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Preface to the Special Issue "Logic and Games": Feeling the Rhythms of a Field

Logic, games, and computation Logic and games have a natural interface, and one that works even in two directions. Logic can be, and in fact, it is used fruitfully to analyze major structures in agency — and games are of course the mathematical model par excellence for strategic social agency. Call this direction, in current terminology, "logic *of* games". But logic is also an ability that typically manifests itself in multi-agent skills such as argumentation or communication, ever since the birth of the field, and such skills have game-theoretic structure, as can be seen in many standard methods of the field today. Call this converse direction, again in current terminology, "logic *as* games". The use of bringing these themes together shows today in newly merging interface areas such as 'epistemic game theory', that provide fresh research impetus both ways.

But really, the meeting place of disciplines is still broader than might seem from this brief description. Social interactive reasoning also has a constructive face, just like constructive methods naturally complement proving theorems: it is about procedures for getting things done. The "that" and the "how" have always lived together, from Euclid's *Elements* until today — and often the constructive face of logic, concerned with the "how", shows itself in the form of algorithms, and other notions from computer science. Thus, we are really talking about a triangle of logic, games, and *computation*, or if you wish, Logic, Game Theory, and Computer Science.

It is a good idea of the publishers of "Studies in Logic" to devote a special issue to this area, and see some of what's cooking. There is nothing like a standard description available here (but see [4] for at least one broad look at what is going on), so it's best to take the pulse of the field by looking at what a young generation is doing, at conferences and in journals. In fact, boundary setting may not be appropriate yet in this phase of expansion, since new themes keep coming up. E.g., it may soon be necessary to expand the above triangle of fields with one more that fits very naturally, viz. Cognitive Science, since exquisite skills in social interaction and organization seem to be about the most characteristic feature of what makes humans human.

A very brief map of the area Before I get to my main task, introducing the contents of the papers in this special issue, it may be helpful to give the reader a slightly more concrete picture of current research directions at the interface of logic, games, and

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computation. What is there to be investigated specifically in the above arena? Of course, with what follows, I make no claim whatsoever as to completeness — though I may well succeed with achieving exhaustiveness.

I already mentioned *epistemic game theory*, where game theorists investigate, among other things, basic assumptions on belief, knowledge, preference, and rationality that lead to strategic equilibria in games of various sorts. (There is much more to this field than my short thumb-nail description: cf. [7, 19, 20]). Epistemic game theory has been moving to a richer notion of a game as not just a set of possible moves and histories ordered by preference, but of a game as played by agents that can be of different major types: competitive or cooperative, optimistic or pessimistic, resource-bound or idealized, and so on. When logic is mixed into this perspective, the result has been described as theory, not of games, but of *play*, viewed as a process that can have, in principle, many stages of interest: deliberation and strategy formation, actual play and belief revision, and post-game rationalization or 'spin'.

But all of these themes can also occur on their own, with computer scientists joining in. For instance, [10] is a whole collection of essays on current research into one core notion, that of a *strategy*, from different angles, from logic and game theory to computer science and cognitive science. Other computational themes enter when we think of players operating under resource constraints. This happens, for instance, in the 'short-sight games' of [12, 17], where players only see part of a whole game tree, a scenario that is much closer to cognitive reality, but that also raises quite delicate computational and logical issues in its modeling. Another logical and computational theme that is coming to the fore concerns the difference between finite games that stand for terminating social scenarios, and *infinite games* representing some ever-ongoing process. This long-term shift takes us to temporal logics of long-term agency, limit-learning theory, evolutionary game theory, and eventually, interfaces between logic and the mathematical theory of dynamical systems ([2, 22]), that are attracting increasing attention these days. Often, the best strategies in infinite games can be played by simple *automata*, and there is a fast-growing mathematical theory in this line ([11, 23]) where the preceding themes meet with automata theory in modern sophisticated forms. One more reason why the latter interface makes sense is that games may well be our best model for modern *interactive computation*, rather than the Turing machines of the past, and in that case, games even provide the very meaning of, say, programming languages ([1]).

Striking out in yet another direction, social reality involves much more than individual agents, and one conspicuous direction (known from social choice theory and coalitional game theory) is the study of group actors. *Networks of social actors* are becoming a big theme at the interface of logic, computer science, and the social sciences, since here is where many of the information waves of public opinion in today's society take place, for better or for worse ([14, 18]). Game models in this area linking logic and computation include 'Boolean games' ([13]), social network games ([8,

21]), and various technology-driven social scenarios (cf. [9] on modeling changing social relations in mobile phone-based communication, using techniques for protocol analysis from computer science). These games naturally feed into the broader area of social decision making intertwining action, information, and belief with themes from ethics, such as the functioning of deontic norms. In this way, even traditional themes from philosophy enter the playing field.

Finally, perhaps the most striking social phenomenon of all is our *natural language* that enables communication and agency. Games form an important ingredient in the modern study of natural language: cf. the survey [3] for several ways in which this happens; and for a highly stimulating perspective on the role of language in arbitrary games, see [5]. Thus, we set the boundaries of the above area even wider, to include linguistics and cognitive science. For instance, [16] discuss games that test for actual performance measured against logic-based game theory, and on another track, [6] design a 'tacit communication game' as a way of probing experimentally how efficient languages arise spontaneously in social tasks.

