A UML Profile for Enterprise Ontology

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Abstract. Enterprise Ontology (EO) is a new subject that applies the Ψ-theory to the development and conception of social information systems. This theory, proposed by Jan Dietz, is based on the Language Action Perspective. In order to model an enterprise this theory presents a modelling method composed by four distinct aspect models, which use a collection of tables and diagrams to express themselves. A domain specific language was supplied for those diagrams that it is not standard or easily portable. In order to make these diagrams more useful and available this paper proposes the use of the Unified Modelling Language (UML) to represent EO most important diagrams where the EO main concepts are shown. The use of UML will bring some important benefits such as portability, interoperability, wider audience and understanding among others. In this sense a UML 2 profile has been created for representing the diagrams mentioned. An example of application of this profile is shown and an extended discussion of its creation is made. This will address the difficulties and issues found when metamodelling the solution using UML and will help to assess the feasibility of UML for this kind of problems.

1 Introduction

The Ψ-theory proposed by Jan Dietz [2] provides the foundations for designing and engineering of enterprises seen as social information systems. This theory captures the stable essence of any organization by focusing on commitments and the way people interact using language. This focus on language rather than material actions or technology comes from the Language Action Perspective view of the world (see, for example, [14]) in which it is based. The Ψ-theory comprises a modelling method composed by four distinct aspect models: the construction model, the process model, the action model and the state model. A methodology named "Design and Engineering Methodology for Organizations" (DEMO) is the basis for this modelling method [2], [3]. As many modelling methods, a few diagrams are used as a way of expression. Because these diagrams constitute the main communicational mean for representing the structure of the enterprise according to the Ψ-theory we are interested in include these diagrams together with other diagrams in information system development projects. This is not easy due to the proprietary language used by these diagrams and its lack of interoperability with other modelling languages. Also a formal verifi-

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cation is not automatically made and there are only a small number of tools to work with those diagrams. To overcome these problems we propose to use the Unified Modelling Language (UML), to express the most important diagrams of those models. UML is today a *de facto* standard widely used for modelling purposes, having numerous tools available and its use will bring us some important benefits such as:
A wider audience will be able to use and understand the diagrams.

- Diagram interoperability and inclusion in software projects
- Formal representation and automatic verification of the diagrams

In this sense this paper presents and proposes a new UML 2 profile for representing those different types of diagrams. The difficulties and issues raised in the profile creation will also be the focus of this work because they will show the feasibility and the problems of using UML for such purposes.

This paper is organised as follows: section 2 presents related work, section 3 summarizes the main concepts of Enterprise Ontology (EO), the proposed UML Enterprise Ontology profile will be shown and exemplified in section 4, section 5 will present issues and rationale related to the EO profile development and finally, conclusions will be given in section 6.

2 Related Work

We found just a small number of papers that refer to the use of UML with DEMO. In [13], Shishkov and Dietz suggest using DEMO to derive UML use cases. In this work a mapping from DEMO Business Transactions to UML Use Cases is proposed. In fact there is a general tendency to separate the use of DEMO and UML. For example, in [7] DEMO is used to model the business processes prior to information systems modelling using UML. Nevertheless, the most significant work relating UML and DEMO is [11]. In this paper instead of a direct UML representation it is proposed a language mapping between DEMO models and UML. This mapping is accomplished in three phases: first a concept mapping between both languages is made, next a notational mapping is performed and at last there is a diagram transformation. In fact, a similar approach is taken when we create the UML profiles as we will see. In UML profiles concept matching is used to find the appropriate metaclasses corresponding to the DEMO model elements, also a notational option is taken for the created stereotypes and finally some new diagrams are created for showing the new model elements. Even so according to this paper it will be necessary to have the original DEMO diagrams instead of a direct UML representation as we pretend.

Regarding UML profiles much work has been done and some references will be pointed afterwards when appropriate.

