Ontological Framework Aimed to Facilitate Business Transformations

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Abstract. Information systems aimed for the analysis and management of enterprises perceive the reality through their embedded data patterns. These data patterns must be sufficient to store the information about transformations of business processes, products and organizational structure over time. Moreover, customization, extension and integration of data models have not to impede organizational changes. However, there is a lack of approaches to data modelling that fit with the changing nature of business objects and that allow the seamless extension and sharing of knowledge between business-nodes of networking organizations. This paper introduces a new ontological framework for consistent data modelling based on the notions of the Enterprise Ontology and the Object Paradigm. After explanation of the core elements of the proposed formal ontology, we exemplify the use of the ontology for creation of the information system aimed for the diagnosis of traceability problems in supply networks.

Keywords: Data Modelling, Ontology, Organizational Semiotics, Object Paradigm, Business Objects Semantics, Business Process Model, Enterprise Ontology.

1 Introduction

Nowadays the quality of the data models implemented in Information Systems and their interfaces is insufficient. The research reported in [1] concerns the problems of transferring the knowledge about enterprises into information systems. Intersubjective reality of enterprises [2] is built in communication and production processes [3]. Consequently, a conceptual schema [4] with active semantics is required for successful knowledge representation inside the information systems.

On the other hand, new technologies, new markets, globalisation, mergers and acquisitions require enterprises to transform and engineer themselves to deal with these challenges and new realities. Furthermore, enterprise information systems need to be continuously aligned with the corresponding business processes. Consequently, information systems of enterprises have to meet the requirements of integrability, interoperability and extensibility. This in turn leads to the necessity of the ontological core[1] of knowledge bases and the implementation of related reusable data patterns. It means that separate information about actors, their roles and interactions, production activities and lifecycles of products must be united to the integrated whole to bring the operation of the information systems of enterprises. In addition, the event concept has to be embedded into the conceptual schema of enterprises, because of the event-driven architecture of the information systems aimed for enterprise management.

Creation of the conceptual schema [4] of enterprises usually follows the conceptual modelling languages, frameworks and standards like ARIS, BPMN, ORM, etc. However, the majority of these standards relates to the process-oriented view of enterprises and do not reflect their inter-subjective aspect. Therefore, the loss of the linguistic and interpersonal part of the social world within the conceptual schema, related domain ontology and the referenced data create a drawback for effective perception and simulation of human interactions by information and communication technologies.

In this paper, we present a new modelling method and the corresponding ontology-based data meta-model that has an ability to keep comprehensive system representation of enterprises. Together they form an ontological framework, which supports transformation of organizations. In addition, we demonstrate application of the method to supply networks. Following the standard approach [6], we express the proposed ontological core in OWL and use the Apache Jena[2] framework to work with the knowledge base built upon the ontological core.

In our research, we actively exploit an approach to the enterprise modelling that is based on the notion of Enterprise Ontology [7]. The enterprise ontology aims to design the enterprise in its essential form [7] integrating all views of the enterprise into a comprehensive whole. We also use the particular methodology DEMO (Design and Engineering Methodology for Organizations) [7] detailed in section 2 as the complete theory and the methodology of enterprise ontology. Our goal is to translate the essential, comprehensive, concise, coherent and consistent [7] core of DEMO-based conceptual schema of enterprises into reusable conceptual artefacts of ontology-based data meta-models by the means of semantic modelling paradigms.

Also in our research, we use the modelling constructs of the Object Paradigm [8] to represent the Enterprise Ontology as the ontological core of information systems. This paradigm provides holistic modelling constructs that are aligned with non-attributed DEMO approach to enterprise modelling and offers detailed ontological modelling guidelines through the BORO (Business Object Reference Ontology) methodology [9]. The Object Paradigm creates patterns sufficient for modelling of changing entities like processes and products. Moreover, in order to provide clear referencing to things in the world, the Object Paradigm considers everything as objects where the object identity is a key factor for distinguishing objects from each other [9]. Therefore, the object paradigm eliminates subjectivity of the modelling process and provides the basis for creation of reusable data patterns in dynamically changing enter-

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1 In this paper, we will not elaborate on the importance of ontologies for the integration of heterogeneous data. Those, who are interested in this topic, are referred to [5], [6]

2 `http://jena.apache.org`

prises. This paradigm is a reliable approach to avoid semantic divergence of the ontological core [10].