I could go on, and add challenges that move from merely interpreting the world to changing it, tying all the above themes to activities that *improve* the quality of our social procedures, be it via game-based argumentation theory, or connecting up with the world of 'gaming' that seems to be taking over from traditional education these days. But by now, the reader can also work out such potential activist implications for herself. It is high time to see what this volume contains.

What is in this issue *Huimin Dong and Olivier Roy* analyze games as sources of permissions to act for participating agents, and emphasize how these permissions have a universal character: any play according to the relevant solution concept is acceptable. In this perspective, systems of deontic logic may be viewed as high-level descriptions and reasoning styles for 'best action' of agents based on some underlying lower-level social mechanism. However, the relevant notion of permission is unlike the usual one in deontic logic, not being a dual of obligation, and the authors show how its logic can be axiomatized in a number of related ways, some of them going back to earlier work on free choice permission in deontic logic and its 'inversion' of standard modalities. *Davide Grossi and Paolo Turrini* revisit the 'short-sight games' that they introduced in earlier influential work, where players only have a limited view of the total extensive game that they find themselves in, a common situation for agents with bounded resources. Intuitively, short sight correlates with imperfect knowledge of a game, and the authors make this intuition explicit by showing how to enrich extensive games with epistemic indistinguishability relations as well as plausibility orders. The resulting models connect up nicely with an earlier dynamic-epistemic analysis of the game solution method of backward induction in terms of announcing rationality by Baltag, Smets & Zvesper. As a result, suitably modified earlier dynamic characterizations of backward induction can be transferred to short-sight games. *Kai*

Li and Yanjing Wang consider extensive games of imperfect information from another angle, showing how the usual game-theoretic picture of such games may harbor intuitive confusions, which make common 'intuitive readings' of game trees with information sets occasionally suspect. They clarify all this by means of a formal model of games that, amongst other things, makes a sharp distinction between 'game rules' and 'player assumptions'. They then show how to deal with the dynamics of game play between agents of various types, using ideas from dynamic-epistemic update as well as epistemic temporal logic, encoded in a new complete logic. This approach provides a bridge between modal-style logics of games and the tradition of 'game description languages' designed to encode generic results about whole classes of game rules. *Eric Pacuit* revisits Aumann's fundamental theorem in epistemic game theory which says that players with the same prior and with common knowledge of their posteriors must have the same posterior. In the subsequent literature, this has been analyzed as a scenario for iterated acts of information update: when updating in the same way, even with different information, agents cannot 'agree to disagree': their posteriors will be the same. He then discusses recent probabilistic refinements of Aumann's result due to Monderer & Samet, and through a series of interesting examples, finds limits to their style of analysis. Finally, he shows how all this provides an arena for dynamic-epistemic logics that incorporate probabilistic update, which can deal with a wide variety of informational scenarios that lead to long-term behavior. *Rohit Parikh* revisits the fundamental topic of connections between knowledge, belief and action that lie at the heart of decision theory and game theory. Using a judicious mix of striking concrete examples and technical results, he shows how we can infer beliefs about facts, or even about other agents from given behavior, by rationalizing that behavior in terms of dominant strategies (full-fledged game-theoretic solution algorithms are often not needed). Parikh also considers the other side of the coin, namely how beliefs influence actions, and offers some original perspectives, including how knowledge and belief also influence and power. While the paper is light and playful, it raises a number of interesting technical conjectures along the way about epistemic models, bisimulation, and games that can be played using these models. *Yunqi Xue and Rohit Parikh* consider the flow of opinion through networks of agents, the source of many (sometimes not so benign) phenomena in our modern information society, and in particular, the analyze the role of experts in this process. Building on ideas from Girard, Liu & Seligman, but using different rules geared toward scenarios with a leading role for experts, they show how beliefs form and are modified over time in social networks, and they investigate when coordination equilibria form in such distributed systems, depending on network topology as well as the dynamic update rules. This style of analysis also contains some interesting refinements of current dynamic logics of social networks, going back to Parikh's earlier work on 'language splitting' in belief revision, since experts may have their own areas of expertise represented by different sublanguages of the total network language.

Conclusion This issue of "Studies in Logic" offers a rich set of themes, including cutting-edge work from both China and abroad. Of course, any single journal issue is just a sample, and one could easily fill follow-up issues with other work in this area. A good example are the many varied game-related contributions found in the Proceedings of LORI-V, the Fifth International Conference on Logic, Rationality and Interaction held at Taipei in October 2015 ([15]), a major venue for work like this. One can also find further work on logic and games when just scanning the map of East Asia, from universities in Chongqing to Guangzhou, and up north to Nanjing, Tianjin, Beijing, and on to Japan. But however this may be, the reader will have seen by now that the label 'logic and games' is really like a Chinese-style calligraphic panel above a door through which one can step into an exciting and fast-moving world today. And we can only thank the editors of this journal for holding open that door.

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