WORKFLOW-BASED ACQUISITION AND SPECIFICATION OF FUNCTIONAL REQUIREMENTS

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Abstract. The paper deals with knowledge-based business process (BP) modeling and user requirements acquisition. The peculiarity of this approach is knowledge-based modeling of the enterprise management (control) interactions. The interactions of enterprise management functions (information processing and decision making) and enterprise primary activities (product development processes) are considered from the control point of view - any enterprise management function is formally predefined as Elementary Management Cycle (EMC) and presented as Workflow model (WFM). Six types of specialized WFM are defined and deployed for knowledge-based BP modeling and user requirements acquisition process. Two types of logical gaps are identified by transformations of Workflow models from empirical one to knowledge based WFM.

Keywords: knowledge-based business process modeling, user requirements acquisition, control point of view, Enterprise Meta-Model, enterprise management (control) function, Use Case Model.

1 Introduction

Many mistakes in the area of business process (BP) modeling and user requirements acquisition can be avoided when applying formalized (algorithmic) methods of business domain analysis, BP modeling control and user requirements generating. Usually user requirements acquisition process starts from the construction of the Use Case Model (UCM). In this case UCM is constructed by IS designer which takes BP model as a source of knowledge about problem domain without examining such empirical BP model according to some formal or formalized criteria. From our point of view only verified and validated BP model (i.e. examined through formalized criteria domain knowledge) should be stored in the knowledge repository of CASE tool, and should be used to control knowledge of user and analyst also to verify IS project solutions. This repository could be used for the generation of IS design stage models too. The set of components types and relationships types of Enterprise Model is regulated by formalized specification, which is called Enterprise Meta-Model [5].

There is a great number of Enterprise modeling methods and approaches, which defines the Enterprise components (such as CIMOSA, GERAM [3], IDEF suite, GRAI), standards (ISO 14258, ISO 15704, PSL, ISO TR 10314, CEN EN 12204, CEN 40003) [10]. For instance, UEML is aimed to development of enterprise architecture or enterprise modeling language based on Enterprise Meta-Model [12].

However, the integration of Enterprise modeling techniques into the information systems development process is still not sufficient [13], [14], [15], [16]. A characteristic feature of CASE methods is their empirical nature, because the project models repository of CASE system is composed on the basis of empirical information about problem domain - information about problem domain is not verified through formalized criteria. The problem domain knowledge eliciticitation process relies heavily on the analyst and user; therefore it is not clear whether the knowledge about this problem domain is adequate. The human (an expert, user) plays the pivotal role in problem domain knowledge acquisition process, and few formalized methods of knowledge acquisition control are taken into consideration. Another typical disadvantage of present-day CASE methods should be also mentioned: at design stage models are constructed in an interactive mode and only several IS design stage models are partly generated. Currently, in the first stage of IS development life cycle (LC), CASE systems generate a diagram of functional hierarchy according to problem domain model, while in the last stage of LC, application code (prototype of user interface) and data base specification is generated according to UML Class model. Other IS project models are constructed interactively, i.e. designer, analyst and programmer interactively create IS project models through analyzing models, designed in earlier stages. Therefore, gaps of IS engineering process occur due to the human factor. These gaps mean, that the project model is formed in an interactive way (when the human participates), but not in an algorithmic one. This determines the incompatibility of IS project models and the incoherence of IS designing process, because in IS engineering process human is overloaded.

* The work is supported by Lithuanian State Science and Studies Foundation according to High Technology Development Program Project "Business Rules Solutions for Information Systems Development (VeTIS)" Reg. No. B-07042.
This paper deals the knowledge-based approach to business process (BP) modeling and integration with computer-aided specification of user functional requirements. The similar (in some extent) approaches are described in [1], [2], [11] and [15].

The approach to use case and conceptual models through business modeling is presented in [11]: the use cases are elicited and structured on the basis of the business processes of the organization, represented by Role Diagram, Sequence Diagram and process diagram.

The steps of BP model transformation to functional requirements specification, specified in the form of use case diagrams is described in the [1], [2]. This approach is meta-model based since the meta-models for use case diagrams and for business process models are defined and the mapping between these two meta-models is defined.

