Epistemic Game Theory: An Overview*

Adam Brandenburger†

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The following three articles survey some aspects of the foundations of non-cooperative game theory. The goal of work in foundations is to examine in detail the basic ingredients of game analysis.

The starting point for most of game theory is a "solution concept"–such as Nash equilibrium or one of its many variants, backward induction, or iterated dominance of various kinds. These are usually thought of as the embodiment of "rational behavior" in some way and used to analyze game situations.

One could say that the starting point for most game theory is more of an endpoint of work in foundations. Here, the primitives are more basic. The very idea of rational–or irrational–behavior needs to be formalized. So does what each player might know or believe about the game–including about the rationality or irrationality of other players. Foundational work shows that even what each player knows or believes about what other players know or believe, and so on, can matter.

Investigating the basis of existing solution concepts is one part of work in foundations. Other work in foundations has uncovered new solution concepts with useful properties. Still other work considers changes even to the basic model of decision making by players–such as departures from the expected utility model or reasoning in various formal logics.

The first article, EPISTEMIC GAME THEORY: BELIEFS AND TYPES, by Marciano Siniscalchi, describes the formalism used in most work on foundations. This is the "types" formalism going back to Harsanyi [2, 1967-68]. Originally proposed to describe the players' beliefs about the structure of the game (such as the payoff functions), the types approach is equally suited to describing beliefs about the play of the game or beliefs about both what the game is and how it will be played. Indeed, in its most general form, the formalism is simply a way to describe any multi-person uncertainty. Harsanyi's conception of a "type" was a crucial breakthrough in game theory. Still, his work left many fundamental questions about multi-person uncertainty unanswered. Siniscalchi's article

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†Address: Stern School of Business, New York University, New York, NY 10012, adam.brandenburger@stern.nyu.edu, www.stern.nyu.edu/∼abranden

surveys these later developments.

The second and third articles apply these tools to the two kinds of uncertainty mentioned. The second article, EPISTEMIC GAME THEORY: COMPLETE INFORMATION, concerns the case where the matrix or tree itself is 'transparent' to the players, and what is uncertain are the actual strategies chosen by the players. The third article, EPISTEMIC GAME THEORY: INCOMPLETE INFORMATION, by Aviad Heifetz, has the opposite focus: it covers the case of uncertainty about the game itself. (Following Harsanyi, the third article focuses on uncertainty about the payoffs, in particular.)

Both cases are important to the foundations program. Because Nash equilibrium is 'as if' each player is certain (and correct) about the strategies chosen by the other players (Aumann and Brandenburger [1, 1995, Section 7h]), uncertainty of the first kind has played a small role in game theory to date. Uncertainty of the second kind is the topic of the large literatures on information asymmetries, incentives, etc.

Interestingly, though, von Neumann and Morgenstern [3, 1944] already appreciated the significance of both complete and incomplete information environments. Indeed, they asserted that phenomena often thought to be characteristic of incomplete-information settings could, in fact, arise in complete-information settings [3, 1944, p.31]:

> Actually, we think that our investigations–although they assume "complete information" without any further discussion–do make a contribution to the study of this subject. It will be seen that many economic and social phenomena which are usually ascribed to the individual's state of "incomplete information" make their appearance in our theory and can be satisfactorily interpreted with its help.

This is indeed true, as work in the modern foundations program shows. (Some instances are mentioned in what follows.) Overall, the foundations program aims at a 'neutral' and comprehensive treatment of all ingredients of a game.

References

[1] Aumann, R., and A. Brandenburger, "Epistemic Conditions for Nash Equilibrium," *Econometrica*, 63, 1995, 1161-1180.

[2] Harsanyi, J., "Games with Incomplete Information Played by 'Bayesian' Players, I-III," *Management Science*, 14, 1967-68, 159-182, 320-334, 486-502.

[3] Von Neumann, J., and O. Morgenstern, *Theory of Games and Economic Behavior*, Princeton University Press, 1944 (Sixtieth Anniversary Edition, 2004).