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Repository-Centric Process Modeling - Example of a Pattern Based Development Process

Jacob Geisel, Brahim Hamid, Jean-Michel Bruel

Abstract Repositories of modeling artefacts have gained more attention recently to enforce reuse in software engineering. In fact, repository-centric development processes are more adopted in software/system development, such as architecture-centric or pattern-centric development processes.
In our work, we deal with a specification language for development methodologies centered around a model-based repository, by defining both a metamodel enabling process engineers to represent repository management and interaction and an architecture for development tools.
The modeling language we propose, has been successfully evaluated by the TERESA project for specifying development processes for trusted applications centered around a model-based repository of security and dependability (S&D) patterns.

Key words: Metamodel, Model-Driven Engineering, Process, Security, Dependability, Repository, Pattern

1 Introduction

Non-functional requirements such as Security and Dependability (S&D) [12] become more and more important as well as more and more difficult to achieve, particularly in embedded systems development [17]. Such systems come with a large number of common characteristics, including real-time and temperature constraints, security and dependability as well as efficiency requirements. In particular, the development of Resource Constrained Em-

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bedded Systems (RCES) has to address constraints regarding memory, computational processing power and/or energy consumption. The integration of S&D features requires the availability of both application domain specific knowledge and S&D expertise at the same time. Hence capturing and providing this expertise by means of a repository of S&D patterns and models can enhance embedded systems development. We seek mechanisms which allow a safer, easier and faster RCES development processes.

Modeling software and system process is fundamental in order to improve the quality of applications. The main goal of these processes is to provide to organizations with the means to define a conceptual framework. For this reason, several tentatives (including those developed by the OMG[1]) have been proposed to model software process. For instance, the SPEM [10] specification is used for describing a concrete software development process or a family of related software development processes. It conforms to the OMG MOF metametamodel and is defined as a UML profile.

In this paper, we study the RCPM metamodel which defines a new formalism for system development processes. This formalism is centered around a repository of modeling artefacts, providing new concepts related to repository management and interaction. The paper also presents the design environment for process modeling, supporting reuse in form of predefined libraries of process element types. These libraries may be used to facilitate process modeling from scratch or to adapt existing process models for certain domains. Furthermore, the design environment offers the ability to build new type libraries based on the recommendations of a targeted domain.

The rest of this paper is organized as follows. In Section 2, we introduce the context and background related to this work. Then, Section 3 details the specification of the repository-centric process modeling language. Section 4 describes our proposed tool implementation through an example of a process model from Railway domain targeting RCES applications. In Section 5, we present an extract from a process enactment to develop an RCES application. In Section 6, we review some principal existing process metamodels close to our work. Finally, Section 7 concludes and draws future work directions.

2 Development Context and Background

2.1 Development Context

The proposed methodology promotes a model-based approach coupled with a repository of modeling artefacts. In this vision, the modeling artefacts derived from (resp. associated with) domain specific models aim at helping the application developer to integrate these artefacts as building blocks.

[1] Organization normalizing the UML language

The repository presented here is a model-based repository of modeling artefacts. Concretely, the repository is a structure that stores specification languages and the modeling artefacts coupled with a set of tools to manage/visualize/export/instantiate these artefact in order to use them in engineering processes. For instance, to define an engineering discipline for S&D that is adapted to RCES, a repository-centric engineering process model will have to recognize the need to separate expertise on applications (represented by an application designer), expertise on security and dependability (represented by an S&D engineer), and expertise on repository-based development (represented by a model-driven and pattern engineer).

2.2 Process Models and Artefacts

Models are used to denote some abstract representation of system engineering processes. Specifically, we need models to represent the process activities, models to encode the artefacts and software platforms to test, to simulate and to validate the proposed solutions. Accordingly, comprehension, study and analysis of system engineering processes require the seek of models which make it as easy as possible to express and to encode them with the following characteristics:

- Intuitive: to develop them and teach them,
- Practical: to test and validate them by a simple implementation.
- Formal: to prove their correctness using formal method tools,

As a benefit, the study of problems on high-level models allows deducing properties on other less abstract models. Here, we deal with the two first characteristics through metamodeling technique and its associated implementation environment.