The peculiarity of our approach to knowledge-based business process (BP) modeling and user requirements acquisition is the modeling of any enterprise management function as formally defined unit - Elementary Management Cycle (EMC) [5], [7]. So, the enterprise management functions (information processing and decision making) and enterprise processes (primary activities, product development processes) are considered from the management (control) point of view as predefined structure, namely – the EMC.

The modified Workflow modeling notation is used for representation of the components of enterprise management function required by definition of the EMC [7]. The specialized Workflow models of six types are developed and deployed for representation of knowledge-based user requirements acquisition process [9].

2 The principles of knowledge-based engineering

Systems analysis of trends of IS engineering methods refines the trend towards the knowledge–based engineering, it shows the cause of feasible changes in architecture of CASE tools. The principles of knowledge-based IS engineering (KB ISE) were refined by analysis of trends of IS engineering [4]. The Enterprise Model (EM), Enterprise Meta-Model (EMM) and formal Enterprise model (i.e. some theoretically defined Enterprise Management Framework [7]) are the obligatory concepts of any knowledge-based CASE method and obligatory components of knowledge-based CASE tool.

The knowledge-based CASE process is defined and constructed on the basis of knowledge acquired by the Enterprise Meta-Model as an obligatory layer of the Knowledge Base – a part of the Repository of knowledge-based CASE tool [6].

The underlying functionality of knowledge-based CASE tool (the destination) is verification of IS project (i.e. a set of IS models) against the CASE tool Knowledge Base content. The user is considered as an intermediate between the Real World (an Enterprise) and IS developer. The user knowledge about Enterprise is limited (related with some role of user in enterprise activities), and consequently – user requirements are role dependent, so, could be inconsistent.

The consistent pattern of the Real World (Enterprise activities) is conceptualized and formally defined as specification of Enterprise (including Enterprise Meta-Model and Enterprise model). The development of Enterprise Meta-Model is a fairly complicated problem, related with developments in the areas of enterprise modeling, the concepts of control theory [8] and management control [5], [7].

Figure 1 depicts the architecture of the CASE system enhanced by the Knowledge Base. The Knowledge Base of the CASE system consists of two parts: an Enterprise Meta-Model (EMM) and Enterprise Model (EM). An Enterprise Meta-Model is the generic level model; an Enterprise Model includes the partial and particular level models in accordance with GERAM [3].

![Figure 1. The architecture of knowledge-based CASE system](image-url)

Usually, the IS development problems occur when acquired BP related (empirical) information (aimed for user requirements specification) has to be verified and validated.
The Knowledge Base of the enhanced CASE system is supposed to be the third active source of Enterprise knowledge (next to Analyst and User) for information systems engineering. Enterprise Meta-Model (EMM) in this enhanced environment of information system development is a source of pre-defined knowledge, and is used to control the process of business domain knowledge acquisition and analysis, requirements specification and development of IS project specifications (for instance, UML models). At first steps of IS development it is used to control the construction of an Enterprise Model for a particular business domain.

Knowledge-based IS development supposes that all stages of IS development life cycle are supported by the CASE system’s Knowledge Base. Enterprise Model is used as an alternative source of knowledge (next to IS developer knowledge) during the IS development process.

The Knowledge Base of the CASE system (in conjunction with appropriate algorithms) assures the consistency among the business process models and IS design models, gives new possibilities for verification and validation of IS development deliverables at the life cycle steps.

Problem domain knowledge (which is examined through formalized criteria) should be stored in the knowledge repository of CASE tool and should be used to control empirical information of user and analyst as well as to verify IS development solutions. This repository of enhanced CASE tool is used for the generation of IS engineering design stage models too.

3 Approach to elicitation of domain knowledge

The elicitation of user requirements is the initial stage of traditional IS development life cycle, starting with enterprise modeling. Most of user requirements acquisition techniques are based on empirical information provided by the user (business domain expert) and systemized by the analyst. Therefore, the user and the analyst are two sources of information in traditional IS engineering. Problems occur when empirically acquired problem domain information (enterprise model, requirements) has to be verified and validated.

The Enterprise Knowledge Repository of CASE system (containing the EMM and particular Enterprise Model) is considered to be the third source of domain knowledge for IS development stages – both for user requirements analysis and specification and for other IS development life cycle stages.

