

SPEM 2.0 Extension for Pervasive Information Systems

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Abstract: Pervasive computing is a research field of computing technology that aims to achieve a new computing paradigm. In this paradigm, the physical environment has a high degree of pervasiveness and availability of computers and other information technology (IT) devices, usually with communication capabilities. Pervasive Information Systems (PIS), composed by these kinds of devices, bring issues that challenge software development for them. Model-Driven Development (MDD), strongly focusing and relying on models, has the potential to allow: the use of concepts closer to the domain and the reduction of semantic gaps; higher automation and lower dependency to technological changes; higher capture of expert knowledge and reuse; an overall increased productivity. Along with the focus and use of models, software development processes are fundamental to efficient development efforts of successful software systems. For the description of processes, Software & Systems Process Engineering Meta-Model Specification (SPEM) is the current standard specification published by the Object Management Group (OMG). This paper presents an extension to SPEM (version 2.0) Base Plug-In Profile that includes stereotypes needed to support a suitable structural process organization for MDD approaches aiming to develop software for PIS. A case study is provided to evaluate the applicability of the extension.

Key-Words: MDD, PIS, SPEM, pervasive, ubiquitous, software engineering, process, information systems.

1 Introduction

Pervasive/Ubiquitous Computing [1, 2] represents a recent thinking about computing and its integration on users' life and environment. It aims to achieve a new computing paradigm, one in which there is a high degree of pervasiveness and availability of interconnected IT devices in the physical environment. In consequence, interest arises in new or improved forms of information systems, such as Pervasive Information System (PIS) [3], that take advantage of the overall availability of computing. Dissemination of computing and heterogeneous information technology devices and platforms, the high pace of technological innovations, and volatile requirements challenge software development for these new forms of systems.

During last decade, Model-Driven Development has gained emphasis due to efforts and promotion of standards and initiatives on modeling [4]. Raising the traditional level of abstraction for system's conception and design, MDD automates, as much as possible, the transformation of models and the generation of the final code. An MDD approach to

software development enables higher independence from the technological platform that supports the realization of the system. MDD has the potential to offer key pathways that enable software developers to cope with complexity inherent to PIS. MDD enhances the efficiency of the software development, the resilience, the robustness, and the evolution of systems. CASE tools, which are of primary importance to an effective MDD development, have evolved to accommodate MDD concepts and techniques. Current MDD concepts and techniques and supporting CASE tools are not sufficient for an MDD approach to be adopted in the context of PIS development. A proper PIS development demands an approach that recognizes particularities of PIS and that takes advantage of a MDD orientation. This approach has to establish a suitable strategy for the development of PIS based on appropriate conceptual framework.

Software Development Processes (SDPs), as well as generalized adoption of models, are fundamental to efficient development efforts of successful software systems. SDPs, incorporating best practices, evolved from ad-hoc, passing by

waterfall, to iterative and incremental [5]. SDPs are subject of research, improvement, practice, and standardization. SPEM [6] is a current standard published by the OMG [7] for the description of systems and software processes. SPEM provides, to process engineers, conceptions for modeling method contents and processes. Published SPEM research works haven't focused yet MDD approaches that take explicitly into account PIS characteristics. The work described in this paper contributes to this specific matter. This paper presents a SPEM 2.0 Base Plug-in extension based on a conceptual framework suitable for software development for pervasive information systems. This extension aims to provide process engineers with model elements that allow them to more precisely describe software processes for software development of PIS.

This document structures its content as follows: section 1 contextualizes software development for pervasive information systems; section 2 gives insight into related works; section 3 gives an overview of the proposed development framework for PIS and presents the extension to SPEM 2.0 Base Plug-in; section 4 presents a case study used to evaluate the extension applicability; section 5 presents the conclusions and finishes this document.

2 Related Work

Reasoning about software development processes needs solid conceptual structures and convenient representations for description of relevant process characteristics. Standard meta-modeling approaches for modeling processes, such as SPEM, provide such conceptions and representations. SPEM is a process meta-modeling approach that is subject of use, extension, and research by the process engineering community. Some examples of these uses and extensions are next briefly pointed out.

