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Using XMI and MOF for Representation and Interchange of Software Processes

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Abstract

Software Processes involve many different aspects. ereby, to represent them in a system can result a ficult task. One way of making this work easier is to ablish the different aspects in a conceptual chitecture with varying abstraction levels etamodels, models, metadata, data), which can be ecified, designed and constructed independently. The oblem that then arises is how to deal suitably with the ferent abstraction levels. We propose MOF and XMI ndards as a solution.

This paper describes the advantages of using MOF d XMI to represent software processes. A concrete mple is presented using a software process tamodel, which illustrates the basic components of a ocess software.

Introduction

A software process consists of a set of concurrent l cooperative activities, that are as much related to the 'elopment and maintenance of software, as to the ject management and product quality.

Software processes are intrinsically complex since y involve many activities, many types of knowledge information, and many people, each of them with erent responsibilities and skills [1]. Due to this nplexity it is advisable to develop a conceptual onomy which, based on the idea of encapsulated ers, divides the concepts into different levels of traction such as metamodel, model, metadata, and ı. Thanks to this division the different layers can be cified, designed and constructed independently.

However, when different abstraction levels are defined ltilevel conceptual architectures), correct management of the data and metadata and the relationship between these becomes an essential aspect.

The MOF standard is "a model for specifying, constructing, managing, interchanging and integrating metadata in software systems [6]. Thereby, by using this standard a correct management of the metadata and data may be performed systematically.

Another advantage of the MOF-model is that it can be represented by UML diagrams (a well-known and widely used standard). MODL language (Meta Object Definition Language) can also be used, although in order to use the models automatically and to be portable among different tools in a Software Engineering Environment it is more advisable to represent them by using a metadata interchange standard such as XMI (XML Metadata Interchange), based on XML (extensible Markup Language).

The aim of this paper is to present the advantages of using MOF and XMI for the representation and interchange of software processes. The content of this paper are organized as follows: Section 2 describes the MOF standard, its features, and how it may be represented by XMI. Section 3 outlines a software process metamodel in order to illustrate how to represent it by using MOF. Section 4 presents a repository and a tool which, based on the previous standards, have been developed to manage software processes. And finally section 5 comments on related work and ends with some conclusions.

2. MOF Standard

MOF (Meta-Object Facility) is a standard supported by OMG (Object Management Group). This standard includes two main parts:

- MOF architecture, formed of four metadata levels,

which propose a generic pattern for the construction of systems centered on the metadata.
- The MOF model, which is the standard language for the metadata that define different classes of metadata.

An important aspect of MOF is its definition of model. In real life a model is an abstraction of the reality. For MOF the concept of model has a wider meaning. A model is any collection of related metadata because:

- they describe interrelated information.
- All the metadata defined follow a set of rules which define their structure and consistency (in other words, they are based on an abstract language).
- The metadata have meaning in a common semantic frame.

2.1 Conceptual Architecture

The main proposal of MOF is to support any type of metadata and to allow the incorporation of new ones when it is necessary. In order to reach this goal MOF uses four layers architecture similar to other standard proposals for metadata such as CDIF (CASE Data Interchange Format) by ISO/IEC (2000) [3] or OIM (Open Information Model) by the Meta-Data Coalition [5] which has recently been joined to OMG, adopting the MOF standard. In general all these standards include the following layers:

- *Users objects* layer, includes all the information that it is necessary to describe. This information is often known as "data".
- *Models* Layer, formed of metadata which describe the information. Joined metadata are considered as models (according to the previous definition of model).
- *Metamodels* Layer, includes the descriptions (meta-metadata) that define the structure and semantic of the metadata. Joined meta-metadata are considered metamodels.
- *Meta-metamodel* Layer, includes the description of the structure and semantic of the meta-matadata. Thereby, it is a language to define different classes of metadata.

The architecture of MOF is also based on the previous layers but MOF adds some details, thus being more flexible and powerful than other earlier proposals. The main MOF features are:

- MOF is object-oriented, thereby it supports metamodel constructors similar to UML constructors. Thus, it supports any kind of metadata which can be described using object-oriented techniques of modeled.
- MOF is formally defined by using its own constructors. Thus, the meta-metamodel (in other words, MOF) is auto-descriptive.

