LECTURE

2

Introduction to Systems Science

Veronika Vlčková, Zuzana Bělinová

LECTURE 2 - OVERVIEW

Theoretical foundations

Basic terms

Advanced definition of system

SOURCES OF SYSTEM THEORY - PHOLOSOPHY

already ancient Greeks knew that the **„the whole is more than the sum of its parts“** (Aristotle)

1749 E. B. Condillac Tract about system: „...any system is not anything else then a distribution of different parts of any art or science with the known order, where all of these are mutually maintaining and where concluding parts are resolved by initiatory...“

L. von Bertalanffy (since 1928):
first phase - knowledge in biology
second phase - searching of analogies in farther science branches
third phase - questions already mathematical theory of systems

INTRODUCTION TO SYSTEMS SCIENCES

Mutually independent pieces of knowledge from the fields of biology, physics and social science in the first two decades of the 20th century played probably the decisive role in the process of Systems Sciences formation.

It was evidently proved that the **relations / interactions are often more important for the “function“ and “comprehension“ of the selected object, than the nature of the respective parts of the same object**.

It was also proven in successive steps that in such cases it was possible to find similar, analogical processes in qualitatively totally diverse objects.

INTRODUCTION TO SYSTEMS SCIENCES

The evolution of Systems Sciences has been catalyzed by the significant advances in

- Systems Thinking
- Mathematics
- Computer Science

from the mid of 20th century

Systems Sciences proved competent in coping with an **“organized complexity“, heterogeneity and openness**.

Many branches of human activity, above all **transportation and telecommunication**, belong to these categories. That is why we deal with them at this faculty.

SYSTEM ENGINEERING

Goal: to be able to solve complicated systems

Systems Engineering is part of System Science

What does it mean?

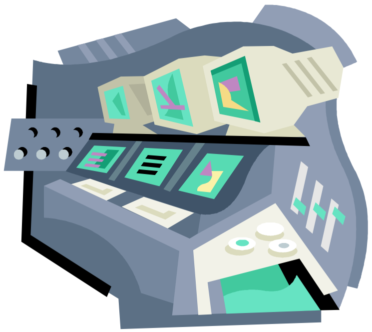
Science: process of community knowledge of certain kind with certain recourses

SYSTEM

The word SYSTEM has today many different meanings

In system theory

- **system is a model of object from real world**
- **used for its analysis, projection or utilization and control based on system attributes of this object**



ENGINEERING - GENESIS

- develop of techniques (machines, engines, their controlling and managing functions, a construction versus utilization of them)
- different rate of development of branches - the „less developped branches“ has to gain by finding new ways etc.
- effect of a commercialisation to an utilization of results, costs x profit x target of a market effect
- necessary division of labour as a result of a specialisation causes a development of scientific fields
- subsequently developing the possibilities to use particular subject from the new scientific fields, however necessary compliance with the compatibility between „oldies” and news
- most modern solving methods must be commonly and en bloc portable, it means necessary „learnable“ procedures

genesis of engineering = a genesis of new methods, procedures, techniques for projection, production, and using of tools and subjects of the branches ===> greater effectiveness, influence, faster, higher customisation, manageability, collective teachability

ENGINEERING AS A WAY TO SOLVE TASKS

Contains basic principles of work with the:

- subject of analysis
  - Including the measurability, scalability, standardization and portability
- particular engineering methods
  - Organization of work in relation to the system model,
  - Documentation of the procedures in order to be able to ensure reproducibility, and also learnability

ENGINEERING - METHODICAL PRINCIPLES

- measurability of objects (contingent on the ability to name the phenomena and to find required metric);
- ability to find an algorithm (enabling to get a certain result from a certain start point);
- demonstrability (following the valid rules increases reliability, safety and utilization of results);
- documentability (a necessary condition to prove the three previous attributes of engineering);
- portability (allows the repeatability and reproducibility of achieved results);
- ability of organizing (excellent attribute of engineering making the engineering more transparent and effective);
- effectiveness (the achievement of the certain rate of success in regard to the goal behaviour of the object)

SCIENCE

Scientific branch requires:

- Distinguish the subject of the branch
- Creation of a new terminology
- Applicability
- Theoretical background

Methodology

- fitness and applicability of methodics and methods (set of requirements as a justification for formation of scientific branch)

Methodics

- set of methods

Method

- Process description

THEORY

a set of **ordered observations** about certain kind of measured phenomena - to allow describing and explaining of these phenomena

General theory - the collection of any observations in certain branch: an answer to the question „*WHAT?*"

Mathematical theory - a (mathematical) way of describing of observations for portability of these between branches on the basis of the (mathematical) abstraction as an answer to the question : „*HOW TO DESCRIBE?*"

Constructional theory - a creation of methodical and technical tools for an analysis, a projection and a realisation phenomena's in the certain branch - as an answer to the question: „*HOW TO MAKE AND TO CONTROL?*"