The presented BP modeling and user requirements acquisition process is developed from management (control) point of view [5]. The workflow model notation is selected for representation of BP models. This knowledge–based approach includes transformations of few types (modifications) of the workflow model:

- Workflow Model of Business Processes (VP_WFM), this is the traditional workflow model aimed to specify an expert knowledge (empirical information) about problem domain processes, material and informational flows and actors;
- Workflow Model of Processes (P_WFM) is a part of VP_WFM) and includes only material processes, material flows and related actors of the problem domain,
- Workflow Model of Functions (F_WFM) - and includes only informational flows and related actors of the problem domain,
- Workflow Model of Processes without Gaps and Workflow Model of Functions without Gaps are intermediate results in transformations from empirical workflow model (VP_WFM) to knowledge-based workflow model (FS_WFM).
- Workflow Model of Functional Composition (FS_WFM) is developed from control point of view and specifies the composition of definite business management function in accordance with definition of EMC [7], [5].

The refinement of formally correct enterprise management function is a sequence of BP model transformations. The algorithms of four types for transformation of the empirical BP model (VP_WFM) to formally correct enterprise management function (FS_WFM) are developed already:

A1. The algorithm which identifies informational activities and material processes (presented in empirical workflow model (VP_WFM) and separates VP_WFM into Workflow Model of Processes (P_WFM) and Workflow Model of Functions (F_WFM);
A2. The algorithm which identifies and eliminates logical gaps in the P_WFM;
A3. The algorithm which identifies and eliminates logical gaps in the F_WFM;
A4. Validation of the composition of particular management function model (FS_WFM) according to the formal definition of enterprise management function (predefined as Elementary Management Cycle (EMC) [5]).

The major steps of problem domain analysis and knowledge acquisition are presented in Figure 2:

Step 1. Acquired problem domain knowledge is presented as traditional workflow diagram (VP_WFM),
Step 2. Traditional workflow diagram (VP_WFM) is transformed into P_WFM and F_WFM when separation algorithm is performed. Yet, in the transformation process logical gaps may occur. A logical gap is a semantic discontinuity between the elements of the problem domain model (for instance, workflow model).

Step 3. Logical gaps in the P_WFM and F_WFM models are identified by the algorithms of the P_WFM and F_WFM analysis and eliminated by the analyst. The application of these algorithms requires an additional analysis of the problem domain. The result of logical gaps elimination are P_WFM and F_WFM without logical gaps. In such eliminating process VP_WFM is also updated with knowledge about processes, activities, information flows or material flows of a particular problem domain.

This process is called the first quality assuring cycle of computerized problem domain knowledge and it is based on formal enterprise management cycle model defined in [7]. The algorithm defining functional composition is performed at the next step of the stage of workflow model based computerized problem domain knowledge acquisition and analysis. During this process, completeness of functional composition, which controls each process, is verified. (i.e. it is verified weather F_WFM functional elements – activities, controlling each process, are specified). The lacking activities are identified on the basis of enterprise Meta-Model composition. The process of functional composition algorithm performance indicates activities, which exist in the enterprise problem domain, but are not specified in F_WFM. Information flows, which relate these activities, are also indicated in this process. Material processes, information activities, material and information flows (which are indicated during performance of functional composition algorithm) complement VP_WFM by new elements.

This process is called the second quality assuring cycle of domain knowledge acquisition process and it is based on formal enterprise management cycle model defined in [7]. The result of functional composition defining algorithm is FS_WFM. This model specifies the internal composition of particular material process management function, i.e. F_WFM model activities (which are attributed to Interpretation, Information Processing and Decision Making and Realization) and their relating information flows.

![Figure 2. The workflow model based problem domain knowledge acquisition and analysis](image)

3.1 The initial Workflow Model of Business Process

Primary knowledge about problem domain is acquired to initial BP model, represented as workflow model VP_WFM. When designing Workflow Model of Business Processes (VP_WFM). The VP_WFM represents empirical information (user and analyst give knowledge about problem domain) about material processes, enterprise activities, informational and material flows and actors of a particular problem domain. The Workflow Model of Business Processes is designed using notation of traditional workflow model. The main components of traditional workflow model are Actors, Activities and Flows. In graphical notation Activities and Flows are signed by symbols without reference what nature (material or informational one) business process and flow belong to, i.e. the signing element is the same of information flow and material flow as well as informational activity and material process. In order to make the process of problem domain knowledge
acquisition more effective it is advisable to modify traditional workflow model by establishing flows of two types: material and informational. The modified workflow model is called Workflow Model of Business Processes (VP_WFM).