SPEM is used as a language to express process proposals aiming to achieve particular goals or to be implemented by supporting tools. In the context of security requirements, D. Mellado *et al.* [8] use SPEM 2.0 to describe a security requirements engineering process for SPL (SREPPLine). The framework proposed defines, besides the process, a reference meta-model and a tool that implements the meta-model and supports the process. They present the SREPPLine structure, the SREPPLine activities structure, a XML grammar for the security reference model, and tables defining the most important work products, guidance, roles, and task definitions for the SREPPLine process. M. Kuma *et al.* [9] use SPEM 2.0 to model a software development process that extends the AUTOSAR (AUTomotive Open

System ARchitecture) standard [10]. N. Ibrahim *et al.* [11] use SPEM 2.0 to express the process defined in the proposed approach for propagating requirement changes into high-level designs. This approach also suggests a product meta-model that, defining a conceptual model for volatile requirements and its requirements, sustains the process model. O. Avila-García *et al.* [12] propose a DSTL (Domain-Specific Transformation Language) called MTTL (Model Template Transformation Language) to specify transformations (specializations) of model templates based on feature models. They use SPEM 2.0 to describe the product and the SPL (Software Product Line) development process for a model family. N. Kerzazi *et al.* [13] present an automated approach to software process modeling called DSL4SPM (Domain-Specific Language for Software Process Modeling). This approach provides a conceptual framework for designing processes and support to a multi-view oriented process modeling. A tool, also called DSL4SPM (and which implements SPEM 2.0), demonstrates the potential of the approach. The approach explores attributed relationships among model components in order to enhance the semantics of process models, allowing for multiple views. In a Software Process Improvement (SPI) perspective, the tool provides support for process model evolution with comparison of evolution of states. In the context of SPI, P. V. Martins *et al.* [14] performs a comparative study of process meta-models approaches, namely SPEM, OPEN Process Framework (OPF), and Standard Meta-model for Software Development Methodologies (SMSDM). They propose a process meta-model (called PIT-ProcessM) addressing issues related to SPI.

SPEM is also subject of extension proposals in order to acquire properties or to be able to fulfill specific needs in process engineering; some of these extensions also provide supporting tools. M. Silva *et al.* [15] present a meta-model for software artifacts providing a new way to represent artifact content. This is realized through the provision of an extension to the Unified Modeling Language (UML) [16]/Meta Object Facility (MOF)[17] and SPEM. D. Silingas *et al.* [18] present a framework supporting wizard-based modeling guidance in UML tools. Their work presents a UML profile that extends SPEM 2.0 and supports the specification of method models in order to generate the appropriate modeling guidance wizards. A MagicDraw plug-in [19] implements a prototype of the framework and two different wizards illustrate the approach. In the context of process enactment, several extensions to SPEM are next referred. R. Ellner *et al.* [20] analyze

SPEM issues regarding behavior modeling, planning, and configuration of SPEM. Considering these issues, they propose a SPEM 2.0 extension to enable automatic enactment of SDPs. The solution proposed goes by the substitution of behavior interfacing concepts of SPEM and the introduction of additional extensions to support the enactment of SDPs. R. Bendraou *et al.* [21] propose an extension to SPEM 2.0 specification (called xSPEM), that provides concepts deemed as needed to enact a process model. These concepts allow SPEM 2.0 process models “*to be checked through a mapping to Petri nets and monitored through a transformation into BPEL*” [21]. D. Riesco *et al.* [22] aim to formalize the transformation of SPEM (v1.1) activities into Business Process Model and Notation (BPMN) [23] subprocesses. This allows that a software process, described with SPEM 1.1, may be used as input into a workflow engine. This work establishes a basis to automate a SDP by “*(...) automation of business processes using workflow technology*”. Formalisms are expressed using RSL (RAISE Specification Language) formal language of RAISE (Rigorous Approach to Industrial Software Engineering) method. N. Debnath *et al.* [24] propose a solution to “*automate the management of activities*” of a SDP described by a SPEM (version 1.1) specification. This is accomplished through transformation of these activities into workflow subprocesses based on the BPMN standard. The transformation is done by the language Query/Views/Transformation (QVT) standard [25]. The BPMN model can be “*(...) turned into a workflow specification under BPEL4WS [26] or XPDL [27] languages*”, which may be used in a workflow engine. Also in the context of process enactment, but additionally taking into account a model-driven process modeling context, R. Maciel *et al.* [28] present an integrated approach for MDA process modeling and enactment. They extend SPEM 2.0 meta-model with some specializations for modeling MDA processes and provide a supporting tool. They present two case studies that allowed the evaluation of the approach. A. Koudri *et al.* [29] consider that current process modeling languages lack on integrating Model Based Engineering (MBE) into system and software process models. As such, they present an extension to SPEM 2.0, called MODAL (Model Oriented Development Application Language) that introduces additional concepts for the definition and elicitation of a model-based process. Among the concepts introduced or refined in this extension are: intention, strategy, models as work products, process components, and constraints. In the context

of process variability, T. Martínez-Ruiz *et al.* [30] consider that for processes which are to be adapted for different contexts, a Software Product Line (SPL) based approach is a proper approach. The authors consider that SPEM 2.0 does not provide suitable mechanisms for such approach. Consequently, they suggest new variability mechanisms based on concepts of variation points and variants for modeling a SPL. These mechanisms are proposed in an extension to SPEM 2.0.

