Agent-based Systems

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Introduction

Timetable

CS404 - Agent Based Systems

Weeks: 16 (14 Jan 2019-20 Jan 2019)

	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
Mon						CS404L 140 Agent Based Systems MS.02 15-24 TURRINI.P				
Tue							CS404S 35 Agent Based Systems S0.21 16-24 TURRINI.P	CS404S 35 Agent Based Systems MS.05 16-24 TURRINI.P		
Wed										
Thu									CS404L 140 Agent Based Systems WOODS-SCAWEN 15-24 TURRINI.P	
Fri								CS404L 140 Agent Based Systems IMC0.02 15-24 TURRINI.P		
Sat										
Sun										

The module

Labs	five in total, every other week, starting form the next
Coursework	50% of the mark (deadline early April)
Exam	50% of the mark

Lectures

Location	Available online. It changes.
Description	Syllabus, notes and material on the course webpage
Capture	**On** (but I would attend the lectures)
Homepage	`https://warwick.ac.uk/fac/sci/dcs/teaching/modules/cs404/`

Labs

Exercises	Questions on explained material
Tutors	There will be at least one tutor each time
Exams	Some exercises are previous exam papers of mine
Solutions	Key exercises will come with model answers

Tip 1: go to the labs and do all the exercises.
Tip 2: write everything down, even when you think it's trivial.

Coursework

- The coursework will be a Python-based implementation of a strategic agent, participating in an auction. The goal is to make money.
- You are going to be playing against one other.
- It's not a programming exercise, although it involves programming. The focus is on the strategic behaviour itself.
- There will be a coursework handout lecture (week 3), where everything will be explained in details, and a coursework hints lecture (week 10), to discuss some basics, in case you are lost.

Exam

- Questions on the material explained.
- Focus will be on precise applications of learnt techniques.
  - This means no questions like:
    "What's your view on Artificial Intelligence?"
  - But rather:
    "This is the problem: calculate the solution"
- It won't be a memory game.
  The goal is to reward the understanding of the subject.
- Everything I explain is examinable.

Interaction

- This is a course on multi-agent interaction, and I like interaction.
- The vast majority of the slides will be available before the lecture, but some will not, because I want you to think on the spot.
- All the slides will be available after the lecture.
- Don't be scared of saying wrong things (before the exam).

Questions

1. Ask them in class
2. Come and talk to me after the lectures
3. Office hour: Monday and Friday 15:00-16:00 (MSB227)
4. Send me an email (`p.turrini@warwick.ac.uk`)

Artificial Intelligence with many agents

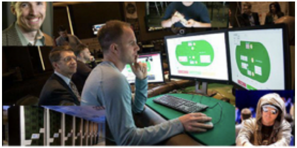
The toolbox for the design of interactive decision-makers

Artificial Intelligence with many agents

AlphaGo
Defeats the World Champion 4-1
(March 2016)

The toolbox for the design of interactive decision-makers

Artificial Intelligence with many agents

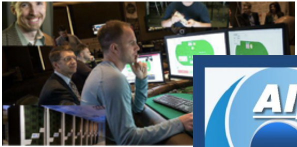


Libratus
Wins 1.7M dollars from top players
(January 2017)

AlphaGo
Defeats the World Champion 4-1
(March 2016)

The toolbox for the design of interactive decision-makers

Artificial Intelligence with many agents



Libratus

Wins 1.7M dollars fro

(January 20

AlphaGo

he World Champion 4-1

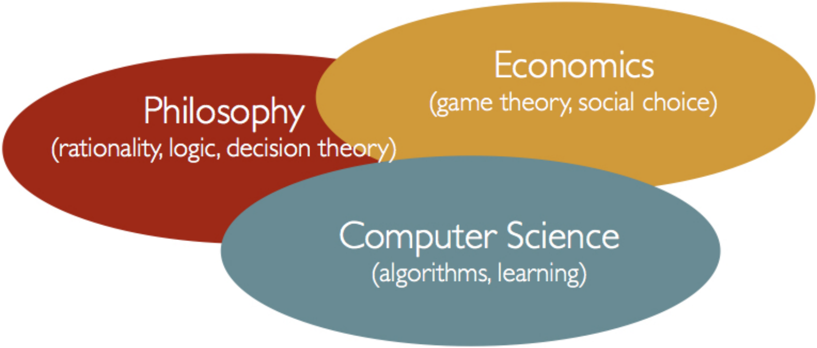
(March 2016)

