Self-Study 1: Systems and Systems Thinking

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Introduction

In this self-study, you will read about complex systems and systems definition. You will then prepare a short presentation addressing four points. The assignment is to be performed alone. As part of this exercise, you will prepare and upload a presentation. You have one week to submit your work.

This submission will not be graded but will only be count as a pass/fail.

Learning Objectives

- Recognise the distinction between different systems definitions.
- Learn crucial concepts of systems thinking.
- Understand major steps in the historical development of systems thinking.

Assignment

This is the first self-study of this course and complements the material introduced in Lecture 01. The completion of this exercise is compulsory for all students.

You are required to read the material provided below and create a presentation addressing the tasks listed in the next section. The material provided consist in a series of definitions that complement the discussion followed in Lecture 01, and three separate readings that provide additional insights on system thinking. You are asked to read the material provided before creating a short presentation addressing the tasks outlined in the next section. Here, we provide the submission guidelines and assessment criteria.

You are required to submit your solution as a pdf slide deck.

Tasks

The slides should address the following points.

- Explain what is the difference between *complex* and *complicated*. For what reason engineers should learn from economists and social scientists?
  Are there 'laws' for complex systems? **(Slide I)**

- Explain what are the influences from psychology, biology on establishing systems concepts. According to Bertalanffy, describe what the aims of general system theory are. **(Slide II)**
- Explain the what is the fundamental difference between closed and open systems. **(Slide III)**
- Explain what the aim of cybernetics is. Explain how the 'complex system' perspective evolved between 1956 and today. **(Slide IV)**

1 Systems and Systems Analysis

1.1 Definitions

- gr. $\sigma\upsilon\sigma\tau\eta\mu\alpha$ (System)

(a) arranging $\Longrightarrow$ activity (systematising)

(b) the arrangement $\Longrightarrow$ result (a system)

- Systems are collections of *elements* that are *connected* in such a way that they give the system a *recognisable* and *stable* shape which is meant to perform a specific *function.*

- Systematising $\Longrightarrow$ organising, putting into an order
  Systems are *constructed*! According to which criteria?
  - Example: Nations, industries, firms
  - example: Genealogical tree of Germanic languages, Traditional model (see Figure 1)

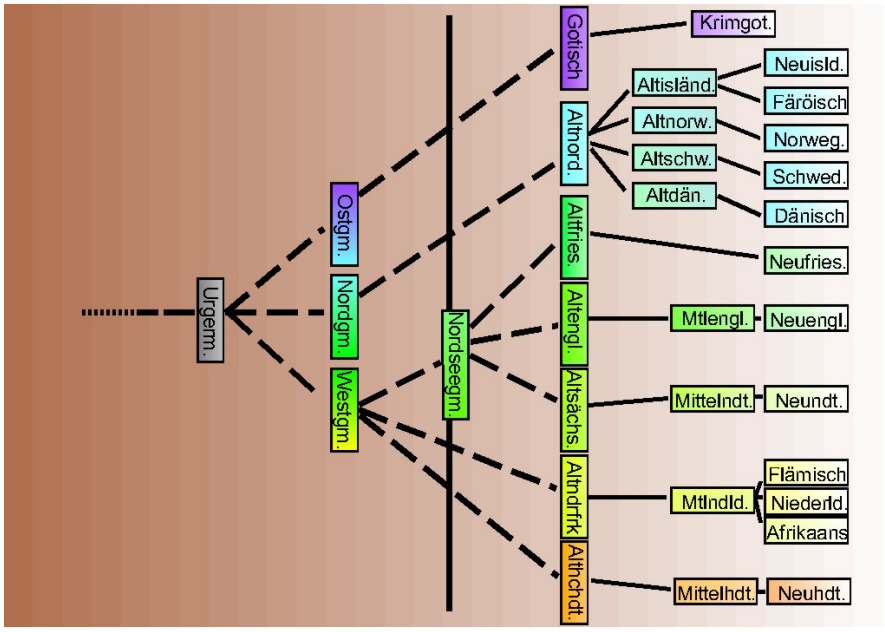

Figure 1: http://titus.fkidg1.uni-frankfurt.de/didact/idg/germ/germstam.htm

- Systems as composites
  - Components? $\Longrightarrow$ Elements (Building blocks, Units, Parts, ...)

