

Emergence in Cognitive Multi-Agent Systems

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- Reactive Systems
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Emergence in Cognitive Multi-Agent Systems

overview



Emergence – essential issue in the engineering of multi-agent systems.

- lower (micro) level – simple entities that interact.
- higher (macro) level – complex behaviour of the system as a whole.

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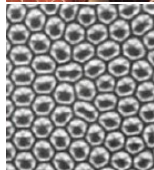
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- Most studies of emergence use reactive agent systems.

- Cognitive systems are more capable.



What **emergents** could be obtained if agents were **cognitive**?



■ Definitions of Emergence

Emergence is:

- the concept of some **new** phenomenon arising in a system that wasn't in the **system's specification** to start with.

[Standish, 2001]

- coherent emergents at the **macro-level** that **dynamically** arise from the **interactions** between the parts at the micro-level. Such emergents are **novel** with respect to the individual parts of the system.

[De Wolf and Holvoet, 2005]

- in the context of an interacting set of agents whose dynamics are expressed in a vocabulary D , a **global** phenomenon – static or dynamic, but nevertheless invariant – that is observed by the agents or by an external **observer** and can only be interpreted in a **vocabulary** D' that is different from D .

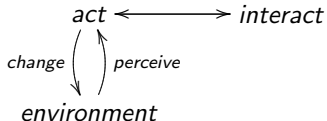
[Beurier et al., 2002]

Important: emergence allows obtaining a function / behaviour of higher level from the interaction of lower level entities.



- Emergence in Reactive Agent Systems

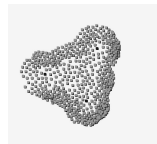
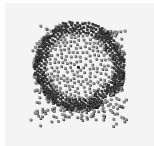
· Simple behaviour:



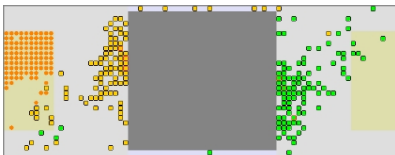
· Examples of emergents:



[Beurier et al., 2002]



[Zambonelli et al., 2004]



[Picard and Toulouse, 2005]



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Types of emergents:

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mobility	states	other features	emergents
fixed	binary	live / die rules	conservation of species ; gliders [Gardner, 1970]
mobile	multiple	attraction & repulsion	shape formation [Zambonelli et al., 2004]
		reinforcement learning	multi-level shapes [Beurier et al., 2002]
		transportation of resources	area coverage [Bourjot et al., 2003]
			accumulation of resources [Randles et al., 2007]
			traffic direction [Picard and Toulouse, 2005]



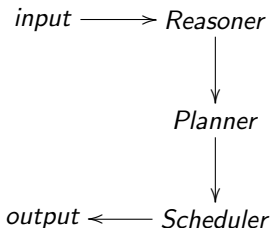
Cognitive agents feature:

- beliefs / knowledge
- desires / goals
- intentions
- plans

information about **self**

- what it wants to do
- what it is able to do
- how it can do it

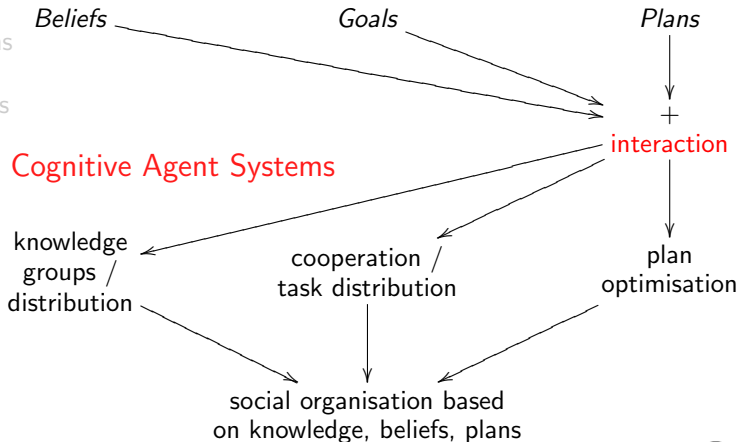
Components:



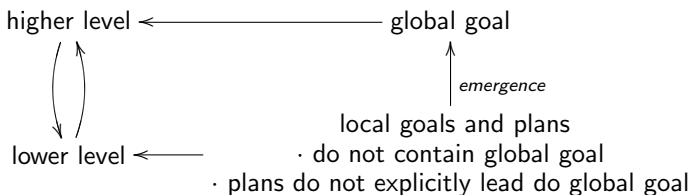
Expected emergents are based on

- components of cognitive agents
- interaction – attraction, repulsion, exchange

■ Emergence in Cognitive Agent Systems



Expected behaviour:



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- Cognitive emergence – achieving a high level **global goal** through the interaction between agents that follow their **own, individual, possibly selfish,** goals.



Cognitive multi-agent system for data distribution.

System specification:

- capacity: 4 chunks; data in the system: 6 chunks.
- communication only with the 8 neighbours
- agent objectives
 - ▶ ready for incoming data \Rightarrow keep capacity $\leq 75\%$
 - ▶ get interesting data (if capacity $< 75\%$)
 - ▶ inform other agents of current content

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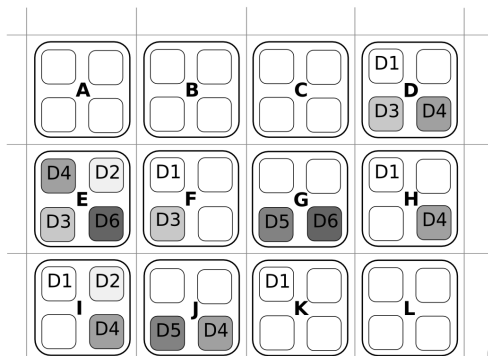
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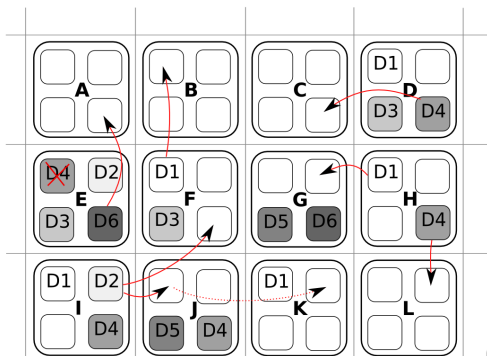
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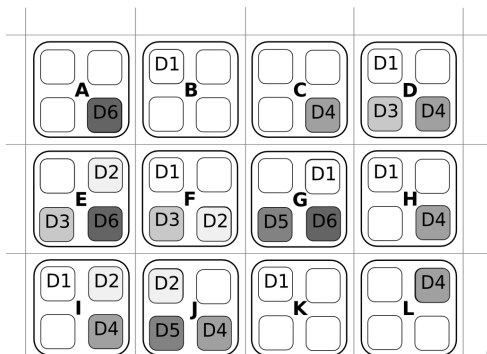
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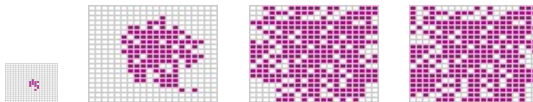
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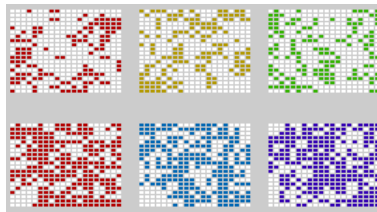
Results: data storage, distribution and availability

Output:

- distribution of one data chunk in a system with 6 chunks:



- distribution for 6 chunks of data, after stabilisation:



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- Emergence is a key issue in the study of multi-agent systems.

- Reactive Systems

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- As computing capabilities grow, even for small devices, the cognitive approach becomes a promising direction of development.

- Cognitive Emergence

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- Emergents in cognitive agent system are expected to relate not only to position and state, but to organisation based on beliefs, goals and plans.

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