LECTURE 5: Multiagent Interactions

KK04203 Intelligent Agents

Taken and modified from "An Introduction to MultiAgent Systems"
by Michael Wooldridge, John Wiley & Sons, 2009, COMP310 course of UoL by Terry Payne
and "Agent Technology for e-Commerce" by Maria Fasli

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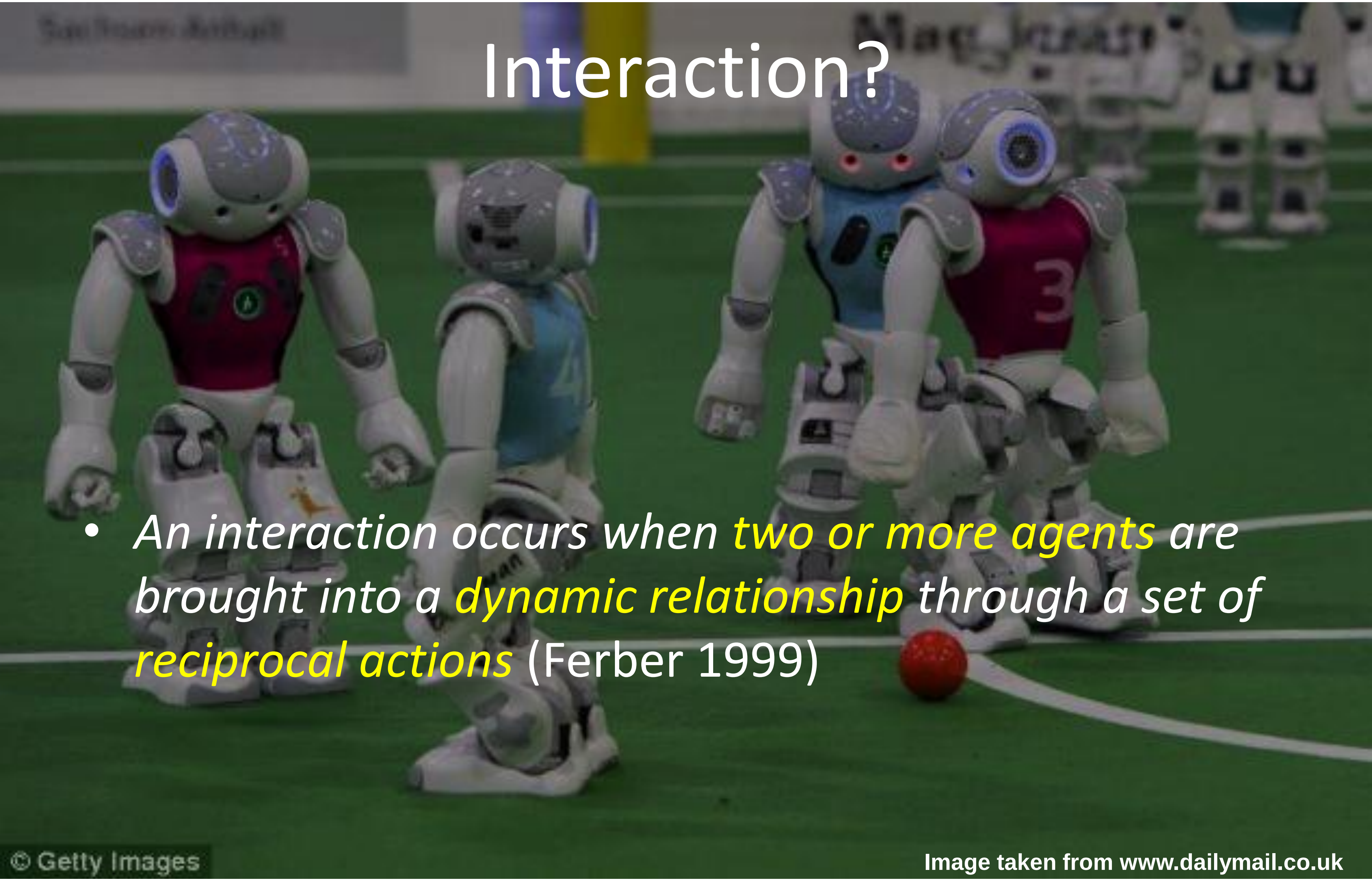
Expected learning outcomes

- To understand the concept of agent interactions
- To understand the solution concepts for MAS interactions

Outline

- Interactions definition
- Modes of interaction
- MAS interaction
- Solution concepts
- Agents interaction examples
- Summary

Interaction?