- Setup? ⟹ Structure, Organization
- Hierarchies: Systems and subsystems

1.2 Structure, Function, Organization

- Structure
  - relation/networking of elements
  - spatiotemporal structures (incl. dynamics)
  - difference between equilibrium and non-equilibrium structures
- Organization
  - logical ⟹ combination of processes
    - example: maieutic cycle (⟶ Systems Engineering, lecture 2)
  - hierarchical ⟹ each level comprises lower levels while preserving its autonomy partially
    - example: decision processes / flow of information (see Figure 2)

Figure 2: Hierarchical system of decision processes

- Function
  - collective trait of proceeding processes
  - set for self-renewal⟹
    autopoiesis (autos=yourself, poiein=to do)
    examples: biological cells, psychological systems
  - distinguished by external function or control ⟹
    allopoiesis (allo=external), example: machines

2 Systems thinking

2.1 System types – Philosophy of Science

- Conceptual versus objective systems
  - Conceptual ⟹ Systems as groupings of terms/ concepts
  - Objective ⟹ Systems as natural/ built entities
- In the 18^{th} century: "objective" understanding of systems
  - Lambert: Systems as "purposefully composed entities"
    (Johann Heinrich Lambert (1728-1777): Mathematician, Physicist, Astronomer, famous (among other things) for his work on hyperbolic functions and his hypothesis that our solar system is part of the milky way)
- Starting from the 19^{th} century: "conceptual" understanding of systems as schools of thought
  - Leibniz, Kant: Philosophy ("Systems" of thought – Denksysteme)
  - Hegel, Comte: Inclusion of social systems
- From the mid of the 20^{th} century: Return to an "objective" understanding

2.2 Antecedents to modern systems theory

- "General Systems Theory"
  - L. v.Bertalanffy (Biology)
    - Focus: Commonalities between systems in physics, biology and social sciences
  - K. Boulding (Econ.), A. Rapoport (Sociology, "TFT")
  - Society for General Systems Research (est. 1956), now: International Society for the Systems Sciences ISSS, http://www.isss.org/
- Cybernetics/ Control theory
  - gr. kybernetes - the mate (Steuermann). The term *Kybernetik* was made famous by Norbert Wiener, but was already used by Ampére and Plato in order to describe the influence of "governance" on systems.
  - N. Wiener, *Cybernetics* (engl. 1948, dt. 1961): mathematic models of regulatory processes
  - W. Ross Ashby (psychiatry)
    - *Introduction to Cybernetics*
      http://pespmc1.vub.ac.be/books/IntroCyb.pdf

  * Idea of "Control loops", Focus on negative feedbacks
    Adjustment to a desired value ("Sollwert")

- "Systems Dynamics"
  - J. W. Forrester: Study of urban/economic systems
  - D. Meadows: Club of Rome $\Longrightarrow$ *limits to growth*
  - Representation: Systems of coupled differential equations

2.3 Recent developments – An overview

- Approaches in mathematics/ physics
  - R. Thom: Catastrophy theory
  - Nonlinear dynamics, chaos-theory
- Theoretical concepts
  - H. Haken: Synergetics ("the theory of joint effects")
  - I. Prigogine: Theory of dissipative structures
  - Complex systems theory/ self-organization theory
  - H. Maturana/F. Varela: Autopoiesis theory
    radical constructivism
  - N. Luhmann: Theory of social systems
- Simulation tools/ data analysis
  - Nonlinear time-series analysis, multi-agent-models
  - Neural networks, cellular automata, grid computing

3 Reading

The following texts can be found in our Literature section in Moodle. They provide some insights into systems concepts and systems thinking and are used here also as *food for thought*, i.e. for illustrative purposes.

3.1 Engineering complex systems

- Download Nature-427.pdf and read the 1 page text.
- This is a short conceptual essay published in the prestigeous journal *Nature*. It refers to complex systems and the challenges they put on the engineering sciences.

3.2 On the history of systems theory

- Download Bertalanffy.pdf and read the two short sections from the introduction of L. v. Bertalanffy's book *General System Theory* (1968).
- *On the History of Systems Thinking* (pp 10-17) gives you some first-hand reflections (from the perspective of 1968) why systems science became of interest. *Aims of General System Theory* (pp 36-41) reflect Bertalanffy's approach to establish a general theory, which however never became generally accepted.

3.3 An introduction to cybernetics

- The book by W. R. Ashby (1956) can be downloaded from:
  `http://pespmc1.vub.ac.be/books/IntroCyb.pdf`
- Read chapter 1 *What is new?* (pp 1-6) in order to see how Ashby introduced cybernetics and its peculiarities.