2.3 DSL Buildung Process

Domain Specific Modeling Languages (DSML) [2] have recently increased in popularity to cover a wider spectrum of concerns. A process defining those DSMLs reuses many practices from Model-Driven Engineering. For instance, metamodeling and transformation techniques. SEMCO[2] is a set of federated DSLs working as a group, each one relevant to the key concern. A DSL process [3] is divided into several kinds of activities: DSL definition, transformations and consistency and relationships rules as well as design with DSLs and

[2] `http://www.semcomdt.org`

[3] DSL process defines how development projects based on DSL are achieved.

qualification. The first three activities are achieved by the DSL designer and the two last ones are used by the final DSL user.

There are several DSML environments available. In our context, we use the Eclipse Modeling Framework (EMF) [15] open-source platform to support such a building process and to create our tool suite. Note, however, that our vision is not limited to the EMF platform.

2.4 Working Example

The illustrating example is a simple variant of the well-know V-Model. In this process model, the developer starts by requirements engineering/ specification, followed by system specification. In a traditional approach (non repository-of-pattern-based approach) the developer would continue with the architecture design, module design, implementation and test.

In our vision, instead of following this phases and performing their related activities, which usually are time and efforts consuming as well as errors prone, the system developer merely needs to select appropriate patterns from the repository and integrate them into the system under development (Figure 1 shows the process and points out the phases with repository interactions). For each phase, the system developer executes the search/select from the repository to instantiate appropriate patterns in his modeling environment and then integrates them in his models following an incremental process. The downside of this approach is that in a very early stage of the development, mainly during the requirements and design phases, the requirements engineers and the system architects have to be aware of existing patterns.

3 Repository Interaction Metamodel

In the following subsection, we highlight the sub-metamodel architecture of the Repository- Centric Process Metamodel (RCPM), while the next subsections concentrate on the presentation of the repository interaction part of the RCPM metamodel.

3.1 RCPM

The RCPM is a metamodel defining a new formalism for system development process modeling based on a repository of modeling artefacts. The RCPM metamodel contains different sub-metamodels, as shown in Fig. 2, which offer different capabilities. RCPM is oriented to support:

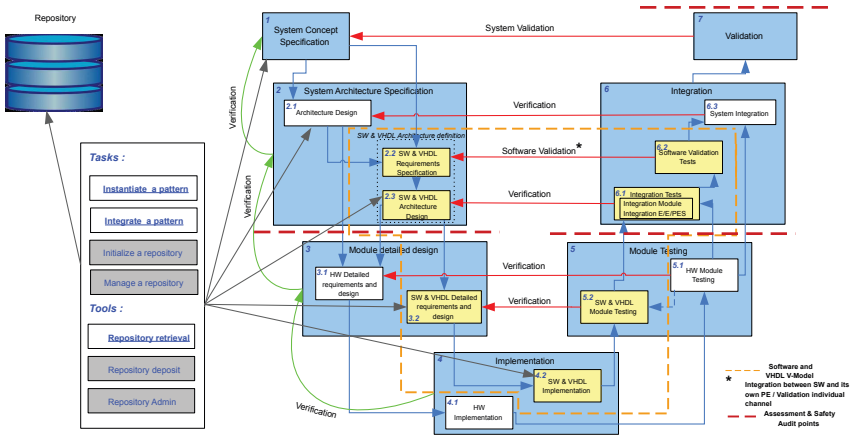

Fig. 1 Railway Engineering Process Lifecycle

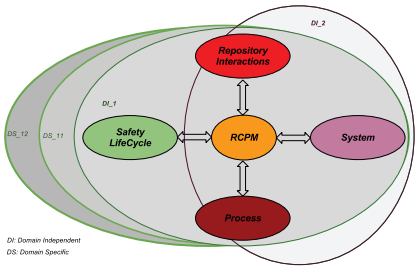

Fig. 2 Design principles of RCPM

- *The development of embedded systems.* The metamodel orients to facilitate the modeling the development of embedded systems, including the concepts of partitions which are popular in embedded system development.
- *Reuse of existing solutions.* The metamodel enables to model existing modeling artefacts and their integration process. For instance, the metamodel supports the repository-centric design methodology, introducing new concepts on repository management and interactions with the traditional process metamodel.
- *A safety process lifecycle.* As we can find in standards as IEC 61508 [7], there are more and more requirements for transforming traditional processes to safety processes to meet specific safety requirements of systems or software. This metamodel adds the concepts used in the safety lifecycle to support this kind of process model, such as verification and validation [4].

