DIGITAL ENTERPRISE MANAGEMENT IN CYBERSPACE

Kurbonov Said Akbarovich
Independent researcher of the Higher School of Business and Entrepreneurship

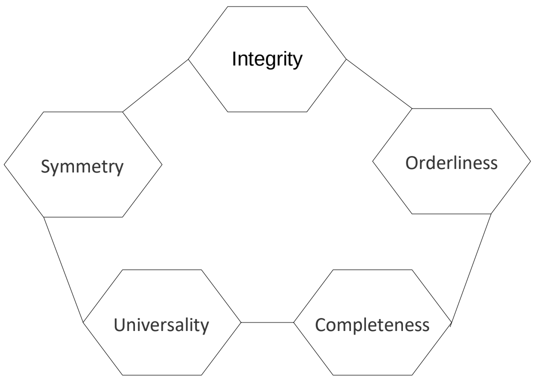
Abstract: The article describes the results of a study of cybernetic enterprise management based on the model and technology of digital twin and the concept of IEM (intelligent enterprise managing) system. The digital twin model is a meta-model of a real enterprise and a digital enterprise, that exchange information and informationally interact with each other. Cybernetic management is a stage in the development of digital management. The article formalizes the basic principles of cybernetic management. It is shown, that the “mirroring” technology, borrowed from their theory of database replication, is based on the double enterprise model. This mirroring allows to reflect all real processes in cyberspace. In cyberspace, based on a system of standardized management and standardization rules, optimal production processes are modeled and transferred to a real enterprise. The article describes a virtual conveyor model, that is built as an analogue of value chains. It is shown, that the set of virtual conveyors forms a kind of artificial neural network.

Keywords: management, digital management, social cybernetics, mutual display technology, cyberspace, digital economy, intellectual management.

Introduction: The widespread use of the technology of Internet of things and the cyber-physical system led to the formation of a direction in management, called social cybernetics. Digital technologies led to the emergence of digital management and digital business transformation. Digital control has a wide application in the technologies of the Internet of things and cyber-physical systems. The ideas of cyberphysical systems led to cybernetic management. Using the ideas of replication from database theory, the theory of enterprise virtualization and the possibilities of the Internet of things led to the formation of Mutual mapping technology (“technology of mutual display”) which creates a digital twin of a real enterprise in cyberspace. The digital twin in cyberspace is an analogue of the “mirror” from the theory of database replication. However, unlike the passive mirror in the field of databases or in the data space, the digital twin of the enterprise is an active model in cyberspace and activates all the actions, that take place in the real space of the enterprise. At the same time, two-way “mirroring” is carried out. It consists in the fact, that information from the real space of the enterprise is transferred to the twin cyberspace and vice versa, information from cyberspace is transferred to the real space of the enterprise. The cybernetic twin of the enterprise and its original are equal. The duality of mirroring is that not only the reflection changes synchronously with the original, but the managed company copies the changes in the digital twin online. This is reflected by the term “mutual display”. A study of Mutual mapping technology and its associated IEM system concept opens additional possibilities for management and production. Issues of social cybernetics are currently studied insufficiently. This article fills in this gap.

Methods of research: The basis of the study is cybernetic analysis, structural analysis, comparative analysis and qualitative analysis. Publications in the field of social cybernetics and digital enterprise management, as well as materials on the technologies of the Internet of things were used as materials.

The basis of management is IEM - the intelligent operating systems of the enterprise, which replaced ERP - resource planning systems. IEM abbreviation means intelligent enterprise managing. Literally, this means intelligent enterprise management [4, 5]. In a broad sense, this concept is interpreted as a set of theorems of social cybernetics, which model the evolution of a real system and are focused on maximizing the profit of an organization in a free market environment. The main components of IEM are shown in fig. 1.



They are orderliness, integrity, symmetry, completeness, universality.

Figure 1 IEM components

Integrity is also interpreted as solidity. The solidity of the IEM system guarantees the reliability of the system data. Reliability in the mathematical sense means that either (D) all the data contained in the IEM datacontainer is reliable, or they are unreliable (¬D) all together. Intermediate states are impossible. This principle is formally reflected in expression (1).

