Aspects of modern systemic approach (II): beyond the dynamic systems classification and analysis of representation models

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ABSTRACT

General Systems Theory (GST), as well as Systems Theory (ST), are in the attention of scientists everywhere. Their research has highlighted both an approach to micro-systems and especially to macro-systems, in both cases these being the ends of the current world range seen from a purely scientific perspective. For the present study, an attempt was made to bring to the fore only a part of the entire international debate on the notion of system. Objective of the study experienced such a limitation with respect to the scope of dynamic systems. As such the paper goal was to familiarise the reader with the diversity of concepts and develpment stages specific to the General Systems Theory and Systems Theory, in particular with the dynamic systems classification and analysis of associated models.

Keywords: GST, dynamic system, systems classification, analysis methodologies.

1. INTRODUCTION

The system, seen both as an organizational unit of matter and in relation to the subsystems it integrates, respectively to the supersystem in which it can be integrated, is defined as a set of identical or different elements linked together by connections that function as a whole. . As a natural continuation, of defining and understanding the concept of system, through this paper we resumed the subject, the notion of system thus acquiring new valences.

Starting from the classical theory of systems operating with I-O type systems, while the modern and post-modern theory of systems operates with I-S-O type systems, we decided to present a classification of systems and implicitly of models.

Physical systems are based on a series of material components whose properties and interrelationships can change over time, so the inputs and outputs of systems can be classified into three categories: matter, energy and information. From a functional point of view, however, the inputs and outputs of the physical systems can be formally described by an equivalent matrix (see Table 1).

Table 1. The system having the inputs and outputs represented by the matrix

Inputs (x)		**Outputs (y)**							
		a	b	c	d	e	f	g	h
Material	solid	x							
	liquid		x						
	gas			x					
	particles				x	x	x	x	
Energy	mechanic	x							
	thermal	x	x	x					

	electric				x	x		
	magnetic						x	x
Information	analogous	x	x		x		x	
	digital			x		x		x

The three categories of inputs and outputs (matter, energy and information) are subdivided, so that a point located at the intersection of inputs and outputs represents a certain class of the system and corresponds to a certain area of interest.

2. MATERIAL AND METHOD

A system of which processes and subsystems are not defined because the object of research doesn't need this thing, it's called a black-box system. For most systems is necessary to identify and define processes that occur and the meaning of characteristics for each of them. A system can be analyzed regarding its environment, to the character of its activities, to the nature of its connections, its complexity and finally regarding its predictability levels. Making a systems classification in concordance to the affirmation before implies the existence of a collection of objects and some criteria which ordering, and grouping is made. In the case of systems this identifies with the ordering collection. The documentation stage for making this material consisted in consulting some articles from the specialized literature, which refer, in one form or another, to the classification of the systems, respectively to the types of afferent models. Their analysis and interpretation in my own way led to the classification in this study, which I consider extremely important for subsequent studies.

3. RESULTS AND DISCUSSION

3.1 Systems classification

Based on the criteria mentioned before and on derivative properties out of the structural-unitary, causal-dynamic and informational of systems they can be classified (split and grouped) into classes [1-3], systems belonging to a class having similar properties and behaviors. From now on we will mention the main characteristics of every system mention before, as follows [4-6]:

a) From the character of activities point of view, we can define a first typology of systems -*deterministic systems* and *probabilistic systems* (*stochastic systems*).

A deterministic system operates in conformity with well determined set of rules, so regarding its future behavior, it can be correctly determining if its current state and operational characteristics are precisely known. For example, mechanical systems, equipment's, installations, software etc. Are deterministic system which behavior can be determined.

Economic systems, including business ones, and other systems as well (biological ones in that regard) have a nondeterministic behavior, generated by the probability of internal perturbations to happen (arrhythmic supplying, installation and equipment's breakdowns, employees claims etc.) or external ones(market segments reduction, new competitor apparitions - species, strong fluctuations of request and living conditions etc.).

