the workshop shares the title of the volume. Totally 29 papers are included in the volume and each one is called a chapter. The contents are divided into four parts:

Part I : Convergence and summability
Part II : Singular integrals and multipliers
Part II : Integral operators and functional analysis
Part IV : Asymptotics and applications

A quick look at these sub-titles clearly indicates the diversity of the papers presented in the conference.

The title of the volume could be misleading at least to some of the readers. This book is not on control theory in the traditional sense of the word. It does not deal with control systems governed by some state equation of evolution (ordinary differential equation or partial differential equation) which exhibits singularities or blow-up or any such divergent mechanisms. Controllability and stabilizability of such systems or optimal control problems associated with such systems are not the issues addressed in this text. The book does not deal with many divergent problems and notorious infinities interesting for physicists and occurring in quantum field theory and particle physics.

What are then the divergent processes alluded to in the title? The most classical example is provided by divergent series of real numbers. By control and management of this divergence, it is meant to use one or other of various summability methods (e.g. Cesaro, Abel, Borel summability procedures) to sum such series. It is well known that oscillations and cancellations play essential role in the success of these summability methods.

The above phenomenon occurs already in finite-dimensional spaces such as real-number system. An example in infinite-dimensional spaces is given by the convergence analysis of Fourier series. If its coefficients are absolutely summable then the series converges uniformly. On the other hand, if the coefficients are only square summable then we do not have uniform convergence. How to make sense of the series in this situation? The idea is to consider a different inequivalent metric which is possible in infinite-dimensional spaces. Indeed, Parseval's equality establishes that the Fourier series is then convergent in the space of square integrable functions. Thus a change in the metric does the trick and serves as a tool of control and management in this situation. Several papers found in this volume are devoted to the convergence analysis of the following series: Vilenkin–Fourier series, Wavelet series, Legendre series, Fourier–Bessel series, etc.

Examples of this type of divergent situations and remedies for them are abundant in the literature. In fact, they are heart and soul of obtaining significant results in analysis. Articles appearing in this book are testament to this fact.

Let me cite here the example of singular integrals, the prototype of which is Hilbert transform. A method of summing such integrals and proving their existence is provided by a cut-off procedure avoiding the singularity and taking the limit in a suitable topology. This process is called principal value limit and once again cancellations are in the forefront. Similar questions of convergence can be asked in the case of Fourier integrals, psuedo-differential operators and more general oscillatory integrals. Articles in Part II address such questions.

Part III is a mixed bag of papers dealing with a range of questions concerning elliptic boundary-value problems, extremal problems, Hardy-type inequalities for integral operators, etc.

Part IV is devoted to applications in the sense that the theoretical questions analyzed here are coming from different areas: optimal control theory, differential geometry, sampling theory and partial differential equations.

The above description gives an idea of some examples of divergent processes treated in this book. It is found generally that the articles are well written highlighting the contribution of the authors and giving appropriate references. However, the book suffers the same fate as most conference proceedings do: it is not well focussed and the questions discussed are too diverse. The only unifying aspect between them is that the approach to different problems is analytical. Nowadays, it is rare to find researchers who will be interested in the wide range of topics presented here. Of course, individual papers taken separately will attract the attention of a section of researchers in analysis. The value of the volume would definitely have been more if a separate part containing survey papers in the field had been included.

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Electrodynamics by William E. Baylis, Birkhauser Verlag AG, Klosterberg 23, CH-4010 Basel, Switzerland, 1998, pp. 400, sFr. 88.

The subject matter of the book is electrodynamics and several of its aspects. The core relations in this area are of course Maxwell's equations which relate the variation of electromagnetic field to the sources of charges and currents. Once the electromagnetic field is known, the motion of charged particles in the field can be described by Lorentz force equation. The principal objects discussed in this volume are therefore Maxwell equations and the Lorentz force equation and their applications. This is definitely a classical topic and a thoroughly studied area and the reader may wonder why this book is being published in the series 'Progress in Physics'. The novelty lies in the approach of the author which I explain now.

