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MODELLING – A TOOL FOR PROBLEM-SOLVING

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Abstract: *The title and content of the present article seem to be thematically archaic, but the present knowledge about modelling as a tool for problem-solving is incredibly miserable; therefore, actually, the article is up to date. There are many individuals who are caught off by the question what exactly is, in that sense, the real essence of modelling, even though some of them write about it, and even teach it. In fact, the answer can be found in already the 27-year-old publication "Computational models in engineering practice" by the two authors from Brno. Three years ago, another publication "Systems Methodology" appeared in Brno (Janicek, 2014); it discusses modelling in terms of systems approach. These authors from Brno also published the book "Expert Engineering in systems approach", which is also dedicated to solving the problems by modelling. Literature sources thus exist; however, reading is not very popular, especially as for Czech subject-field books. Nevertheless, publications from the West do not always guarantee the quality of information and knowledge. Therefore, this article recapitulates the essence of modelling, its graphic display, types of modelling and terminology of modelling in Czech and English equivalents.*

Keywords: Model, Essence of modelling, Structure of model, Types of modelling, Computational modelling.

1. Essence of modelling

Problems $P_R(\Omega)$ on entities Ω can be solved by two basic approaches, direct and indirect.

A direct approach means to solve the problem without any auxiliary objects. Is it necessary to build a dam? So it is built without prior work with any of its models. Is it charlatanism? Of course, it is. But it is quick.

Indirect approach (Fig. 1a) – The essence is that to solve the problem of $P_R(\Omega_1)$ on the primary object Ω_1, the subject S uses an appropriate purpose-built secondary object Ω_2 (also called the auxiliary object, the model object), which should facilitate a solution on the primary object Ω_1 for the subject S. The findings in relation to the solved problem, obtained on the object Ω_2, are transferred to the primary object Ω_1 by image Z. In the early days of modelling, the model object Ω_2 used to be a real physical object on which the observations and experiments were implemented and findings had a verbal form. Image Z may have in this case a **natural** level (based on the natural abilities of humans to consciously create the image of the object Ω_2, and based on the acquired findings to create an image of the object Ω_1 on Ω_2), or a **scientific and technological** level (utilizes the natural abilities + scientific and technological knowledge). This type of modelling was identified as prehistoric experimental modelling.

For further development of modelling, it was characteristic that the auxiliary physical object (experimental object) served for measurements which were processed mathematically. This means that on the object Ω_2, the investigator generated a system of numerical variables $\Sigma(\Omega_2)$, which were then transmitted via image Z to the system of numerical variables $\Sigma(\Omega_1)$. This was the basis for solving the problem $P_R(\Omega_1)$ on the object Ω_1 (Fig. 1b). It is logical that in this case it is possible to use for Z the term of **systems image.**

The model object may have a **real** essence (physical object) or **abstract** (system of information, knowledge, numerical variables, fuzzy variables). If the model object Ω_2 is formed by two or more sub-

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models, it is **hybrid modelling**.

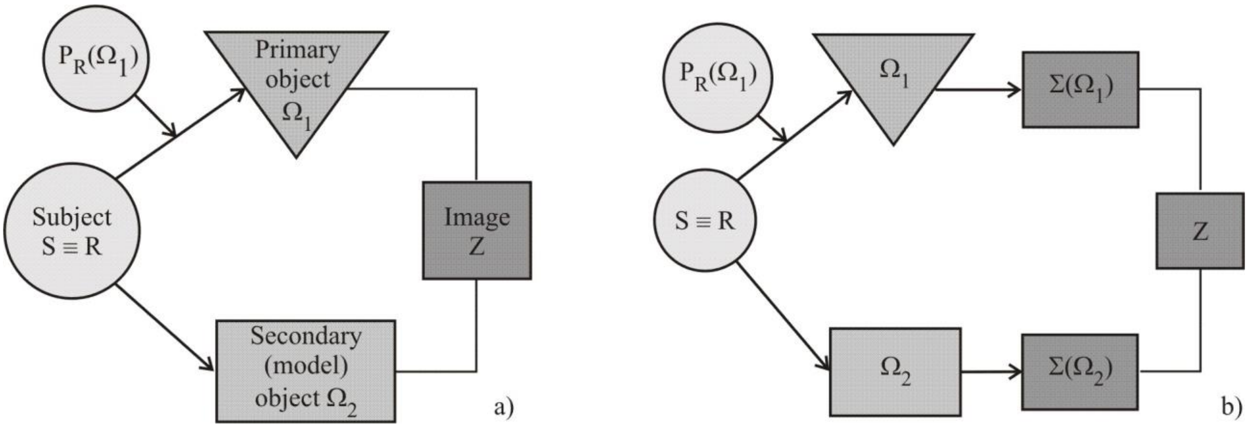

Fig. 1: Elements of essential structure of modelling.

