

CS3910

Computational Intelligence

Literature review

What practical applications has self-organisation been used in, and what was the impact of using self-organisation in those applications?

**Literature searching strategy** –

First planning my search based on a topic or area with what I already know and record it for the bibliography. As well as information that I do not currently know about the given subject and using focused and thought about keywords to find relevant literature using tools such as Aston’s library, and online bibliographic databases such as SCOPUS.

Developing keywords such as synonyms, alternative spellings etc to be able to find and extend to a wider range of publications that I can find involving the topic I care about and I will be using a keyword mind map to divide my searches into various subtopics which will help me see and visualise which nouns/synonyms are most effective for that given area.

**Introduction:**

This literature review is aimed at answering the question, “what applications self-organization has been used in, and what was the impact of using self-organization in that application.” By structuring the literature review based on a few themes or topics, that directly relate to self-organization I aim to gain a better understanding in this topic area by looking at and discussing the similarities or differences of each article and how they relate to each other and support the themes I have used to organise this review.

**Emergent behaviours of self-organization in different applications:**

Self-organization is a process by which a system has been constructed internally from itself without any external input —F. E. Yates et al. (1978), Self-Organizing Systems: The Emergence of Order. There have been many applications that have been built off this underlying concept of self-organization. Each piece of research shows that there are many emergent behaviours that arise from the implementation of these applications, these emergent traits are products of the system’s individual agents collaborating with each other which in the small scope of things seem insignificant, but when looked at as a whole is very useful and achieves the intended goal of the application which can be perceived as a more “intelligent” behaviour.

Jolana Sebestyénová and Peter Kurdel’s research, [1] looks at how using self-organization with a swarm of robots can be used in applications that make robots perform jobs that are too dangerous to humans, such as search and rescue or searching for targets in a battle environment. By using each individual robot as agents of the system which communicate between one another, and perform actions based on the environment and other agent’s actions. Ultimately generating an emergent behaviour which is a co-ordinated search area. This is like collective intelligence, this emergent property that can be observed is the intended goal of the system.

Similarly, a different application which uses self-organization that also produces emergent behaviours is [2], this paper proposes you can create complex yet efficient wireless networks. By using the mobile devices (nodes) as agents which communicate to each other like how [1] uses robots, the common issue that arises when designing and constructing networks are energy consumption, robustness and adaptability [2]. The communication between these individual components is what produces the emergent behaviour, that the intended designers of the system wanted to create to achieve their goal in improving energy consumption on a wireless network which is supported by the experiments they performed.

[3], also demonstrates and supports the theme of emergent behaviours when using self-organization. It shows how layout automation can be produced by utilising the concepts of self-organization, representing modules as individual components that have small goals and the local interactions between each other when collated, emerges a high-level control system which shows how self

organization can autonomously move, rotate and deform modules based on constraints to produce various layout solutions. The results in this study indicate that self-organization in fact improves the layout of devices for possible solutions.

These research papers show that the concept of self-organization brings about emergent behaviours, from the interactions of individual components within the system. This behaviour is the intended product that will meet the goal of the application. The impact of using self-organization in these applications is significant, as the results from their respective experiments show improvements on what can currently be done already, or even an alternative solution for implementation. Take [1], for example the simulation results using the same parameters based on previous research in the field show that self-organization enhances the number of steps taken to achieve a goal state. Similarly, [2] offers an alternative implementation of constructing wireless networks for improving energy consumption by using a multi-agent-based model using mobile devices.

However, [4] an application that uses self-organization to regulate and manage a smart grid, continuously adapting and updating itself to efficiently direct power amongst different constituencies. states that in some cases the emergent behaviour brought from the collective interactions may produce an unwanted side effect which may in fact hinder the intended goal of the system. Therefore, the author proposes a safety measure based off other applications and research to ensure that this does not occur by ensuring that the controller architecture which feeds the agents information does not prematurely give information, in case factors change.

When comparing to other applications that self-organization has been used in such as [1] and [2], it may be beneficial to take careful consideration into how the agents get information from their environment and design it as such so that the information given to the agents at run-time is correct to devoid any unwanted emergent behaviours which conversely effect the system. Like [4], [1] has done this by ensuring that each agent is controlled with reactive programming to react to its environmental factors, so it is able to adapt to unforeseen circumstances and minimise the risk of failure. Conversely, [2] and [3] do not mention unwanted emergent behaviours or talk about any features of their application that take it into account implying a potential weakness of their applications that could be critical to the success of the system when it comes to adaptability and durability.