Analytic approaches to Maxwell equations are quite common. After the impact of Yang–Mills theories, geometrical approaches using differential forms are also well known in electromagnetism. Apart from these, there are also methods based on operator algebras to field theory. The approach of the present book is different. It exploits the Clifford algebraic structure found in Minkowski space–time manifold. This idea is not new and its application in physics dates back to the works of Dirac in the relativistic quantum theory of electron. The Clifford algebra (denoted by $Cl_{1,3}$) used then was generated by the four-dimensional space E^4 provided with Minkowski metric. The choice of this algebra is made on the assumption that it is necessary for a covariant description of the relativistic phenomena. Somewhat surprisingly, the approach followed by the author of the present volume shows that the above assumption is not entirely correct and one could work with a smaller algebra (denoted by Cl_3) called Pauli algebra. It is the Clifford algebra generated by Euclidean three-dimensional space E^3. The crucial observation is that the paravector subspace of Cl_3 can serve as the tangent space of the four-dimensional Minkowski space–time manifold. As illustrated amply in the book, there are several advantages in this approach. The geometry associated with Clifford algebras is definitely one of them. Covariant formulation of Maxwell equations and Lorentz force equation is another. Once this is done, all other associated phenomena can be neatly analyzed in this formulation. Indeed, using the above formulation, the author treats a variety of phenomena such as propagation of waves in vacuum and in homogeneous media, effects due to interfaces and boundaries, polarization, radiation from accelerating charges and Lorentz–Dirac equation which describes the interaction of the charge with its own radiation field. The list is seemingly endless.

In this endeavour, projectors in the Clifford algebra play an essential role. These zero divisors prevent the algebra from being a division algebra. As only expected, Lorentz transformations also play an important part. Via Pauli spin matrices, these transformations are modelled as elements of SL (2; C) and this greatly simplifies the manipulations.

The organisation of the material in the book and the presentation of the ideas are impeccable. Each chapter concludes with a set of problems which complement the text. It is an added bonus that complete solutions to these problems are available from the publishers for teachers who may give courses based on this book. This book will be useful for mathematical physicists with strong interest in electromagnetism.

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Microwave, millimeter-wave and submillimeter-wave vacuum electron devices by Rajeshwari Chatterjee, East-West Press Limited, 105, Nirmal Towers 26, Barakhamba Road, New Delhi 110 001, 1999, pp. 460, Rs. 325.

The author's venture to write a treatise on a topic like vacuum electron devices is commendable. She has chosen an interesting topic in electromagnetic fields in which one gets an opportunity to exemplify the basic principles of not only time-dependent fields but also of time-independent fields unlike in the usual areas of microwave engineering like circuits, antennas and wave propagation. (We all know how, while dealing with the usual areas of microwave engineering, only the time-dependent field concepts need to be applied.) For instance, see the topics on the formation of an electron beam by an electron gun or the confinement of an electron beam by a focusing structure (Ch. 4). In developing an understanding of these topics, time-independent field concepts have been used. On the other hand, time-dependent field concepts have been used in topics like the interaction structures for vacuum electron devices (Ch. 5 and 6) and interaction between an electron beam and electromagnetic waves (Ch. 2, 7, 8 and 10). Topics like electron emitter or cathode, which are the heart of a microwave tube (Ch. 3), and issues related to fabrication and processing of electron tubes (Ch. 11) are usually given little importance amidst electromagnetic details of electron devices in many books. It is gratifying to note that the author has taken care to dedicate separate chapters to these topics.

The material of this volume has been collected from an extensive survey of literature. The list of references provided should prove to be very useful to the reader. I suggest that, while reading the book and building up relevant concepts, the reader should go through the original references to remove any conceptual doubts. Also, at this stage I will fail as a reviewer if I do not bring out some specific points relevant to the contents, concepts and presentation of the volume.