In this paper, we concentrate on presenting the repository part of the RCPM metamodel. For a general description and other referenced metamodel concepts see [3].

3.2 Repository Interaction sub-Metamodel

Our specification language is described by a metamodel that we call Repository Interaction Sub-Metamodel, as depicted in Figure 3. It constitutes the base of our process modeling language, describing all the concepts (and their relations) required to capture all the facets of Repository Interactions.

The principal classes of the metamodel are described with the Ecore notations of the Eclipse Modeling Framework[4] in Figure 3 as well as the link with the libraries models [5]. As we shall see, we define a set of libraries with a set of tasks and steps dedicated to specify the repository interaction tasks and steps during the process model enactment. These libraries will be used as external models to type the process tasks. The meaning of the main elements of the metamodel with the working example are described in the sequel.

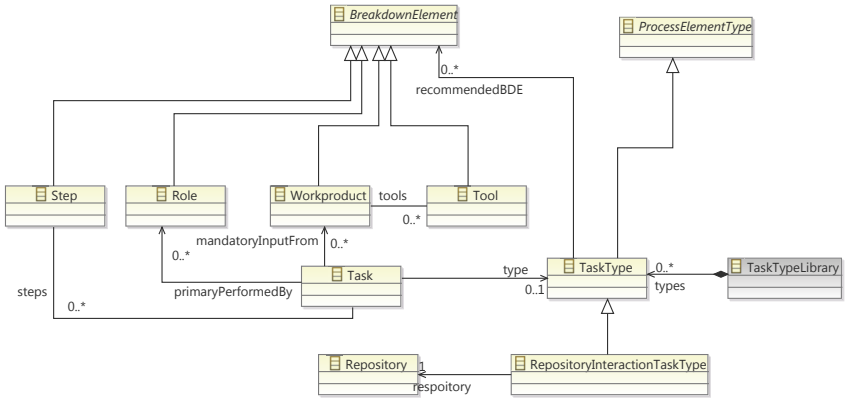

Fig. 3 Overview of the Repository Interaction Sub Metamodel

- BreakdownElement. A BreakdownElement is an abstract generalization for any Process Element that is part of a breakdown structure. Any of its concrete sub-classes can be used to compose an Activity*[6].

[4] `http://www.eclipse.org/modeling/emf/`

[5] We use *gray* to label concepts imported from the library model

[6] Elements marked with * are not shown in Figure 3, please refer to [3] for more details

