The Space of Buildings and Their Information Models as a Triad Structure

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Abstract. The article is devoted to an approach to the study and explanation of information processes of buildings and their information models over time, that is, in the course of their functioning: both during their life path and in the life cycle, when the physical part of a building ceases to exist, and information about its functioning is transferred using general data to create other buildings. Through the functionality of a building as a system, its commonality with cyberphysical systems is shown, and through the position on the position on the three-dimensional reflection in living nature, a tool for describing the space of buildings, structures and their information models is proposed in the form of a system categorical triad approach, supplemented by the position on the Ukhtomsky dominant, the position of category theory and the method of analogies. Using this infographic description of the subject area of buildings and their information models, you can create six basic and three derived results that are elements of the space of a cyberphysical system. It is possible to get a larger number of system elements through determining the results of the effects of results on each other. The presented systemic categorical triad approach based on infographic modeling does not depend on the initial number of parameters and the amount of data that are reduced to triads through monads and dyads and can be effectively investigated.

1. Introduction

The system-structural approach to the study and explanation of building information processes and their information models over time (hereinafter referred to as Buildings) allows us to define Buildings as functional systems. Since the "functional system" (P. K. Anokhin) differs from the rest by the ordered structure and adaptive nature of its behavior, which leads to the achievement of a certain expedient effect [1], therefore, the Building can be classified as a cybernetic system, more precisely, as a complex dynamic system. Information support of modern Buildings in the course of their life-line and in their life cycle is carried out using their information models or digital twins. This allows us to consider modern Buildings as a set of cyber-physical systems (E. Lee). Formally, being a technical object and a cybernetic system, a modern Building can also be described by the modern cyberphysical term "System of Systems" (System of Systems, SoS).

The need to consider technical objects (buildings, ships, machines, cars, computers, etc.) over time in order to make (better) management decisions requires defining a space that includes the dimensions (criteria) that define it. The definition of this space is complicated by the fact that information about
technical objects, as a cybernetic category, circulates over time in at least two environments: natural and virtual ones. In this connection, it becomes necessary to consider the dimensions of this space — the domain area — taking into account these environments.

The statement about three-dimensional reflection in living nature was expressed not only at the philosophical level, but also studied in the framework of system engineering, bio-Cybernetics [Anokhin P. K., 2].

Three-dimensional, three-part division of the subject area in scientific knowledge is, apparently, necessary and sufficient in terms of the number of dimensions of the research space.

A "monad" (one-dimensional) space is the simplest, monofunctional, and elementary structure. In this space, the Building is considered as a whole, without division into parts, which does not always take into account the real practical relationships and mutual influences of different parts (monads). There are four potential types of interactions: 1) perception, 2) impact, 3) transmission. 4) the changes shown in Fig.1:

![Figure 1](image1.png)

**Figure 1.** Monad "Functioning of the building" (life line of the Building).

According to the decomposition principle, a monad can reflect either a single entity or an entire category.

The next, "dyad" (two-dimensional) space already becomes a system structure. In this space, the Building is considered as a model of paired relationship and mutual influence. There are three possible types of interactions in the dyad, as shown in Figure 2:

1) control and regulation through the directed action of one monad on another;
2) cyclical relationship of monads;
3) counteraction of monads.

![Figure 2](image2.png)

**Figure 2.** Dyad "The Existence of The Building".

The subsequent "triad" (three-dimensional) space allows, in addition to the system structure, to consider the relationship of "monads" and "dyads", that is, complex dynamic systems, which are modern Buildings. There are five possible types of interactions in a triad, as shown in Figure 3:

1) a sequence of directed actions in a three-point cyclic relationship of monads ("wheel");
2) multidirectional relationship of monads in the form of forward and reverse cycles;
3) and 3.1) loading the system by the action of the control monad ("complex");
4) the reaction of the system and its monads to the control action (afference);
5) the fifth type of interaction is potentially possible, but not fully realized at the same time, by connecting the components of the triad simultaneously through the above four effects (a complex dynamic system, a "matrix").
Any complex research spaces with a set of monads greater than three can be approximated by a set of models of systems equivalent in results with dimensions 1, 2, or 3 [3].

