CoCoRICo-CoDec : rapport d'étape

19 octobre 2016

This report describes the progress of the project

Computation, Communication, Rationality and Incentives in Collective and Cooperative Decision Making

from its start to end of July 2016. The report is structured along the work packages described in the project proposal.

1 WP1: Computation, approximation, verification

- Coordinator: Olivier Spanjaard (LIP6).

This work package focuses on the computational difficulties of the various multiagent optimization problems considered in the project. The specificity of the problems studied in the project is that each agent has her own individual preferences and one aims at producing a feasible solution that complies with these preferences. The problems investigated by the participants of the WP in the first 18 months of the project fall within two main categories:

- finding a collective solution (jointly used by a group of agents) to a problem where the set of possible solutions has a combinatorial structure. Examples of such problems studied in the project include picking a set of movies to put on a plane's entertainment system [Skowron *et al.*, 2015], selecting a subset of projects to fund under a budget constraint [Benabbou and Perny, 2016], implementing multiple referenda and committee elections [Amanatidis *et al.*, 2015; Aziz *et al.*, 2016c], compounding a balanced recruiting committee [Lang and Skowron, 2016], or determining a common itinerary for a group of agents [Fanelli and Greco, 2016; Galand and Lust, 2015a,b].
- determining a fair allocation of indivisible goods to agents. Examples of such problems studied in the project include the reallocation of resources to achieve mutually better outcomes [Aziz *et al.*, 2016a], the *Santa Claus* problem where one looks for a max-min allocation of objects among agents [Baumeister *et al.*, 2016], the assignment of papers to reviewers according to the bids made by the reviewers in a conference management system [Oudghiri *et al.*, 2016], object allocation problems under constraints [Gourvès *et al.*, 2016b; Greco and Lang, 2015], or designing the scientific program of a conference with multiple parallel sessions [Caragiannis *et al.*, 2016].

The issues tackled in the undertaken research works include the followings:

- designing algorithms able to handle ordered aggregation operators or Lorenz dominance relations in order to compute fair solutions to multiagent optimization problems [Amanatidis *et al.*, 2015; Oudghiri *et al.*, 2016; Galand and Lust, 2015b,a];
- studying the complexity of computing and verifying Pareto optimal committees (given a rule to lift each individual preference relation over candidates to a preference relation over committees) [Aziz *et al.*, 2016c,a];
- designing solution procedures based on a partial knowledge of the preferences of the agents and that are able to determine possibly or necessary optimal solutions to multiagent optimization problems [Aziz *et al.*, 2016a; Benabbou and Perny, 2016];
- defining formal models expressive enough to capture various group decision problems where the set of possible solutions has a combinatorial structure [Gourvès *et al.*, 2016b; Greco and Lang, 2015; Skowron *et al.*, 2015].
- giving a synthetic study of complexity results for extensions of median orders to different types of remoteness [Hudry, 2015].

For all these issues, the different tasks put forward in the proposal have been tackled: analysis of the computational complexity and identification of tractable instances (Task 1.2), design of polynomial approximation algorithms and study of approximability (Task 1.4), practical computation of solutions and experiments (Task 1.6). Table 2 synthesizes the tasks achieved in each article.

	complexity	tractable instances	approximation	practical computation
collective solution	[Amanatidis *et al.*, 2015] [Aziz *et al.*, 2016c] [Fanelli and Greco, 2016] [Lang and Skowron, 2016] [Skowron *et al.*, 2015] [Caragiannis *et al.*, 2016] [Hudry, 2015]	[Amanatidis *et al.*, 2015] [Aziz *et al.*, 2016c] [Fanelli and Greco, 2016] [Lang and Skowron, 2016] [Skowron *et al.*, 2015] [Caragiannis *et al.*, 2016]	[Amanatidis *et al.*, 2015] [Lang and Skowron, 2016] [Skowron *et al.*, 2015] [Caragiannis *et al.*, 2016]	[Benabbou and Perny, 2016] [Galand and Lust, 2015b] [Galand and Lust, 2015a]
fair allocation	[Aziz *et al.*, 2016a] [Baumeister *et al.*, 2016] [Oudghiri *et al.*, 2016] [Gourvès *et al.*, 2016b] [Greco and Lang, 2015]	[Aziz *et al.*, 2016a] [Baumeister *et al.*, 2016] [Oudghiri *et al.*, 2016] [Gourvès *et al.*, 2016b] [Greco and Lang, 2015]	[Baumeister *et al.*, 2016]	[Baumeister *et al.*, 2016] [Oudghiri *et al.*, 2016]

Table 1: Classification of the publications according to the tasks of WP1.