- TASK. A Task is a WorkBreakdownElement* that represents the work that should be done in an Activity*. The Task should be related to a Role, a WorkProduct and, if necessary, a Tool. In our example, as visualized in Figure 1 we define a set of Tasks, which are related to repository management (*initialize a repository, manage a repository*) and those related to repository interactions (*instantiate a pattern, deposit a pattern, integrate a pattern*). The later Task is not strictly related to repository interaction, but may lead to some repository interactions. A Task is decomposed into Steps, which detail what exactly is done in which order. A Task has normally WorkProducts (mandatory or optional) as input and output.
- STEP. A Step is a detailed description of the work to be done. It is the smallest entity in the decomposition of Process*, Phase*, Activity* and Task. It describes the elementary step, which leads to the realization of a WorkProduct. For instance, *instantiate a pattern* task may be decomposed into three steps: *search a pattern in the repository*, *select the appropriate one from the search results list* and finally *import the selected one into the development environment*.
- ROLE. A Role describes the role of an actor in a Process/Phase/Activity/Task. It is generally linked to the realization of a WorkProduct for a specific Task using a specific Tool. In our example, we can associate *repository manager* role to the actor responsible of the *manage a repository* task and *system engineer* role to actor responsible of the *instantiate a pattern* task.
- WORKPRODUCT. A WorkProduct is a special BreakdownElement that represents an input and/or output for a Task. The WorkProduct is related to a Task and a Role. A *pattern* is a key workproduct of the proposed process model.
- TOOL. A Tool represents the tool used to fulfill a Task and to realize a WorkProduct. Here, we deal with a set of tools supporting to the repository management (*Repository Admin*) and repository interactions (*Repository Retrieval*).
- PROCESSELEMENTTYPE. The ProcessElementType allows to type a ProcessElements*, adding mandatory or optional properties to a ProcessElements*, as well as references to different Phases*, Roles, Tools, WorkProducts or Activities*.
- TASKTYPE. A TaskType allows to type a Task to reuse capitalize knowledge about Roles, Tools, WorkProducts and Steps. This Type links these information.
- REPOSITORYINTERACTIONTASKTYPE. A RepositoryInteractionTaskType is a specialization of a TaskType introducing the idea of Repository. Thess TaskTypes can be linked to a Repository. In our example, we could define *instantiate a pattern* as REPOSITORYINTERACTIONTASKTYPE instance.
- TASKTYPELIBRARY. A Library containing TaskTypes which are common to an application domain or standard recurring TaskTypes and can be reused to type recurring Tasks in a process or Tasks in different processes.

The repository specific interaction tasks may be grouped into one or multiple libraries to foster reuse.

- Repository. It describes the repositories used in development process. As the repository-centric development processes are more and more adopted in software/system development, such as architecture-centric or pattern-centric development processes. In our example, we use a repository of S&D patterns.

4 Tool Architecture and Implementation

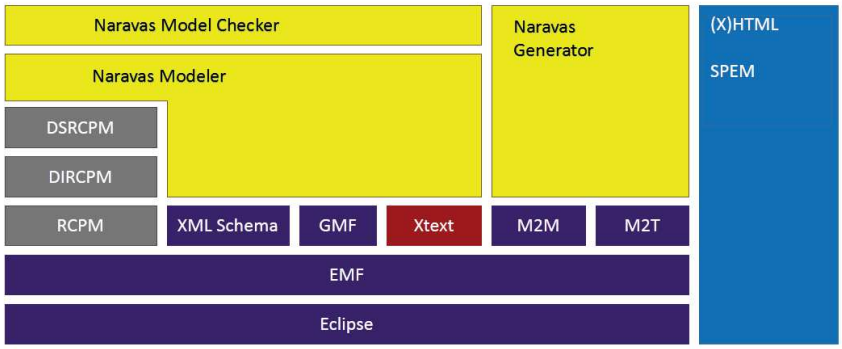

Fig. 4 Overview of the Naravas Architecture

Using the proposed metamodels, ongoing experimental work with *SEMCOMDT*[7] (SEMCO Model Development Tools, IRIT's editors and platform as Eclipse plugins) is realized, testing the features of *Naravas*, a tool for formalizing process models and documentation generation. In the following subsections, we present our tooling. Figure 4 depicts the architecture of the development framework based on Eclipse Technologies.

4.1 How the Process Model Editor is Built?

We used the Eclipse EMF based Ecore editor to model our Repository-centric Process Metamodel (RCPM), creating one Ecore file containing the three packages needed for the process model, the core package, the type package and the process package. Minor modifications have been applied on the

[7] `http://www.semcomdt.org`

metamodel to support an EMF based editor and HTML documentation generation. The generated editor code was modified to limit the user actions on the ones needed and to enhance user experience (e.g. modifying the process model creation workflow).

The second part of the project was to create the HTML code generator based on Acceleo[8], a Model-to-Text (M2T) component of the Eclipse Modeling Framework. We developed modularized code transformation templates, generating one HTML file per process model object and type and managing the links among them.

