DEVELOPMENT OF INFORMATION TECHNOLOGY TO SUPPORT MANAGEMENT DECISIONS USING THE PROBABILISTIC INFERENCE IN A TEMPORAL KNOWLEDGE BASE

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Abstract. The purpose of the article. The purpose of the article is to develop a technology for the support of management decisions in the conditions of uncertainty based on the probabilistic output in the temporal knowledge base. The technology provides an increase in the effectiveness of organizational management at the tactical and strategic levels of the organizational hierarchy.

Research methods. Methods of decision-making support, methods of probabilistic inference in the knowledge base.

The main results of the research. The problem of construction of managerial decisions in the conditions of uncertainty is considered. This problem is related to the discrepancy between the practical need for management decision making using knowledge bases and the capabilities of existing knowledge-based methods that use only causal relationships. An analysis of the structure of the process of preparation of management decisions was made. It is shown that the general structure of the process of making managerial decisions involves a consistent solution to the tasks of preparing and implementing a solution. When solving the task of preparing a solution, a set of possible managerial decisions is formed. The task of realization of the decision involves its choice and implementation. Structuration of temporal dependencies in the structure of the management solution is performed. The method of generalization of temporal dependences is developed. The technology of management decision support using the temporal knowledge base is suggested. The developed technology allows you to build many alternative managerial decisions in the form of controlling impacts or the corresponding sequence of states of the control object with the estimation of the probability of implementation of each of the alternatives of management decisions. The resulting set of alternative management solutions is a complex management solution and may be associated with a certain level of organizational hierarchy. This provides the opportunity to form a comprehensive management solution both at the level of individual units and at the organizational level as a whole.

Scientific novelty. The method of generalization of temporal dependencies is proposed, which, based on the transformation of the input temporal rules at the level of separate control actions and taking into account the hierarchy of context

artifacts, enables to construct rules for a given level of the context hierarchy. The technology of support of managerial decisions as sequences of actions on the basis of probabilistic output in the temporal basis of knowledge is proposed.

Practical significance. Technology provides more effective management decisions in uncertainty due to the choice of the most probable sequences of control actions by the decision maker.

Keywords: *management decision, decision support, temporal dependence, temporal knowledge base.*

Problem statement.

The process of making managerial decisions is carried out in conditions of uncertainty at the strategic and tactical levels of enterprise management. This process consists of a consistent solution to the tasks of finding and selecting and implementing solutions. In solving the first problem, it is necessary to identify an abnormal situation and formulate a set of alternative solutions to get out of this situation. This task is labor-intensive due to the need to build possible solutions in the absence of complete information on the state of the object of management. It is decided taking into account the knowledge of the decision maker. Therefore, knowledge-based approaches are used to support managerial decisions. According to the above mentioned approaches, a logical output in the knowledge base is used to form the set of alternatives to managerial decisions. The managerial decision includes an algorithm for executing control actions that has temporal characteristics, that is, the terms of execution, the duration of individual actions, and so on. This testifies to the urgency of developing methods and technology to support managerial decisions based on the output in the knowledge base, taking into account the temporal aspect of management decisions.

Analysis of recent research and publications.

In tactical decision support systems modeling and knowledge-based approaches are applied at the tactical level of organizational management. The latter implies the use of logical derivation in knowledge bases [1]. Traditionally, such knowledge bases contain causal relationships. To remove these dependencies, communicative methods [2] are used, which are intended to transform the implicit knowledge of experts by default [3]. Deleting such knowledge requires a lot of time and additional checks for inconsistency. An alternative approach to decision support is the seizure and use of built-in knowledge [4]. This makes it possible to continuously replenish the BR in an automated way [5].

However, existing approaches to using embedded knowledge are focused on information retrieval and information systems [6] and do not include temporal dependencies. At the same time, such dependencies determine the sequence of processing the constituents of the control object - artifacts and, therefore, are important in constructing a managerial decision as a sequence of control actions [7].

Thus, there is a discrepancy between the need to formulate managerial decisions using knowledge bases and the capabilities of existing knowledge-based methods that use only causal relationships.

The aim of the study.

The purpose of the article is to develop a technology to support management decisions under uncertainty on the basis of probabilistic output in the temporal knowledge base for improving the effectiveness of organizational management at the tactical and strategic levels of the organizational hierarchy.

