Teamwork in Intelligent Software Agent and Robotic Systems

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Trends in the History of Computing
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An agent is a computer system that is capable of independent action on behalf of its user or owner.
Expanding Computer Science: Agents

An Agent

An agent is a computer system that is capable of independent action on behalf of its user or owner.
Expanding Computer Science: Multiple Agents
A Multi-Agent System

The field of multi-agent systems is influenced and inspired by many other fields:

- Economics (Game Theory)
- Philosophy
- Logic
- Social Sciences
- Ecology
- Biology
- etc.
Cooperative Multi-Agent System
From individual agents to collective behavior
Prediction Market

A prediction market is a market-based mechanism used to:
- combine the opinions on a future event from different people
- forecast the possible outcome of the event based on the aggregated opinion
A Prediction market is

a market-based mechanism used to

- combine the opinions on a future event from different people and
- forecast the possible outcome of the event based on the aggregated opinion
Will the new distribution requirements proposal pass?
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Dr. Binnington under fire for a comment on the proposal

September 15

Provost DeMeritt endorses the proposal

November 3

Security
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Ummm... based on the information I got, seems that the security has a 52% chance of happening.

And my analysis of the information I got, says that it has a 65% chance of happening.

And my definitive blog says it is going to be 47%
Will the new distribution requirements proposal pass?

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Student survey reveals overwhelming support of the proposal

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Based on new information, I revise my estimate to 52%-70% chance of happening.

My new prediction is that it has a 65% 68% chance of happening.

I have revised it to be 47% 89%
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Prediction Market

70%

68%

89%
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The general feeling about the distribution requirements proposal passing is ...after some number crunching calculations...75%

70%

68%

89%

Prediction Market
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Prediction Market

Aggregation Mechanism
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The security for “Will the new distribution requirements proposal pass?” has a current market price of 0.75

70% 68% 89%

Prediction Market

Aggregation Mechanism
Software trading agents perform calculations and trade on behalf of human traders

Provides testbed for modeling different strategic behaviors of traders.
Solution

- Develop a formal, game-theoretic model of the trading agent behavior in prediction markets including
  - impact of information from external sources on trading agent decisions/behavior,
  - a solution concept for calculating the equilibrium strategies of the trading agents
Benefits

- Information aggregation is pervasive... Internet-based social networks, sensor networks, daily lives of people, etc.
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- Information aggregation is pervasive... Internet-based social networks, sensor networks, daily lives of people, etc.
- Our results give better understanding about how the information aggregation process responds to changes in strategic decision making and information-related parameters
From a Multi-Agent to a Multi-Robot System
What is a robot?
Two main components

- Sensors: to “understand” the world around
- Actuators: to “act” (do actions) on the world around
What Does a Robot Do?

Sense, Plan and Act

- **Sense** - get information from sensors
- **Plan** - use the sensed information to decide to do things (e.g., go down the hallway, turn left, go 3 meters, and stop)
- **Act** - do the thing (e.g., turn 60 degrees with a velocity of 0.2 meters/sec)
The three key questions in Mobile Robotics

- Where am I?
- Where am I going?
- How do I get there?
<table>
<thead>
<tr>
<th>The three key questions in Mobile Robotics</th>
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To answer these questions the robot has to:

- have a model of the environment (given or autonomously built)
- perceive and analyze the environment
- find its position/situation within the environment
- plan and execute the movement
How to Design a Robot?

Hierarchical

Sense → Plan → Act

Reactive

Sense → Act

Hybrid

Plan → Sense → Act
Multi-Robot System

- Tasks may be complex.
  - A robot is limited in the space it covers and perceives.
- The efficiency of scale.
  - Building simple robots is easier, cheaper and more flexible.
Multi-Robot System

Motivations for multi-robot systems

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Taxonomy of Approaches

Centralized
- Fully Centralized
- Centralized Allocation

Distributed
- Emergent
- Intentional
- Hybrid
  - Reactive
  - Behavior-Based
  - Market Based
Environmental Monitoring

Focus on tasks, in which robots...

- observe the environment for events in a cooperative manner
Environmental Monitoring

Focus on tasks, in which robots...

▶ observe the environment for events in a cooperative manner

Applies to...

▶ search-and-rescue,
▶ surveillance,
▶ minefield clearance
Challenge: Robots make mistakes!

Sensors can be “noisy”. We need error tolerance!
Simple Individual Rules $\rightarrow$ Collective Behavior
Team Approximation

Boolean network

Probabilistic model

0.375
Results
Agents form coalitions (teams).

Actions are taken by groups of agents.

Transferable utility: the choice of coalitional actions (by all coalitions) determines the payoff of each coalition.

- the members of the coalition then need to divide this joint payoff.
Decide to call reinforcement

Decide to explore area 1

Decide to consult expert advice from a software agent
Cooperation in Environmental Monitoring

Heterogeneous System of Robots and Agents

Combine reactive, distributed and market-based approaches.
Cooperation in Environmental Monitoring

Heterogeneous System of Robots and Agents
Combine reactive, distributed and market-based approaches.

- Each robot/agent has a task (individual or may belong to the team).
- All robots have a common goal.
- Design cooperative games (voting) to decide on coalitions.
Coordination for Environmental Monitoring

Application: Healthcare/Service

More than 11 million people live with physical/mental disabilities or are aging and need personal assistance.

- Use cooperative (robots, agents, sensors, human) systems for life enhancement applications.
Coordination for Environmental Monitoring
Coordination for Environmental Monitoring
The Other Type of Cooperation
The Other Type of Cooperation
Thank You!
Questions?

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