The VP_WFM is applied to problem domain acquisition process because it is sufficient for capturing knowledge about business processes, actors, material and information flows. It is simple and easily mastered too. Meta-Model of Workflow Model of Business Processes is presented in Figure 3.

Two types of VP_WFM flows are identified and used for VP_WFM separation into P_WFM and F_WFM during the next stage of problem domain knowledge acquisition and analysis. Each Business Process of VP_WFM, except initial and final ones, has material and (or) informational input and output. Business Process can be of either material or informational nature. A Business Process which is related to material flows is defined as business process of material nature, while a business process that is related to informational flows is defined as business process of informational nature. Business processes of material nature and their material input or (and) output flows, are specified as material processes with these flows in P_WFM when separation algorithm is performed. Business processes of informational nature and their informational input or (and) output flows, are specified as informational activities with these flows in F_WFM when separation algorithm is performed.

The component Business Process of VP_WFM is defined as the sequence of organizational actions, which transform inputs into outputs. Material Flow is a material input and (or) output of business process, supplying material resources necessary to perform the process. Material input (output) of business process is not a mandatory element of each business process. The component Information Flow is informational input and (or) output of business process, intended to control it. VP_WFM actors are human, group of humans or organizational unit, which perform business process and are responsible for its successful performance. The prototype of VP_WFM modeling tool is developed on the base of MS “VISIO 2000” tool and MS “Access 2000” database management system. The business process model VP_WFM is formed in two main steps when applying the suggested prototype.

3.2 Model of Processes: material transformation activities

The Workflow Model of Processes (P_WFM) specifies material processes (they are singled out of the VP_WFM, and have material inputs and (or) outputs) and actors, who implement them. A Process is a partially ordered set of steps, which can be executed to achieve some desired material end-result. A Process consumes material resources (it is an input of the process) and produces some material output – products or services. The internal components of the Process are sub-processes, tasks and operations. Definitions of material flow and actor of the model P_WFM are analogical to that of the model VP_WFM. The Meta-Model of the P_WFM is presented in Figure 4.
3.3 The Model of Functions: information transformation activities

Information Activities, Information Flows and Actors are the components of Workflow Model of Functions (F_WFM). Informational Activity is enterprise function, or it’s component, which processes information flows when changing information input into information output. Each material process is controlled by at least one function, which consists of informational activities and information flows, linking these activities. Material transformation Process (See Fig. 4) is totally controlled by enterprise function, while activity controls this process partly. Definitions of Information Flow and Actor in the Model of Functions (F_WFM) are like that in Model of Process (VP_WFM). The Meta-Model of the F_WFM is presented in Figure 5.

![Figure 5. The Meta-Model of Workflow Model of Function (F_WFM)](image)

3.4 Principles for Separation of Information Flows and Material Flows

The initial verification stage of acquired domain knowledge is a process, which separates the empirical workflow model (the VP_WFM) into two workflow models: the P_WFM concerning the material flow transformations and the F_WFM concerning the information flow transformations.

When the VP_WFM is decomposed into P_WFM and F_WFM, the some inconsistency of problem domain specifications (informational gaps in the workflows) are identified. This is a step of BP model verification. For decomposition of VP_WFM into model of material transformation activities (P_WFM) and model of information transformation activities (F_WFM) the main three rules are applied. The first rule – if Business Process input and (or) output (specified in VP_WFM) are Information Flows, this Business Process will be specified as Information Activity with input and (or) output flows in the F_WFM. Second rule – if Business Process input and (or) output (specified in VP_WFM) are Material Flows, this Business Process will be specified as Process with material input and (or) output flows in P_WFM. Third rule – an Actor is specified as an Actor in the F_WFM activity or in the P_WFM.

Figure 6 gives an example of decomposition of the some particular model VP_WFMp. The VP_WFMp specifies Business Processes VP1, VP2 and VP3, Information Flows I1 and I2 and Material Flow M1. Using the first rule of decomposition, Business Process VP2 and Information Input I1 are specified in F_WFMp as Activity F2, which has information input I1.

