FBS-PPRE, an Enterprise Knowledge Lifecycle Model

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Abstract The stages of an industrial product life-cycle can be described using process networks. A more generic and complete modeling is requested to improve the effectiveness of the knowledge life-cycle management related to the product.

Three aspects have to be considered.

- First, knowledge is extracted from specific processes and is often of a high complexity level. It is used by different users at different times, transmitted from one user to one another even if they are concerned by different points of view.
- Second, modeling is highly influenced by the used software that often considers particular views. The consequences are information redundancy, lack of integration of the different views and lack of information completeness.
- Third, knowledge is not static: the whole enterprise processes affect it. As a result, the transformations of knowledge have to be modeled but this is still a major difficulty for the usual models.

Consequently, a new generic and structuring model based on the FBS concepts (Function, Behavior and Structure) is proposed. These concepts are applied to four objects (PPRE): the Processes, the Products (objects stemming from the processes), the Resources (objects needed to realize the processes) and the External effects (constraints having an influence on the processes).

Keywords: FBS; Lifecycle; knowledge; information system

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1 Context and Difficulties Inherent to Knowledge Management

The general reference system (Fig. 1), shared between all the actors, makes the concurrent engineering easier: each department can intervene at any time on the design process, before choices become very costly or irreversible. The aim is to find the best compromise between cost, quality, delays and risk.

The general reference system is composed of two main models: the product model and the process model. The product data changes during time and highly depends on the context. A real linkage of the product and process data is desirable: in fact, the transformation of a product data can be considered as the result of a process applied to this product.

The general reference system is made of different models to improve the management of different types of knowledge.

Knowledge management implies a wide range of problematic areas:

- Transmission and acquisition of knowledge are complex processes;
- The influence of human resources is real and not negligible: a knowledge management methodology is not exclusively the result of a particular conceptual model: human factors have to be taken into account. In order to achieve the goals, it is very important to explain the objectives of the routine changes. The role of the managers is also crucial;

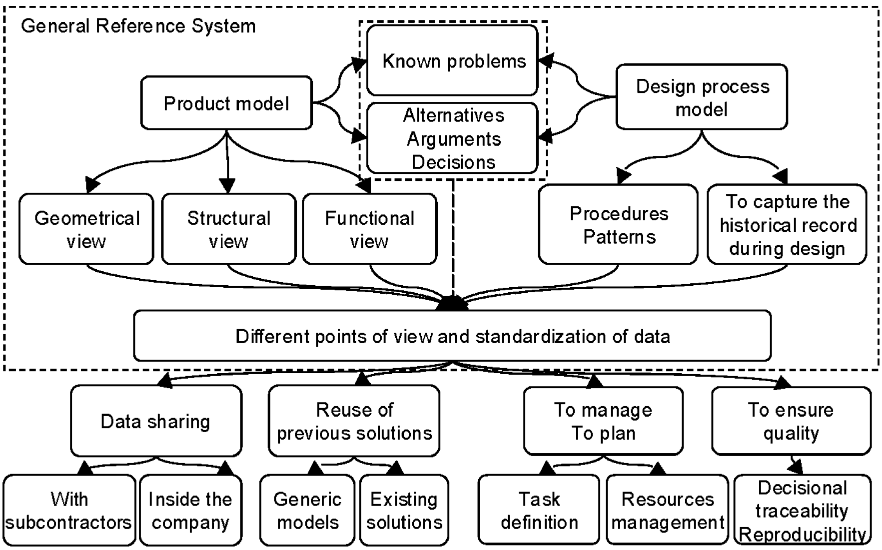

Fig. 1 Content and applications of the general reference system [9]

- Modeled objects are of high complexity: the granularity of the systems and the interactions between its elements implies emergent properties difficult to grasp. The understanding of the whole did not enable the understanding of its parts. Thus, the model should be multilevel and homogeneous.
- The system is always evolving: the knowledge about this system can be uncertain or incomplete. It would be interesting to provide a dynamic management of the information. A coherent and homogeneous management of the "Process/Product/Resource/External effect" information may help.

2 Different Approaches to Model the Enterprise Objects

We will present hereafter different PPR and PPRE approaches found in literature and we will compare their application domains.

The objective of these models is to model the information of the whole product lifecycle. To reach this goal, different objects have to be modeled: the bibliographical study is thus PPR or PPRE oriented. We define the PPRE objects hereafter.

2.1 The Enterprise Objects

The process object is a sequential, spatial and hierarchical organization of activities using resources to make products (or outputs).

The resource object is an object contributing to the process without being its purpose.

The product object is the result of the process, the object that the process intends to modify.

The external effect object is an object acting as a constraint (positive or not) on the process/product/resource system. It is a part of the context, which is foreseeable or not and that can disturb the process progress.

2.2 Different Views for a Same Object

The functional view: the functions describe in an abstract way the aim of an object. The operational functions are formulated independently of any particular solution. On the opposite, the technical functions depend of the technical choices.

The behavioral view: the behavior describes the dynamic aspect of an object. It includes a set of rules (continuous models) and sequential states graph (discrete model) representing the transformation of an object stimulated during a process.

The structural view: the structure defines the elements that are parts of the object. It defines also the attributes of these parts.

2.3 PPRE Approaches Synthesis

Different approaches have been analyzed: IDEF0 [8], IDEF3 [11], SAGEP [13], GRAI [2, 3], PATTERN [5], FBS [4, 7, 14, 15], MOKA [1, 12], HARANI [6]. The Table 1 quickly presents the views included in these methodologies.

It shows that there is a lack of completeness in all these approaches. For example, the external effects are not modeled and often not taken at all into account.

