

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:

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

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

David Hitchcock



Reasoning About Rational Agents:

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aims at satisfying individuals preferences valuing economic freedom and viewing markets favourably Behavioural research however shows that individuals preferences are often unstable Robert Sugden proposes a reformulation of normative economics compatible with psychology of choice

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Table of Contents Reasoning About Rational Agents

1. Understanding the eBook Reasoning About Rational Agents
 - The Rise of Digital Reading Reasoning About Rational Agents
 - Advantages of eBooks Over Traditional Books
2. Identifying Reasoning About Rational Agents
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Reasoning About Rational Agents
 - User-Friendly Interface
4. Exploring eBook Recommendations from Reasoning About Rational Agents
 - Personalized Recommendations
 - Reasoning About Rational Agents User Reviews and Ratings
 - Reasoning About Rational Agents and Bestseller Lists
5. Accessing Reasoning About Rational Agents Free and Paid eBooks

- Reasoning About Rational Agents Public Domain eBooks
- Reasoning About Rational Agents eBook Subscription Services
- Reasoning About Rational Agents Budget-Friendly Options
- 6. Navigating Reasoning About Rational Agents eBook Formats
 - ePub, PDF, MOBI, and More
 - Reasoning About Rational Agents Compatibility with Devices
 - Reasoning About Rational Agents Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Reasoning About Rational Agents
 - Highlighting and Note-Taking Reasoning About Rational Agents
 - Interactive Elements Reasoning About Rational Agents
- 8. Staying Engaged with Reasoning About Rational Agents
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Reasoning About Rational Agents
- 9. Balancing eBooks and Physical Books Reasoning About Rational Agents
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Reasoning About Rational Agents
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Reasoning About Rational Agents
 - Setting Reading Goals Reasoning About Rational Agents
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Reasoning About Rational Agents
 - Fact-Checking eBook Content of Reasoning About Rational Agents
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development

- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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