The outline of the paper is as follows. First, the theoretical background of our work is summarized in section 2. Proposed ontological framework of the information systems, which support business transformations, is outlined in section 3. Then, the proposed framework is compared with the existing generalized upper-level ontology for networking organizations in section 4. Finally, section 5 provides conclusions and directions for further research.

2 Theoretical background

Following the aforementioned requirements to the information systems aimed for enterprise management, we merge a well-founded theory about the operation of enterprises with the theory of information modelling. Hereafter, both theoretical pillars are explained.

2.1 DEMO theory and methodology of Enterprise Ontology

In our research, we apply the DEMO methodology [7] to conceptualize enterprises taking into account their communication perspective and volatility. Based on the strong theoretical basis, the DEMO methodology describes the function and construction of social organizations by their ontological models that are essential and complete at the conceptual level, logical and free from contradictions, compact and succinct, independent of its realization and implementation issues [7]. Nowadays the Enterprise Engineering Institute[3] advances and disseminates this methodology.

The interpretive and intersubjective perspective of the methodology comes from considering an enterprise as a discrete dynamic system, of which the elements are social individuals or actors, each of them able to communicate with others by performing coordination acts and to contribute to bringing about the goods and/or services by performing production acts [7]. By performing coordination acts actors express their intensions and comply with commitments towards each other regarding the performance of production acts [7]. For example, they request, promise, state, and accept the result of some production act. By performing these two kinds of acts, actors transfer the world into the new states characterized by resulted coordination and production facts. Thus, the changes that are brought about as the result of the actions of the subjects are discrete. This means that they are considered to take place instantaneously, and that there is a finite number of changes within a certain period [11].

The methodology emphasizes uniform communication patterns between autonomic actors involved in a business deal. These patterns, also called transactions, always involve two actor roles (the initiator and the executor) and consist of the certain coordination acts and the production act of particular type. The actor, who starts the transaction and eventually accepts the results, is called the initiator, the other one, who

[3] Enterprise Engineering Institute, `http://www.demo.nl`

actually performs the objective action, is called the supplier or executor. A transaction consists of three phases: the order phase, the execution phase, and the result phase. During each of the phases of a transaction, new transactions may be initiated, the result of which is needed to proceed with the original one. In this way transactions are chained intersubjective world. By means of the DEMO models, it is possible to achieve a solid understanding of the types of transactions taking place in an organization, the participants involved in these transactions, the information that is needed and created during the transactions, and the relationship between the different transaction types [11].

DEMO transaction concept distinguishes between inter-subjective and objective world. According to DEMO, when engaged into communication, social individuals are trying to influence each other's behavior, in other words, an act of saying is an act of doing [11]. Thus, the coordination acts and their results (coordination facts) relate to the inter-subjective world. By performing production acts actors of enterprise change the states of products or services related to the objective world. The distinction of these two worlds at the conceptual level gives an opportunity for coherent modelling of business processes and product lifecycles of enterprises.

Finally, the methodology builds a comprehensive view on the interaction and management processes of an enterprise in four Aspect Models [7]. These models can be considered as the core for unified description of specified business processes in organization by the use of universal concepts. Through these models, it is easy to identify the roles of business agents, their potential communications and possible changes in production world. Moreover, the Aspect Models are free from Entity Paradigm’s defects of seeing things [8], such as foundation on an inconsistent set of concepts as well as poor semantics for the description of relationships, identity and changes of objects over time. Applying the methods of the BORO methodology to the Aspect Models it is easier to get the true set of the business objects of the enterprise and their signs [8].

2.2 Object Paradigm for Data Modelling

Business transformations require flexible and re-usable information systems that can respond to changes smoothly. In other words, a data model should cater for new changes and needs without a substantial change occurring to its constructs. That is why the authors focused on creation of the ontological data models of enterprises. The Object Paradigm (OP) proposed by Partridge [8] has advantages in the area of ontology engineering over other approaches.

Firstly, the models based on the OP are free from semantic divergence [10] because of the extension-based approach to modelling. Data modelers should be prevented from subjective conceptualisation of business context. Extraction of dimensional business objects from the conceptual model of an enterprise (e.g. the Aspect Models in our approach) alleviates modelling errors and biases. In this research, the set of dimensional business objects related to the DEMO theory of organizational ontology constitutes the ontological core for data model of any organization. According to aforementioned points of the DEMO theory, the objects of the core are actor roles, actors, coordination and production facts (per se events); processes - the compositions of dimensional actors, products and resources; transactions - the states of processes, etc.

