

Differential Games A Mathematical Theory With Applications To Warfare And Pursuit Control And Optimization Rufus Isaacs

Broadly a differential game is one in which, as the action progresses, both the environment and the decisions available to the players are subject to a consistent, logical law, so that the problem is amenable to mathematical analysis. Usually the action is continuous and solutions can actually be obtained for a wide range of problems of extended conflict between two antagonists. The applications include various models of battles, pursuit and evasion games, dogfights, and other contests of maneuvering, such as football, and some aiming and evasion problems. By allowing one player to be passive, certain programming procedures can be optimized. A chapter is devoted to collision avoidance, in which the players cooperate rather than conflict. In what are termed games of degree the players respectively seek to maximize and minimize some numerically valued payoff. In games of kind the criterion is sharp, such as whether or not capture will occur in a pursuit situation. The two types have separate but related theories. The text concludes with chapters on the case of incomplete information and the practical aspects of applications to warfare. (Author).

Differential games theory is the most appropriate discipline for the modelling and analysis of real life conflict problems. The theory of differential games is here treated with an emphasis on the construction of solutions to actual problems with singular surfaces. The reader is provided

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with the knowledge necessary to put the theory of differential games into practice. Matrix Games, Programming, and Mathematical Economics deals with game theory, programming theory, and techniques of mathematical economics in a single systematic theory. The principles of game theory and programming are applied to simplified problems related to economic models, business decisions, and military tactics. The book explains the theory of matrix games and some of the tools used in the analysis of matrix games. The text describes optimal strategies for matrix games which have two basic properties, as well as the construction of optimal strategies. The book investigates the structure of sets of solutions of discrete matrix games, with emphasis on the class of games whose solutions are unique. The examples show the use of dominance concepts, symmetries, and probabilistic arguments that emphasize the principles of game theory. One example involves two opposing political parties in an election campaign, particularly, how they should distribute their advertising efforts for wider exposure. The text also investigates how to determine an optimal program from several choices that results with the maximum or minimum objective. The book also explores the analogs of the duality theorem, the equivalence of game problems to linear programming problems, and also the inter-industry nonlinear activity analysis model requiring special mathematical methods. The text will prove helpful for students in advanced mathematics and calculus. It can be appreciated by mathematicians, engineers, economists, military strategists, or statisticians who formulate decisions using mathematical analysis and linear programming. The theory of two-person, zero-sum differential games started at the beginning of the 1960s with the works of R. Isaacs in the United States and L.S. Pontryagin and his school in the former Soviet Union. Isaacs based his work on the Dynamic Programming method. He

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analyzed many special cases of the partial differential equation now called Hamilton Jacobi-Isaacs-briefly HJI-trying to solve them explicitly and synthesizing optimal feedbacks from the solution. He began a study of singular surfaces that was continued mainly by J. Breakwell and P. Bernhard and led to the explicit solution of some low-dimensional but highly nontrivial games; a recent survey of this theory can be found in the book by J. Lewin entitled *Differential Games* (Springer, 1994). Since the early stages of the theory, several authors worked on making the notion of value of a differential game precise and providing a rigorous derivation of the HJI equation, which does not have a classical solution in most cases; we mention here the works of W. Fleming, A. Friedman (see his book, *Differential Games*, Wiley, 1971), P.P. Varaiya, E. Roxin, R.J. Elliott and N.J. Kalton, N.N. Krasovskii, and A.I. Subbotin (see their book *Positional Differential Games*, Nauka, 1974, and Springer, 1988), and L.D. Berkovitz. A major breakthrough was the introduction in the 1980s of two new notions of generalized solution for Hamilton-Jacobi equations, namely, viscosity solutions, by M.G. Crandall and P.-L. Twenty papers are devoted to the treatment of a wide spectrum of problems in the theory and applications of dynamic games with the emphasis on pursuit-evasion differential games. The problem of capturability is thoroughly investigated, also the problem of noise-corrupted (state) measurements. Attention is given to aerial combat problems and their attendant modelling issues, such as variable speed of the combatants, the three-dimensionality of physical space, and the combat problem, i.e. problems related to 'role determination'. Recent interest in biological games and mathematical finance make this classic 1982 text a necessity once again. Unlike other books in the field, this text provides an overview of the analysis of dynamic/differential zero-sum and nonzero-sum games and simultaneously