AlphaZero

Defeats the best open source engine
28-0, after 9 hours of self-training
(December 2017)

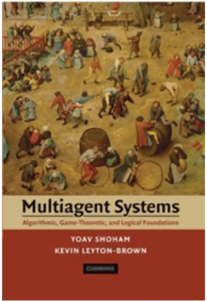
The toolbox for the design of interactive decision-makers

Connections



Important private investments: Google DeepMind

The starting kit



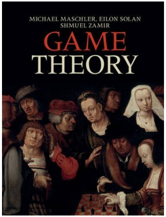
Y. Shoham and K. Leyton-Brown
Multiagent Systems: Algorithmic, Game-Theoretic and Logical Foundations
www.masfoundations.org

Helpful background basics

Discrete mathematics, probabilities, algorithms, logic.

Other important references

- M. Maschler, E. Solan and S. Zamir
  Game Theory
- Y. Shoham and K. Leyton-Brown
  Essentials of Game Theory
- S. Russel and P. Norvig
  Artificial intelligence: a modern approach



One of the most exciting books ever written

It's very useful to look at different ways of presenting the same topic!

Acknowledgments

This course would not have been possible without:

Nathan Griffiths
(the previous lecturer)

Ulle Endriss
(and his material on game theory)

Mr (soon Dr) Alex Carver
(He who created the coursework)

Agents

An **agent** is a formal model of decision-maker which:

- lives in a world, made of states
- is goal-oriented (wants to achieve some states, or sequences of states)
- has a view-point on the world
- can take actions to change the world into a different state

AlphaGo is an agent,
A Dyson vacuum cleaner is an agent,
James Bond is an agent.

An abstract comprehensive theory of (rational) decision-making

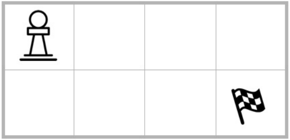
One agent

- *Up*, *Down*, *Left*, *Right*
- Wants to catch
- Hitting the wall results in no movement

Goal: Devise a plan to reach the objective.

Complications

- actions might not be fully controllable (uncertain actions, noisy environment etc)
- the agent might not know how states are connected
- the agent might not know their goal
- time might decrease the value of the goal
- the state space can be huge, and too difficult to fully calculate



We can see this as a constrained optimisation problem:
"What is the best course of actions I can take,
given the information I have about the interaction?"

Rationality

Robert J. Aumann

Nobel Prize in Economics

'A person's behaviour is **rational** *if it is in their best interests, given their information.'*

Agents (not only humans) can be rational!

Rational Agents

Robert J. Aumann

Nobel Prize in Economics

'An **agent***'s behaviour is* **rational** *if it is in their best interests, given their information.'*

Agents (not only humans) can be rational!

Multi-agent Systems

A **multi-agent system** is any situation with more than one agent.

- their goals might be interdependent (one against the other, or they need one another to achieve them)
- each have view points on the world, the other agents, and view points about the other agents viewpoints!
- their choices are interdependent, too: the world state changes as a function of what **all** agents do.

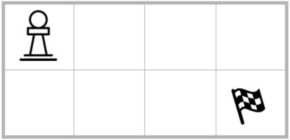
More than one agent

- ♙ moves
- 🏁 moves too!
- ♙ wants to catch 🏁
- 🏁 wants to catch ♙

Complex strategic behaviour

More complications

- turn-taking or simultaneous actions?
- cooperation or competition?
- difference in view-points, are agents playing the same game?
- many agents, and many games played at the same time



A complex constrained optimisation problem:

"What is the best action I can take, **given** the information I have about the environment and the opponents, and the information I have about the information they have about me, and the information I have about the information they have about the . . . (too long to write) . . . ?"