These approaches do not tend to be universal. Nevertheless, they are of great interest in their application area. Their use can also be complementary. The worst thing is that the integration of these approaches remains quite uneasy, making a view of the whole enterprise quite difficult.

Another observation is that the dynamic of the views remains partial, restricted to the product view: in these models, the resources or the processes structures cannot evolve.

Table 1 Comparison of different "process/product/resource/external effect" approaches

		IDEF0	IDEF3	IDEF 0+3	SAGEP	GRAI	PATTERN	FBS	MOKA	HARANI
Process	Function	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No
	Behavior	No	No	No	Yes	No	No	No	No	Partial
	Structure	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	Time management	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Product	Process/product link	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	Function	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Behavior	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Structure	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Resource	Process/resource link	Yes	Yes	Yes	Partial	Yes	Yes	No	Yes	Partial
	Function	No	No	No	Unclear	Yes	Yes	No	No	Yes
	Behavior	No	Yes	Yes	No	Yes	No	No	No	Partial
	Structure	No	No	No	Unclear	Yes	Yes	No	No	No
External effect	Process/External effect link	Yes	No	Yes	Yes	Yes	No	No	No	No
	Function	No	No	No	No	No	No	No	No	No
	Behavior	No	No	No	No	No	No	No	No	No
	Structure	No	No	No	No	No	No	No	No	No

3 Proposition of a Generic Model: the FBS-PPRE Model

We will now introduce our proposition of a new FBS-PPRE model.

The FBS (Function, Behavior and Structure) approach seems to be an interesting base for enterprise object modeling. However, the model remains incomplete and considers only one type of object: the product.

3.1 FBS-PPRE Model

We propose an extension of the FBS approach, the FBS-PPRE model. It integrates the fundamentals concepts needed to model the different enterprise objects.

The FBS-PPRE (Function, Behavior, Structure – Process, Product, Resource, External effect) is the result of the use of FBS modeling for the four objects views: the process view, the product view, the resource view and the external effect view. The external effect view is interesting to define the context. These views are based on two main concepts, “Enterprise object” and “Object” concepts.

“Enterprise object” is a generic concept dedicated to encapsulate the concepts of process, product and resource. This encapsulation will enable a more homogeneous and efficient management of these three concepts. An “Enterprise object” is defined as an enterprise entity or an entity controlled by the enterprise. It has a real influence on the company behavior. Nevertheless, the external effects can not be included in this generic concept (they’re not always controlled by the company).

The more generic concept of “object” is thus used and defined as “an entity playing a role in the company”.

This concept aims at managing the different objects independently of their roles [10].

3.2 Process, Product, Resource and External Effect Roles

We postulate that the concepts of process, product, resource and external effect are abstract and circumstantial. This implies that an object cannot be considered during its whole lifecycle as a process, a product a resource or an external effect.

Actually, an object can have different roles during its lifecycle. For example, we can consider a designer creating the design of a part with a CAD tool. The CAD drawing will be the *product* of its study. Nevertheless, this object will be considered as a *resource* of the manufacturing design *process*. We consider now a sub-contractor acting usually as a company *resource*. It can also be an *external effect* if it is not able to deliver the order in time.

Thus, an object is not, but plays a role of process, product, resource or external effect at a particular stage of its lifecycle. An "object role" defines the circumstantial use an object. The roles can be process, product, resource or external effect.

3.3 Objects Nature

The objects cannot be classified by roles (they are circumstantial). They will be classifed by nature.

We will consider five objects nature:

- Material (object that can have a concrete form);
- Organizational;
- Temporal (object that can play a process role);
- Software (including the generated documents);
- Energetic.

"Object nature" is a concept linked to intrinsic parameters of the object. The nature can be temporal, material, software, organisational or energetic.

To say that an object is material will not implicate that this object physically exists. Only at the end of the processes (design, manufacturing) will the material product be created. For example, a car is material object (its main function "move people and objects" implies that this object is material). Different representations (often of software nature) will help to define the object before it becomes concrete.

3.4 Objects Structure

The objects structures could be mainly considered as the decomposition of an object into sub-objects. The main classes are thus *object* and *assembly* (used to define decompositions).

Nevertheless, these two classes are not sufficient. To take into account the sequence of temporal objects, the class *next* is used.

3.5 Functions of an Enterprise Object

The functions of an object are independent of the roles. The functions describe the behavior of the object when it is used (the object has a resource role).

The functions will be linked directly to the object, not to their roles.

3.6 Behavior of an Enterprise Object

The behavior management is an originality of the FBS-PPRE model. The Fig. 2 presents a graphical representation aiming at making this management more explicit.

In order to simplify the script, an "object playing a role of process" will be replaced by "process element" and the script simplifications will be the same for the products, the resources and the external effects.

The process element (in the center of the representation) plays a major role in the FBS-PPRE model:

- It links the different objects playing a role in the activity. It helps at defining the context;
- It also helps at managing the behavior of the product, of the resources and of the external effects.

The states are representative of the structure changes. They are the inputs and outputs of the process element. They represent the discontinuous behavior of the objects.