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stresses the role of different information patterns. The first edition was fully revised in 1995, adding new topics such as randomized strategies, finite games with integrated decisions, and refinements of Nash equilibrium. Readers can now look forward to even more recent results in this unabridged, revised SIAM Classics edition. Topics covered include static and dynamic noncooperative game theory, with an emphasis on the interplay between dynamic information patterns and structural properties of several different types of equilibria; Nash and Stackelberg solution concepts; multi-act games; Braess paradox; differential games; the relationship between the existence of solutions of Riccati equations and the existence of Nash equilibrium solutions; and infinite-horizon differential games.

This volume contains fifteen articles on the topic of differential and dynamic games, focusing on both theory and applications. It covers a variety of areas and presents recent developments on topics of current interest. It should be useful to researchers in differential and dynamic games, systems and control, operations research and mathematical economics.

One of the definitive works in game theory, this volume takes an original and expert look at conflict solutions. Drawing on game theory, the calculus of variations, and control theory, the author solves an amazing array of problems relating to military situations, pursuit and evasion tactics, athletic contests, and many more. Clearly detailed examples; numerous calculations. 1965 edition.

Game theory has revolutionised our understanding of industrial organisation and the traditional theory of the firm. Despite these advances, industrial economists have tended to rely on a restricted set of tools from game theory, focusing on static and

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repeated games to analyse firm structure and behaviour. Luca Lambertini, a leading expert on the application of differential game theory to economics, argues that many dynamic phenomena in industrial organisation (such as monopoly, oligopoly, advertising, R&D races) can be better understood and analysed through the use of differential games. After illustrating the basic elements of the theory, Lambertini guides the reader through the main models, spanning from optimal control problems describing the behaviour of a monopolist through to oligopoly games in which firms' strategies include prices, quantities and investments. This approach will be of great value to students and researchers in economics and those interested in advanced applications of game theory.

The goal of this textbook is to introduce students to the stochastic analysis tools that play an increasing role in the probabilistic approach to optimization problems, including stochastic control and stochastic differential games. While optimal control is taught in many graduate programs in applied mathematics and operations research, the author was intrigued by the lack of coverage of the theory of stochastic differential games. This is the first title in SIAM's Financial Mathematics book series and is based on the author's lecture notes. It will be helpful to students who are interested in stochastic differential equations (forward, backward, forward-backward); the probabilistic approach to stochastic control (dynamic programming and the stochastic maximum principle); and mean field games and control of McKean-Vlasov dynamics. The theory is

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illustrated by applications to models of systemic risk, macroeconomic growth, flocking/schooling, crowd behavior, and predatory trading, among others. It all started with von Neumann and Morgenstern half a century ago. Their Theory of Games and Economic Behavior gave birth to a whole new area of mathematics concerned with the formal problems of rational decision as experienced by multiple agents. Now, game theory is all around us, making its way even into regular conversations. In the present book, Mehlmann presents mathematical foundations and concepts illustrated via social quandaries, mock political battles, evolutionary confrontations, economic struggles, and literary conflict. Most of the standard models--the prisoners' dilemma, the arms race, evolution, duels, the game of chicken, etc.--are here. Many non-standard examples are also here: the Legend of Faust, shootouts in the movies, the Madness of Odysseus, to name a few. The author uses familiar formulas, fables, and paradoxes to guide readers through what he calls the "hall of mirrors of strategic decision-making". His light-hearted excursion into the world of strategic calculation shows that even deep insights into the nature of strategic thought can be elucidated by games, puzzles, and diversions. Originally written in German and published by Vieweg-Verlag, this AMS edition is a translation tailored for the English-speaking reader. It offers an intriguing look at myths and paradoxes through the lens of game theory, bringing the mathematics into sharper focus at the same time. This book is a must for those who wish to consider game theory from a different

