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A meta-model based approach to the description of resources and skills

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ABSTRACT

The management of intra- and inter-organizational business processes is a significant issue that influences company's success. Many business processes are not fully automated and require human interaction. Therefore, responsibilities for tasks have to be assigned by workflow management systems. Common resource models allow the selection of resources according to their roles, thus neglecting competences and skills. In this article we present an extensible resource meta-model that allows the modeling of resources including their competences, skills and knowledge. Furthermore we propose the usage of these criteria to enable a more flexible assignment of resources to tasks. In particular our approach fosters the alignment of business process modeling and human resource planning. This combination facilitates several opportunities on both sides and offers potential for enhanced scheduling of adequate resources in comparison to pure role based decisions.

Keywords

Business Process Management, Resource Modeling, Human Resource Planning, Skill Management.

INTRODUCTION

Increased interconnectedness promotes enterprise cooperation, as well as simplified comparability of offers, and thereby induces a raised contention. Especially the growth in electronic commerce is accompanied by the requirement to be able to react swiftly to changed market situations (Bieberstein, Bose, Walker and Lynch, 2005). As a suitable response to these circumstances companies need to adjust, transform and improve their business processes continuously (Doubrovski, Grundler, Hogg and Zimmermann, 2005; Lenz and Oberweis, 2003). Thereby updated business processes enforce the adaptation of affected information technology and resources. The alignment of these systems entail enlarged complexity in management, thus the paradigm of the service oriented architecture (SOA) could establish as a de facto standard (Dostal, Jeckle, Melzer and Zengler 2005; Doubrovski et. al., 2005). Despite the fact that the majority of current approaches concentrate on fully-automated parts of business processes, the importance of human interaction in workflows has been pointed out (Zur Mühlen, 2004).

While the coordination of tasks and resources according to business processes is a major task of workflow management systems (van der Aalst and Kumar, 2001; Zur Mühlen, 2004; Hollingsworth 2005), the redesign of business processes necessitates tracing changed requirements and assignment of appropriate resources to tasks. Currently scheduling mechanisms for assignment of human resources are based on role descriptions (Ferraiolo, D. F., Sandhu, R., Gavrila, S., Kuhn, D. R., and Chandramouli, R., 2001). Although it is a common consensus that roles stipulate competences and skills, explicit modeling of interdependencies between roles, available resources and competences is neglected so far. Yet an efficient selection of appropriate resources (e.g. in order to reduce waiting times and costs or to enhance the quality of outputs) has to be based on business processes, available resources, demanded competences, and if necessary strategies to acquire further resources and services, to perform the defined tasks. The latter entails additional and precise interaction between business process management and human resource departments.

The remainder of this article is organized as follows: The next section provides a brief overview on resource management, followed by a section that comprises competence and skill management, including related work and standardization efforts. The section meta-models for resource description illustrates our meta-model approach, followed by a demonstration. The paper is concluded by a summary and suggestions for future research work.

RESOURCE MANAGEMENT

Resources are entities (e.g. employees, production lines, data objects or materials) that can be assigned to a workflow task (Russell, N., van der Aalst, W., ter Hofstede, A. & Edmond., D., 2005). During runtime they can be requested in order to complete the objective of this task. In this context resources can either be the executing actor (therefore resources are also referred as actors or performers) or just be utilized by another resource to complete the task (Hollingsworth 2005). All relevant resources have to be comprised in a resource model, thereby facilitating their coordination by a workflow management system. Resource management must prevent or handle concurrent access to resources or access to spatially respectively temporally unavailable resources appropriately As mentioned above the emerging interconnection and the implementation of inter-organizational business processes raise the complexity of resource management (Dostal et. al., 2005; Bieberstein et. al., 2005). The following characteristics of resources are relevant for the rest of the paper:

- *The number of resources to be managed*: in large-scale enterprises this will be large just by accounting the number of employees, but even in small and medium-sized companies large amounts of resources might be involved if the required equipment is included.
- *Access to resources*: can be subject to rules, including business rules, statutory provisions or safety regulations for which compliance has to be ensured.
- *Distribution of resources*: resources can be distributed across several locations, in turn limited knowledge or limited access rights may be available.
- *Resource capabilities*: even for similar resources skills may be differing a lot (e.g. the execution time for assigned tasks may be variable even if resources belong to the same category).
- *Implicit resource access*: the access to resources can imply the usage of other resources; therefore this can be a significant cost factor.
- *The current state of a resource*: state and availability of resources must be monitored; in particular the allocation of unavailable or already overburdened resources must be prevented.
- *Spatial and temporal constraints*: The localization of the resources is critical in scheduling; e.g. worldwide operating project teams display a challenge, hence spatial distribution influences availabilities (Cook and Churcher 2005).
- *Resource properties may alter over time*: Particularly capabilities and competences of resource may change during their life-cycle (e.g. a product line might be upgraded, thereby increasing its throughput).

These characteristics require that, in addition to the process view, business analysts gain access to resource models. Hence insights in the organizational structure, current occupancy states and a prediction of future occupancy states of resource allow an adequate analysis of business processes.

