Proposing a Knowledge Engineering Based Approach for Process Capability/Maturity Models Customization

Jean Carlo R. Hauck[1,2], Christiane Gresse von Wangenheim[1], Fergal Mc Caffery[2], Aldo von Wangenheim[1]
[1]Federal University of Santa Catarina (UFSC)
Florianópolis/SC – Brazil
gresse@gmail.com
[2] DkIT – Dundalk Institute of Technology
Dundalk/Co. Louth, Ireland
jeanhauck@gmail.com

Abstract

Software Process Capability/Maturity Models (SPCMMs) are repositories of best practices for software processes suitable for assessing and/or improving processes in software intensive organizations. Yet, although there is a trend to customize such models to specific domains, little research is done on how such SPCMMs should be developed with quality. In this paper, we, therefore, propose a systematic approach to support the customization of SPCMMs for specific domains. The approach is developed based on standard development processes integrating Knowledge Engineering techniques and experiences on how such models are currently developed in practice. First feedback from piloting the approach in the customization of ISO/IEC 15504, CMMI and MPS.BR for the SaaS scenario indicates that the approach can be useful for creation of SPCMMs.

Keywords

Knowledge Engineering, Process Reference Models, Process Capability/Maturity Models

1 Introduction

Software Process Capability/Maturity Models (SPCMM) are repositories of best practices for software processes, based on good engineering and process management principles, organized with the concept of process capability and/or maturity, suitable for assessing and/or improving processes [1]. Various generic process capability/maturity models have been developed by the software engineering community, such as, CMMI-DEV [2] and ISO/IEC 15504 [3], and their use for software process improvement and assessment is well established in practice. Yet, as these generic models intend to cover a wide range of diverse types of software products and services, processes, technologies, etc., their application in practice often requires a customization to the specific context [4]. Diverse specific software development domains have specific process quality needs that should be covered. Likewise, there are specific standards for software development, especially in the case of regulated sectors, such as health care, that must be observed by the software development process in order to provide the necessary alignment to these domain-specific standards. In order to facilitate such an adaptation, we can observe a current trend to the development of customizations of those generic process models for specific domains. Various initiatives have taken place to specialize and refine generic software process capability/maturity models adapting best-practices for process improvement in specific software development domains/sectors, such as SPICE4SPACE [5], OOSPICE [6], SMCMM [7], etc.

However, most of these initiatives do not adopt a systematic approach for the customization of those generic standards and models [8]. Actually, literature detailing how software-related process capability/maturity models are developed / evolved / adapted is extremely rare [9]. Standardization organizations, like ISO or IEEE, define high-level generic processes for developing and publishing standards. However, they do not describe how to customize existing models or provide detailed technical support for the specific development of SPCMMs.

Alternatively, these SPCMMs may be defined as “best practices” knowledge repositories. Focusing on the extraction and modeling of the knowledge (although, in our case, there is no intention to implement a knowledge-based system), Knowledge Engineering (KE) may provide an important contribution. To date, KE approaches have not been applied to this specific aim.

In this context, we present a proposal for such an approach, based on an analysis on how existing customizations have been performed, integrating standard development procedures and KE techniques. The main contribution of this paper consists on the definition of an innovative methodological process for the customization of the generic SPCMM for specific software development domains. In section 2, the background of SPCMMs is presented. Section 3, presents related software process improvement (SPI) and KE research. In section 4, our approach is proposed, and section 5 presents results from its pilot application. Conclusions and future works are presented in section 6.

2 Related Work

Although, diverse software process capability/maturity model customizations have already taken place [10], research on how to perform such customizations in a systematic way is sparse. One of the few works in this respect is done by Bruin & Rosemann [10], who propose a sequence of steps for the development of Maturity Assessment Models: (i) the definition of the scope of the model, (ii) the design of a new model, (iii) population of the model using domain components as source of specific needs, (iv) test, (v) deployment, and (vi) maintenance of the model. Although, this work considers specific domain needs, it does not address in detail the customization of domain-specific best practices from generic models.

