Chapter 15
Generic System Models:
Background and Related Work

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ABSTRACT

Systemic and holistic approaches provide a new way of thinking about, understanding and designing systems. In this chapter we aim to highlight the most significant and influential work in this trend, and in particular the achievements of cybernetics, systemics and coordination modeling. Starting with cybernetics, related topics like cybernetic orders, self-organization, autopoiesis and conversation theory are explained. Systemics, and especially general system theory, provide a general language and terminology to express and model systems independent of any research domain. Together with integral and system thinking, this leads to a paradigm shift in understanding and modeling complex and non-linear systems. Concretely, we introduce the meta model of Schwarz which was the starting point of our own generic system model URANOS. Finally, the coordination theories and models which had a great impact on our research on human-centered design are outlined.

INTRODUCTION

Our research is rooted in artificial intelligence, but also focuses on coordination, pervasive computing and human-computer interaction (HCI). In this context we mainly study coordination models, middleware design and pervasive technologies. Our latest research findings indicate that a paradigm shift is required, in particular for addressing human-machine interaction. We need to change our point of view, so that human beings can be holistically integrated into our models and systems. This brings our research focus back to generic approaches, like cybernetics and general system theory.

The chapter starts with a section on "Cybernetics", an interdisciplinary research field, studying system governance and dynamics from a very generic point of view. Different approaches within cybernetics are central for URANOS, like first and second-order cybernetics, self-organizatio n, autopoiesis and conversation theory.

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Some fundamental work in systemics, which is based on cybernetics, is presented in the section "Systemics." This work brought forth systems and integral thinking, which help to holistically conceive systems. Our model URANOS has its roots in this domain, especially in the meta physical model from E. Schwarz, explaining reality from different epistemological standpoints.

In the "Coordination" section evolutionary research on coordination is outlined. Coordination had a huge influence in developing URANOS, since URANOS is a continuation of our generic coordination model. In particular, the theories, models and languages most influencing for our work are presented. Finally, "Summary" section summarizes the background and related work on generic systems.

CYBERNETICS

Many research fields like mathematics, physics, computer science, biology and sociology face the challenge of modeling and analyzing complex and non-linear systems. Cybernetics, as an interdisciplinary approach, addresses this topic. The term "Cybernetics" originally comes from the Greek "κυβερνητικη" (kybernetike), meaning "governance" or "steersman". Cybernetics is primarily concerned with behavioral issues like goal directedness, functional behavior, complex decision-making and learning, rather than the structural organization of a system. It provides a generic framework in which systems (artificial or natural) can be ordered, related and understood (Ashby, 1957).

This section begins with the origin of cybernetics. Thereafter, two cybernetic orders are presented, followed by the principles of self-organization and autopoiesis. Finally, cybernetic conversation theory closes this section.

Origins

In the 1940's and 1950's the *Macy Conferences* (Pias, 2016) brought together post-war intellectuals from different research areas like electro- and mechanical-engineering, mathematical logic, biology, anthropology, psychology, linguistics and philosophy. The participants, among others W. McCulloch, M. Mead, N. Wiener, H. von Foerster, J. von Neumann and C.E. Shannon (C.E. Shannon participated in the conference as a guest), aimed to explore common principles expressed in their research domains. It became apparent that feedback and control loops exist in different research domains. In many cases, they cause endless recursion, which is regarded as very problematic.

Based on the Macy Conferences and his study of control and feedback loops, N. Wiener wrote his book *Cybernetics: or Control and Communication in the Animal and the Machine*, where he defined cybernetics as *"the scientific study of control and communication in the animal and the machine"* (Wiener, 1948). One of the major concerns in his book was feedback loops that can be found in human and animal reflexes as well as in technical systems. This led to his intention to develop a general theory describing organizational and control relations within systems, artificial or natural. The confluence of N. Wiener's work and the Macy Conferences was the birth of cybernetics.

The focus was originally on processes which occur either in machines or living systems. This also included cybernetic implications on cognitive and social systems, as addressed by N. Wiener (Wiener, 1950). Ever since, cybernetics has become an interdisciplinary study of complex systems and system