Week 1, Lecture 2: Strategies

- A formal definition of the world:
  - states
  - transitions
  - actions
  - winning conditions
- Strategies, as opposed to actions.
- Results on ‘simple’ games: Chess and Zermelo’s theorem.

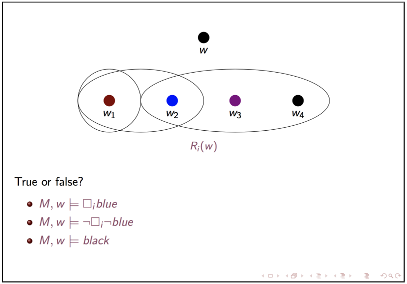
The very basics of strategic behaviour in multi-agent interaction.

Week 1, Lecture 3: Knowledge

- What it means "to know" something:
  - a mathematical definition of knowledge
  - properties of knowledge
- What it means to know something, "together":
  - general knowledge
  - distributed knowledge
  - common knowledge
- Knowing that versus knowing how

Week 2: Logic

- Agents that can reason
  - What are inferences?
  - Why are they useful?
- Modelling reasoning in logic
  - Restricting the language
  - Expressivity and complexity
- Modal logic
  - Worlds and possible worlds
  - Connection with set theory



Week 2: Logic

- How to reason with knowledge:
  - epistemic logic
- How to reason with strategies:
  - coalition logic
- How to reason with goals and preferences:
  - preference logic

$$K_i\varphi \to K_iK_i\varphi$$

"if I know something, then I know that I know it""

Expressing complex strategic reasoning within one simple language

Week 3: Expected Utility

- Logical languages:
  - succinct
  - elegant correspondences
- But, sometimes, we need a more fine-grained structure
- From formulas to numbers

A probability space or probability model is a sample space Ω with an assignment $P(w)$ for every $w \in \Omega$ s.t.

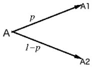
$0 \leq P(w) \leq 1$

$\Sigma_w P(w) = 1$

Week 3: Expected Utility

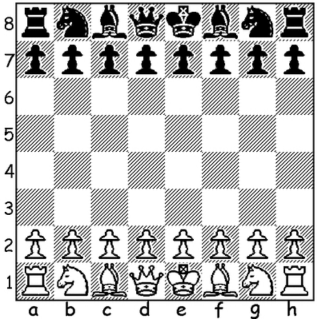
- Probabilistic beliefs:
  - conditional probability
  - Bayesian reasoning
- utility and preferences
  - von Neumann-Morgenstern Representation Theorem
- Rationality as expected utility

Lottery $A = [p, A_1;\ (1-p), A_2]$



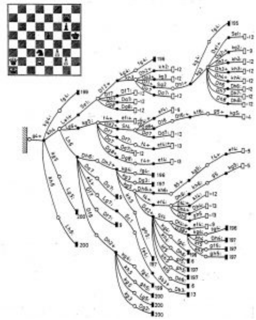
The mathematics of rational behaviour

- Rational players
- Interdependent actions
- Conflict



Week 4: Games

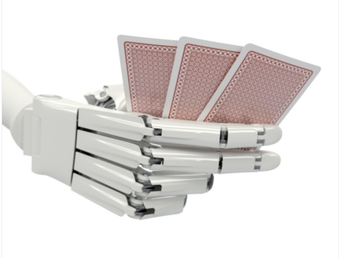
- Strategic games:
  - equilibria
  - expected utility in games
- Extensive games:
  - backwards induction
  - relation to strategic games
  - imperfect and incomplete information