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perspective: one that embraces science, literature, and real-life conflict. The Game's Afoot! would make an excellent book for an undergraduate course in game theory. It can also be used for independent study or as supplementary course reading. The connections to literature, films and everyday life also make it highly suitable as a text for a challenging course for non-majors. Its refreshing style and amusing combination of game theoretic analysis and cultural issues even make it appealing as recreational reading.

This collection of selected contributions gives an account of recent developments in dynamic game theory and its applications, covering both theoretical advances and new applications of dynamic games in such areas as pursuit-evasion games, ecology, and economics. Written by experts in their respective disciplines, the chapters include stochastic and differential games; dynamic games and their applications in various areas, such as ecology and economics; pursuit-evasion games; and evolutionary game theory and applications. The work will serve as a state-of-the art account of recent advances in dynamic game theory and its applications for researchers, practitioners, and advanced students in applied mathematics, mathematical finance, and engineering.

Suitable for advanced undergraduates and graduate students, this text introduces the stability theory and asymptotic behavior of solutions of linear and nonlinear differential equations. 1953 edition.

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Games provide mathematical models for interaction. Numerous tasks in computer science can be formulated in game-theoretic terms. This fresh and intuitive way of thinking through complex issues reveals underlying algorithmic questions and clarifies the relationships between different domains. This collection of lectures, by specialists in the field, provides an excellent introduction to various aspects of game theory relevant for applications in computer science that concern program design, synthesis, verification, testing and design of multi-agent or distributed systems. Originally devised for a Spring School organised by the GAMES Networking Programme in 2009, these lectures have since been revised and expanded, and range from tutorials concerning fundamental notions and methods to more advanced presentations of current research topics. This volume is a valuable guide to current research on game-based methods in computer science for undergraduate and graduate students. It will also interest researchers working in mathematical logic, computer science and game theory. This text offers an exceptionally clear presentation of the mathematical theory of games of strategy and its applications to many fields including economics, military, business, and operations research.

This is an introduction to game theory and applications with an emphasis on self-discovery from the perspective of a mathematical modeller. The book deals in a unified manner with the central concepts of both classical and evolutionary game theory. The key ideas are illustrated throughout by a wide variety of well-chosen examples of both

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human and non-human behavior, including car pooling, price fixing, food sharing, sex allocation and competition for territories or oviposition sites. There are numerous exercises with solutions.

A comprehensive, self-contained survey of the theory and applications of differential games, one of the most commonly used tools for modelling and analysing economics and management problems which are characterised by both multiperiod and strategic decision making. Although no prior knowledge of game theory is required, a basic knowledge of linear algebra, ordinary differential equations, mathematical programming and probability theory is necessary. Part One presents the theory of differential games, starting with the basic concepts of game theory and going on to cover control theoretic models, Markovian equilibria with simultaneous play, differential games with hierarchical play, trigger strategy equilibria, differential games with special structures, and stochastic differential games. Part Two offers applications to capital accumulation games, industrial organization and oligopoly games, marketing, resources and environmental economics.

This book gathers the most essential results, including recent ones, on linear-quadratic optimal control problems, which represent an important aspect of stochastic control. It presents results for two-player differential games and mean-

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field optimal control problems in the context of finite and infinite horizon problems, and discusses a number of new and interesting issues. Further, the book identifies, for the first time, the interconnections between the existence of open-loop and closed-loop Nash equilibria, solvability of the optimality system, and solvability of the associated Riccati equation, and also explores the open-loop solvability of mean-field linear-quadratic optimal control problems. Although the content is largely self-contained, readers should have a basic grasp of linear algebra, functional analysis and stochastic ordinary differential equations. The book is mainly intended for senior undergraduate and graduate students majoring in applied mathematics who are interested in stochastic control theory. However, it will also appeal to researchers in other related areas, such as engineering, management, finance/economics and the social sciences.