4.2 Process Model Designer: Naravas

Naravas is an EMF tree-based editor for specifying models of processes, libraries of types and generation of documentation. Naravas implements several facilities conforming to the RCPM metamodel.

4.2.1 Library Design

The design environment of the type libraries is presented in Figure 5. The figure represents a Task Type Library for Repository Task. The Task Types presented here are identically to the ones presented in Figure 1. For instance, the second Repository Interaction Task Type (Artefact Instantiation) show the mandatory steps (*Search repository*, *Select Patterns in Repository* and *Import Patterns to IDE*), the optional Roles, the Tool and the output Work Product for a Task typed by this type. The other Task Types in this library represent Tasks with Repository Interactions, encountered multiple times in the shown process (e.g. Repository Management, Artefact Publishing, Artefact Retrieval).

4.2.2 Process Model Design

The design environment is presented in Figure 6. Naravas enables the user to model processes in a tree-based manner. There is a design palette on the right (enabled by a right click on an element), a tree view of the project on the left and the main design view in the middle. As we shall see, the design palette is updated regarding the targeted process element. The used example shows the Railway Application Process built by Ikerlan. It represents the Repository, the Phases, Activities, Tasks, Steps, Roles, Tools, Work Products and Flows among the Elements, such as Control, Retrieve, Verification and Validation

[8] `http://www.eclipse.org/acceleo/`

Flows. The Process model editor allows to add, delete, move and modify the elements, as well as conformance validation. It also allows the import of external resources, such as Process Element Type Libraries. The usage of the Task Types is shown in Figure 7. When creating a Task, it is possible to type it from the Task Types already defined in a Library. By choosing a Type (*Repository Interaction*), the mandatory Steps, Work Products, Roles and Tools are filled in automatically (*Search Repository*, *Select Artefact in Repository*, *Import Artefact to IDE*), and the mandatory ones are proposed in addition to the standard items when creating new entities.

