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**Modeling a system**

*Modeling - the study of objects of knowledge on their models; construction and study of models of real-life objects, processes or phenomena in order to obtain explanations of these phenomena, as well as to predict the phenomena of interest to researchers.*

**Modeling type**

*Due to the ambiguity of the concept of "model", in science and technology there is no single classification of types of modeling: the classification can be carried out according to the nature of the models, according to the nature of the objects being modeled, according to the areas of application of modeling (in engineering, physical sciences, cybernetics, etc.).*

*Currently, according to the modeling technology and field of application, the following main types of modeling are distinguished:*

***1) Information Modeling*** *- the model of an object, presented in the form of information describing the parameters and variables of the object, which are essential for this consideration, the connections between them, the inputs and outputs of the object and which allows, by submitting information about changes in the input values ​​to the model, to simulate the possible states of the object.*

*An information model (in a broad, general scientific sense) is a collection of information that characterizes the essential properties and states of an object, process, phenomenon, as well as its relationship with the outside world.*

***2) Computer modelling -*** *the process of computing a computer model (otherwise a numerical model) on one or more computational nodes. Implements the representation of an object, system, concept in a form different from the real one, but close to the algorithmic description. Includes a set of data characterizing the properties of the system and the dynamics of their change over time*

***3) Math modeling -*** *mathematical representation of reality , one of the versions of the model as a system, the study of which allows you to obtain information about some other system. A mathematical model, in particular, is intended to predict the behavior of a real object, but always represents one or another degree of its idealization.*

***4) Modeling biological systems -*** *direction in biological modeling, namely the process of creating models of biological systems with their characteristic properties. Any biological system can become an object of modeling. Biological modeling is an important task in systems and mathematical biology. Computing systems in biology are aimed at the development and use of efficient algorithms, data structures, visualization and communication tools for computer modeling of biological systems.*

***5) Cliodynamics -*** *a new interdisciplinary area of ​​research that combines the approaches of historical macrosociology, theoretical history, mathematical modeling of long-term social processes, the construction and use of historical databases, studies of social evolution, historical demography, etc. The task of cliodynamics should be to search unifying theories and testing them on the basis of various data sets - historical, archaeological*

***6) Mathematical and cartographic modeling -*** *it is «the construction and analysis of mathematical models based on data taken from the map (maps), the creation of new derived maps based on mathematical models. The MCM is characterized by a systemic combination of mathematical and cartographic models, in which chains and cycles are formed: a map - a mathematical model - a new map - a new mathematical model, etc.»*

***7) Molecular modeling -*** *the collective name of methods for studying the structure and properties of molecules by computational methods with subsequent visualization of the results, providing their three-dimensional representation under the conditions specified in the calculation*

***8) Digital modeling -*** *a method of studying real phenomena, processes, devices, systems, etc., based on the study of their mathematical models using a digital computer. The program executed by the digital computer is also a kind of Model of the investigated object. With digitalization, special problem-oriented modeling languages ​​are used; one of the most widely used languages ​​in modeling is the CSMP language, developed in the 60s. in the USA. Ts. M. Is notable for its clarity and is characterized by a high degree of automation of the process of studying real objects.*

***9) Logical modeling -*** *is a procedure for checking the functioning of a logic circuit using a computer. Its main goal is to test the function of the designed logic circuit without its physical implementation, since after the circuit has been manufactured, it is not easy and expensive to make changes to it with modern technology. Verification is performed by comparing the simulation results obtained for the designed propulsion system with the specification. In this case, both logical functions and timing relationships are checked.*

***10) Pedagogical modeling -*** *development and creation of a formal model of the pedagogical process or its components, reflecting the main ideas, methods, forms, means, techniques and technological solutions, which are subject to further experimental study in the conditions of a real pedagogical process.*

***11) Psychological modeling -*** *a formal model of a mental or socio-psychological process, that is, a formalized abstraction of this process, reproducing some of its main, key, in the opinion of this researcher, moments for the purpose of its experimental study or for the purpose of extrapolating information about it to what the researcher considers to be special cases of this process.*

***12) Statistical modeling -*** *study of objects of knowledge on their statistical models. “Statistical models are necessary for the theoretical study of the influence of fluctuations, noise, etc. on processes. When stochastic processes are taken into account, the movement of the system will no longer obey dynamic laws, but the laws of statistics. In accordance with this, questions can be raised about the probability of a particular movement, about the most probable movements and about other probabilistic characteristics of the system's behavior ”.*