3 Enterprise Ontology

Enterprise Ontology (EO) captures the essential aspects of any organization by focusing on the ontological level of business where people interact, commit themselves and

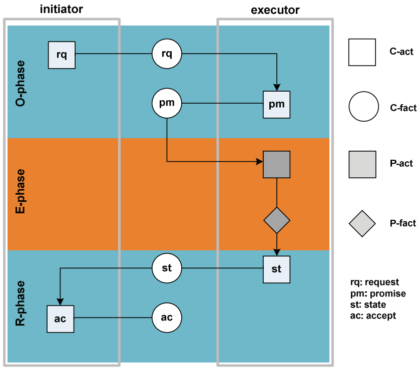


Fig. 1. The Basic Transaction Pattern (adapted from [3]).

produce results. At this level people use language acts as the driver of any business transaction or coordination acts. EO is about the construction and operation of an organization. The Ψ-theory establishes the basis and the theoretical support for EO. The Ψ-theory is composed by four axioms and one theorem. The first axiom – the Operation Axiom – presents an organization as a group of actors performing two kinds of acts: coordination acts (C-acts) and production acts (P-acts). C-acts are language acts used by actors to engage themselves in commitments and to ultimately originate the P-acts responsible for producing the effective work. The result of performing a C-act is a coordination fact (C-fact), whereas the result of performing a P-act is a production fact (P-fact) or production result. The second axiom – the Transaction Axiom – comes from the observation that P-acts and C-acts seems to occur in a universal pattern called *transaction*. This *transaction* is a key concept of the Ψ-theory and EO. The complete transaction pattern is seen as a socionomic law that underlies the conducting of any business always and everywhere. This *transaction* has its roots in the notion of conversation for action [14] and the Workflow Loop [8] both from the Language Action Perspective. In fig. 1 we depict the basic transaction pattern which has three phases: an order phase where the negotiation about the P-act to be executed takes place. In this phase two types of C-acts are usually performed: a request by the initiator actor and a promise to accomplish it by the executor actor. The next phase is the execution phase where the P-act is actually performed. Finally, the result phase ends the transaction with the performance of a C-act stating the completion of execution of the P-act by the executor actor and a C-act by the initiator actor accepting the result. The third axiom – the Composition Axiom – is concerned with the interrelation of P-facts in a production world (the P-world). In particular the enclosing relationship between transactions is analysed. Finally, the fourth axiom – the Distinction Axiom – is about the human abilities that have a significant role in performing C-acts namely the *performa*, *informa* and *forma* abilities. The *performa* ability is considered the *essential* human ability for doing business and is part of the ontological level of EO. The *Organization Theorem* completes the Ψ-theory by stating that “the organization of an enterprise is a heterogeneous system that is constituted as the layered integration of three homogeneous systems: the B-organization (from business), the I-organization (from intellect), and the D-organization (from Document)” [2, p.115].

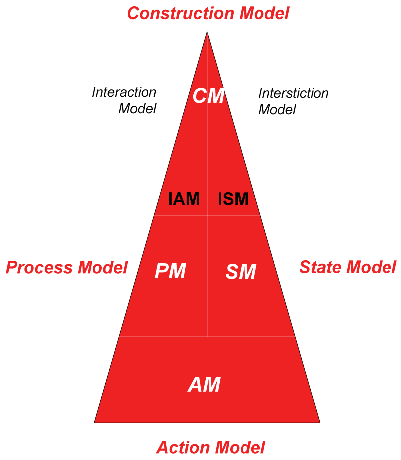


Fig. 2. The four DEMO aspect models (adapted from [2]).

