PAPER • **OPEN ACCESS**

Digital platform for an adaptive lifecycle management system for construction objects

To cite this article: A A Morozenko *et al* 2020 *J. Phys.: Conf. Ser.* **1679** 042007

Digital platform for an adaptive lifecycle management system for construction objects

A A Morozenko[1,4], A A Zyablov[2] and I A Kheruvimov[3]

[1] Department of construction of thermal and atomic power stations, Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 139337, Russia
[2] JCS EC "ASE", Dmitrovskoe shosse, 2/1, Moscow, 127434, Russia
[3] Digital practices LLC, Presnenskaya embankment, 12, FL 67, of.6-1, Moscow, 123112, Russia

[4] E-mail: MorozenkoAA@mgsu.ru

Abstract. The article presents studies aimed at the formation of an adaptive management system based on the information approach and digitalization of management processes. A conceptual dynamic model of an adaptive control system for large-scale and technically complex construction objects, consisting of two control loops with a description of their functional purpose, is proposed. The material proposes a programming technique based on the schedule of key project events, which is the basis for building a reference model for project implementation. In turn, the reference model is the main element of the adaptive control loop, represented by transition operators written in a matrix form convenient for machine use. Based on the resource approach for the effective development of control actions, it is proposed to distinguish three levels of management decisions: operational, tactical and strategic. The interfaces and services of the adaptive control system are systematized and classified, as a description of its digital profile. The study presents the results of the practical implementation of the proposed approaches by the author's software package, which is the basis for the formation of an adaptive control system.

Digital technologies have long and firmly become part of the arsenal of science and technology as an effective tool for research, management, and automation of intellectual work. Today, no one is surprised by robotic industrial complexes, supercomputing and communication systems, the creation of artificial intelligence [1].

At the same time, despite the widespread use of digital technologies, in a number of industries their influence on production processes and management processes can be considered insufficient [2-4].

The widely used BIM technology in construction effectively solves a number of problems associated with computer-aided design and detailed design, however, this system practically does not solve the issues of organizational construction of production structures, and even more so their management. Various design, construction and scientific organizations, understanding the broad prospects and potential of the introduction of modern methods of organizing construction and management, themselves develop information and management systems, but these attempts are isolated and do not lead to a tangible effect [5-7]. This is largely due to the fragmentation of work, the lack of personnel with construction and digital competencies and the complexity of the task, the solution of which, as it can be seen, is on the border of construction and information science.

Analysis of the ways of possible development of effective management methods for the creation of large-scale construction projects makes it possible to propose to focus on the development of an adaptive management system for key events in the life cycle of technically complex and unique construction projects. The operation of the control system is explained using a simplified diagram (figure 1).

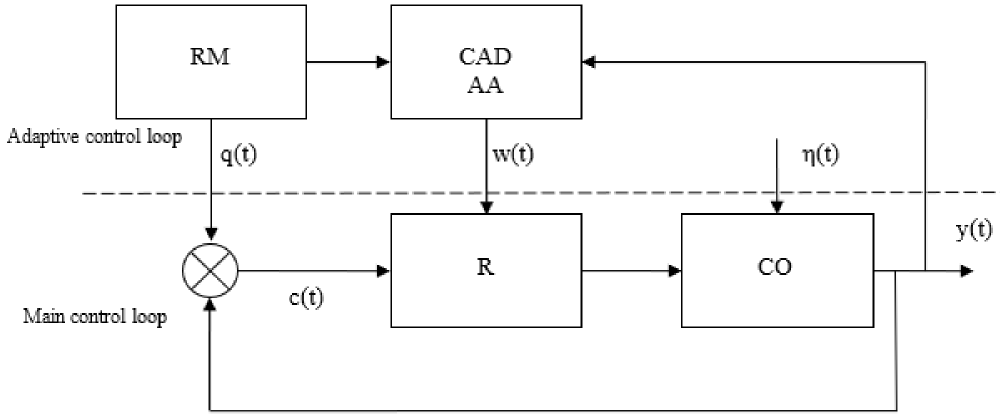

Figure 1. Conceptual model of an adaptive control system: RM-reference model, R-regulator, CO-construction object, CAD-computational and analytical device, AA-adaptive algorithm, q(t)-programmed parameter value, c(t)- signal counteracting the perturbation action of η(t); w(t)-adaptive device error signal.

As can be seen from the diagram, the adaptive control system consists of two loops: the main loop solves the problems of programmed control with compensation of disturbing influences, and the adaptive control loop generates an error signal, which is the difference between the current parameters and construction indicators (programmed values of these indicators).

