How can we share solutions to complex systems problems across domains and application areas?

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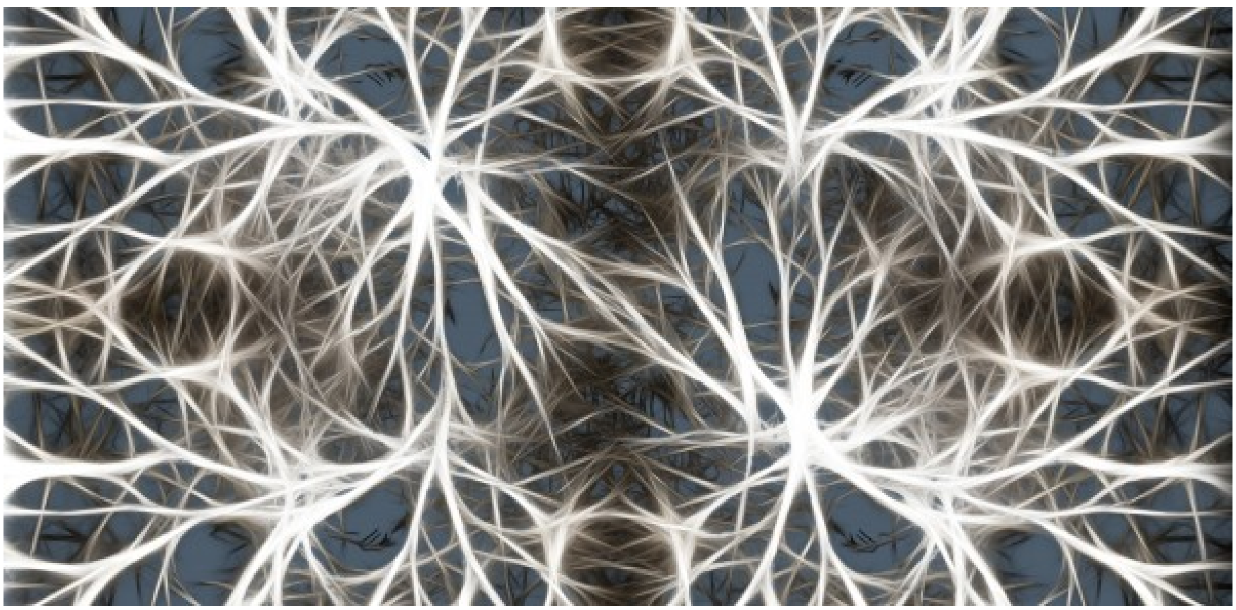

Credit: Gerd Altmann on Pixabay

What do power networks, transportation hubs, weather patterns, commercial organisations and swarming robots have in common?

For those seeking to understand, manipulate or build these systems, their 'complex' nature often demands approaches going beyond reductionist scientific models or traditional engineering design methods. These complex systems are often considered to be intractable because of their unpredictability, non-linearity, interconnectivity, heterarchy and 'emergence'. Although in many cases these attributes are framed as a problem, there are also cases in which they can be exploited to encourage intelligent, robust, self-organising behaviours.

To date, discourse on 'complexity' has tended to originate from the scientific domains taking a systems perspective, such as Systems Biology, Network Science and Complexity Science. This discourse emphasises the need for a more integrated, 'holistic' approach to understanding systems. Findings from these domains serve as the foundations for several emerging technologies and emerging disciplines, such as synthetic biology, socio-technical systems engineering, and swarm robotics.

More broadly, engineers, designers, managers and policy-makers across all sectors need to be able to think in terms of complex systems to be able to address the problems that we are facing.

But what does it mean to describe systems as complex? How do these complex systems differ from the more easily understood 'modular' systems that we are familiar with?

Vocabulary in this area is often dangerously inconsistent. For example, the terms 'emergence', 'complex', and 'complicated' are used differently by different disciplines, and often differently even within the same discipline. This makes it very difficult to understand whether people are really talking about the same thing, and whether the systems being described are different in superficial or profound ways. On the one hand, failing to identify the underlying similarities between systems (whether modular or complex) results in missed opportunities for sharing knowledge, best practices and methods. On the other hand, failing to identify the underlying differences between different systems results in practices and methods being misapplied.

To address problems with translating between disciplines, Chih-Chun Chen and Nathan Crilly at the Cambridge Engineering Design Centre have published 'A primer on the design and science of complex systems '.This introduces complex system constructs by building them up from basic concepts, and contrasting them with more familiar constructs that are associated with modularity. For example, 'emergence' can be understood with respect to a breakdown in how a system's functions are mapped to the structures that perform those functions. Abstract diagrams that are independent of any particular domain are used to represent the constructs that are discussed. These are illustrated with worked examples to make the explanations more accessible for those who have no experience with 'complexity'. The primer is intended to provide both an introduction to complex systems constructs for those new to the topics discussed, and also a basis for cross-domain translations for researchers and practitioners wishing to engage with other fields when addressing the systems problems they are working on.

Provided by University of Cambridge

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