This work offers a concise but wide-ranging introduction to games, including older (pre-game theory) party games and more recent topics like elections and evolutionary games and is generously spiced with excursions into philosophy, history, literature and politics.

This book has been written to address the increasing number of Operations Research and Management Science problems (that is, applications) that involve the explicit consideration of time and of gaming among multiple agents. It is a

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book that will be used both as a textbook and as a reference and guide by those whose work involves the theoretical aspects of dynamic optimization and differential games.

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The performance of a process -- for example, how an aircraft consumes fuel -- can be enhanced when the most effective controls and operating points for the process are determined. This holds true for many physical, economic, biomedical, manufacturing, and engineering processes whose behavior can often be influenced by altering certain parameters or controls to optimize some desired property or output.

This volume lays the mathematical foundations for the theory of differential games, developing a rigorous mathematical framework with existence theorems. It begins with a precise definition of a differential game and advances to considerations of games of fixed duration, games of pursuit and evasion, the computation of saddle points, games of survival, and games with restricted phase coordinates. Final chapters cover selected topics (including capturability and games with delayed information) and N-person games. Geared toward graduate students, *Differential Games* will be of particular interest to professionals in the

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fields of electrical engineering, industrial engineering, economics, and mathematics. Although intended primarily for self-study, it can be used as a core or ancillary text in courses in differential games, game theory, and control theory. Branches of mathematics and advanced mathematical algorithms can help solve daily problems throughout various fields of applied sciences. Domains like economics, mechanical engineering, and multi-person decision making benefit from the inclusion of mathematics to maximize utility and cooperation across disciplines. There is a need for studies seeking to understand the theories and practice of using differential mathematics to increase efficiency and order in the modern world. Emerging Applications of Differential Equations and Game Theory is a collection of innovative research that examines the recent advancements on interdisciplinary areas of applied mathematics. While highlighting topics such as artificial neuron networks, stochastic optimization, and dynamical systems, this publication is ideally designed for engineers, cryptologists, economists, computer scientists, business managers, mathematicians, mechanics, academicians, researchers, and students.

Gain some insight into the game of life... Game Theory means rigorous strategic thinking. It is based on the idea that everyone acts competitively and in his own best interest. With the help of mathematical models, it is possible to anticipate the

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actions of others in nearly all life's enterprises. This book includes down-to-earth examples and solutions, as well as charts and illustrations designed to help teach the concept. In *The Complete Idiot's Guide® to Game Theory*, Dr. Edward C. Rosenthal makes it easy to understand game theory with insights into: ? The history of the discipline made popular by John Nash, the mathematician dramatized in the film *A Beautiful Mind* ? The role of social behavior and psychology in this amazing discipline ? How important game theory has become in our society and why

This excellent 1981 treatment of the mathematical theory of entropy gives an accessible exposition its application to other fields.

Differential Game Theory with Applications to Missiles and Autonomous Systems explains the use of differential game theory in autonomous guidance and control systems. The book begins with an introduction to the basic principles before considering optimum control and game theory. Two-party and multi-party game theory and guidance are then covered and, finally, the theory is demonstrated through simulation examples and models and the simulation results are discussed. Recent developments in the area of guidance and autonomous systems are also presented. Key features: Presents new developments and how they relate to established control systems knowledge. Demonstrates the theory

