The Evaluation Criteria of Workflow Metamodels

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Abstract. This paper defines the evaluation framework of workflow metamodels, based on a list of evaluation criteria. The presented evaluation criteria combine domain specific evaluation approach and some of the existing quality metrics, defined in the field of software. Well established evaluation criteria of workflow metamodels should enable their comparison, selection and proper use of methods and tool built upon them. The final result is a list of nine categories of evaluation criteria, decomposed into more than forty subcategories, but the list of subcategories is extendable. The practical validation of proposed evaluation highlighted some topics for future research.

Keywords. Workflow, modelling, business process, metamodel, evaluation criteria

1. Introduction

Over the last decades Business Process Management (BPM) has been identified as a solution for resolving complexity, as well as defining and managing tasks in heterogeneous environments. The role of workflow in the BPM has significantly changed in recent years, from the process definition, to the model driven development (MDD). The terms of business process and workflow are related and widely discussed in literature. Business process can be defined as a set of activities ordered in a structured way, whose final aim is to provide valuable results for the customer. In a broad sense, workflow is used to denote the movement of documents and/or tasks through a work process, how tasks are structured (a set of tasks/actions), who performs them (people and computer system), what their relative order is (the order in which specific work is performed), how they are synchronized, what is the time required to complete tasks, what are information flows between tasks and how tasks are being tracked.

A continuing interest from the research and commercial community also triggered adequate academic and commercial research and development. Currently many of modelling languages and tools are used for workflow definition in the BPM systems. The large number of available modelling methods and tools and their diversity caused a lack of integration and interoperability, difficulties at selection, as well as the problems when heterogeneous approaches should be effectively combined.

The emerging need of standardization and integration of workflow-related methodologies and tools mobilised both academic and industrial communities on development and evaluation of business process and workflow metamodels.

Based on the comparative analysis of related work, analysis of current workflow metamodels and frameworks and current standards, this paper defines a list of criteria that can be used as evaluation dimensions of workflow metamodels. The presented evaluation criteria combine domain specific evaluation approach and some of the existing quality metrics, defined in the field of software.

2. Workflow Metamodels

Generally, a metamodel is the conceptual model of a modelling methodology, representing concepts and relations between concepts, frames, rules, constrains and theories, applicable and useful for the modelling in a predefined class of problems. While a model is an abstraction of phenomena in the real world, a metamodel is an abstraction of the model itself. A mMetamodel comprises an explicit description (formalized specification) of constructs, rules and notation for building domain-specific models. Although the concept and the theory of metamodels and metamodelling are widely discussed and applied in many scientific, business and real life domains, they do not exist in a strict, universal form.
The goal of this paper is not to give a profound explanation of metamodels, metamodeling theory and system engineering, but rather to describe how the term of metamodel is applied in this paper.

Strictly understood, the term of metamodel can be put in relation with the OMG’s MOF (Meta Object Facilities), which is an abstract framework and a four-layered architecture for defining and managing metamodels, neutral of any technology [11]. MOF is applied on the abstraction hierarchy of the OMG's Unified Modelling Language (UML) [10] and some other specifications and standards, like the Product Data Management Enablers Specification [9], aimed to the management of the product engineering process and the Business Process Definition Metamodel (BPDM) [8]. The BPDM is:

- a representation of business process modelling concepts and relationships
- a MOF-based metamodel, consistent with the MDA (Model Driven Architecture) approach in providing a representation that separates implementation choices to other stages of system design, but it is not simply an extension or profile of UML or EDOC
- a metamodel for the Business Process Modelling Notation (BPMN) supporting its graphical notation, accompanied by an XMI standard format for model exchange, with added support for SOA

During the last decade a number of initiatives have been undertaken in order to propose and standardize reference enterprise architectures, as well as data and process models. CIMOSA (Computer Integrated Manufacturing Open System Architecture) represents one of the most popular enterprise modelling architectures, defining concepts and rules to facilitate the building of open computer integrated manufacturing (CIM) systems (http://www.cimosa.de/). It was developed by the AMICE Consortium, in an EU project. Another example of vertical process reference models is the Supply-Chain Operations Reference (SCOR). It has been developed and endorsed by the Supply-Chain Council (SCC) as the cross-industry standard diagnostic tool for supply chain management (http://www.supply-chain.org/cs/root/home). UN/CEFACT’s Modelling Methodology (UMM) [15] prescribes a standardized way to perform business process and information modelling for E-Commerce. It uses UML as language and can help to create executable business choreographies in business process languages such as BPEL or BPSS.

