OPTIMAL CONTROL
AND SEMICONTINUOUS VISCOSITY SOLUTIONS

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ABSTRACT. We study the value function for an optimal control problem with upper semicontinuous terminal data. We prove that the upper semicontinuous envelope of the value function is the unique semicontinuous viscosity solution of the Bellman equation and that it coincides with the value function obtained when using relaxed controls.

0. INTRODUCTION AND SUMMARY

In [2] we introduced an extension of the theory of viscosity solutions for Hamilton–Jacobi equations of the form $\Lambda(u) \equiv u_t + H(t, x, D_x u) = 0$ if $(t, x) \in (0, T) \times R^n$ and $u(T, x) = g(x)$. The classical theory in which g is assumed to be continuous was initiated in the pioneering paper of Crandall and Lions [4]. Our extension is to allow semicontinuous terminal data g but we require the Hamiltonian $H(t, x, p)$ to be convex (for upper semicontinuous g) in p. For lower semicontinuous terminal data we require concavity. This convexity assumption is satisfied in problems of optimal control of ordinary differential equations, where we are dealing with the Bellman equation.

From now on we discuss only the upper semicontinuous (u.s.c) case with the lower semicontinous case being entirely analogous.

The problem with u.s.c data, of course, is that we can only deal with u.s.c candidate functions as solutions to the Bellman equation since it is known that discontinuities propagate in first order problems. This leads to the difficulty that the definition of viscosity supersolution is vacuuous in general because it requires the existence of a smooth function, say ϕ for which $u - \phi$ achieves a minimum at some point and $\Lambda(\phi) \le 0$ at this point. There is no problem with the definition of viscosity subsolution, which requires that $u - \phi$ achieve a maximum and then $\Lambda(\phi) \ge 0$ at the max point. In [2] we defined u to be

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Viscosity Solutions and Optimal Control Robert James Elliott,1987 *A Concise Introduction to Classical Mechanics* Vakhtang Putkaradze,2025-06-03 Mechanics is one of the oldest and most foundational subjects in undergraduate curricula for mathematicians physicists and engineers Traditionally taught through a classical or analytical approach modern advancements have introduced a geometric perspective that has found applications in diverse fields such as machine learning climate research satellite navigation and more This book bridges the gap between classical mechanics and its modern geometric counterpart Designed for students and educators it presents the essential topics typically required in mechanics courses while integrating a geometric approach to deepen understanding Key features include Clear explanations of core concepts including Lagrangian mechanics variational methods canonical transformations and systems with constraints Numerous solved problems and real world examples to solidify understanding Sample midterms and final exams to help students prepare for coursework and assessments Every chapter includes a looking forward section outlining modern applications of the material The book minimizes mathematical abstraction introducing only the necessary concepts to make the material accessible and practical Whether you re a student looking to master the essentials or an instructor seeking a fresh perspective this book provides a comprehensive approachable and modern exploration of mechanics **Optimal Control and Viscosity Solutions of Hamilton-Jacobi-Bellman Equations** Martino Bardi,Italo Capuzzo-Dolcetta,2009-05-21 The purpose of the present book is to offer an up to date account of the theory of viscosity solutions of first order partial differential equations of Hamilton Jacobi type and its applications to optimal deterministic control and differential games The theory of viscosity solutions initiated in the early 80 s by the papers of M G Crandall and P L Lions CL81 CL83 M G Crandall L C Evans and P L Lions CEL84 and P L Lions influential monograph L82 provides an tremely convenient PDE framework for dealing with the lack of smoothness of the value functions arising in dynamic optimization problems The leading theme of this book is a description of the implementation of the viscosity solutions approach to a number of significant model problems in op real deterministic control and differential games We have tried to emphasize the advantages offered by this approach in establishing the well posedness of the c responding Hamilton Jacobi equations and to point out its role when combined with various techniques from optimal control theory and nonsmooth analysis in the important issue of feedback synthesis Advances in Mathematical Economics Volume 7 Shigeo Kusuoka,Akira Yamazaki,2006-06-22 A lot of economic problems can be formulated as constrained optimizations and equilibration of their solutions Various mathematical theories have been supplying economists with indispensable machineries for these problems arising in economic theory Conversely mathematicians have been stimulated by various mathematical difficulties raised by economic theories The series is designed to bring together those mathematicians who are seriously interested in getting new challenging stimuli from economic theories with those economists who are seeking

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connection with partial differential equations as well as the recent development of the fully nonlinear theory including nonlinear expectation second order backward stochastic differential equations and path dependent partial differential equations Their main applications and numerical algorithms as well as many exercises are included The book focuses on ideas and clarity with most results having been solved from scratch and most theories being motivated from applications It can be considered a starting point for junior researchers in the field and can serve as a textbook for a two semester graduate course in probability theory and stochastic analysis It is also accessible for graduate students majoring in financial engineering *Continuous-time Stochastic Control and Optimization with Financial Applications* Huyên Pham,2009-05-28 Stochastic optimization problems arise in decision making problems under uncertainty and find various applications in economics and finance On the other hand problems in finance have recently led to new developments in the theory of stochastic control This volume provides a systematic treatment of stochastic optimization problems applied to finance by presenting the different existing methods dynamic programming viscosity solutions backward stochastic differential equations and martingale duality methods The theory is discussed in the context of recent developments in this field with complete and detailed proofs and is illustrated by means of concrete examples from the world of finance portfolio allocation option hedging real options optimal investment etc This book is directed towards graduate students and researchers in mathematical finance and will also benefit applied mathematicians interested in financial applications and practitioners wishing toknow more about the use of stochastic optimization methods in finance **Relative Optimization of Continuous-Time and Continuous-State Stochastic Systems** Xi-Ren Cao,2020-05-13 This monograph applies the relative optimization approach to time nonhomogeneous continuous time and continuous state dynamic systems The approach is intuitively clear and does not require deep knowledge of the mathematics of partial differential equations The topics covered have the following distinguishing features long run average with no under selectivity non smooth value functions with no viscosity solutions diffusion processes with degenerate points multi class optimization with state classification and optimization with no dynamic programming The book begins with an introduction to relative optimization including a comparison with the traditional approach of dynamic programming The text then studies the Markov process focusing on infinite horizon optimization problems and moves on to discuss optimal control of diffusion processes with semi smooth value functions and degenerate points and optimization of multi dimensional diffusion processes The book concludes with a brief overview of performance derivative based optimization Among the more important novel considerations presented are the extension of the Hamilton Jacobi Bellman optimality condition from smooth to semi smooth value functions by derivation of explicit optimality conditions at semi smooth points and application of this result to degenerate and reflected processes proof of semi smoothness of the value function at degenerate points attention to the under selectivity issue for the long run average and bias optimality discussion of state classification for time nonhomogeneous continuous processes and multi class