For designing and engineering organizations EO is supported by the DEMO methodology. The DEMO methodology defines the required steps for that purpose and uses a modelling method composed by four distinct aspect models: the construction model, the process model, the action model and the state model that together constitutes the complete ontological knowledge of an organization (fig. 2). The construction model (CM) specifies transactions types, associated actors roles and information banks (conceptual stores of C-facts or P-facts). The CM is divided in two similar models: the *interaction model* (IAM) and the *interstiction model* (ISM) that shows us respectively the active and the passive influences between actor roles. The *process model* (PM) details the CM by showing the specific transaction patterns for each transaction type in the CM. The *action model* (AM) is the most detailed level and it specifies the action rules that serve as guidelines for the actors. The last model, the *state model* (SM) specifies the *state space* of the P-world. It includes object classes, fact types, result types and ontological coexistence rules. In general these models are expressed by different diagrams and tables. Table 1 show us the different diagrams and tables used by each of them and what they depict. As it is shown the AM doesn't use any diagram and the SM uses a very specific type of diagram that doesn't presents directly the main concepts of EO, namely the transaction types, and we decided not to represent them using UML. Thus, in this work we will be interested in provide UML diagrams to mirror the following diagrams: ATD, PSD and ABD.

4 The Enterprise Ontology Profile

In figure 3 a part of the metamodel for the UML Profile created for EO is presented. In this metamodel it is shown the equivalent UML elements for the DEMO Actor Transaction Diagram (ATD) elements. The corresponding stereotypes and constraints for this profile are detailed in table 2. Discussion of the creation of the complete profile is made in the next section.

Table 1. DEMO aspect models.

Model	Expressed by	Typical contents
Interaction	Actor Transaction Diagram (ATD)	Actor roles, transaction types and their connecting links
	Transactions Result Table (TRT)	Transaction and result types
Process	Process Structure Diagram (PSD)	C-act/C-result, P-act/P-result, causal and conditional links and responsibility areas of actor roles
	Information Use Table (IUT)	Process steps and object class, fact types or result types
Action	Action Rule Specifications (ARS)	Action rules
State	Object Fact Diagram (OFD)	Object classes, fact types, result types and existential laws
	Object Property List (OPL)	Property types, object classes, scales
Interstriction	Actor Bank Diagram (ABD)	Information banks, actor roles and information links
	Bank Contents Table (BCT)	Object classes, fact types, result types and production banks

Table 2. EO stereotype definitions part 1 – ATD elements.

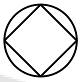
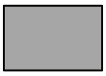
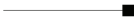
Name	**TransactionType**	
Extended Class	**Class**	**Notation**
Description	Represents the transaction type concept.	
Constraints	------	
Notes	The name of the transaction should be a capital T followed by the transaction number (ex: T02)	
Name	**Actor Role**	
Extended Class	**Class**	
Description	Represents the elementary actor role concept.	
Constraints	------	
Notes	No special notation. Usually it is shown as a rectangle with the actor role name inside. The actor role name should be a capital A followed by the actor role number (ex. A02)	
Name	**CompositeActorRole**	
Base Class	**ActorRole**	**Notation**
Description	Represents the composite actor role concept**.**	 As a class but filled using a gray colour
Constraints	------	
Notes	The actor role name should be the capitals CA followed by the actor role number (ex. CA03)	
Name	**ActorRoleLink**	
Extended Class	**Association**	
Description	A relationship between an actor role and a transaction type	
Constraints	1) It is a binary association 2) Must connect a TransactionType and an ActorRole element 3) It is an abstract metaclasse	
Name	**InitiatorLink**	
Base Class	**Actor RoleLink**	
Description	A special kind of an ActorRoleLink that connects an ActorRole and a TransactionType where the ActorRole plays the role of the initiator of the transaction	
Constraints	------	
Notes	Usually no adornments are shown. There is an implicit navigation from the actor role to the transaction.	

Table 2. EO stereotype definitions part 1 – ATD elements(cont).

Name	**ExecutorLink**	
Base Class	**Actor RoleLink**	**Notation**
Description	A special kind of an ActorRoleLink that connects an ActorRole and a TransactionType where the ActorRole plays the role of the executor of the transaction	 The line end with the black square must be connected to the actor role
Constrains	------	
Notes	There is an implicit navigation from the transaction to the actor role.	
Name	**Organization**	
Extended Class	**Package**	**Notation**
Description	Represents a group of actor roles and transaction types which belong and take place inside an organization	Organization Name
Constrains	------	
Notes	The name of the package is placed upon its upper boundary line	

A special UML diagram – the AT diagram – one of diagrams which we propose for this profile is a special case of a UML Class diagram. This diagram is used for showing actor roles and transaction types and the links between them and mimics the original DEMO ATD. In figure 4 an example of an ATD is given and in figure 5 the same diagram is reproduced with the EO profile applied to it.

