PhD on Correlated Equilibria and Learning

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Topic

Game theory is a branch of mathematics formalizing and analyzing decision-taking with interactions (chess, Go, economics, auctions, networks, biology, etc.). The main focus is on showing the existence of stable strategy or utility profiles, computing these and analyzing the convergence of learning rules.

There is no unique definition of stability and many solution concepts have been defined. In the non-cooperative direction, the dominant one is called Nash equilibrium. From a decision-theoretic perspective, this concept is intrinsically relevant but its success is essentially due to the systematic existence of Nash equilibria in finite games [7][6] and more generally in a large classe of games. However, it is known [8] that computing Nash equilibria may be hard (despite of the latter existence property) because of some underlying combinatorial problems.

A more general solution concept, called correlated equilibria, was proposed in [1]. Correlated equilibria generalize Nash equilibria by allowing for a collective behavior taking the form of a joint probability distribution (not of product form) over the players' pure strategies. This correlation can be interpreted as resulting from preplay communications or recommendations by a correlation device, also called mediator. Despite of this generalization, correlated equilibria are guaranteed to exist as a superset of Nash equilibria. Furthermore, computing them is of lower complexity [8] because the problem consists in solving a set of linear equations & inequalities [4].

From a learning (including machine learning) perspective, correlated equilibria have also been promising and (rather weak) conditions on games & regret-based learning rules (defining for each agent how to update her behavior) inducing convergence of the strategy profiles to the set of correlated equilibria have been shown [3]. It was shown in [5] that any finite game can be reduced to a dual reduction or an elementary game, with fewer strategies but inheriting some equilibria from the original game.

The latter computational and convergence properties have important algorithmic consequences, but not only, since these are some of the main arguments invoked to justify for correlated equilibria as a relevant alternative to Nash equilibria.

In terms of applications, correlated equilibria, their properties and related reduction techniques appear particularly relevant when adressing complex systems and games where Nash equilibria are hard to compute or where collective behavior (as preplay communications or synchronization) has a prominent role. This is typically the case in networks, economics and biology.

However, despite of the appealing properties of correlated equilibria, a recurrent game-theoretic difficulty holds in the analysis or play: the multiplicity of equilibria and their selection [4]. In this thesis, we aim at opening new research directions and proposing new relevant solutions to this problem.

PhD scientific objectives

Despite of the appealing properties of correlated equilibria (see Section 1), game-theoretic difficulty holds [4]. In fact, for a given game, many (Nash, thus) correlated equilibria may exist and identifying the relevant ones is a challenging problem only partially solved by reduction methods or candidate refinements.
This problem also holds in learning in games [2]. In fact, even if the players' learning rules imply convergence to a subset of correlated equilibria, there is no clear understanding of why and how the players' select this particular subset among others and how they could select another subset satisfying alternative properties.

In this thesis, we propose to adress this challenge by,

- studying correlated equilibria, their properties, their role in learning in games and games reduction or projection techniques,
- studying the correlated equilibria selection problem and its connections to cooperative games,
- designing and analyzing relevant properties, algorithms and learning rules solving solving the problems.

Methodology and planning

- Preliminary studies and state-of-the-art,
- Identification or design of toy examples exhibiting the difficulties and challenges to be addressed,
- Identification of hypothesis on the origin of these difficulties and candidate solutions,
- Validation and updates of the hypothesis and candidate solutions on toy examples,
- Scientific papers,
- Generalization, refinements & numerical experiments, etc.
- Manuscript

Scientific references

[1] R. Aumann. Subjectivity and correlation in randomized strategies. Journal of Mathematical Economics, 1974.
[2] H. P. Borowski, Jason R. Marden, and J. S. Shamma. Learning efficient correlated equilibria. CoRR, abs/1512.02160, 2015.
[3] Nicolo Cesa-Bianchi and Gabor Lugosi. Prediction, Learning, and Games. Cambridge University Press, USA, 2006.
[4] R. B. Myerson, Game Theory: Analysis of Conict. Harvard University Press, 1991.
[5] R. B. Myerson, Dual reduction and elementary games. Games and Economic Behavior, 1997.
[6] J. Nash, Non-cooperative games. Annals of Mathematics, 1951.
[7] J. F. Nash. Equilibrium points in n-person games. Proceedings of the National Academy of Sciences, 1950.
[8] N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani. Algorithmic Game Theory. Cambridge University Press, USA, 2007.

Profile

Education

- **Top-ranked MSc or engineering degree** in mathematics, applied maths (optimization, game theory, machine learning, etc.), computer science or math-eco
- Past experiences (as internships) in game theory and learning are valuable

Scientific & technical skills

- Mathematics (game theory is valuable but not mandatory)
- Algorithms & machine learning
- Programming : python

Soft skills

- rigor
- patience
- logic
- sociability
- flexibility
- autonomy

Orange

Team

At Orange Labs, you will take part in a research team including researchers in mathematics and computer science, engineers, experts in machine learning and data scientists.
The mission of the team is to enlighten the future by designing and analyzing mathematical models and algorithms solving theoretical or applied problems (typically in networks science and economics).
Many research works and innovations are conducted by permanent researchers, PhDs or post-docs with academic partners in the framework of collaborations or projects.

What's interesting in this PhD?

This PhD gives you the opportunity to take part in a research team of a large company and to study a very interesting problem at the interface of mathematics, computer science and technologies.