optimization and development of the multi dimensional Tanaka formula for semi smooth functions and application of this formula to stochastic control of multi dimensional systems with degenerate points The book will be of interest to researchers and students in the field of stochastic control and performance optimization alike **Computational Methods for Fluid-Structure Interaction** Jean-Marie Crolet,Roger Ohayon,1994-04-05 Fluid structure interaction is a new theme of investigation in computational methods covering many applications in both engineering and medical sciences This book deals with various examples of interaction between a fluid and a structure and each author presents for the different problems involved the method which is considered to be the most appropriate Hamilton-Jacobi Equations: Approximations, Numerical Analysis and Applications Yves Achdou,Guy Barles,Hitoshi Ishii,Grigory L. Litvinov,2013-05-24 These Lecture Notes contain the material relative to the courses given at the CIME summer school held in Cetraro Italy from August 29 to September 3 2011 The topic was Hamilton Jacobi Equations Approximations Numerical Analysis and Applications The courses dealt mostly with the following subjects first order and second order Hamilton Jacobi Bellman equations properties of viscosity solutions asymptotic behaviors mean field games approximation and numerical methods idempotent analysis The content of the courses ranged from an introduction to viscosity solutions to quite advanced topics at the cutting edge of research in the field We believe that they opened perspectives on new and delicate issues These lecture notes contain four contributions by Yves Achdou Finite Difference Methods for Mean Field Games Guy Barles An Introduction to the Theory of Viscosity Solutions for First order Hamilton Jacobi Equations and Applications Hitoshi Ishii A Short Introduction to Viscosity Solutions and the Large Time Behavior of Solutions of Hamilton Jacobi Equations and Grigory Litvinov Idempotent Tropical Analysis the Hamilton Jacobi and Bellman Equations *Applied Stochastic Analysis* M. H. A. Davis,Robert James Elliott,1991 A collection of 22 articles based on papers presented at a workshop held at Imperial College London April 1989 They concern applications of stochastic analysis the theory of stochastic integration martingales and Markov processes to a variety of applied problems centered around optimization of dynamical systems under uncertainty Topics covered include characterization and approximation for stochastic system models problems in stochastic control theory and various facets of nonlinear filtering theory and system identification Annotation copyrighted by Book News Inc Portland OR **Recent Developments in Nonlinear Partial Differential Equations** Donatella Danielli,2007 This volume contains research and expository articles based on talks presented at the 2nd Symposium on Analysis and PDEs held at Purdue University The Symposium focused on topics related to the theory and applications of nonlinear partial differential equations that are at the forefront of current international research Papers in this volume provide a comprehensive account of many of the recent developments in the field The topics featured in this volume include kinetic formulations of nonlinear PDEs recent unique continuation results and their applications concentrations and constrained Hamilton Jacobi equations nonlinear Schrodinger equations quasiminimal sets for Hausdorff measures Schrodinger flows into Kahler manifolds and parabolic obstacle

problems with applications to finance The clear and concise presentation in many articles makes this volume suitable for both researchers and graduate students **Stochastic Processes, Finance and Control** Robert J. Elliot,2012 This Festschrift is dedicated to Robert J Elliott on the occasion of his 70th birthday It brings together a collection of chapters by distinguished and eminent scholars in the fields of stochastic processes filtering and control as well as their applications to mathematical finance It presents cutting edge developments in these fields and is a valuable source of references for researchers graduate students and market practitioners in mathematical finance and financial engineering Topics include the theory of stochastic processes differential and stochastic games mathematical finance filtering and control *Recent Developments in Well-Posed Variational Problems* Roberto Lucchetti,Julian Revalski,2013-03-09 This volume contains several surveys focused on the ideas of approximate solutions well posedness and stability of problems in scalar and vector optimization game theory and calculus of variations These concepts are of particular interest in many fields of mathematics The idea of stability goes back at least to J Hadamard who introduced it in the setting of differential equations the concept of well posedness for minimum problems is more recent the mid sixties and originates with A N Tykhonov It turns out that there are connections between the two properties in the sense that a well posed problem which at least in principle is easy to solve has a solution set that does not vary too much under perturbation of the data of the problem i e it is stable These themes have been studied in depth for minimum problems and now we have a general picture of the related phenomena in this case But of course the same concepts can be studied in other more complicated situations as e g vector optimization game theory and variational inequalities Let us mention that in several of these new areas there is not even a unique idea of what should be called approximate solution and the latter is at the basis of the definition of well posed problem

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