A probabilistic system is controlled, on the other hand, by the chance of events to happen, its behavior being in this case hard to determine because of the internal and environment random perturbations that it must withstand. When such systems are investigated there is no certainty that specific outputs can be obtained from specific inputs and the events that occur are hard to predict and their influence on the internal processes are also hard to predict.

b) From an internal connections behavior point of view there can be pointed out the following types - *open structure systems* and *closed structure systems*.

Open structure systems point out the functional dependence between inputs and outputs and the influence of external perturbations on base activities. In such systems there is an informational subsystem that receives the general inputs and produces an informational output, which, together with external disturbances, influences the main subsystem, and produces the general output of the system.

Closed-ended systems highlight, in addition to the functional dependence between output and input variables, the inverse connection through which inputs are influenced by the nature of outputs. If this connection is processed by one or more subsystems before directly influencing the input, we speak of feedback systems.

c) Another typology can be obtained based on the existence of the environmental adaptability property of the systems, in which case we can highlight *non-adaptive systems(conventional systems)*, characterized by the lack of this property, respectively *adaptive systems* which, in turn, may have open or closed structure [4].

Adaptive systems consist of a main subsystem, which may be responsive, automatic, closed or open, as well as an adaptation system, which may be an informational entity having as input the vector of adaptation criteria and disturbances, and as output an adaptation vector. For the active subsystem, the input consists of the composition of the adaptation vector with the input vector, to which is added the influence of environmental disturbances, and its output can be expressed by an adaptation function. Such an open-ended adaptive system is specific to management systems in which the decision of the basic subsystem depends on a set of decision criteria.

Closed structure adaptive systems differ from open structure systems by having a reverse connection through which the adaptation function requires the adaptation subsystem, based on information on the output of the basic subsystem, to output the vector of adaptation variables as input to the main subsystem.

Depending on the adaptation criteria used, we can highlight conventional adaptive systems, in which the criteria have a fixed value and optimal systems, in which the criteria represent an objective to be optimized. These systems can be adaptive to inputs, when they can perform its function of adaptation to the environment only by changing inputs, or adaptive by structure, when adaptation to the environment is achievable by changing the organizational structure, technology, information-decision, management and so on.

d) Another typology can be established according to the internal and external functionality of the systems.It refers to the necessary correlations that must exist between the component subsystems and between them and their environment, in order to achieve the established objectives.

From the point of view of functionality, *concentrated systems* can be highlighted, in which the component subsystems can have identical or complementary functionalities in order to achieve a single purpose and *distributed systems*, made up of subsystems with distinct functionalities that pursue their own, precise objectives. a global goal.

e) A distinct typology of grouping and classification of systems can be established according to the following types of connections (see Fig. 1) [5]:

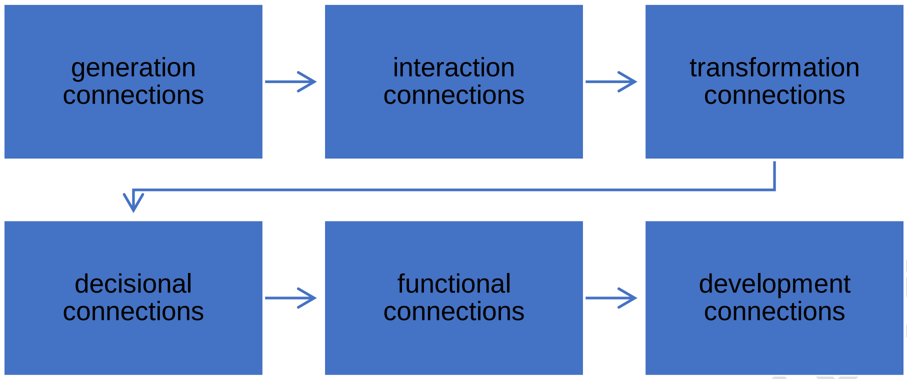

Fig. 1. Schematic representation of the connections between the systems

- *generation connections* - have a temporary character and appear if two or more subsystems interact in order to achieve a common objective or a new subsystem incorporated in the structure of the reference system;