***13) Structural modeling -*** *it is a shortcut to a diverse set of methods used by scientists in both experimental and observational research in science, business, and other fields. It is most commonly used in the social and behavioral sciences.*

***14) Physics simulation -*** *a method of experimental study of various physical objects or phenomena based on the use of a model that has the same physical nature as the object under study*

***15) Economic and mathematical modeling -*** *the sphere of theoretical and applied scientific activity, the purpose of which is the mathematically formalized study of economic objects, processes and phenomena. Along with the simplest geometric methods within the framework of mathematical economics, tools of integral and differential calculus, matrix algebra, mathematical programming, and other computational methods are used, recurrent and differential equations are compiled and solved*

***16) Simulation modeling -*** *a research method in which the system under study is replaced by a model that describes the real system with sufficient accuracy (the constructed model describes the processes as they would in reality), with which experiments are carried out in order to obtain information about this system. Such a model can be “played” in time, both for one test, and for a given set of them. In this case, the results will be determined by the random nature of the processes. Based on these data, one can obtain fairly stable statistics.*

***17) Evolutionary modeling -*** *uses signs of Darwin's theory to build intelligent systems (methods of group accounting, genetic algorithms). It is part of the broader field of artificial intelligence - computational intelligence.*

***18 )Graphic and geometric modeling -*** *section of mathematical modeling - allows you to solve various problems in two-dimensional, three-dimensional and, in general, in multidimensional space.*

***19) Full-scale modeling -*** *this is a simulation in which a real object is associated with its enlarged or reduced material analogue, which allows for investigation by means of the subsequent transfer of the properties of the studied processes and phenomena from the model to the object based on the theory of similarity.*

***20) Metamodeling -*** *it is the process of creating metamodels. Metamodels are a means of building models (for example, formal languages ​​or graphical notations for describing the structure of classes, properties, and relationships). ... It reads information about the data structure from the model and the metamodel, and automatically adjusts to them.*

**Simulation process**

*The modeling process includes three elements:*

***subject (researcher)*** *- bearer of activity, consciousness and cognition; an individual who cognizes the external world (object) and acts on it in his practical activity; a person or a consolidated group of persons (for example, the scientific community), society, culture or even humanity as a whole, opposed to cognizable or transformable objects.*

***object of study*** *- in science, it means the main field of application of the forces of scientists. In one science (scientific direction), however, there can be several objects of research, which make up a logically connected entity and the goal of research in this science (scientific direction).*

***a model that defines (reflects) the relationship between the cognizing subject and the cognized object.***

*The first stage of building a model presupposes some knowledge of the original object. The cognitive capabilities of the model are determined by the fact that the model displays (reproduces, imitates) any essential features of the original object.*

*The question of the necessary and sufficient degree of similarity between the original and the model requires a specific analysis. Obviously, the model loses its meaning both in the case of identity with the original (then it ceases to be a model), and in the case of an excessive difference from the original in all essential respects. Thus, the study of some aspects of the modeled object is carried out at the cost of refusing to study other aspects. Therefore, any model replaces the original only in a strictly limited sense.*

*From this it follows that for one object, several "specialized" models can be built that focus on certain aspects of the object under study or characterize the object with varying degrees of detail.*

*At the second stage, the model acts as an independent object of research. One of the forms of such research is the conduct of "model" experiments, in which the conditions for the functioning of the model are deliberately changed and the data on its "behavior" are systematized. The end result of this stage is a set (body) of knowledge about the model.*

*At the third stage, knowledge is transferred from the model to the original - the formation of a set of knowledge. At the same time, there is a transition from the "language" of the model to the "language" of the original. The process of transferring knowledge is carried out according to certain rules. The knowledge about the model should be adjusted taking into account those properties of the original object that were not reflected or were changed during the construction of the model.*

*The fourth stage is the practical verification of the knowledge obtained with the help of models and their use to build a generalizing theory of an object, its transformation or control.*

*Modeling is a cyclical process. This means that the first four-stage cycle can be followed by a second, third, etc. In this case, knowledge about the object under study is expanded and refined, and the original model is gradually improved. Disadvantages discovered after the first simulation cycle, caused by little knowledge of the object or errors in building the model, can be corrected in subsequent cycles.*