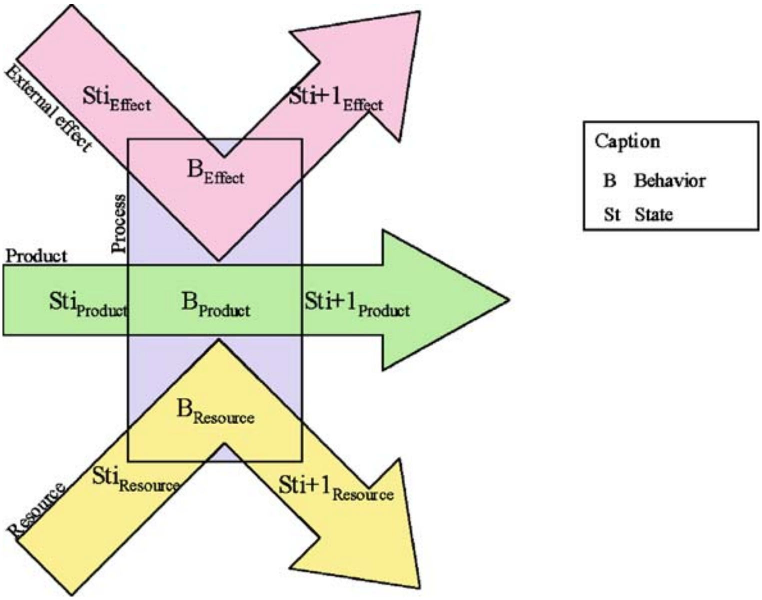

Fig. 2 FBS-PPRE behavior management

3.7 UML Class Diagram of the FBS-PPRE Model

Simplified UML Class Diagram of an Object

The different objects share the same UML class diagram tough they can play different roles and they can have different natures (cf. Fig. 3). It avoids any objects conversion from one role to one another.

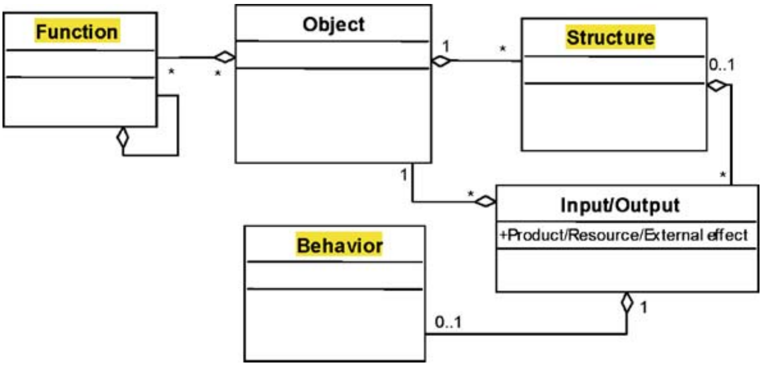

Fig. 3 Simplified UML class diagram of an object

Each object is represented using the usual views of the FBS approach: the *function*, the *behavior*, and the *structural* views.

As previously mentioned, the *behavior* is not directly linked to the *object*: the link is made through the *input/output* class. This class is dedicated to associate a temporal object (which could have a process role) to other objects (having a role of product, resource or external effect). The behavior of an object is thus relative to a particular process object: the objects can have as many behaviors as links to temporal objects.

UML Class Diagram of the Structural View

The Fig. 4 presents the UML class diagram of the structural view.

The main classes of the structural model are *structure* and *assembly*: an object is composed of sub-objects, which could also be composed of sub-objects.

The usual assembly types are *AND, OR, XOR*. For the temporal objects is made the distinction between the *synchronous AND* and the *asynchronous AND* (in the same way the *synchronous OR* and the *asynchronous OR*).

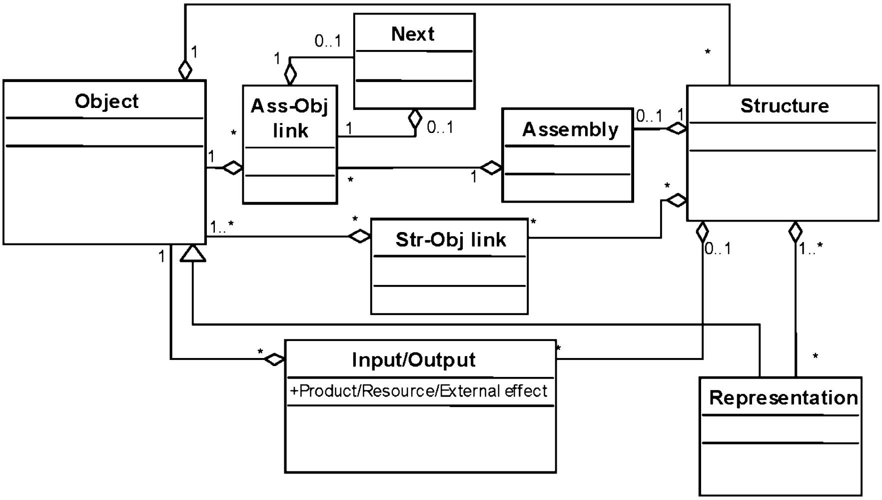

Fig. 4 UML class diagram of the structural view

The *ass-obj class* is dedicated to the linkage of an *object* to an *assembly*. It includes the cardinality of the element in the *assembly*. The class called *next* enables the modeling of temporal objects sequences.

The *str-obj link* class is used to define transversal links between objects included or not in the considered structure (the structure would be just a hierarchical tree if only the *assembly* and *ass-obj link* classes were used): it enables the modeling of mechanical links, of electrical links, of interactions between activities of a temporal object, etc. It could also be useful to define variants of an object.

The *representation* class enables the definition of particular views of an object structure. A representation is a particular type of object.

When a representation is modified, it will influence the knowledge related to the parent object. For example, the CAD file of a part increase the knowledge related to the part. As a consequence, a process related to a representation is a subprocess of a process related to the parent part.

UML Class Diagram of the Functional View

The Fig. 5 presents the UML class diagram of the structural view of an object.