Mettler [11] performs a deeper analysis on the fundamentals of process maturity models, putting the main phases described in [10] under a design science research perspective. In this context, the phases are compared to a model user perspective of the maturity models, indicating a need for more formal methods and studies. Salviano et al. [12] propose the generic framework PRO2PI for the development of process capability/maturity models, based on the authors previous experiences of developing diverse models. The framework consists of seven steps: (i) initial decisions; (ii) sources (of good practices) analysis, including literature, surveys of practitioners, and others; (iii) strategy for development, including how the community of interest will be involved; (iv) model design using ISO/IEC 15504 as the general structure for modeling; (v) draft model development; (vi) draft model validation; and (vii) model consolidation from an analysis of the validation of draft model results. This work represents initial research towards achieving an approach for the customization of software process capability/maturity models. To date, no detailed support is available in relation to this research. Matook and Indulska [9] propose a QFD-based approach for reference modeling incorporating the voice of the reference model users and presenting a compressed measure for the quality of such models. Their approach also provides a means for managing quality reference model development including the following phases: (i) problem definition; (ii) requirements analysis; (iii) information gathering; (iv) setting conventions and rules; (v) documentation; (vi) construction and design and (vii) evaluation. This research works presents the first steps towards the development of more systematic support for the development of reference models. However their principal focus is on the model construction, with no coverage provided of its usage and evolution. Likewise, they do not provide detailed methodological support for the customization of SPCMMs.

Based on a systematic literature review [8] and a survey [13], we also observed that, most publications which propose model customizations (52% of more than 50 models) do not report on how the customization has been done.

From a KE point of view, the customization of such models relates to knowledge acquisition, collecting best practices of a specific domain by customizing generic SPCMMs to domain-specific models. A generic life cycle for KE includes (i) knowledge identification; (ii) knowledge specification and (iii) knowledge refinement [14]. Currently, there exist several methodologies, frameworks and approaches that provide detailed support for the KE development life cycles, such as, e.g., CommonKADS [15]. Yet, again, the usage and evolution of the knowledge models is typically not covered. In addition, KE techniques have so far, not yet been applied for the customization of generic SPCMMs knowledge to specific domains. Therefore, we can observe a lack of methodologies that offer substantial support for the customization of SPCMMs

3 A Knowledge Based Approach for Process Reference Model Customization

In order to facilitate the customization of SPCMMs and to increase the quality of these, as well as increase their adoption rate in practice, we are developing a KE-based approach presented in this section. The approach is based on an analysis of: (i) how currently such customizations are made; (ii) standard development procedures; and (iii) KE techniques.

How it is being developed

With the objective of developing an approach based on scientific procedures we are following the steps presented in figure 1. We started the development with a theoretical approach, covering: KE, SE/SPI and process modeling concepts and approaches. In order to elicit the state of the art with respect to how domain-specific SPCMMs are developed, we performed a systematic literature review [8]. As a result, we identified 52 capability/maturity models, yet, most of them lacking details as to how they were developed. Therefore, we performed a second step, a survey among the authors of the models [13] with the objective to obtain additional information on how these models have been developed.

Based on these results and our experiences in customizing SPCMMs, we developed the first version of a systematic approach for the customization of SPCMMs. The approach itself is being developed under a KE perspective [15] [16], using the customization experiences observed in the literature and descriptions obtained from model authors [8] [13], phases and steps of the ISO International Standard development process [17] and IEEE standard development process [18], PRO2PI [12], and the framework for process maturity models development proposed in [10].