- *An interaction occurs when two or more agents are brought into a dynamic relationship through a set of reciprocal actions* (Ferber 1999)

Image taken from www.dailymail.co.uk

Interactions

- Interactions develop as a result of a series of actions whose consequences influence the future behavior of agents
- May be direct or indirect, intended, or unintended
- Interaction assumes:
  - Agents that are capable of acting and/or communicating
  - Situations that promote interaction
  - Dynamic elements allowing for local and temporary relationships among agents

Elements of Interactions

- **Goals**: Goals of different agents can be conflicting. goal(A) $\rightarrow \neg$satisfies(goal(B))
- **Resources**: Resources are limited, other agents may want to use them as well. Conflicts may arise
- **Expertise/skills/capabilities**. Agents may lack the necessary skills, expertise of capabilities for accomplishing one or more of their tasks. They may require the 'help' of others.

Agent characterisation

- **Self-interested/ antagonistic agents**: incompatible goals, interested in maximising own utility, competitive
- **Cooperative/ nonantagonistic agents**: compatible goals, interested in maximising own and the entire system utility

Modes of Interaction

Goals	Resources	Skills	Modes
Compatible	Sufficient	Sufficient	Independence
Compatible	Sufficient	Insufficient	Simple cooperation
Compatible	Insufficient	Sufficient	Obstruction
Compatible	Insufficient	Insufficient	Coordinated cooperation
Incompatible	Sufficient	Sufficient	Pure individual competition
Incompatible	Sufficient	Insufficient	Pure collective competition
Incompatible	Insufficient	Sufficient	Individual competition over resources
Incompatible	Insufficient	Insufficient	Collective competition over resources

MAS Interaction

$$
\begin{array}{llll}
u_i(\omega_1) = 1 & u_i(\omega_2) = 1 & u_i(\omega_3) = 4 & u_i(\omega_4) = 4 \\
u_j(\omega_1) = 1 & u_j(\omega_2) = 4 & u_j(\omega_3) = 1 & u_j(\omega_4) = 4
\end{array}
$$

⬇

$$
\begin{array}{llll}
u_i(D, D) = 1 & u_i(D, C) = 1 & u_i(C, D) = 4 & u_i(C, C) = 4 \\
u_j(D, D) = 1 & u_j(D, C) = 4 & u_j(C, D) = 1 & u_j(C, C) = 4
\end{array}
$$

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Payoff matrices:

		i	
		defect	coop
j	defect	1 1	4 1
	coop	1 4	4 4

Agent j is the *row player*

Agent i is the *column player*

Solution concepts

- Given any scenario, the basic question need to be answered is: ***What should I do?***
  - **Dominant strategies**
  - **Nash equilibria**
  - **Pareto efficiency**
  - **Maximising social welfare**

Dominant strategy

- A strategy s_i for agent *i* is dominant if it is the best response to all of agent *j*'s strategies – s_i gives the highest pay-off to *i* when played against s_j
- Unfortunately, there isn't always a dominant strategy

$$
\begin{array}{llll}
u_i(D,D)=1 & u_i(D,C)=1 & u_i(C,D)=4 & u_i(C,C)=4 \\
u_j(D,D)=1 & u_j(D,C)=4 & u_j(C,D)=1 & u_j(C,C)=4
\end{array}
$$