The main class of the functional view is the *function* class: an object has functions that can be split in sub-functions.

The *feature* class is linked to the *structure*. In fact, a part can be designed using predefined *features* that have the requested *functions*. A feature includes a set of *solution patterns* (geometric shapes, manufacturing process, etc.).

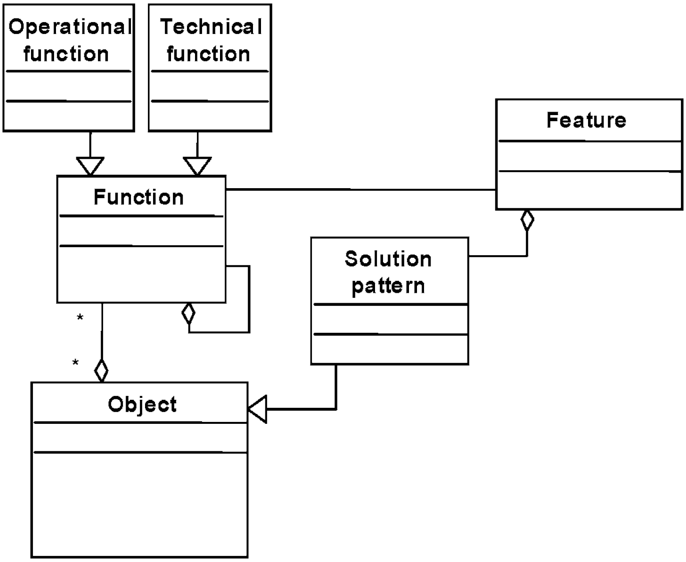

Fig. 5 UML class diagram of the functional view

UML Class Diagram of the Behavioral View

The Fig. 6 presents the class diagram of the behavioral view.

The behavior is contextual: an object behavior is always linked to a process element, thus improving the context definition. The class called *Input/Output* is used to link the object to its *behavior* and to the *structure* of a temporal element.

The *expected* or *real behaviors* include *input* and *output states,* a *status* (under process, completed, cancelled, etc.), a *shutter release* (describing the requested conditions to begin the activity) and *behavior laws* representing the continuous part of the behavior.

The *states* are inputs and outputs of a process element. The states are instant views of the structure: a state can refer to a particular *representation* of the structure (for example the position of the arms of a robot), but it can also refer to different versions of the *structure* (for example an arm of the robot can be replaced by another one with different properties).

The *performance indicators* are defined in a simple way as a comparison between the *real behavior* and the *expected behavior.*

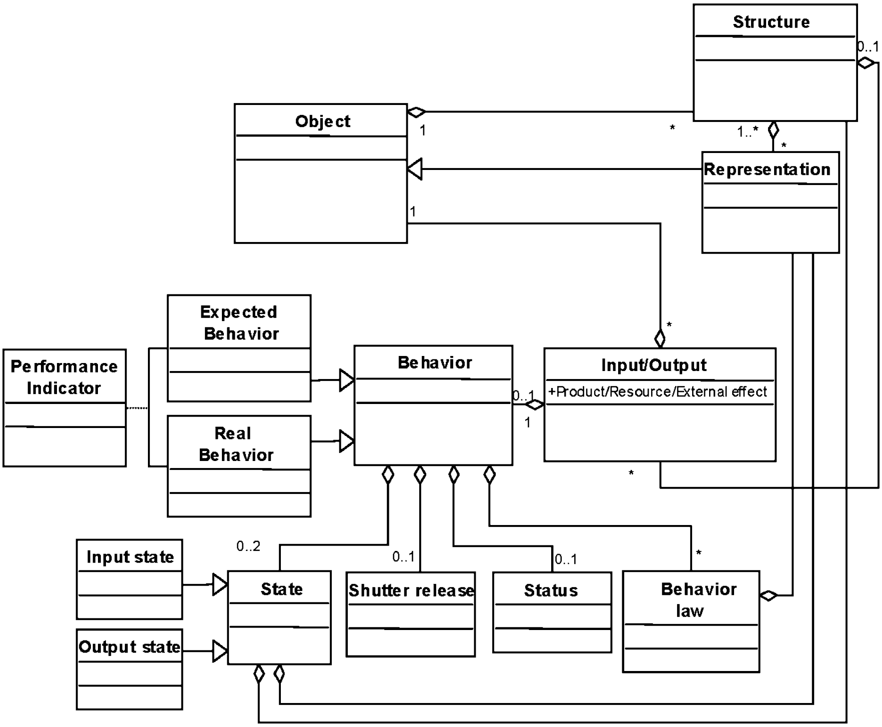

Fig. 6 UML class diagram of the behavioral view

The model includes also the *external effects*. They are linked to the process element using the *Input/Output* class. They have a real influence on the behaviors. In fact a behavior is always the result of a particular context.

UML Class Diagram of the FBS-PPRE Model

The Fig. 7 presents the integration of the different partial view already described: that is the complete class diagram of the FBS-PPRE model.