Secondly, as other perdurantist approaches, the OP assumes that all objects have a temporal dimension in addition to spatial ones. The OP modelling principles developed based on perdurantism unambiguously explains objects' identity through changes (states and events), their relationships and classification. The consideration of spatio-temporal extensions of any object, the dynamic classification and identification allows to model business processes and lifecycles of products of enterprises (section 3).

Finally, the BORO methodology provides the set of essential information patterns of relationships between objects for modelling the connection between business processes and production facts, to wit: whole-part, before-after, pre-condition. As it was explained by Partridge [8], these patterns are essential and comprehensive for description of the sequence of physical activities like carving and selling of a statue.

The ideas of the OP formed the basis of several international modelling standards: ISO 15926, MODAF, DoDAF, MODEM. The last three standards are based on the IDEAS (International Defence Enterprise Architecture Specification) foundation[4]. The IDEAS project was aimed to develop an ontology-based data exchange format for military Enterprise Architectures. Despite the fact that the data meta-model of the standard was built by the means of BORO methodology, the IDEAS data meta-model is not suitable to store complete information about operation of an enterprise. However, in this research the authors extend the IDEAS data format by the concepts of Enterprise Ontology with the use of BORO modelling principles. Moreover, the authors use the IDEAS notation to represent graphically created data meta-model.

3 Proposed Ontological Framework

3.1 Philosophical and Mathematical Stands of the Framework

As for many other ontologies matching with the OP, we built our ontological framework from the objects and their relationships. The top level of objects comprises common concepts of 'class' or 'type' (a set of objects), 'class of classes' or 'powertype' (a set of classes), 'tuple' (a binary, two-ended relationship), 'individual' (an object that has spatio-temporal extent) (fig. 3.1.1). In the data meta-model, we use the concept 'type' instead of 'class' because of two reasons. Firstly, we want to highlight the subjective nature of created sets of objects according to the notion of ontological parallelogram invented by J. Dietz [7]. Then, we try to re-use the upper-level ontology of the IDEAS standard where it is appropriate.

Following the BORO methodology, we built the hierarchy of relationships via reification of relationships from the objects they refer. Specific types of relationships between objects are the classification relationships (class-member) and the specifica-

[4] The International Defence Enterprise Architecture Specification standard: `http://www.ideasgroup.org`

tion relationships (class-subclass). For all relationships between objects the modelling logic of the BORO methodology was applied, e.g. the notions of inheritance, ban on circularity, deducing descendant, virtual descendant, etc.

According to BORO, we consider business objects of enterprises as four-dimensional objects, which are timeless. Perdurants, i.e. the entities, which for only a part exists if we look at them at any given period of time, provide the opportunity to model lifecycles of products and business processes instead of well-known description of the static states of an enterprise. In the scope of this research we do not consider abstract objects related to the operation of enterprises such as risks, goals, norms, etc.

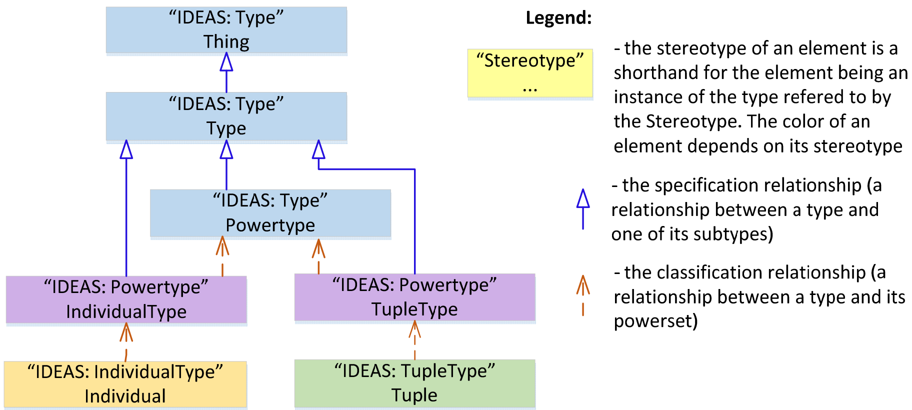

Fig. 3.1.1. The top level of proposed ontological framework

In compliance with both foundation theories, at any moment we can consider an enterprise in a particular state, which is simply defined as a set of objects. According to the DEMO theory, there are two kinds of objects: stata (singular: statum) and facta (singular: factum) [7]. A statum is something that is the case, has always been the case, and will always be the case. In other words, it is an inherent property of a thing or an inherent relationship between things [7]. Timeless classes, tuples and individuals of the proposed framework fit to the definition of stata of the DEMO theory without any contradiction with the OP. Contrary to a statum, a factum is the result of the effect of an act [7]. The notion of factum matches the notion of event. Thus, aforementioned production and coordination facts are the events of changing the states of business object(s). Certain types of stata and facta of some enterprise can be observed through the Aspect Models of this enterprise.

