Grip on Complexity

How Manageable are Complex Systems? [3]

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Preface

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- **transitions** from one system state, or phase, to another; their understanding unravels the possibilities and impossibilities of predicting and influencing the dynamics of change;
- the **resilience** of complex systems to external shocks or disruptions; can resilience be influenced to exert control.

Our Complex World

Scientific research increasingly reveals hyperconnectivity in nature, industry and society.

- The banking crises of 2008 with nonlinear dependencies and shocks in every direction affecting society at large.

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- The AIDS epidemic arose from societal changes such as urbanisation and the associated changes in human traffic patterns.

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- The systems can be defined at different levels of aggregation

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- Rules that work today may prove counterproductive when circumstances change
- Calls for tighter regulations add to a reservoir of data that is already beyond our ability to analyse.

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- How can we manage these systems?
- How do we respond to uncertainties?
- Society today needs answers and tools if it is to cope with the many problems that result from highly connected, dynamic and interoperable social and physical systems.

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- which itself may be subject to evolution.
- In many cases the network structure is only implicitly known, as it may be concealed within massive quantities of empirical data.

Complexity Science

Complexity scientists study the global dynamics of the system as a whole, rather than looking at individuals. Complex systems are recognised by some or all of the following dynamics:

- Self-organisation and adaptation
- Transition
- Fragility and resilience

Self-organisation and adaptation

In certain parameter regiems, when the number of constituents breaches a critical density, coordinated behaviour ensues and patterns emerge. Exampes include:

- swarming among birds, insects and fish
- growth and development of the human body
- the evolution of the World Wide Web

Complex systems can also evolve and adapt to changing environmental conditions:

- evolutionary development in biology (through mutation and selection)
- and the rapid adaptation of individuals in crisis situations.

Transition

Positive feedback or random forcing can lead to transitions between metastable states. When a system is pushed beyond a tipping point, return to its initial state may be practically impossible. Examples include:

- phase changes in materials
- irreversible ecological changes
- climate change, and
- economic instabilities [1].

Fragility and resilience

The behaviour of self-organised, adaptive systems may be highly robust with respect to external perturbations. The system can be pushed far from its equilibrium and still return to it when the external force is removed. Yet other systems may be quite sensitive and vulnerable to certain perturbations. Examples of resilience in complex systems include:

- homeostasis in biological organisms
- the robustness of the internet despite random failures and vulnerability to targeted attacks, and
- self-organisation via social networks

Because complex systems are so inter-connective, we must look beyond an isolated system to address certain questions. Our questions are inherently multi-disciplinary.
For example: how might impending climate change destabilise a geographical region politically?
To answer this we need to understand the interplay between:

- climate variables
- hydrology
- agriculture
- socio-economics and
- political models

What is new? Is it urgent?

Complex systems have always been round, and they have learned to function by an evolutionary, trial and error process.
People have succeeded in engineering systems with a complexity beyond our understanding, which can nevertheless affect our welfare and lifestyle.
Examples:

- the globally connected banking systems
- the internet's social networks, and
- the increased mobility and urbanisation of society which contributes to the global spread of diseases.

Complexity itself is the problem

In many cases complexity (or our misunderstanding or mismanagement of it) is the source of the problem itself.

Examples:

- epidemics
- escalating conflicts, and
- market crashes

To address such problems we must develop methods:

- to influence,
- manage, or otherwise
- get a grip on complex systems.

Some example projects of the NWO Complexity program

- Prediction when vegetation will disappear
- Nature versus nurture in brain disorders
- Passenger behaviour following public transportation delays
- Stability of ecosystems
- Why ocean currents change
- The immune system and the spread viruses
- Structure in highway chaos
- Financial instability
- How can we program our biological clocks?

Research challenges ahead

Predicting the behaviour of complex systems is a central theme of complexity research. If we can predict, can we also manage and control? Traits such as:

- resilience
- chaotic dynamics
- adaptive behaviour, and
- self-organisation

imply that complex systems may resist attempts to control them.

How much or how little can we manage complexity?

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