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Analysis of Systems for Coordination of Enterprise Subsystems Control

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Abstract: Any automated production, at the current stage, must have systems or control modules that serve to coordinate the subsystems of the entire enterprise. Control in this case occurs through the use of separate modules responsible for monitoring each individual subprocess. Software modules are being developed for such processes, which combine monitoring and operational regulation under the processes, which allows to one degree or another to reduce the risk of damage or failure of all production links. Thus, the creation of a computer-integrated management system for coordinating the functioning of the subsystems of the enterprise is an urgent and timely task. This paper analyzes the basics of building a production subsystem control system. Algorithms for the operation of such systems are also considered.

Key words: Subsystem, Manufacture, Subsytem Coordination, Control System.

Introduction

To date, the globalization of network integrations has become widespread and has an impact on the competitiveness of international production [1]-[10]. The key issue of integration is the coordination of activities of distributed objects in such a way as to have the necessary data on the placement of these objects.

With the development of worldwide monopolistic enterprises, manufacturing companies shifted their focus from a single enterprise to international production networks. Meanwhile, network sustainability is a key issue in responding to fierce international competition and competitive advantage in global manufacturing.

Coordination mechanisms are a plan for coordinating the activities of individual subsidiaries and "getting the most" from far-reaching activities. In addition, due to different production priorities, ranging fr`om quality, flexibility, delivery time, the coordination of

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objects in network production is obviously greater. As long as such coordination is agreed, the mechanisms must be adapted to the specific activities in which the plan is used, which must take into account the priorities of network production to share the benefits of network integration [11]-[19]. Therefore, different methods and approaches can be used here [20]-[35].

Related works

Currently, the complexity of automated production leads to the need for a system or control module that serves to coordinate the subsystems of the entire enterprise. A large number of scientists are engaged in the development of coordination systems in various fields. Let us consider several works devoted to this topic.

The paper [36] considers the entropy method and the coupling coordination model that are used to analyze and measure the coupling coordination relationship between the economy, the ecological environment, and the health system of China's green production from 2009 to 2016.

Malik, A. I., & Kim, B. S. in [37] consider a two-echelon supply chain management coordination issues in a flexible production system at a smart factory. The necessity of coordination and flexibility is essential for the success of supply chain management.

The authors in [38] note that with the high-quality development of the economy, the logistics industry is bound to move towards high-quality development. By establishing the index system of high-quality economic development and logistics, this work has measured their high-quality development level and analyzed their coupling coordination degree by using the coupling coordination model.

The coordination of a manufacturing network is a challenging task and may be contingent upon the manufacturing environment [39]. The IIoT enablers (digital technologies, connectivity, data, capabilities and management) are highly related to the manufacturing network coordination mechanism. The results indicate that IIoT initiatives and manufacturing network coordination should be designed to support each other [39].

Omicini, A. in [40] propose agent coordination contexts that allow engineers to encapsulate rules for governing applications built as agent systems, mediate the interactions amongst agents and the environment, and possibly affect them so as to change global application behaviour incrementally and dynamically.

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Researchers in [41] present a mathematical model, aiming to minimise tardiness penalties and reduce manufacturing cost in order to solve the manufacturing resources coordination and tasks allocation problem in dynamic manufacturing environments. The experimental results verify that this coordination approach not only can reduce processing costs effectively in a static environment but also has a good control performance against disturbances in a dynamic environment.

Thus, we see a variety of studies in various fields devoted to the problem of creating a coordination system for production. Further in this article, we will analyze the main stages of creating such a system, as well as the algorithms that can be applied.

Subsystems Control Coordination and Algorithms

Formal coordination mechanisms are related to the basic structure of organizational units and activities in networks. These mechanisms are embodied in organizational structures and procedures, in other words, formal coordination builds a structural approach to the relationships between objects.

In addition, centralization, i.e. the level and position of the decision-making body, and the standardization of processes and procedures are included in formal coordination mechanisms. A typical example of formal coordination mechanisms includes the exchange of standard documents.

In addition, numerous studies point to headquarters control, for example, a high level of enterprise control is necessary to streamline production, while centralized control can only be achieved when dispersed facilities are aligned with a common goal and structure. Therefore, the concept of control demonstrates strong elements of formal coordination mechanisms.

Informal means of coordination can be achieved through interaction and communication within institutions, training, program development and transfer of managers. For example, this technique is a broad transfer of managers to create a verbal network and include "emigrants" in its composition.

As a formal approach is a subtle mechanism of intangible approaches, that is, they cannot be easily established in the organization, their success depends on the permanence of relations between objects.

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Likewise, communication as a means of informal coordination between the host institution and headquarters is crucial for all offshore (science-intensive) activities.

Any coordination task is presented in the form of hierarchical systems. The general scheme of coordination in a two-level system boils down to the fact that elements are transferred to the center of a set of work options.

Each option is a vector indicator of an element, acceptable from the point of view of its local restrictions. Based on the options obtained from the elements, the center forms a plan that is optimal from the point of view of the entire system. This plan is transmitted to the elements and elaborated by them.

However, during the modeling of complex systems, it is impossible to take into account a sufficiently large number of real factors, because this will lead to the complication of the system.

Therefore, it is necessary to enter into the model only a limited number of such factors, which for one reason or another are considered the most important. At the same time, two approaches are possible.

Factors not considered in the description of the model can be considered completely unimportant and completely ignored when making decisions using this model.