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through simulation examples and models. Covers two-party and multi-party game theory and guidance. Accompanied by a website hosting MATLAB® code. The book is essential reading for researchers and practitioners in the aerospace and defence industries as well as graduate students in aerospace engineering. A rigorous introduction to optimal control theory, with an emphasis on applications in economics. This book bridges optimal control theory and economics, discussing ordinary differential equations, optimal control, game theory, and mechanism design in one volume. Technically rigorous and largely self-contained, it provides an introduction to the use of optimal control theory for deterministic continuous-time systems in economics. The theory of ordinary differential equations (ODEs) is the backbone of the theory developed in the book, and chapter 2 offers a detailed review of basic concepts in the theory of ODEs, including the solution of systems of linear ODEs, state-space analysis, potential functions, and stability analysis. Following this, the book covers the main results of optimal control theory, in particular necessary and sufficient optimality conditions; game theory, with an emphasis on differential games; and the application of control-theoretic concepts to the design of economic mechanisms. Appendixes provide a mathematical review and full solutions to all end-of-chapter problems. The material is presented at three levels: single-person

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decision making; games, in which a group of decision makers interact strategically; and mechanism design, which is concerned with a designer's creation of an environment in which players interact to maximize the designer's objective. The book focuses on applications; the problems are an integral part of the text. It is intended for use as a textbook or reference for graduate students, teachers, and researchers interested in applications of control theory beyond its classical use in economic growth. The book will also appeal to readers interested in a modeling approach to certain practical problems involving dynamic continuous-time models.

Game theory is the theory of social situations, and the majority of research into the topic focuses on how groups of people interact by developing formulas and algorithms to identify optimal strategies and to predict the outcome of interactions. Only fifty years old, it has already revolutionized economics and finance, and is spreading rapidly to a wide variety of fields. LQ Dynamic Optimization and Differential Games is an assessment of the state of the art in its field and the first modern book on linear-quadratic game theory, one of the most commonly used tools for modelling and analysing strategic decision making problems in economics and management. Linear quadratic dynamic models have a long tradition in economics, operations research and control engineering; and

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the author begins by describing the one-decision maker LQ dynamic optimization problem before introducing LQ differential games. Covers cooperative and non-cooperative scenarios, and treats the standard information structures (open-loop and feedback). Includes real-life economic examples to illustrate theoretical concepts and results. Presents problem formulations and sound mathematical problem analysis. Includes exercises and solutions, enabling use for self-study or as a course text. Supported by a website featuring solutions to exercises, further examples and computer code for numerical examples. LQ Dynamic Optimization and Differential Games offers a comprehensive introduction to the theory and practice of this extensively used class of economic models, and will appeal to applied mathematicians and econometricians as well as researchers and senior undergraduate/graduate students in economics, mathematics, engineering and management science.

The subject theory is important in finance, economics, investment strategies, health sciences, environment, industrial engineering, etc.

Graduate-level text surveys games of fixed duration, games of pursuit and evasion, the computation of saddle points, games of survival, games with restricted phase coordinates, and N-person games. 1971 edition.

This text opens with the theory of 2-person zero-sum games, 2-person non-zero

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sum games, and n-person games, at a level between non-mathematical introductory books and technical mathematical game theory books. Includes introductory explanations of gaming and meta games. Includes numerous exercises and problems with solutions and over 30 illustrations. 1986 edition. This book describes the latest advances in the theory of mean field games, which are optimal control problems with a continuum of players, each of them interacting with the whole statistical distribution of a population. While it originated in economics, this theory now has applications in areas as diverse as mathematical finance, crowd phenomena, epidemiology, and cybersecurity. Because mean field games concern the interactions of infinitely many players in an optimal control framework, one expects them to appear as the limit for Nash equilibria of differential games with finitely many players as the number of players tends to infinity. This book rigorously establishes this convergence, which has been an open problem until now. The limit of the system associated with differential games with finitely many players is described by the so-called master equation, a nonlocal transport equation in the space of measures. After defining a suitable notion of differentiability in the space of measures, the authors provide a complete self-contained analysis of the master equation. Their analysis includes the case of common noise problems in which all the players are affected by a common Brownian motion. They then go on to explain how to use the master equation to prove the mean field limit. This groundbreaking book presents two important new results in

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mean field games that contribute to a unified theoretical framework for this exciting and fast-developing area of mathematics.