To achieve the goal, the following tasks are solved:

- analysis of the structure of the process of preparing management decisions;
- structuring of temporal dependencies in the structure of management decision;
- development of the method of generalization of temporal dependencies;
- formation of information technology supporting management decisions using developed methods and models.

Presentation of research material.

The proposed technology integrates a number of models and methods developed by the author [8-11]. It is based on a generalization of the process of making managerial decisions.

The general structure of the decision-making process involves the consistent solution of the tasks of preparing and implementing the decision (Fig. 1).

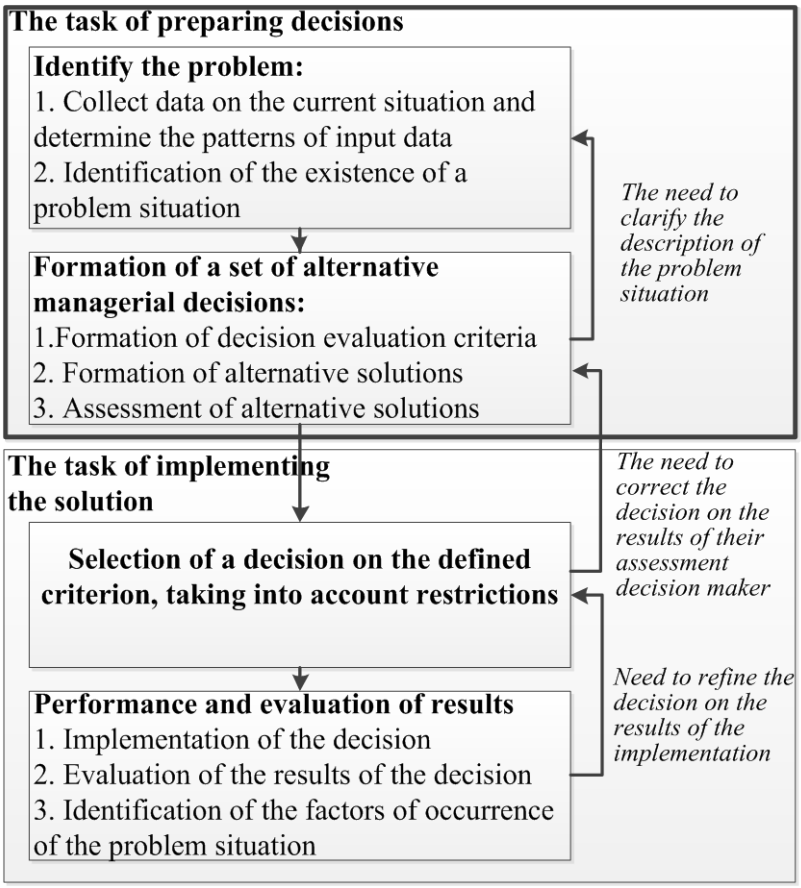

Fig. 1 – Generalized decision-making process

When solving the problem of preparing a solution, a set of possible managerial decisions is formed. Preparation of solutions consists of identifying a problem situation. Initially, the collection of data on the status of the organizational system. The result is context-sensitive data patterns that allow you to identify a problem situation. Then a set of alternative managerial decisions is being made. At this stage, the criteria for evaluating these decisions, the set of alternative solutions in the form of ordered sets of actions, as well as the estimation of each of these decisions by the determined criterion, are formed.

The task of implementing the solution involves the choice and implementation of the solution. The choice of rational or limited-rational decision is performed by the ODA according to the defined evaluation criterion and the existing restrictions.

The implementation of the solution consists in its implementation (coordination and implementation), the evaluation of the results, as well as the analysis of the cause of the problem situation.

To solve the problems are:

- Data characterizing the state of the organizational system;

- Formalized explicit knowledge about objects and processes of management, for example, their models;

- Informal knowledge about context-dependent patterns of functioning of the object of management; such knowledge reflects the experience of staff and depends on the level of the hierarchy in the organizational structure of the enterprise.

The analysis of the process of making managerial decisions makes it possible to make such conclusions. First, for the decision maker to make effective decisions, it is necessary to have a set of pre-prepared and evaluated criteria for management decisions. Secondly, the preparation of a spectrum of all possible managerial decisions for the problem situation, as well as the identification of

data patterns and this situation is carried out under uncertainty and therefore requires considerable resources.

