Game-Theoretic Approaches to Multi-Agent Systems

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The Setting

- More than one agent in the environment:
  - Tasks can be solved faster
  - Sometimes essential (sensor networks, robotic soccer, …)
  - Solutions should be robust!
  - Should tolerate heterogeneous team structures if possible
- Sometimes, the agents might not be cooperative …

Example 1: Robotic Soccer Team

- Do not interfere with your team mates
- Take over role if it is not filled
- Try to fill the role that optimizes the group utility

Example 2: Robot Exploration

- A group of robots should explore a maze and construct a common map
- Each robot goes to the closest unexplored point
- Can we be better than that?

Thanks to Wolfram Burgard!

Example 3: Office Delivery

- Team of robots
- They all have tasks assigned to them
- They all are selfish and want to minimize their work
- *Negotiation*:
  - Reassignment of tasks
  - Agree on acceptable solution

Game Theory

- Games:
  - Finite set of players
  - Set of strategies
  - Utility for each player depends on the chosen strategy profile
- Solution of a game:
  - Nash-Equilibrium: strategy profile where there is no incentive for any individual to deviate.

Example: Prisoner's Dilemma

- Two prisoners are put in separate cells and are questioned. They have the following options:
  - If they both do not confess, they are punished only for a minor crime
  - If one confesses and the other one doesn't, the former one is freed and the other goes to jail for a very long time
  - If both confess, they are sentenced to a moderate amount of time to jail
- Equilibrium: Both confess
- Even worse: This is a dominant strategy

	Player 2 confesses	Player 2 doesn't confess
Player 1 confesses	P1: 2 P2: 2	P1: 10 P2: 0
Player 1 doesn't confess	P1: 0 P2: 10	P1: 8 P2: 8

Application of Game Theory

- Analysing strategic situations in economy, politics, or war
- ➢ Problem: Humans often act "irrationally" (e.g., in auctions)
- Analysing and synthesising multi-agent-systems
- ➢ These are by design rational
- ➢ Game theory as a theoretical basis for MAS
- ➢ Self interest over global optimization
  - ❖ More robust
  - ❖ Still satisfies some criteria
  - ❖ Makes everybody happy (when there are different interests)

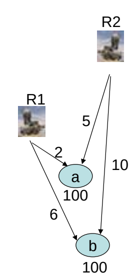
The Exploration Game

- At each point of time:
  - the utility of reaching an unexplored area first is

    C – d

    - where *C* is a large constant
    - and *d* is the distance to the area
  - If the area is not reached first, the utility is *-d*

Example Situation



	R2: a	R2: b
R1: a	R1: 98 R2: -5	R1: 98 R2: 90
R1: b	R1: 94 R2: 95	R1: 94 R2: -10

General Properties

- Choosing the point, nobody else but oneself is closest, is the dominant strategy
  - This characterises the Nash equilibrium
- The game theoretic solution corresponds to the *greedy algorithm:*
  - Iteratively, we select the pair of location and robots that have not been chosen yet and are closest to each other
  - Is not the optimal solution (i.e. does not maximize social welfare)
- Is more robust and flexible than central control

Result

Game theoretic solution

No coordination

Game Theory …

- What happens if two robots are both very close?
- What if we can exchange tasks?
- What do we do if the cost computation is computationally very costly?
- General theory behind it
  - Do we always have a Nash equilibrium?
  - How do we compute it?
  - How do we negotiate
  - What happens if we can form coalitions?
  - How can we design games so that the agents achieve a common goal?