Computational Game Theory (BE4M36MAS)

Branislav Bošanský, Tomáš Kroupa, Michal Jakob

bosansky@fel.cvut.cz

Artificial Intelligence Center
Department of Computer Science
Faculty of Electrical Engineering
Czech Technical University in Prague

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

agents autonomously act in an environment in order to reach their goal

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

agents **autonomously** act in an environment in order to reach their goal

Agent is fully accountable for its state. Agent accepts requests and individually decides about its actions

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

agents autonomously **act in an environment** in order to reach their goal

Agent perceives the environment and it is able to react to observed changes.

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

agents autonomously act in an environment in order to **reach their goal**

We are considering intelligent agents that can evaluate the state of the environment (e.g., using a utility function) and they act such that their goal is fulfilled (utility is maximized)

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

So where is game theory?

Multi-Agent Systems → Computational Game Theory

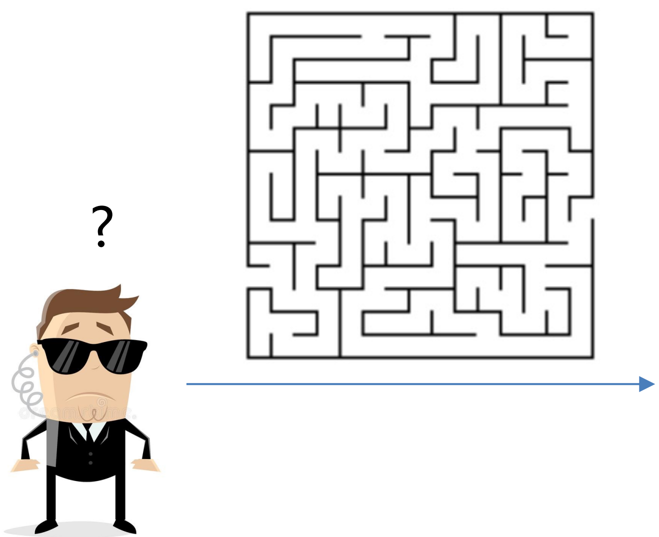
in Artificial Intelligence, we often use **agent(s)**

So where is game theory?

Game theory describes optimal behavior of an agent in a multi-agent environment where plans and decisions of the other agents are explicitly considered.

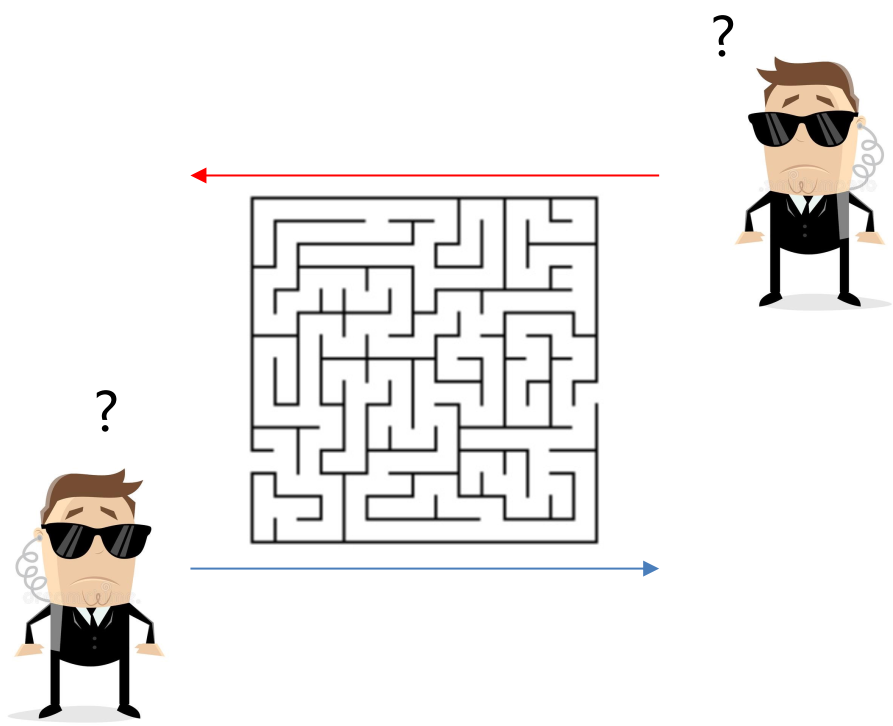
Multi-Agent Systems → Computational Game Theory

Game theory describes optimal behavior of an agent in a multi-agent environment where plans and decisions of the other agents are explicitly considered.