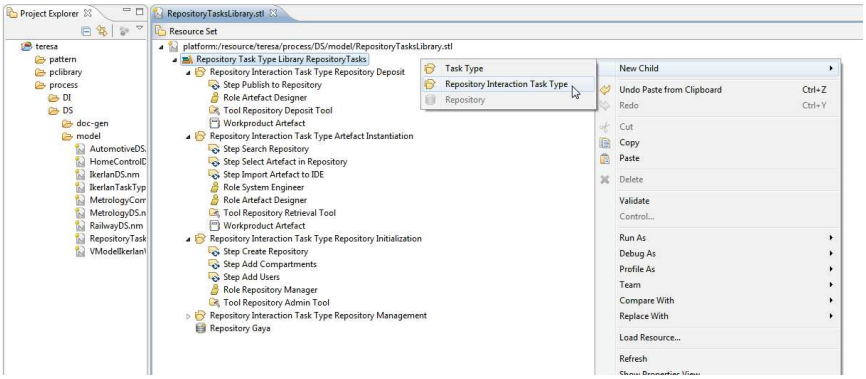

Fig. 5 Naravas for Library Design Environment

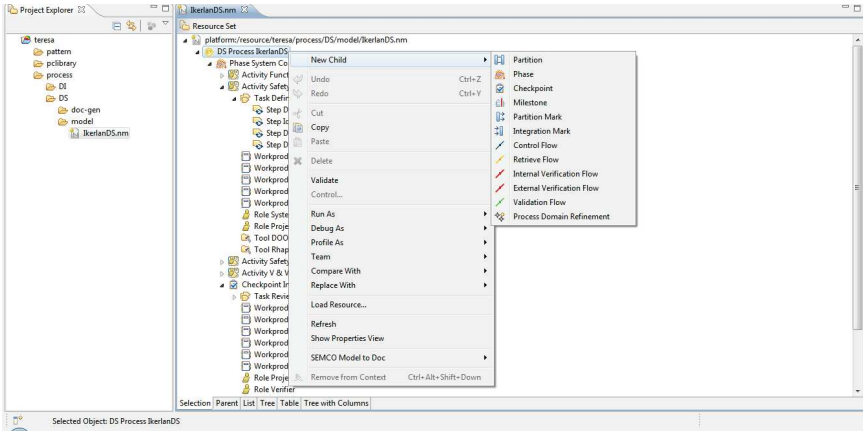

Fig. 6 Naravas Process Design Environment

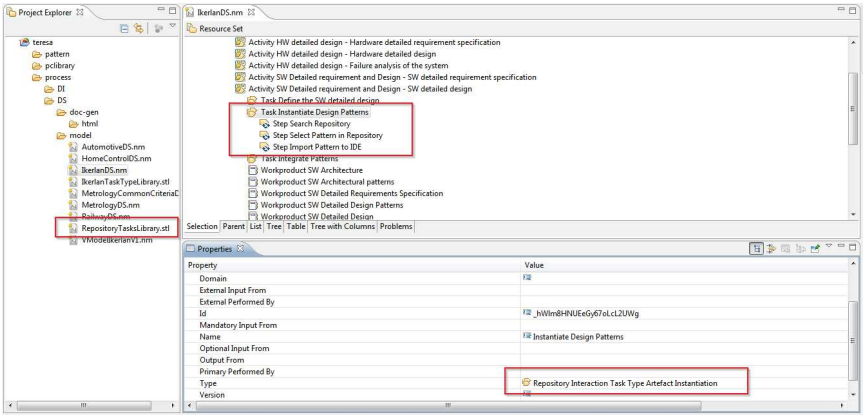

Fig. 7 Example of the Usage of a Library - Repository Interaction Task Types

4.2.3 Conformance Validation

Further, using EMF features, we added the metamodel conformance validation to the editor. The process validation tool is used to guarantee design validity conforming to the process metamodel. Process model validation starts by right clicking on Process Core and pressing the *Validation* tool. In our example, the process model built by Ikerlan for the railway domain can be validated, where a violation of a metamodel construct will yield an error message (see Figure 8).

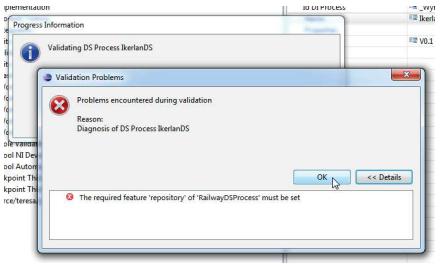

Fig. 8 Process Validation

4.2.4 Documentation Generation

Documentation generation of a process model is triggered by running the *SEMCO Model to Doc* tool. Our implementation allows so far to generate HTML documentation using M2T transformations through Acceleo.

5 Process Model Enactment

In this section we will present an extract of the process model and its enactment to build an industry control application from the railway called *Safe4Rail* acting as a TERESA case study. In this case, SIL4 level is targeted. A repository of patterns for TERESA called Gaya was built. Gaya contains so far (as of March 2013):

- Users. 5 organizations and 10 users.
- Patterns. 59 S&D patterns.

The following table depicts a subset of inputs and outputs consumed and produced during the chosen activities of the process enactment, mainly those related to the repository. Repository Interactions are highlighted, as well as results from Repository Interaction.

6 State of the Art

State of the Art of process metamodels have been analyzed from a perspective of repository interactions, embedded systems and safety lifecycles support. Process metamodels can be modeled from different types of views: activity-oriented, product-oriented and decision-oriented views [13, 6]. Most process metamodels and process frameworks based on metamodels adopt the activity-oriented views, such as SPEM, RUP and OPF.

The SPEM (Software & Systems Process Engineering Metamodel) [10] is a *de facto*, high-level standard for process modeling used in object-oriented software development. The scope of SPEM is intentionally limited to the minimal elements necessary to define any software and systems development process, without adding specific features for particular development domains or disciplines. The goal is to accommodate a large range of development methods and processes of different styles, cultural backgrounds, levels of formalism, lifecycle models, and communities.