[4] uses an observer, controller architecture which only feeds information to the agents based on a defined goal (improve performance), in the event of failure it would result in large economic loss and even endanger human life. it also indicated that not all emergent behaviours are beneficial and that any application that uses self-organization should consider how to manage these unwanted behaviours to optimise their systems.

Therefore, it may be a crucial consideration for systems that choose to implement self-organization, that they find ways to deal with unpredicted emergent behaviours so that their system can function correctly as expected and avoid any system failures.

The impact of using self-organization in these applications is clear, with each paper highlighting how the use of this evolutionary algorithm has improved performance when compared to other implementations of the same application and enable the system to actively adapt its agents to changes from the environment making it more robust resulting in various beneficial emergent behaviours.

**Collective Intelligence in self-organization applications:**

Mentioned previously in the papers that utilised self-organization for their own applications each gave rise to their own emergent behaviours. You can consider self-organization and the way it has been implemented into different systems as a collective intelligence. Since individual components of the system will engage and interact with each other, seemingly noncomplex actions. But combined is a higher or more significant behaviour that can be seen [5].

All the papers previously talked about, their applications display collective intelligence and this concept is closely related to emergent behaviour. [1] represents robots as individual agents where by themselves are not intelligent but combined with agents of the collective group can achieve a task which requires form of intelligence. E.g. being able to co-ordinate individual search paths for each agent in conjunction with each other to cover a wide area and find specific targets.

This can also be seen in [2], each mobile device communicating to each other to establish strong wireless connections and optimise the network during run -time. Alone these devices cannot achieve such a complex goal. Additionally [3], and [4] also make use of various individual agents to create an emergent behaviour which can be seen as collective intelligence.

To further support the concept that self-organization can be seen to carry collective intelligence, a research paper found [8] that navigates aircrafts during flight by reconfiguring the aircraft’s flight path during run-time in relation to environmental factors and changes. By using various components in conjunction with each other, DES (Dynamic Expert system), CS (Control System) and KB (Knowledge base). Whereby each component interacts and communicates with each other to calculate the flight path. By definition given by [5] this is collective intelligence. Results from this article show that efficiency of navigation is improved due to early detection of errors.

It is evident that systems or applications that have multiple components can effectively use self-organization and reap the benefits that this evolutionary algorithm provides, to create a system that is independent and able to self-adapt to meet a goal.

Suggesting systems that have multiple agents may be able to use self-organization to its full potential, as the concept of the algorithm synergises with the infrastructure of the model representing the system’s agents as components to communicate and collaborate to achieve a goal. Compared to a system that has very few agents.

Overall, showing that the emergent behaviour self-organization produces in applications is brought about from collective collaboration between individual components which improves application performance which is indicative of their respective results proving the impact of this algorithm to be extremely positive in these discussed applications.

**Self-Adaptiveness in self-organization applications:**

A commonality between the applications that use self-organization is that all their systems result in being adaptable which is only possible due to the collective interactions that adjust themselves based on environmental changes.

In [6] it proposes a self-adaptive mechanism for coalitions formation in a robot network. Implementing it in such a way that if any unpredictable events occur; such as robot failure or weak communication, the system self-regulates (adapts) how it distributes its agents amongst its targets. Similar to how the application in [1] adapts its agents to deal with environmental changes or how [4] changes the distribution of power according to information that is fed to the agents.

Additionally, [7] talks about using self-organization for its adaptive capabilities outlining where this feature would be most suitable involving an application for an “intelligent shop-floor”. Where the shop-floor updates and reallocates, its resources based on time-based requirements i.e. what resource does the shop floor need now and where. Which closely resembles the self-adaptive nature of [6], [4] and [1]. Indicating that self-adaptiveness is an inherent factor that is embedded into systems that use self-organization.

The adaptive nature of self-organization is ideal for this application due to the constant changing and need for reconfiguration of the shop-floor where change is brought about from the customer’s needs. Meaning, the system must be adaptive and robust to cater for the consistent changes that self-organization can provide.

