A Model-driven and Service-oriented framework for the business process improvement

Andrea Delgado[1], Francisco Ruiz[2], Ignacio García-Rodríguez de Guzmán[2], Mario Piattini[2]

[1]Computer Science Institute, Faculty of Engineering, University of the Republica Julio Herrera y Reissig 565, CP 11300, Montevideo, Uruguay
[2]Technologies and IS Depto.,Faculty of Computer Science,University of Castilla-La Mancha, Paseo de la Universidad No.4, CP 13071, Ciudad Real, España

adelgado@fing.edu.uy,
{francisco.ruizg, ignacio.grodriguez,mario.piattini}@uclm.es

Abstract: *Business Process Management (BPM) importance and benefits for organizations to focus on their business processes is nowadays broadly recognized, as business and technology areas are embracing and adopting the paradigm. The Service Oriented Computing (SOC) paradigm bases software development on services to realize business processes. The implementation of business processes as services helps in reducing the gap between these two areas, easing the communication and understanding of business needs. The Model Driven Development (MDD) paradigm bases software development in models, metamodels and languages that allow transformation between them. The automatic generation of service models from business process models is a key issue to support the separation of its definition from its technical implementation. In this article, we present MINERVA framework which applies Model Driven Development (MDD) and Service Oriented Computing (SOC) paradigms to business processes for the continuous business process improvement in organizations, giving support to the stages defined in the business process lifecycle from modeling to evaluation of its execution.*

Key words: business process, Business Process Management (BPM), Service Oriented Computing (SOC), Model Driven Development (MDD), business process improvement, business process measures.

1. Introduction

The progressive adoption of the Business Process Management (BPM) [4][44] paradigm by organizations, defined as the activities that organizations do to optimize or adapt their business processes to the new organizational needs, puts the spotlight on the business process lifecycle as defined in [60][31][56], and on tools and technologies to support each stage. A business process is defined as a set of activities performed in coordination in an organizational environment to reach a business objective [60]. BPM Systems (BPMS) are generic software systems driven by explicit representations of business processes to coordinate their execution [60]. The implementation of business processes as services helps in reducing the gap between business and Information Technology (IT) areas, easing the communication and understanding of business needs. It also promotes the independence between the definition and modeling of business processes, and their implementation into a specific technology, allowing changes in each one with minimal impact on the other.

Service Oriented Computing (SOC) refers to software development based on services to support distribute low cost interoperable evolving and massive applications [36]. A service provides an implementation which provides business logic and data, a service contract which specifies the operations and pre and post conditions, and an interface to expose the functionality [26]. Service Oriented Architecture (SOA) [26][17] is a software architecture style which constitutes an specific realization of SOC, implemented in general by Web Services (WS) [58].

Model Driven Development (MDD) bases the software development on models, using as first order artifacts metamodels, models and languages which allow transformations between them [29][51]. Model Driven Architecture (MDA) [25][30][33] is a standard realization of MDD by the Object Management Group (OMG) [34], which specifies three views of a system as models: i) the

Computation Independent Model (CIM) to specify software requirements; ii) the Platform Independent Model (PIM) to specify the solution to the problem; and iii) the Platform Specific Model (PSM) related to a specific technology. The main characteristic is model transformation defined as the process of converting one model into another model of the same system, supported by other OMG standards as the Meta Object Facility (MOF) [32] to define the four level metamodel architecture, and the Query/View/Transformations (QVT) [40] for model transformations, among others.

We have defined a framework comprising methodologies, concepts and tools for the automated development of service oriented solutions from business processes, combining the application of SOC and MDD paradigms to business process, named MINERVA which stands for "Model drIveN & sErvice oRiented framework for the continuous business process improVement & relAted tools". It is defined to support the business process life cycle as defined in [60], covering the four phases of: Design and Analysis, Configuration, Enactment and Evaluation.This article is an extension of the one [12] published by the 5th Workshop on Engineering Service-Oriented Applications (WESOA'09) in the International 7th Conference on Service Oriented Computing (ICSOC'09), adding information on the proposal and its defined dimensions. The rest of the document is organized as follows: section 2 presents the MINERVA proposal describing its general elements, in section 3 the dimensions of MINERVA are detailed showing its main elements; in section 4 the related work is mentioned and finally in section 5 the conclusions and future work are discussed.

2. MINERVA proposal

MINERVA (Model drIveN & sErvice oRiented framework for the continuous business process improVement & relAted tools) constitutes a framework for the business process improvement based on the business process lifecycle [60] that is defined in three dimensions: conceptual [13], methodological [14] and tool support [11]. It also takes into account the Business Process Maturity Model (BPMM) [5] OMG standard, and measures for the design [31] and execution of business processes [43], which will drive the improvement effort in the business process lifecycle. Starting from the modeling of business processes in the Business Process Modeling Notation (BPMN) [6], MINERVA automatically obtains from these models service design elements expressed in UML [53], specifically several diagrams in Service Oriented Architecture Modeling Language (SoaML) [46], to the execution of processes expressed in WS-BPEL [59] or XPDL [62] in a suitable process engine. These steps cover the phases of Design and Analysis (only design), Configuration (partial) and Execution (partial) from the business process lifecycle [60]. In Fig. 1 the general framework defined by MINERVA for the automatic derivation of services from business process models is shown.