None of the research works presented deals simultaneously with MDD concerns and PIS issues. Some of the extensions described touch in some of concerns also considered in research work herein presented: (i) research works [28] and [29] deal with tailoring SPEM in order to incorporate MDD concerns; (ii) research work [30] focus on software process lines and deals with variability. As it will be next explained, the conceptual framework for PIS and the proposed extension deal, in some extent, with functional variability that derives into elementary development processes. The work presented in this paper considers a conceptual framework for PIS. This framework explicitly deals with MDD and PIS concerns and proposes a consistent strategy for structuring software development for this kind of systems.

3 Extending SPEM for PIS

This section presents the research work performed for providing a suitable approach and a SPEM representation to software development in the context of pervasive information systems.

3.1 Conceptual development framework

Research has been performed [31] to bring the application of MDD concepts and techniques to software of PIS. We consider [3] a conceptual framework to sustain an approach for software development of PIS that take into account MDD potential and the PIS characteristics, particularly, heterogeneity and functional variability. The conceptual development framework introduces and describes concepts framed on three structural perspectives called dimensions. Based in these dimensions, the development framework considers two main development views: one concerning the overall development process, and a second concerning to individual development processes.

The three referred dimensions are: resources, functional, and abstraction dimension. As it can be figured out from Fig. 1, resources dimension sets up

several categories of devices with similar characteristics and capabilities. The functional dimension sets up different functionalities required in the system that can be assigned to devices in the system for its realization. The assignment of a specific functional profile to a specific resource category results in a functional profile instance that is realized by devices in that resource category.

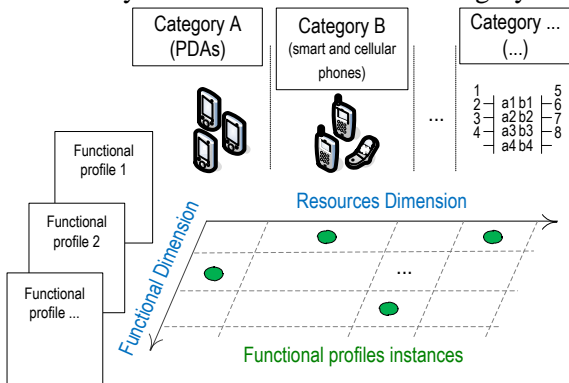


Fig. 1 - Functional and Resources Dimension.

Each functional profile instance has a corresponding development structure which embodies an elementary development process aiming to realize that instance. The abstraction dimension respects, in an MDD context, to the levels of abstraction that elementary development process may have (from PIM, passing by PSM, to generated code; see Fig. 2).

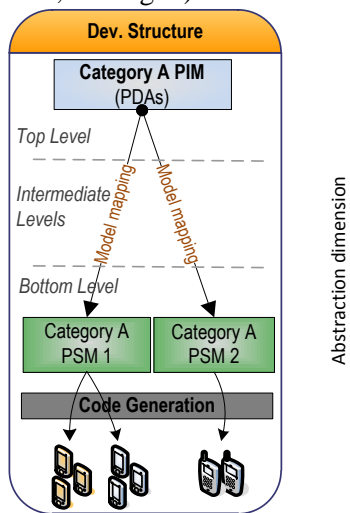


Fig. 2 - Development Structure.

The framework structures the development into a global process and several elementary processes. Fig. 3 illustrates a general schema of the development framework. The global development process is responsible for modeling requirements and for establishing high-level and global system models. Based on these models, it sets up functional profiles and categories of resources, as well as high-level platform-independent model (PIM) for each

functional profile instance. The global development process has the responsibility for making all the necessary arrangements for integration of the several artifacts that result from elementary development processes and for final composition, testing, and deployment of the system. Elementary development processes are responsible for software development of the parts of the system that realize specific functionalities related to specific resource categories. For each development structure, an adequate software development process may be chosen, as long as it respects the principles of the approach globally adopted. The implicit strategy suitable to this development framework eases the assignment of elementary development processes to different collaborating teams and, eventually, the outsourcing of the development. MDD concepts and techniques may be applied in order to improve the development and the quality of the system.

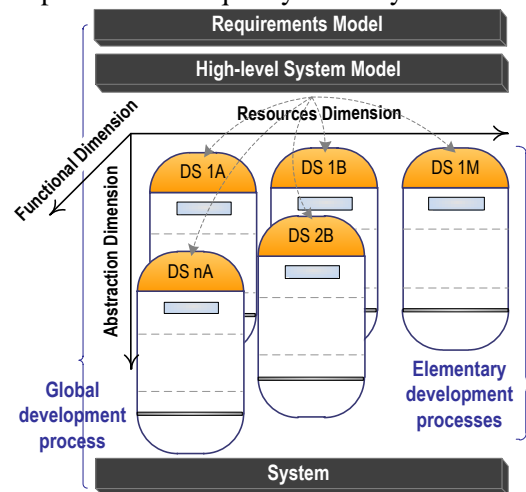


Fig. 3 - Development framework for PIS.