On the other hand, according to the second approach, it is possible not to introduce unimportant factors into the mathematical model, but to take into account their influence, assuming that the reaction of the model to one or another action (choice of an alternative) can be known only approximately or vaguely.

Such structures are hierarchical, and the advantages of automated management, in which there is a large number of simple tasks at the lower level, and a small number of complex tasks at the higher levels, include a decrease in the total cost of processing information in the system and an increase in the bandwidth of host machines in the network, and as well as resistance to interference.

System-critical functions continue to be performed by local control systems when the host machine or communication link fails. The general problem of optimal management of hierarchical systems is usually posed as a static optimization problem, i.e., the problem of functioning at sufficiently large intervals of time, during which the dynamics of the processes can be neglected, is considered.

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Thus, it can be said that it is optimal to build a hierarchical two-level system based on formal coordination, due to the possibility of implementing centralization, that is, the levels and positions of the decision-making body, and the standardization of processes and procedures included in official mechanisms, as well as the decomposition of modules, which provides a more accurate risk assessment.

There are two types of algorithms for coordination of control systems for coordination of enterprise subsystems: iterative; without iterative.

In the iterative procedures available today (the Danzig-Wulf algorithm, the Kornai-Liptak algorithm, methods based on the introduction of the Lagrange function or its various modifications, optimization algorithms, the generalized scheme of the iterative algorithms of Aliyev and Liberzon), the optimal solution is determined in the process of iterative exchange of information between the center and elements.

Although there are several options for implementing such algorithms, the most common algorithm is:

a) starting with a possible solution of the shortened main program, it is necessary to formulate new objective functions for each sub-task, so that the sub-tasks will offer solutions that improve the current goal of the main program;

b) tasks are re-solved taking into account new target functions. The optimal value for each task is offered to the main program;

c) the main program includes one or all of the new solutions that were generated by sub-task solutions based on the respective ability of these solutions to improve the goal of the original task;

d) the main program performs x iterations of the simplex algorithm, where x is the number of included columns;

e) if the goal is achieved, proceed to step a. Otherwise, continue;

e) the main program cannot be further improved by any new solutions from sub-tasks, therefore – return.

At each step of the iterative process, the locally optimal problems of the elements and the coordinating problem of the center are solved. According to coordination methods built on the basis without iterative algorithms, coordination is carried out as a result of a one-time exchange of information between levels.

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Mostly non-iterative algorithms are reduced to the construction of a set of effective solutions for organizational hierarchical systems.

Thus, it can be concluded that the iterative algorithm is optimal according to the criterion of specification of tasks and their solution at each step of management and monitoring.

A typical example of complex systems can be computer-integrated manufacturing, where it is necessary to coordinate various engineering tasks and exchange data between various specialized tools. The information flow of an enterprise can be classified into two parts: technical data and management data.

The systems of the management part mainly includes applications for business engineering, stock management, but also production planning and control.

The technical track consists, for example, of applications to support product design (CAD), programming with numerical control of machines (CAM) or quality control (CAQ).

The coordination of subsystems in computer-integrated manufacturing is critical to ensure consistent product data (eg, specifications) in addition to CAD, PDM.

Since each subsystem stores data in a separate private storage and uses its own data model, taking into account the specialties of the respective applications, there are many dependencies between the subsystems.

The coordination process should begin by tracking changes to, for example, the CPC and business engineering system to updating production plans and making changes to the parts procurement process.

Even if the employee performs his operations locally and does not know about the operations that must be performed clearly and bring the system to a clearly defined state.

It is even more important if changes are made not only in the department, but also in the production department (for example, to adapt certain product properties), which leads to simultaneous coordination processes.

The coordination process itself must be applied depending on the complex systems (for example, system-wide consistency of product data), ensuring that the operations in the relevant subsystems are such that they are performed with certain performance guarantees.

Various efforts have been made in computer-integrated manufacture to overcome the problem of applying (rather basic) dependencies: avoiding contradictions that lead to

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duplication of product data, keeping heterogeneous and autonomous application systems under control.

The first approach is to change the priority or goal of preserving local autonomy of participating application systems and integrating local programs into global ones.

Then, access to global data is possible only through integrated applications, where global integrity is ensured in a traditional way.

A further development of the approach is the introduction of an additional database outside the existing application systems by additionally copying global data.

Then, global integrity constraints can be defined for global integration database data.

However, the additional overhead should be considered as replication, which results in additional costs.

Synchronous communication mechanisms can also be used to maintain data consistency after local operations and ensure global integrity.

Instead of the overhead of a centralized database, additional effort must be made by defining inter-application communication. This leads to a fairly loose interconnection of application systems and does not allow maintaining complex coordination processes in complex systems.

Considering the described facts, it can be determined that the system should be quite simple and not have excessive connections between modules. We can say that the optimal solution is to develop modules that are independent of each other, and to introduce an additional database for logging failures.

Conclusion

Within the scope of this work, we analyzed the existing systems for coordinating the functioning of enterprise subsystems, algorithms, concepts and coordination schemes.

It was found that for this type of software it is optimal to build a hierarchical two-level system based on formal coordination, this is due to the possibility of implementing centralization and standardization of processes and procedures included in the mechanisms, as well as decomposing modules, which gives a more accurate assessment of risks. Decomposition, in turn, will lead to the simplification of the system, not the formation of simple connections between modules.

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Each module, in turn, must have its own module data source and a separate interface, which allows analyzing the production and parameters of the module at each moment in time.

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