MANAGEMENT OF COMPETENCES AND SKILLS

As outlined before frequently alternating market requirements strengthen competition and entail alignment of competences. Thus maintaining and acquiring competences significantly contributes to success or failure of an enterprise. In addition to technologies and services, the staff of a company is a key part which is responsible for the formation of core competences (Povalej, and Weiß, 2007). For long-term success, it is therefore essential for companies to align competences and skills of their employees according to changed requirements. Furthermore the assistance of (further) educating new competences, skills and proficiency levels through training or further education measures has to be part of competence management. Hence it is necessary to i) trace the development of competences and ii) exchange competence models between departments to facilitate the alignment of competence profiles.

Intra-organizational Competence Management

Managing the information about existing competences is mainly perceived by human resource departments (HR). The formation of competence profiles is basically applied in recruitment processes (HR-XML, 2004). Reasons for recruitment measures are either the enrollment of new competences or an increase in existing capacities suited to tackle larger demand volumes on the market. Up to now personnel departments align their recruitment measures along recruitment processes, but not according to the needs of domain-specific business processes.

Competence profiles are usually developed by informal communication of other departments and HR. However the examination of combinations of competence profiles and requirements of business processes is insufficient; thus a formal derivation of actual requirements is not possible. This is owed to the fact that competences and skills are neglected in the field of business process modeling. There competences are considered to be an implicit part of process and organizational roles but are not explicitly modeled (Russell and van der Aalst, 2008; van der Aalst and Kumar 2001). For an enhanced support of human resource recruitment processes, a formal method is mandatory that allows to infer competence profiles from business process models.

Competence Standards and Exchange

Make-or-buy decisions, as well as the assignment of partial orders to subcontractors impose to locate appropriate resources respectively reliable partners. A significant criterion that allows a sound resource selection is conformance to competence requirements. Therefore resource competence description standards are required to enable appropriate comparisons of contractors, thereby complementing standardized descriptions of business process interfaces.

Numerous international organizations deal with the standardization of competence descriptions; currently the majority of resulting standards include the concepts competence, skill and knowledge. Although the semantics of these concepts are different depending on the respective standard, some are similar and partially overleaping. In our point of view Figure 1 characterizes these concepts. According to this diagram a competence is formed by a set of skills and knowledge in a specific context; skills are built on knowledge. This perception is similar to the definitions of eCCO (eCCO, 2005).

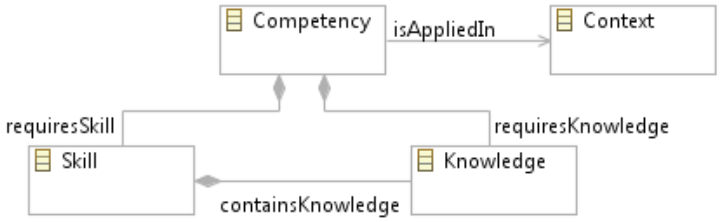

Figure 1. Conceptual relationships between competence, skill and knowledge

The European Framework for e-Skills and competences is the result of an initiative at European level (eCCO, 2005; e-Skills UK, 2008; CEN Workshop Agreement, 2008), partially funded by the European Union. The framework currently describes 32 categories of competences interesting for users, customers and providers of products and services in the information and communications technology sector. Furthermore the framework considers qualification and certification schemes for training and further education with accent for public institutions. The framework bundles insights from preceded and parallel work (CEN Workshop Agreement, 2004; Winterton, Delamare-Le Deist and Stringfellow, 2005; Povalej and Weiß, 2007). Nevertheless precise and formal definitions are not included; an approach that takes a first step towards this is illustrated in (Povalej, Stucky, and Weiß, 2009).

Further approaches to describe data for human resources planning and competences are HR-XML, which is promoted by the same titled consortium (HR-XML, 2004) and RCD (IEEE, 2006) – both are XML-based. HR-XML follows the objective to characterize a complete set of standardized data definitions relevant for HR. The data definitions given by set of XML schemas that can be used to infer data that may be used in combination with business process models for resource selection – below this will be picked up again.

META-MODELS FOR RESOURCE DESCRIPTION

Various studies and research papers have examined the description of resources in the context of business processes (Oberweis, 1996; van der Aalst and Kumar, 2001; van der Aalst, Kumar and Verbeek 2003; Zur Mühlen, 1999; Zur Mühlen 2004) so far. Most of these descriptions are not MOF-compliant meta-models (OMG, 2006) but abstract definitions; therefore we will discuss them uniformly as meta-models. These approaches share the understanding that human resources can be associated and grouped with role descriptions. Roles are attached to tasks and therefore may be used during process execution to ensure that only personnel associated to these roles is selected for task completion. Furthermore most meta-models distinguish between organization-related roles (e.g. head of a department) and business process-related roles (such as process owner); while the organization-related roles describe organizational structures, business process-related roles represent the relationship between business process instances and human actors.

The majority of the resource meta-models neglect the relationship between resources and competences. Approaches like (van der Aalst et. al., 2003) mention competences, but do not consider them any further. Others state that competences should be connected to the roles and personnel that fulfils a role should also cover these competences (Zur Mühlen, 2004). Some current standards for process execution, such as WS-BPEL, do not even allow the description of non-technical resources (OASIS, 2007). Therefore extensions like BPEL4people (OASIS, 2007) and WS-Human Task (OASIS, 2009) have been defined. The latter offer only plain resource descriptions that also neglect competences and organizational structures and instead concentrate on the participants' process-related roles (Russell and van der Aalst 2008). In conclusion the description of competences is not covered, rather competences required by a role are considered to be known implicitly. Due to that lack of details no target-oriented interaction with human resource departments can be derived by the analysis of business process models.