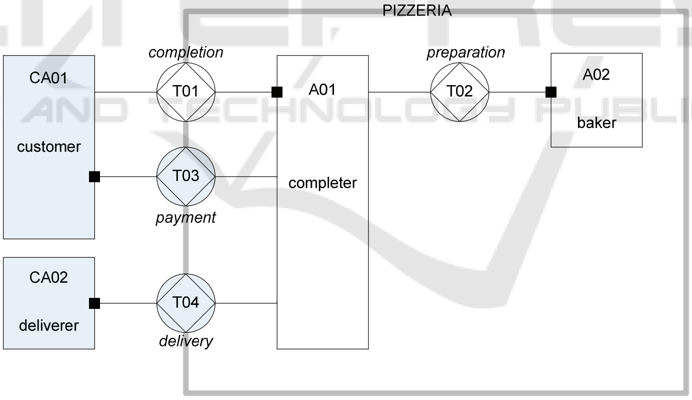


Fig. 3. Example of the DEMO ATD of a pizzeria (adapted from [2]).

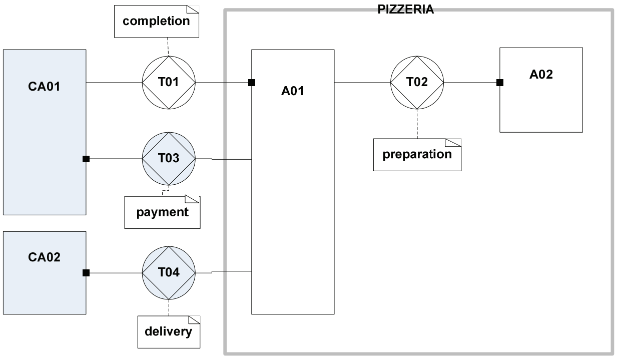


Fig. 4. An UML AT Diagram applied to the pizzeria example using the EO Profile.

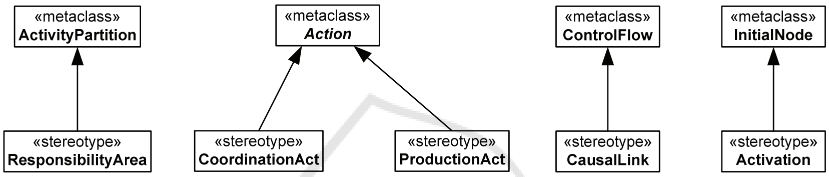


Fig. 5. EO profile metamodel part 2 - UML representation of PSD elements.

In figure 6 it is shown the second part of the EO profile which includes the equivalent UML elements for the DEMO Process Structure Diagram (PSD) elements. The corresponding stereotypes and constraints for this profile are detailed in table 3.

Table 3. EO Profile stereotype definitions part 2 – PSD elements.

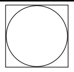
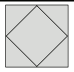
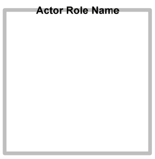
Name	**CoordinationAct**	
Extended Class	**Action**	**Notation**
Description	Represents the C-act concept.	
Constraints	------	
Notes	Just one symbol meaning the combination of a C-act with a C-result	
Name	**ProductionAct**	
Extended Class	**Action**	**Notation**
Description	Represents the P-act concept.	
Constraints	------	
Notes	Just one symbol meaning the combination of a P-act with a P-result	
Name	**ResponsibilityArea**	
Extended Class	**ActivityPartition**	**Notation**
Description	Represents the responsibility area concept	
Constraints	isDimension = true	
Notes	It will not be possible to have nesting of actor roles because each actor role establishes a unique dimension.	

Table 3. EO Profile stereotype definitions part 2 – PSD elements(cont).