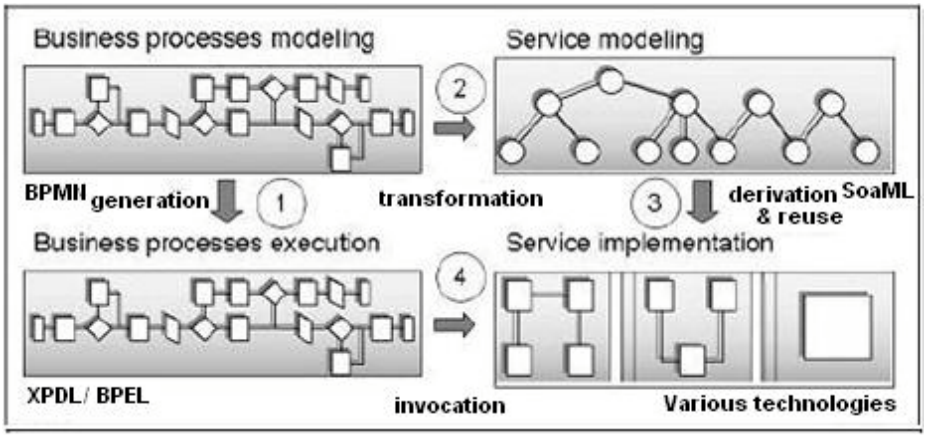

Fig. 1: Business processes and services relationships in MINERVA

Fig. 1 illustrates the steps for the automatic derivation of services from business processes, which constitutes a part of MINERVA. The proposal begins with the modeling of business processes in BPMN, shown on the top left corner in figure 1, which constitutes the input to the defined development process. From this model other two complementary models are obtained: (1) automatic generation of the process specification in some executable/interpretable language like WS-BPEL/XPDL, and (2) (almost) automatic generation of the design model of the required services to implement the process, expressed in UML using the SoaML profile. From the services in the design model the implementation model is automatically obtained in step (3) for the selected technological platforms. Finally, both implementations are related to connect the business process execution, where from business processes expressed in some language (WS-BPEL/XPDL) running in a process engine, components

implementing the obtained services are invoked.This process is supported by a service oriented methodology to guide the development of services from business processes.

To support the business process continuous improvement covering the rest of the life cycle, it is necessary to add elements to the framework. Any improvement program is based on the availability of data regarding aspects of the object of the improvement, analyzing the collected data and applying the acquired knowledge to modify the analyzed object. Therefore, we need to collect data, in the form of measures about relevant aspects, which can come from two sources: business process models and execution. We will integrate both types of measures, since we need the models from which to obtain the services to be verified with respect to quality measures, i.e. complexity, prior to the generation. The execution can be analyzed applying techniques such as Process Mining [54], i.e. to establish conformance between models and processes; to extend the models with new information extracted from event logs; to register execution measures in event logs to analyze and improve the processes. This will cover the rest of the business process lifecycle phases of Analysis, Execution and Evaluation [60]. Also, a continuous improvement process is being defined, adapted from [8], to guide the improvement process to be followed to obtain the defined objectives and results for the business process.

3. Dimensions of MINERVA

The framework integrates elements into three dimensions: conceptual, methodological and tool support. The conceptual dimension provides the basis for understanding all through the framework; the methodological dimension contains approaches for the continuous business process improvement process and for the development of service oriented software based on business processes; and the tool dimension integrates tool support in the form of an open workbench for all defined stages.

3.1 Conceptual dimension

The conceptual dimension aims to define concepts, terminology and relations between them to be used all over the framework. First of all, we are defining an ontology to relate business processes to their implementation as software services. The main objectives for the inclusion of an ontology in the MINERVA proposal are: to define, organize and reuse knowledge about concepts involved in the management of business processes and their life cycle, as well as their design and implementation based on services and the relationship between them.

An ontology defines the relevant elements (concepts, relationships) for the domain under study, providing meaning to the vocabulary and formalizing restrictions on its use [20]. Agreeing on the terminology used to define meaning and relationships between concepts helps us identify which elements of reality are important to use in metamodels and models representing such reality, filtering not necessary knowledge. It also establishes the basis for defining transformations from business process to service metamodels and models as in Business Process Metamodel Definition (BPMD) [3], BPMN and SoaML.

Based on the lifecycle of business processes [60], we have identified five groups for the main conceptual elements required in Business Process Management. Therefore, sub-ontologies are defined for: modeling, simulation, execution, measurement and evaluation of business processes. To support service orientation, there are two main conceptual groups which define the sub-ontology modeling and service-oriented implementation. The general ontology proposed is defined based on high-level packages that bring together related concepts, which is shown in Fig. 2.