This contribution will present a technique that combines explicit description and modeling of resources, competences and their relationships by the definition of an appropriate meta-model. Furthermore this model will be the basis for model editors, instance models and their transformation - according to (Miller et. al., 2003). In particular the meta-model will be capable to associate resources and competences independently of roles, this allows to trace further education and training procedures.

RESOURCE META-MODEL

The following subsection will outline details of our MOF-compliant resource meta-model (RMM) for the description of resources. The benefit of a meta-model for resource and competence description is multifold. Initially the meta-model allows precise and formal definitions of domain specific concepts and their relationships (realized through abstract syntax definition). Furthermore there are several additional side-effects in software development. On the one hand MOF-compliant meta-models can leverage the degree of automation (through transformations); on the other hand instances (models) that comply with meta-models reflect domain requirements and ensure the creation of valid descriptions (France and Rumpe, 2007). Also RMM can enhance information interchange and if necessary alignment of competence profiles defined by human resource departments on the one hand and business process models contrariwise. This does not only imply that competence profiles may be used to describe resources that execute a task of a business process but also includes the possibility of adjustments to competence profiles driven by business process requirements. In accordance to quality standards for modeling the RMM is designed as extensible and reusable meta-model, allowing industry sector dependent specializations.

RMM is subdivided into three model parts. The top-level part provides general resource descriptions. As specialization of the general meta-model the human resource meta-model (HRMM) represents personnel resources and organizational structures. Furthermore descriptions of competences are covered by the competence meta-model (COMM). As depicted below, all model parts are connected together and thereby allow references and associations between model instances. Open standards are used for meta-models, since all partial models are implemented as MOF-compliant ecore-models (Steinberg, Budinsky, Paternostro and Merks, 2008).

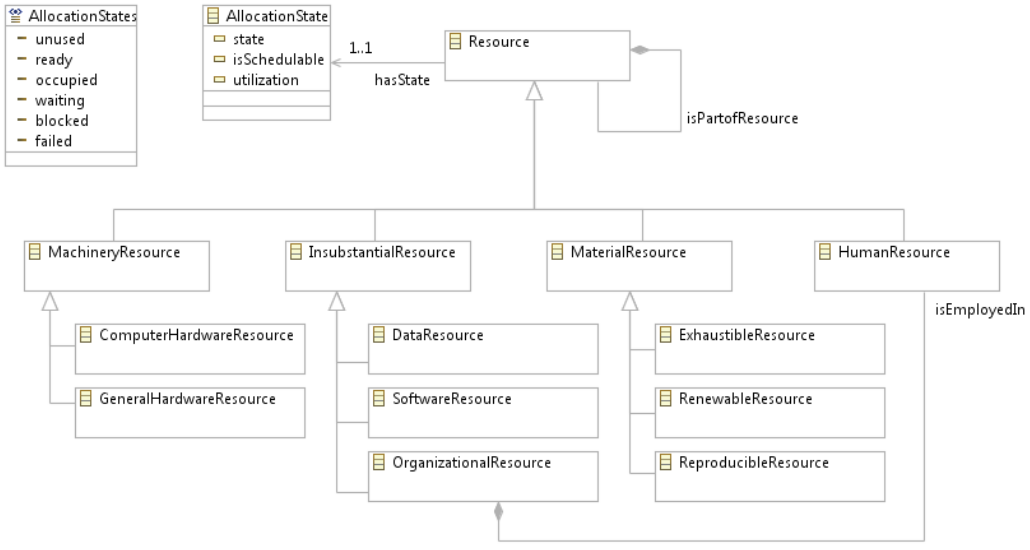

Figure 2. Resource Meta-model (RMM)

Additional attributes, generalizations of elements, further meta-model classes or specialized meta-models may extend the RMM. Typically meta-model extensions attach supplementary details or describe industry sector specific semantics (e.g. extensions for the description of special technical resources, electronic services or additional attributes to cover means for sustainability measurement). As a result RMM is both reusable and extensible. The following subsections illustrate the design of the meta-model parts and semantics of the contained elements. First the meta-model part for general resource description will be outlined (Figure 2).

The central element of this meta-model is the `Resource` (Russell, N., et. al., 2005), an abstract class that encapsulates common properties shared by more specialized resources. Moreover a `Resource` can be part of another `Resource`, such as a machine part belongs to the machine. While process execution requires the determination of responsible resources for the completion of a task, the exigency to evaluate the degree of resource utilization and remaining capacity arises. Therefore the element `AllocationState` enables to keep track of necessary information, the property utilization determines the degree of utilization and allows to determine whether it is possible to assign additional tasks; this may be used during process execution or in simulation experiments. Another measure is given in the `state` property of the `AllocationState`, the according enumeration `AllocationStates` provides typical state descriptions.

All further resource classes are specializations of `Resource`. They have these properties in common and define a set of resource types - which might be extended, as stated earlier. The general resource meta-model distinguishes currently between a set of classes (`InsubstantialResource`, `MaterialResource`, `MachineryResource` and `HumanResource`) that exemplify resource classifications. Furthermore there are some specializations of these classifications (`ComputerHardwareResource`, `GeneralHardwareResource`, `DataResource`, `SoftwareResource`, `OganizationalResource`, `ExhaustibleResource`, `RenewableResource` and `ReproducibleResource`). These specializations are by no means universal, but represent types often used in business processes. If necessary, it is possible to extend the RMM by more classes for assigning resources or, where appropriate, supplementary meta-model parts (such as HRMM).