Thus, recognizing the problem situation and forming a set of possible management decisions in this situation is a "bottleneck" of the considered process, which determines the relevance of their automated support. In this case, it is necessary to take into account the uncertainty not only about the values of the parameters of the organizational system as an object of management, but also on the management process. The second component of uncertainty relates to the use of ODA and performers of informal personal knowledge when selecting and implementing managerial decisions at tactical and strategic levels of management. This indicates the importance of using knowledge-oriented decision support with the ability to quickly replenish the knowledge base with the personal knowledge of the performers.

The structure of a management decision in the form of a context-dependent sequence of control actions, between which there are temporal and contextual dependencies, is shown in Fig. 2.

The managerial decision Π_i includes a sequence of control actions that corresponds to the transitions between the states of the control object.

$$\Pi_i = \left\langle u_{i,1}^0, ..., u_{i,j+1}^{i,j}, ..., u_{aim}^{i,J} \right\rangle : u_{i,j+1}^{i,j} \to \pi_{i,j+1}^{i,j}, \pi_{j+1}^{j} = \left\langle s_j, s_{j+1} \right\rangle, \quad (1)$$

where $u_{i,j+1}^{i,j}$ - management action i - managerial decision; $s_{i,j+1}$ - j - state of the object of management, in the implementation i - management decision; π_{j+1}^{j} - transition between the states of the control object.

On the set of states $S = \{s_j\}$ a subset of allowable transitions between states is given $\Pi = \{\pi_{j+1}^{j}\} \subseteq S \times S$.

Each permissible conversion can be used in one or more alternative management options. Then, if we know a few variants Π_i, then we can form weighted temporal dependences $R_i = \{r_{i,j+1}^{i,j}\}$ for each managerial decision. Subsequently, these dependencies can be used to build new managerial decisions Π_i^*.

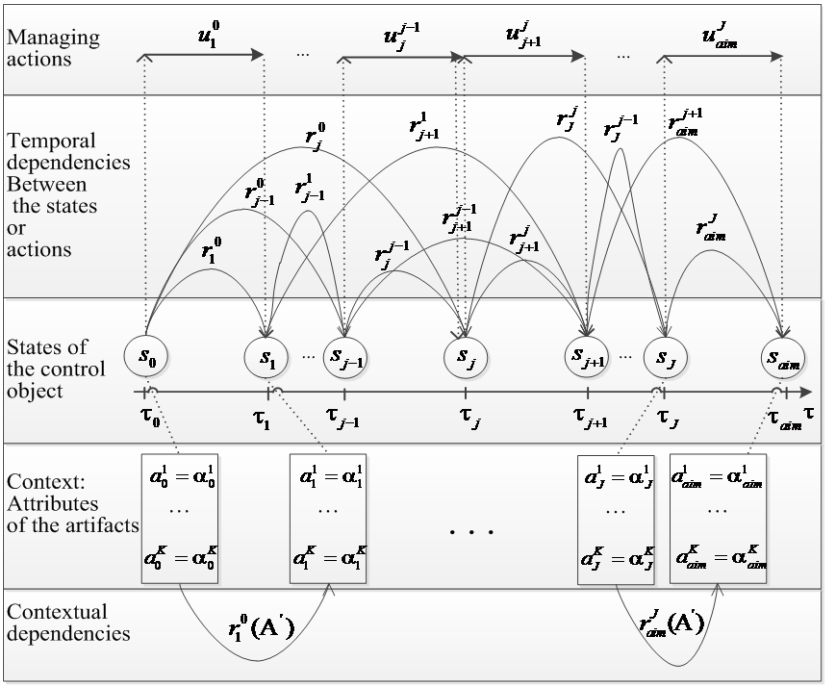

Fig. 2 - Temporal dependencies in the structure of management decision

That is, the general approach to maintaining managerial decisions based on temporal dependencies is to formulate rules $r_{i,j+1}^{i,j}$ for known decision variants, and to further use these rules to construct new alternate sequences of control actions. The result of support is a comprehensive management solution in the form of:

$$\mathcal{M}_U = (S = \{s_0, \{s_j\}, s_{aim}\}, \Pi = \{\Pi_i\}, R, L), \quad (2)$$

where $R = \{R_i\}$ – set of temporal rules; L - evaluation of temporal rules that determines their weights for given transitions between states S.