![Figure 6. Decomposition of empirical BP model](image)

The component Business Process VP2 is related with Actor V1, so, according to the third separation rule this actor is depicted as Actor V1 in the model F_WFMp. According the second separation rule, Business
Process VP3 and material input M1 are depicted as Material Process P2 with material input M1 in the model P_WFM. Business Process VP3 and its information input I2 are depicted as Activity F3 with information input I2. Business Process VP1 is related with information outputs I1 and I2, also material output M1. According to the first VP_WFM separation rule, VP1 is depicted as Activity F1 with information outputs I1 and I2 as well as according to the second rule, VP1 is depicted as Material Process P1 related with material output M1.

Each Process, except the initial and final ones, must have material input flows and material output flows. Analogical requirement obtains regarding Activity, simply its input and output flows are informational ones. If this condition is not complied with, the models F_WFM or P_WFM has some logical gaps, that are eliminated when process and function gaps eliminating algorithm A2 and A3 are performed. The prototype of the BP model decomposition system is developed on the base of MS “VISIO 2000” tool and MS “ACCESS 2000” data base management system.

3.5 The Elimination of Logical Gaps

A logical gap is a semantic discontinuity among the elements of the enterprise management function, presented in the notation of workflow model. Identification of semantic discontinuity among elements of management function is based on the formal definition of Elementary Management Cycle [5], [7]. The logical gaps could appear when problem domain knowledge is acquired incompletely. To eliminate gaps of P_WFM, logical gaps detecting and eliminating algorithm is applied. Logical gaps of P_WFM are identified during the analysis of input and output flows of each material process. A logical gap in the P_WFM and F_WFM is identified if some Process or Activity is not related to input or output flow. Except the first and the last Processes of the workflow model each Process of the P_WFM must be related to at least one input Material Flow and one output Material Flow, in the same as each Activity of the F_WFM must be related to at least one input Information Flow and one output Information Flow.

The logical gaps elimination algorithm for model F_WFM is analogical to that of model P_WFM. The main difference in these algorithms is the nature BP model nodes (activities, processes) and relationships (flows): the activities and flows of model F_WFM are informational one, and flows and processes of model P_WFM are material one. If input and output of some activity in the FS_WFM are information flow “Process Output”, incorrect type of activity (Impossible) is identified. The components Activities of the FS_WFM, according to composition of Enterprise Meta-Model, cannot have informational input and output flows of the same type. The components Activities, which have information input and output flows (“Process Output”, “IP Input”, “IP Output”, “Process Input”) of analogical type, can exist neither.

If input of some Activity is “Process Output” and output of Activity is “IP Input”, this Activity will be a component of management function, it is called Interpretation (see Fig. 7) [5]. The component Interpretation of management function is set of rules, intended to transform information flow “Process Output” into “IP Input”, which is prepared for IP processing. Interpretation is a necessary component of management function, because “Process Output” information flow can mismatch data format, determined for functional IP element input “IP Input”. If input of Activity is “IP Input” and output of Activity is “IP Output”, this Activity is component IP of management function (see Fig. 7). The component IP is mainly intended to control process of information processing and decision making. If input of Activity is “IP Output” and output is “Process Input”, this Activity is a part of management function called Realization (see Fig. 7) [5]. The component Realization transforms “IP Output” data (processed in IP stage) into “Process Input” format (aimed to direct control of Process).

There are some cases when F_WFM activities define several component parts of enterprise management function, according to activity input and output flows. If activity input is “Process Output” and output is “IP Output”, the activity will have such functional components as IP and Interpretation as well as information flow “IP Input” (which links IP and Interpretation). If activity input is “Process Output” and output is “Process Input”, activity will consist not only of Interpretation, IP and Realization but also “IP Input” (which link Interpretation and IP) and “IP Output” (which link IP and Realization). Such composition indicates that this activity is function.

Activity input “IP Input” indicates two possible types of outputs: “IP Output” and “Process Input”, while enterprise output “Process Input” indicates activities IP and Realization as well as information flow “IP Output” (which links IP and Realization). Activity input “Process Input” and output “Process Output” signal an error in F_WFM, thus such type of activity is impossible.