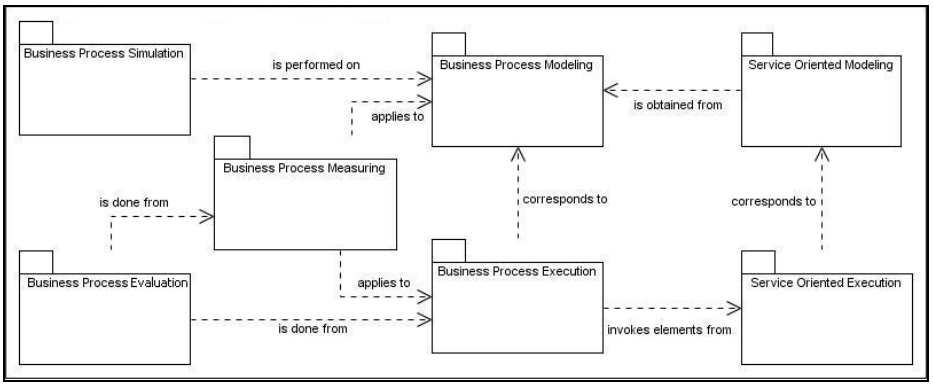

Fig. 2: High level ontology for Service Oriented Business Processes

In Fig. 2 the sub-ontologies packages and their relations are shown. The Business Process Execution sub-ontology corresponds to the Business Process Modeling sub-ontology meaning that the elements from the second one trace to the elements from the first one, the same occurs for the Service Oriented Modeling sub-ontology which corresponds to the Business Process Modeling sub-ontology. On the other hand, elements from the Business Process Execution sub-ontology "use" elements from the Service Oriented Execution sub-ontology, where an execution of a business process in a business process engine will invoke the execution of services corresponding to the activities in the defined business process model flow.

The other three sub-ontologies act over the mentioned ones: Business Process Measuring sub-ontology integrates measures for business process models and execution [43], and contains elements adapted from the Software Measurement Ontology (SMO) [19]. The Business Process Evaluation sub-ontology uses elements from measuring and execution sub-ontologies, defining other elements to analyze them like Process Mining [53] for execution logs analysis. The Business Process Simulation sub-ontology defines elements to simulate and understand various characteristics of models prior to their execution.

So far, we have defined the Business Process Modeling sub-ontology (BPMsO) and the Service Oriented Modeling sub-ontology (SOMsO), the complete definition of these two sub-ontologies can be seen in [13]. For business process modeling, the main references are the BPMN [6] and BPDM [3] OMG standards which were evaluated to define the BPMsO. In service orientation there are many standards defining ontologies and reference models and metamodels, generally carried out by organizations related to SOA and WS, for instance, the following ones were evaluated: SoaML [46] from OMG, Web Services Architecture (WSA) [58] from W3C, Service Oriented Architecture Reference Model (SOA RM) [48] and Service Oriented Architecture Reference Architecture (SOA RA) [47] both from OASIS, Service Oriented Architecture Ontology (SOA Ontology) [45] from Open Group. Fig. 3 shows the main elements and relationships of the BPMsO and the SOMsO.

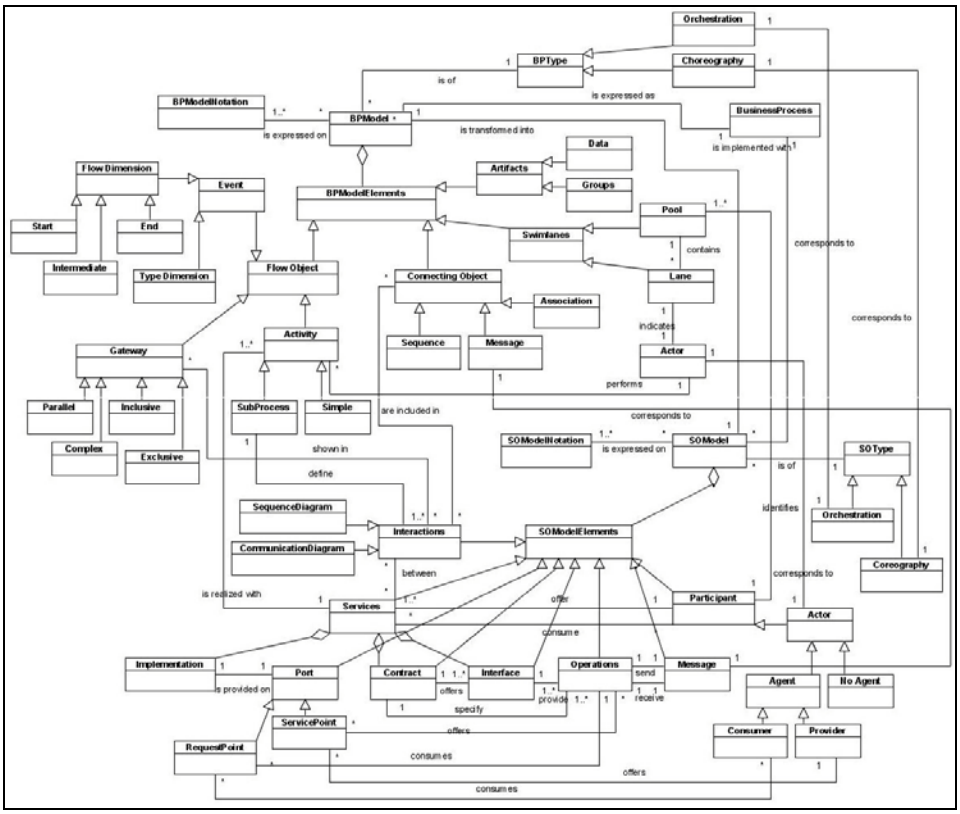

Fig. 3: Business Processes and Service Oriented Modeling sub-ontologies

In Fig. 3 main concepts and relationships between business process and service modeling sub-ontologies are shown. In business process modeling, real business processes existing in the organizations are represented as RealBP, which can have a type (BPType) that can be Orchestration or Choreography, and are expressed as business process models in (BPModel). These models are composed of defined elements (BPModelElements), which describe modeling elements of business processes based on standards BPDM and BPMN, and valid notations to specify them

(BPModelNotation). Among the defined elements for a business process (BPModelElements) the BPMN known grouping is used: flow objects, connector objects, pool/lanes and artifacts.

