

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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AAMAS'07 May 14–18 2007, Honolulu, Hawaii, USA.
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Reasoning About Rational Agents

Michael T. Cox, Anita Raja



Reasoning About Rational Agents:

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Foundations of Rational Agency Michael Wooldridge, A. Rao, 2013-03-09 Over the past decade rational agency has come to be recognised as a central theme in artificial intelligence Drawing upon research on rational action and agency in philosophy logic game theory decision theory and the philosophy of language this volume represents an advanced comprehensive state of the art survey of the field of rational agency as it stands today It covers the philosophical foundations of rational agency logical and decision theoretic approaches to rational agency multi agent aspects of rational agency

including speech acts joint plans and cooperation protocols and finally describes a number of approaches to programming rational agents Although written from the standpoint of artificial intelligence this interdisciplinary text will be of interest to researchers in logic mainstream computer science the philosophy of rational action and agency and economics **ECAI 2004** Ramon López de Mántaras, Lorenza Saitta, 2004 This is the Golden Age for Artificial Intelligence The world is becoming increasingly automated and wired together This also increases the opportunities for AI to help people and commerce Almost every sub field of AI had now been used in substantial applications Some of the fields highlighted in this publication are CBR Technology Model Based Systems Data Mining and Natural Language Techniques Not only does this publication show the activities capabilities and accomplishments of the sub fields it also focuses on what is happening across the field as a whole

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

conference were carefully reviewed and selected from numerous submissions The papers are organized in topical sections on argument based reasoning argumentation and dialogue as well as strategic and pragmatic issues On Reasoning and Argument David Hitchcock,2017-04-06 This book brings together in one place David Hitchcock s most significant published articles on reasoning and argument In seven new chapters he updates his thinking in the light of subsequent scholarship Collectively the papers articulate a distinctive position in the philosophy of argumentation Among other things the author develops an account of material consequence that permits evaluation of inferences without problematic postulation of unstated premises updates his recursive definition of argument that accommodates chaining and embedding of arguments and allows any type of illocutionary act to be a conclusion advances a general theory of relevance provides comprehensive frameworks for evaluating inferences in reasoning by analogy means end reasoning and appeals to considerations or criteria argues that none of the forms of arguing ad hominem is a fallacy describes proven methods of teaching critical thinking effectively **Logics in Artificial Intelligence** Luis Fariñas del Cerro,Andreas Herzig,Jérôme Mengin,2012-09-07 This book constitutes the refereed proceedings of the 13th European Conference on Logics in Artificial Intelligence held in Toulouse France in September 2012 The book includes 3 invited talks 36 regular papers and 5 system descriptions selected from 107 submissions The papers cover various aspects of theory and methods of logic for artificial intelligence

Knowledge Processing and Decision Making in Agent-Based Systems Lakhmi C Jain,Ngoc Thanh Nguyen,2009-01-17 Knowledge processing and decision making in agent based systems constitute the key components of intelligent machines The contributions included in the book are Innovations in Knowledge Processing and Decision Making in Agent Based Systems Towards Real World HTN Planning Agents Mobile Agent Based System for Distributed Software Maintenance Software Agents in New Generation Networks Towards the Automation of Telecom Processes Multi agent Systems and Paraconsistent Knowledge An Agent based Negotiation Platform for Collaborative Decision Making in Construction Supply Chain An Event Driven Algorithm for Agents at the Web A Generic Mobile Agent Framework Toward Ambient Intelligence Developing Actionable Trading Strategies Agent Uncertainty Model and Quantum Mechanics Representation Agent Transportation Layer Adaptation System Software Agents to Enable Service Composition through Negotiation Advanced Technology Towards Developing Decentralized Autonomous Flexible Manufacturing Systems *The Oxford Handbook of the History of Ethics* Roger Crisp,2013-01-31 This original and comprehensive volume explores the history of philosophical ethics in the western tradition from Homer until the present day Leading experts in the field use their expertise and specialist knowledge to illuminate key subjects and ideas in contemporary ethics and survey the history of the discipline *Metareasoning* Michael T. Cox,Anita Raja,2011 Experts report on the latest artificial intelligence research concerning reasoning about reasoning itself **Morality, Authority, and Law** Stephen Darwall,2013-03-21 Stephen Darwall presents a series of essays that explore the view that morality is second personal entailing mutual accountability and

the authority to address demands He illustrates the power of the second personal framework to illuminate a wide variety of issues in moral political and legal philosophy

Moral Knowledge Ellen Frankel Paul,Fred Dycus Miller,Jeffrey Paul,2001 Philosophers since ancient times have pondered how we can know whether moral claims are true or false The first half of the twentieth century witnessed widespread skepticism concerning the possibility of moral knowledge Indeed some argued that moral statements lacked cognitive content altogether because they were not susceptible to empirical verification The British philosopher A J Ayer contends that They are pure expressions of feeling and as such do not come under the category of truth and falsehood They are unverifiable because they do not express genuine propositions The second half of the twentieth century brought a revival of interest among philosophers in moral and political questions Whether or not ethics can be founded upon a rational basis continues to preoccupy the philosophical community even now

Agent and Multi-Agent Systems: Technologies and Applications Adam Grzech,2007-07-07 This book constitutes the refereed proceedings of the First International Symposium on Agent and Multi Agent Systems Technologies and Applications KES AMSTA 2007 held in Wroclaw Poland in May June 2007 Coverage includes agent oriented Web applications mobility aspects of agent systems agents for network management agent approaches to robotic systems as well as intelligent and secure agents for digital content management

Aquinas's Moral Theory Scott Charles MacDonald,Eleonore Stump,1998 This volume explores the ethical dimensions of a wide selection of philosophical and theological topics in Aquinas s texts It covers topics central to ethics such as happiness moral virtue and natural law as well as related topics pertaining to the metaphysical basis of Aquinas s account of goodness the ramifications of his ethical concerns for his philosophy of language and the significance of his philosophical psychology for his ethics

The Community of Advantage Robert Sugden,2018 Normative analysis in economics usually 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

Handbook of the Philosophy of Medicine Thomas Schramme,Mary Jean Walker,2025-09-30 This is the second edition of Springer s first wide ranging multi authored handbook on philosophy of medicine It covers the underlying conceptual issues of many important social political and ethical issues in health care and as such provides a single source of information for this far ranging and still developing field This new edition of this authoritative handbook includes topics that have gained momentum in the last couple of years This second edition introduces and develops nearly one hundred topics concepts and issues in the field It is written by distinguished specialists from multiple disciplines including philosophy health sciences nursing sociology political theory and medicine Many complicated social and ethical issues in health care are based on conceptual problems most prominently on the definitions of health and disease or on epistemological issues regarding causality or diagnosis Philosophy is the discipline that deals with such conceptual metaphysical epistemological methodological and axiological matters This handbook covers

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