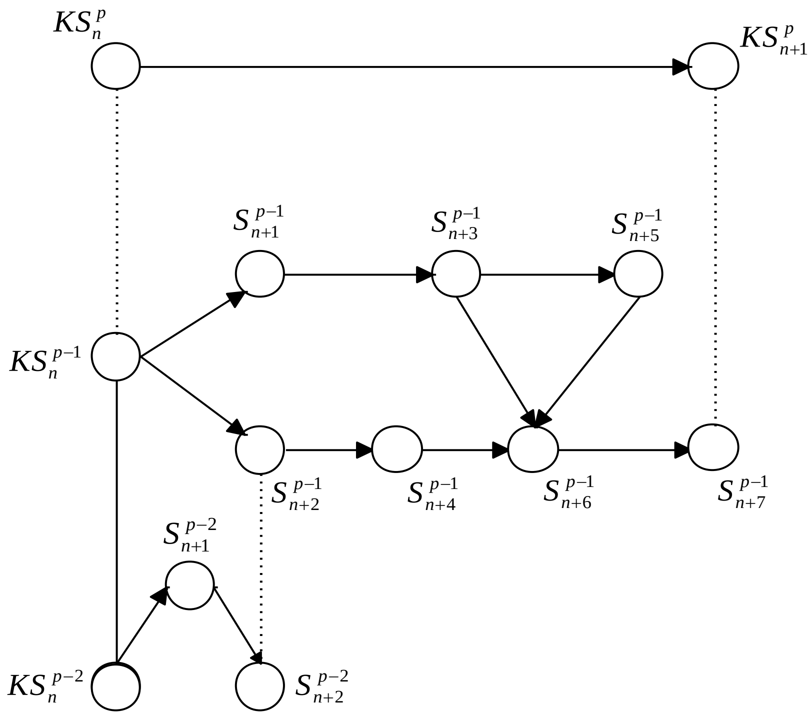

Figure 2. Conceptual model of key project events.

The adaptive control loop contains an essential part of the system: the reference model of the control system. In fact, the reference model of the object is a digital analogue of the controlled object. A characteristic of this model is that it is not stationary. At each moment of the project implementation, it changes its configuration and current parameters. It is extremely difficult to create such a model based on an analytical approach; moreover, the model loses its clarity and is not seen as a real construction object.

To address this issue, it is advisable to use the graph theory and programming techniques based on the schedule of key project events, where the event is taken as the project unit [8]. A chain of key events in the implementation of the project ultimately leads to the achievement of the construction goal.

$$C=\sum_{n=1}^{n=m} KS_n^p=\sum_{n=1}^{n=k} S_n^{p-1}=\sum_{n=1}^{h=l} S_n^{p-2}$$

Details of project events can be reduced to the elementary level of events that are implemented on the basis of carrying out operations or elements of operations. Figure 2 explains this point. Having built a schedule of key project events, indeed a logical-semantic model of the project is created. Having filled it with technological content, a reference model for project implementation is obtained.

An example confirming the practical application of the presented conceptual model is the method of interconnection of various processes in a construction project, implemented in the Plan-R program complex for capital construction project management by Digital Practices. An integrated project schedule, including work on all types of activities, is a collection of several local schedules, the corresponding work between which is directly related to each other. However, contrary to the traditional approach to the formation of network models, the connection of local project schedules in Plan-R is carried out not only with the help of logical dependencies, but through a single work coding system, in accordance with which the binding codes are assigned. Link codes must be assigned to all local project schedule jobs. Using these codes, the software package automatically generates typical system technological interactions within the integrated schedule. The calculation module as part of Plan-R (figure 3) enables on the basis of the schedule for the main project activity (as part of an integrated schedule), for example, the schedule of construction and installation works, to automatically calculate and determine the directive (target) terms of work for all construction and installation work of processes (design, equipment supply, obtaining permits and approvals).