Based on the above-mentioned research conducted in the past in relation to the subject areas of bio-cybernetics and information modeling in construction, it can be summarized using the method of analogies and the principle of "mapping" from category theory:

- The results of phylogenetic development of organisms are displayed in the field of construction as a body of normative information (documentation) about Buildings, reflecting their functions in the life cycle. This is knowledge integrated into public opinion and includes various expert systems and knowledge bases in construction.

- The results of the ontogenetic development of organisms are displayed in the field of construction as knowledge about a specific Building, which is a stable pattern of data recorded during the functioning of the Building. These are, in other words, stable, repetitive homeostatic reactions of a Building to certain impacts in the course of its life line and waiting to be included in the corpus of normative information about Buildings.

- The results of mutations in organisms are displayed in the construction area as a reflection of the Building's specific impacts in real time of its functioning. In other words, the homeostatic reaction of a Building to any kind of impact (smart reaction) or data on the building's own activity to prevent any kind of impact (smart action) in real time.

2. Method

Since the time of Plato and the neo-Platonist Proclus a triad (Greek. τριάς) in general scientific discourse means a unity formed by three separate members/parts, or a structural trinity or dynamic three-phase nature of a process or phenomenon. Later, Hegel actually absolutized the triad through the stages of the process: "thesis - antithesis-synthesis". Accordingly, the Marxist research approach also used the triad to characterize the development process in the law of "negation of negation" [4].

There are various approaches to the representation of systems, objects of informatization, which include the cyberphysical system in the form of "system categorical", "trinitarian", "triangulation", "S-representations" [5], [6], [7], [8].

Based on the above, to solve the problem of choosing the necessary and sufficient number of dimensions of the space of technical objects for their differentiation [9], a triad representation of the...
cyberphysical Building system is proposed, that is, the Building space can be considered as a systemic categorical triad.

Methods of working with such a triad are proposed to be associated with the method of analogies, the method of displaying categories, and the method of infographic modeling of systems, which offers a modern scientific and practical direction of research-infography [10]. This allows us to consider the triad as an infographic model.

Our own research experience [11], [12], [13] indicates whether the traditional triad representation is supplemented with the following conditions:

1) the "monad-dyad-triad" ontogenesis is considered as a function of time of both the sequential "Chronos" type and the event-based quantum "Kairos" type.
2) the monad is a proto-system, a "thing-in-itself" and has the category "Internal".
3) in the dyad, the second monad that appears has the category "External"
4) in the triad, the third monad that appears has the category "New Internal"
5) in the triad, according to Ukhtomsky's doctrine of the dominant [14], there is a dominant "loading". It is directed from the "New Internal" monad to the process of cyclic interaction between the "Internal" and "External" monads (Fig. 3, action 3);

"Loading" is considered to be the control effect of one of the monads exerted on the interaction of the other two monads of the triad. The loading monad does not have a direct relationship with the interacting two monads (Fig. 3, action 3.1). For example, the goal of "loading" from the ADR monad as a control effect on the cyclic interaction of the LFL and LFC monads (Fig.3) is to improve the quality of this interaction without changing the level of competence of the positions of the interacting monads.

For the space (subject area) of a Building, it is proposed to define three dimensions as follows:
1) "life line" (the number and functionality of the states of buildings and structures in the natural environment — the life line or the process of functioning);
2) "life cycle" (the number and functionality of states of information models of Buildings and structures in a virtual environment — the life cycle through the transfer of knowledge to other Buildings).
3) "useful adaptive result" (the number and functionality of homeostatic actions of a Building in a virtual environment and their reflection in the natural environment);

Each of these measurements is a criterion (variable) for studying a Building in natural and virtual environments.

Working with triads, researchers distinguish the concept of "triad closure", which is a semantic measure that connects a dyad and a monad into a triad. Similarly, a dyad closure is a semantic measure that connects two monads into a dyad.

In the cyberphysical system under consideration, the Building dyad closure is time, a time function that links the "life line" and "life cycle" monads into the "existence"dyad. The triad closure of a Building is knowledge as predicative information linking the dyad and monad into a "useful adaptive result".