*Now it is difficult to indicate an area of ​​human activity where modeling would not be applied. For example, models have been developed for the production of cars, the cultivation of wheat, the functioning of individual human organs, the life of the Sea of ​​Azov, the consequences of an atomic war. In the future, for each system, its own models can be created; before the implementation of each technical or organizational project, modeling should be carried out.*

**Fundamentals of Scientific Modeling**

**Simulation for direct measurements and experiments**

*Models are commonly used when it is impossible or impractical to create experimental conditions under which scientists can directly measure results. Direct measurement of results under controlled conditions will always be more reliable than simulated estimates of results.*

*In modeling and simulation, a model is a purposeful simplification and abstraction of the perception of reality due to physical and cognitive constraints.*

*Modeling is a manageable task because the model is aimed at solving specific questions or problems that have been asked.*

*Simplifications are intended to omit all known and observable entities and their relationships that are not relevant to the task at hand. Abstraction aggregates information that is important but not needed in the same detail as the object of study. Both actions, simplification and abstraction, are done purposefully. However, they are made based on the perception of reality. This perception is already a model in itself, since it is associated with physical limitations.*

*There are also limitations on what we can formally observe with our current tools and methods, as well as cognitive barriers that limit what we can explain with existing scientific theories. Such a model includes entities, their behavior and their formal relationships and is often referred to as a conceptual model. To create such a model, it must be implemented through computer simulations. This requires a large sample through applications such as numerical approximation or the use of heuristics. Despite all these epistemological and computational limitations, simulation has been recognized as one of three key components of scientific methods: theory building, modeling, and experimentation.*

**Simulation**

*Simulation is a complex process of model behavior within the given simulation conditions. Static simulation provides information about the system at a certain given moment in time (usually at equilibrium, if such a state exists). Dynamic simulation provides information over time. Simulation brings the model to life and shows how a specific object or phenomenon will behave. Simulation can be useful for testing, analysis or training in cases where objects or concepts of the real world can be represented as their models.*

**Structure**

*The structure is a fundamental, but often intangible concept in itself recognition, observation, genesis, preservation of the constancy of patterns and relationships of modeled entities. From a child's verbal description of a snowflake to a detailed scientific property of magnetic fields.*

**Systems**

*A system is a collection of interacting or interdependent entities, real or abstract, that form an integrated whole. In general, a system is a structure or a collection of different elements that together can lead to results that cannot be obtained by the elements themselves. [6] The concept of an “integrated whole” can also be formulated in terms of a system that embodies a set of relationships that differ from the relationship of a set to other elements and from the relationship between an element of a set and non-relational elements.*

*There are two types of system models: 1) discrete, in which the variables change instantly at certain points in time and 2) continuous, when the state variables are continuously changing in time.*

**Creating of Model**

*Modeling is the process of creating a model as a conceptual representation of some phenomenon. Typically, a model will only deal with some aspects of the phenomenon under consideration, and two models of the same phenomenon may differ significantly, that is, the differences between them will not only be in the simple renaming of their constituent components.*

*Such differences may be due to different requirements of the end users of a given model, or conceptual or aesthetic distinctive preferences of the creators of the model and their decisions made during the modeling process. The considerations of the creators that can influence the structure of the model may be in the area of ​​personal professional preference for, for example, the use of a shortened ontology, or the preference for the use of statistical versus deterministic models, discrete versus continuous, etc.*

*In any case, the users of the model need to understand the assumptions made by the creators that are aimed at a particular use of the model.*

*An abstraction is required to build a model. Assumptions are used in modeling to indicate the scope of the model. For example, special relativity takes an inertial frame of reference. This assumption was contextualized and further explained by general relativity. A model makes accurate predictions when its assumptions are valid and is likely to fail to make accurate predictions when its assumptions are not met. Such assumptions often coincide with the moment when old theories are replaced by new ones (by the way, general relativity also works in non-inertial frames of reference).*

**Model evaluation**

*The model is evaluated primarily for its consistency with empirical data; any model inconsistent with reproducible observations should be modified or rejected. One way to change the model is to limit the scope over which it matches observations with a high degree of confidence. For example, Newtonian physics, which is very useful, except for very small, very fast and very massive phenomena in the world. However, compliance with empirical data alone is not sufficient for the model to be accepted as valid. Other factors that are important in evaluating a model include:*