Taking into consideration all stated above, in this paper we are using the broader understanding of metamodels, covering the following:

- Generic models describing the entire family (class) of modelling instances in more general terms
- Conceptual models describing functional information and other relevant aspects of the problem domain on a high abstract level, suppressing non-critical details
- Reference models defining a common model for the construction of workflow systems and identifying how it may be related to various alternative implementation approaches
- Vertical models focused on specific business domain or industry
- Business pattern based on best practice of some domain, which can be reused and transformed into explicit models
- Ontologies expressing the nature of the specified universe of discourse by utilizing a vocabulary, a grammar and rules how they can be used together.

We can conclude that the main role of workflow and process metamodels is definition, representation, diagrammatical visualisation and gaining of understanding of concepts, structure and behaviour of some methodology. This role can be extended to other problems, but this requires appropriate evaluation framework, as described further in this paper.

3. Related Work and State-of-the-Art

Different approaches, concepts, methods, metamodels and tools concerning BPM and workflow systems have been extensively discussed in relevant scientific and professional studies. Some of these approaches are standardized. Important inputs for the evaluation of metamodels are in the field of evaluation of process modelling languages and in the field of comparison of information system design methodologies. These comparisons focus on the
syntax and semantics of modelling methods and the underlying languages, but also stress some non-technical aspects.

From the point of view of this paper, object of interest are research efforts concerning workflow metamodels and their evaluation. List of such studies is respectable.

Lei and Singh [7] identified categories of metamodels and proposed a list of eight evaluation dimensions: granularity, control flow, data flow, organizational model, role binding, exception handling, transaction support and commitment support in terms of flexibility. Zur Muehlen [17] has focused on the evaluation of workflow management systems using their metamodels. Becker et al. [2] developed Guidelines of Modelling (GoM) that comprise a set of both general and user-specific guidelines. Three of them are mandatory (guideline of correctness, guideline of relevance and guideline of economic efficiency) and three are optional principles (guideline of clarity, guideline of comparability and guideline of systematic design). Johannesson et al. [5] analysed in their paper three issues: business orientation (more in terms of understandability), traceability (more in terms of commitment support) and information correctness. Carvallo et al. [3] developed the quality model for the workflow type of tools. Wolf and Harmon highlighted workflow system requirements [16]. Kalnins and Vitolins [6] addressed in their paper: possibility to model data flows, process data, different types of tasks (in terms of applicability and business orientation), control structures and resource management. YeongSeok et al. [18] established quality evaluation metrics for BPM. Rolón et al. [12] defined a set of metrics for the evaluation of maintainability of conceptual models of business processes.

4. Methodology

Evaluation criteria of workflow metamodels are a subject matter of quality. That was the reason to seek out the basic ideas for determination of evaluation criteria of workflow metamodels in the field of software quality metrics, i.e. in the ISO 9126 [4] that is an international standard for the evaluation of software. This standard defines the quality model and classifies software quality in a structured set of characteristics and sub-characteristics that are further divided into attributes. The attributes are not defined in the standard, but it is presumed that their later definitions should be later provided, i.e. some metrics is needed. The basic set of evaluation criteria was extended by some non-technical and domain specific attributes, following ideas presented by Carvallo et al. [3].

The final result is a list of nine categories of evaluation criteria, described and decomposed into subcategories.

5. List of evaluation criteria

Considering different, sometimes conflicting requirements, the list of evaluation criteria for workflow metamodels and frameworks can be nominated, as follows:

I. Domain of application

Applicability of workflow metamodel and models built upon it means business orientation and possibility to apply it for the specified class of problems and types of processes [6], but also partly corresponds to usability and suitability. Generality means that the methodology and metamodels as its constitutive parts are applicable as generally as possible, in order to be shared by various communities and classes of problems. As opposed, the term speciality means applicability to the class of problems distinguishable from others of the same general category.

