

Complex Negotiations in Multi-Agent Systems



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Abstract

Multi-agent systems (MAS) are distributed systems where autonomous entities called agents, either human or software, pursue their own goals. The MAS paradigm has been proposed as the appropriate modeling approach for the deployment of applications like electronic commerce, multi-robot systems, security applications, and so forth. In the MAS community, the vision of open multi-agent system, where heterogeneous agents can enter and leave the system dynamically, has gained strength as a potentially interesting modeling paradigm due to its conceptual relation with technologies like world wide web, grid computing, and virtual organizations. Given the heterogeneity and agent's self-interest, conflict is a candidate phenomenon to arise in multi-agent systems.

In the last few years, the term agreement technologies has been used to address all the mechanisms that, directly or indirectly, promote the resolution of conflicts in computational systems like multi-agent systems. Among agreement technologies, automated negotiation is proposed as one key mechanism in conflict resolution due to its analogous use in human conflict resolution. Automated negotiation consists of an automated exchange of proposals carried out by software agents on behalf of their users. The final goal is the achievement of an agreement with all the involved parts.

Despite being studied by scholars in Artificial Intelligence for several years, several problems have not been addressed by the scientific community yet. The main objective of this thesis is proposing negotiation models for complex scenarios where the complexity may stem from (i) limited computational capabilities or (ii) the necessity to accommodate the preferences of multiple individuals. In the first part of the thesis we propose a bilateral negotiation model for the problem of negotiation in Ambient Intelligence (AmI), a domain with a special emphasis

on computational efficiency due to the limited capability of AmI devices. In the second part of the thesis we propose several negotiation models for agent-based negotiation teams. A negotiation team is a group of individuals that acts together as single negotiation party due to its common interests in the negotiation at hand. The complexity of negotiation teams resides in the fact that despite having common interests, intra-team conflict is also present. As far as we are concerned, the topic of negotiation teams in MAS is introduced with this thesis.

Resumen

Los sistemas multi-agente (SMA) son sistemas distribuidos donde entidades autónomas llamadas agentes, ya sean humanos o software, persiguen sus propios objetivos. El paradigma de SMA ha sido propuesto como la aproximación de modelo apropiada para aplicaciones como el comercio electrónico, los sistemas multi-robot, aplicaciones de seguridad, etc. En la comunidad de SMA, la visión de sistemas multi-agente abiertos, donde agentes heterogéneos pueden entrar y salir del sistema dinámicamente, ha cobrado fuerza como paradigma de modelado debido a su relación conceptual con tecnologías como la Web, la computación grid, y las organizaciones virtuales. Debido a la heterogeneidad de los agentes, y al hecho de dirigirse por sus propios objetivos, el conflicto es un fenómeno candidato a aparecer en los sistemas multi-agente.

En los últimos años, el término tecnologías del acuerdo ha sido usado para referirse a todos aquellos mecanismos que, directa o indirectamente, promueven la resolución de conflictos en sistemas computacionales como los sistemas multi-agente. Entre las tecnologías del acuerdo, la negociación automática ha sido propuesta como uno de los mecanismos clave en la resolución de conflictos debido a su uso análogo en la resolución de conflictos entre humanos. La negociación automática consiste en el intercambio automático de propuestas llevado a cabo por agentes software en nombre de sus usuarios. El objetivo final es conseguir un acuerdo con todas las partes involucradas.

Pese a haber sido estudiada por la Inteligencia Artificial durante años, distintos problemas todavía no han sido resueltos por la comunidad científica todavía. El principal objetivo de esta tesis es proponer modelos de negociación para escenarios complejos donde la complejidad deriva de (i) las limitaciones computacionales o (ii) la necesidad de representar las preferencias de múltiples individuos. En la

primera parte de esta tesis proponemos un modelo de negociación bilateral para el problema de las negociaciones en la Inteligencia Ambiental (AmI), un dominio con un énfasis especial en la eficiencia computacional debido a las características de los dispositivos que podemos encontrar en el escenario. En la segunda parte de esta tesis proponemos diversos modelos de negociación para equipos de negociación. Un equipo de negociación es un grupo de individuos que actúa como una única parte en el proceso de negociación debido a sus intereses comunes. La complejidad en los equipos de negociación reside en el hecho de que, pese a tener intereses comunes, el conflicto dentro del equipo también está presente. En lo que nos concierne, el tema de los equipos de negociación en SMA es introducido con esta tesis.

Resum

Els sistemes multi-agent (SMA) són sistemes distribuïts on entitats autònomes anomenades agents, ja siguin humans o programes, persegueixen els seus propis objectius. El paradigma de SMA ha sigut proposat com una aproximació apropiada per a aplicacions com el comerç electrònic, els sistemes multi-robot, aplicacions de seguretat, etc. En la comunitat de SMA, la visió de sistemes multi-agents oberts, on agents heterogenis poden entrar i eixir del sistema dinàmicament, ha pres força com a paradigma de modelatge degut a la seua relació conceptual amb tecnologies com la Web, la computació grid, i les organitzacions virtuals. Degut a la heterogeneïtat dels agents, i al fet d'estar dirigits pel seus propis objectius, el conflicte és un fenomen candidat a aparèixer en els sistemes multi-agent.

En els darrers anys, el terme tecnologies de l'acord ha sigut usat per a referir-se a tots aqueixos mecanismes que, directa o indirectament, promouen la resolució de conflictes en sistemes computacionals com són els sistemes multi-agent. Entre les tecnologies de l'acord, la negociació automàtica ha sigut proposta com a un dels mecanismes clau en la resolució de conflictes degut al seu ús anàleg en la resolució de conflictes entre humans. La negociació automàtica consisteix en l'intercanvi automàtic de propostes per part d'agents software en el nom dels seus usuaris. L'objectiu final es aconseguir un acord amb totes les parts involucrades.

Malgrat haver sigut estudiada per la Intel·ligència Artificial durant anys, diversos problemes encara no han sigut resolts per la comunitat científica. El principal objectiu d'aquesta tesi és proposar models de negociació per a escenaris complexos on la complexitat deriva de (i) les limitacions computacionals o (ii) la necessitat de representar les preferències de múltiples individus. En la primera part d'aquesta tesi proposem un model de negociació bilateral per al problema de la Intel·ligència Ambiental (AmI), un domini amb un èmfasi especial en la eficiència computacional

degut a les característiques dels dispositius que podem trobar en l'escenari. En la segona part d'aquesta tesis proposem diversos models de negociació per a equips de negociació. Un equip de negociació és un grup d'individus que actua com a una única part en el procés de negociació degut als seus interessos comuns. La complexitat en els equips de negociació resideix en el fet que, encara que tenen interessos comuns, el conflicte dins de l'equip també està present. En allò que ens concerneix, el tòpic dels equips de negociació en SMA és introduït en aquesta tesis.

To my family.

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$$\forall x, \quad \textit{Supported}(x, \textit{Victor}) \longrightarrow \textit{Thanks}(\textit{Victor}, x).$$

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