

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

**Ramon López de Mántaras, Lorenza
Saitta**



Reasoning About Rational Agents:

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Reasoning about Rational Agents

Michael J. Wooldridge, 2000 One goal of modern computer science is to engineer computer programs that can act as autonomous rational agents software that can independently make good decisions about what actions to perform on our behalf and execute those actions Applications range from small programs that intelligently search the Web buying and selling goods via electronic commerce to autonomous space probes This book focuses on the belief desire intention BDI model of rational agents which recognizes the primacy of beliefs desires and intentions in rational action The BDI model has three distinct strengths an underlying philosophy based on practical reasoning in humans a software architecture that is implementable in real systems and a family of logics that support a formal theory of rational agency The book introduces a BDI logic called LORA Logic of Rational Agents In addition to the BDI component LORA contains a temporal component which allows one to represent the dynamics of how agents and their environments change over time and an action component which allows one to represent the actions that agents perform and the effects of the actions The book shows how LORA can be used to capture many components of a theory of rational agency including such notions as communication and cooperation

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

Logic and Philosophy of Science in Uppsala D. Prawitz, Dag Westerståhl, 2013-06-29 The International Congresses of Logic Methodology and Philosophy of Science which are held every fourth year give a cross section of ongoing research in logic and philosophy of science Both the invited lectures and the many contributed papers are conducive to this end At the 9th Congress held in Uppsala in 1991 there were 54 invited lectures and around 650 contributed papers divided into 15 different sections Some of the speakers who presented contributed papers that attracted special interest were invited to submit their papers for publication and the result is the present volume A few papers appear here more or less as they were presented at the

Congress whereas others are expansions or elaborations of the talks given at the Congress A selection of this kind containing 38 papers drawn from the 650 contributed papers presented at the Uppsala Congress cannot do justice to all facets of the field as it appeared at the Congress But it should allow the reader to get a representative survey of contemporary research in large areas of philosophical logic and philosophy of science About half of the papers of the volume appear in sections listed at the Congress under the heading Philosophical and Foundational Problems about the Sciences The section Foundations of Logic Mathematics and Computer Science is represented by three papers Foundations of Physical Sciences by six papers Foundations of Biological Sciences by three papers Foundations of Cognitive Science and AI by one paper and Foundations of Linguistics by three papers

Agency and Autonomy in Kant's Moral Theory Andrews Reath,2006-02-23 Andrews Reath presents a selection of his best essays on various features of Kant s moral psychology and moral theory with particular emphasis on his conception of rational agency and his conception of autonomy The opening essays explore different elements of Kant s views about motivation including his account of respect for morality as the distinctive moral motive and his view of the principle of happiness as a representation of the shared structure of non moral choice These essays stress the unity of Kant s moral psychology by arguing that moral and non moral considerations motivate in essentially the same way Several of the essays develop an original approach to Kant s conception of autonomy that emphasizes the political metaphors found throughout Kant s writings on ethics They argue that autonomy is best interpreted not as a psychological capacity but as a kind of sovereignty in claiming that moral agents have autonomy Kant regards them as a kind of sovereign legislator with the power to give moral law through their willing The final essays explore some of the implications of this conception of autonomy elsewhere in Kant s moral thought arguing that his Formula of Universal Law uses this conception of autonomy to generate substantive moral principles and exploring the connection between Kantian self legislation and duties to oneself The collection offers revised versions of several previously published essays as well as two new papers Autonomy of the Will as the Foundation of Morality and Agency and Universal Law It will be of interest to all students and scholars of Kant and to many moral philosophers

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

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

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

Vulnerability, Autonomy, and Applied Ethics Christine Straehle, 2016-10-04 Vulnerability is an important concern of moral philosophy political philosophy and many discussions in applied ethics Yet the concept itself what it is and why it is morally salient is under theorized Vulnerability Autonomy and Applied Ethics brings together theorists working on conceptualizing vulnerability as an action guiding principle in these discussions as well as bioethicists medical ethicists and public policy theorists working on instances of vulnerability in specific contexts This volume offers new and innovative work by Joel Anderson Carla Bagnoli Samia Hurst Catriona Mackenzie and Christine Straehle who together provide a discussion of the concept of vulnerability from the perspective of individual autonomy The exchanges among authors will help show the heuristic value of vulnerability that is being developed in the context of liberal political theory and moral philosophy The book also illustrates how applying the concept of vulnerability to some of the most pressing moral questions in applied ethics can assist us in making moral judgments This highly innovative and interdisciplinary approach will help those grappling with questions of vulnerability in medical ethics both theorists and practitioners by providing principles along which to decide hard cases

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

Minimal Morality Michael Moehler, 2018-03-09 Michael Moehler develops a novel multilevel social contract theory In contrast to existing theories in the liberal tradition it does not merely assume a restricted form of reasonable moral pluralism but is tailored to the conditions of deeply morally pluralistic societies which may be populated by liberal moral agents nonliberal moral agents and according to the traditional understanding of morality nonmoral agents alike Moehler draws on the history of the social contract tradition especially the work of Hobbes Hume Kant Rawls and Gauthier as well as on the work of some of the critics of this tradition such as Sen and Gaus Moehler's two level contractarian theory holds that morality in its best contractarian version for the conditions of deeply morally pluralistic societies entails Humean Hobbesian and Kantian moral features The theory defines the minimal behavioral restrictions that are necessary to ensure compared to violent conflict resolution mutually beneficial peaceful long term cooperation in deeply morally pluralistic societies The theory minimizes the problem of compliance in morally diverse

societies by maximally respecting the interests of all members of society. Despite its ideal nature, the theory is in principle applicable to the real world and for the conditions described most promising for securing mutually beneficial peaceful long term cooperation in a world in which a fully just society due to moral diversity is unattainable. If Rawls' intention was to carry the traditional social contract argument to a higher level of abstraction, then the two level contractarian theory brings it back down to earth.

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.

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