HISTORY of COMPLEX SYSTEMS RESEARCH

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Content

1. Reductionism and holism (philosophy of science, success stories of the twentieth century science: quantum physics and molecular biology)

2. Systems theory, cybernetics, nonlinear science

3. Dynamic structures: from being to becoming

4. New sciences and humanities
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General System Theory

Ludwig von Bertalanffy (1901-1972): Vienna
(The Austrian - Hungarian monarchy)

All physical, chemical, biological and psychological systems are governed by the same fundamental principles.

- A BIOLOGIST, who worked on the basic principles of the life
- A SCIENTIST inherently ethical who aimed at improving the human condition
- A PHILOSOPHER, ahead his time, who searched universal laws of organization
- A MAN acting as a citizen of the world, then learning to be aware of humanity’s enigmas

http://bertalanffy.iguw.tuwien.ac.at
Basic Concepts of the Systems Approach

1. A system is a whole that functions as a whole by virtue of the interaction of its parts roughly speaking a bundle of relations

2. Analytic and Synthetic Methods

3. Closed versus Open Systems
   (a) Closed systems do not interact with other systems
   (b) Open systems interact with other systems outside of themselves.

"living forms are not in being, they are happening, they are the expression of a perpetual stream of matter and energy which passes through the organism and at the same time constitutes it".

The Bertalanffy’s conceptual model of the living organism as an open system has had revolutionary implications for behavioral and social sciences."
Cybernetics

- information
- feedback control
- self-organization
Warren McCulloch (1898 - 1969)

- Warren McCulloch (1898-1969)
- the real pioneer of the interdisciplinarity
- logic based physiological theory of knowledge
- W.S. McCulloch and W. Pitts: A Logical Calculus of the Ideas Immanent in Nervous Activity (1943)
- The big experiment on Experimental Epistemology
McCulloch founded a new field of study based on this intersection of the physical and the philosophical. This field of study he called "experimental epistemology," the study of knowledge through neurophysiology. The goal was to explain how a nerve network produces idea.
Cybernetics in retrospective

- Cybernetics vs. AI
- 0, 1 vs. symbol manipulation
- Cybernetics, artificial intelligence, cognitive science
- Second-order cybernetics: autonomous system, role of observer, self-referential systems
- Connectionism vs. computational neuroscience

Grand Utopia: Towards a unified theory: Metaphysics, Logic, Psychology and Technics
Theory of Dissipative Structures

- Mechanics vs. Thermodynamics
- Ilya Prigogine (Nobel Prize in chemistry in 1977) and the Brussels school
- Structures: equilibrium and non-equilibrium
- Temporal, spatial and spatiotemporal structures
- Example: chemical oscillation (Belousov-Zhabotinskii - BZ-reaction)
- Fluctuations: over determinism
- Noise-induced transitions ("order from noise")
chemical waves (spatiotemporal pattern)

chemical chaos: irregular temporal pattern

spatial pattern (Turing structures: morphogenesis)
seashell: spatial pattern

spatial pattern (urban segregation)

zebra stripes: spatial pattern

spatial pattern (opinion distribution)
Synergetics

Hermann Haken; disorder $\leftrightarrow$ order transition (between equilibrium and non-equilibrium structures)

The basic principles of Synergetics are easily clarified in light of the example of Benard-Convection. In this case a liquid is heated from underneath. Following a temperature difference between the bottom and top surface, a macroscopic movement of the liquid begins in accordance with a specially ordered pattern. The molecules move in such a way that a rolling movement within the liquid becomes identifiable. Because of the increase in temperature, the liquid expands and the specific weight of the single molecules decreases, which results in an upward movement of the liquid elements. Up until a certain temperature, the upward movement can not overcome the internal friction. The liquid remains, therefore, in a macroscopic resting condition, notwithstanding fluctuations.
Systems theory, cybernetics, nonlinear science

Synergetics

Benard convection cell: hexagonal convection cells, caused by surface tension gradients, that are formed when a thin layer of silicone fluid is heated from below (left photograph). Aluminum powder floating in the fluid makes the horizontal and vertical motions of the fluid visible. The cells are named after French fluid mechanist H. Benard, who first described them in his doctoral thesis in 1900.
Synergetics

Multistable perception
Synergetics

Bistability
Catastrophe theory

CT: fashionable in 70-s and 80-s
Rene Thom
originated from qualitative theory of differential equations
nothing in common with Apocalypse or UFO

loss of stability

Catastrophe landscapes
demonstrate that gradual and sudden changes in behavior can occur in the same system under different circumstances
The fold catastrophe

Universal unfolding
the genesis (from left to right) or destruction (right to left) of an attractor with linear change of the control parameter $a$ from positive to negative values or vice versa. Out of the degenerate critical point $(0, 0)$ of the organizing centre $x^3$, critical points are "shaken loose" (unfolded) by the family $x^3 + ax$. As long as $a < 0$ a stable state of a process remains "caught" or locked in the low potential of the attractor basin.
A catastrophe theory-based oil price model (Woodcock, 1978)
The latitude and longitude in this case represent the elasticity of demand and level of competition in the crude oil market. The height of the landscape represents the price of oil. The model illustrates situations involving monopoly, oligopoly, and pure competition. The folded nature of the landscape surface suggests the existence of conditions supporting high and low price ranges. Paths such as (a - b - c - d - e) on the landscape surface illustrate how decreasing competition can lead to sudden increases in price. Paths such as (e - d - f - b - a) reflect sudden price declines due to increasing competition as new suppliers enter the market place.
Dynamic structures: from being to becoming
New sciences and humanities