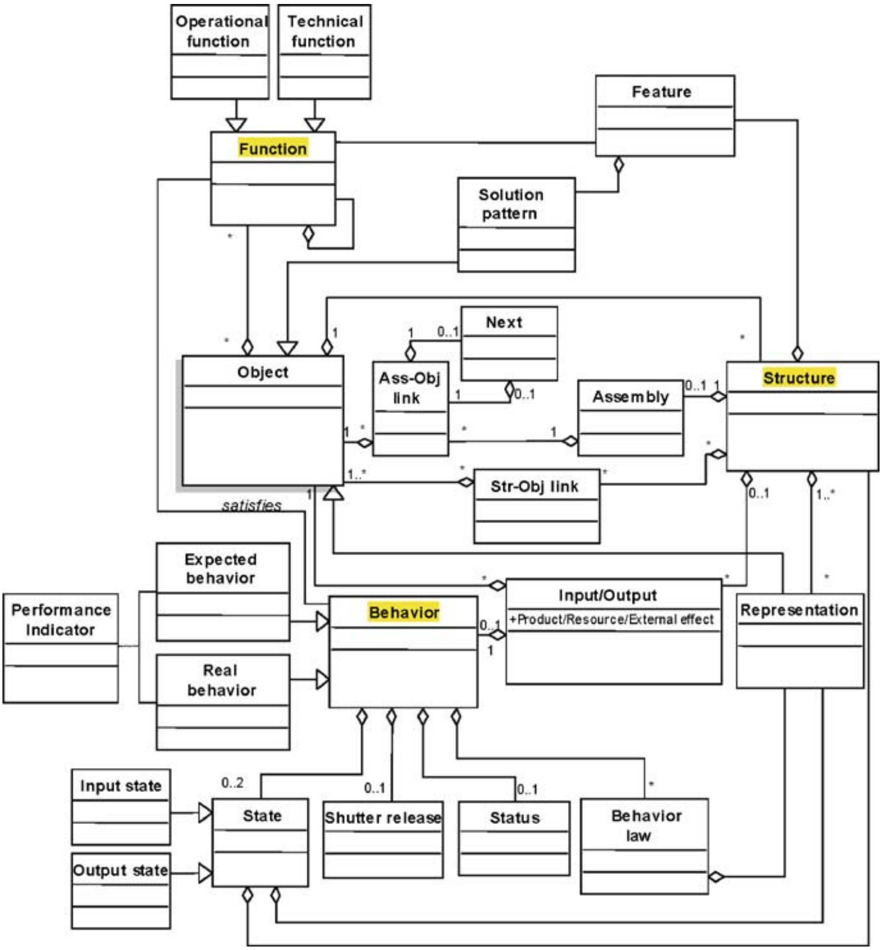

Fig. 7 UML class diagram of the FBS-PPRE model

4 Use of the FBS-PPRE Model

We will now present FBS-PPRE instantiation of industrial examples.

FBS-PPRE modeling should be considered as a knowledge-structuring tool. It is compatible with different knowledge management methodologies: the high completeness of FBS-PPRE offers a wide-open connectivity and adaptability to particular needs.

4.1 FBS-PPRE Model Instantiation Examples

The scriptural conventions have to be first defined. The representation of the five objects natures is proposed in Fig. 8. Objects can be refined in sub-objects; the *decomposition* operator (cf. Fig. 9) realizes the link between levels.

The *representation* operator (cf. Fig. 9) realizes the link between an object and its representations (CAD files, spreadsheets files, etc.). The roles are related to a temporal object (cf. Fig. 10). The discontinuous behaviors are represented trough their states, status and transitions (cf. Fig. 11).

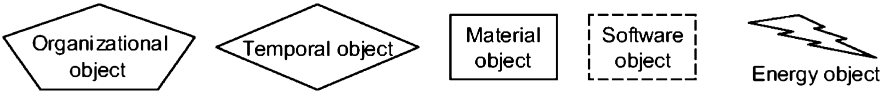

Fig. 8 Representation of the objects nature

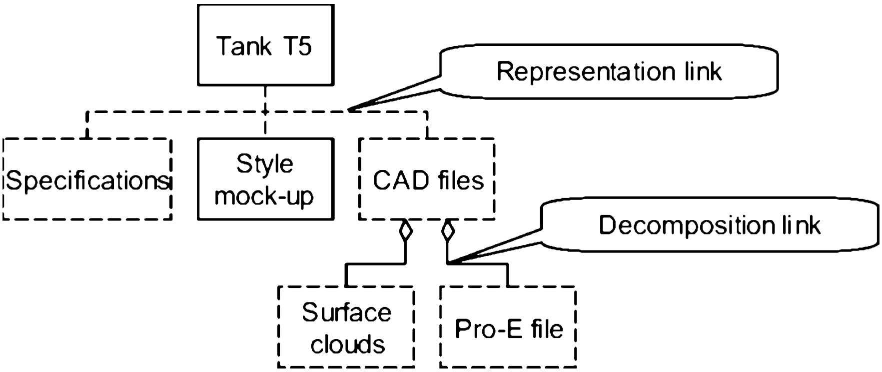

Fig. 9 Representation of the structural view

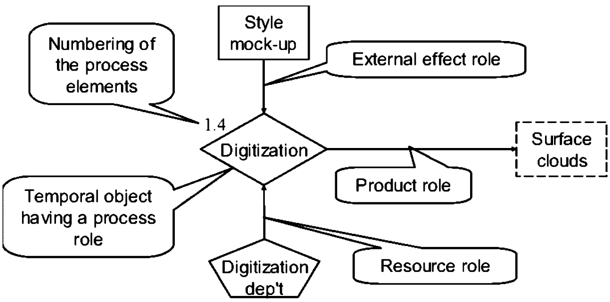

Fig. 10 Representation of objects roles

The representation of functions and behavior rules is proposed in Fig. 12. As commented in Fig. 12, expected and realized behavior rules and laws are represented by frames. The Fig. 13 presents the representation of the links between temporal objects.