Name	**CausalLink**
Extended Class	**ControlFlow**
Description	A link used to show the control flow between C-act and P-acts.
Constraints	------
Notes	It is equivalent of the causal link
Name	**Activation**
Extended Class	**InitialNode**
Description	It represents the start of a process. It can be placed inside a Responsibility Area meaning self activation or outside meaning external activation.
Constraints	------
Notes	

As in the case of the AT Diagram a new UML diagram – the Process Structure Diagram - was created to show DEMO PSD using UML. This diagram is a special case of a UML Activity Diagram. Unfortunately UML diagrams are not part of the main specification of UML, they are not model elements, therefore we have to introduce these diagrams informally and it will not be possible to formalize some aspects of the diagrams, for example positioning rules for the included elements. An example of a PSD is given in figure 7. In figure 8 it is shown a UML PS diagram with the EO Profile applied.

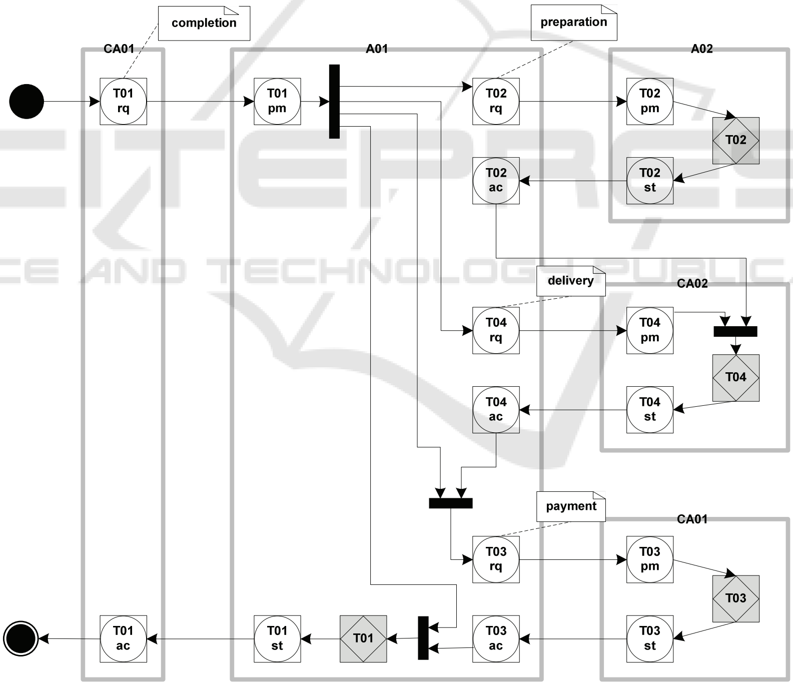


Fig. 6. An UML PS Diagram applied to the pizzeria example using the EO Profile.

Figure 9 shows the third and last part of the EO profile which includes the equivalent UML elements for the DEMO Actor Bank Diagram (ABD) elements. The corresponding stereotypes and constraints for this profile are detailed in table 4. Also a new UML diagram – the Actor Bank Diagram - is proposed for representing the DEMO ABD. This diagram is also a special case of a UML Class Diagram. This diagram is very similar to the ATD.