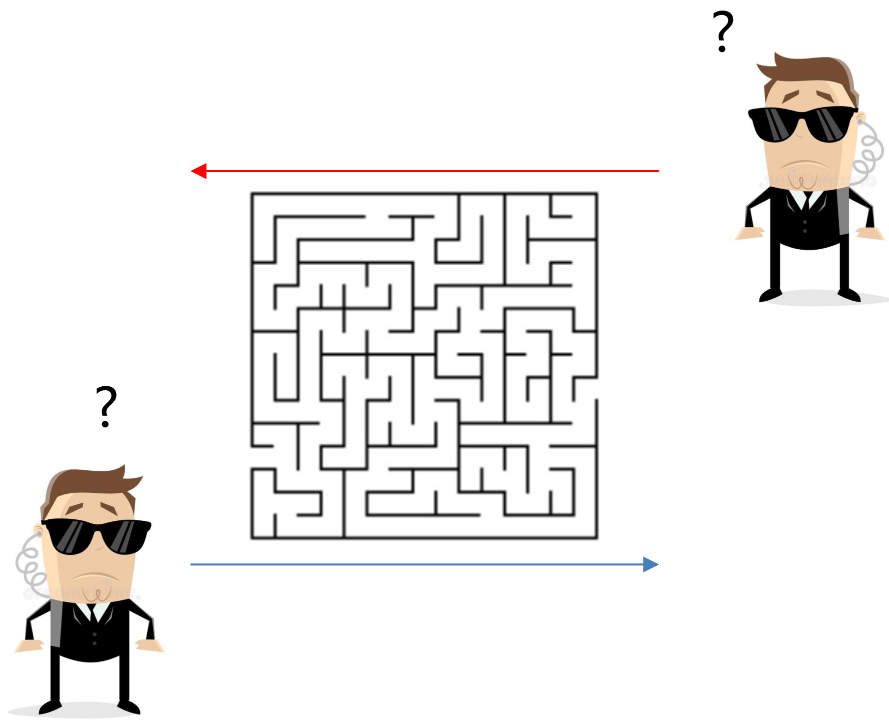
Multi-Agent Systems → Computational Game Theory

Game theory describes optimal behavior of an agent in a multi-agent environment where plans and decisions of the other agents are explicitly considered.



Multi-Agent Systems → Computational Game Theory

Game theory describes optimal behavior of an agent in a multi-agent environment where plans and decisions of the other agents are explicitly considered.



Other agents are not part of the environment (no known fixed strategy).

We know (only) their goal.

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

Why **computational** game theory?

Multi-Agent Systems → Computational Game Theory

in Artificial Intelligence, we often use **agent(s)**

Why **computational** game theory?

We want to know how to implement such agents → we are interested in algorithms that find optimal behavior.

What kind of problems we are going to solve?

Computational Game Theory

What kind of problems we are going to solve?

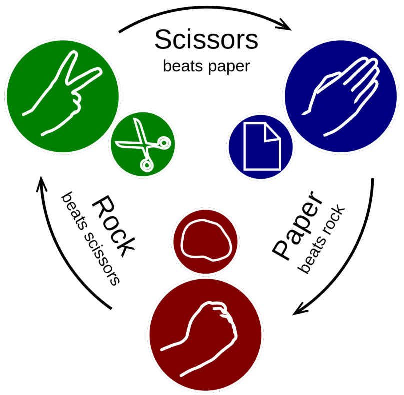
Non-cooperative game theory

Cooperative game theory

Computational Game Theory

What kind of problems we are going to solve?

One-shot games



Sequential / Dynamic

Computational Game Theory

What kind of problems we are going to solve?

Generic games

- formal representations and domain-independent algorithms for many problems

Auctions, social choice, …

- modeling and solving specific games (the restriction allow us to reason about larger problems)

Computational Game Theory

Topics			
Normal-form games	Non-cooperative	Domain-independent	One-shot
Extensive-form games			sequential
Stochastic games			sequential
Resource allocation		Domain-specific	One-shot
Auctions			One-shot / sequential
Social choice			One-shot / sequential
Cooperative games	cooperative	Domain-independent	One-shot

So why do we study game theory (MAS) at all?