The foregoing comparison of two theories represents only the tip of the analysis that should be completed in future. However, the high coherence between conceptualization and modelling theories results in a strong connection between the conceptualization of an enterprise and its ontological data meta-model. In other words, in our approach there is a theoretical basis of the correspondence between our (human) mental enterprise model and the model representation of information systems.

In order to keep comprehensive knowledge about changing systems, the ontological framework of enterprise data models must comprise their *static*, *kinematic*, and *dynamic* perspectives [12]. Whereas under statics of a system we understand its states and transition space (the set of allowed transitions). By kinematics is understood the time dimension in the transition space. By dynamics is understood the mechanism that causes transitions (state changes) to take place. Following the BORO methodology, we differentiate the temporal parts – the states –of products, human and non-human resources. In addition, we extended BORO information patterns (before-after, whole-part, pre-condition) for the modelling of transition space. Temporal constituent of transitions appears in the data itself, as well as in the form of events in the ontology. The mechanism of transitions embedded into the proposed ontological framework duplicate the notions of organizational ontology [7].

3.2 The Main Elements of the Ontological Framework

In order to keep complete organizational knowledge in the ontology-based data model, the concepts of organizational ontology must be embedded into the ontological framework of the model. Hereafter, we explain the main parts of the created ontological framework.

In the definition of actors (agents), actor roles and business processes as well as their states we follow the IDEAS standard. The interested reader is referred to http://www.ideasgroup.org. The only new object added to this part of the meta-model is the sub-class 'Transaction' of the class 'ProcessState'. Members of the 'Transaction' class are all possible transactions of enterprises. Then, in order to link business processes and their production acts with product states, classes 'Product' and 'ProductState' were invented. New elements are highlighted in bold in fig. 3.2.1.

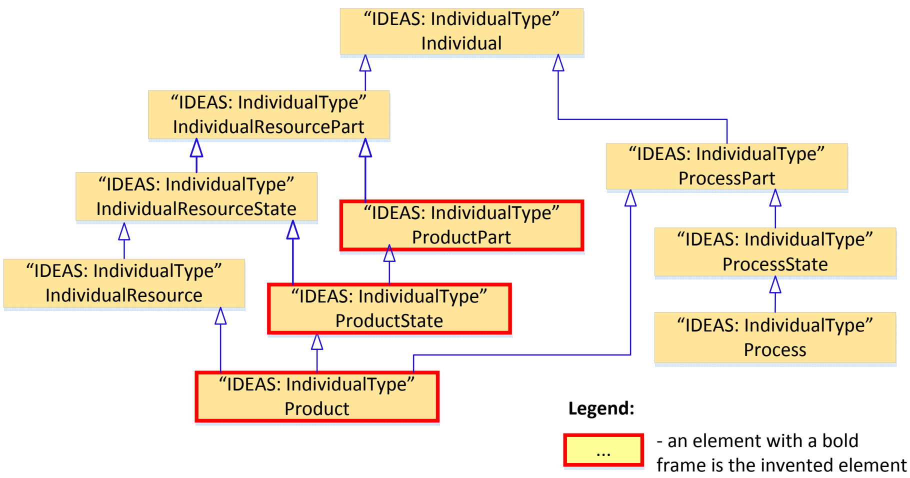

Fig. 3.2.1. Product is a process part

Following the conclusions in section 3.1, all events of enterprises were divided on two classes: ‘CoordinationFact’ and ‘ProductionFact’. According to the DEMO theory [7], the certain types of coordination facts can occur in communications of actors. In the proposed framework all these types are presented through classes, e.g. ‘Request’, ‘Promise’, ‘State’, ‘Accept’, etc. Members of these classes are coordination facts of certain types.

In the proposed framework many sub-classes of tuples before-after and whole-part were created, e.g. ‘processStateBeforeAfter’, ‘eventWholePart’, ‘transactionStartEvent’, etc. Following the BORO methodology, at least one new class of tuples was created for each invented class of individuals. However, we will not dwell at length on these classes, because they are sub-classes of the standard IDEAS tuples.

