Foundations of Complex Systems

Focus Area Utrecht University (2014 - 2017)

PIs: Henk Stoof and Hans Heesterbeek
Complex Systems news update

NWO Invitation for Expressions of interest Grip on Complexity
Deadline 1 March 2016

Complexity Laboratorium Utrecht (CLUe) launched

• Aim: to reduce the barriers of UU scientists to use concepts and techniques from Complexity Science (CS) and to stimulate interaction among UU researchers from different fields
• Availability of software, hardware and visualisation tools
• first lunch meetings on 4 March and 20 May, 2016
• approx. 5-6 lunch meetings per year
Programme

11:45 - 12:15  Arrival and lunch

Opening:

12:15 - 12:30  CLUe Developments
               Henk Dijkstra, IMAU, UU

Keynote Talk:

12:30 - 13:00  The Protein Sequence-Structure Landscape: A Rosetta Stone for Complexity
               Erik A. Schultes, Leiden Institute of Advanced Computer Science

CS Software Applications:

13:00 - 13:15  1) Beyond Turing: from Spatial Pattern Formation to Pattern Destabilization
                Koen Siteur, Copernicus Institute of Sustainable Development

13:15 - 13:30  2) NetLogo Agent-Based Modelling Software as a Tool for Understanding
                Emergence in Complex Systems
                Brian Dermody, Copernicus Institute of Sustainable Development

Venue: Buys Ballotgebouw, Room 2.62, Princetonplein 5, De Uithof, 3584 CC Utrecht.
Complex Systems news update

• Rob Philips, professor in Biophysics and Biology at Caltech, will give a colloquium on 12 May 2016 at UU with title: “How Schrodinger’s cat became a cat”

• Robin Ball, professor Theoretical Physics and founder of the Complexity Centre at Warwick University visits Utrecht at the moment for 3 months as a Visiting Professor, colloquium to be announced

• The 2016 Conference on Complex Systems, 19 -23 September in Amsterdam, www.ccs2016.org
Critical Transitions in Natural Systems

Henk Dijkstra
Institute for Marine and Atmospheric research Utrecht
Department of Physics, Utrecht University
What is a critical transition?
Characteristics

Qualitative change in behavior

On a time scale shorter than a typical forcing time scale
Forcing - response relations

Example: diffusion

Example: radiation

Dependent on nonlinear processes and feedbacks
Critical conditions

Tipping point:
The corresponding critical point at which the future state of the system is qualitatively altered.
Local behavior

observable

\[ \frac{dx}{dt} = \lambda - x^2 \]
Elementary transitions (co-dim 1 bifurcations)

- **Saddle-node** (non-existence)
  \[
  \frac{dx}{dt} = \lambda - x^2
  \]

- **Pitchfork** (symmetry-breaking)
  \[
  \frac{dx}{dt} = \lambda x - x^3
  \]

- **Transcritical** (exchange of stability)
  \[
  \dot{x} = \lambda x - \omega y - x(x^2 + y^2)
  \]

- **Hopf** (spontaneous oscillations)
  \[
  \dot{y} = \lambda y + \omega x - y(x^2 + y^2)
  \]
Fast-slow systems
Effects of noise

- Plot showing the effect of noise on a system with parameters: $F = 1.1$
- The plots illustrate the time evolution of $y$ and $F$ with time $t$.
1. Sharp peaks
2. Continuous background
3. Elevated energy in certain frequency bands
Pleistocene Ice Ages

Raymo et al., (2008)
Fast-slow systems

$\delta^{18}O$

$\delta^{18}O$

(time (kyr BP))

(time (kyr BP))
Tipping elements in the climate system

A component of the Earth system, at least sub-continental in scale (~1000km), that can be switched – under certain circumstances – into a qualitatively different state by a small perturbation.

Lenton et al., (2008)
Summary

Critical transitions are associated with positive feedbacks, and many of these feedbacks occur in natural systems.

Dynamical systems theory provide a systematic approach to understand critical transitions.

Many of these transitions share similarities on an abstract level of description.