Each state is characterized by a set of attributes $s_j = \{a_j^k\}$ for which values α_j^k are given. Each of the attributes specifies the properties of elementary objects that are part of the control object. According to IBM terminology, such objects are called artifacts.

Temporal rules, as shown in Fig. 2, specify the relationship between the states of the object of management in general, or for a subset of properties of these states.

In [11], the temporal type rules X (NeXt) for the sequence of control actions, F (Future) for actions between which there are other actions, as well as context-sensitive rules of the type U (Until), are proposed and used.

The proposed technology uses the above-mentioned management decision structure, the temporal rules, probabilistic derivation methods [9, 10] and is based on the method of maintaining management decisions under conditions of uncertainty based on temporal knowledge.

The method of support of managerial decisions takes into account the level of organizational hierarchy based on the use of the results of the method of generalization of temporal dependencies.

The method of generalizing temporal dependencies allows you to construct rules for a given level of the context hierarchy.

The input method of the method is the set of artifacts (elementary objects) Af^0 that correspond to the current level of the hierarchy of the context of executing actions on the control object.

This level of hierarchy can be set, for example, through one of the levels of organizational management. This level defines the appropriate set of artifacts. So, the definition of a specific unit causes a set of artifacts belonging to this unit: documents, equipment, performers, etc.

The method includes the following steps:

Stage 1. Selection of a subset of artifacts Af^* that determines the states of an object of management at a given level of the context hierarchy Af^0.

At this stage, the artifacts that belong only to the subset Af^0 specified in the input data are selected. For example, if an employee performs work in several divisions of an enterprise, then only the artifacts with which he works in the unit Af^0 will be selected.

This stage is performed in the case when the list of artifacts in the input data is not explicitly defined.

Stage 2. Selection of a subset of states S^* of the control object for a subset Af^*. The condition for selection of states S^* is as follows:

$$S^* = \{s_0, \{s_j^*\}, s_{aim} : \forall a_j^k \in s_j^* \; \exists a_n^l = a_j^k, a_n^l \in af_n^*, af_n^* \in Af^*\}, \quad (3)$$

where a_n^l – attribute of the artifact af_n^*.

Step 3. Formation of the rules of the type X (NeXt) for the specified level of the context hierarchy.

The purpose of this stage is to combine rules from the lower levels of the hierarchy into one rule at a given hierarchical level.

Step 3.1. Converts the rules of type F (Future) to rules of type X in the case if the initial and final states are set at the level Af^0.

Step 3.2. The combination of sequential rules X into one rule X is performed for the case if the intermediate states do not correspond to the level Af^0.

Stage 4. Formation of the F (Future) rules for the specified level of the context hierarchy.

This step is performed similarly to step 3.2 and differs only with the type of rules.

Step 5. Formation of rules of type U (Until) for the specified level of the context hierarchy.

At this stage, rules are set with contextual conditions only for a given level of the context hierarchy.

Stage 6. Calculate the weight of the received rules.

The method of supporting managerial decisions includes the stages of analysis of the current situation and the formation of a comprehensive management solution.

At the stage of the situation analysis, the selection of the sequence of states that led to the current state s_j, the formation or selection of temporal dependences for this sequence of states, the comparison of the weight of the received dependences with the total weight of the temporal rules corresponding to the alternative management decision, that is, the alternative sequence of control actions, is performed. By comparison, the presence or absence of an atypical (abnormal) situation is detected. It is believed that the situation is abnormal in the case of a significant deviation of the weight of the temporal rules. Since the weight of the temporal rules is determined depending on the likelihood of their use, this stage allows you to distinguish between unlikely situations. Such situations are considered as abnormal at the next stage.

At the stage of forming a complex managerial decision on the temporal knowledge base, the rules are selected taking into account the specified level of the context hierarchy. Using these rules creates a set of alternative sequences of actions, which is part of a comprehensive management solution. Each sequence is evaluated based on the weight of the temporal rules that it describes.

In the case that the current situation is abnormal, the temporal dependences for the state s_j are formed at subsequent stages. After an optional semantic verification, the resulting dependencies are added to the database.

