

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

**Francesco Ademollo, Fabrizio
Amerini, Vincenzo De Risi**



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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 **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 *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 *Oxford Studies in Normative Ethics Volume 11* Mark Timmons, 2022-02-03 OSNE is an annual forum for new work in normative ethical theory Leading philosophers advance our understanding of a wide range of moral issues and positions from analysis of competing normative theories to questions of how we should act and live well OSNE is an essential resource for scholars and students working in moral philosophy **Enterprise Information Systems VI** Isabel Seruca, José Cordeiro, Slimane Hammoudi, Joaquim Filipe, 2006-07-08 This book contains the best papers of the Sixth International Conference on Enterprise Information Systems ICEIS 2004 held in Porto Portugal and organized by INSTICC Institute for Systems and Technologies of Information Communication and Control in collaboration with PORTUGALENSE UNIVERSITY who hosted the event Following the route started in 1999 ICEIS has become a major point of contact between research scientists engineers and practitioners on the area of business applications of information systems This conference has received an increased interest every year from especially from the international academic community and it is now one of the world largest conferences in its area This year five simultaneous tracks were held covering different aspects related to enterprise computing including Databases and Information Systems Integration Artificial Intelligence and Decision Support Systems Information Systems Analysis and Specification Software Agents and Internet Computing and Human Computer Interaction The sections of this book reflect the conference tracks 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 **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 *The Routledge Handbook of the Philosophy of Economics* Conrad Heilmann, Julian Reiss, 2021-11-29 The most fundamental questions of economics are often philosophical in nature and philosophers have since the very beginning of Western philosophy asked many questions that current observers would identify as economic The Routledge Handbook of Philosophy of Economics is an outstanding reference source for the key topics problems and debates at the intersection of philosophical and economic inquiry It captures this field of countless exciting interconnections affinities and opportunities for cross fertilization Comprising 35 chapters by a diverse team of contributors from all over the globe the Handbook is divided into eight sections I Rationality II Cooperation and Interaction III Methodology IV Values V Causality and Explanation VI Experimentation and Simulation VII Evidence VIII Policy The volume is essential reading for students and researchers in economics and philosophy who are interested in exploring the interconnections between the two disciplines It is also a valuable resource for those in related fields like political science sociology and the humanities **Cognitive Carpentry** John L. Pollock, 1995 A sequel to the author's How to Build a Person this work builds upon that theoretical groundwork for the implementation of rationality through artificial intelligence It argues that progress in AI has stalled because of its creators reliance upon unformulated intuitions about rationality Instead the author bases the OSCAR architecture upon an explicit philosophical theory of rationality encompassing principles of practical cognition epistemic cognition and defeasible reasoning One of the results is the first automated defeasible reasoner capable of reasoning in a rich logical environment

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 New Palgrave Dictionary of Economics and the Law Peter Newman,2016-04-30 A great deal of economics is about law the functioning of markets property rights and their enforcement financial obligations and so forth yet these legal aspects are almost never addressed in the academic study of economics Conversely the study and practice of law entails a significant understanding of economics yet the drafting and administration of laws often ignore economic principle The New Palgrave Dictionary of Economics and the Law is uniquely placed by the quality breadth and depth of its coverage to address this need for building bridges Drawn from the ranks of academics professional lawyers and economists in eight countries the 340 contributors include world experts in their fields Among them are Nobel laureates in economics and eminent legal scholars First published in 1998 and now available in paperback for the first time The New Palgrave Dictionary of Economics and the Law has established itself as a classic reference work in this important field **Thinking and Calculating** Francesco Ademollo,Fabrizio Amerini,Vincenzo De Risi,2022-07-04 This volume collects 22 essays on the history of logic written by outstanding specialists in the field The book was originally prompted by the 2018 2019 celebrations in honor of Massimo Mugnai a world renowned historian of logic whose contributions on Medieval and Modern logic and to the understanding of the logical writings of Leibniz in particular have shaped the field in the last four decades Given the large number of recent contributions in the history of logic that have some connections or debts with Mugnai s work the editors have attempted to produce a volume showing the vastness of the development of logic throughout the centuries We hope that such a volume may help both the specialist and the student to realize the complexity of the history of logic the large array of problems that were touched by the discipline and the manifold relations that logic entertained with other subjects in the course of the centuries The contributions of the volume in fact span from Antiquity to the Modern Age from semantics to linguistics and proof theory from the discussion of technical problems to deep metaphysical questions and in it the history of logic is kept in dialogue with the history of mathematics economics and the moral sciences at large **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.

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