3.2 The SPEM extension

SPEM 2.0 is defined as a meta-model as well as a UML 2 Profile (concepts are defined as meta-model classes as well as UML stereotypes). SPEM 2.0 meta-model describes the structures and the structuring rules needed to express and maintain development method content and processes. It is a MOF-based model and reuses some elements from UML 2 meta-model (key classes from UML 2 Infrastructure [32]). The SPEM 2.0 UML Profile provides an alternative representation to the SPEM 2.0 meta-model. It defines a set of stereotypes that allows presenting SPEM 2.0 methods and processes using UML 2, and relies on the SPEM 2.0 meta-model to define all of its constraints. In addition to SPEM 2.0 Profile, the specification also defines a convenience profile called “SPEM 2.0 Base Plug-in Profile” [6] that provides other useful stereotypes.

In the context of the software development for PIS, we propose additional stereotypes to the SPEM 2.0 Base Plug-in. This extension does not affect the SPEM meta-model itself. The proposed stereotypes extend two main groups of stereotypes defined in SPEM 2.0 Base Plug-in: the "ActivityKind" and "WorkProductKind" stereotypes. Fig. 4 and Fig. 5 illustrate, respectively, the new "ActivityKind" and "WorkProductKind" stereotypes (white boxes contain the predefined kinds; grey boxes contain the proposed additional kinds). The following paragraphs describe these new stereotypes, grouped by each of those kinds.

Regarding to "ActivityKind" stereotypes (Fig. 4), in addition to the predefined "Process", "Phase", and "Iteration" stereotypes, we propose the stereotypes "FrameworkSupport" and "Transformation" along with its specializations "ModelTransformation" and "CodeGeneration". Additionally, to the "Process" of "ActivityKind", we propose as specializations the "GlobalProcess" and "ElementaryProcess" stereotypes. The purpose of each of these "ActivityKind" stereotypes is explained in the following paragraphs. The illustration of their use is exposed in section 4, which relates to the case study.

The "GlobalProcess" stereotype allows the representation of the global process that encompasses the overall development of the system (as considered in the development structure). The convenience of this stereotype arises since an approach consistent to the development structure will have two major types of processes: a global process and several elementary development processes. This stereotype allows representing such overall process and also to relate with the overall main activities. The "ElementaryProcess" stereotype allows the representation of an elementary development process that exists for a Development structure associated with each functional profile instance. The convenience of this stereotype is analogous to the "GlobalProcess"

stereotype: this stereotype allows the representation of an elementary development process and of the relationships of its inherent main activities.

The "Transformation" stereotype is an abstract generalization that represents the activities of transformation models or other artifacts. Model-based/driven approaches are rich on these transformations; the specializations of this abstract stereotype allow to represent such transformations and to give further emphasis on its formalization. Specializations of this the "Transformation" stereotype are "ModelTransformation" and "CodeGeneration" stereotypes, which are next described.

The "ModelTransformation" stereotype, a specialization of the "Transformation" stereotype, intends to represent activities that transform models into other kinds of model. The "CodeGeneration" stereotype intends to represent activities that transform models into code, or any other suitable artifact into code (for example, source code into executable code).

The "FrameworkSupport" stereotype has a particular use. It does not map into any element of the development structure, but is essential for the overall structuring of development structure. The "FrameworkSupport" stereotype intends to represent any special activity related to the organization and deployment of the development framework, such as assisting the definition of the resources categories, functional profiles, functional profile instances, or elementary development processes.

Regarding to the "WorkProductKind" stereotypes (Fig. 5), in addition to "Artifact", "Deliverable", and "Outcome" stereotypes, we propose "FunctionalProfile", "ResourceCategory", and "FP_Instance" stereotypes. These stereotypes aim to represent work products directly related to the development structure. These stereotype are convenient as they allow the representation of structural elements of the development structure.

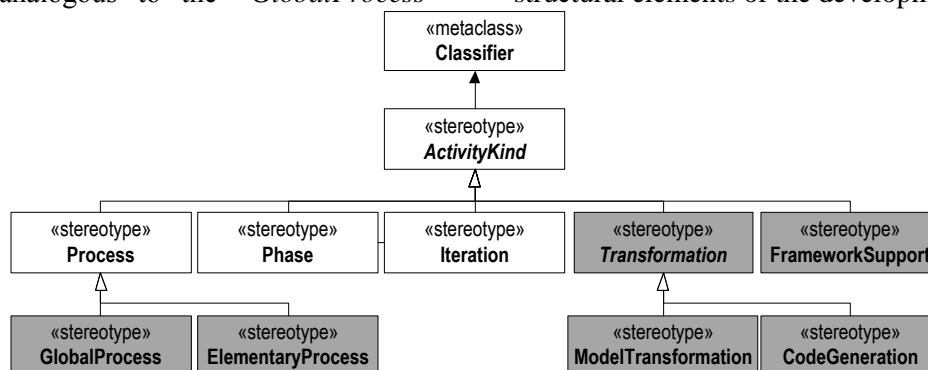


Fig. 4 - New "ActivityKind" stereotypes.