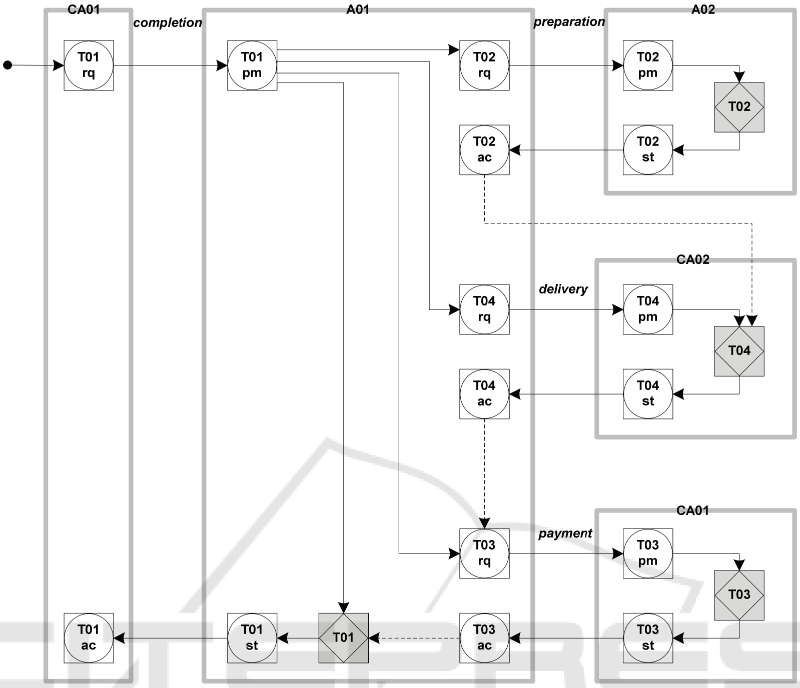


Fig. 7. Example of the DEMO PSD of a pizzeria (adapted from [2]).

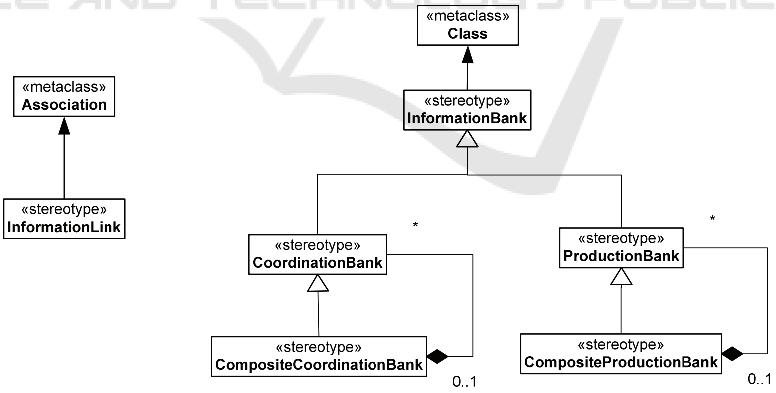

«metaclass» Class
«stereotype» InformationBank
«metaclass» Association
«stereotype» InformationLink
«stereotype» CoordinationBank
*
«stereotype» CompositeCoordinationBank
0..1
«stereotype» ProductionBank
*
«stereotype» CompositeProductionBank
0..1

Fig. 8. EO profile metamodel part 3 - UML representation of ABD elements.

Table 4. EO Profile stereotype definitions part 3 – ABD elements.

Name	**InformationBank**	
Extended Class	**Class**	
Description	A production or a coordination bank.	
Constraints	------	
Notes		
Name	**CoordinationBank**	
Base Class	**InformationBank**	**Notation**
Description	Represents a coordination bank	○
Constraints	------	
Notes	The coordination bank name should be the capitals CB followed by the bank number (ex. CB02)	
Name	**CompositeCoordinationBank**	
Base Class	**CoordinationBank**	**Notation**
Description	Represents a composite coordination bank	●
Constraints	------	
Notes	The composite coordination bank name should be the capitals CCB followed by the bank number (ex. CCB02)	
Name	**ProductionBank**	
Base Class	**InformationBank**	**Notation**
Description	Represents a production bank	◇
Constraints	------	
Notes	The production bank name should be the capitals PB followed by the bank number (ex. PB03)	
Name	**CompositeProductionBank**	
Base Class	**ProductionBank**	**Notation**
Description	Represents a composite production bank	◆
Constraints	------	
Notes	The composite production bank name should be the capitals CPB followed by the bank number (ex. CPB04)	
Name	**InformationLink**	
Extended Class	**Association**	**Notation**
Description	A connection relating actor roles and information banks	----------------------
Constraints	1) It is a binary association 2) Must connect an InformationBank and an ActorRole	
Notes		

