

A Framework for Reasoning about Rational Agents

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ABSTRACT

We propose an extension of alternating-time temporal logic, that can be used for reasoning about the behavior and abilities of agents under various rationality assumptions.

Categories and Subject Descriptors

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—Multiagent Systems; I.2.4 [Artificial Intelligence]: Knowledge Representation Formalisms and Methods—Modal logic

General Terms

Theory

Keywords

multi-agent systems, game theory, temporal logic, rationality

1. INTRODUCTION

Alternating-time temporal logic (ATL) [1] is a temporal logic that incorporates some basic game theoretical notions. In this paper, we extend ATL with a notion of *plausibility*, which can be used to model and reason about rational behavior of agents. In our approach, some strategies (or rather *strategy profiles*) can be assumed plausible, and one can reason about what can be *plausibly* achieved by agents under such an assumption.

This idea has been inspired by the way in which games are analyzed in game theory. First, game theory identifies a number of *solution concepts* (e.g., Nash equilibrium, undominated strategies, Pareto optimality) that can be used to define rationality of players. Then, we usually *assume* that *players play rationally* in the sense of one of the concepts, and we *ask about the outcome of the game under this assumption*. Note that solution concepts do not only help to determine the right decision for “our” agent. Perhaps even more importantly, they constrain the possible (predicted) responses of the opponents. For many games the number of all possible outcomes is infinite, although only some of them “make sense”. Still, we need a notion of rationality (like subgame-perfect Nash equilibrium) to

discard the “less sensible” ones, and determine what should happen had the game been played by ideal players.

There are two possible points of focus in this context. Research within game theory understandably favors work on *characterization* of various types of rationality (and defining most appropriate solution concepts). Applications of game theory, also understandably, tend toward using the solution concepts to predict the outcome in a given game (i.e., to “solve” the game). The first issue has been studied in the framework of logic, for example in [2, 4, 10, 11]; more recently, game-theoretical solution concepts have been characterized in dynamic logic [7], dynamic epistemic logic [3], and ATL [13, 8]. The second issue seems to have been neglected in logic-based research: papers by Van Otterloo and his colleagues [14, 16, 15] are the only exceptions we know of (and each of them commits to a particular view of rationality). Here, we try to fill in this gap, and propose a general, modal logic-based framework for reasoning about behavior and abilities of rational agents.

2. ATL

The language of Alternating-time Temporal Logic [1] is defined over a set Agt of agents and a set Π of propositions, and consists of the following formulae:

$$\varphi ::= p \mid \neg\varphi \mid \varphi \wedge \psi \mid \langle A \rangle \gamma, \quad \gamma ::= \bigcirc \varphi \mid \Box \varphi \mid \varphi U \psi,$$

where $p \in \Pi$ and $A \subseteq \text{Agt}$. Informally, $\langle A \rangle \varphi$ says that agents A have a collective strategy to enforce φ . ATL formulae include the usual temporal operators: $\bigcirc$ (“in the next state”), $\Box$ (“always from now on”) and U (strict “until”). Additionally, $\bigcirc$ (“now or sometime in the future”) can be defined as $\bigcirc \varphi \equiv \top U \varphi$.

The semantics of ATL is defined in *concurrent game structures*:

$$M = (\text{Agt}, Q, \Pi, \pi, \text{Act}, d, \alpha),$$

consisting of: a set $\text{Agt} = \{1, \dots, k\}$ of agents; set Q of states; set Π of atomic propositions; valuation of propositions $\pi : Q \rightarrow P(\Pi)$; set Act of actions. Function $d : \text{Agt} \times Q \rightarrow P(\text{Act})$ indicates the actions available to agent $a \in \text{Agt}$ in state $q \in Q$. A move vector in state q is a tuple $\langle m_1, \dots, m_k \rangle \in d(q)$ where $d(q) = \prod_{a \in \text{Agt}} d_a(q)$ is the set of all move vectors in q . Finally, α is a transition function which maps a state $q \in Q$ and a move vector $\langle m_1, \dots, m_k \rangle \in d(q)$ to another state $q' = \alpha(q, \langle m_1, \dots, m_k \rangle)$.

A *computation* or *path* $\lambda = q_0, q_1, \dots$ is an infinite sequence of states such that there is a transition between each q_i, q_{i+1} . We define $\lambda[i] = q_i$ to denote the i -th state of λ . λ_{Agt} denotes all paths of M . The set of all paths, starting in q , is given by $\lambda_{\text{Agt}}(q)$.

A (memoryless) strategy of agent a is a function $s_a : Q \rightarrow \text{Act}$ such that $s_a(q) \in d_a(q)$. The set of strategies for agent a is denoted by Σ_a . A collective strategy s_A for team $A \subseteq \text{Agt}$ specifies an individual strategy for each agent $a \in A$. Now, $\Sigma_A =$

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Reasoning About Rational Agents

**Luis Fariñas del Cerro, Andreas
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Computational Logic in Multi-Agent Systems Fariba Sadri, 2008-10-23 This book constitutes the thoroughly refereed post conference proceedings of the 8th International Workshop on Computational Logic for Multi Agent Systems CLIMA VIII held in Porto Portugal in September 2007 co located with ICLP 2008 the International Conference on Logic Programming The 14 revised full technical papers and 1 system description paper presented together with 1 invited paper were carefully selected from 33 submissions and went through at least two rounds of reviewing and improvement The regular papers address topics such as interdependencies and co ordination of task based planning in multi agent systems interval temporal logic game theoretic concepts for reasoning about rational agents proof theory for multi agent epistemic logic transformational semantics for evolving logic programs EVOLP programming languages based on BDI models agent oriented early requirements engineering framework heuristic algorithms for agent negotiation as well as argumentation *Innovative Concepts for Agent-Based Systems* Walt Truszkowski, Chris Rouff, 2003-08-21 This book constitutes the thoroughly refereed post proceedings of the First International Workshop on Radical Agent Concepts WRAC 2002 held in McLean VA USA in January 2002 The 32 revised full papers presented together with an invited article 6 poster papers and 2 panel reports were carefully reviewed and selected for inclusion in the book The papers are organized in topical sections on adaptation and learning agent based software engineering agent architectures agent communication and coordination and innovative applications

Argumentation in Multi-Agent Systems Iyad Rahwan, Pavlos Moraitis, 2009-02-16 During the last decade Argumentation has been gaining importance within Artificial Intelligence especially in multi agent systems Argumentation is a powerful mechanism for modelling the internal reasoning of an agent It also provides tools for analysing designing and implementing sophisticated forms of interaction among rational agents thus making important contributions to the theory and practice of multiagent dialogues Application domains include nonmonotonic reasoning legal disputes business negotiation labor disputes team formation scientific inquiry deliberative democracy ontology reconciliation risk analysis scheduling and logistics This volume presents the latest developments in this area at the interface of argumentation theory and multi agent systems The 10 revised full papers presented together with 3 invited papers from the AAMAS 2008

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