In service oriented modeling the real business processes are implemented by means of a service model (SOModel). This model contains modeling elements (SOModelElements) and is expressed by a valid notation for services (SOModleNotation). As a key element of the service model the Service concept is identified, which is composed of an Implementation providing the required functionalities, a Contract that specifies the provided Operations and Interface/s that offers functionality. Provider and Consumer Agents exchange defined Messages.

Main relationships between the BPMsO and the SOMsO refer to the correspondence between their key elements:

- BPMsO.pool → SOMsO.participant
- BPMsO.actor→ SOMsO.actor
- BPMsO.activities → SOMsO.services
- BPMsO.sub-processes → SOMsO.interactions
- BPMsO.gateways → SOMsO.interactions
- BPMsO.connectors → SOMsO.interactions
- BPMsO.messages → SOMsO.messages

These relations are based on the definitions of the involved concepts, in other cases, they are related to other dimensions of MINERVA such as the methodological one, which defines that the business sub-processes modeled are described by UML interaction diagrams (mostly sequence ones) where the flow defined by the gateways and the associated connectors in the process are shown. The activities will be implemented as services; the atomic ones will be associated with simple services which will provide the required functionality to realize them, most complex activities like process or sub-process will be realized by the combination of identified simple services which will be presented in interaction diagrams modeling the flow of the complex service.

3.2 Methodological dimension

In this dimension the methodological approaches are integrated into MINERVA. For the definition of the methodology for the continuous improvement of business process based on its life cycle we are currently evaluating the continuous improvement process PMCompetisoft integrated into COMPETISOFT [8] to adapt it. For the service oriented software development process a methodology [14] is integrated which was previously defined identifying a core set of disciplines, activities, deliverables and roles to be added to the development process used in the organization.

The first proposal of the methodology was defined upon a base process adapted from the Rational Unified Process (RUP) [24]. The Business Modeling, Design and Implementation Disciplines to model the business processes and the software services to implement them conforms the focus of the defined core. This proposal was validated in case studies in academic context and improved based on its application, adding activities and deliverables in other Disciplines – which are not presented in this article- such as: testing, quality, configuration and service management, and deployment. Aspects concerning the RUP extension like using Business and System Use Cases and Models were later removed from the methodology and generalized to the COMPETISOFT process model.

The core Disciplines, Activities, Deliverables and Roles presented here differ from the first proposal in many ways. First of all, they are independent of the RUP and its elements, and secondly, they are focused on modeling business processes and sub-processes, indicating how to derive the services from them. In our current work, the transformations between models are being defined, including the use of metamodels to make this derivation as automatic as possible. The Business Modeling Discipline defines two main activities to identify and model business processes. In the Design Discipline five activities are defined to identify, categorize, specify, reuse and define the services and their orchestration or choreography. In the Implementation Discipline the designed services are developed. Fig. 4 shows the Disciplines, activities and its execution flow as a BPMN process model.

Fig. 4 shows how the methodology defines several related activities to develop service oriented systems from business processes. In the Design Discipline, it can be seen that the three first activities are grouped, because although the sequential flow has to be followed, they can be performed jointly. Conceptually the methodology can be added as a plug-in to the development software process used in the organization, including the defined elements to guide the service oriented development from business processes. To make the integration of the methodology as a service oriented plug-in in other development process effective, we are working on its implementation with the Software Process

Engineering Metamodel (SPEM) [50] using the Eclipse Process Framework Composer (EPF Composer) [16] as part of its integration in MINERVA. Fig. 4 also shows an example of the conceptual integration of the methodology with the development process used in the organization, where, for example, the existing Requirements Discipline sub-process is performed concurrently with the identification of business processes added, as indicated by the concurrent flow (gateway AND).