$D \vee \neg D = 1$ (1)

Completeness means the closeness and security of the IEM system data warehouse - All information is placed in a tightly closed container, inside which the enterprise operates. The IEM System encapsulates all interpreted information about the execution of a company's business processes. If we denote the data of the enterprise as D, and external effects as E, then the principle of completeness can be written in the form of expression (2).

$D \cap E = \varnothing$ (2)

Orderliness. The imperative of orderliness of IEM forces to the standardization of all business processes, introduced into the system loop. In the correct introduction methodology - all the value chains of the enterprise. The simultaneous arrangement of all value chains is the crystallization of an enterprise from a state of vague uncertainty into a transparently formalized manageability. If there is a management language Lc, including a standard alphabet, standardized operations and rules for the formation of operations, then many value chains (VC) belong to this language. This principle is formally reflected in expression (3)

ЦСС$\subseteq Lc$ (3)

Symmetry means a dynamic, symmetrical model of a real and digital enterprise system. IEM System implements a symmetric digital model, a one-for-one cybernetic reflection of a managed enterprise. A real RME enterprise model is created in the real RP parameters space.

The DME digital enterprise model is created in the DP digital parameter space. Between them, from the standpoint of information I, there is an informational correspondence, shown in expression (4).

$I(RME) = I(DME)$ (4)

Expression (4) describes the informational state. From the standpoint of logic [], the models of real and digital enterprises are equivalent, as shown in expression (5) R

$ME(RP) = DME(DP)$ (5)

Expression (5) describes the informational and logical state. The parameters of the virtual IEM model evolve synchronously with the changes of a living business. This dynamic process is shown in expression (6).

ΔS (RME) → ΔRP (6)

Expression (6) means, that a change of the state of a real enterprise ΔS(RME) in real space entails a change of the parameters ΔRP of a real enterprise. This change in ΔRP entails a change of parameters ΔDP in the virtual digital space. This cause-and-effect process is reflected by the expression (7).

$\Delta RP \rightarrow \Delta DP$ (7)

Change of the parameters ΔDP of a digital enterprise entails a change of the state ΔS(DME) of the digital enterprise in virtual space. This management process is reproduced by the expression (8).

$\Delta DP \rightarrow \Delta S\ (DME)$ (8).

A change in the state of a digital enterprise when reflected in a multitude of management languages (management rules) produces management effects on the digital enterprise. This management process is reproduced by the expression (9).

$\Delta S\ (DME) \cap Lc \rightarrow Cd\ (DME)$ (9)

Management effects on a digital enterprise are replicated to the space of a real enterprise and create management effects on a real enterprise. This management process is reproduced by the expression (10).

$Cd\ (DME) \rightarrow Cd\ (RME)$ (10)

The management effects on the real enterprise transfer it into a new state S *. This management process is reproduced by the expression (11).

$Cd\ (RME) \rightarrow S * (RME)$ (11)

the new state S* corresponds to the target state St. This informational process is reflected by expression (12).

$S * (RME) = S\text{ц}(RME)$ (12)

Thus, the real enterprise is managed, during which the following is used: cause-and-effect relationship, state models, equivalence rules and management processes. The set of expressions (4) - (12) reflects the management chain of managing a real enterprise using a digital twin. Universality. Universality reveals the quality content of the management language. This language is not arbitrary, but includes management standards, standardized management rules, acceptable optimality criteria. It should be emphasized once again, that this language is not a language of descriptive description, but the language of cybernetic management, which includes rules, regulations and rules for constructing new rules.

The cybernetics of the IEM system models an arbitrary enterprise in not only the parameter space, but also in the space of technological chains (production rules). In fact, it models the "value chains" (VC value chains). And that makes cybernetic management, according to the IEM's "cyber optically optimal management theorem", the best possible management. The ability to optimally model arbitrary business processes naturally leads to universal functionality. In the digital space DME any logically consistent functional can be implemented. Thus, a unified IEM system a) replaces any private-functional ABC-systems (ERP, CRM, WMS, MES, BPM, PAS, ...) - all at once and at the same time, b) by providing their functional with a previously unattainable quality level, as well as to universal industry applicability (in essence, the equivalent of the previous one): in the business of any industry, the scale and complexity of operations. The set of models of the "value chain" (VC) is actually a model of an artificial neural network. It set the universal functional of management decisions. This provides high intellectual quality of enterprise management. At the same time, the quality of the functional, provided by the IEM system, will be higher than any highly specialized solution. This is due to the fact, that the management language of the system includes all possible management situations and action rules in these situations. As a result, the IEM system guarantees the highest possible efficiency in solving any formalized task in the field of business process management of an arbitrary organization.