Significant addition to the IDEAS elements was made based on the pre-condition information pattern proposed by Partridge [8]: the ‘perConditionEvent’ tuple class and its sub-classes characterises relationships between the individual state and the state change event. This class of tuples is essential for modelling of business processes and product lifecycles.

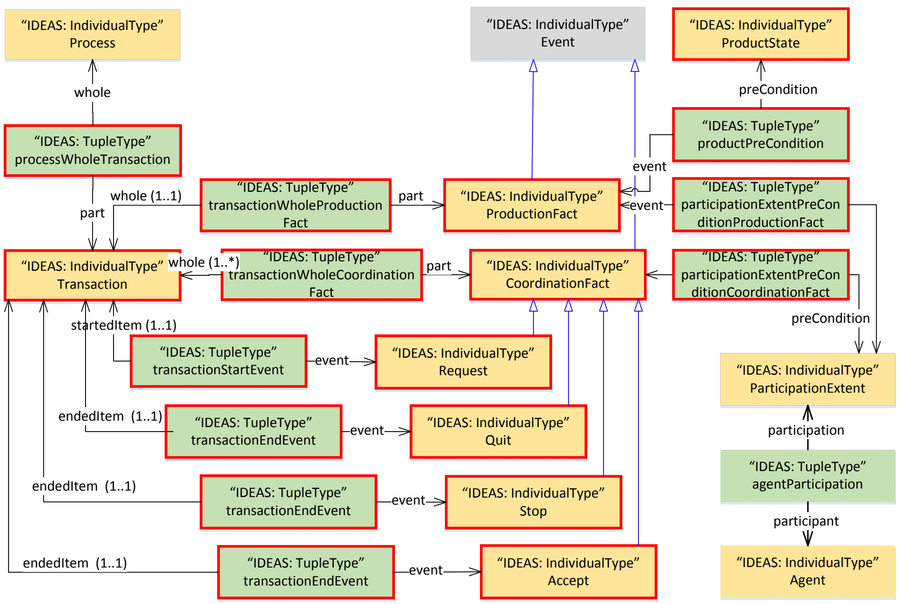

Fig. 3.2.2. Generic information pattern of business transactions

Based on the invented classes and tuples, the transaction information pattern (fig. 3.2.2) was proposed. This pattern reflects interactions between the initiator and the executor of business transactions, changes of a product resulted the transaction, the relation between certain transaction and a whole business process.

Because of the lack of space, this section does not contain the full description of the created framework. The framework as well as its domain-specific extension (section 4) were expressed in OWL and downloaded to the triple store. Then the set of tools was created on Apache Jena platform in order to retrieve information from the knowledge base instantiated the framework.

4 Some Benefits of The Ontological Framework

In this section, we listed some benefits of using the proposed framework for data modelling in enterprises and information systems tending to transformations.

4.1 Comparative Analysis of The Proposed Data Meta-Model

Despite on the universally recognized knowledge representation language OWL, nowadays there are no common agreements about the methods of semantic data modelling and the evaluation procedure of created models. Nevertheless, our goal is building the flexible perception of changing reality by information systems through data.

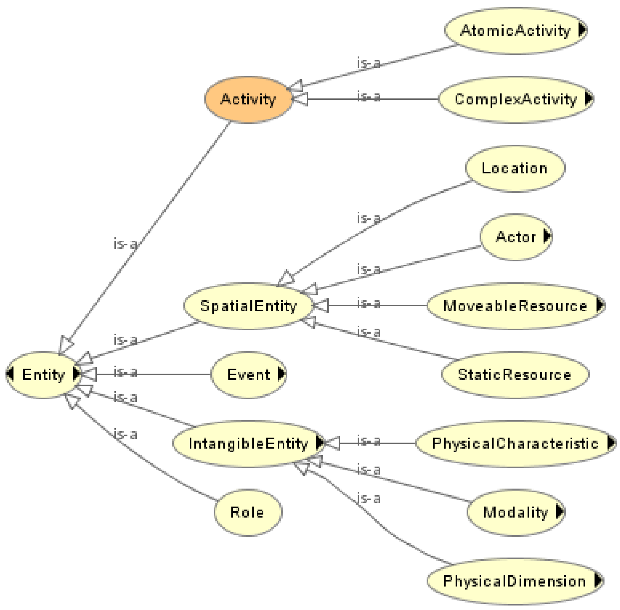

Fig. 4.1.1. Integrated semantic data meta-model of the EU 7th Framework program

The more knowledge is extracted by the information system from data, the more power we will associate with the related data meta-model. Hereafter, we compare the proposed ontological framework with the integrated semantic data meta-model of three projects of the EU 7th Framework program (FP7): EURIDICE[5], iCargo[6], e-

[5] http://www.euridice-project.eu
[6] http://i-cargo.eu

Freight[7]. These projects put joint efforts on development of the new generation of information systems in logistics, including the multilayered semantic meta-model [13].

