

Emergent Intelligence of Large-Scale Multi-Agent Systems

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Abstract: Large-scale multi-agent systems exhibit emergent behaviour which is remarkably similar to that found in complex adaptive systems such as ecology, global economy, language, large cities and human brain.

An analysis of the behaviour of a multi-agent road transportation scheduler containing thousands of agents engaged in the simultaneous allocation of loads and drivers to trucks and trucks, roads and loading/unloading bays to journeys, shows that software agents autonomously (without being instructed) and collectively (through a process of negotiation) make many decisions that can be characterised as intelligent. Here are some examples: (a) in response to unpredictable events (such as the arrival of new orders, cancellation of previously allocated orders, failures of trucks and closures of roads), agents autonomously re-schedule the operation in a way that accommodates the disruptive event in real time and causes minimum disruption to unaffected parts of the schedule; (b) agents decide whether to compete or co-operate with each other; (c) agents form coalitions whenever a group of agents realises that they have certain interests in common and abandon them when coalitions stop being effective; (d) agents incrementally build a schedule and when the scheduling process starts giving diminishing returns, destroy it and start building a new schedule from scratch; (e) agents learn from experience by discovering patterns of behaviour that lead to successful results and converting these patterns into rules for scheduling; (f) agents anticipate the arrival of orders based on experience and schedule them in advance, correcting the schedule if the anticipated orders do not materialise.

Observations of large-scale multi-agent systems show that intelligent behaviour emerges from agent interaction; it is not present when individual agents act independently.