Principles of construction of a digital twin

Figure 2 shows the principles of construction of a digital twin An enterprise in real space and a digital twin in cyberspace form a meta-system.

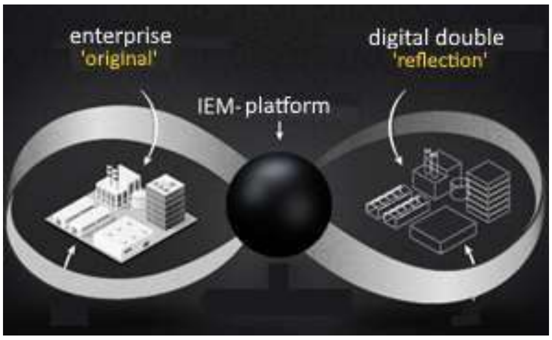


Figure 2 Meta-system of the enterprise and its reflection.

A meta-system consists of two equivalent opposing systems, one of which is (A) a real managed organization. Digital system (B) is the managing. The state of a managed enterprise changes over time under the influence of a large number of external and internal factors - consumers, competitors, suppliers, employees, automatic computer services and self-managed production and logistics equipment. All changes of the original (ΔA) are replicated to the digital twin (B) online.

$\Delta A \rightarrow \Delta B; \rightarrow \Delta B = \Delta A \rightarrow Lc \wedge B$ (13)

$Lc \wedge B \rightarrow \Delta B *$ (14)

$\Delta B * \rightarrow \Delta A *$ (15)

$S(\Delta A *) = S(G)$ (16)

The mechanism of information interaction of the original (A) and digital twin (B) is given in expressions (13) - (16). Expression (13) describes the informational situation, in which a change of the parameters and state of a real enterprise ΔA is replicated to a change of the parameters of a twin ΔB. In this case, there is a complete equivalence of the parameters of the original and the twin ΔB = ΔA. Changes to the parameters of the twin are replicated to the set of standardized rules of the management language Lc. As a result of the information interaction of the made changes, management changes ΔB * in the twin are generated, which is shown in expression (14). Then, the reverse process of transformation of the changes of the twin ΔB * into changes of the parameters of the original ΔA * takes place. These changes perform management functions and transfer the state of the original enterprise S(ΔA *) into the target state S(G), as shown in expression (16). At the same time and synchronously, all the events of the evolution of the digital twin (for example, the consequences of the automatic execution of business logic algorithms) are reflected in material reality - either through the actions of company employees (managed by the IEM system), or through equipment and services, direct managed by the robots of the digital twin - websites, industrial robots, conveyors, CNC machines, automatic cash registers, warehouse loaders and other. In the case of directively managed equipment, the replication of the "digital twin → reality" changes is not difficult: for example, the stacker-truck receives the command “take the pallet from cell 12335R6 and leave it in the delivery area in cell E23456F3”. This command is promptly executed. It should be noted, that personnel, involved in the direct execution of business processes, are often the cause of errors in the executive system. Because of this, to control the actions of employees, the visual interfaces of both the desktop console and various specialized applications for arbitrary software platforms, in particular mobile devices, are used. Replication of the “digital twin → enterprise” changes with the participation of personnel in the general case consists in waiting for the IEM operating system to transfer to a state, that will allow the execution of this business process to continue.