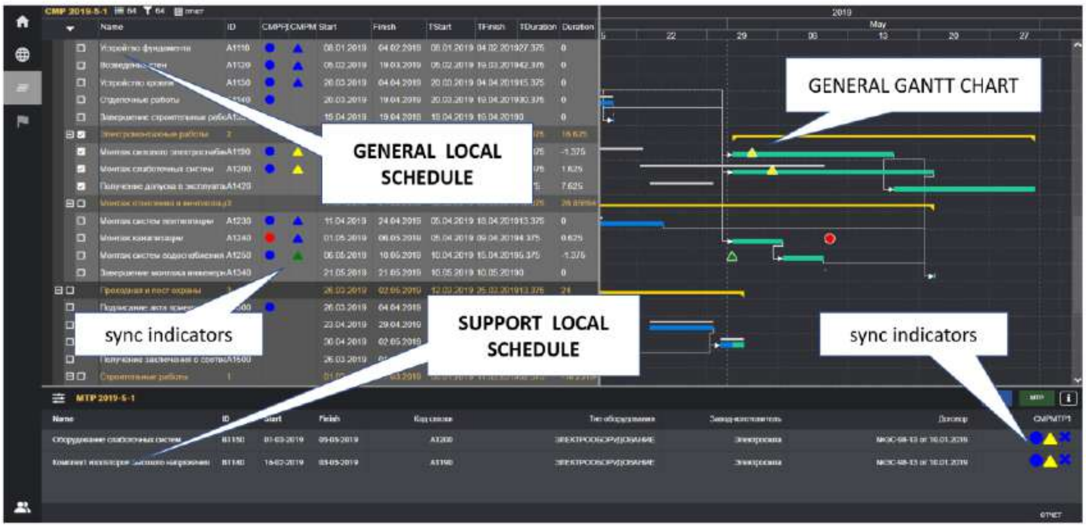

Figure 3. Interface for automated communication and indication of the synchronization of the general and support schedules.

Thus, the software package implements one of the most important elements of the adaptive loop of the studied control model - the reference chart model. The current, regularly updated integrated schedule related to the main loop of the management model naturally acquires various deviations in terms of work from the target model, influencing the timing of key events of the entire project. The module for monitoring key events in Plan-R enables to analyze the predicted deviation of the timing of key events in relation to the reference model of the project, thereby generating the same error signal (figure 4).

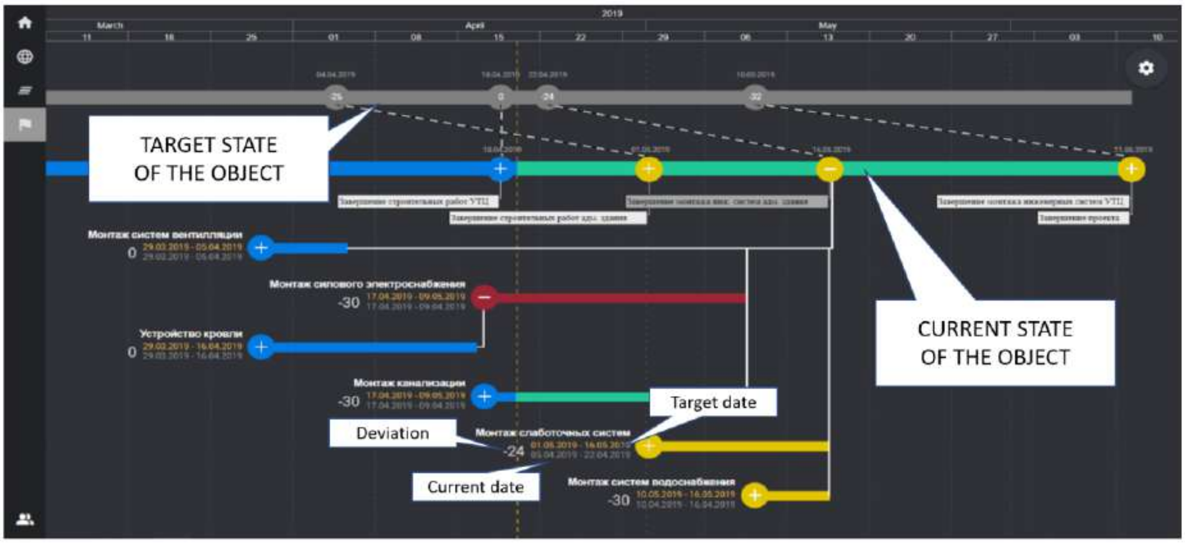

Figure 4. Visualization of states of key project events.

To clarify this signal, the software package automatically generates control chains of work for each key event separately, thereby determining the sources of desynchronization. What is more, the computational and analytical device as part of the adaptive loop is implemented as a mechanism for indicating time collisions between the corresponding works, local graphs as part of the integrated project schedule. Plan-R automatically detects the desynchronization of the timing of the work of the various activity types, generating color indicators (the color of the indicator characterizes the degree of criticality of the detected collision), which in general is an error signal between the construction process and the reference model. Using the data on predicted shifts in the timing of key events and identified time collisions by the project office, a signal is generated to counter the disturbing effect. Compensating measures introduced into the integrated schedule allow it to return to the target model as much as possible.