An impression has been given in the book that microwave tubes are characterised by electron velocities much less than the velocity of light that would make the relativistic effects unimportant (for instance, see the early part of Section 1.3). But there exist several devices in the family of conventional microwave tubes too (for example, the relativistic travelling-wave tubes (TWT)) in which relativistic effects are considered; thus, for that matter, one need not go even up to the gyro-devices. Also, while discussing the difference between the analysis of an accelerator and that of a microwave tube (Section 1.3), a very important point relevant to power-transfer mechanism has been left out. This refers to (i) the coupling of the 'slow' space-charge wave to the circuit wave for the transfer of power from the electron beam to electromagnetic waves, and (ii) the coupling of the 'fast' space-charge wave to the circuit wave for the transfer of power from electromagnetic waves to the electron beam. This could have been explained with the help of Chu's kinetic power conservation theorem, which is a very important concept in the study of vacuum electron devices that has been kept outside the scope of the volume. The author has taken up devices like the helix travelling-wave tube for study in which the coupling of the slow space-charge wave to a circuit wave is responsible for the amplification of power. Also, the same device may be prevented from oscillating by providing an increased pitch section near the output to couple the fast space-charge wave to the circuit wave. Incidentally, while working out the formula for the gain of TWT, the author has obtained the circuit equation that involves the characteristic impedance of the slow-wave circuit (Ch. 7). A more rigorous and correct approach could have been made to deduce the circuit equation, and hence also the gain formula, that involves interaction impedance instead of characteristic impedance. In fact, the author has introduced the concept of interaction impedance in the same chapter while discussing the principle of a backward-wave oscillator. For practical situations, the characteristic impedance widely differs in value from interaction impedance. It is correct to use interaction impedance in the beam-wave interaction process, and the characteristic impedance in the coupling of RF power in and out of the slow-wave structure.

The design of an electron gun and that of a focussing structure for microwave tubes is based on the principles of the formation and confinement of an electron beam, respectively. Therefore, it would have been appropriate if Chapter 4 were entitled either as 'Formation and confinement of an electron beam' or 'Electron guns and focussing structures'. Indeed this chapter is intended to deal with these two tube parts and the relevant principles. Also, an important relevant concept has added to the value of the book—the theory of electrostatic lenses. The value of this chapter would have increased considerably if a method were given as to how to include the effect of the lens effects of the anode aperture in the gun design, and hence find out at least the basic output parameters, namely, the interelectrode spacing, the cathode and anode-aperture sizes, and the 'throw' (the position of the beam waist/throat from one of the gun electrodes), with particular reference to a convergent-flow Pierce electron gun derived from a spherical-cup cathode.

Also, I think the title of the chapter on fast-wave devices (Ch. 10: Cyclotron resonance devices or fast-wave devices) is not appropriate. This is because all the fast-wave devices are not necessarily based on the principle of cyclotron resonance maser (CRM) instability. The gyromonotrons (also called gyrotrons), gyro-klystrons and gyro-TWTs dealt with in the chapter are certainly CRM-instability devices. (Incidentally, 'gyrotrons' have been misspelled as 'gyratrons' throughout the volume). But the ubitrons, which have been dealt with in the same chapter, are not based on the principle of CRM instability, though both an ubitron and a gyro-device share a commonality between them in that both belong to the class of bremsstrahlung devices, in which the electron beam is made periodic and the device is operated at the point of intersection between the beam-mode line and the waveguide-mode curve in the ω–β dispersion plot. Therefore, 'cyclotron resonance devices' should have been dropped from the title and only 'fast-wave devices' retained. It should be mentioned that only small-orbit gyrotrons/gyro-TWTs have been dealt with in this book; large-orbit devices involving a 'waveguide-axis-circling' beam of electrons have been kept out of the scope of the book. Also, while discussing the harmonic operation of the device, the author has missed a very important point, the very purpose of harmonic operation, which is to reduce the required background magnetic flux density. I would also like to mention that neither the principle of operation of a peniotron has been explained correctly nor has it been stated anywhere that a peniotron is essentially a high-efficiency device. Obviously, the author has not explained why a peniotron is so distinct in that it enjoys high efficiencies in the family of fast-wave devices.

The coverage of the state-of-the-art in a separate chapter is certainly useful and informative, but is far from complete (Ch. 12). The information provided in the chapter could have been put as additional reading material—as an extension of the topics treated in the appropriate and relevant chapters of the book, instead of presenting in a separate chapter.

The author's attempt to cover many a topic of vacuum electron devices in a single treatise has probably made the development of many concepts and related mathematical treatment in-complete and far from being self-contained. I am sure the readers would like to carefully examine the relevant concepts with the help of references—so meticulously collected and provided by the author—and fill up the lacunae. The vacuum electron-device community must be grateful to the author for dedicating her efforts to writing this treatise.

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