Virtual conveyors are one of the new technologies, acceptable only in the digital enterprise twin. It can also be considered as a dynamic digital model. Virtual enterprise conveyors can be considered as a multi-agent system. Traditionally, a conveyor is a mechanism for sequencing material production processes. The enterprise’s IEM operating system totally synchronizes business processes of any industry, of any complexity, of any scale. In a digital enterprise, a conveyor is modeled as a value chain (VC). Virtual conveyors include stages, that are tightly coupled and each sharply follows the other. Any business and any organized human activity can be modeled on value chains (conveyors). There can be many models of VC at the enterprise, but in real practice, only a few value chains work within a single company at a time. An employee can be a link of the VC. In the presence of a digital twin, its activities are controlled and it is cautioned against errors. Wearing of bracelets by high-speed train drivers can be an example. The bracelet controls its psychophysical state and, if the driver has abnormalities, the bracelet, as a digital control device, signals this to the control room and limits some actions of the driver, that the digital system considers inadequate, using the technology of cyber-physical management. The day-to-day operations of the company under the management of the IEM operating system do not require management intervention Cybernetic management through its virtual conveyors (cybernetic reflections of real VCs) pushes semi-finished products on their own - from start to finish. Dispensation is required only in case of force majeure (the car broke down, the electricity turned off, etc.). Exceptional situations of the operational level (for example, find the goods in the warehouse was not found) are also standardized and processed automatically by the system.

The regular conveyor has three weak points.

- territorial - can work only locally, in the perimeter of this production site
- functional - applicable only to tangible goods
- lack of flexibility (rigidity) - unfinished goods move along a tightly fixed path, and only in one direction.

Thus, any contingency situation requires either to stop the conveyor at all, or to remove semi-finished products from it for subsequent manual processing. Changeover (for example, to change the type of output products) is a very expensive process. The set of restrictions leads to the fact, that the classic conveyor is cost-effective only in large-scale (mass) production of tangible goods. Virtual conveyors of the IEM operating system are free from all the limitations of a mechanical predecessor. They guarantee the conveyor order in business operations of any type, while the physical executors of neighboring parts of the value chain can work on different continents. A virtual conveyor can have any level of variety of connections between the stages of the VC. For example, not only a unidirectional chain (vector), as Ford had, but also cycling rings with retrograde motion (for example, successive “test-return to revision” cycles). For some types of "products" (of any kind - including intangible services), some stages may be excluded. Other types of products may fall onto the conveyor from the middle. The number of simultaneously “product” variants, advancing along the conveyors, is unlimited - while the system guarantees the use of adequate business logic for each “product”. There can be a lot of virtual conveyors themselves for each assortment group, down to a single “product”. At the same time, a digital enterprise can simultaneously manage a large number of VCs of any complexity level. Thus, an enterprise, equipped with an IEM system, receives a sequencing tool, that combines all the advantages of mass and small-scale production without their significant disadvantages. Value chains, intersecting in a business management center, have cyber symmetry in the living world in the form of multi-agent systems.

Discussing the results: There are a number of limitations to the use of this technology. For example, the statement “a digital enterprise can simultaneously manage a large number of VCs of any complexity level” is conditional. It considers by default, that computing resources are enough for processing. Also, the statement "of any scale and any complexity" is conditional. Currently, large scales and high complexity create a big data problem, which is an informational barrier to management. Therefore, the statement "of any scale and any complexity" is applied only to medium-sized, small enterprises. It is also not applicable to enterprises with significant territorial distribution, since this violates the condition of integrity (solidity). Informational flows and significant delay times are characteristic for distributed enterprises. Subsidiary enterprises, which are analogues of natural multiagent systems, are more promising. The multi-agent mechanism is inherent in this model and this is its advantage.

Conclusions: Cybernetic management is a new step in the development of digital production and management technologies. The digital twin model allows to create a digital cyberspace, that controls material production due to manageability. This work shows the basic formal principles of the functioning of the meta-system of twin enterprises. The theorem of "cybernetically optimal management" remained outside the framework of the discussion. However, the objective of this article was to disclose the technological essence of the model and formally describe the basic principles, that will be detailed and expanded in specific situations. However, this approach is applicable Advances in Economics, Business and Management Research, volume 138 364 only to medium-sized enterprises and localized in one geographical location so far. The IEM project should be implemented as a project of a complex integrated system with the inclusion of cyber-physical systems. De facto, cyber-physical systems are replacing dated automated digital systems.

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