

NGI101x - Characteristics of complex systems I

Hello I'm Eve Mitleton-Kelly, I'm the founder and director of the complexity research program at the London School of Economics. What we will be looking at over the next two videos are the generic characteristics of complex systems. In the first video, we will discuss the characteristics that we have come to understand through systems theory that are essential for us to build on to then develop a fuller understanding of complexity theory. So let me show you what we are going to look at. So the first video will look at the connectivity, inter-dependence, feedback and emergence. And in the second video we will look at the other characteristics. Let's start with connectivity. But first of all to understand complex behavior. Complex behavior arises from interaction, and complexity theory focuses on relationships. The theory does not focus on the entities themselves but on the relationships between them. The other key characteristic of complex theory is that complex systems can create new order. This is the jargon, and I hope that you will understand what that means over the course of the next two videos.

Connectivity and interdependence, what I would like to emphasize is that there are degrees of connectivity. In other words, connectivity between entities does not remain the same over time, it can vary in quality and in intensity. And when I talk about entities, I mean anything from individuals interacting, to groups, to whole organizations, to whole economies. So entities refers to all those, simply because all the principles of complexity we will be discussing are scale invariant, they apply at all scales. So let's go back. Connectivity, there are two things to actually look at. One is strength of coupling, which is how strongly related the interacting entities may be. And the other one is epistatic interactions. Now this term comes from biology, but let me explain what it means in a human context.

Some of you would have gone through a process of actually hiring people, you look at their cv, you interview them, and you'll point someone that you feel is going to make a very good contribution to the rest of the team. Six months down the line, you find that that person has not actually made that contribution. Now one of the possibilities is that the other members of the team have not actually allowed that new member to make that contribution. So what that means in the definition, is that the fitness contribution made by one individual will depend upon related individuals. The opposite of course will also be the case, and it could be that the person that may appear at the beginning to be shy or withdrawn, in the right environment, may then flower and actually make a very, very good contribution. So that is epistatic interactions. As I said, is the fitness contribution made by one individual that will depend upon related individuals.

We of course are constantly being encouraged to increase our connectivity to increase our networks. However, we need to be aware of what might happen if we push that too far, because intense interconnectivity also creates quite intricate dependences. So the system becomes to be very dependent, or the different parts become very dependent on each other, and these dependences cannot be pulled apart. The outcomes are often non-deterministic and the point here is that complexity does not argue for ever increasing

connectivity. Why? Because if we push the system too far into being connected it then becomes too inter-dependent and it becomes fragile. And this may lead to complexity catastrophe. Let me give you an example.

An American group has done a study, the study was done in 2010. They took 500 corporations with the highest stock trading volume and they were analyzed. What they did is they looked at five economic sectors, technology, which you see in blue. Oil, in dark grey, other basic materials like grey, finance linked to real estate, dark green, and other finance, light green. Now please observe 2003 and 2008. In 2003 each sector, each economic sector was interconnected within itself, but you can see the sectors quite separate, they are distinct. In 2008, that's only 5 years later, you cannot see that distinction, that clear distinction between the 5 economic sectors. Furthermore, what has happened is that finance linked to real estate, which is right at the center of it, which is the dark green, is at the very heart of the global financial system. What that meant was that the system had become too interconnected, too interdependent and that had made the system fragile. So it did not take much to actually topple the system. And that is the danger of intense interconnectivity and interdependence.

The second finding was that the sectors, as they came together, changes in one affected the other. And you can see from this graph how the 5 sectors are actually moving together and this is just a period of just ten years. The question is why? Why does this happen? And I hope that by understanding the characteristics of complex systems we will come to understand why these phenomena actually take place. One of the first characteristics I want to explain when we move beyond connectivity and interdependence is feedback. There are two types of feedback, and I want to actually explain the technical difference between positive feedback and negative feedback. Now, counter intuitively, positive feedback tends to cause system instability, while negative feedback tends to cause system stability. Let me explain what that means.

First of all let's look at positive feedback. Now, this is a stampede. Now imagine what happens when a few sheep are frightened, they start running, the faster they run, the more they panic, the more they panic, the faster they run. The first few sheep that started will then attract other sheep and more sheep will follow and you can then see what actually happens. You get a stampede. So it is actually making the system unstable. So positive feedback tends to cause system instability, and it can very quickly lead to a bank run or even a global financial crisis. And of course what happens is there is positive feedback in the loss of confidence, so it feeds upon itself. A little loss of confidence leads to more loss of confidence and that keeps on increasing. So positive feedback feeds on itself and makes the difference greater. So what we see there is of course the number of cattle running, the overall level of panic increasing and feeding into itself. Now let's look at the opposite.

Negative feedback tends to make a system self regulating and it can produce stability. Let me then explain that. This is a very simple mechanistic system. It's a ballcock. So when you press the lever the water will empty, when the water empties, the valve opens and the

water comes in and it refills the system. As the water rises, the ballcock rises and then, when the water reaches the right level, the valve is closed and no more water comes into the system. That is a very efficient, very simple system and it has a single equilibrium point.

Now what our mistake is, is that very often we actually make the assumption that what applies to a very simple mechanistic system will also apply to a complex system. The assumption there is that the right amount of correction can be applied in the most timely manner and that is not the case. The other assumption is that there is a single equilibrium point. Now an economy, which is a complex system, may have both positive and negative feedback at the same time and it will have multiple equilibria. Not just a single equilibrium point. Now, what we then need to understand is the next principle of emergence. Now, most of us, if you have done any kind of reading in complexity, you will have come across emergence. And the idea of emergence is that individual agents, this could be individual people, as I said, groups etcetera, interacting together create something which is both unpredictable and it has a bottom-up effect. But that is only half the story. Most of us I think are aware of only half the story.

Research on the brain has actually shown us a second process. The second process said that once the emergent comes into being, there are two things that happen. It affects the agents in two ways, it can both constraint certain behaviors, while at the same time it can open up new possibilities.

Let me give you an example. Culture is an emergent process. It arises through the interaction of everyone in a particular organization or society. I am a member of the London School of Economics, there are certain things I would not dream of doing. In other words, my behavior is constraint through the emergent process which is the culture. However, at the same time there are doors open to me because I'm a member of the London School of Economics, that would not be open to me as an individual. So can you see when we put the two processes together how dynamic that process is. So we got individual agents interacting and creating the emergent at the macro level. But once the emergent has been created it then affects the interacting entities in those two different ways. So we have that constant very dynamic process happening.

So emergent properties can be processes, can be qualities can be patterns. They arise from interaction and they cannot always be predicted. They are not additive or cumulative. Let me explain what that means. If you were to take a group of people and ask them, invite them, to a brainstorming session. What comes out of that brainstorming session will be quite different than if you were to take exactly the same people, put them in separate rooms, give them exactly the same question and then compare the outcomes. You cannot add the individual answers and come to the same outcome as you will get from the group working together in the brainstorming session. So what that means is that emergence is a systemic property, it is a property of the system working together, interacting together, to create the emergent property. And is not additive or cumulative, in other words, it is more than the sum of the parts. It is also, think about it, as a process of transition from micro

agent interaction to macro-structures, and macro-structures are the emergent processes, qualities, patterns. Learning, culture, innovation are all emergent processes, but also new ways of organizing, and new organizational forms can also be emergent. When we look at the challenges of managing complex systems, we will then focus on that much more.

So to summarize, what we have looked at are the four basic characteristics of complex systems. These have already been articulated by systems theory, which are connectivity, interdependence, feedback and emergence. And in the next video we will look at the other characteristics, which arise from the theories from complexity.

Thank you.