2.2 The MOF Model

The MOF model (level M3 in the conceptual architecture of MOF) is the meta-metamodel for the description of a metamodel belonging to level M2. It plays a roles similar to UML [7], being an abstract language for definition of UML models, which would be in level M1 of the MOF architecture. UML and MOF have the same main concepts and constructors. The UML concepts such as Class, Association, Package, Attribute, Constraint, etc, have their equivalents in MOF (although with some simplifications).

The difference between both is that: First, MOF is a level higher (in abstraction) than UML. Second, they have been designed for two different types of model: Metadata in the case of MOF and data (objects) in the case of UML.

2.3 MOF and XMI

The relationship between MOF and XMI is evident, since XMI is a metadata interchange format defined according to MOF. XMI joins three standards considered critical by the current information system industry: XML, UML and MOF. Thus, allowing system developers to share models and metadata via Internet and also reducing the number of metadata interchange formats used. In order to use XMI is necessary to define a set of DTD production rules to transform metamodels based on MOF into DTDs (Document Type Definition) in XML format. These DTD's are used like syntax for the construction of documents.

There is some correspondence between MOF and XMI. One of them is between the XML DTDs and the metamodels belonging to MOF level M2. Another is produced between the MOF metadata (level M1) and XML documents, Figure 1 shows these relationships. As Figure 1 indicates, the two modules which form the XMI specification access to the MOF interfaces to obtain the information about the models and metamodels and from these to construct the corresponding XML documents and DTDs. Therefore, XMI documents allow the establishing of one correspondence between two consecutive abstraction levels (levels M3-M2 or levels M2-M1).

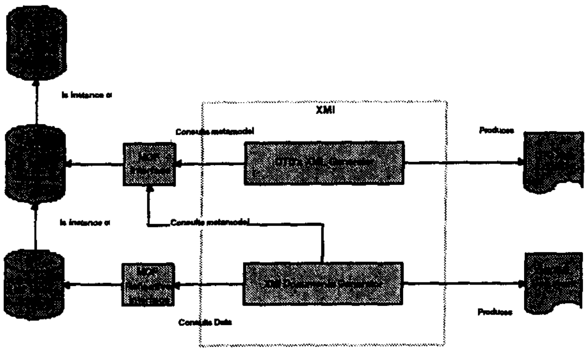

Figure 1: Relationship between MOF and XMI

XMI has the advantage of enabling that the metadata to be interchanged like files or flows with a standard format based on XML. Moreover, the architecture offers a wide range of implementation possibilities for developers.

3. Software Process Metamodel

There are different proposals for the process metamodel. For instance, SPEM (Software Process Engineering Metamodel Specification) [10] proposes an OMG metamodel based on UML and MOF. This paper presents one more simple metamodel (for details see [8]) which illustrates the basic components of software processes (see Figure 2). In a wider metamodel the classes *project* and *constraint* were also considered. However, here they have been omitted in order to focus on the elements of a project.

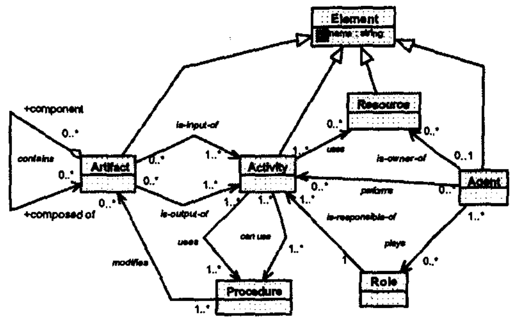

Figure 2. Software Process Metamodel

The following tables show the relationship between the basic MOF constructors and the elements displayed in Figure 2. In order not to make this paper too long, only seven relationships are represented, although there are fifteen in reality. Table 1 displays the relationships between M3 and M2 level.