The RUP (IBM's Rational Unified Process Framework) and its extension RUP SE (SE stands for System Engineering) are derived from the Unified Process Framework [8]. Both metamodels are, like SPEM, described by a UML profile and define a Process Modeling Language (PML). The OPEN

Phase	Activity	Task				
Module Detailed Design	SW Detailed requirement and Design - SW detailed requirement specification	Define the SW detailed requirements				
		Step	Role	Tool	WP in	WP out
		Analysis and Definition	SW Architect, SW Designer	Rhapsody, DOORS	SW Requirements Specification, SW Architecture	SW Detailed Requirements Specification
	SW Detailed requirement and Design - SW detailed design	Define the SW detailed design				
		Step	Role	Tool	WP in	WP out
		Define Internal Description	SW Designer	Rhapsody	SW Architecture, SW Detailed Requirements Specification	SW Detailed Design
		Define Components	SW Designer	Rhapsody		
		Define Interfaces	SW Designer	Rhapsody		
		Define Communication	SW Designer	Rhapsody		
		Generate SW Detailed Design	SW Designer	Rhapsody		
		Instantiate Design Patterns				
		Step	Role	Tool	WP in	WP out
		Search Repository	SW Designer	**Repository Retrieval Tool**	SW Architecture, **SW Architectural patterns**, SW Detailed Requirements Specification, SW Detailed Design	**SW Detailed Design Patterns**
		Select Patterns in Repository	SW Designer	**Repository Retrieval Tool**		
		Import Pattern to IDE	SW Designer	**Repository Retrieval Tool**, Rhapsody		
		Integrate Patterns				
		Step	Role	Tool	WP in	WP out
		Elicitation	SW Designer	Rhapsody	SW Detailed Design, **SW Detailed Design Patterns**	SW Detailed Design with integrated Patterns
		Binding	SW Designer	Rhapsody		
		Consolidation	SW Designer	Rhapsody		

Table 1 Description of the Railway Process Enactment (Extract from the Module Detailed Design)

Process Framework (OPF) [11] is a componentized OO development methodology underpinned by a full metamodel, encapsulating business as well as quality and modeling issues.

In addition to the above mentioned process metamodels, exist other activity-based metamodels like OOSPICE [5] and SMSDM [14]. Other types of process metamodels such as decision based etc., do not orient to safety critical system development. As far as we know, the studied process metamodels unfortunately do not support safety related development processes explicitly or facilitate the modeling of safety lifecycles. Many safety critical systems use Safety Instrument Systems (SIS) to manage the safety lifecycle, however, these SIS do not have process metamodels. Works like [1] propose to model different standards and try to give recommendations during the application development.

[16] presents a survey of business process model repositories and their related frameworks. This work deals with the management of a large collections of business processes using repository structures and providing common repository functions such as storage, search and version management. It targets the process model designer allowing the reuse of process model artefacts. A comparison of process model repositories is presented to highlight the degree of reusability of artefacts. For example, the repository for process models described in [9], supports activity, control-flow and monitoring aspects. The metamodel described in this paper may be used to specify the management and the use of this kind of process models. In fact, a process model aspect or the process model as a whole of the aforementioned process models can be seen as artefacts supported by our metamodel. In return, the vision of the business process model repositories may be used in our work to manage the process element type libraries.

7 Conclusion

In our work, we target the development of a modeling framework built around a model-based repository of modeling artefact in order to be used in an MDE approach for trusted RCES applications in several domains. In this paper, we have proposed a modeling language to specify repository-centric process models, providing new appropriate concepts related to repository management and interaction. The design environment supports reuse in form of libraries of types, facilitating process modeling. The later may be used to specialize process models for a certain domain. In this case, the library is build on the recommendations of the targeted domain. Furthermore, we walk through a prototype with EMF editors supporting the metamodel. Currently the tool is provided as part of a tool-suite named *SEMCOMDT* as Eclipse plugins.

The design environment presented here has been evaluated in two use studies from TERESA industrial partners mainly for a repository of S&D and resource property and pattern modeling artefacts. By this illustration, we can validate the feasibility and effectiveness of the proposed specification and design frameworks.

As future work, we plan to study new libraries for additional process elements. Also, we will seek new opportunities to apply the framework to other domains.

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