The technology of support for managerial decisions based on the probabilistic inference in the temporal knowledge base as inputs uses information about the current state of the control object. The technology includes the following steps.

Stage 1. Analysis of the current state of the control object, taking into account the temporal dependencies.

At this stage the verification of the typical or non-typical of the current state is performed using the method [8]. The main idea of the test is to compare the weight of the temporal rules for the current and alternative state sequences. The current sequence of control actions has led to the current state of the control object. Alternative sequences reflect the possible successful implementation of managerial decisions.

In the case of a typical current state of implementation of other stages of technology is unnecessary. Stage 1 will be cycled every time a new state occurs.

If the current state is non-standard, then a new management solution needs to be implemented.

Stage 2. Verification of the organizational hierarchy level.

At this stage, the choice of probabilistic method is performed. In the event that the condition $Af \equiv Af^0$ is fulfilled, you must go to step 3. Otherwise, the transition to step 4 is performed.

Note that the implementation of the above condition indicates the choice of a detailed solution that reflects all operations on the processing of artifacts at the level of individual performers.

If the condition is not fulfilled, then the solution is formed at a given level of the organizational hierarchy.

Stage 3. Formation of a detailed integrated management solution using the method [9].

After completing this stage, you will be transitioning to step 6.

Stage 4. Specification of temporal rules for a given level of the hierarchy.

This stage is preparatory to the formation of a comprehensive management solution and involves a generalization of temporal dependencies for a given level of the hierarchy considered by the above method.

Stage 5. Formation of a comprehensive management solution for a given level of the hierarchy by the method [10].

Stage 6. Semantic verification and selection of management decisions.

At this stage, from an ordered subset of decisions that were formed as a result of probabilistic output, decisions whose semantics does not correspond to the subject domain are excluded.

Conclusions.

The proposed method of generalization of temporal dependencies implements the transformation of input temporal rules at the level of separate control actions into rules for a given level of the context hierarchy, taking into account the hierarchy of context artifacts, which makes it possible to construct a hierarchy of managerial decisions according to the organizational structure of the control object.

The developed technology of support of managerial decisions on the basis of probabilistic output in the temporal knowledge base uses the model of management decision, the method of decision support using the temporal knowledge base, the method of generalizing the objects of the control object, the method of detecting abnormal states, and also the methods of probabilistic conclusion in the temporal knowledge base.

Technology makes it possible to build a set of alternative managerial decisions in the form of control actions or an appropriate sequence of states of the management object, with the estimation of the probability of implementing each of the alternatives of management decisions. The resulting set of alternatives to managerial decisions is a complex management solution and can be linked to a certain level of organizational hierarchy.

Technology provides more effective management decisions in uncertainty due to the choice of the most probable sequences of control actions by the decision maker.

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РОЗРОБКА ІНФОРМАЦІЙНОЇ ТЕХНОЛОГІЇ ПІДТРИМКИ УПРАВЛІНСЬКИХ РІШЕНЬ НА ОСНОВІ ЙМОВІРНІСНОГО ВИВОДУ В ТЕМПОРАЛЬНІЙ БАЗІ ЗНАНЬ

Анотація. Мета статті. Метою статті є розробка технології підтримки управлінських рішень в умовах невизначеності на основі ймовірнісного виводу в темпоральній базі знань для підвищення ефективності організаційного управління на тактичному та стратегічному рівнях організаційної ієрархії.

Методи дослідження. Методи підтримки прийняття рішень, методи ймовірнісного виведення в базі знань.