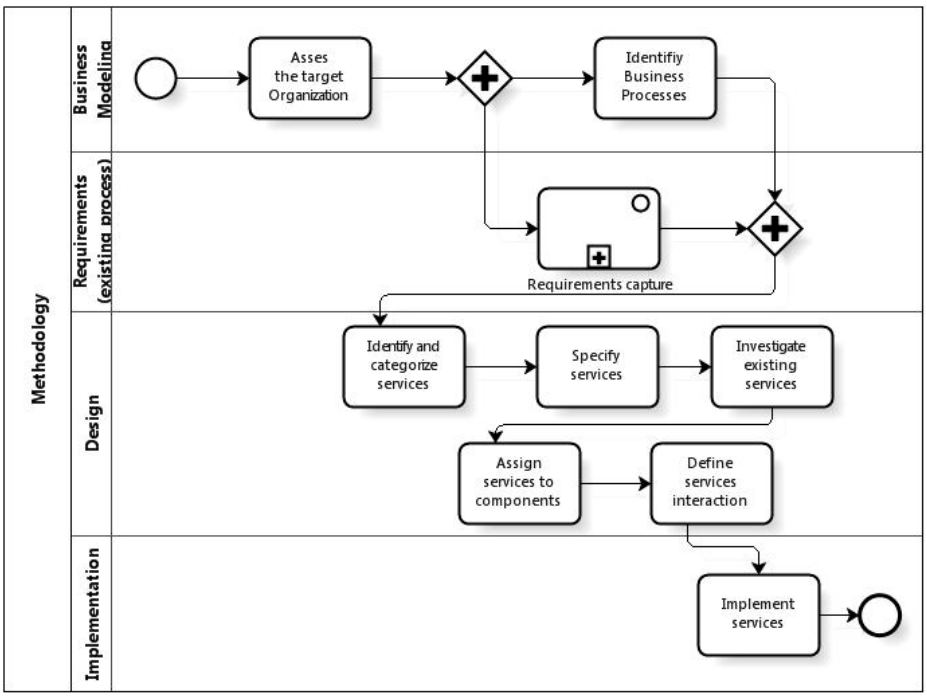

Fig. 4: Service Oriented development Methodology as BPMN process

The methodology also defines input and output deliverables (i.e. Services document) and responsible and participant roles for the defined activities, as well as a detailed description of objectives and tasks to be carried out when performing the activity. In Tab. 1 a summary of the defined elements related to the presented activities are detailed. It is worth mentioning that in the Business Modeling Discipline using process patterns [55] for business process modeling is recommended, which will help us assure the minimum quality characteristics of the correctness of the model regarding the specified requirements. The methodology does not include the automatic support to derive services from business processes yet; it is one of our working lines, which we believe will serve as a basis for the service based business process implementation and execution improvement.

Activity	Objective	Inputs/Outputs	Roles
Assess the target Organization (MN1)	Obtain the organization map, its processes and technologies	I:Meetings with clients/ O:Evaluation of the Target Organization Document	Analyst, Architect
Identify Business Processes (MN2)	Model business processes, flow, involved roles, associated functionalities	I: Evaluation of the Target Organization Document, minutes of meetings with clients, O:BP Document	Architect, Analyst
Identify and categorize services (D1)	Define and classify the services to carry out the business processes and functionalities	I: SW Architecture, BP, Requirements, Services Documents, O: Services Document,SWArchitecture	Architect,Analyst, Developer
Specify services (D2)	Define contract of services, their operations, parameters, etc.	I:Services Document O:Services Document	Architect, Analyst
Investigate existing services (D3)	Reuse services, components, implemented functionalities	I: Services Document and Catalogue, O: Services Document and Catalogue	Architect, Analyst

Activity	Objective	Inputs/Outputs	Roles
Assign services to components (D4)	Define service implementation	I: Services and Design Documents, O: Services and Implementation Docs.	Architect, Developer
Define services interaction (D5)	Define the sequences of invocation of services to carry out the business processes	I: BP, Services and Requirements Documents, O:Services and Implementation Docs.	Architect,Analyst, Developer
Implement services (I1)	Build the services as they were designed	I: Services, Design and Implementation Docs., O: Implemented service	Developer

Tab. 1: Elements defined in the methodology related to the presented activities

3.3 Tool dimension

The tool dimension gives support to the defined methodologies and automation of transformations between the different models used in MINERVA. The integrated environment, which is currently under definition, proposes the use of different tools for each phase of the business process life cycle to support the defined concepts in all framework dimensions. The main objective is to give tool support to the modeling and execution of business processes implemented as services, and to the automation of generation of services from business processes. For the business process modeling included in the Design phase of the business process life cycle, we are currently evaluating Bizagi [2] and Visual Paradigm [57] tools, among others, which provide BPMN; because the proposal defines that the business modeling has to be performed by the business analyst in conjunction with computer analysts. One of the main outputs of this phase is the business process model in XMI [61] format, so it could be later imported by other tools, like tools for simulation and validation of models in the Analysis phase, or software development in the Configuration phase. For the software development support for business processes, in the Configuration phase, the use of IDE Eclipse [15] is proposed, with an adequate plug-in to load the business process model made in the previous phase, i.e. the Visual Paradigm plug-in [57] or the SOA Tools Platform Project (STP) [49] which integrates a modeler with BPMN.

To transform the business process models into service oriented UML artifacts, applying model driven development principles, these have to be marked with some information, i.e. the type of activity like “service task” with input and output specified messages. So, to obtain, for example, a service class model from a business process model, supported by the defined ontologies to relate business process and services models, QVT transformations are defined from the BPDM of BPMN, to the SoaML metamodel using the Eclipse plug-in MediniQVT [28]. Other UML elements could also be obtained from the business process model in BPMN, for example interaction diagrams to show the identified sub-process flow. After applying the QVT transformations, a PIM will be obtained expressed in the SoaML profile, from which to generate the PSM to the desired technology platform. On the other hand, at the moment of generating the specification of the business process in an executable/interpretable language like WS-BPEL/XPDL, some marks have to be used too, to allow the generated components to be invocated from the process execution flow.

From the execution of the process, log files will be obtained containing the defined information to collect, to be analyzed in the Evaluation phase using the ProM [38] tool by means of the different plug-ings it provides. With the collected information, the improvements to be done in the business process to increment its efficacy and efficiency could be evaluated, for example if a specific activity is taking too much time to be performed, we could investigate the cause and provide the possible improvements. The continuous improvement process we are working on, will define which activities to perform and how to carry on them to obtain the desired result.