- In the above example, for both agents, cooperation is the dominant strategy

Nash Equilibrium

- Strategies s_1 and s_2 for agents i and j form a Nash equilibrium if *they are the best response to each other*
- In general, s_1 and s_2 are in Nash equilibrium if:
  1. under the assumption that agent i plays s_1, agent j can do no better than play s_2; and
  2. under the assumption that agent j plays s_2, agent i can do no better than play s_1.
- *Neither agent has any incentive to deviate from a Nash equilibrium*
- Unfortunately:
  1. *Not every interaction scenario has a Nash equilibrium*
  2. *Some interaction scenarios have more than one Nash equilibrium*

Nash Equilibrium

- **Matching pennies** – if same face, agent *i* wins, otherwise agent *j* wins

	i heads	i tails
j heads	1 -1	-1 1
j tails	-1 1	1 -1

No pure strategy Nash equilibrium

Pareto Efficiency

- A solution is Pareto efficient *if there is no other outcome that improves one agent's utility without making other agent worse off*
- A solution/ outcome *w* is Pareto inefficient if there is another outcome *w'* that makes at least one agent better off without making anybody else worse off – some utility is wasted

Maximising social welfare

- The social welfare of an outcome *w* is the sum of utilities of each agent for the outcome *w*:

$$\sum_{i \in Ag} ui(w)$$

- May be appropriate if all agents within a system have the same 'owner' (the overall utility of the system is more important, not individual agents)