5 EO Profile Creation

If we want to have the benefits of using UML tools such as model interchange, model validation and model storage it is necessary to create UML Profiles instead of a complete metamodel for representing the DEMO diagrams. Thus, and in order to build these profiles we should follow some guidelines (see for example [4]). In a general and simple view these guidelines recommend to create first a domain metamodel, to choose from this metamodel the relevant elements, to extend the appropriate UML metamodel elements with some of those elements and to define additional constraints and tagged values (see [12]). In our case we found as not necessary to create the domain metamodel because we already have the domain elements which correspond to the DEMO diagram elements. In spite of skipping this step and although simple the remaining process it has many issues, difficulties and compromises specially because we are metamodeling non object-oriented theories. In the next sections some of the issues and problems found for each DEMO diagram will be reported. It should be also noted that the EO UML profile that was created uses version 2.1.2 of the UML superstructure and infrastructure specifications [9], [10].

5.1 Development Issues - AT Diagram

The ATD diagram shows mainly actor roles, transaction types and links connecting them. For transaction types we don't have any similar UML model element and in this situation it is usual to extend the metaclass 'class' as a representation of a concept. Thus, the initiator or executor links between transaction types and actor roles should be expressed using the association metaclass. This is the most powerful relationship between model elements that is used to connect classifiers. The problem is the representation of actor roles. In UML we have an actor element that matches the concept of an actor role, it is a classifier and support associations as well but this element has limited capabilities compared to classes. So, the best solution was to express actor roles using classes as well. This will allow a more powerful expression of actor roles, it will permit to create composite actor roles based on elementary actor roles using the inheritance and composition concepts of object-orientation and it will have some extra benefits when creating the EO profile elements for the PSD DEMO diagram. The last ATD element that we need to represent is the boundary of an organization. This is a grouping element that joins transactions, actor roles and links belonging to an organization, but some transactions with external actor roles are not placed completely inside the organization boundary but are seen as belonging to the boundary itself. This cannot be represented used the common UML grouping element, the package. Elements of a package belong to the package and not to its boundary. Other UML grouping elements such as the activity partition or the subject (of a use case) are not suited for this purpose, they can only surround very specific UML model elements and the related concepts don't match with our goals. So, we adopted as a solution to use the package extension but to limit the elements of the organization package for being transaction types where all the actors are organizational actor roles and all the actor roles belong to the organization. A possibility is to show the boundary transaction types using a second package which includes only boundary transactions.

Regarding the notation we choose to make the UML Profile elements close to the original notation used in the DEMO diagrams. UML allows some flexibility in the notation and this possibility to make it close to the original or to the traditional UML as identified in [1] is used by our solution.

5.2 Development Issues - PS Diagram

The DEMO PSD shows two combined symbols for correspondingly C-acts/C-results and P-acts/P-results. The links between these symbols are made using causal and conditional links. Also external and self-activation lines are used to represent the start of the depicted processes. A last element in these diagrams is a grouping element defining the responsibility area of an actor role. Giving the "business process" nature of these kinds of diagrams it would be most useful to represent them using an UML activity like diagram. For this purpose their elements should be equivalent to the typical UML activity elements. In fact this is possible because the main elements, C-acts/C-results and P-acts/P-results, can be represented by extending the UML action element. If we consider just the C-acts and P-acts, they are both some kind of action and they are suited to be represented as actions. We should make implicit the produced C-results and P-results; it will be possible to see them as the output of the corresponding actions. Regarding the notation we will make it close to the original PSD elements. We choose to represent C-acts and P-acts using the combined symbol and thus making explicit the associated C-results and P-results. The C-act/C-result symbol is depicted as a single UML element hiding the combined nature of the symbol. This symbol results from joining a circle – a C-fact (or C-result) type - and a square – a C-act type - but this combination cannot be made using UML. There is no possibility to combine two different UML elements without creating a new element with no connection to the original symbols. The same applies to the P-act/P-result symbol which uses a square for the P-act and a diamond for the P-fact (or P-result) type that it is represented as a single symbol. UML doesn't allow us to combine model elements but we took advantage of the flexibility in the notation. Regarding the causal link it is in fact a kind of a UML control flow causing the flow to jump from one act to the next. In the case of the conditional link there is no equivalent UML element but we can use some of the UML elements to produce the same effect as the conditional link. In the case of the conditional link appear at the end of a conditional branch it can be replaced by a decision node at the beginning of the branch and a merge node at the end. In case of appearing at the end of a concurrent branch it can be replaced by a fork at the beginning and a join at the end. This last case is illustrated in fig. 8. In the PSD also responsibility areas are used to delimit a group of acts performed by an actor role. In this case an extension of activity partition is suited for this goal and can play the same role. This solution is optimal because we choose before to use UML extended class elements for actor roles. Thus, actor roles will be the responsible agents for the corresponding C-acts or P-acts. At last for activation lines UML also provide model elements, we can use the *Initial node* of the activity diagram connected to a C-act using a control flow to express the starting point of a process. If this Initial node lies inside a responsibility area where it is connected to a C-act it means a self activation, otherwise if it lies outside the responsibility area it means an external activation. Just a final remark to point the necessity of including a final flow node to indicate the end of a process. There is no similar model element in the original PSD.