Classes M3	Classes M2 (instances M3) Abbreviation	
MOF Class	Act	Activity
	Age	Agent
	Art	Artifact
	Ele	Element
	Pro	Procedure
	Res	Resource
	Rol	Role
MOF Attribute	Name	Class: Element
MOF Relationship	Contains-Art-Art	Artifact contains Artifact
	Plays-Age-Rol	Agent plays Role
	Is input of-Art-Act	Artifact is input-of Activity
	Is owner of-Age-Res	Agent is owner of Resource
	Is responsible of Rol-Act	Role is responsible of Activity
	Is output of -Art-Act	Artifact is output of Activity
	Is a-Act-Ele	Activity is a element

Table 1. Example of Relationships M3-M2

The following step is to represent the relationships M2-M1. In this case the Classes M1 act as instances of the previous level (class M2). Table 2 displays such relationships. The activities represented are the "non-plannable maintenance activities", in other words, those that are performed when there is urgent corrective maintenance. As in the previous case not the whole table is shown, just an example.

Classes M2	Classes M1 (instances M2)
Act Activity	Error analysis
	Intervention closing
	To fill in documentation
	To perform unit testing
	Urgent corrective intervention
	To investigate and analyse causes
	To perform corrective actions
Age Agent	Maintainer
	User
Art Artifact	Test case
	Software elements to correct
	Documentation about the corrective actions performed
	Old software element
	Corrected software element
Contains-Art-Art Artifact contains Artifact	"Software product" contains "Documentation"
Plays-Age-Rol Agent plays Role	"Maintainer" plays "Maintenance staff"
	"User" plays "User"
IsInputOf-Art-Act Artifact is input of Activity	"Software element to correct" is input of "To perform corrective actions"
	"Old software element" is input of "To fill in documentation"

Table 2. Examples of relationships M2-M1

4. A Repository for Software Process Metamodeling

In order to make the management of the software process metamodel automatic, a repository was developed.

The repository had two main goals:

- Offering the information contained in the repository to all that need it.
- Importation / exportation of models and meta-models.

In order to attain its goals the repository uses four conceptual levels based on the MOF standard (see Table 3).

Level	MOF	Repository	Examples
M3	MOF-model (meta-meta-model)	MOF-model	MOF-class
M2	Meta-model	Generic SP meta-model	Activity
M1	Model	SP models (concrete methods and techniques)	Codification
M0	Data	SP instances	Codification of the PXB module

Table 3. Correspondence between the conceptual levels of MOF and the Repository.

Level M0 is where the real specific software projects (with time, cost and resources restrictions) are found. The data dealt with at this level are instances of the concepts defined in the upper level M1. The specific models in level M1 represent the methods and techniques specific for each application domain. Level M2 corresponds to the software process (SP) generic meta-model. In M3, the last conceptual level, the SP meta-model of M2 level is represented as an MOF-model. An MOF-model basically comprises of two types of objects: MOF-class and MOF-association (from our point of view these are the principal objects, although others do exist: packages for reuse purposes, types of data, etc.). Consequently, all the concepts represented in level M2 are now considered examples of MOF-class and MOF-association [9]. For example "Activity", "Resource" or "Artefact" are examples of MOF-class and "Activity uses Resource" or "Artefact is input of Activity" are examples of MOF-association.

In Figure 3 we can see the basic operation scheme of the Repository tool with its principal functions. As can be seen in this figure, the repository provides generic

CASE tools for meta-modeling with two basic services: the storage and importation of meta-models. The CASE tool for meta-modeling calls up these services from its control layer and provides repository with all the necessary information (contained in a set of objects grouped in the specified class hierarchy) for the generation of the XMI documents that represent the correspondence between the different levels and the DTD that represents each type of XMI document generated. For the generation of XMI documents and their associated schemes, the repository tool uses the generation rules specified in the XMI standard. Finally, the manipulation of the repository, that is to say, the storage and retrieval of information at document level, is carried out using the Document Object Model (DOM) [12]. This standard provides a collection of classes that represent the hierarchic structure on which all XML documents are based. The model provides classes that represent documents, nodes, list of nodes, etc., with the necessary properties and methods for the construction and editing of XML documents.