The “*ResourceCategory*” stereotype intends to represent a work product that defines a resource category. Resource categories, as devised by the development structure, are the elements present in the resources dimension of the development structure. The “*FunctionalProfile*” stereotype intends to represent a work product that defines a functional profile. Functional profiles, as devised by the development structure, are the elements present in the functional dimension of the development structure. The “*FP_Instance*” stereotype intends to represent a work product that defines a functional profile instance. A functional profile instance, as devised by the development structure, is an element that results from the assignment of a particular functional profile to a particular resource category.

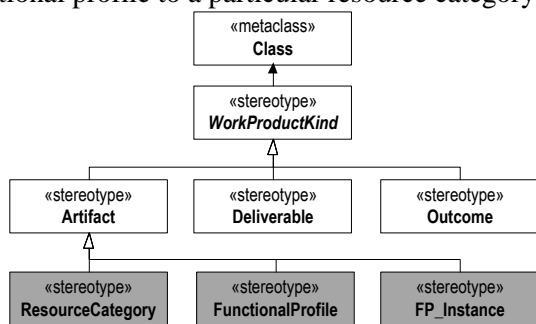


Fig. 5 - New "WorkProductKind" stereotypes.

4 Case Study: uPAIN Project

uPAIN (Ubiquitous Solutions for Pain Monitoring and Control in Post-Surgery Patients) [33] is an information system solution for hospital anesthesiology services.

4.1 General Description

uPAIN assists monitoring and controlling pain of patients that stay a relatively long period of recovery after being submitted to a surgery. During this period, patients receive analgesics in order to minimize the pain that increases as the effects of the anesthesia gradually disappear. The administration of analgesics, controlled by means of specialized devices called PCAs (patient controlled analgesia), is based on the personal characteristics of the patient and the kind of surgery to which the patient has been submitted. The PCA can be described as “*a medication-dispensing unit equipped with a pump attached to an intravenous line, which is inserted into a blood vessel in the patient’s hand or arm. By means of a simple push-button mechanism, the patient is allowed to self-administer doses of pain relieving medication (narcotic) on an ‘as need’ basis*” [33]. The main idea behind the uPAIN

system is to replace the PCA push-button by an interface on a PDA (personal digital assistant). By this way, while still allowing the patient to request doses from the PCA, the system create records in a database of those requests along with other data considered relevant by the medical staff.

uPAIN system intends to provide a platform that enables improvement of pain treatment services. It allows: (i) to establish automatic regular assessment and registering of pain level, as well as to provide for an enhanced and faster individual therapeutic prescription to pain symptoms; (ii) to provide support for written therapeutic protocols and storage of the therapeutics treatment given to patients; (iii) to facilitate to the Director of the Anesthesiology Services: the adjustment of the monitoring and controlling equipment to the particular capabilities of each different person composing his staff; the supervision of all staff activities for nocturne or weekend periods. The uPAIN system also allows the hospital staff, through wireless networks, to also remotely control and monitor the pain outside the hospital network (through 3G networks). Fig. 6 illustrates the architectural solution for uPAIN system. It reflects the devices and communications technology needed to accomplish the functionality expected from the uPAIN system.

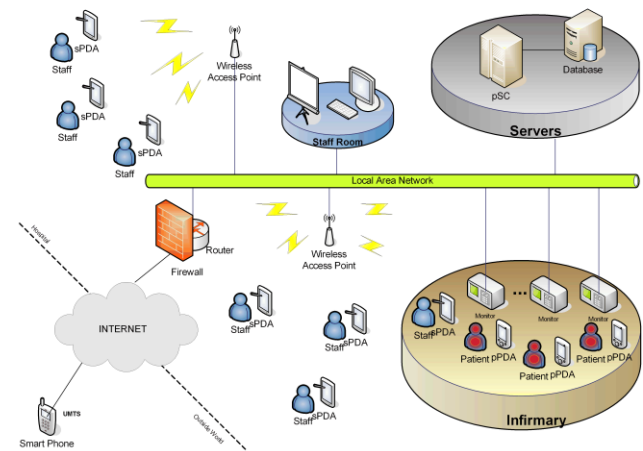


Fig. 6 - General architecture for the uPAIN system.

uPAIN connects, by a computer network system, the monitoring equipment and the PCA; it also supports communication among staff and patients. This enables, from the staff point of view, the ubiquity of the system’s functionality. A central server (pSC) receives information sent by the patient PDA (pPDA). This server is responsible for the management of all services provided by uPAIN. It provides support for data acquisition from all medical equipment, for accessing databases, and for managing requests from all the pPDAs and the staff PDAs (sPDAs).

