Defining Agents via Strategies: Towards a view of MAS as Games

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Extensional x Intentional Models

Some Examples

- Naive Set Theory $\times$ Axiomatic Set Theory
- Computable Functions $\times$ Turing Machines
- Alternative World Views $\times$ Logical Modal Theories
- Behavior/Communication $\times$ Process Calculus Terms
- Models $\times$ Theories

Diff. Intensional Flavors

- Process Calculi Terms $\times$ Presentation of Modal Theories
- Automata $\times$ Logical Modal Theories
- Reactive Systems $\times$ Rewriting Systems
- Reactive Systems $\times$ First-Order Logic + Modal Logic
- BDI Agents $\times$ LORA Theories

The "Intention $\times$ Extension" relationship in Practice

Consistency and Completeness

- Is there an Extension ??
- Is there an (interesting) Intention ??
- Is the intended extension the right one ???

How to know that in practice ?

- Gödel's theorems show that even for "simple" theories the answer for those questions are strongly related each other and are either negative or unknown.
- In most of the cases it is not possible to know that. (Theory of Science)

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TECMF-DI-Rio: Technology in Formal Methods

The role of The Formal Analysis of Systems/Theories

Provide techniques, tools and methodology to work out the Principle of False-ability of Theories towards the (Formal) validation of software/specification.

Known Techniques/Tools

- Ad-hoc and Systematic Testing.
- Simulation (stochastic).
- Modal Logic and Model-Checking Algorithms.
- Process Calculi, μ-calculus proof-system.
- Theorem Proving.

Game-Theory: From the Quantitative to the Qualitative Approach

In Social and Economic Sciences

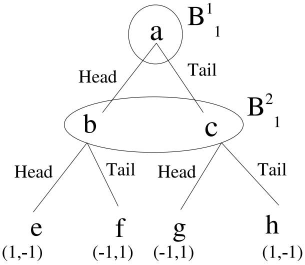
- Game Theory has been used as an important Formal (Math) Analysis tool.
- Existence of: Winning Strategies, Nash Equilibria, Subgame Perfect/Imperfect Equilibria, in competitive games, are conceptually meaningful.
- The *core* of a coalition game plays interesting concepts in cooperative environments.

Game-Theory: From the Quantitative to the Qualitative Approach

Why not Model-Checking games ?

Previous work in *ATL*[Alur,Henziger and Kupperman] and *GAL*[TECMF].

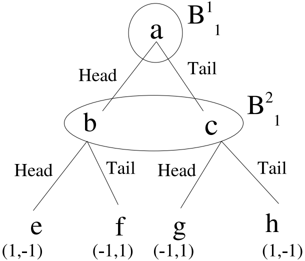
Extensive Games



An extensive game is:

- A Game Tree
- A partition of the nodes among players
- Strategies (for each player)
- Payoffs at terminal nodes.

Extensive Games



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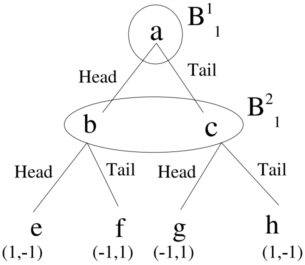

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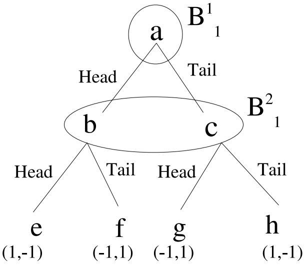

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Games $\times$ MAS

MAS validation by means of quantitative based games

- A quite useful tool for auctions formal (math) Analysis.
- Agent-based modeling and Nash Equilibria Analysis in Power Market [KABC2003].
- A Game-Theoretic approach for power aware middleware [MV2005]
- Many more......

Games $\times$ MAS

A Foundational Question

Why can we use game-theoretic tools for MAS validation ???

Our contribution

- Class G of MAS, such that, there is no simultaneous action occurrence from different agents, and, the set o Desires, Intentions and Beliefs of each agent is a finite set of propositions.
- Lemma I: Every MAS belonging to G is, essentially, a Game.
- Lemma II: Every Game can be implemented as a MAS. Equilibria are Optima Desires Satisfaction.

Work-in-Progress

Conjecture: Every BDI based MAS is a Coalition Game with transferable payoff.
Corollary: Agent's rationality = Player's rationality

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The Agent's Individual Behavior

Agent's Control Loop

$B := B_0$; $I := I_0$;
While(true)
get next percept ρ;
$B := \mathit{brf}(B, \rho)$;
$D := \mathit{options}(B, I)$;
$I := \mathit{filter}(B, D, I)$;
$\pi := \mathit{plan}(B, I)$;
$\mathit{execute}(\pi)$;
end-while;

The Planning

A Planning is a partial mapping from Sets of Possible into Sets of Possible Worlds

Agents as Players

Agent Concept	Game Concept
Beliefs	State-Description
Intention	Strategy
Desires	Maximization of Payoffs

The payoff is associated to the number of desires satisfied in a possible behavior of the MAS

Proof-sketch of Lemma I

- A MAS is identified with its extensional Model M (T Kripke Semantics S).
- Define $s \equiv s'$ in the situation model Sit_M, iff, they are bissimilar and elementarily equivalent.
- $Sit_M / \equiv$ provides the game tree of G_M.
- The source of the actions in $Sit_M / \equiv$ defines the players.
- Strategies of p_a are determined by each action taken by agent a.
- The payoff of a terminal node is the number of desires satisfied at the node, for each agent.
- ==> Subgame Equilibria of G_M will correspond to states with maximal social satisfaction of M.

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Agents as Players: Integrated View

Agency Theory	Game Theory
Agents Groups	Players
Common Beliefs	Game Tree
Agent's Intentions	Player's Strategies
Desires Satisfaction[1]	Existence of Equilibria

[1] Here we refer to the satisfaction of desires of a set of agents

Proof-Sketch of Lemma II

- Each agent corresponds to a player.
- The desire of the player is to maximize the payoff.
- Beliefs are state descriptions of the extensive game.
- The strategies of each player determines the Planning of the each agent.
- ==> States of maximal social of M (if any) are subgame perfect equilibria of the game.

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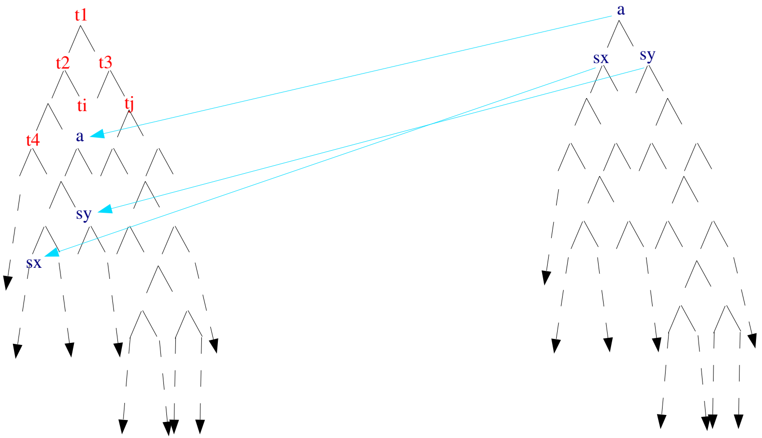
Time is important in BDI Agents

Return

Temporal Structures and Substructures



The Situation Semantics

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