- *interaction connections* - are the most common types of connections and have the property of remaining relatively stable for a longer period of time, keeping them directed to the appearance or disappearance of components without affecting the interactions between other components. The connections can be of material, energetic, financial, informational, human nature and according to their kind, in the respective system coexist structures of the same type;

- *transformation connections* - are a particular case of those of operation and consider bringing some of the component subsystems from an initial state to a specific final state, given or not. In this case the subsystems no longer have different functionalities, they aim to achieve the same objective. In the transformation process, these connections are no longer stable, depending on the stages of the transformation process and a series of system-specific restrictions;

- *decisional connections* - have a complex character, being a combination of development and functional connections, and which materialize based on principles, methods or management models. These connections are stable during the period in which the objective is pursued and their study is essential for defining the informational-decisional structure of the system;

- *functional connections* - have informational character and appear when there is a correlation between the subsystems that fulfill their own functions and which, in turn, represent the conditions for achieving the function of the whole system. The subsystems of an enterprise, for example, through their specific functions contribute to the achievement of the function of the enterprise (meeting a market demand). The correlation of the subsystems is made through the manufacturing plan and the organization and functioning regulation that specify the coordination and subordination of the subsystems;

- *development connections* - are a particular case of generation connections and they involve essential changes, of a qualitative nature, in the structure of the system.

These connections are more stable and operate over longer periods of generation, which is why they require prospective system investigation methods and techniques.

Based on the connections set out above, the following categories of systems can be highlighted in the analysis and design of the systems, in relation to the structures, namely:

- systems with hierarchical structure - are organized from the information-decision-making point of view on most hierarchical levels, the component subsystems forming a tree. The specific connections of this structure revise the links in both existing and existing sub-systems between the systems at the upper levels and those at the lower levels; There are only information links between the subsystems on the same level.
- systems with a hierarchical structure - cannot be represented as a tree, the component subsystems being connected directly in the form of a network.
- systems with mixed structure - are based on the tree representation and are made up of subsystems organized on hierarchical levels, and the related subsystems at each level can be formed from the elements in the hierarchical structure.

According to the nature of the elements, we distinguish the following types of systems: material, energetic, informational, financial, mathematical, linguistic, etc. According to the nature of the operating systems, the systems are classified into linear and linear systems, to which other types are added (see Fig. 2).

The concepts presented above are particularly useful in the analysis of systems and constitute basic elements of the specific language used in the process of investigation, modeling and design of systems, which we can group in detail, as follows, in:

a) *Continuous systems* vs *Discrete systems*

Continuous time systems are those systems in which the input, state, and output quantities are values at any given time belonging to the set of real numbers. Continuous time systems can be continuous smooth or continuous analog. Continuous systems satisfy the property that for any initial state and any continuous input function, the state function and the output function are also continuous functions. Continuous time systems that do not satisfy this property are discontinuous systems. Continuous time systems are described by differential equations.

Discrete-time systems are those systems in which input, state, and output quantities are only valid at certain discrete times of time. Discrete-time systems in which the discretization of time is uniform (with constant pitch), that is, where is the period (tact) and are called discrete systems. Choosing, by convention, results in discrete systems time is an integer variable.

Discrete physical systems contain a clock generator (clock), so they are artificial, man-made systems. Discrete systems in which the variables of one or two distinct values ("0" and "1") are called sublogical systems, and finite systems in which variables have a large number of values are called numbers. Systems that contain both continuous and discrete elements are called sampled systems. The interconnection of continuous and discrete subsystems is achieved through analog-to-digital and digital-to-analog converters. The numerical signals obtained by the periodic discretization of the continuous signals are called sampled signals.