2. Generalized structure of model

The previous text introduces the term of a model object in the sense that it is an auxiliary object that allows for solving the problem on a specific primary object $\Omega_{1.}$ A systems theory of modelling uses also the term of **model** in the following two meanings. The first meaning is understood as a system of real and abstract elements, which is needed for modelling. It has the following elements: object model $\Omega_2 \equiv O_M$, system of variables $\Sigma(\Omega_1)$ on the primary object Ω_1, system of variables $\Sigma(\Omega_2)$ on the model object Ω_2, image Z between the respective systems of variables, method of MR solving of problem P_R (Ω_1), appropriate hardware mHW and software mSW. Elements of model are drawn into the basic structure of modelling in Fig. 2 in light grey colour.

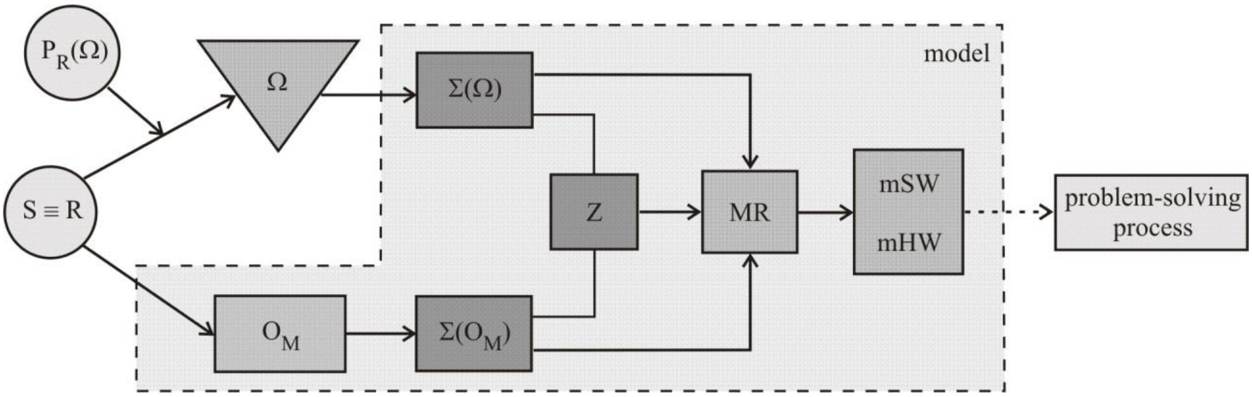

Fig. 2: Generalized structure of model (light grey).

In the other meaning, the term of model is used **as a result of simplification process** of characteristics, properties and behaviour of real entities to such a level so that the "simplified" entity could "work" in the problem-solving process using modelling (see the issues of computational sub-models).

2.1. Types of modelling

The above-mentioned philosophy of modelling leading to its simple basic structure also allowed for a simple **definition of each type of modelling** on the basis of this consideration. The model object Ω_2 can be anything that allows for problem-solving on the object Ω_1. Depending on the nature of the object Ω_2 and the type of image Z, the existing modelling can be divided into the following types:

- **Mental modelling** – Ω_2 is the human brain and thought processes going there.
- **Prehistoric material modelling** – Ω_2 is a material object, image Z is natural.
- **Similarity modelling** – it is a hybrid modelling because the model object Ω_2 has a real part and an abstract one (see below). Objects Ω_1 a Ω_2 are structurally identical (e.g. turbines) with identical processes (running of turbines). However, they differ in size (e.g. a small model turbine Ω_2 and a large real turbine Ω_1). On the real part of $\Omega_{2,}$ experiments are carried out while the abstract part of Ω_2

represents knowledge from experiments which are used to create a system of essential variables / lit / on the primary object Ω_1. Image Z is of systems nature. Specifically, it is a computational image of equality between the similarity numbers on the objects Ω_1 and Ω_2.

- **Analogue modelling -** it is a hybrid modelling because the model object Ω_2 has also a real and abstract part. This type of modelling uses the analogy of physical processes (processes that are formally described by the same differential equation (DR) and the same boundary conditions OP), regardless of the type of real object). On the real part of $\Omega_{2,}$ experiments are carried out. The abstract part of Ω_2 represents the knowledge from the experiments, which are used to create a system of essential variables $\Sigma(\Omega_1)$ on the primary object Ω_1 and to create essential variables $\Sigma(\Omega_2)$ on the model object. Image Z expresses conformity of DR and of OP to Ω_1 and Ω_2.
- **Knowledge-based modelling** – is an empty expert system for processing of knowledge from a set of experts from a particular field. System $\Sigma(\Omega_2)$ is a subject-field expert system filled with a set of knowledge.
- **Theoretic modelling** – Ω_2 is an appropriate theory (descriptive, mathematical, graphic)
- **Computational modelling** –Ω_2 is a set of mathematical theories. System $\Sigma(\Omega_2)$ is a suitable mathematical theory that is acceptable in accordance with the system of essential variables $\Sigma(\Omega_1)$, i.e. formed on Ω_1.
- **Data-based modelling** – Ω_2 is a set of statistical methods. System $\Sigma(\Omega_2)$ is a suitable statistical method for processing the data of a particular type: quantitative (regression analysis method), qualitative (analysis of variance), quantitative + qualitative (covariance analysis), fuzzy (fuzzy statistics).
- **Formal modelling** – Ω_2 are formal structures that:
  a) are **analogies to living nature**. These include expert systems (simulating human thinking), genetic algorithm (simulating the evolution of biological species on earth), artificial network (simulating the processes of biological neural networks).
  b) **purely formal structures (**meta algorithms, rule-based systems, syntactic recurrent trees)**.**