In HRMM the model element `HumanResource` reflects manpower (Figure 3). Following the results of scientific examinations (Oberweis 1996; van der Aalst and Kumar, 2001; van der Aalst et. al., 2003; Zur Mühlen, 1999; Zur Mühlen 2004) and implementations of common workflow management systems, the HRMM allows the association of roles and human resources.

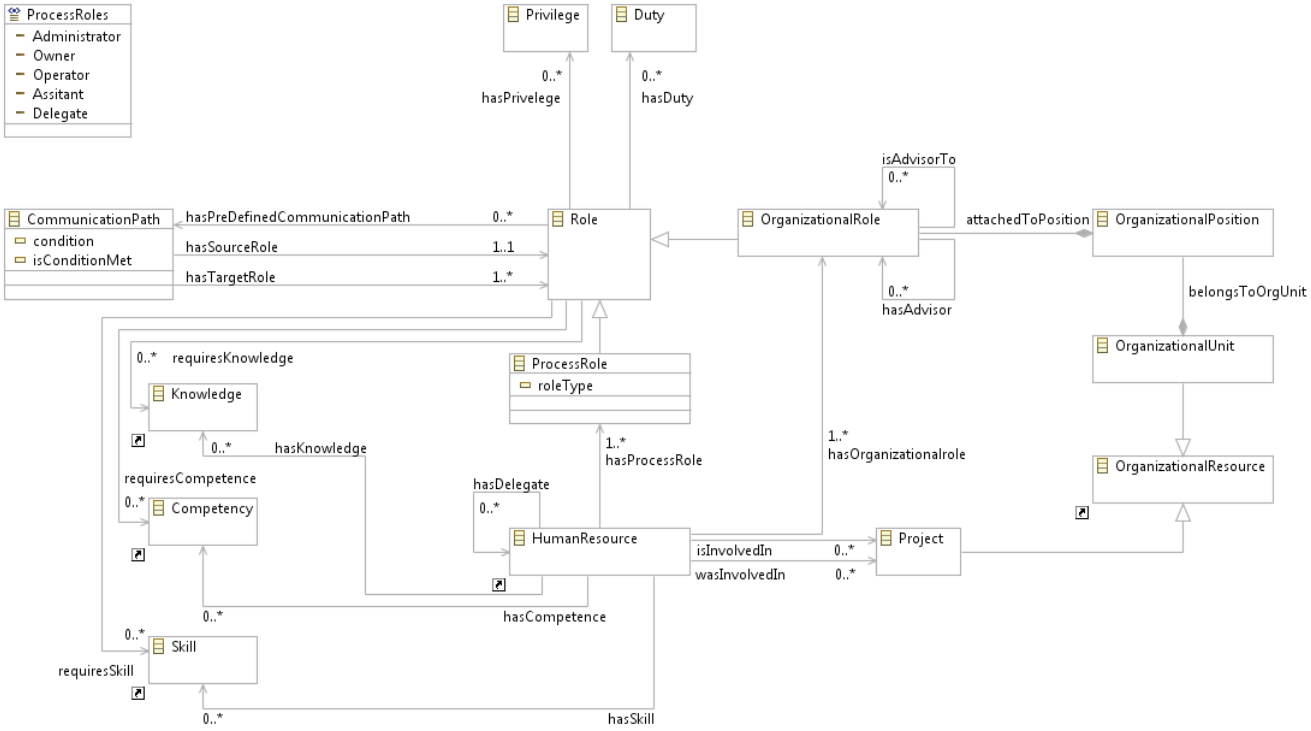

Figure 3. Human Resource Meta-Model (HRMM)

The HRMM allows to distinguish between organizational and business process-related roles (`OrganizationalRole` and `ProcessRole`). While organization-specific properties of a user's role indicate organizational hierarchies (as reflected in the meta-model by `OganizationPosition`, `OrganizationalUnit` and the relations `hasAdvisor` and `isAdvisorTo`), the business process-related role is used to describe the relationship between human resources and their assigned tasks or processes (OASIS, 2009; van der Aalst et. al., 2003) (as illustrated by `ProcessRole` and the enumeration `ProcessRoles`). Furthermore according to conventional scheduling mechanisms the organization-related roles determine appropriate resources for task execution. Both role types share the properties and associations of their super class `Role`; these are rights (`Privilege`), obligations (`Duty`) and defined communication channels (`CommunicationPath`), e.g. for reporting or escalation mechanisms. The model elements `OganizationPosition` and `OrganizationalUnit` substantiate organizational role descriptions and are of the type `OrganizationalResource`, which is referenced directly from the general RMM part (shown in Figure 3 by the shortcut icon below the model element). In addition a person can be associated with projects; this denotes projects in which the person is currently active. Since the project may include teams, a team description might be added to HRMM according to (van der Aalst and Kumar, 2001) in the future.