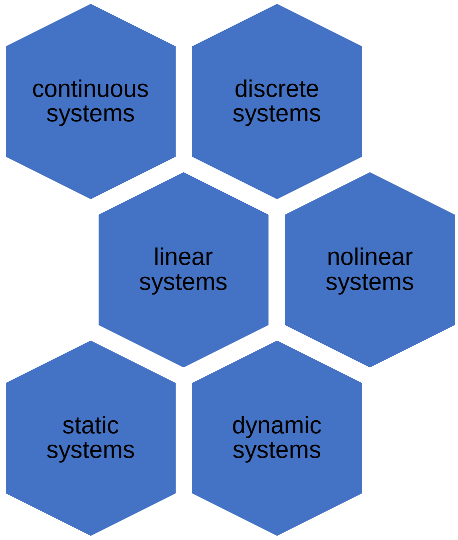

Fig. 2. Schematic representation of the physical systems typology

b) *Linear systems* vs *Nonlinear systems*

Let $x(t)$ and $y(t)$ be the input and respectively the output signals of the system S, so that the transformation denoted by $y(t)=Sx(t)$ of the input signal $x(t)$ into the output $y(t)$ takes place. We say that the system S is called linear system, because it satisfies the addition and the homogeneity property. By addition property we mean that an input $x_1(t)$ of the system S produces an output $y_1(t)$, respectively an input $x_2(t)$ of the same system produces an output $y_2(t)$, then both inputs acting simultaneously $x_1(t)+x_2(t)$ will produce the output $y_1(t)+y_2(t)$.

Mathematically, additivity presupposes if

$$x_1(t)\xrightarrow{system}y_1(t) \quad (1)$$

and

$$x_2(t)\xrightarrow{system}y_2(t) \quad (2)$$

then

$$x_1(t)+x_2(t)\xrightarrow{system}y_1(t)+y_2(t) \quad (3)$$

Homogeneity, from a mathematical point of view, shows us if

$$x_1(t)\xrightarrow{system}y_1(t) \quad (4)$$

then

$$k\cdot x_1(t)\xrightarrow{system}k\cdot y_1(t) \quad (5)$$

In accordance with those mentioned above, $y(t)=x\sin(t)$ is a linear system, and $y(t)=ax(t)+b$ is a nonlinear system.

Linear systems are therefore those which, under any conditions, verify the principle of superposition (superposition of effects), i.e. for which the sum of the effects of the causes is equal to the effect of the causes. The system obtained by interconnecting two or more linear subsystems is also a linear system. The reciprocal of this statement is not always true, ie the linearity of a system does not necessarily imply the linearity of the component subsystems. For the linear systems a unitary theory was elaborated, sufficiently rigorous and cohesive.

Linear systems, on the other hand, are those systems that do not satisfy all cases of the principle of superposition (i.e. those systems that are not linear). The unconstructive way of defining linear systems (by denying some properties) and the multitude of ways of manifesting nonlinearities lead to the idea of the impossibility of constructing a unitary theory of linear systems. Consequently, linear systems are studied on classes of systems, constructively defined based on common properties (for example, classes of continuous and linear systems on portions, classes of systems with static relay characteristics, classes of first-order linear systems, etc.).

Linear systems are described by linear mathematical equations (algebraic, differential or with differences), and nonlinear systems by nonlinear equations. The study of linear systems can be performed in a unitary way, much simpler, easier and more precise. For example, physical (mechanical) systems are usually linear systems. Nonlinear systems that are weak in the field of civil servant studied are considered, by most, to be linear lines in portions.

c) *Static systems* vs *Dynamic systems*

Let $x(t)$ and $y(t)$ be the input and respectively the output signals of the system S, so that the transformation denoted by $y(t)=Sx(t)$ of the input signal $x(t)$ into the output $y(t)$ takes place. We say that the system S is called a static system if the output $y(t)$ depends only on the current value of the input $x(t)$.

We also say that the system S is called a dynamic system if the output $y(t)$ depends on both the past and the future value of the input $x(t)$. The static, respectively the dynamic character of a system can be represented schematically, and understood by the examples:

- static systems: $y(t)=5x(t)$, $y(t)=ax(t)$, and $y(t)=tx(t)+2x(t)$;
- dynamic systems: $y(t)=x(5t)$, $y(t)=x\cos(t)$, and $y(t)=tx(t)+x(t-1)$.