4. Related work

Some of the most relevant works in the area comprising the integration of MDD and SOC paradigms to business processes are as follows: [7] defines a methodological framework with a language based on Petri Nets for modeling, verification and prototyping of business processes. It differs from ours in the notation and languages used, among the approach to obtain services from business processes. In [9] the main focus is the development of service oriented Web Systems defining models, metamodels and transformations between them to obtain a service composition model which expresses the interaction of services to perform business processes. In [10] they integrate a business value model

from which to derive software artifacts, specifically adding the business view and models, and transformation from them to use case model. Differently, we based the generation of services on business process models using BPMN models as first input. [35] proposes a business rules driven approach for the development of adaptive collaborative service oriented business processes. It provides a framework for the development of business collaborations with three dimensional views: collaboration aspects, business and technical requirements. Differently, we don't integrate the use of business rules to guide the development and if they are used is only as business process extra information. In [39] a service oriented design approach is proposed, to relate services modeled in different levels of abstraction: business and application, with techniques based on ISDL: profiles to relate models and model conformance. In our proposal a different approach and language is used to relate them.

In [41] models and metamodels for services are defined to relate them to business processes and the underlying architecture, focusing the derivation of services on three architectures: brokerless, centralized and decentralized broker, providing a technical focus, which is not treated in our proposal. [63] defines patterns to guide the definition, transformation and implementation of technical processes using software services from business processes in which they call process-driven service oriented architecture. Differently, our proposal does not classify processes, and does not use patterns to link models, as they are successively refined starting from BP models. [22] proposes a model driven approach to relate business process with software services in a target (distribute) three layered architecture. The business process are modeled in UML deriving an analysis model which is then mapped to elements in the design model defined in the existing target architecture, and then to the implementation model. [52] also proposes a model driven approach but for collaborative service oriented architecture, to transform BPMN models into UML models and BPEL models. It defines a collaborative SOA metamodel composed of three views: service, information and process; the business process model is transformed to each one. Differently we use the SoaML UML profile to specify services, and a different approach to define transformations and the support tools.

Other proposals that integrates only one of the MDD or SOC paradigms to business processes which are worth mentioning are as follows: [21] defines a set of transformation patterns, called realization types, to transform a business process into a technical process based on existing services provided by internal systems, defining levels to identify the quality of the transformation between them. Although our proposal also takes into account existing services, it does not relate or constraint the business process because of services. Also in [18] a pattern based technique is used in a layered architecture defined in a framework for the designing of EI architectures, for service identification, transformation from business models to service architecture, among others. Process, domain and SOA patterns are identified which are implemented and organized in pattern catalogues, and can be instantiated, suggested to apply compared, modified and merged. So far we do not use a pattern approach apart from recommending using the process patterns in business processes modeling. In [1] a four level architecture and a design process to develop B2B applications are defined. It proposes to select the services to realize business process from an existing repository, registry or catalog. It is different to our proposal that our methodology is more general and not restricted to B2B or WS applications. In [23] a three level conceptual framework is defined to relate business process with implemented services, adding a service mediating layer, and defining five related layers. A Service Invocation Coordinator (SIC) is defined to implement service invocation.

Other approaches aim to relate business processes and software services as in [27] in which UML software artifacts like use cases, activity and collaboration diagrams are automatically obtained from business processes expressed in BPMN, which differs from ours since we derive directly from BPMN models the needed services. [37] defines phases, activities and artifacts for the development of services associated with business processes. It differs from ours in that although it defines guides for a service oriented development, it is focused on the implementation of services as WS, adding technical aspects that cannot be used with other technologies. [42] proposes modeling of business process realization by services diagrams, identifying services, and integrating business process modeling and object modeling by means of a Business Services Model (BSM), a mediator between requirements and implementation. It is complementary to our proposal in the identification of services from business process but differs in the derivation steps and proposal.

5. Conclusions and future work

We have presented the ideas and work behind the definition of the MINERVA framework for the continuous improvement of business processes, based on the joint application of the SOC and the MDD paradigms to business processes. The implementation of business processes by software

services helps in closing the gap between business and IT areas. Our proposal includes the integration of business people into the business process modeling stage in the development process. A service oriented methodology based on business processes is integrated, and all the stages are supported by a variety of tools.

An ontology was defined that allows defining and relating concepts from business process models to service oriented models. The metamodels from which we are defining the QVT transformations, use those concepts allowing us to understand the elements we want to obtain for software design and implementation from business process models. We are working on the automatic generation of services from business processes, which will serve as a basis for the improvement of the implementation and execution of service based business processes.

We are also working in the definition of the continuous improvement process based on the business process lifecycle, which will guide the activities to perform for assessing modeling and execution of business processes to find improvement opportunities. For helping in doing the assessment, modeling and execution measures will also be integrated, basing its elements, relations and use in the measuring ontology.

Acknowledgments:

This work has been partially funded by the Agencia Nacional de Investigación e Innovación (ANII,Uruguay), ALTAMIRA project (Junta de Comunidades de Castilla-La Mancha, Spain, Fondo Social Europeo, PII2I09-0106-2463) and INGENIO project (Junta de Comunidades de Castilla-La Mancha, Spain, Consejería de Educación y Ciencia, PAC08-0154-9262).

References

[1] Baghdadi Y., *ABBA: an architecture for deploying business-to-business electronic commerce applications*, Journal of Electronic Commerce Research and Applications,Vol.3, Isue 2, 2004, p.190-212, ISSN 1567-4223

[2] *BizAgi Process Modeler* <http://www.bizagi.com>

[3] *Business Process Definition Metamodel (BPDM)*, v.1.0, OMG, <http://www.omg.org/spec/BPDM/1.0>

[4] *Business Process Management Initiative*, <http://www.bpmi.org/>

[5] *Business Process Maturity Model (BPMM)*, v.1.0, OMG, <http://www.omg.org/spec/BPMM/1.0>

[6] *Business Process Modeling Notation (BPMN)*, v.1.2, OMG, <http://www.omg.org/spec/BPMN/1.2>

[7] Chen, A., Buchs, D., *A Generative Business Process Prototyping Framework*, 17th International Workshop on Rapid System Prototyping (RSP'06), Chania, Crete, June 2006.