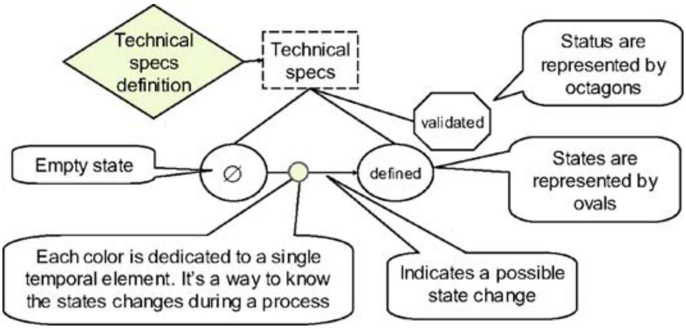

Fig. 11 Representation of discontinuous behaviors

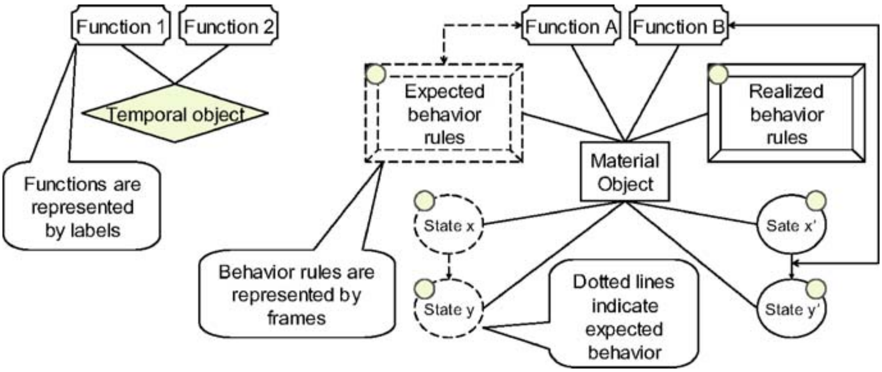

Fig. 12 Representation of functions and behaviors

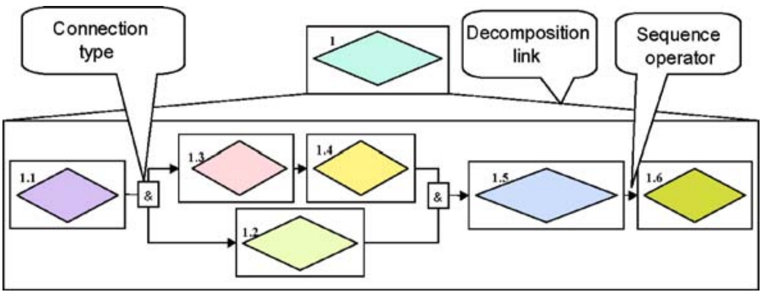

Fig. 13 Representation of the links between temporal objects

The FBS-PPRE representation is now defined. We will propose hereafter instantiations of the model trough the study of industrial examples.

4.2 Case Study Number 1: Design of a Motorcycle Tank

The tank is a part on the top of the motorcycle. Its design is constrained by different parameters:

- Its shape needs to be perfectly complementary to the other parts in order to maximize its capacity;
- The top part of the tank remains visible (the part is just painted). The shape needs to looks really nice and to be compatible with the ergonomic constraints (it influences the driver position);
- The legislation affects also the design.

In order to validate the ergonomic and style constraints, the reverse engineering process is selected to realize the top part of the tank shape. Nevertheless, the bottom part of the shape can be designed directly using a CAD tools.

The amount of production is small. For this reason, a roto-molding process is used. This manufacturing process will add specific constraints.

A FBS-PPRE instantiation example of the tank design is proposed in Fig. 14 and Fig. 15.

In order to improve the legibility of the representation, the process elements sequence (cf. Fig. 14) is not represented on the diagram including the product elements, the resources and the external effects (cf. Fig. 15).

In fact, the completeness of the model is very high and it is thus necessary to extract different partial representations to avoid too much links crosses.