Several studies state that roles include specific competences, however these are not explicitly modeled so far. In order to tackle this issue HRMM integrates competence descriptions, represented by the model elements `Competence`, `Skill` and `Knowledge` (these elements are reused from the competence meta-model, which is outlined below). These concepts may be added to roles, as well as to human resources – of course other resources may have competences, too, nevertheless these are not part of HRMM. Besides revealing details about resources, explicit modeling of competences allows matching of resources and roles, thereby enabling sound decisions for allocation of new or idle roles. In a subsequent step the usage of competence information is beneficial for the allocation of resources to tasks. This means that within business processes not only role based but also competence driven assignments may be modeled and controlled by a scheduler. The utilization of competences to assign resources to tasks, may therefore restrict or extend the selection of acceptable resources - we will clarify this in our use case example.

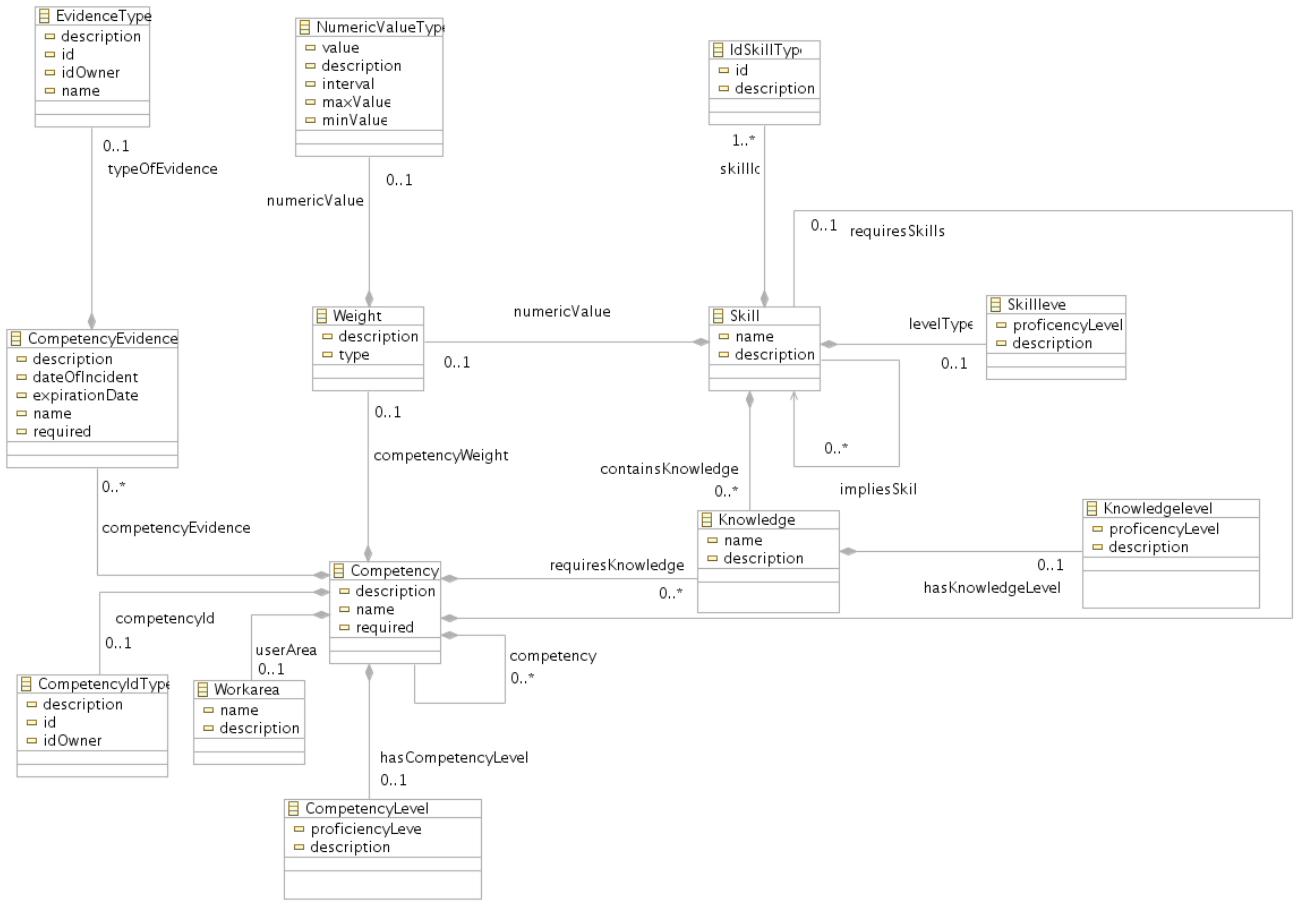

Figure 4. Competence Meta-Model (COMM)

Finally the competence meta-model (COMM) completes RMM. COMM as illustrated in Figure 4 is derived from HR-XML (HR-XML, 2004) and combined with results and concepts of (Povalej, et. al., 2009), as well as the European Framework for e-Skills and competences. This derivation was chosen since HR-XML is widespread and it enables a straightforward transformation of existing HR-XML models to RMM models. As previously discussed, competence models are mainly used by HR to accompany recruitment processes, thus being completely separated from business process modeling. RMM tackles this issue, since it is designed to integrate both model types thereby exploiting potential synergies. Besides the reuse of competence models in business processes modeling, derived requirements from business process models may be included in competence models vice versa, thereby improving correlative HR competence profiles and enhancing their accuracy (De Coi, Herder, Koesling, Lofi, Olmedilla, Papapetrou, and Sibershi, 2007).