Agents interactions

- Competitive & zero-sums interactions
- The prisoner’s dilemma

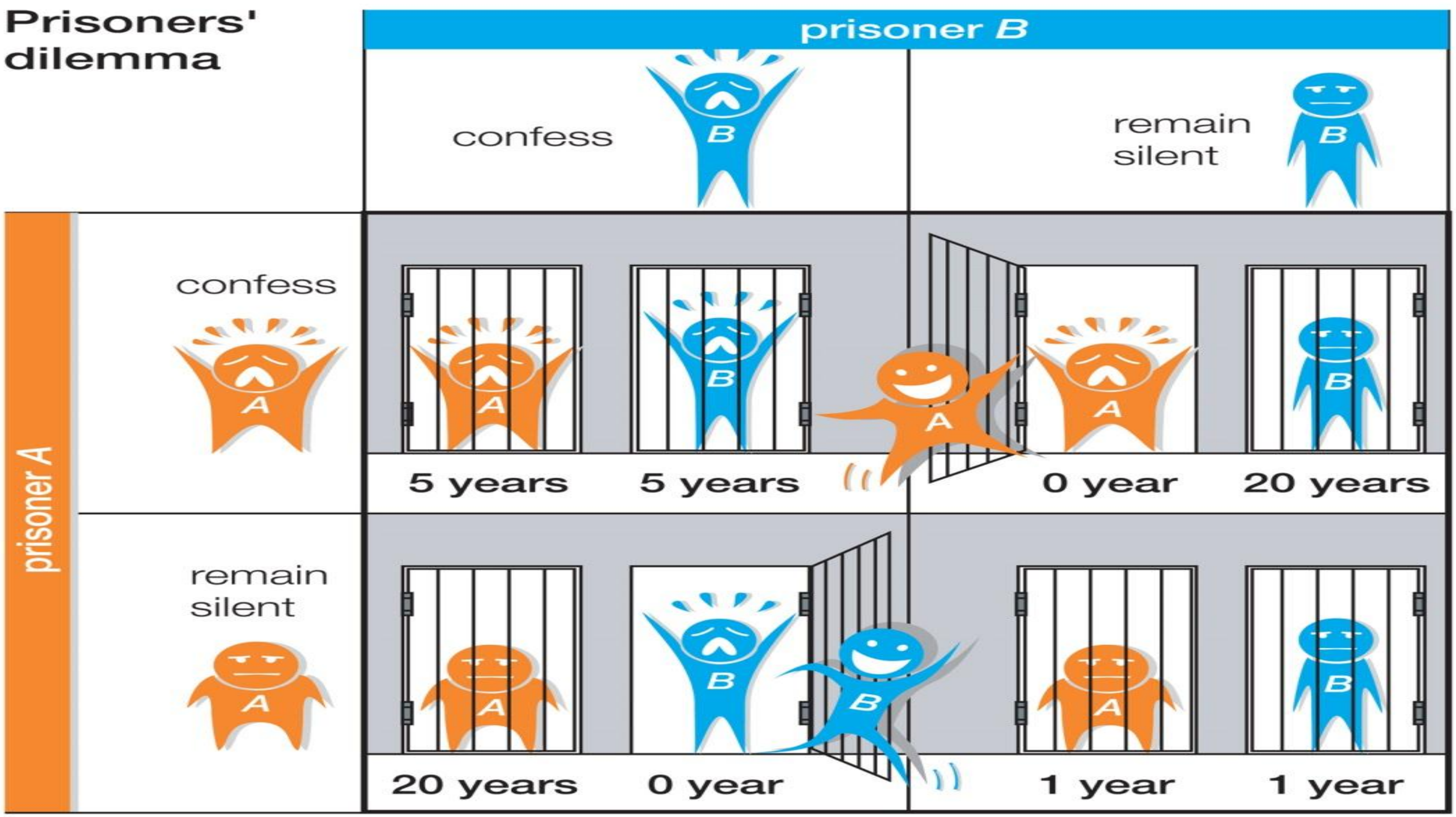
Competitive & zero-sums interactions

- Where preferences of agents are diametrically opposed we have *strictly competitive* scenarios
- Zero-sum encounters are those where utilities sum to zero:

$$u_i(\omega) + u_j(\omega) = 0 \qquad \text{for all } \omega \in \Omega$$

- For example: chess, checkers and most of the games
- The best outcome for me is the worst for you!

The prisoner's dilemma



The prisoner's dilemma

- Two men are collectively charged with a crime and held in separate cells, with no way of meeting or communicating. They are told that:
  1. **if one confesses and the other does not, the confessor will be freed, and the other will be jailed for three years**
  2. **if both confess, then each will be jailed for two years**
  3. **Both prisoners know that if neither confesses, then they will each be jailed for one year**

The prisoner's dilemma

- Defects = confessing
- The numbers show how good an outcome is for the agents

	i defects	*i* cooperates
j defects	2	0
	2	5
j cooperates	5	3
	0	3

$U_i(D,D) = 2,\ U_i(D,C) = 5,\ U_i(C,D) = 0,\ U_i(C,C) = 3,$

$U_j(D,D) = 2,\ U_j(D,C) = 0,\ U_j(C,D) = 5,\ U_j(C,C) = 2,$

Order of preferences

$(D,C) >_i (C,C) >_i (D,D) >_i (C,D)$ and

$(C,D) >_j (C,C) >_j (D,D) >_j (D,C)$

The prisoner's dilemma

- Defects = confessing
- The numbers show how good an outcome is for the agents

	i defects		*i* cooperates	
j defects		2		0
	2		5	
j cooperates		5		3
	0		3	

The best strategy??

If the other player cooperates, I will defect
If the other player defects, I will defect

The prisoner's dilemma

- The *individual rational* action is *defect*
  This guarantees a payoff of no worse than 2, whereas cooperating guarantees a payoff of at worst 0
- So defection is the best response to all possible strategies: both agents defect, and get payoff = 2
- But *intuition* says this is *not* the best outcome: Surely they should both cooperate and each get payoff of 3!

The prisoner's dilemma

- This apparent paradox is *the fundamental problem of multi-agent interactions*
  It appears to imply that *cooperation will not occur in societies of self-interested agents*

Solution concept & prisoner's dilemma

- **D** is the dominant strategy
- (**D**, **D**) is the only Nash equilibrium
- All other outcomes except (**D**, **D**) is Pareto efficient
- (**C**, **C**) maximizes social welfare

Summary

- Elements of interactions have been defined
- Solution concept and MAS interaction were presented
- **What's next?**
  - Cooperation