2 WP2: Communication

This work package is dedicated to the study of the communication cost of the various mechanisms considered in this project (voting, resource allocation, coalition structure formation). We are interested in the following questions: what amount of information needs to be exchanged so as to find the winner(s), to determine an optimal allocation of resources, to find a stable coalition structure?

2.1 Incomplete preferences; ordinality vs. cardinality

Interesting collective decision mechanisms often require agents to specify a lot of information. To start with, voting rules require agents to rank all alternatives, which is often unpractical from a cognitive point of view, as soon as the number of alternatives is more than a small number (such as 4 or 5); a good trade-off is then to consider *incomplete rankings* on which variants or approximations of voting rules are applied. Even more problematic is the assumption, often required in fair division or coalition structure formation, that agents should rank all subsets of objects or all subsets of agents. In such a case, a good trade-off is to rank only singletons, and apply a preference extension principle to derive a preference over subsets. One of our goals is to evaluate the quality of the trade-off between the amount of information required and the quality of t solution obtained in these various settings. The following works advance the state of the art towards this direction.

Viappiani (2016) studies the connection between scoring rules and distance measures between rankings. In particular, it has been previously known that Borda count is equivalent to finding the ranking that minimize the sum of Spearman distances (defined as the sum of the squares of the displacement of each candidate) with the rankings given in input. In this paper this result is extended in a number of ways: considering positional scoring rules (that are associated with a newly defined positional Spearman distances), considering partial ranking and considering a "biased" form of Borda that gives an advantage to specific candidates.

Voting [Viappiani, 2015] studies the connection between scoring rules and distance measures between rankings and applied this characterization to the clustering of complete or incomplete rankings. The paper extends, in a number of ways including the consideration of partial rankings, the previously known result that the Borda count is equivalent to finding the ranking that minimizes the sum of Spearman distances with the rankings given in input. [Aziz *et al.*, 2015] redefine tournament solutions from incomplete tournaments. In a multiwinner election context, [Aziz *et al.*, 2016c] rank single candidates and apply several preference extensions for inducing an ordering over feasible subsets; for each of these extensions they study the problem of finding a Pareto-optimal committee or that of checking whether a committee is Pareto-efficient.

Fair division A common assumption in fair division consists in assuming that agents have additive preferences and specify a numerical value for each good. However, there are contexts where it is unpractical or undesirable to ask agents to give numerical values. A solution, that consists in asking them to *rank* the objects and then induce values from ranks, has been proposed and studied in [Baumeister *et al.*, 2016].

Cooperative games Classical notions for evaluating the importance of an agent in a cooperative game, such as the Shapley or the Banzhaf value, require the knowledge of a numerical value representing the gain that each coalition can achieve. As knowing these values is often not possible, Moretti and Öztürk [2016] consider *ordinal* power indices, for which they give a axiomatic study.

2.2 Incremental elicitation

While computing a solution from a partial description of agents' preferences can often be seen as a good trade-off between solution quality and communication costs, sometimes it can be improved by an interactive elicitation protocol, where agents first specify a small amount of information, and then receive more queries until a satisfactory solution is found. The following works study such incremental elicitation protocols for various collective decision making problems:

Voting on combinatorial domains With a focus on group knapsack problems, where agents must agree on a set of objects to be collectively chosen, [Benabbou and Perny, 2016] propose an incremental approval voting protocol that interleaves preference elicitation and search, using 'approval queries' (asking an agent whether her utility for a set of items exceeds her approval threshold or not), in order to determine the best feasible set of items, without requiring full elicitation of the agents' preferences. [Benabbou *et al.*, 2016] propose an interactive protocol for determining the Borda winner in a voting context where the alternatives are described with respect to multiple attributes and the individual preferences are initially unknown. More precisely, assuming that individual preferences are representable by linear multi-attribute utility functions, they propose an incremental elicitation method aiming to determine the Borda winner while minimizing the communication effort with the agents.