SYSTEM SCIENCE

3 differnet attitudes

- axiomatic (deductive) = from axioms new findings are deduced in the form of sentences
- experimental (inductive) = validated observations or measurements, definitions are formed based on experiments
- gnoseological = on the basis of social experience

SYSTEM SCIENCE BACKGROUND THEORIES

- **structural** - dealing with the whole and composition from its parts, the function (whole behaviour) is derived from the structure of the whole
- **functional theory** – based on the behaviour, dynamics of systems, interactions with its surroundings (from the behaviour we presume what the structure is
- **linguistic theories** – dealing with the ability to name, express and communicate the knowledge on the whole and all its characteristics (both the structure and the functions). The emphasis is on the correct interpretation - so that the system is well accepted by its surroundings

SYSTEM PROPERTIES

goal of engineering:

to control an object = > the creation of a model => system model (model of the object in the real world)=> need to describe and identify the system on two levels:

- Static structure
- Dynamic behaviour – changes and development in time

System characteristics used for description are of two types:

- Basic - related to the known existence of the system (not constructed)
- Secondary – derived from the basic characteristics (cardinality M, identity I, competence C)

SYSTEM DEFINITION

System is evaluated structure

$S = (A/F, R/P, M, \gamma, \delta, I, E, C)$

- A is a set of elements / automata
- F is a set of functions of elements; F defines the ability of system.
- R is a set of relations among elements
- P parameters on relations
- γ is goal oriented behaviour
- δ is species / type focused behavior (genetic code)
- I is system‘s identity
- E is system‘s ethics
- C is system‘s competence

SYSTEM‘S IDENTITY

- expresses (in as compact form as possible) the relation of the complex system with its neighborhood

Where do I belong?

Why I am doing this?

Am I efficient?

...

DIFFERENT VIEWS ON SYSTEM IDENTITY

Formal (how to describe)

Gnoseological (epistemological) (how to find it)

Constructive (how to control it and to manage it)

FORMAL VIEW ON IDENTITY

identity as a (static) logic function identicalness

$$O_i = O_j,$$

or (dynamic) process function *f* of using the object and its abilities described as

$$y = f(x)$$

where x it the object description

F is function of using the object

Y is the result – how the object is accepted and used

GNOSEOLOGICAL (EPISTEMOLOGICAL) VIEW ON THE IDENTITY

process of knowing itself and its surroundings, where it is used, etc.

- first „what I am“, then „what I can“

If we aim to identify ourselves with certain image, there arise questions, such as:

- if the image is stable and objective
- if the process of an image handling are not subject to technological development

The solution is to verify the process using

a) *diagnostics of disturbances* in the function of identifying itself with the image and to

b) *asking questions regarding the* state of knowledge (is it really so or can there by some other possibility?)

CONSTRUCTIVE VIEW ON IDENTITY

To be able to construct the parameter of identity, it is necessary to:

- Match the object and its model
- Create system formulation of the identity parameter

Difference from the initial identity explanation, meaning really matching (identicalness) of two objects

⇒the identity now describes the correspondence between

- the expected (or actual) state
- the usage of this state

CONSTRUCTIVE VIEW ON IDENTITY

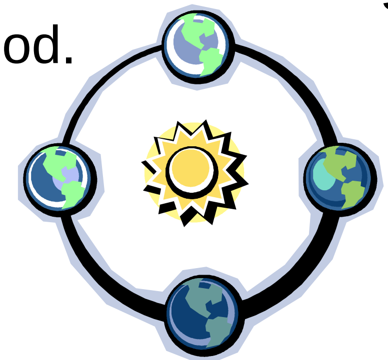
The identity parameter can be defined at two basic levels:

- (A) Internal,
- (B) External

(A) Level describes system internal prerequisites

- can be constructed in the dimensions of type, uncertainty and relative weight of goal – oriented processes.

(B) Level expresses the measure of usefulness in the neighbourhood, the impact of the system on the neighbourhood.



SYSTEM'S IDENTITY - INTERNAL

Quantitative construction of Identity forms a 7 dimensional vector of the components:

1. "Tuning": **Tu = ΣIFR / Σ IF,** where Σ **IFR** means the number of all regular interfaces in the respective system, while Σ **IF** means the total number of interfaces in this system

2. "Type": **Tp =** Σ δ **/ M,** where Σ δ means the number of strong processes in the system of interest, while **M** means systems magnitude (*i.e. the cardinality of the set of Systems processes*).

3. "Goal - weight": **Gw =** Σ γ **/ M,** where Σ γmeans the number of goal - oriented processes in the system of interest, while **M** means systems magnitude.

4. "Goal – stability": **Gs = 1 – D (**γ **),** where **D (**γ **)** means the averaged dispersion of goal – oriented processes in the system of interest.

SYSTEM'S IDENTITY - EXTERNAL

5. "Extrovert orientation" : **Ex = OUT / (IN+OUT)**, where **OUT** is total number of output states (i.e. the sum of the output boundary element states of the system of interest) while **(IN+OUT)** is total number of the states of the system boundary elements.