[8] *COMPETISOFT – Process Improvement for Iberoamerican Small and Medium Enterprises (SME)*, CYTED, <http://alarcos.infcr.uclm.es/Competisoft>

[9] de Castro, V., Marcos, E., López Sanz, M., *A model driven method for service composition modelling: a case study*, International Journal of Web Engineering and Technology, Vol. 2, No. 4, 2006, p.335-353, ISSN 1476-1289

[10] de Castro V., Vara Mesa J. M., Herrmann E., Marcos E., A Model Driven Approach for the Alignment of Business and Information Systems Models, Mexican International Conference on Computer Science (ENC'08), Mexicali, Baja California, Mexico, October 2008.

[11] Delgado, A., García - Rodríguez de Guzmán, I., Ruiz, F., Piattini, M.: *Tool support for Service Oriented development from Business Processes*, 2nd International Workshop on Model-Driven Service Engineering (MOSE'10) in 48th Int. Conf. on Objects, Models, Components, Patterns (TOOLS'10), Málaga, Spain, June 2010.

[12] Delgado, A., Ruiz F., García-Rodríguez de Guzmán, I., Piattini, M., *MINERVA: Model drIveN and sErvice oRiented framework for the continuous business processes improVement & relAted tools*, 5th Workshop on Engineering Service-Oriented Applications (WESOA'09) in 7th Int. Conf. on Service Oriented Computing (ICSOC'09), Stockholm, Sweden, November 2009.

[13] Delgado, A., Ruiz, F., García - Rodríguez de Guzmán, I., Piattini, M.: *Towards an ontology for service oriented modeling supporting business processes*, 4th International Conference on Research Challenges in Information Science (RCIS'10), Niza, France, May 2010.

[14] Delgado, A., Ruiz, F., García - Rodríguez de Guzmán, I., Piattini, M.: *Towards a Service-Oriented and Model-Driven framework with business processes as first-class citizens*, 2nd International Conference on Business Process and Services Computing (BPSC'09), Leipzig, Germany, March 2009.

[15] *Eclipse, The Eclipse Foundation* <http://www.eclipse.org>

[16] *Eclipse Process Framework Composer (EPF Composer)* <http://www.eclipse.org/epf/>

[17] Erl, T., *SOA: Concepts, Technology, and Design*, Prentice Hall, 2005, ISBN 0-13-185858-0

[18] Gacitua-Decar V., Pahl C., *Pattern-based business-driven analysis and design of service architectures*, 3rd International Conference on Software and Data Technologies SE (ICSOFT'08), Porto, Portugal, July 2008.

[19] García, F., et al., Towards a Consistent Terminology for Software Measurement, Journal of Information and Software Technology, Vol. 48, Issue 8, 2006, p.631-644, ISSN 0950-5849

[20] Gruber,T.R.,A translation approach to portable ontology specifications, Knowledge Acquisition,5(2),1993, p.199-220

[21] Henkel,M., Zdravkovic,J., *Supporting Development and Evolution of Service-based Processes*, IEEE International Conference on e-Business Engineering (ICEBE'05), Peking, China, October 2005

[22] Herold S., Rausch A., Bosl A., Ebell J., Linsmeier C., Peters D., A Seamless Modeling Approach for Service-Oriented Information Systems, 5th International Conference on Information Technology: New Generations (ITNG'08), Las Vegas, USA, April 2008

[23] Hu J., Grefen P., Conceptual framework and architecture for service mediating workflow management, Journal of Information and Software Technology, Vol. 45, Issue 13, 2003, p. 929-939, ISSN 0950-5849

[24] IBM – Rational Unified Process (RUP), <http://www- 306.ibm.com/software/awdtools/rup/>

[25] Kleppe A.,Warmer J., Bast W., *MDA Explained. The Model Driven Architecture: Practice and Promise*, Pearson Education, 2003, ISBN 032119442

[26] Krafzig, D. Banke, K. Slama, D., Enterprise SOA, Service Oriented Architecture: Best Practices, Prentice Hall, 2005, ISBN 978-0131465756

[27] Liew,P., Kontogiannis,K. Tong,T., A Framework for Business Model Driven Development,12th International Workshop on Software Technology and Engineering Practice (STEP'04), Chicago, USA, September 2004

[28] Medini QVT, ikv++ technlogies ag, <http://projects.ikv.de/qvt>

[29] Mellor, S., Clark, A., Futagami, T., *Model Driven Development - Guest editors introduction*, IEEE Computer Society, Vol. 20, Issue 5, September 2003, p.14-18, ISSN 0740-7459

[30] Mellor S., Scott K.,Uhl A.,Weise D., *MDA Distilled: Principles of Model-Driven Architecture*, Addison Wesley, 2004, ISBN 978-0201788914

[31] Mendling, J., *Metrics for process models*, Springer, 2008, ISBN 978-3-540-89223-6

[32] *Meta Object Facility (MOF)* v. 2.0, OMG, <http://www.omg.org/spec/MOF/2.0/>