This book uses a small volume to present the most basic results for deterministic two-person differential games. The presentation begins with optimization of a single function, followed by a basic theory for two-person games. For dynamic situations, the author first recalls control theory which is treated as single-person differential games. Then a systematic theory of two-person differential games is concisely presented, including evasion and pursuit problems, zero-sum problems and LQ differential games. The book is intended to be self-contained, assuming that the readers have basic knowledge of calculus, linear algebra, and elementary ordinary differential equations. The readership of the book could be junior/senior undergraduate and graduate students with majors related to applied mathematics, who are interested in differential games. Researchers in some other related areas, such as engineering, social science, etc. will also find the book useful.

A fundamental introduction to modern game theory from a mathematical viewpoint
Game theory arises in almost every fact of human and inhuman interaction since oftentimes during these communications objectives are opposed or cooperation is viewed as an option. From economics and finance to biology and computer science, researchers and practitioners are often put in complex decision-making scenarios, whether they are interacting with each other or working with the evolving

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technology and artificial intelligence. Acknowledging the role of mathematics in making logical and advantageous decisions, *Game Theory: An Introduction* uses modern software applications to create, analyze, and implement effective decision-making models. While most books on modern game theory are either too abstract or too applied, this book provides a balanced treatment of the subject that is both conceptual and hands-on. *Game Theory* introduces readers to the basic theories behind games and presents real-world examples from various fields of study such as economics, political science, military science, finance, biological science as well as general game playing. A unique feature of this book is the use of Maple to find the values and strategies of games, and in addition, it aids in the implementation of algorithms for the solution or visualization of game concepts. Maple is also utilized to facilitate a visual learning environment of game theory and acts as the primary tool for the calculation of complex non-cooperative and cooperative games. Important game theory topics are presented within the following five main areas of coverage: Two-person zero sum matrix games, Nonzero sum games and the reduction to nonlinear programming, Cooperative games, including discussion of both the Nucleolus concept and the Shapley value, Bargaining, including threat strategies, Evolutionary stable strategies and population games. Although some mathematical competence is assumed, appendices are provided to act as a refresher of the basic concepts of linear algebra, probability, and statistics. Exercises are included at the end of each section along with algorithms for the solution

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of the games to help readers master the presented information. Also, explicit Maple and Mathematica® commands are included in the book and are available as worksheets via the book's related Website. The use of this software allows readers to solve many more advanced and interesting games without spending time on the theory of linear and nonlinear programming or performing other complex calculations. With extensive examples illustrating game theory's wide range of relevance, this classroom-tested book is ideal for game theory courses in mathematics, engineering, operations research, computer science, and economics at the upper-undergraduate level. It is also an ideal companion for anyone who is interested in the applications of game theory.

Few branches of mathematics have been more influential in the social sciences than game theory. In recent years, it has become an essential tool for all social scientists studying the strategic behaviour of competing individuals, firms and countries.

However, the mathematical complexity of game theory is often very intimidating for students who have only a basic understanding of mathematics. *Insights into Game Theory* addresses this problem by providing students with an understanding of the key concepts and ideas of game theory without using formal mathematical notation. The authors use four very different topics (college admission, social justice and majority voting, coalitions and co-operative games, and a bankruptcy problem from the Talmud) to investigate four areas of game theory. The result is a fascinating introduction to the world of game theory and its increasingly important role in the social sciences.

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The classical optimal control theory deals with the determination of an optimal control that optimizes the criterion subjects to the dynamic constraint expressing the evolution of the system state under the influence of control variables. If this is extended to the case of multiple controllers (also called players) with different and sometimes conflicting optimization criteria (payoff function) it is possible to begin to explore differential games. Zero-sum differential games, also called differential games of pursuit, constitute the most developed part of differential games and are rigorously investigated. In this book, the full theory of differential games of pursuit with complete and partial information is developed. Numerous concrete pursuit-evasion games are solved (?life-line? games, simple pursuit games, etc.), and new time-consistent optimality principles in the n-person differential game theory are introduced and investigated.

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