Opinion aggregation and information diffusion [Grabisch and Rusinowska, 2016a,b] consider a model of opinion formation based on aggregation functions, where each player modifies his opinion by arbitrarily aggregating the currrent opinion of all players. A player 1 is influential for another player 2 if the opinion of 1 matters for 2; they generalize influence from individual players to coalitions whose opinion matters for a player. For the qualitative analysis of convergence, knowing the aggregation functions of the players is not required, but one only needs to know the influential coalitions for every player; [Grabisch and Rusinowska, 2016a] propose interactive elicitation protocols that permit to fully determine the influential coalitions.

2.3 Distributed mechanisms

While elicitation assumes that communication can take place between the agents and a central authority, in some other cases it can take place between the agents themselves, who interact in a decentralized way. The following works aim at designing distributed protocols for various collective decision making problems., which all take place in the context of resource allocation.

[Damamme *et al.*, 2015] consider the simple resource allocation setting consisting in assigning exactly one resource per agent. They identify a natural domain where convergence to a Pareto-optimal allocation can be guaranteed, and show that the worst-case loss of welfare is as good as it can be under the assumption of individual rationality, and they provide a number of experimental results, showing that such dynamics often provide good outcomes.

[Chevaleyre *et al.*, 2016] study fully distributed mechanisms for resource allocation in which agents can locally agree on deals to exchange some of the goods in their possession. They study convergence properties for such distributed mechanisms when used as fair division procedures. They also introduce an extension of the basic framework where agents are vertices of a graph representing a social network that constrains which agents can interact with which other agents.

In fair division of indivisible goods, a natural, fully distributed protocol to allocate the objects is using sequences of choices (or picking sequences), where at each stage, a designated agent picks one object among those that remain. Bouveret and Lemaître [2016] revisit the problem by showing that any Pareto-optimal allocation (under additive preferences) is sequenceable, but that the converse is not true anymore. This asymmetry leads naturally to the definition of a three-step "scale of efficiency": Pareto-optimality, sequenceability without Pareto-optimality, and non-sequenceability.

	incomplete preferences	interactive elicitation	distributed mechanisms	succinct languages
voting	Viappiani [2015] Aziz *et al.* [2016c] Aziz *et al.* [2015]	Benabbou *et al.* [2016] Benabbou and Perny [2016]		Barrot and Lang [2016]
fair allocation	Baumeister *et al.* [2016]		Bouveret and Lemaître [2016] Chevaleyre *et al.* [2016] Damamme *et al.* [2015]	
coalition formation	Moretti and Öztürk [2016]			Lang *et al.* [2015] Aziz *et al.* [2016b]
opinion aggregation		Grabisch and Rusinowska [2016a]		Endriss *et al.* [2016]

Table 2: Classification of the publications according to the tasks of WP2.

2.4 Domain restrictions and preference representation languages

Another way of helping agents to express their preferences is by provide them with a language for succinct preference representation. These languages generally come with a restriction on the preference relations they are able to express (and with an increase of computational complexity).

Voting on combinatorial domains Barrot and Lang [2016] define a family of rules for approval-based voting on combinatorial domains, where voters cast *conditional approval ballots*, allowing them to approve values of a variable conditionally on the values of other variables.

Coalition structure formation [Lang *et al.*, 2015] propose a new representation setting for hedonic games, where each agent partitions the set of other agents into friends, enemies, and neutral agents, with friends and enemies being ranked. [Aziz *et al.*, 2016b] study hedonic games with dichotomous preferences, where each player?s preference relation partitions the set of coalitions of which that player is a member into just two equivalence classes: satisfactory and unsatisfactory. They develop a succinct , logical representation for such games.