4.2 SPEM Description

The phases, main activities, tasks, artifacts, deliverables of the uPAIN project, as also as their relationships, are graphically visible through the SPEM model presented in Fig. 8. As it can be seen in Fig. 8, uPAIN project organized its main development activities through several main groups: Project management; Requirements Analysis and Elicitation, Research and Technological Development, Exploration and Evaluation of the Application, and Medical Research.

Taking into account the uPAIN architecture, the use of suitable profiling and framing techniques [34] allows to obtain the framing structure for uPAIN system (illustrated by Fig. 7). This structure shows the functional profiles the established functional profiles.

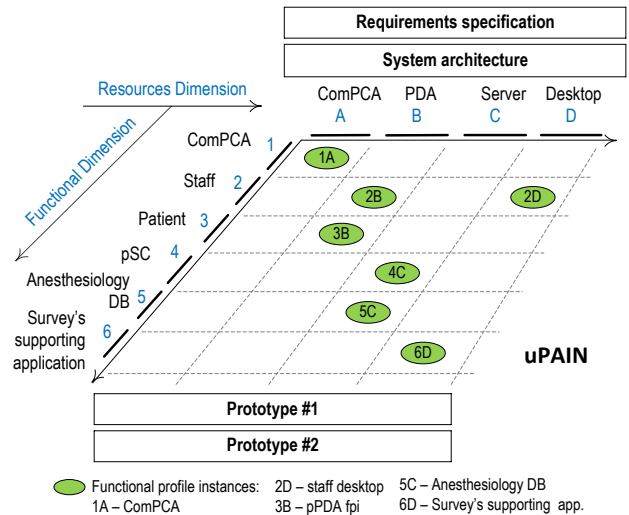


Fig. 7 - Framing structure for uPAIN.