3.6 Knowledge-based Model of management function

The result of functional composition verification algorithm is knowledge-based model of enterprise management function, represented in the workflow modeling notation as FS_WFM (Workflow Model of Functional Composition). The Meta-Model of the knowledge-based management function FS_WFM is presented in Figure 7.
Components of the model F_WFM are specified in the knowledge-based model of enterprise management function FS_WFM as formally defined components of the EMC [7], as well presented in the Enterprise Meta-Model [5]. The model FS_WFM specifies only one management function, which controls one or more processes, specified in the model P_WFM. In accordance with the internal structure of management function which is defined by Enterprise Meta-Model, there are three types of F_WFM activities: Information activity of interpretation, information activity of processing and decision making (IP), Information activity of realization. Each activity of the model F_WFM can correspond to one of the above mentioned component parts of management functions. Algorithm, which defines functional composition of management function, determines what part of management function activities belong to and what material process do they control in the model F_WFM.

![Figure 7: Meta-Model of knowledge-based management function (FS_WFM).](image)

4 Principles of functional requirements generation

Traditionally, the UCM is aimed to specify functional requirements for particular task (information processing activity). Using identifiers of Enterprise Model elements, it is possible to single out knowledge, related to that task, and depict them according to UCM designing rules.

Enterprise knowledge repository of CASE system is an active “participant” of knowledge based IS engineering process. It is an extra source of domain knowledge besides user and analyst. In traditional IS engineering only user and analyst stand for the source of knowledge about problem domain. On the basis of this method, interactive user requirements (Use Case models) generating algorithms were created. They control user requirements specification process. Such opportunity (to control generation process) is ensured by CASE tool enterprise knowledge repository. Knowledge (stored in the repository) becomes a criteria, which controls actions of user and analyst, i.e. it reduces human factor influence in the user requirements acquisition, analysis and specification stage of IS engineering. Possibilities of enterprise model based UCM generation (starting with different knowledge about enterprise) are illustrated in Figure 8.
Notionally, UCM can be generated according to any Enterprise Model component (Class of EM): EM=(Process (P), Function (F), Information Activities (IA), Information Flows (IF), Actor (A), Event (E), Goal (G), Business Rule, etc.) [5]. In case of UCM generation for EM Class Process (P*), material processes (existing in definite EM*) and related actors are specified in such resulting UCM for Process (P*). This type of UCM is called the UCM of processes.

The UCM of function (see UCM (F*) in Fig.8) is aimed to specify the components of definite enterprise management function and related actors. The components of Use Case model of Function are as follows: (Function (F), Information Activities (IA), Information Flows (IF), Actors (A)).

Likewise the UCM, generated for the EM Class Actor (A*), specifies material processes, functions and informational activities related with definite Actor (A*). The UCM generated for EM Class Goal specifies Functions, related to organizational goals, and their components (informational activities). The UCM could be generated as well for such EM Classes as Material flow, Information flow, Information Activity and Business Rule.

5 Conclusions

The problems of the knowledge-based BP modeling and user requirements design have been discussed. The Enterprise model is considered as the major source of knowledge in information systems engineering. The Enterprise model formalizes the structure and behaviour of organizational system in order to understand business enterprise, specify requirements and improve the process of information systems design and implementation.

The enhanced CASE system’s Knowledge Base should include the Enterprise Meta-Model that would define the architecture of the enterprise knowledge to be stored. The EMM is used as the “normalized” knowledge architecture to control the process of construction of an Enterprise model for the particular business domain. The usage of such Enterprise model facilitates the automation of the whole IS development process. Some work in this area has already been done [5]. The architecture of the knowledge-based CASE system for the enhanced IS engineering is presented in this paper.

The knowledge-based Use Case model generation principles are presented. The Enterprise Meta-Model is used as the source of formalized enterprise knowledge for requirements specification step. The approach for the user requirements specification generation is based on the Enterprise Meta-Model and Enterprise Model stored in the enhanced repository of CASE system. The enterprise processes, management functions, and their interactions are considered as the critical components of the knowledge accumulated as Enterprise model in the knowledge base of CASE system. User requirements specification algorithms were created to generate Use Case models for particular element of Enterprise Model: enterprise management function, enterprise process, actor, goal and activity. This approach could be used to enhance the functionality of CASE tools. This approach ensures the knowledge-based user functional requirements specification, which is verified and validated against enterprise knowledge model, acquired on the basis of formalized Enterprise Meta-Model and Enterprise Model.
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