3. Computational modelling

The previous section stated that the model object for computational modelling is a **mathematical theory** MT. To be usable, it must be mathematically solvable, there must be a computing device allowing for problem solving process, algorithm development for the problem - solving process, there must exist the input data related to the problem to be solved. Logically thought out: the term of **mathematical modelling** is not appropriate because, though the existence of mathematical theory is a necessary pre - condition to solve the problem, it is not sufficient in order to implement the computation.

Engineering Mechanics is mainly engaged in the so-called **causal problems concerning technical entities**. They are distinguished by the inputs to the algorithm that are formed by causes (entity environment, geometry and topology of entity, bonds between the entity and the environment, entity activation, influence on the entity, particular characteristics of entity); outputs are formed by the consequences induced by causes (processes on the entity, entity states, entity manifestations, consequences of manifestations).

All these causes and also the consequences have certain real properties and behaviour. For computational modelling, it is necessary to describe the properties and behaviour of entities by certain characteristics, and they should be expressed by quantitative variables (if possible). Given to the limited abilities of humans to transform the elements of objective reality to the elements with which it is necessary to perform some operations (e.g. computational), it is not possible to avoid certain simplifications of reality. What we receive after the transformation of objective reality to "usable reality" can be denoted as a model of the respective cause or consequence, particularly as its **computational sub-model**. One of the steps of the algorithm in computational modelling is the creation of these sub-models:

Model of entity environment, model of entity geometry, model of entity topology, model of bonds between the entity and the environment, model of entity activation, model of influences on the entity, model of particular properties of the entity, model of processes on the entity, model of entity state, model of entity behaviour, model of entity manifestations, model of entity consequences, model of entity limit states. Computational modelling (CM) can be classified as follows:

- Classical CM;
- Simulation CM;
- Computational optimization;
- Identification of systems;
- Soft modelling;
- Sensitivity analysis.

4. Creating the terms in modelling

A spontaneous process of terms creation, without any rules how to create them, often leads to vagueness of created terms. This applies in general, i.e. also for the sphere of modelling. To modify the terms of "modelling" and "model" that stand in sentences as subjects, a part of the sentence, termed an attribute, should be used. It may be congruent (before the subject, taking the form of an adjective) or incongruent (after the subject and it is one or more nouns). A congruent attribute can be converted to incongruent (reverse is true, which leads to a change in meaning of the term.

- **Congruent attribute** (adjectives) before the words "model" and "modelling" are used to express:
  a) **Essence of model and modelling**. Then, **what** is the essence of model and modelling? Answers: material, experimental, theoretical, computational, data-based, hybrid, knowledge-based, etc. Therefore, defining a type of modelling by the adjective before the word modelling is used if the modification of the term "modelling" refers to:
  b**) Characteristics of variables describing the model and modelling**. Then, **what** characteristics have the model and modelling? Answers: static, dynamic, deterministic, stochastic, fuzzy, isolated, closed, chaotic)
  c) **Approach to the subject of modelling.** Then, what approach has the individual to models and modelling? Answers: intuitive, conscious, non-systems, systems.
- **Incongruent attribute**. It is one or more nouns placed after the words "model" or "modelling". It is used if we ask the question: the model or modelling of what? Answers: geometry, material, properties, activation, interactions, constitutive relations, states and manifestations of entities, consequences of manifestations, etc.

  Therefore, the correct term is "model of entity geometry" (i.e. the geometry of what? - entity). The term "geometrical model" means that the model has a graphic layout (sketch, drawing), which is something else. Another example: "model of material constitutive relations", which means that the constitutive relations of a particular material are mathematically modelled. The term "constitutive model" would mean that modelling is of constitutive essence, constitutive property, or uses a constitutive approach – but this all is nonsense.

  On the basis of what terms of modelling are employed by the authors in their articles, an idea is given of whether or not they conceived the essence of modelling. The contributions of our authors to English periodicals should be written considering the systems conception in terms of content and terminology, regardless of how they are written in abroad. Even there the authors "may be mistaken".

5. Conclusions

Who wants to, he/she will understand. Who does not, there is a plenteous literature. It is just about your willingness. It is not easy, but worth doing it. Open the gate to a systems approach to problem-solving and you will find yourself in another world. System methodology is used to solve various scientific and technical problems, e.g in the construction industry (Kala et al., 2017).

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