What is it good for?

Computational Game Theory

Computational Game Theory is an essential part of AI and computer science

Computational Game Theory

Computational Game Theory is an essential part of AI and computer science

Evaluation of algorithms in games mark important milestones of AI:

- Checkers (1994)
- Chess (1998)

Computational Game Theory

Computational Game Theory is an essential part of AI and computer science

Evaluation of algorithms in games mark important milestones of AI:

- Checkers (1994)
- Chess (1998)
- AlphaGo (2015)
- DeepStack (2017)
- AlphaStar (2019)
- …

Computational Game Theory

Computational Game Theory is an essential part of AI and computer science

Game-theoretic algorithms can be applied in a range of problems:
- security games

Computational Game Theory

Computational Game Theory is an essential part of AI and computer science

Game-theoretic algorithms can be applied in a range of problems:

- security games
- auctions (e.g., to search keywords)

Computational Game Theory

Computational Game Theory is an essential part of AI and computer science

Game-theoretic algorithms can be applied in a range of problems:

- security games
- auctions (e.g., to search keywords)
- voting (preference aggregation)
- …

Computational Game Theory

What is AI about?

Computational Game Theory

What is AI about?

Often, it is about designing algorithms that can solve difficult problems as good (or better) as people.

Computational Game Theory

What is AI about?

Often, it is about designing algorithms that can solve difficult problems as good (or better) as people.

Game Theory steps in:

- well-defined formalisms
- it is challenging from the optimization perspective
  - single-agent problem is one level optimization (maximum/minimum)
  - games are about seeking a saddle point (bilevel optimization)

Computational Game Theory

So what will you learn (in general)?

Computational Game Theory

So what will you learn (in general)?

- formally capture an abstract problem
  - e.g., during the course you will have to formalize a complex sequential game with imperfect information

Computational Game Theory

So what will you learn (in general)?

- formally capture an abstract problem
  - e.g., during the course you will have to formalize a complex sequential game with imperfect information
- define objective criteria to optimize
  - capture correctly desired utilities and verify (is this something you (your algorithm) really want to achieve?)

Computational Game Theory

So what will you learn (in general)?

- formally capture an abstract problem
  - e.g., during the course you will have to formalize a complex sequential game with imperfect information
- define objective criteria to optimize
  - capture correctly desired utilities and verify (is this something you (your algorithm) really want to achieve?)
- new algorithms
  - many of them based on linear programming

Computational Game Theory

Lecturers:

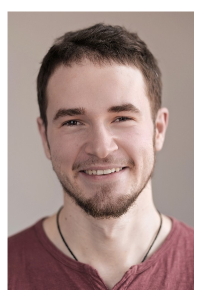
Branislav Bošanský

Tomáš Kroupa

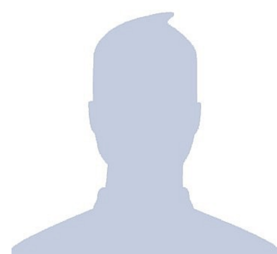
Michal Jakob

Tutors:

Dominik Seitz



Michal Šustr



Tomáš Votroubek

Aditya Aradhye

Computational Game Theory

Assessment (zápočet) from the labs: get at least 25 pts. (out of 50)

- 2 homework assignments
- 1 midterm test

Computational Game Theory

Assessment (zápočet) from the labs: get at least 25 pts. (out of 50)

- 2 homework assignments
- 1 midterm test

Exam (subject to change if necessary due to COVID restrictions)

- primarily a written exam
- brief oral part (if necessary)
- at least 25 pts. (out of 50 pts.)

Computational Game Theory

Assessment (zápočet) from the labs: get at least 25 pts. (out of 50)
- 2 homework assignments
- 1 midterm test

Exam (subject to change if necessary due to COVID restrictions)
- primarily a written exam
- brief oral part (if necessary)
- at least 25 pts. (out of 50 pts.)

Study from the books!
- Shoham, Y. and Leyton-Brown, K.: Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations.
- Weiss, G. (eds): Multiagent Systems, second edition, MIT Press, 2013
- Russel, S. a Norvig, P.: Artificial Intelligence: A Modern Approach (2nd edition), Prentice Hall, 2003