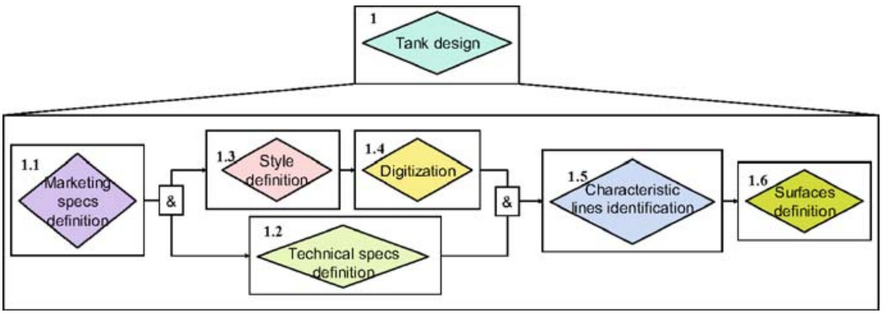

Fig. 14 Activities of the tank design

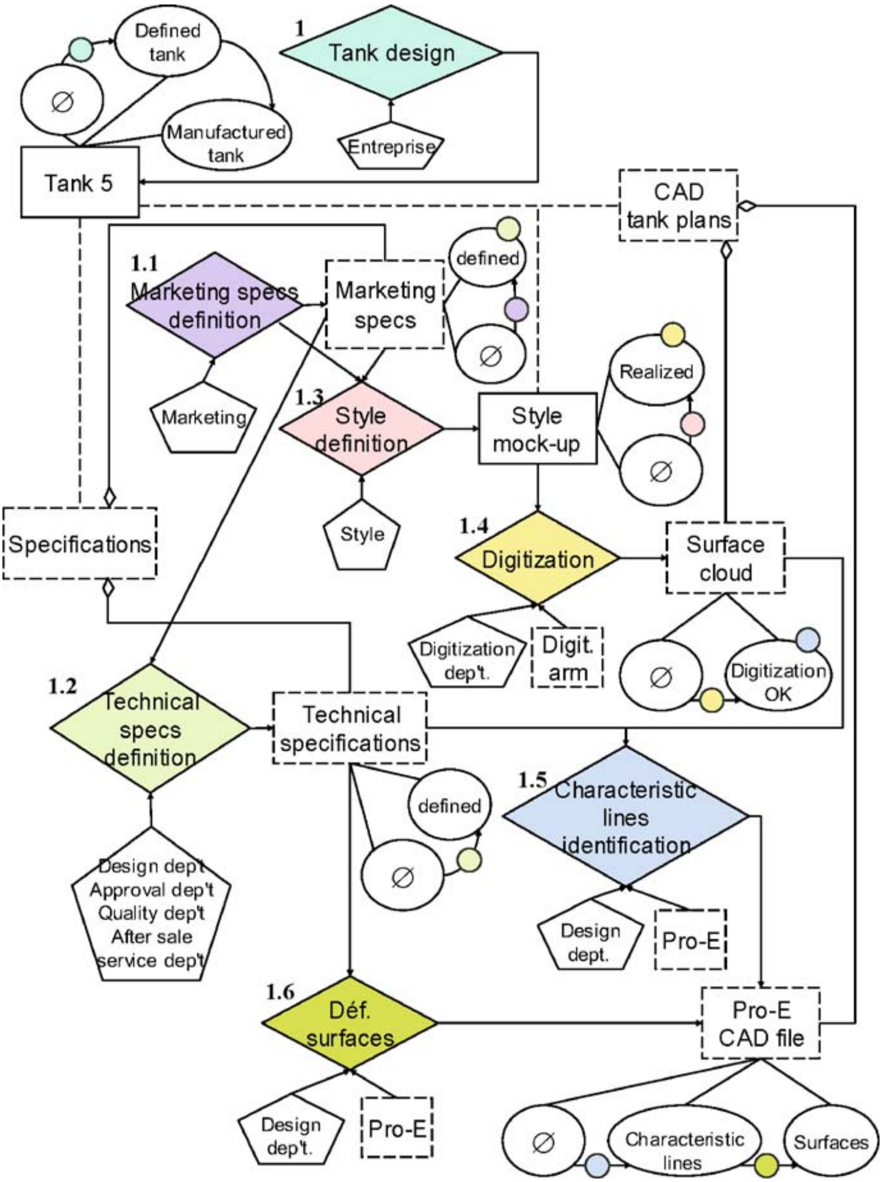

Fig. 15 FBS-PPRE representation of the tank design

The Fig. 15 highlights the interest of the representation class of the FBS-PPRE model (cf. paragraph after Fig. 4):

- Top-level processes interact with the product (in this example, the tank) and its states;
- Sub-level processes enable the definition of product representations. The products of these processes (the outputs) are representations (physical mock-up, CAD file, etc.) but not the product itself.

The *representation* links indicate that the knowledge included in the various documents describes particular views of the tank.

An interesting point is that a partial uncoupling between levels and activities is possible: the users of a particular representation (consider for example the activity of digitization) do not need to have in mind all the knowledge related to the tank.

4.3 Case Study Number 2: Definition of the Tank Specifications

This case study will present the use of the functional and behavioral views of the FBS-PPRE model.

In the first case study, the specifications of the tank were just composed of two documents: the technical specifications and the marketing specifications.

If this approach remains compatible with the FBS-PPRE model, it is not optimal. In this case study, the functional views and the expected behaviors of the model will be used. This other modeling option has the advantage of presenting the specifications elements in the object lifecycle i. e. in their context.

The example studied here is not exhaustive (very few functions of the tank are considered), the objective is just to present the transcription methodology from specifications to functional and behavioral entities.

The Fig. 16 presents the simplified transcription result of the tank specifications.

The function *to contain fuel* is considered. It can be split in *vehicle autonomy* and *standard conformity*:

- An expected behavior linked to *standard conformity* is the *leak flow* when the tank is full and turned over: for this reason, it is quite logical to link the *standard conformity* function to the *leak flow* expected behavior. This behavior is defined relatively to the *homologation* process and constrained by the *NF standard*. This process also indicates the tank state during the *homologation* process: *full and turned over*.
- The *vehicle autonomy* function results from a wide range of parameters. Nevertheless it can be considered as resulting from the *vehicle consumption* and from the *tank capacity*. The consumption will be evaluated in order to calculate the expected tank capacity:
  - The *consumption* is linked to the *motorcycle* object. At this stage of the design process, a material representation of the motorcycle already exists: the *rolling demonstrator*. It is a prototype using the majority of the mechanical parts of the final motorcycle. Nevertheless, the shapes of the aesthetic parts are not finalized at this stage.

– The demonstrator consumption can be measured using the standards conditions. The real behavior of the demonstrator (linked to the *consumption measuring* process) is spilt in three representations elements: the *average consumption*, the *90 km/h consumption*, the *120 km/h consumption.*
– The average consumption will be used to calculate the tank capacity (it is a representation of one of the tank structural view). The *average consumption* and the expected *autonomy* are constraining the *capacity calculation* process.