Static systems (no-memory systems) are zero-order systems (without state variables), with the value and output at the time determined by the input value at the same time. In these systems, the output (in its entirety) instantly tracks (without delay) the variations during the input. Physical static systems do not contain components capable of storing and transferring significant quantities of mass and energy.

Dynamic systems (memory systems) have an order greater than zero and are characterized by the presence of transient motions. Dynamic physical systems include in the components of elements capable of accumulating and transferring, with finite speed, significant amounts of mass and energy. Static systems are described by algebraic equations, and dynamic systems by differential or differential equations. The study of a complex system, consisting of most interconnected subsystems, is considerably simpler when some of the subsystems are static. A subsystem is considered static when it has a negligible response time compared to the response time of another subsystem within the studied system.

d) *Monovariable systems* vs *Multivariable systems*

The monovariable systems had a single input and a single output. Multivariable systems had at least two inputs and two outputs. In addition, at least one output is influenced by at least two inputs. Single-input ($m=1$) and multi-output ($p>1$) systems, as well as multi-input ($m>1$) and single-output ($p=1$) systems, can be reduced to m , respectively p , variable systems. Variable systems are also called SISO (single input-single output) systems, and multivariable systems are also called MIMO (multi input-multi output) systems.

e) *Open systems* vs *Closed systems*

Open systems (called open-structure systems) are characterized by a one-way flow of information. Closed systems (closed-structure systems or closed-loop systems) are systems in which a bidirectional flow of information can be highlighted, through which the output size of an element of the system influences the future state of the respective element, through other elements of the system.

f) *Dead time systems* vs *No dead time systems*

In the case of physical systems with distributed parameters, at which the speed of propagation of the phenomenon is relatively low (in the case of mass transfer processes and those with heat transfer), the output quantities and the input quantities can be highlighted a clear delay, of dead time type. Thus, if the input quantity changes in the form of a step at the moment $t_0 = 0$, the effect becomes observable at the output starting from a certain moment. The time interval in which the effect is imperceptible at the exit is called the dead time. Analysis and synthesis of dead time systems is much more difficult than in no dead time systems. In the simplest case, the mathematical equations of the dead time systems contain the input variable $x(t-\tau)$ instead of the input variable $x(t)$.

g) *Systems with constant parameters* vs *Systems with variable parameters*

Systems with constant parameters (invariant systems) have a fixed structure and internal parameters constant in time, and systems with variable parameters (variant systems) have at least one internal parameter variable in time. The state of a system with constant parameters initially in steady state (characterized by the time constancy of all input, state and output variables) can be modified only from the outside, by the action of the input variables. Systems with constant parameters are described by equations with constant coefficients, and systems with variable parameters by inequalities with variable coefficients.

h) *Systems with concentrated parameters* vs *Systems with distributed parameters*

Physical systems with concentrated parameters are those in which it can be considered, with sufficient precision, that the physical quantities associated with any element of the system have the same value at all points of the element. On the other hand, physical systems with distributed parameters are those in which at least one physical quantity associated with a dimensional element of the system has values that differ significantly from one point to another, ie has values distributed along the line, in plan or space.

Because all physical (mechanical) objects are of the spatial type, to determine the character of the distributed concentrate, the time of propagation of the phenomenon in the spatial directions of the object is taken into account, which depends on the size of the object and the speed of propagation. The dynamic behavior of continuous systems with concentrated parameters is described by ordinary differential equations, and that of systems with distributed differential parameter parameters with partial derivatives.

Given the complexity of mathematical formalism in systems with distributed parameters, given that the modeling error due to the abandonment of the distributivity hypothesis falls within acceptable limits (it is below 10%), it is preferred to consider the system analyzed as with concentrated parameters. In such situations, distributed parameter systems can be treated in a manner specific to concentrated parameter systems, choosing as local physical output variables associated with a point or representative (usually extreme) positions of the physical object.

