Review of "Game Theory and Mechanism Design",

authored by Y. Narahari

Game Theory and Mechanism Design is an easily accessible introduction to the theories of games and mechanism design, and their applications to problems at the intersection of mathematics, economics, and computer science. The specific applications discussed in the book include resource allocation, standard auctions, sponsored search auctions in Internet advertising, and the problem of stable matching.

While the theory of games focuses on the modeling of conflict situations and the analysis of outcomes, mechanism design focuses on the 'reverse engineering' of games to achieve desired outcomes. The book's Preface correctly states that there are many excellent text books and monographs on game theory. But most of these are inspired by applications in the social sciences and economics. What sets this book apart is (1) the emphasis on applications from computer science and engineering, and (2) the treatment of mechanism design and game theory on an equal footing.

Game theorists from the beginning have been interested in questions related to the computation of equilibrium strategies. Lemke and Howson Jr. (1964) described an algorithm for finding an equilibrium in a bimatrix game and thus provided a 'constructive proof' of the existence of an equilibrium. Earlier, Brown (1951) suggested 'fictitious play' as an iterative method that agents could employ to 'learn' their equilibrium strategies. The term 'bounded rationality' was coined in the 1950s to describe the idea that an individual's decision is limited by issues of computational tractability. The limitation may arise due to either structural constraints (resulting in cognitive constraints) or due to limited time to perform the computations. However it was only in the late 1990s that computer scientists began a serious study of the question of complexity of computation of equilibrium strategies.

This reviewer is less familiar with the history of mechanism design. The description in the book suggests that mechanism design has passed through a similar history. It is only with the emergence of Internet search engines and

e-commerce, when these enabled fertile application domains for mechanism design, that computer scientists became seriously interested in the design of mechanisms.

The book is an outcome of the confluence of these two fields – game theory and mechanism design on the one hand and computer science on the other. A lot remains to be understood at this intersection, for example computational aspects of combinatorial auctions, dynamic mechanism design, etc., that there is an greater need for the coming together of game theorists, mechanism designers, computer scientists and engineers. This book will provide an accessible 'two-way door' through which computer scientists and engineers from one side and economists, sociologists, and game theorists from the other side can easily pass and learn about the other's domain.

The book is divided into three parts. The initial chapter of Part I, which deals with noncooperative game theory, describes several motivating examples that have counterintuitive outcomes. These are well-chosen to capture a reader's attention and to draw him into probing the book further. Then, in a series of short chapters, the book introduces the key ideas of game theory. The shortness of the chapters is another attractive feature of the book. The many examples in the initial chapters will enable the reader to test the theory's predictions when the analysis begins in chapter five. The general scheme that is followed is that of a soft introduction of the examples followed by a more formal analysis at a later point, after the required definitions and tools have been introduced.

The existence of equilibria is shown using techniques from linear algebra and mathematical analysis. Simon (1945) had already pointed out in his insightful review of the classic *Theory of Games and Economic Behavior* by von Neumann and Morgenstern (1944) that while the techniques of the subject are not difficult, a certain mathematical maturity is required. The author of *Game Theory and Mechanism Design*, through his lucid explanations, has made every effort to make the techniques accessible. The last chapter of the book summarises the necessary mathematical preliminaries.

It is the clear exposition of mechanism design that will make this book an outstanding and useful reference. The topic of design is always a more difficult subject to write about. 'Analysis' is often simpler to handle because it usually deals with a 'given' system. 'Design' is more difficult to handle because of the multitude of possibilities that can achieve the same end goal. The two introductory mechanisms in the first chapter of Part II already highlight this point. One is a mechanism designed by a wise mother to ensure

fair division of a cake so that both of her two children are satisfied with the outcome. The other is a mechanism designed by a wise king that elicits truth in a conflict situation where two mothers claim a child as their own. These examples have clearly been chosen with the aim of drawing the reader deeper into the book. But they also suggest that any good exposition of a theory of design must explore the design space and justify a good choice. An additional complication is the often unknown boundary between the possible and the impossible.

The book expertly guides the reader through the maze of impossibility theorems, suggests alternative means to get around them, to arrive eventually at some positive results. These are some spectacular mechanisms that include Vickrey's second price auction and Myerson's revenue maximising mechanism. The book's masterful treatment of this subject makes it a 'must read' for every computer scientist or engineer aspiring to apply the theory of mechanism design to his problem.

Part III is on the theory of cooperative games. A notable chapter here is the application to matching markets and college admissions.

Given the advertisement that the book is at the intersection of game theory and computer science, this reviewer hoped to see a more detailed proof of the complexity of computing an equilibrium. The corresponding chapter stops at the level of a discussion. Similar is the case for the famous impossibility theorem in social choice due to Arrow and the result that the deferred acceptance algorithm for college admissions leads to a stable outcome. However, the book provides a wealth of references where an interested reader can probe further.

The historical details on some influential researchers of game theory and mechanism design will be a source of inspiration to the readers.

This reviewer hopes that the book will play the role of a catalyst in bringing game theorists, mechanism designers, computer scientists, and engineers closer to each other. The author is overly modest in stating that the primary objective of the book is to present the essentials of game theory and mechanism design to an engineering audience. Economists, sociologists, and others interested in the theory of games will equally well benefit from an understanding of the computational questions and related applications described in *Game Theory and Mechanism Design*.

Rajesh Sundaresan
Indian Institute of Science