The approach clearly demonstrates the volume and necessary labor costs only in order to create the necessary interaction of various production structures to ensure the technological process. Despite the use of digital tools, the very process of interconnection and in essence the creation of an integrated construction schedule is based on the use of manual labor of highly qualified specialists. It is possible to change this situation with the help of digitalization of design and management of construction processes.

Returning to the diagram of the key project events, it is necessary to list the conditions for the transition from event to event. It is proposed to describe the transition process from one event to another by a transition operator $W_n^p \to n+1$, in which, in a certain order, the work and the necessary resources are described to achieve the next event [10]. All transition conditions are attributed. It is obvious that the operator of the transition from one elementary event to another will have a description of the operation and the necessary resource for its implementation (materials, components, the number of performers and their qualifications, the necessary devices and mechanisms). An approximate view of the transition operator is shown in figure 5.

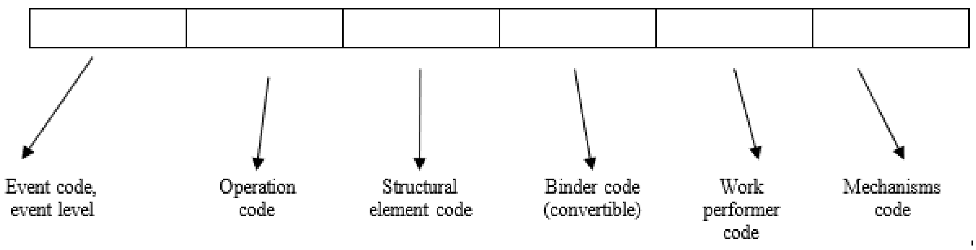

Figure 5. An approximate view of the elementary transition operator.

By attributing all transition operators according to the level characteristics, to the ordinal number in the diagram, an algorithmic language for describing the construction process, convenient for machine use is obtained.

Thus, we come to the formation of a project reference model, where the structural part of the logical connections of the executive elements of the project must be conducted from the highest (first level) to the elementary, and the digital (content) part from the elementary to the highest, as the sum of elementary operators.