Основні результати дослідження. Розглянуто проблему побудови управлінських рішень в умовах невизначеності. Ця проблема пов'язана із невідповідністю між практичною потребою формування управлінських рішень з використанням баз знань та можливостями існуючих знання-орієнтованих методів, що використовують лише причинно-наслідкові залежності. Виконано аналіз структури процесу підготовки управлінських рішень. Показано, що узагальнена структура процесу прийняття управлінських рішень передбачає послідовне вирішення задач підготовки та реалізації рішення. При вирішенні задачі підготовки рішення виконується формування множини можливих управлінських рішень. Задача реалізації рішення передбачає його вибір та імплементацію. Виконано структуризацію темпоральних залежностей у структурі управлінського рішення. Розроблено метод узагальнення темпоральних залежностей. Запропоновано технологію підтримки управлінських рішень з використанням темпоральної бази знань. Розроблена технологія дає можливість побудувати множину альтернативних управлінських рішень у вигляді послідовностей управляючих дій або відповідних послідовностей станів об'єкту управління з оцінкою ймовірності реалізації кожного із альтернативних варіантів управлінських рішень. Отримана множина альтернативних варіантів управлінських рішень складає комплексне управлінське рішення та може бути зв'язана із визначеним рівнем організаційної ієрархії. Це дає можливість сформувати комплексне управлінське рішення як на рівні окремих підрозділів, так і на рівні організації в цілому.

Наукова новизна. Запропоновано метод узагальнення темпоральних залежностей, який на основі перетворення вхідних темпоральних правил на рівні окремих управляючих дій та з урахуванням ієрархії артефактів контексту дає можливість побудувати правила для заданого рівня контекстної ієрархії. Запропоновано технологію підтримки управлінських рішень як послідовностей дій на основі ймовірнісного виводу в темпоральній базі знань.

Практична значимість. Розроблена технологія забезпечує більш ефективне прийняття управлінських рішень в умовах невизначеності за рахунок вибору найбільш ймовірних послідовносте управляючих дій особою, що приймає рішення.

Ключові слова: *управлінське рішення, підтримка прийняття рішень, темпоральна залежність, темпоральна база знань.*

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РАЗРАБОТКА ИНФОРМАЦИОННОЙ ТЕХНОЛОГИИ ПОДДЕРЖКИ УПРАВЛЕНЧЕСКИХ РЕШЕНИЙ НА ОСНОВЕ ВЕРОЯТНОСТНОГО ВЫВОДА В ТЕМПОРАЛЬНОЙ БАЗЕ ЗНАНИЙ

Аннотация. Цель статьи. Целью статьи является разработка технологии поддержки управленческих решений в условиях неопределенности на основе вероятностного вывода в темпоральной базе знаний. Технология обеспечивает повышения эффективности организационного управления на тактическом и стратегическом уровнях организационной иерархии.

Методы исследования. Методы поддержки принятия решений, методы вероятностного вывода в базе знаний.

Основные результаты исследования. Рассмотрена проблема построения управленческих решений в условиях неопределенности. Данная проблема связана с несоответствием между практической потребностью формирования управленческих решений с использованием баз знаний и возможностями существующих знание-ориентированных методов, использующих только причинно-следственные зависимости. Выполнен анализ структуры процесса подготовки управленческих решений. Показано, что обобщенная структура процесса принятия управленческих решений предполагает последовательное решение задач подготовки и реализации решения. При решении задачи подготовки решения выполняется формирование множества возможных управленческих решений. Задача реализации решения предусматривает его выбор и имплементацию. Выполнена структуризация темпоральных зависимостей в составе управленческого решения. Разработан метод обобщения темпоральных зависимостей. Предложена технология поддержки управленческих решений с использованием темпоральной базы знаний. Разработанная технология позволяет построить множество альтернативных управленческих решений в виде последовательностей управляющих воздействий или соответствующих последовательностей состояний объекта управления с оценкой вероятности реализации каждого из альтернативных вариантов управленческих решений. Полученное множество альтернативных вариантов управленческих решений составляет комплексное управленческое решение и может быть связано с определенным уровнем организационной иерархии. Это дает возможность сформировать комплексное управленческое решение как на уровне отдельных подразделений, так и на уровне организации в целом.

Научная новизна. Предложен метод обобщения темпоральных зависимостей, который на основе преобразования входных темпоральных правил на уровне отдельных управляющих действий и с учетом иерархии артефактов контекста дает возможность построить правила для заданного уровня контекстной иерархии. Предложена технология поддержки управленческих решений как последовательностей действий на основе вероятностного вывода в темпоральный базе знаний.

Практическая значимость. Технология обеспечивает более эффективное принятие управленческих решений в условиях неопределенности за счет выбора наиболее вероятных послидовносте управляющих действий лицом, принимающим решения.

Ключевые слова: *управленческое решение, поддержка принятия решений, темпоральная зависимость, темпоральная база знаний.*

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