Judgment aggregation [Endriss *et al.*, 2016] review several different languages for collective decision making problems, in which agents express their judgments over elements of a logically structured domain, and compare these languages according to their relative succinctness.

3 WP3: Strategic Models of Collective Behaviour

This work package focuses on the feasibility and the quality of the collective decision mechanisms taking into account strategic considerations. It is first concerned with predictive devices in voting contexts, on equilibrium refinements and on ressource allocation.

The next lines summarize the main achievements obtained over the last 20 months.

3.1 Voting

The working paper [Erdamar *et al.*, 2016] studies a new concept of strategy-proofness in a framework where voters not only rank candidates but also evaluate them as acceptable or unacceptable. On the other hand, in [Nuñez and Sanver, 2016] the electoral turnout and its relation with the classsical notion of monotonicity is explored. [Bervoets *et al.*, 2015] and [Bervoets and Merlin, 2016] are concerned with vote trading among districts: in [Bervoets *et al.*, 2015] it is shown that this pervasive phenomenon is polynomial with three parties but that it is NP-complete with a larger number of parties, while [Bervoets and Merlin, 2016] adopts an axiomatic approach and establishes the relationship between vote swapping and a restricted form of gerrymandering, which is another way of manipulating elections in representative democracies.

[Kamwa and Merlin, 2015] focuses on the stability of collective rankings of scoring rule when some alternatives are dropped from the set of alternatives. More precisely, given a collective ranking over a set of four candidates, they determine under the impartial culture condition, the probability of each of the six possible rankings to occur when one candidate is dropped.

[Laslier and Nuñez, 2016] presents a review of the literature of the different models in which pivotal voting plays a distinct role, while [Núñez, 2015] proposes a new voting rule that satisfies a weakening of strategy-proofness, called type-revelation. [Laslier *et al.*, 2015] studies the same sort of mechanism with just two voters and prove that, under mild assumptions, it leads to an efficient and individually rational outcome. A new variant of the same voting rule for any number of voters endowed with single-peaked preferences appears in [Nuñez and Xefteris, 2016], together with a study of its efficiency without monetary payoffs.

[Durand *et al.*, 2016] shows that the "Condorcification" of a voting rule, where the original rule is altered to elect the Condorcet winner when one exists, is at most as coalitionally manipulable as the original rule, and that for most of them, the improvement is strict. These results are extended to a broader framework that includes weak orders and cardinal voting rules.

[Gourvès *et al.*, 2016a] analyzes some voting situations under the framework of strategic games: the focus is on the existence of a recent solution concept named "considerate equilibrium", and the possible convergence of the game to such an equilibrium.

3.2 Other Works in Game Theory and Mechanism Design

We mention here two papers concerning game theory and mechanism design.

[Gourvès, 2015] introduces a solution concept, called profitable deviation strong equilibrium, which is between two well-known equilibria: strong equilibrium and super strong equilibrium. This concept can potentially be applied to several classes of collective decision making problems such as voting and fair division.

[Angel *et al.*, 2016] studies the existence of truthful optimal or approximate algorithms for the problem of scheduling a set of tasks each one owned by a different agent in order to minimize the weighted completion time of the tasks. Both the cases with payments and the case without payments are considered.

4 WP4: Development of a Collective Decision Making Platform, and Promotion of its Uses.

- coordinators: Sylvain Bouveret Vincent Merlin

As defined in the initial proposal, this work package 4 has two main objectives. The first objective is the development of a platform dedicated to social choice (Task 1), and the second one aims at using this platform to perform laboratory experiments and to promote collective decision making with real-life demonstrations and experiments (Task 2). Even if we have slightly deviated from the initial schedule, some progress has been made on both directions.

4.1 Task 1: Developing and Testing the Software Platform

During the first year of the project, the set of partners involved in the project have discussed about the intended scope of the software platform, both in terms of social choice problems and use cases (e.g. real-life low-stake social choice, real election settings, lab experiments...). It has been decided that even if the platform should be thought to be easily adapted to new problems, we should focus first on voting situations (possibly embracing a large set of problems including multiple referendums, multi-winner elections and so on). A first sketch of the data model of the new version of the platform (Whale 4) has been developed.