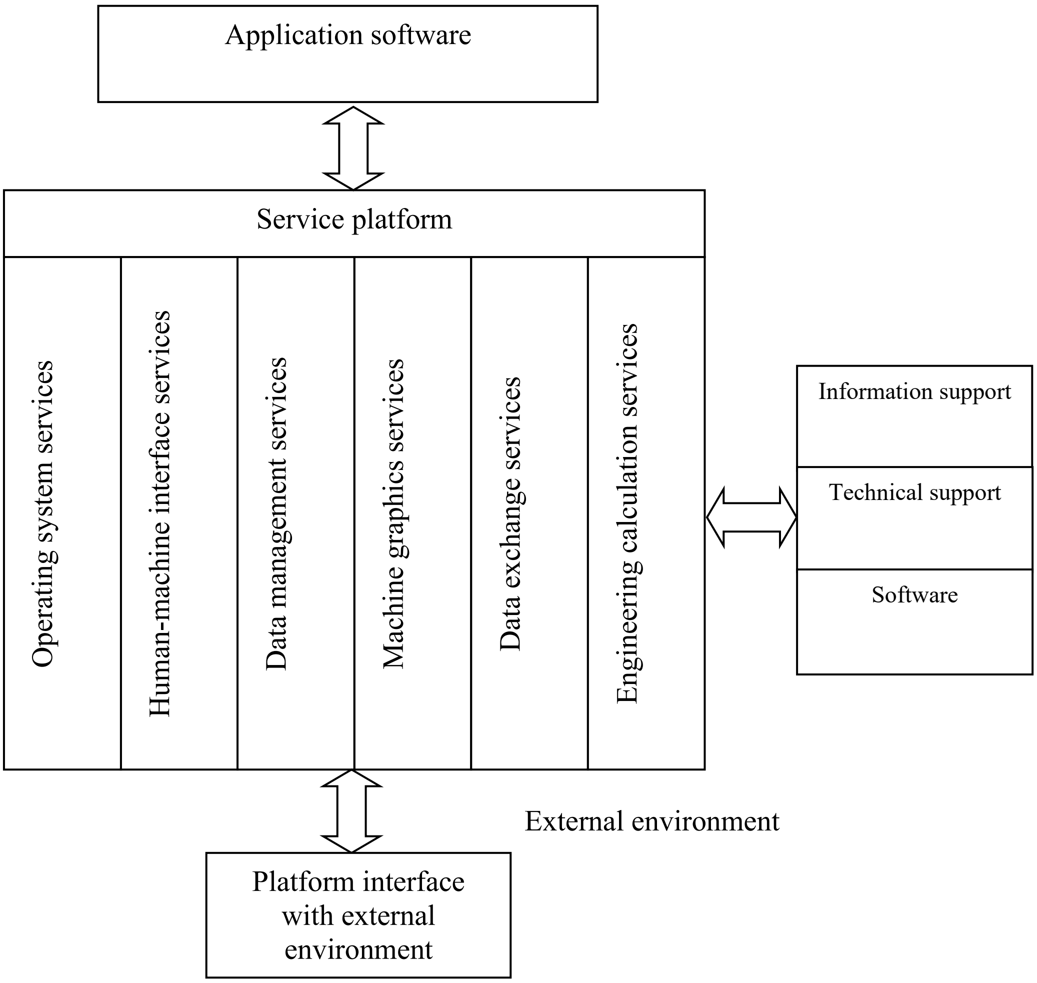

Figure 6. Digital platform for adaptive control system.

It is advisable to start the formation of the control system with its main loop of program control and the creation of the executive part of the control system. The executive control system is a necessary set of functional blocks, including the same type of operations and work. The composition of functional blocks is determined by a specific technology for project implementation. A system of current construction indicators is being developed, compatible with the system of the reference model of the construction project. Based on the system characteristics of current indicators for the reference model construction, the requirements for the computational and analytical device are formulated. The adaptation mechanism should ensure the adaptation of the system to changing operating conditions, and, first of all, transform the organizational management system in accordance with the current phase of the project life cycle. This part of the problem is solved programmatically based on the project reference model.

The development of adaptive system architecture describes its profile. The methodological basis for the development of a profile can be a reference model that defines a conceptual basis and a systematic approach to the classification of interfaces and services (figure 6).

The second task should be considered as a purposeful process of adjusting the parameters of the system and its structure when the nature and conditions of the environment change. This task is solved by developing control actions formed on the basis of an analysis of the dynamics of the environmental parameters and the correspondence to them of the structure and parameters of the system itself. As a result of comparing the data flow on the state of the environment with the logic and capability of the system, three levels of management decisions are generated:

- the operational level implies making a decision that compensates for the current environmental parameters mismatch from the directive values of the system at the level of operations, without changing the structure or operation type. Typically, this is a function for synchronizing operations;
- the tactical level uses the ability to change the structure of the system with the ability to redistribute resources within the system itself;
- the strategic level of decision-making provides for external involvement to compensate for significant deviations of environmental parameters from the calculated ones.

Effective implementation of the proposed principles for creating an adaptive life cycle management system for large-scale and technically complex objects is possible only on the basis of a digital platform, with the involvement of specialized enterprises working in close cooperation with design and construction organizations. In this regard, it is advisable to consider the issue of forming a digital profile of a construction management system as a separate area of training for organizers of construction production with the development of new digital competencies.

Comparing the proposed concept of a life cycle management system for large-scale and technically complex objects based on an information approach and digitalization with the hierarchical, multi-level control systems currently existing in construction, one can see a colossal difference in the speed of information processing, incomparable volumes of information flow, a significant decrease in management personnel, a sharp reduction of non-optimal and erroneous decisions. An adaptive control system on a modern digital platform can implement various algorithms for matching the organizational structure and parameters of a construction object to changing external conditions and approximate the dynamics of events under uncertainty.

Thus, the following conclusions can be drawn. To achieve decisive changes in construction is possible only through the formation of a dynamic organizational structure and the development of adaptive control systems for complex construction complexes. Moreover, this problem should be solved on the basis of an information approach with extensive use of digitalization opportunities.

To carry out a detailed analysis of existing software products for the possibility of using it in an adaptive object management system and interoperability with the created BIM models.

Due to the lack of specialists who are well acquainted with the theory of automatic control, the organization and technology of construction and machine programming at the same time, it is necessary to form centers of digital competence on the basis of authoritative research and educational organizations, to develop digital methods for interpreting real production processes, modeling and programming life cycle of large-scale and technically complex objects in conditions of great uncertainty of upcoming events.

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