3.2 Mathematical representation of systems

The behavior of a system in the dynamic regime (which includes the stationary regime and the transient regime) can be described with the help of a mathematical model, consisting of algebraic equations and differential equations or with differences, as the system is continuous and discrete. The General Systems Teory uses, two distinct ways of representing systems in the time domain: by type I-O (input-output) equations, and I-S-O (input-state-output) equations. The mathematical model of a system is a set of relations and mathematical equations that allow the description of the behavior of the system, the input-output transfer or the input-state-output. Starting with General Systems Ontology and General Systems Metaphysics and ending with the General Systems Theory (as shown in Fig. 3) [6], we can conclude that for each system there is an associated model.

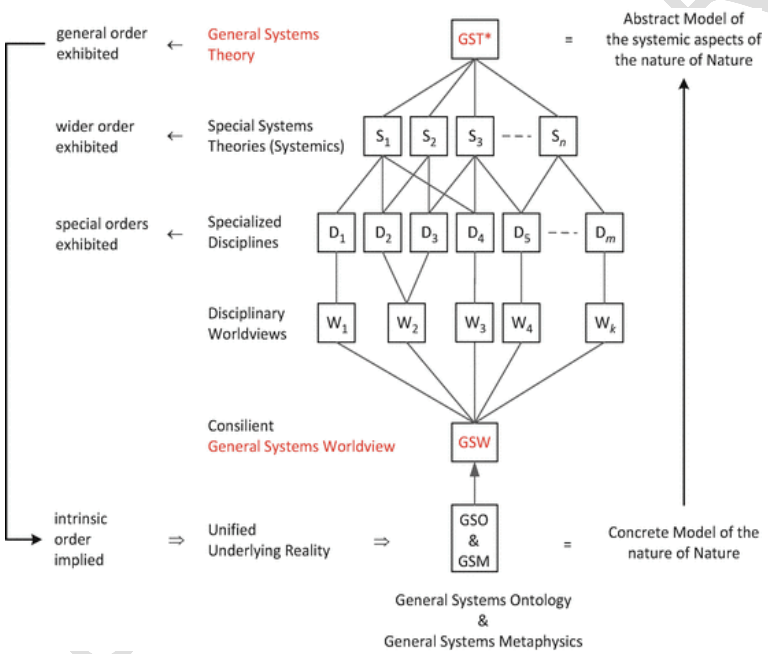

Fig. 3. From General Systems Ontology and Metaphysics to General Systems Theory

A dynamic system (memory system) can be associated with a dynamic model - for the characterization of the dynamic civil servant regime, and a stationary model - for the characterization of the stationary civil servant regime. The stationary regime can be of static type (when the variables of the system are constant in time) or of permanent type (when the form of variation in time of the variables of the system is constant).

The models of static systems and the stationary models of dynamical systems are made up of algebraic equations, while the models of dynamic systems are made up of differential equations (for continuous systems) or equations with differences (for discrete systems).

The dynamic model, by reference to the static model (see Fig. 4), on the other hand, also includes the stationary model, the latter being obtained from the former by a convenient customization (by canceling the time derivatives of the variables - to continuous systems, respectively The stationary model (static type) does not contain time variables.