Real advances have been made on the development side when we have hired an intern to specifically work on this platform. Marie-Jeanne Natete started her internship at the beginning of May and finished at the end of September. During this period of time, she has been able to develop a fully working web platform (Whale 4), that implements all the features of Whale 3, which is easily adaptable, maintainable, meant to be simpler to the users and responsive (adaptable to various kinds of devices like smartphones and tablets). Moreover, this application has been extended to provide data sets of the elections in various formats, including CSV, JSON, and PrefLib, like was defined in the initial proposal. New data visualization techniques has also been implemented.

The platform is now accessible (`http://strokes.imag.fr/whale4`) but still under development and testing. The aim is to have a fully working and tested version of the platform before the Science Fair (*Fête de la Science*), on October, the 13$^{\text{rd}}$ (see next section on dissemination).

Information visualization techniques can help a lot the democratization of social choice, by providing people with some easily interpretable information and, in the end, helping them making informed collective decisions. [Karanikolas *et al.*, 2016] presents the Edge-Compressed Majority Graph, a technique dedicated to the visualization of the majority graph of a preference profile. Using an insight-based evaluation method, it shows that this technique gives better results in conveying information about the preferences than other classical visualization techniques.

4.2 Task 2: Testing and Using the Platform, in Real Life and in Laboratories

The second task of the work package is dedicated to social choice in practice. This task covers two different aspects. The first one is carrying out lab experiments (experimental social choice). The second one concerns the use of social choice in real situations, in other words, dissemination aspects of the project. Regarding the first aspect we have started to work on the organization of voting experiments during the French presidential election next year. We are currently actively discussing practical aspects of the organization of such experiments with local authorities in Hérouville-Saint-Clair (Caen), Grenoble and Strasbourg. The major part of the work with this regard will be made next year.

During the first two years, we have mainly concentrated on the second aspect, namely, dissemination. We have participated in a dissemination contest, *Relais d'sciences* organized by Le Dôme, Caen (formerly *Maison de la Recherche et de l'Innovation*) in April 2016. During this contest, which lasted one day, we had to discuss about Whale and social choice with a group of laypersons which were invited to participate. The aim of the discussion was to build the project of a workshop or exhibition to be shown during the science fair (*Fête de la Science*) in October. Three other teams of scientists were involved in the contest. Even if we did not win, this day was very beneficial to us because it was the occasion of having fruitful discussions about how social choice can be beneficial to real people in everyday life situations.

Our second dissemination action will be to participate to *la Fête de la Science* in Le Dôme, Caen, in October. We will be involved in two different actions. The first one will take place on Thursday, October the 13$^{\text{rd}}$. The aim will be to present Whale 4 to a group of laypersons, discuss about its features, and try to invent new use cases for it. The aim is to raise new ideas of real applications for this kind of platforms. The second action will take place on Saturday, October the 15$^{\text{th}}$ and will be a regular science exhibition where people will be able to experiment and manipulate social choice concepts with Whale 4. This will be a nice occasion of seeing Whale 4 used in a real situation.

5 Meetings

- kick-off plenary meeting: December 5, 2014, Université Paris-Dauphine.
- plenary meeting: June 2, 2015, Université Paris-Dauphine.
- plenary meeting: November 23, 2015, Université Paris-Dauphine.

- meeting, WP4: January 20, 2016, Université de Caen.
- meeting, WP3: February 5, 2016, Université de Caen.
- meeting, WP1+WP2: April 1, 2016, Université Pierre et Marie Curie.
- workshop "Têtes Chercheuses": April 19, 2016, Maison de la Recherche et de l'Imagination, Caen.
- Fête de la Science: October 13-15, 2016, Dôme, Caen.

6 Publications

The references below list all publications of the member of the project that have been supported by CoCoRICo-CoDec. In some rare cases we mention technical reports.

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