The commonality of the triad approach is shown in the fact that the system regularities found in one triad extend to others [9]. The synthesis of triads into higher-level triads generates and makes such a triad an interpretive system in relation to the triads of the lower level [15].

3. Results
The Building space was modeled according to the representation described above. Figure 4 shows the final "triad of triads," an "Intelligent Building", which is an interpretive system in relation to the triads "Knowledge in the object of Technology", "Information model" and "Buildings".
Figure 4. Interpretation system "Intelligent Building" (triad of triads).

The interpretation of the monad notation in this figure is as follows:

Triad "Knowledge in a technological object":
- LFL is the Building's life line;
- LFC is the life cycle of the Building;
- ADR is a useful adaptive result of the Building;

The Triad "Building":
- LBS are load-bearing structural elements of the Building;
- NLS are non-bearing structures of the Building;
- ENN - engineering and other energy and information networks of the Building;

The triad "Information model":
- CRA - generating attributes of the Building;
- GMA - graphic attributes of the Building;
- SMA - semantic attributes of the Building;

The presented system categorical triad approach based on infographic modeling does not depend on the initial number of parameters and the amount of data that can be reduced to basic triads via monads and dyads. Voronoï diagrams can be used, or the inverse of them in the sense of Delaunay triangulation [16], [17].
Figure 5. Results (impacts and loads) for the Smart Home triads, knowledge in a technological object, Information Model, Buildings.

Figure 5 shows the general scheme of the triad with the results of impacts and loads.
An example of describing the parameters of the Building space for interpreting the results based on the triad "knowledge in a technological object" is given (Fig.5):

Table 1. Description of Building space parameters in the triad "Knowledge in a technological object".

| ID | Description | The parameters space of Buildings |
|----|-------------|---------------------------------|
| IR_1 | M1>>M2 (LFL>>LFC) | Status of assignment of phases and stages of the life line of Buildings (or other items of Equipment) for the purposes of their compliance with the selected options for interaction of autonomous development lines in the life cycle of Buildings. |
| IR_2 | M3>>M2 (ADR >>LFC) | Exceptional non-recurring impacts on a building that change critical information containers in regulatory information about Buildings. |
| IR_3 | M3>>M1 (ADR>>LFL) | Identification of exceptions and regularities: stable, repetitive homeostatic reactions of a Building to certain impacts during its life line. Identification of knowledge about the Building. |
| IR_4 | M2>>M1 (LFC>> LFL) | The influence of variants of interaction of autonomous lines of development of Buildings (or other equipment object) in the life cycle of Buildings. |
on the assignment of phases and stages of the life line of this object

A set of homeostatic responses of a Building to any kind of impact or data on the building's own activity to prevent any kind of impact in real time

A set of critical information containers from the corpus of normative information about Buildings for homeostatic reactions of a Building to any kind of impact, or a set of critical information containers for preventing impacts of any kind in real time, A corpus of normative documents about Buildings that reflect their functions in the life cycle.

Analysis of data to identify them in a stable repeating pattern, that is, knowledge about the building. Changing phases and stages in the Building's life line and its cycle.

Examination of the identified knowledge from the life line of the Building for inclusion in regulatory documents.

Examination of regulatory documents for possible changes to the standards based on the results of the identified knowledge from the life line of the Building.

4. Conclusions
1. The research space of buildings and structures together with their information models can be considered using the time function as the space of complex dynamic systems.

2. Complex dynamical systems, of which cyberphysical systems are a part, can be studied using a systematic categorical triad approach, supplemented by the Ukhtomsky dominant position.

3. The described triad approach gives six basic and three derived results, considered as parameters of the triad space as a cyberphysical system. It is possible to get a bigger number of system elements through determining the results of the effects of results on each other.

4. The space of the cyberphysical system "Smart home" consists of three triads and can be described by nine parameters and eighteen parameters of the second level.

5. The presented system categorical triad approach based on infographic modeling does not depend on the initial number of parameters and the amount of data that can be reduced to triads via monads and dyads.

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