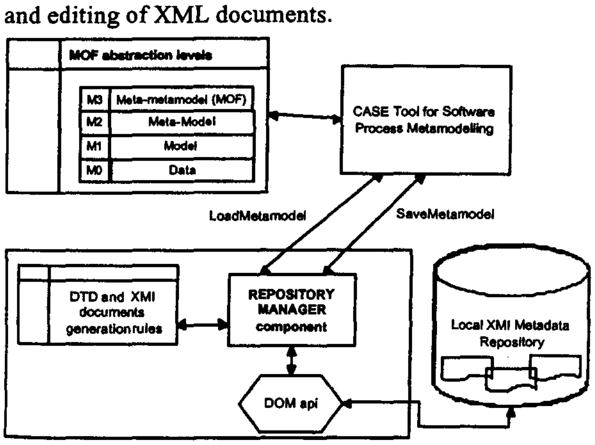

Figure 3. Repository interacting with other MOF-based Tools.

In order to prove the repository efficiency two tools were developed. Both used the repository described. In this paper we are going to comment on MANTIS-Metamod, a tool for representing and managing software process metamodels. For the realization of the application we have used a three-tier architecture [4]. These tiers are: presentation, application logic and storage. This last tier is where the XMI repository is.

To receive user data, the application is composed of a metamodel administrator and of a system of windows that allows a visual description of the classes that make up the core of the MOF model (Package, Class, Datatype, Attribute, Operation, Reference, etc).

The metamodel administrator has a three-shape structure, as does the MOF model: a package contains classes and associations, a class contains attributes and operations, an association contains restrictions etc...

The system of associated windows allows the description of the classes that make up the core of the MOF model. For example, an instance of MOF-class could be the level M2 class "Actor" belonging to the metamodel SMP. This instance of MOF-class, (see Figure 3), makes it possible for any element of the model to use it (visibility=public_vis), it is not abstract (is-abstract=false), it can have supertypes (is-Root=false), it can be a supertype (is-leaf=false) and only one level M1 instance can exist at most (is-singleton=false).

The models defined for the user by means of the interface are validated and internally represented according to the hierarchy of the classes described by the MOF model, as specified in the IDL document attached to the MOF standard.

For the storage of the metamodels (level 2 defined with MOF) we must use XMI that, as it has previously been commented, facilitates the interchange of information and, as a result, gives the tool great flexibility.

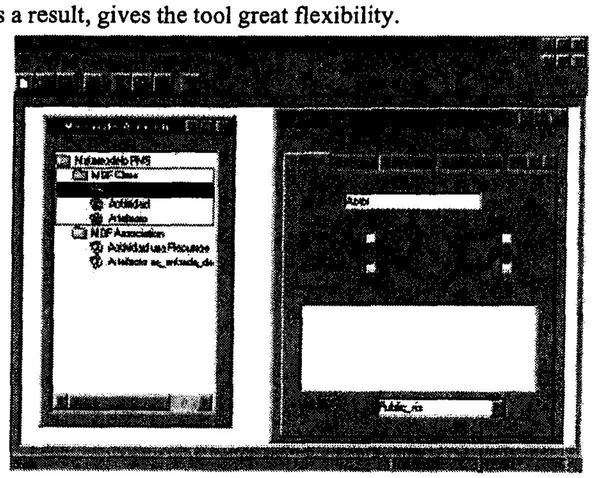

Figure 4. Users can edit models and metamodels by using MANTIS-Metamod

5. Related Work and Conclusions

There are several examples of recent literature that demonstrate the advantages of MOF and XMI for the construction of CASE tool and SEE repositories. The project FAMOOS (Framework-based Approach for Mastering Object-Oriented Software Evolution) is a good example of this [2]. The goal of this project is to build a framework to support the evolution and reengineering of object-oriented software systems. With this aim in mind, FAMIX, a language-independent meta-model (in M2 level of MOF) for describing object-oriented source codes at the program entity level, has been developed [11]. The repository presented in this paper could be used as a repository manager by storing the meta-model FAMIX (together with its associated DTD) and a model (in M1 level) for each of the programming languages used.

This paper has shown how MOF facilitates the representation of software processes, which are very complex, due to the large number of aspects that have to be considered.

On the other hand, a concrete software process metamodel has been described in order to illustrate how it can be represented by using MOF. Finally the tool described has exemplified how information about the software processes can be exported to other systems and how new information may also be imported from other tools that use XMI, thus increasing the interchange of information.

Acknowledgements

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