

Complex Adaptive Systems Overview

Complex adaptive systems are systems composed of multiple diverse elements that are capable of adaptation and thus can evolve over time to exhibit highly complex behavior. But let's start from the beginning by talking a bit about adaptation.

Adaptation is a process or capability through which systems can change in response to some event within their environment. In order for this to happen there needs to be some control or regulatory mechanism within the system.

Cybernetics is the area that deals with a system's regulatory mechanism through what are called feedback loops, where by the actions of a system generates some change in its environment and that change in turn feeds back to effect the system itself.

A classical example given of this is a thermostat that regulates the temperature of a house, the system consists of a central controller where the desired temperature is set, a heater that creates an action that changes the state of the environment, and a sensor to feed back information about the environment to the controller.

Wherever we have this basic degree of interaction and interdependence between elements, we can use the model of an adaptive system and feedback loops to describe its dynamics and thus we can model economies, society and ecosystems in this way.

The different ways in which the interactions between a system and its environment effect each other generates different types of feedback loops, primary among these are what are called positive and negative feedback.

Firstly, Positive feedback is an action that produces more of the same. For example as global temperatures rise, Arctic sea ice melts, as this reflective sea ice disappears the now exposed dark ocean waters absorb more heat which in turn increases global temperature and so on.

In contrast negative feedback produces less of the same action. For example the more the price of apples goes up the less the demand from apple consumers, which in turn feeds back to reduce the price of apples again.

These different feedback patterns in turn give rise to different systems properties for example negative feedback is a form of self-regulation that typically generates very stable systems.

Where as positive feedback loops often have destabilizing effects, an example of how this works may be seen in a grounded flock of birds, any of which is likely to

fly away when it see a neighboring bird fly off, every time another bird reacts and takes flight it increases the likely hood of more birds flying way.

Thus the systems can be said to be unstable due to these positive feed back loop that allows for some small event to propagate through the system. This same dynamic can seen within may other domains such as in financial systems where loss of confidence can cascade through the system generating a bank run.

We have been talking about adaption and feedback loops, but to get complex adaptive systems requires multiple adaptive element interacting, from this micro level interactions adaptive systems can self-organize allowing for the emergence of some macro level pattern.

An example of this might be the formation of a culture, where individuals in close proximity develop standardized method for interaction and coordination through a common set of greetings, language, and rituals. Overtime these micro interactions will develop into a formal cultural system.

These emergent self-organized macro structure, whether they are markets, social institutions or cities then in turn feeds back to effect the actions of individuals within the system both constraining and enabling their future actions.

Given this emergence of new levels of order as the systems evolves, the elements capacity for adaptation and the complex interactions within the system it is almost impossible to predict the future state of a complex adaptive system with any accuracy.

The only viable method for modeling how these systems evolves over times is to simple let them develop and see what happens, fortunately we have computers that can simulate this process.

This method of simulation is called Agent based modeling, where an element is given a simple set of rules that govern its behavior and left to interact to see what macro scale patterns emerge over time. This method has shown that even with very simple rule governing the agent's behavior complex and unpredictable phenomena can arise.

Complex adaptive systems and its friend cybernetics are more than just the study of how birds flow or thermostats work.

They are a whole paradigm with which to understand and model the complex set of interconnected feed back loops that make up the natural, social and technological world we live in.

It is not only these interdependent feedback loops that define the systems properties but also the actual logic that governments when elements respond to a stimulus, take our first example with the thermostat, the control mechanism

did nothing act until a certain temperature was reached this is called a threshold point.

When elements with a similar threshold cluster together such as with our flock of birds then some small event can generate a chain reaction result in a large systemic effect. This system is said to have self organized into a critical state.

Inversely systems with a high degree of diversity between elements will be more robust as the variety between elements will make them more effective in absorbing changes within their environment.