Self-organization Overview

If a system, such as a plant, a building or a car, shows organization we tend to assume that someone or something must have design in that particular order. Self-organization is the idea that this type of global coordination can instead be the product of local interactions.

The theory of self-organization has grown out of many different areas from computer science to ecology and economics. Out of these areas have emerged as core set of concepts that are designed to be applicable to all self-organizing systems from galaxies to living cells. But Lets start by talking a bit about organization itself.

Organization is a highly abstract concept but we can loosely equate it to the idea of order with its opposite being what is called entropy or disorder. Order and entropy are typically measured by scientist in terms of information, that is the more information it takes to describe something the more disordered the systems is said to be.

An example of this might be a piece of metallic substance consisting of tiny magnets called spins, each spin has an particular magnetic orientation and in general they are randomly directed and thus cancel each other out, This disordered configuration is due to its heat energy causing the random movements of the molecules in the material.

When we cool the material down the spins will spontaneously align them self so that they all point in the same direction. To describe the state of the spins in this order system would involve far less information relative to it's original state that requiring unique values for each randomly directed spin.

This process of magnetization is often cited as an example of self-organization, that is the spontaneous appearance of order or global coordination out of local level interactions. But lets take a closer look at how this happens.

As we cooled the material down there was some area that had by chance some spins pointing in the same direction, their alignment generated an increased magnetic force that was exerted upon its neighbors, creating what is called an attractor state, attracting other spins to this configuration.

Each time another spin aligned itself with this particular attractor state it augmented the force it exerted upon other spins through what is called a positive feedback loop that would cascade through the system until all elements were aligned within this new regime.

Another example of self-organization through positive feedback is what is called the network effect, where the more people that use a product or service the greater its value becomes, the telephone and Facebook are such examples becoming more useful as more users join, in this way local connections between individuals can rapidly form into global patterns.

The network effect illustrate the positive relations or synergies between elements that can be created when they coordinate, it is due to the presence of these synergistic relations that the system as an entirety can become more than the sum of its parts, in a process called emergence.

Ant colonies are a classical example given of emergence, ants governed by very simple rules and only local interactions can through their combined activities generate colonies that exhibit complex structures and behavior that far exceed the intelligence or capability of any individual ant and thus is said to have emergent properties.

Ant colonies also illustrate the decentralized structure to self-organizing system, The queen does not tell the ants what to do, instead each ant reacts to stimuli in the form of chemical scent exchanged with other ants, in this way organization is distributed over the whole of the system. All parts contribute evenly to the resulting arrangement.

As opposed to centralized structure such as most social organization that are often dependent upon a single coordinator, this decentralized structure that is inherent to self-organized systems gives them resiliency and robustness, as any element that is damaged can be simple replace by any other given them hug redundancy.

Whether the self-organizing system is a social institution, a technology or eco-system for it to sustain itself over time it must be able to with stand change and interventions from its environment, requiring the system to be both robust to these perturbations and capable of adapting to changes.

The generation of noise and variation within the system is a classical mechanism for achieving this. With out diversity a system can become ridged and develop into what is called a critical state.

An example of self organized criticality, could be an economy who's many industries have developed a dependency upon petro-chemical fuels, this lack of diversity of energy sources means a small disruption in the supply of petroleum from the systems environment could have a large global consequence.

Inversely systems with a high degree of diversity between elements will be more robust as the variety between elements will make them more effective at absorbing change. Eco systems are a classical example of this generating a large variety of specie that make it capable of surviving significant changes within it's environment.

Thus we can see how evolution is a core concept in understanding the dynamics of self-organizing systems, where by attractor states and feedback loops generate the system and periodically perturbations from its environment work to select the most adapted or fittest elements.

As information technology is enabling new forms of organization, people within many domains are faced with practical challenges of how to design and manage self-organizing system, such as computer networks and new forms of social collaborative. All of which are making Self-organization theory particularly relent to challenges of the 21st century.