The mathematics of rational behaviour in interaction

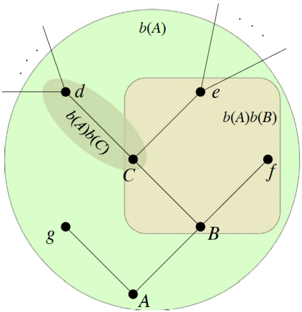
Week 5: Knowing the game

- What do we need to know in order to play rationally?
- We might not be able to fully assess the consequences of our own decisions
- Exploiting the opponents weaknesses and the team-mates' strengths



Week 5: Knowing the game

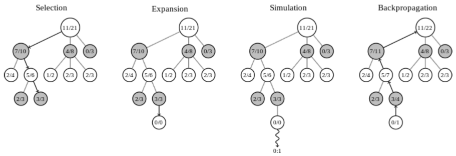
- Common knowledge of rationality and backwards induction (Aumanns Theorem)
- Strategic reasoning in games with limited foresight (like in chess)
- Bluffing, risk, and counterfactual regret minimisa (like in poker)



Procedures for complex strategic thinking
(in games that matter to AI)

Week 6: MDPs and Learning

- Complicating further:
  - discounting
  - patience
  - stochastic actions
- Trial and error:
  - self-play
  - learning from experience

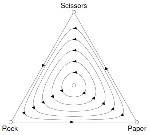


Week 6: MDPs and Learning

- Markov Decision Processes (modelling and optimisation)
- Reinforcement Learning (basics)
- Multi-agent Reinforcement Learning (and connection with repeated games)

Rock-Paper-Scissors

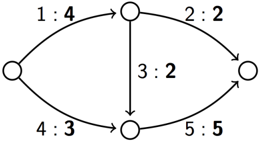
	R	P	S
R	0	-1	+1
P	+1	0	-1
S	-1	+1	0



Modelling rationality with partial observation, in interaction

Week 7: Cooperation

- Agents working together
- Collective decision-making
- Competing within fair rules



Week 7: Cooperation

- Cooperative Games (intuitions and models)
- Solution Concepts (Stability)

$$
\begin{array}{lll}
v(\{1\}) = 0 & v(\{1,2\}) = 7 & v(N) = 10 \\
v(\{2\}) = 0 & v(\{1,3\}) = 6 & \\
v(\{3\}) = 0 & v(\{2,3\}) = 5 &
\end{array}
$$

The mathematics of coopearative behaviour

- Voting (intuitions, models)
- Different rules and interrelations
- What are good voting rules?

$$\triangle \succ_1 \bigcirc \succ_1 \square$$

$$\square \succ_2 \triangle \succ_2 \bigcirc$$

$$\bigcirc \succ_3 \square \succ_3 \triangle$$

$$?$$

Week 8: Social Choice

	A	B	C
Judge 1:	yes	yes	yes
Judge 2:	no	yes	no
Judge 3:	yes	no	no
Majority:	yes	yes	no

A: witness is reliable

B: *if* witness is reliable *then* guilty

C: guilty

note that $A \wedge B \rightarrow C$

- Desirable properties (and corresponding rules)
- Putting them together (impossibility theorems)
- Logic-based voting (judgment aggregation)

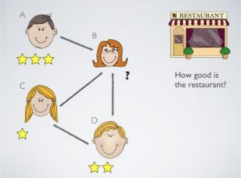
Designing procedures for collective decision-making

Week 9: Social Agents

- How to divide resources fairly?
- How to form coalitions fairly?
- How to design fair evaluation systems?

Week 9: Social Agents

- Fair division (intuitions, protocols)
- Matching (Gale-Shapley Algorithm)
- Social Networks (and online rating)



Designing cooperation and competition, together

Week 10: Recap

- Coursework hints for those who are hopelessly lost
- Review 1 (your input matters!)
- Review 2 (same here)

What we have seen

- The course plan
- Agents: first definition
- Agents and multi-agent systems
- Rationality

Coming next

- Modelling actions, plays and wins
- Strategies