5.3 Development Issues - AB Diagram

The last part of the UML profile concerns the creation of the corresponding UML elements for the DEMO ABD. This diagram is similar to the PSD and it can use most of the elements defined before. We just need to express as well elementary and composite production and coordination banks and information links. These banks are just a kind of databases and can be shown using an extension of the UML class. Also we can use the object oriented mechanisms to differentiate from elementary and composite production and coordination banks. The ABD uses also a combined symbol for a production and coordination bank that refers to an information bank. An information as a general kind of bank can be expressed as a base class and we can use inheritance to derive the production and coordination banks. We lose the combined nature but we gain in expressivity. Finally the information link is naturally expressed as an extension of an association because it relates stereotypes of classes.

Table 5. Summary of identified UML issues.

UML issue	Comments
A diagram is not an UML metamodel element	It is not possible to adequately formalize relationships between diagrams and model elements because the diagrams are not UML elements
UML metamodel grouping elements with limited options	The most important grouping UML element - the package – provides a special kind of grouping that doesn't allow representing elements that belong to two packages simultaneously; this is the case of boundary elements such as some of the transaction types in AT diagrams. Other UML grouping elements such as the Activity Partition and the Subject have limited application given the restrictions in the elements they may contain.
UML metamodel elements usually have hidden aspects	Some simple UML elements cannot be used to represent similar concepts because they cannot be freely associated with other elements. This is hidden and it is a consequence of the rigidity of the UML metamodel when defining these elements. In the case of the *actor* element its limited capabilities make it preferable to use classes to represent actor roles although an *actor* was a better matching concept.
UML metamodel elements without combinations among them	It is not possible to combine different UML elements in one joint element preserving the original meaning of the individual elements. The example was the C-act/C-result and the production bank/coordination bank elements which had unique symbols for the combined element.

6 Conclusions and Future Work

In this paper a UML profile for Enterprise Ontology was introduced. This profile brings important benefits for the underlying DEMO methodology such as:

- Possibility to communicate the diagrams to information system and software development teams and to include them with other diagrams in the same projects
- Interoperability of the diagrams with other model tools
- Consistency, verifiability and formalization of the diagrams

Concerning the profile creation this paper has raised some issues that are resumed in table 5. It should be noted as well that the stereotypes created in this profile introduced a reduced number of constraints in order to have enough freedom when using UML. Some additional constraints can be added if there is the necessity of a more formal and rigid expression of the produced diagrams.

This work is part of a research project that has as a goal to create a unified and fundamental theory for software development that integrates some relevant concepts of three different socio-technical theories, namely Organizational Semiotics [6], the

Theory of Organized Activity [5] and the Language Action Perspective represented in this paper by the Ψ-theory and the DEMO methodology. Concerning the UML profile development issues raised in this paper, they complement another group of issues identified in [1]. As a future work a UML profile of the new theory will be proposed that will share some of the elements and concepts presented in this paper and in [1].

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