[33] *Model Driven Architecture (MDA)* v.1.0.1, OMG, <http://www.omg.org/mda/>

[34] *Object Management Group (OGM)*, <http://www.omg.org/>

[35] Orriens, B., Yang, J., *A Rule Driven Approach for Developing Adaptive Service Oriented Business Collaboration*, International Conference on Services Computing (SCC'06), Chicago, USA, September 2006

[36] Papazoglou, M.; Traverso, P.; Dustdar, S.; Leymann, F.: *Service-Oriented Computing: State of the Art and Research Challenge*, IEEE Computer Society, Vol. 40, No. 11, November 2007, p. 38-45, ISSN 0018-9162

[37] Papazoglou, M., van den Heuvel, W., *Service-oriented design and development methodology*, International Journal of Web Engineering and Technology, Vol. 2, No. 4, 2006, p.412-462, ISSN 1476-1289

[38] *ProM, Process Mining Group,* Department of Mathematics and Computing Science, Eindhoven University of Technology, Eindhoven, The Netherlands, <http://prom.win.tue.nl/research/wiki>

[39] Quartel, D., Dijkman, R., van Sinderen, M., *An approach to relate business and application services using ISDL*,9th International Enterprise Computing Conference (EDOC'05), Enschede,The Netherlands,September *2005*

[40] *Query/Views/Transformations(QVT)* v.1.0,OMG, <http://www.omg.org/spec/QVT/1.0/>

[41] Roser,S., Bauer,B., Muller,J., *Model- and Architecture-Driven Development in the Context of Cross-Enterprise Business Process Engineering*, International Conference on Services Computing (SCC'06), Chicago, USA, September 2006

[42] Rychly M., Weiss P., *Modeling of Service Oriented Architecture: from business process to service realization*, 3rd International Conference on Evaluation of Novel Approaches to Software Engineering, (ENASE'08), Funchal, Madeira, Portugal, May 2008

[43] Sánchez, L., Delgado, A., Ruiz, F., García, F., Piattini, M.: *Measurement and Maturity of Business Processes* Eds.: Cardoso, J., van der Aalst, W., Handbook of Research on Business Process Modeling . Ed. 1, London UK / PA USA, Information Science Reference (IGI Global), pp. 532-556, March 2009, ISBN 978-1-60566-288-6

[44] Smith,H.,Fingar,P., *BPM: The third wave*, Meghan-Kieffer, 2003, *ISBN* 0-920-65233-9

[45] *Soa Ontology (SOA O)*, Open Group, <http://www.opengroup.org/projects/soa-ontology>

[46] *Soa Modeling Language (SoaML)*,v.1.0 Beta1, OMG, <http://www.omg.org/spec/SoaML/1.0/Beta1>

[47] *Soa Reference Architecture (SOA RA)*, Oasis, <http://docs.oasis-open.org/soa-rm/soa-ra/v1.0>

[48] *Soa Reference Model (SOA RM)*, Oasis, <http://docs.oasis-open.org/soa-rm/v1.0>

[49] *SOA Tools Platform Project (STP)*, Eclipse, <http://www.eclipse.org/stp/, http://www.eclipse.org/bpmn>

[50] *Software Process Engineering Metamodel (SPEM)*, v.2.0, OMG, <http://www.omg.org/spec/SPEM/2.0>

[51] Stahl, T.; Volter, M. et. al.: *Model-Driven Software Development: Technology, Engineering, Management*, John Wiley & Sons Ltd., 2006, ISBN 978-0470025703

[52] Touzi J., Benaben F., Pingaud H., Lorré J.P., *A model-driven approach for collaborative service-oriented architecture design*, International Journal of Production Economics, Vol.121, Issue 1,2009, p.5-20,ISSN 09255273

[53] *Unified Modeling Language (UML)* v. 2.2, OMG, <http://www.omg.org/spec/UML/2.2>

[54] van der Aalst, W.M.P., Reijers, H. A., Medeiros, A., *Business Process Mining: an Industrial Application*, Journal of Information Systems Vol.32, Issue 5, 2007, p. 713-732, ISSN 0306-4379

[55] van der Aalst, W.M.P., ter Hofstede, A.H.M., Kiepuszewski, B., Barros, A.P.: *Workflow Patterns*, Distributed and Parallel Databases, Vol. 14, Issue 1, 2003, p. 5–51, ISSN 0926-8782

[56] van der Aalst, W.M.P., ter Hofstede, A., Weske, M., *Business Process Management: A Survey*, International Conference on Business Process Management (BPM'03), Eindhoven, The Netherlands, June 2003

[57] Visual Paradigm & Eclipse plug-in, <http://www.visual-paradigm.com>

[58] Web Services Architecture (WSA), W3C, <http://www.w3.org/TR/ws-arch>

[59] WS- Business Process Execution Language(WS-BPEL), v.2.0, OASIS,<http://docs.oasis-open.org/wsbpel/2.0>

[60] Weske, M., *BPM Concepts, Languages, Architectures*, Springer, 2007, ISBN 978-3-540-73521-2

[61] *XML Metadata Interchange (XMI,)* v.2.1.1, OMG, <http://www.omg.org/spec/XMI/2.1.1/>

[62] *XML Process Definition Language (XPDL)*, v. 2.1, WfMC, <http://www.wfmc.org/xpdl.html>

[63] Zdun, U., Hentrich, C., Dustdar, S., *Modeling Process-Driven and Service-Oriented Architectures Using Patterns and Pattern Primitives*, ACM Transactions on the Web, Vol. 1, No. 3, Article 14, 2007, ISSN 1559-1131