II. Origins

Theoretical foundation means that the modelling framework and the metamodel are well-founded on relevant, widely-accepted and sound theories. Comprehensiveness of the metamodel itself means that it contains concepts and constructs needed to model all the phenomena of reality, i.e. of the object system. Traceability means tracking the decisions back to theoretical foundations and previous metamodels, i.e. from the current metamodel and modelling framework to its origins. This is the vertical traceability. The horizontal traceability means keeping track between releases of the same metamodel or other parts of the methodology. Maturity means that the metamodel and underlying methodology are described, published and standardised, examples of its application and evaluation in both laboratory and industrial environment are given and documented, the computer support of methodology is available, the methodology is supported by user groups, consulting business is growing around the methodology and further development and redesign of initial theory is
undertaken, based on application in industrial environment.

III. Concepts and constructs
Evaluation of metamodels and modelling methods usually starts with the assessment of modelling concepts and constructs. From the point of view of workflow metamodels basic concepts and constructs are: Tasks, Control Flow, Data Flow, Resources Organization and other.

IV. Modelling Language and Notation
Syntax of modelling language is the grammatical arrangement of words in sentences, as set up in the metamodel. It comprises a set of structural (grammatical) rules, reserved words and their parameters and the correct way in which modelling concepts have to be used. Semantics, in the context of modelling theory, deals with the meaning systems of modelling language and concepts, as well as their mapping to the real world. Semantic anomalies are violations of meaning and sense. Visualisation postulates a graphical language relying on already established business process modelling notations [1]. Syntax of graphical languages comprises a notation and rules of structure/patterns that govern the way in which they may be related. The notation is a system of symbols for modelling concepts used to represent unique things. Expressiveness is ability to establish and preserve consistent relationships between models depicting a real-life object and universe of discourse itself, from different perspectives. Naturalness means that the modelling framework inherits concepts and abstractions close to the human mental concepts and way of thinking. Formalization denotes the extent to which a language and inference or transformation rules are formal, i.e. building a formal system. Formalisation entails the ability to process or execute by machines. Execution semantics means that workflow definitions are rich, expressive and formal enough to allow execution by some workflow engine (execution tool), as the final step of the workflow development or just for validation purposes.

V. Cohesion
Cohesion is a measure of how well the artefacts of the metamodel and modelling framework work together to provide a desired functionality and performance. Coherence means that modelling concepts should be related to each other directly or indirectly, to build a coherent framework. Granularity is, generally, a level of detail at which an item is described or some information is viewed or described. In workflow systems, granularity indicates the abstraction level of the basic element, which is usually a task. Course granularity occurs at the context level, where the business processes communicate with external entities. The middle range of granularity is inside the business process where the task can have a fine structure of its subtasks. The finest granularity is the internal definition of the task. Consistency of the modelling framework or the metamodel implies that there are not some conflicting statements, rules or definitions of the same fact or situation. Some of the appearances of inconsistency are redundancy, unnecessary conditions, logical contradiction, subsumed rules, circular rule, naming conflicts (synonyms, homonyms), dangling references, inconsistent generalization/specialization and other logical/semantic contradictions. Completeness means that there is no one relevant modelling concept that could be added to the metamodel without creating inconsistency. Completeness issues are: missing concepts and rules, dead-end rules, unreachable concepts, dangling references, unreferenced attribute values and other unintentional non-determinism. Relevance (usefulness) of the metamodel means it is incomplete after removal of some modelling concept. Relevance depends on the presumed application domain and on the level of abstraction that the metamodel targets. Correctness means both completeness and consistency and has a syntactical and a semantic aspect. Syntactical correctness of a metamodel itself means both completeness and consistency with reference to the underlying theory. Furthermore, syntactical correctness, i.e. completeness and consistency of derived models is defined with reference to the corresponding metamodel. The semantically correct metamodel enables building of models that retain the structural and behavioural features of the corresponding real-life object system.

VI. Openness
Openness is a widely used term that comprises interoperability, replaceability, integratebility and extensibility of different modelling frameworks and metamodels, which are syntactically and semantically harmonized. Replaceability is the opportunity and effort of using the specified method or concept in the place of other methods in the workflow definition and software development environments [4, A.2.6.4]. Interoperability is
the ability of one framework to interact with others [4, A.2.1.3]. Interoperability and replaceability are used in place of compatibility in order to avoid possible ambiguities. **Integrability** is ability to integrate metamodels and build a consistent and comprehensive whole. Openness postulates **modularity**, i.e. that their interface specifications are fully defined, available to the public and maintained according to group consensus. When reached at the meta-level, it is expected to be achieved in models that are further developed, based on these metamodels.