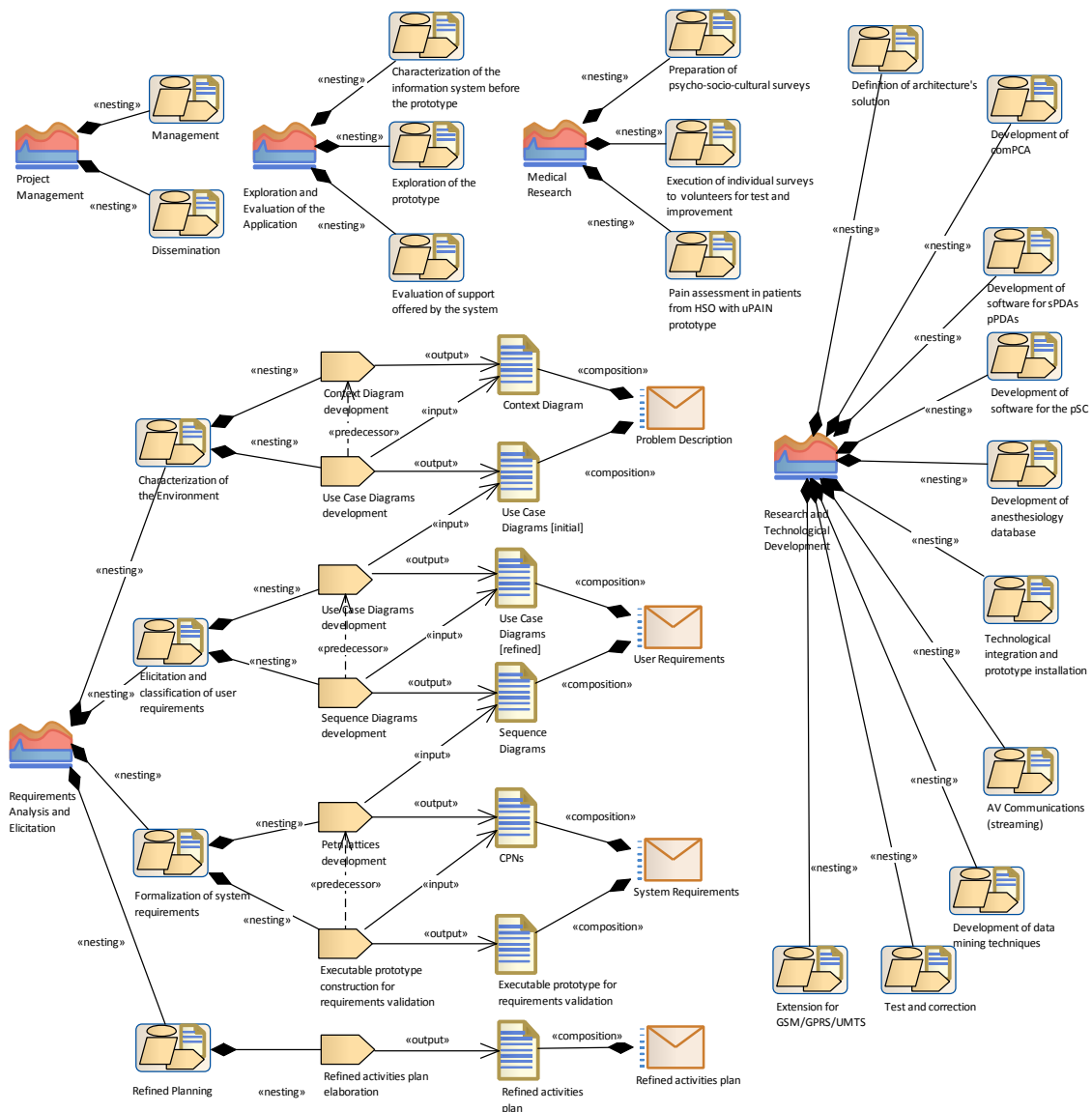


Fig. 8 - uPAIN development process under a SPEM 2.0 perspective (part of).

Fig. 9 describes part uPAIN project according to the conceptual development framework and using the extended stereotypes. The stereotypes enable the explicit representation of resource categories, functional profiles, and functional profile instances associated to the system. In Fig. 9 we can observe that the stereotype «FrameworkSupport» fulfills a central role on the organization and realization of the conceptual development structure (as presented in previous section describing this SPEM extension). Fig. 10 presents a complementary perspective that gives emphasis to the elementary processes and the main activities they incorporate. Particularly, it shows a model transformation activity, named “4SRS application” and identified by the corresponding stereotype «ModelTransformation»; the 4SRS (4 Step Rule-Set) technique allows the transformation of user requirements into a logical system-level architecture representing system requirements.

extension differs from other SPEM extensions, since we extend the SPEM Base Plug-In instead of the SPEM meta-model. By means of a real case study, the extension proved to be able to: (i) suitably represent the concepts inherent to referenced framework, which allowed for a clear perception of the application of inherent concepts; (ii) represent some of the MDD fundamental concepts, such as model transformations. The use of this extension revealed as being able to provide support to: (i) sustain a structured and well-organized set of development process elements; (ii) cope with heterogeneity and quantity of computational devices (through the concepts of resources categories, functional profiles, and functional profile instances); (iii) promote a model-based/driven approach to software development (through use of transformations).

Regarding future work, it is of interest to alternatively express this extension through the SPEM meta-model itself, to perform a deeper integration of process variability mechanisms, MDD, process enactment, and to explore a conception of model-based/driven visibility.

5 Conclusion

This paper describes a SPEM extension based on the conceptual development framework for PIS. This