Essential elements of COMM are `Competence`, `Skill` and `Knowledge`. Fundamentally, a competence can imply further competences, require various skills (`requiresSkills`) and knowledge (`requiresKnowledge`). This subdivision of competences, skills and knowledge is an extension to HR-XML according to (eCCO, 2005). Each of the three concepts has attached level descriptions that describe the degree of proficiency (`proficiencyLevel`). According to COMM a competence may be valid in a certain context (`Workarea`) only, in turn it may be invalid in other areas (e.g. operating a machine may be constrained to its size, such for driver's licenses). Also competences can be associated with evidences (`CompetenceEvidence`) that state dates of achievement and duration of validity. Finally, the addition of weights and evidences to competences respectively skills is used to differentiate their importance for an enterprise or certain business processes. Analogously the meta-model may be extended by other measures for scheduling. The subsequent section summarizes the practical use of RMM on the basis of an example and illustrates the value-added assignment opportunities obtained by the use of competence models.

USE CASE

We present a software development example to illustrate the real-world capability of our approach. In Figure 5 the organizational structure of a small development team is shown. The development team consists of two types of organizational positions: `SoftwareArchitect` and `DataBaseSpecialist`. While the position `SoftwareArchitect` is subdivided by organizational roles `JavaDeveloper` and `J2EEArchitect`, for the position `DataBaseSpecialist`, the roles `Architect`, `Administrator` and `Analyst` are to be distinguished. Finally several persons (type `HumanResource`) are associated with these roles.

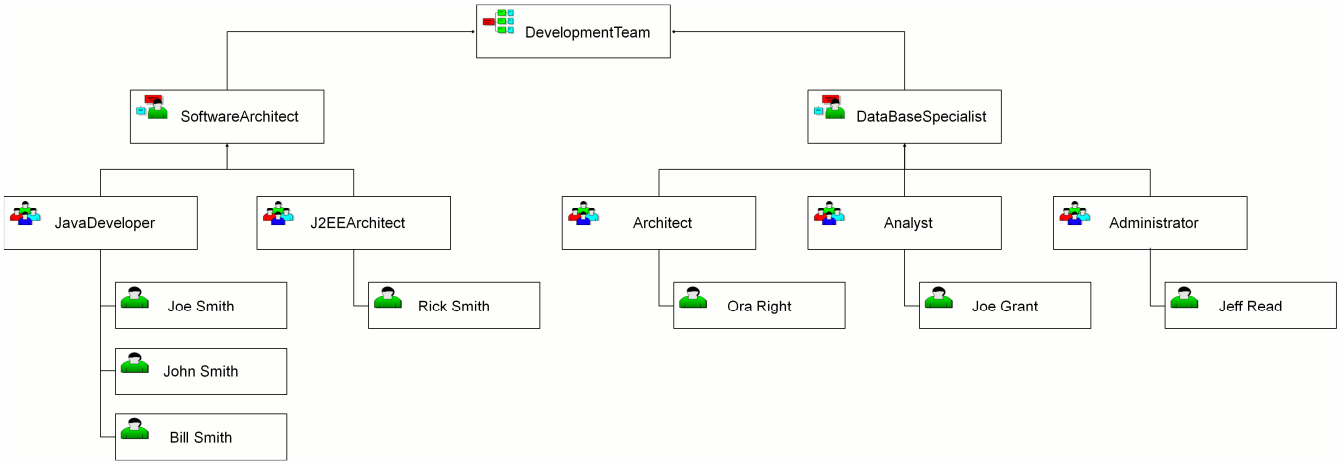

Figure 5. Development team as HRMM instance

Figure 6 depicts two competence profiles. The competence named `ArchitecturalDesign` (Figure 6a) contains knowledge of UML (`UMLLanguage`) and design patterns (`DesignPatterns`) and the skills modeling of class diagrams (`modelUMLClasses`) and the reuse of design patterns (`patternReuse`). Similarly, another competence schema design of relational databases (`SchemaDesign`, Figure 6b) contains the knowledge of the disciplines relational algebra (`relationalAlgebra`) and query languages (SQL) (`sqlLanguage`). Furthermore, the skill to design an appropriate relational schema according to requirements is associated to `SchemaDesign`.