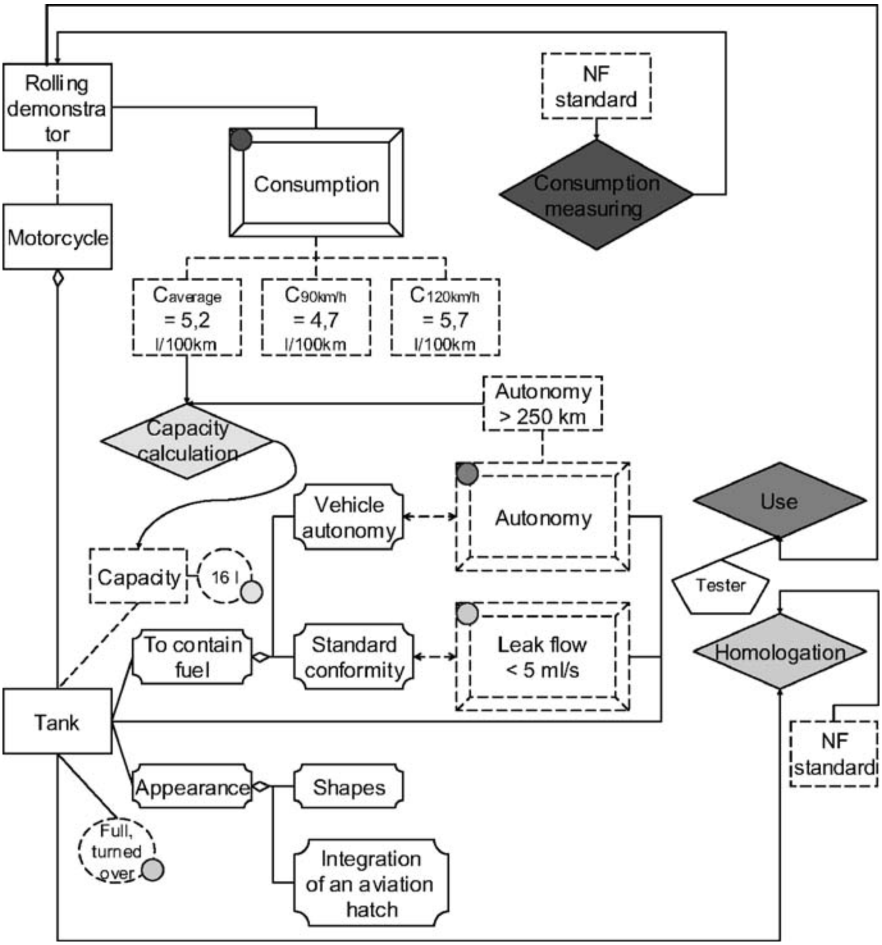

Fig. 16 FBS-PPRE transcription of the tank specifications

5 Conclusion and Prospects

The study of the products lifecycles is one of the main industrial issues. It highlights the role of knowledge capitalization and management.

The significance attached to the processes, to their aim and to their modeling enables the identification of the needs and of the knowledge flows.

The development of the content implies a real integration: the main difficulty remains the representation of the knowledge in order to insure its interpretation, its sharing and its keeping.

The FBS-PPRE model allows advances principally in three domains: the completeness of the modeling, the management of the dynamic of the objects, the conceptual unification.

As regards completeness, the model offers a wider view than the usual approaches. Each object having an influence on the enterprise processes (defined as a temporal, spatial and hierarchical organization of activities) is taken into account trough its role of product (the object is then is the result of the process), of resource (the object is then contributing to the process without being its purpose) or of external effect (the object is then acting as a constraint – positive or not – on the process). Furthermore, each object is modeled with the same views: the functional, the behavioral and the structural views.

The process elements are playing a structural role: they link the products, the resources and the external effects. Due to its definition, the behavior of an object is always linked to a process element: it enables a fine modeling of the dynamic transformation of the modeled elements. In fact, different behaviors can be taken into account: the model makes it possible to characterize the behavior of an object during its use process (the object has then a role of resource), but it also makes it possible to keep the evolution of an object during a process of design, of realization, of dismantling, of recycling, etc (the object has then a role of product). Moreover, this modeling of the dynamic applies whatever the nature of the object: it also makes it possible to manage natively the transformation of the temporal objects.

This strongly increased completeness, in particular with the management of the dynamic of all the objects, could have been reached by an increasing the complexity of the model. That is not the case: due to the generic views of the FBS-PPRE modeling, the enterprise objects can be described according to the same formalism independently of their circumstantial roles of process, of product, of resource, or of external effect.

Furthermore, this conceptual unification is not challenged by the existence of objects of various natures (temporal, material, software, organizational or energy). The model is thus very compact and easier to apprehend: its implementation and its maintenance will also be easier.

These conceptual elements can thus constitute an essential support for the representation of knowledge.

The adoption and the deployment of the FBS-PPRE model can contribute to the analysis, the specification and the follow-up of the enterprise processes. They can lie with an ISO 9001 quality certification process: the objectives of the new standard are indeed in perfect adequacy with FBS-PPRE.

To use this model in the company, a reliable and effective information system should be implemented. A demonstrator already allowed checking the interest of the handled concepts, but it remains inadequate in an industrial context.

The model needs to be validated in large companies in the future. In particular, the companies' profits have to be evaluated. The human and economic parameters as well as the deadlines are generally the limiting factors in this type of projects.

Because of its good completeness, the model can be used as a support for more specific methodologies. One can for example think of:

- The automated reorganization of process elements in order to optimize their execution;
- The extraction of reusable knowledge from the capitalized knowledge thanks to dedicated processes;
- The definition of particular views;
- The specification and the instantiation of specific objects;
- The definition of performance indicators based on the expected and realized behaviors of the FBS-PPRE model.

The avenues worth exploring to this work are thus diversified, and fit in the current scientific trends.

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