The domain-independent core of the FP7 integrated meta-model contains the following classes: ‘activity’, ‘event’, ‘role’, special entities like ‘actor’, ‘static resource’, ‘moveable resource’ (fig. 4.1). ‘Activities’ are connected with ‘roles’ via ‘hasProvider’ and ‘hasConsumer’ relations, whereas roles are assigned to ‘actors’ by ‘hasRole’ relation. Beginning and ending of activities are designated by ‘startEvent’ and ‘endEvent’ accordingly. ‘Activities’ are connected with related resources via ‘hasStaticResource’ and ‘hasMoveableResource’ relationships. If the activity is aimed on moving products, it can be connected with products as the subclasses of ‘MoveableResource’. However, there is no explicit relation between ‘activities’ and ‘products’ in the meta-model.

We instantiated both ontology-based data meta-models by simulated models of supply processes according to their descriptions by the SCOR standard[8]. Then the analytic potential of the models was assessed by the series of SPARQL requests to the OWL knowledge bases. Knowledge extraction was performed through standard-SQL queries, while retaining the expressiveness of the logical representation. The requests related to the known problems of the identity of activities and products over time and the time ordering of actions, events, and states. According with the obtained results, the proposed framework considerably improves the analytical potential of the model.

4.2 One Example of Using the Generic Information Pattern of Business Transactions

In this section, we leave out the proof of the completeness of the generic information pattern of business transactions shortly presented in section 3.2. Instead, we simulated one example of using this information pattern for reasoning.

Imagine the part of supply network comprised by two companies – producer A and surveillance company B. Producer A makes the products of type P and delivers them to customers. Company A verifies their products before delivery or outsources this operation to company B. Company B has many branches located in different time zones. Both companies use the generic information pattern to store data in their own data storages. According to the information pattern of business transactions, we assume that the instances of the following types are available in both storages for each unit of product: ProductId, ProductState, ProductionFact, CoordinationFact, TransactionId, ProcessId, ParticipationExtent.

One day, two companies decided to merge their data storages. Then a data modeler found out that there were two verification transactions for product P#abc tracked in merged data. According to related instances of ProductionFact type, one transaction resulted in the product state ‘Verified_ok’, another transaction resulted in the product state ‘Verified_failed’. Moreover, the instances of ProcessId and ParticipationExtent

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[7] http://www.efreightproject.eu

[8] SCOR Frameworks, `http://supply-chain.org/resources/scor`

related to these transactions had the same values. It was necessary to define the last status of product P#abc delivered to a customer.

We can assume that 1) transactions were performed in different time zones. Thus, the time of transaction execution should be excluded from consideration. 2) Identificators of processes in autonomous companies could coincide. However, it is possible to recreate the sequence of the states of product P#abc using the relations between elements of the information pattern of business transactions. The following properties of the information pattern are used for reasoning:

1. each event resulted production or coordination action is tightly connected with the particular product state. This product state is the precondition of the event. The subclasses of tuples <EventType, ProductState> rigorously define the precondition for each type of events.
2. Certain types of events occur in the transactions of a certain type.
3. Each production event causes the state change of the product.

In assumption that the possible sequence of transactions (a business process) is defined by the data model, it is possible to find out the sequence of product states by the iterative requests: 1) select all transactions related to product P#abc, where the state 'Verified_ok' or 'Verified_failed' is a precondition of any event; 2) consider production events and resulted states of the product in selected transactions. The forgoing example was executed with simulated data.

5 Conclusions

This research was aimed on developing the ontological framework of information systems of enterprises tended to transformations. The authors assume that the proposed solution will facilitate the transfer of knowledge about operation of enterprises to information systems. In addition, the framework will be instantiated by flexible, reusable and integrable data models.

The proposed framework can be instantiated by the reference data for particular organizations in different domains. In this paper, we demonstrated the benefits of using the framework for modelling the standard business processes in supply network.

At the next step of the research, the meta-model will be extended by abstract business concepts and their relations with 4D-business processes. Strategies, goals, norms, rules, etc. will be taken into consideration. In addition, the set of tools will facilitate the work with the framework and knowledge extraction from knowledge bases built upon the framework.

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