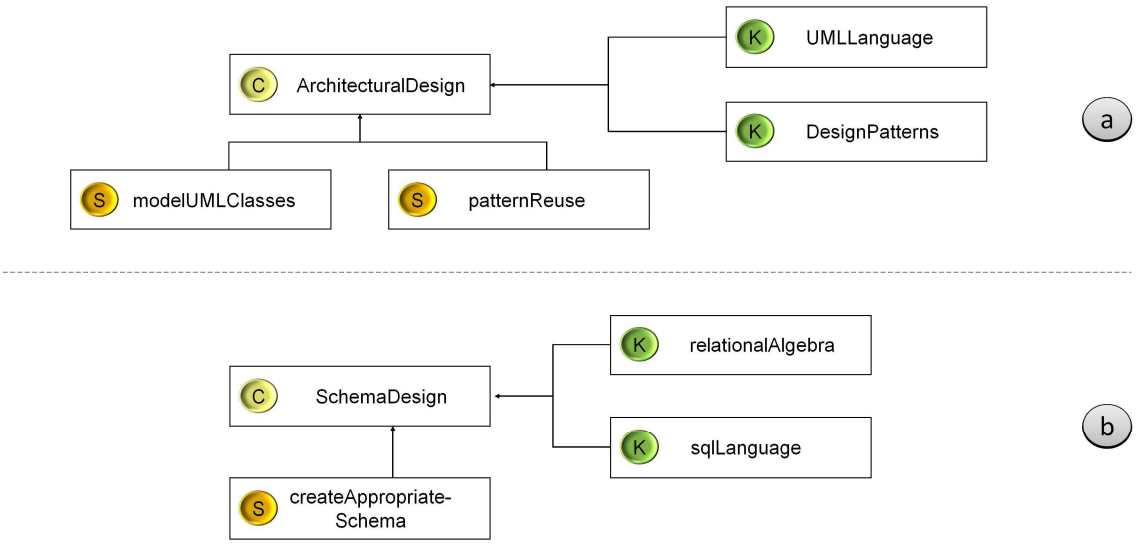

Figure 6. Example - Software Engineering Competences

While some associations between roles and competences might seem to be obvious (such as `ArchitecturalDesign` for a `DataBaseSpecialist`), others are not. Especially competences associated to a human resource but not to its associated roles are difficult to manage if not explicitly modeled. Further education measures for instance may add competences or skills to an employee which may not be derived by role definitions. In our example Bill Smith has the competence `SchemaDesign`, although his role does not (Figure 7).

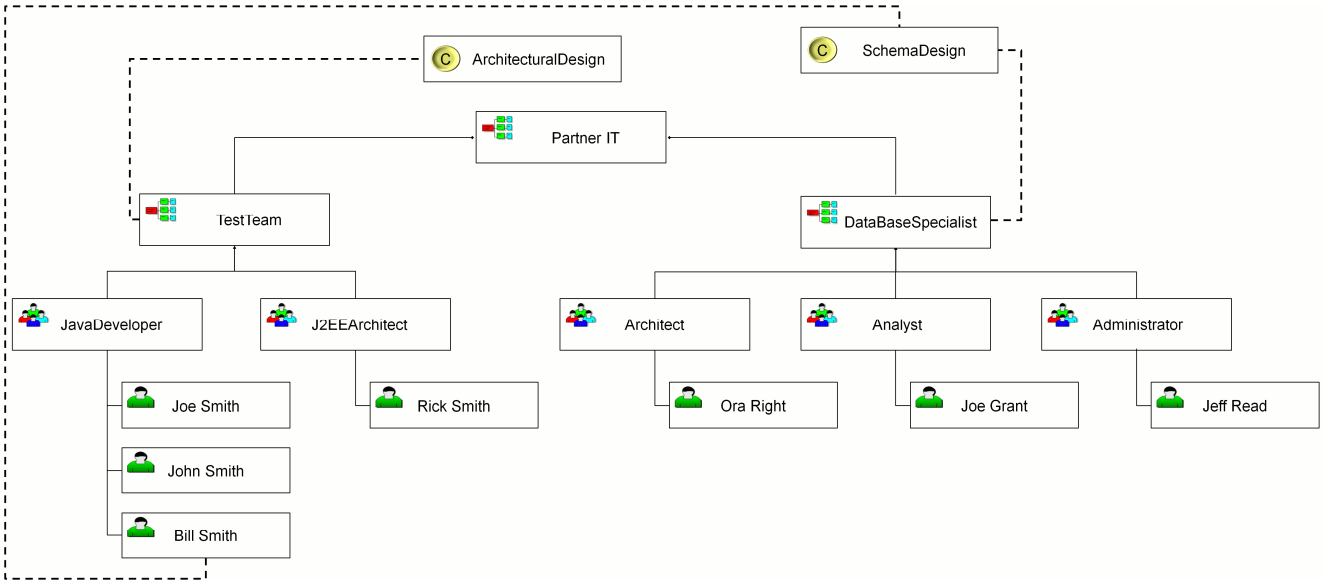

Figure 7. Development team as HRMM instance including competences

The business process illustrated in Figure 8 depicts how the development team handles trouble tickets. Responsibilities are evaluated according to the ticket type. If a ticket causes changes in business process objects that entails changes or creation of database schemas, classical (role-based) scheduling methods will assign this task to a resource associated with an appropriate role (in our example one of the data base specialists). Once the assigned roles are temporally or spatially unavailable, the task remains incomplete. In this case the `JavaDeveloper` Bill Smith (if available) is also qualified to execute this task since he has the competence `SchemaDesign`. However a process engine that allocates the tickets is not capable to assign this task to Bill Smith.