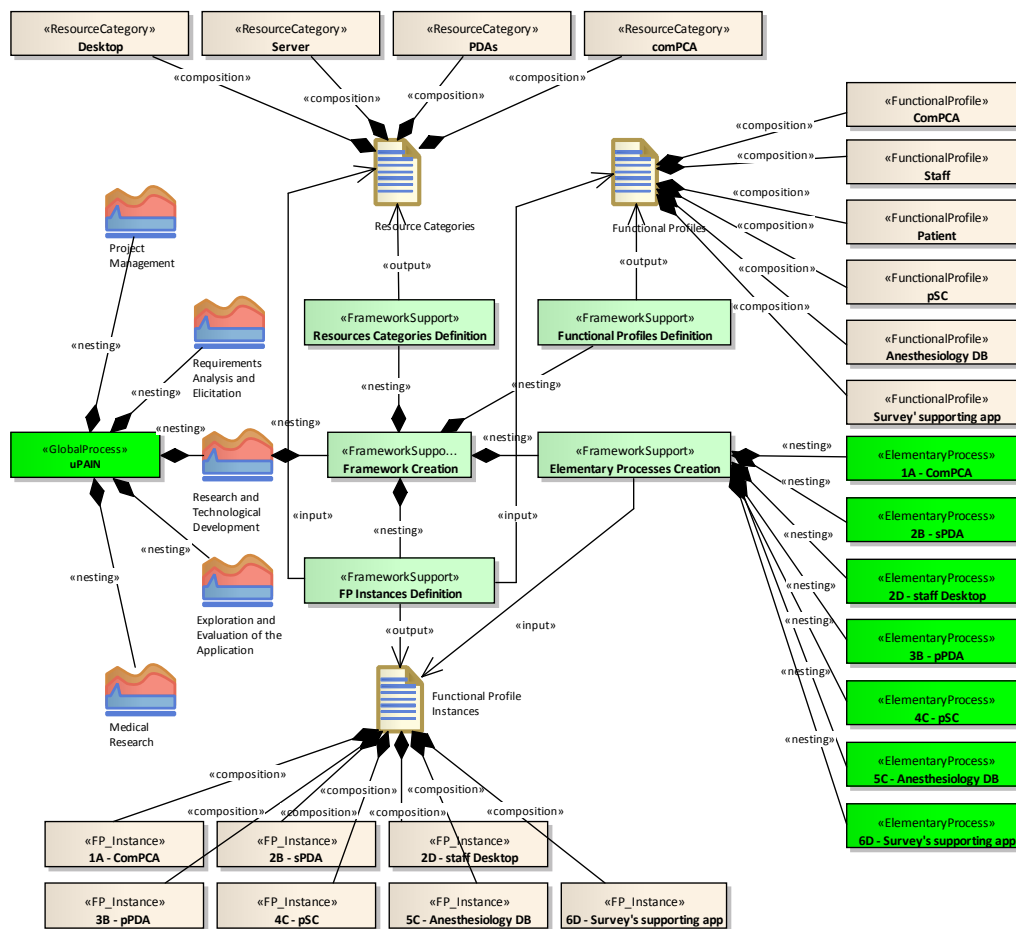


Fig. 9 - uPAIN development process with extended SPEM diagram (major structuring elements).

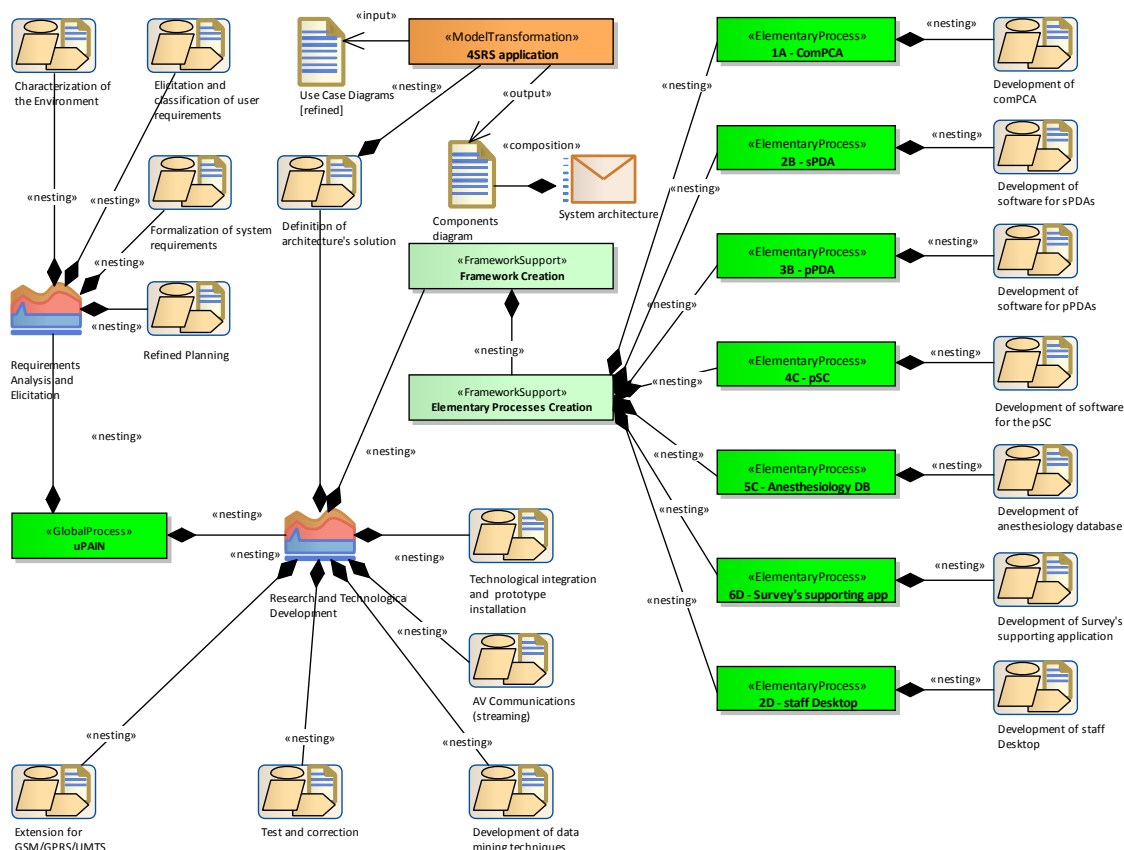


Fig. 10 - uPAIN development process with extended SPEM diagram (transformations and elementary process activities).

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