*1) Possibility to explain past sightings*

*2) The ability to predict future observations*

*3) Cost of use, especially when combined with other models*

*4) Refutability, which allows you to assess the degree of reliability of the model*

*5) Simplicity or even aesthetic appeal*

*Based on the listed criteria, the user of the model can try to quantify it using the utility function, determining for himself the priority «weights» of the variables.*

**Visualization**

*Visualization is any way of creating images, diagrams or animations for a communication message. Visualization with images has been an effective way of communicating both abstract and concrete ideological entities from the very beginning of human history - cave paintings, Egyptian hieroglyphs, Greek geometry, and Leonardo da Vinci's revolutionary technical translation methods for engineering and scientific tasks.*

**Spatial mapping**

*Spatial mapping refers to a methodology that uses a “quasi-global” technique to link the accompanying “coarse” (perfect or low fidelity) to “high fidelity” (practical or high fidelity) models of varying complexity. In engineering optimization, mapping aligns (displays) very quickly a rough model with its associated expensive computational high-precision model to avoid the direct costly optimization procedure for such a model. The mapping process iteratively refines the rough model (surrogate model) by comparing it with the high-precision one.*

**Modeling**

***Modeling -*** *is a type of technical creativity (hobby), the production of reduced models and layouts of various equipment and architectural structures, a copy is created on a certain scale.*

***Modeling is divided into two main areas:***

*construction of working models;*

*bench modeling, that is, the creation of static models that reproduce the appearance of the prototype as accurately as possible.*

**Stand models**

*The stand model accurately reflects only the prototype view. A characteristic difference from the current models is that in bench modeling they strive for the most accurate and detailed copying of prototypes, up to reproducing the smallest details on equipment, color shades, internal equipment, lettering type, imitation of characteristic dirt and damage, etc.*

*Often, it is not just an airplane, tank or steam locomotive of a given type that is reproduced, but a specific historical specimen with all its characteristic individual characteristics, moreover, as of a certain moment in time.*

*The main materials used in bench modeling are plastic and cardboard, although metal and wood are also used. Models can be made in any scale, but there is a generally accepted series - 2: 1, 1: 1, 1: 2, 1: 3, ... 1:24, 1:32, 1:35, 1:43, "0" 1 : 45, 1:48, "S" 1:64, 1:72, "H0" 1:87, "TT" 1: 120, "N" 1: 160 and others.*

*Highly detailed bench model*

*Many enterprises in the world produce both ready-made bench models and sets of parts for self-assembly.*

**Buildable plastic model-copy**

*A prefabricated plastic model-copy is a set of parts industrially made of plastic for self-production (assembly, usually by gluing) of a scale model. The manufacture of such sets, as well as a variety of accessories for them - tools, adhesives, paints, putties, decals and others - is engaged in a whole industry, represented by many enterprises, both large and small.*

**Dioramas**

*A diorama in poster modeling is not quite accurately called a combat or everyday scene recreated in miniature (both actually occurring and arbitrary) using models of technology, a "three-dimensional picture". The most common scale in diorama construction is 1:35, although others are also used (1:16, 1:32, 1:72).*

*The main requirements for dioramas are artistic design, detailed copying (in the case of historical reconstruction), high-quality painting of equipment and figures, imitation of typical pollution, damage to equipment, etc.*

*A small diorama is called a vignette; it may not carry a big idea, but be just a model of equipment on a stand, possibly surrounded by people.*

**Cordless models**

*A relatively simple and cheap type of operating models of airplanes, cars and ships - cordless, that is, moving in a circle "on a leash". This method greatly limits the possibilities of the model's movement and the spectacularity of the demonstration, but it allows holding quite a variety of competitions on a limited area (for example, for speed and realism of action, "air combat", etc.). The cord can serve as both a mechanical control drive and a transmission line for electrical control signals. Cordless models were very common until radio control equipment became miniature and cheap enough.*

**Any variants of drive**

***Timers*** *are most often used in free-flying aircraft models for altitude and range competitions. A timer, mechanical or electronic, after a specified time, forces the model to perform certain maneuvers (transition to level flight, turn, descent).*

***Induction control*** *is a type of radio control. The transmitter antenna is a fairly large closed loop. A model with a receiver equipped with a magnetic antenna can move within this loop. The system operates at a low frequency (tens of kilohertz), the transmitter power is very small, so this solution was offered as a homemade product for beginners.*