A Heuristic Approach to P2P Negotiation

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Abstract. In this paper, we present a formal and executable approach to automated multi-issue negotiation between competitive agents. In particular, this approach is based on reasoning in terms of projections in convex regions of admissible values and is an extension of previous work by Marco Cadoli in the area of proposal-based negotiation. Our goal is to develop a heuristic strategy to flexibly compute the offers and counter-offers so as to fulfill each agent’s objectives and minimize the number of agents’ interactions. The proposed algorithm aims at improving a fundamental parameter of the negotiation process: the interaction complexity in the average case.

1 Introduction

Automated negotiation among software agents is becoming increasingly important as a consequence of the rapid development of web-based transactions and e-commerce. Negotiation is an important subject of study in the branch of Distributed Artificial Intelligence (DAI) and MAS (Multi-Agent Systems), as discussed for instance in [1,2,3,4].

A negotiation process can be defined as a particular form of interaction between two or more agents. As discussed, e.g., in [5] and [6], negotiation is a particular type of interaction in which a group of agents, with a desire to cooperate but with conflicting interests, work together in aim to reach a common goal, or to achieve an agreement that is acceptable by all parties in the process. More formally, negotiation can be defined as “a distributed research in a space of potential agreements” ([7]). In this sense, each participant involves its individual area of interest (also called negotiation space or feasibility region), and intends to reach agreements in that area. Negotiation spaces can be represented by a set of constraints. Then, finding an agreement can be modelled as a constraint satisfaction problem (CSP). In particular, in multi-agent systems the process of negotiation can be represented as a distributed constraint satisfaction problem (DCSP), since the constraints are distributed among different agents ([8]).

In proposal-based negotiation, the information exchanged between the parties is in the form of offers (internal points of the negotiation spaces) rather than constraints, preferences or argumentation. Each agent is able to compute the points to offer in order to reach an agreement. Negotiation terminates successfully whenever the participants on the process, find a point, in the space of negotiation, that is mutually acceptable. That point has therefore to be included
in the common area of all negotiation spaces: i.e., in the intersection of the areas of interests [3].

Agents involved in the process of negotiation need to interact. Usually they are self-interested, since each one has different constraints to satisfy and different benefits, in terms of utility functions, to maximize (or minimize). The utility functions can be represented by new constraints on the agents’ knowledge.

The research work reported here is an extension of previous work by Marco Cadoli, introduced in [9], and presents an heuristic strategy for proposal-based negotiation. The goal is to minimize the number of the interactions between the automated agents involved in the process and thus speed-up the search of an agreement - note that the speed of the process, or time complexity, largely depends on the particular negotiation strategy adopted by each agent. In this approach, negotiation spaces are considered to be convex, i.e., all points between two acceptable points are acceptable as well. The admissible offers are internal points of the negotiation areas, and those will be the only exchangeable information among the involved agents. The participating agents are capable of logical reasoning and are able to reason in means of projections. As discussed below (section 3), reasoning by means of projection can help the agents compute subsequent offers as each one can exclude certain points of the individual negotiation areas.

Both the original Marco Cadoli’s approach and the proposed extension are of interest in Computational Logic because involved agents are assumed to be perfect logical reasoners, and then find a natural realization in logic-based agent-oriented languages. In fact, as discussed in Section 6 we have implemented the extended approach in one of these languages, namely in the DALI language. The rest of this paper is structured as follows. Section 2 is an overview of related work. In section 3 we present the theoretical background and the basic approach to negotiation that we adopt, introduced by Marco Cadoli. In section 4 we discuss our motivations for extending this basic approach. Section 5 is devoted to the presentation of the features of the extended negotiation model. In section 6 we present the implementation of the proposed strategy in DALI. In Section 7 we conclude and outline future work.

2 An Overview

Numerous strategies have been proposed in order to improve the efficiency, completeness and robustness of the process of negotiation (e.g., [9][3][10][11][12][13][14][15][16][17][18][19]). In [10], a number of agent strategies designed for the 2002 TAC (Trading Agent Competition) are reported and compared. These techniques include machine learning, adapted, planning and hybrid agents as well as heuristic-based strategies. The aim of [11], instead, is to determine how an agent (with firm deadlines) can select an optimal strategy based on an incomplete information about his opponent. STRATUM, reported in [12], is a methodology for guiding strategies for negotiating agents in non-game-theoretic domains.