**VII. Usability**
Usability comprises a set of associated features that bear on the effort needed for use. **Understandability** denotes the users’ effort for recognizing modelling concepts, language, notation and the entire metamodel. Conceptual understandability is a subjective assessment of the modelling method’s elements and constructs, which may sometimes be in conflict with the model’s syntactical correctness. **Clarity** refers to representational issues such as a structure, a graphical representation, and a general readability of a metamodel [2]. Clarity means **unambiguity** and distinction between concepts. In visual representation, clarity means using the minimal symbolism necessary to represent some structural or behavioural property on the diagram (i.e. relevance).

**VIII. Maintainability**
Maintainability is the effort needed to make specified modifications of a metamodel [4, 4.5]. **Analysability** of a metamodel is assessed in terms of the effort needed for diagnosis of deficiencies, anomalies and for identification of parts to be modified. **Changeability** bears on the effort needed for modification and fault removal. **Stability** is assessed in terms of the risk of unexpected effect of modifications. **Testability** bears on the effort needed for validation and verification of the modified metamodels. **Extensibility** means that metamodel is extendable with new concepts or some existing concepts are further developed. Extensions should not cause revisions of existing definitions, i.e. the metamodel should be consistent after extensions.

**IX. Pragmatic aspects**
Pragmatics is the study of information structure and the use of language in communicative context. Pragmatics is concerned with bridging the gap between a theory and its implementation in some context. **Operability** is the ability to implement the modelling framework or the metamodel and to use them operationally. **Ability to execute** [7] is one of attributes of operability, which requires appropriate execution semantics, dynamic assignment of actors during the run-time, transaction support, exception handling etc. **Efficiency** is the relationship between the amount of resources and time required to perform some modelling activity and resulting functionality and performance of deliverables. **Adaptability** is the opportunity for specialisation and adaptation of modelling concepts and methods to different domains and organizations [4, A.2.6.1] **Flexibility** means that workflow patterns can really differ in different cases and when performed by different actors. The challenge is to achieve flexibility, but preserve correctness of the workflow system, based on the commitment support.

6. Conclusion
As presented in this paper, well established evaluation criteria of workflow metamodels should enable their comparison, selection and proper use of methods and tool built upon them. Ultimately, this is a prerequisite for building effective workflow systems.

The purpose of this paper was establishment of evaluation criteria for workflow metamodels, based on the comparative analysis of related work, analysis of current workflow metamodels, modelling frameworks, current standards, and practical experience. The presented evaluation criteria combine domain specific evaluation approach and some of the existing software quality metrics.

The final result is a list of nine categories of evaluation criteria, decomposed into extendable list of subcategories.

Proof of the concept and practical assessment of proposed framework was performed on two different cases, where evaluation of metamodels was needed:

1. Selection of modelling methods and metamodels at the project of modelling procedural aspects of case management at Croatian courts [14] (role of the metamodel: comparison, evaluation and benchmarking of different applications and tools; integration platform for the exchange of models, specified in different languages and methods)

2. Process reference model for IT service management (ongoing project, role of the
metamodel: definition, visualisation and gaining of understanding of concepts, structure and behaviour of some theory or domain; organisation- and technology-independent platform for development of models and applications).

Results of assessments are collected by using a simple spreadsheet application and presented in a form of radar graph. Practical application generally confirmed the presented evaluation framework, but also highlighted some topics for future research. First of all, a more precise definition of evaluation criteria is needed to improve clarity of the framework. Assessment of metamodels by using the proposed framework lies on the individual capabilities and competences of its respective users, hence it is subjective. This implies that the quantification, formalization and metrics should be implemented wherever possible, to eliminate subjective assessment. The scope of coverage of evaluation criteria could also be increased beyond the technical and pragmatic issues. The criteria concerning some social and common sense issues, like customer satisfaction, learning organization and teamwork should be further developed.

7. References