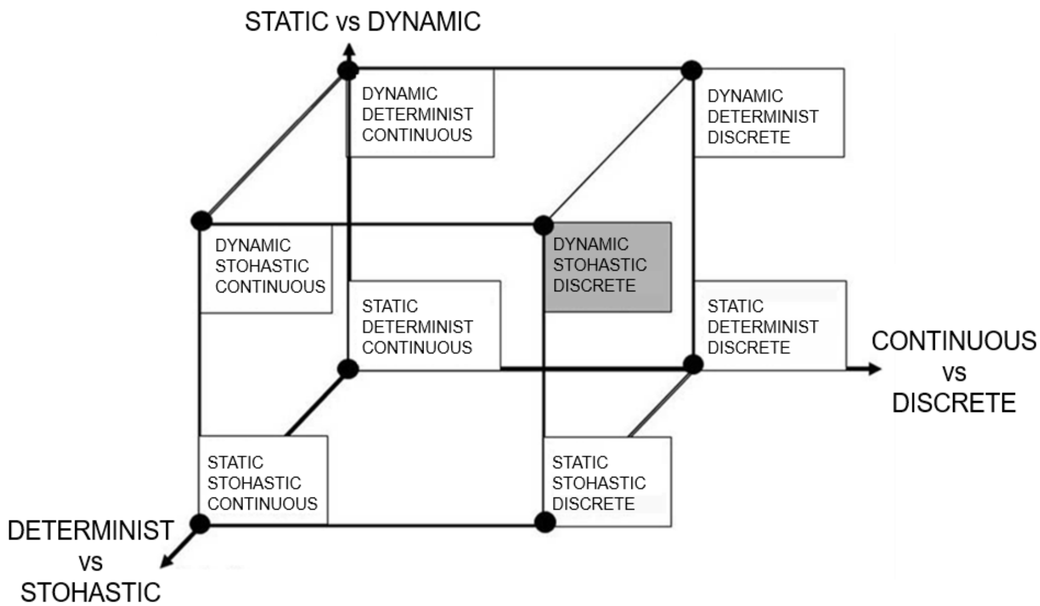

Fig. 4. Schematic representation of dynamic models in relation to static models

Linear systems correspond to linear models (consisting of linear equations), and linear systems - linear models (which contain at least one linear equation). In most practical applications, in order to simplify mathematical formalism, systems with weak nonlinearities are associated with linear and linearized models on portions of the working field.

The modeling of a physical system [7], i.e. the operation of obtaining the mathematical model, can be performed by analytical, experimental or mixed methods. Simulation is the operation of describing the behavior of a system based on its model. Simulation accuracy is mainly based on the accuracy and accuracy of the mathematical model.

Regardless of the method, the modeling operation for dynamic model - as shown in Fig. 5 - is based on considering some working hypotheses, with a simplifying role. Depending on the way of choosing the simplified hypotheses and the degree of their concordance with the real phenomenon, the obtained model is simpler or more complex, reflecting the reality with a different degree of precision.

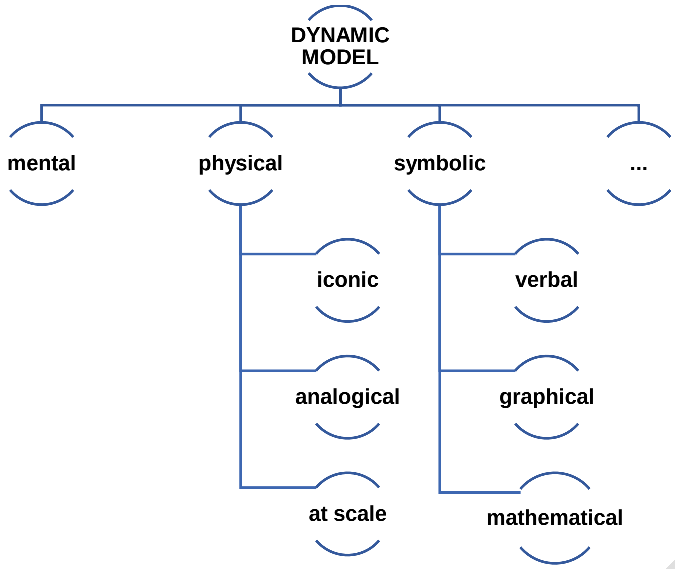

Fig. 5. Different possibilities for representation of dynamic model

If the number of simplified hypotheses considered is large, then the model obtained is simple, robust, easy to process and interpret, but less accurate. None of the very complicated models are recommended, due to the lack of accuracy in determining some parameters, the impossibility of the analytical calculation, the rounding and truncation errors that appear in the numerical processing, etc.

4. CONCLUSION

As it was natural, the notion of system appeared and developed over time, as a result of highlighting common features and behaviors for a number of processes and phenomena in different fields of interest. The classification of systems, as well as the analysis of some models associated with different types of systems have proved to be particularly difficult to approach from only one perspective. As such, it was considered to define a slightly more comprehensive palette for classification, starting from the structural-unitary, causal-dynamic and informational character of the considered systems.

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