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Complex Systems: Where the Predictable and the Unpredictable Coexist

Socrates believed that every human, before their birth, understood the whole universe. Therefore, he believed, if we just ask enough of the right questions we can again reach that knowledge. Although not many people believe in Socrates' premise, his conclusion has shaped modern science. Science is founded on the belief that rules which accurately describe previous behavior can accurately predict future behavior. A couple of millennia after Socrates died, Pierre Simon Laplace reasserted that we could eventually understand the universe well enough to fully predict the future (Mitchell 19). A very new science, the science of complex systems, has created a serious problem for Laplace's theory: a complex system can never be predicted beyond general tendencies.

Although many systems have been described as complex, no definition of complex systems has yet been widely accepted. Also, no method of determining the level of complexity has been widely accepted. A proper definition of complex systems must accurately describe the systems which are already accepted as complex systems. Ideally, the definition could also be used to compare the complexity between two systems. This paper proposes a definition of complex systems. It then shows that the definition adequately describes these complex systems. Finally it explores how the definition can be used to describe the level of complexity in a system.

Complex systems are one of four kinds of systems: simple, complicated, complex, and chaotic. Simple and complicated systems differ only in the amount of information required to understand them. Both are highly predictable. Chaotic systems are the complete opposite. Almost nothing about them can be understood or predicted. Complex systems are neither wholly predictable nor wholly unpredictable. This is such an essential component of complex systems that is a good definition of them: A complex system is a system made up of sub-systems that through individual behavior cause unpredictable results, although with proper research general tendencies of the results can be predicted.

One widely accepted type of complex system is an economy (Mitchell 4). Economies are made up of smaller sub-systems such as companies or individuals. Economist can determine general rules which apply to all economies. For instance when the supply of a product decreases the price of the product will increase. However, economists can not predict what that new price will be. Only the actual interaction between companies and consumers can determine the new price. This fits the definition of a complex system given above.

Another accepted complex system is the immune system in a human body (Mitchell 4). The sub-systems in an immune system are the organs and cells of which it is comprised. Like with economies it is possible to learn and then predict certain things about the immune system. For instance, the immune system will eventually beat a common cold, but it may need some help beating pneumonia. As with economies, the details caused by the interaction of the sub-systems are unpredictable. For instance, no one can predict what cell will have the best fitting mutation for repressing the pathogen. These two examples show that the definition of a complex system given in this paper is in fact a reasonable definition.

This definition can also be used to measure the level of complexity. To demonstrate this, I'm going to use an example from my everyday life: boarding the university shuttle bus. The people boarding the bus are the sub-systems which cause the unpredictable behavior, namely where each one will sit on the bus. Certain cultural tendencies create some reasonable predictability. For instance, people will generally choose to sit by themselves before they sit next to a stranger. The level of complexity is equivalent to the level of unpredictability, therefore, this system can be described as somewhat complex. Unfortunately, the definition breaks down here. There is no way of ascribing a numerical value to the complexity, thus the level of complexity can only be relative to the complexity of another system. In other words, the only way for the level of complexity to be meaningful is to compare two or more similar systems.

A similar system to a group of people boarding a bus is a a group of people boarding an airplane. In most instances of boarding a plane everyone has bought a particular seat. This is still a complex system because there are still unpredictable details such as the order in which the people will board the plane, it is just a much less complex system than the system of the bus.

On the other end of the complexity spectrum, people boarding a train in certain countries is almost completely unpredictable. People mob around the doors and push their way on as quickly as they can. The only predictable aspect of this system is that the people in the front of the crowd will tend to be on the train the more quickly then the people in the back of the crowd. Therefore, by definition, this system is relatively high in complexity.

Returning to the study of economies reveals a further shortcoming of the definition presented in this paper. Consider a company that has a monopoly on a product. The complexity of this system is relatively low because the price is relatively predictable. This lower level of complexity is directly related to higher prices which are bad for the consumer. Conversely an economy with high complexity will have market prices that could quickly change without warning. This can cause panic, shortages, uneven distribution and many other problems. How does the complexity of economics compare to the complexity of the bus, train, and plane in the example above? These two kinds of systems can be compared to systems of a similar type, but are simply too dissimilar to be compared with each other. A better measure of complexity is needed.

Although much is still unknown about these fascinating systems, researchers are slowly making progress. Perhaps soon a definition will be accepted which accurately describes the pre-established complex systems, as the definition presented in this paper does. Perhaps that definition will also be able to objectively compare the level of complexity between all complex systems, not just similar systems.

So how much can we understand about the universe? Contrary to Socrates and Laplace, not everything. Of course Socrates and Laplace cannot be blamed for their ignorance in this matter. They both were brilliant men who helped modern science reach the understanding of complex systems which we now have. Let us not squander this wonderful privilege of knowledge which we now have. Instead, let us continue to make progress in the science of complex systems. After all, we are living in one!