**Conclusion**

The commonalities between all these papers are no coincidence evidence indicates that systems which use self-organization in their applications, adopt perks of adaptiveness and robustness, and seemingly carry collective intelligence which produces an emergent behaviour. Due to the nature of the algorithm, systems can self-adjust and change itself in accordance to the goal at the current time. The fact self-organization has been used in a wide range of applications for different purposes. Shows any application that implements it, is adaptable and robust because it has improved on what can already be done when compared to similar applications with traditional or different approaches, even yielding better results showing that this evolutionary algorithm has had significant impact in all the applications mentioned in this review.

[3] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7451008>

[5] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6527413> T

[8] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6256521>

[7] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6676500>

[6] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7985773>

[6] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8167687> T

[7] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7593295> T

[8] <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8501679> T**Conclusion**

The commonalities between all these papers are no coincidence, evidence indicates that systems that use self-organization in their applications adopt perks of adaptiveness and robustness. Due to the nature of the algorithm, systems can self-adjust and change itself in accordance to the goal at the current time. Due to the fact self-organization has been used in a wide range of applications for different purposes, any application that implements self-organization is adaptable and robust because it has improved on what can already be done when compared to similar applications with traditional or different approaches. Yielding better results showing that this evolutionary algorithm has had significant impact in all the applications mentioned so far.

Annotated Bibliography

1.[Christos Filelis-Papadopoulos](https://ieeexplore.ieee.org/author/38319869200), [Huanhuan Xiong](https://ieeexplore.ieee.org/author/37086019109), [Adrian Spătaru](https://ieeexplore.ieee.org/author/37086153679), [Gabriel G. Castañé](https://ieeexplore.ieee.org/author/38270725400), [Dapeng Dong](https://ieeexplore.ieee.org/author/37070380400), [George A. Gravvanis](https://ieeexplore.ieee.org/author/37282673000), [John P. Morrison](https://ieeexplore.ieee.org/author/37281881700). (2017). A Generic Framework Supporting Self-organisation and Self-management in Hierarchical Systems**.**[2017 16th International Symposium on Parallel and Distributed Computing (ISPDC)](https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=8119479)

This publication looks proposes a generic framework that supports the concepts of self-organisation and self-management which determine the structure of each level within the hierarchy to build complete functioning computer systems. Exploring how small local components evolve to achieve their goal. Making indications and findings where rate of evolution of these automated methods slow down as they get closer to the goal.

## 2. [Mirko Viroli](https://ieeexplore.ieee.org/author/37285078600), [Antonio Bucchiarone](https://ieeexplore.ieee.org/author/37564705400),[Danilo Pianini](https://ieeexplore.ieee.org/author/37586771300),Jacob Beal. (2016). [Combining Self-Organisation and Autonomic Computing in CASs with Aggregate-MAPE](https://ieeexplore.ieee.org/document/7789466/). [2016 IEEE 1st International Workshops on Foundations and Applications of Self\* Systems (FAS\*W)](https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=7784661)

This paper shows how using self-organisation in conjunction with autonomous behaviour MAPE (monitor-analyse-plan-execute) it is possible to create a framework which enables for a self-programming CAS (collective adaptive system) which can then be used in a given application, in this case crowd dispersal in a large scale smart mobility environment. It looks at how a system can be independently adaptive with no human interaction, to solve socio-technical problems using individual components (agents) which react to stimuli and adapt accordingly to address to problems in run-time.

3. Vivek Singh, Garima Singh, Suparna Pande. (2013). Emergence, Self-organization and Collective Intelligence - Modeling the Dynamics of Complex Collectives in Social & Organizational Settings. 2013 UKSim 15th International Conference on Computer Modelling and Simulation

This research explores how the emergent and self-organisation behaviours or products are often coincided with the concept of collective intelligence. Where behaviours of individuals may seem insignificant and small but combined with others can be seen as an intelligent behaviour which achieves a more significant or complex goal and uses an Agent-based modelling and simulation to demonstrate this.

# 4. Asia AL-Karkhi[Maria Fasli](https://ieeexplore.ieee.org/author/37281907700). (2017). Deploying Self-Organisation to Improve Task Execution in a Multi-Agent Systems. *2017 3rd IEEE International Conference on Cybernetics (CYBCONF) Cybernetics (CYBCONF), 2017 3rd IEEE International Conference on*. :1-8 Jun, 2017