6. "Importance" (for the higher system HS) : **ImHS = OUT** δ **/** δ **HS ,** where **OUT** δ is the number of output states of the strong processes of the system of interest, participating in the same time in the strong processes of the higher system HS, and δ **HS** is the total number of strong processes of HS.

7. "Coherence of goals" (with higher system HS) : **CgHS = OUT** γ **/** γ **HS** where **OUT** γ is the number of output states of the goal - oriented processes of the system of interest, participating in the same time in goal - oriented processes of the higher system HS, and γ**HS** is the total number of goal – oriented processes of HS.

SYSTEM'S COMPETENCE

Different viewpoints:

- semantic (the legitimacy of the *subject (someone)* to the *object (something)*)
- axiomatic (based on predefined axioms, for example as an intersection of sets)
- epistemological (knowledge of more different possible explanations, e.g.
  - power of competence – theoretical space where competence may be introduced
  - possible competence – that can be achieved
  - utilized competence – with respect to limitative conditions
- Pragmatic (in relation with applications - occupation, attractions, or subjection or cooperation)

SYSTEM‘S COMPETENCE – AXIOMATIC VIEWPOINT

Competence = intersection of sets of

- Knowledge, abilities
- Language constructs available for the description, interpretation

Can be assessed for different attributes (from the system definition – A, R, M, γ,δ)

For the elements A it can be specified in detail as

- Content (e.g. Material, energetic, information)
- Function (continuous/discrete, deterministic/stochastic, etc.)
- Communicability (ability to establish the connection)

SYSTEM‘S ETHICS

as a question „how much is an enforcement of the certain identity O.K.“ ?

Part of the complex view on the system

- suitability, corectness, acceptability of the behaviour of particular system

Difficulty to formalize it, meassure it

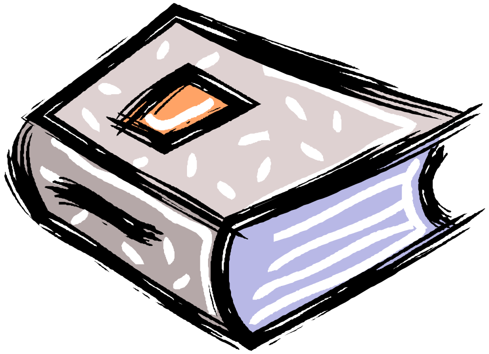
ETHICS CODE

ethics code: necessary input for system engineering to be able to analize and construct the ethics parameter

→*Set of standards and rules together with the metric enabling to measure the* of compliance with the code

(“to answer what is good and what is bad“)

Even when evaluating the ethics the fundamental criterion is the conservation of life, the **survival**



SYSTEM‘S ETHICS – STARTING POINTS

source of ethics (theological, natural, axiomatic, authoritative)

acceptance of ethics (spontaneous, democratic, forced)

ethics carrier (parts of the system)

sense of applying the ethics (survival --> conservation, mutation, accident, catastrophe)

experiences with applications of ethics (local, binary, linear, surface, spaced, timed, social)

SOURCE OF ETHICS

- theology
    - coming from theological statements, spiritual mode
- natural
    - Coming from monitoring system parts, its ordering, etc.

- axiomatic
    - Coming from monitoring system parts, its ordering, etc. but after the formal organization of the results

- authoritative
    - Coming from above with no possibility for discussion or feedback

ACCEPTANCE OF ETHICS

- spontaneous
  – everybody agrees with the code, nobody has problems following it
- democratic
  – the code is enforced by the majority of participants, the minority must follow
- forced
  – the code is enforced by the minority to the majority using its competence

ETHICS CARRIER

Ethics may be based on different aspects of the system – different parts from the system definiton:

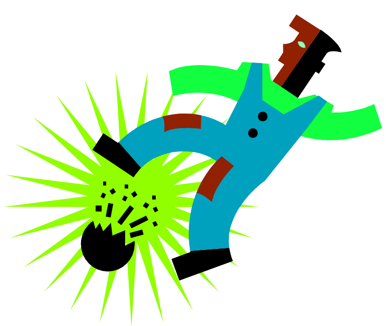
- A/F – elements and their functions
- R/P – relations and their parameters on relations (based on the communication, changing in time)
- γ, δ – system‘s behaviour – in its goals and genetic presumptions

SENSE (REASONS) FOR APPLYING THE ETHICS

Why to apply ethics at all?

In what cases the ethics may help?

- survival – ethic code applies only to the very survival
- conservation – ethic code protects the changelessness of the system (protecting the elements and their functions)
- mutation – ethic code enables the development of the system, as far as the goal and genetic code is preserved
- accident, catastrophe – ethic code applies also to this special cases



EXPERIENCES (SPACE FOR) APPLYING THE ETHICS

Local – the code applies for one system only

Binary – the code applies for two participants

Linear – the code applies for sequence of participants

Surface – the code applies for network (2D) of participants

Spaced – the code applies for group of participants

Timed – the code may vary in time

Social – the code may vary based on other inputs – conditions for survival, etc.

Thank you for your attention

REFERENCES

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