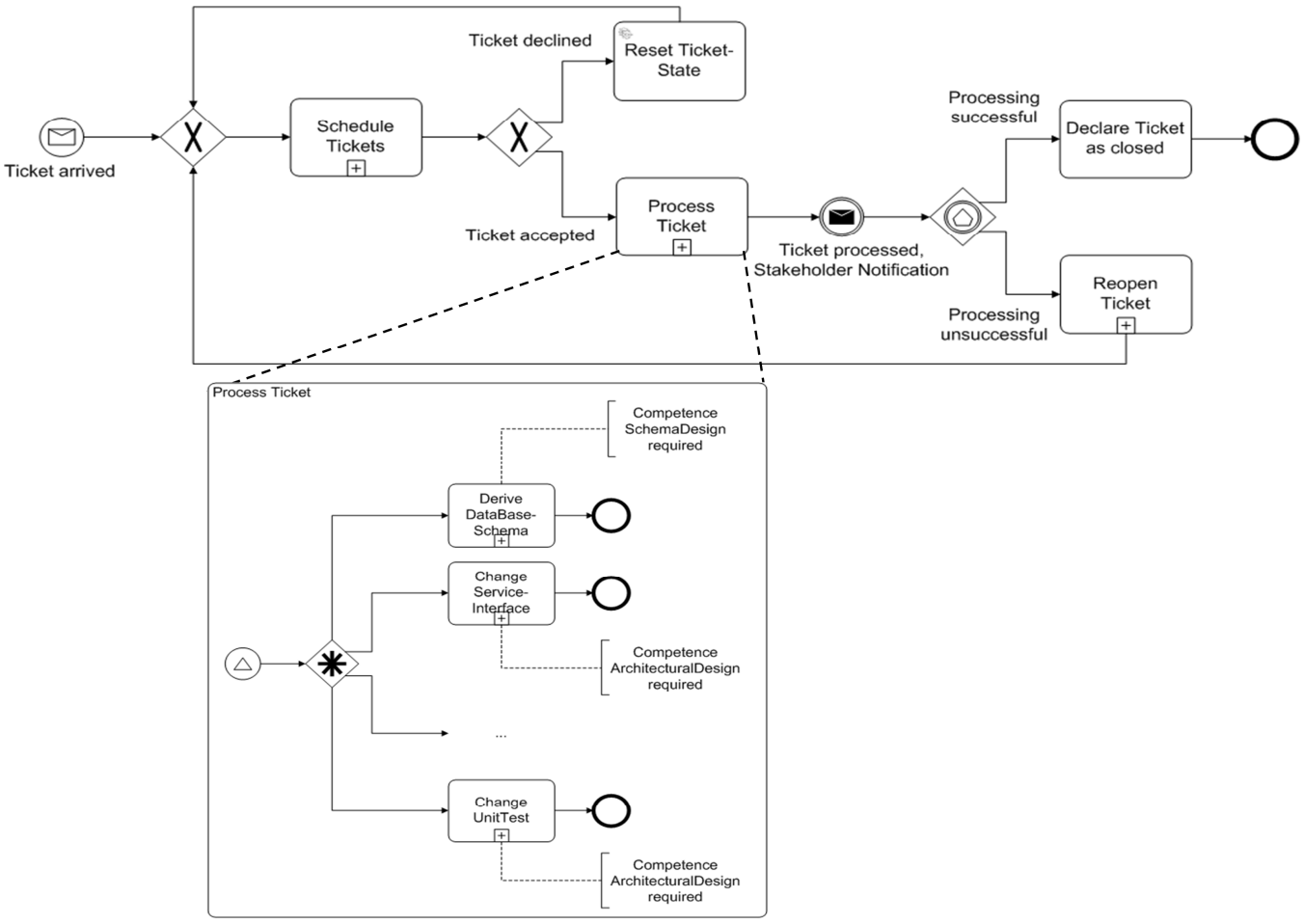

Figure 8. Ticket workflow as BPMN process

This example reveals that assignment decisions can be improved through competence enriched resource models and advanced scheduling mechanisms. In general the association of required competences with tasks instead or in addition to required roles may also restrict possible resources. The latter can occur if required competences or skills are only possessed by some resources. It has to be denoted that some combinations of competences may create business process models that are not executable, because the combination is not met by any resource. Therefore on the one hand, model checks are required; on the other hand it is necessary to develop appropriate mechanisms that allow to measure if a resource is capable to complete a task despite its competences do not exactly match the requirements.

CONCLUSION AND OUTLOOK

In this paper we have outlined aspects of resource and business process modeling; furthermore we have shed light into associations between both modeling disciplines. The presented resource meta-model (RMM) demonstrates the potential of the combination and extension of known concepts in resource modeling, competence modeling and business process management. Particularly during runtime, advantages in allocating resources through explicit modeling of competences can be achieved; the extension of scheduling mechanisms can avoid bottlenecks through more adaptable task assignment strategies. Moreover we were able to exhibit that the systematic combination of staffing strategies and business process modeling generates benefits on both sides. On the one hand competence and resource models of human resource departments can be re-used for the modeling of resources from the perspective of a business analyst; on the other hand competence models of personnel departments can be adapted to the actual needs of the business processes. These adapted competence models can in turn be used to improve recruitment of new employees or to set up measures for further education of the existing personnel.

To extend the concepts outlined in this paper, we plan to improve business process execution by specifying scheduling mechanisms and mechanisms for competence gap analysis, to allow the allocation of resources to tasks based on

competences and skills. Therefore we aim to develop appropriate metrics (in this case, similarity measures) to assess whether a resource has sufficient competences and skills to be utilized for or to be able to perform a certain task. The latter is inevitable since situations may occur in which none of the available or existing resources covers all requirements associated to a certain task. By specifying transformations that combine information provided by directory services (like LDAP) with existing competence models (such as HR-XML) we strive to generate RMM-based resource models automatically. In addition, we plan to enhance our resource meta-model with additional, industry-sector-specific features (such as the description of services or the addition of measures to evaluate sustainability).

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