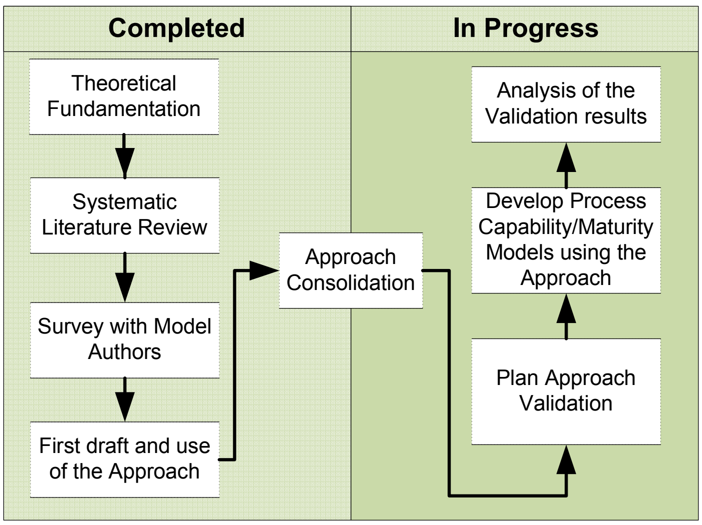

Fig 1. Steps on the development of the Approach

Currently, we are analyzing results obtained from the first usage of a draft version of the approach to consolidate its process and techniques. We will continue the iterative development of the approach while applying it in parallel to customize SPCMMs, until achieving a consolidated state. Then, a validation will be planned, executed and analyzed in order to provide a evaluation of its use.

The proposed Approach

The approach is structured (figure 2) in five phases: (i) Knowledge Identification, (ii) Knowledge Specification, (iii) Knowledge Refinement, (iv) Knowledge Usage and (v) Knowledge Evolution. Each phase is composed by a set of activities that are not necessarily sequentially executed.

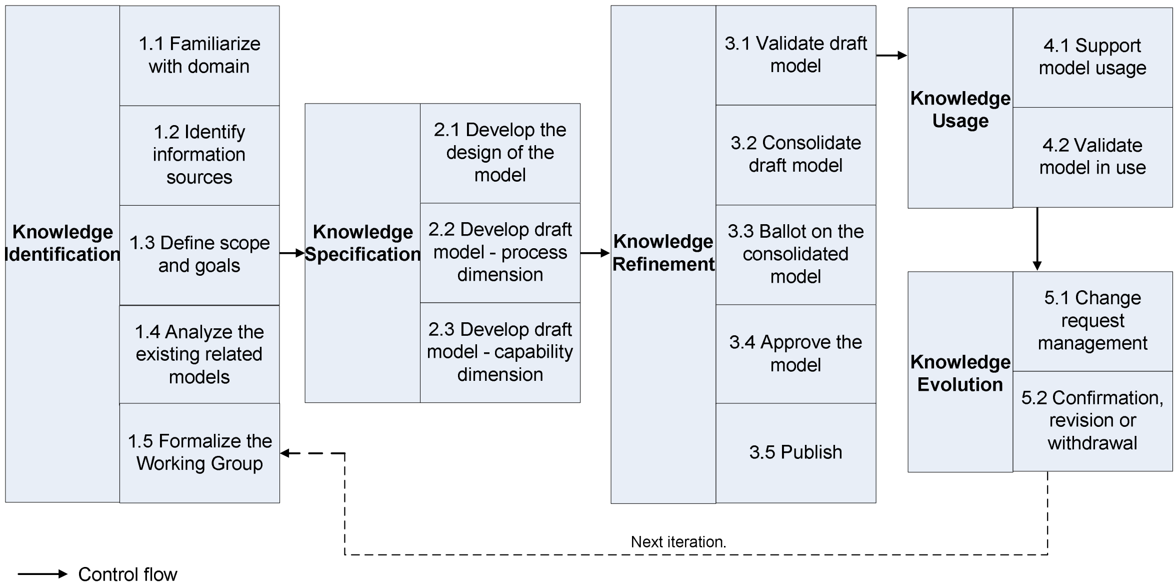

Fig 2. Phases and Activities of the Approach

Phase 1: Knowledge Identification

The main objective of phase 1 is to achieve familiarization with the target domain and a characterization of the context for which the SPCMM will be customized. Related activities are:

Activity 1.1 - Familiarize with domain: Consists in a contextualization in the domain for which the model will be developed. An analysis of domain-related literature provides, in the first place, a deep understanding of exactly what the domain is and its characteristics, providing main concept definitions and terminology, and identifying the underlying general process.

Activity 1.2 - Identify information sources: that will be used as input for the model development. Important information sources consist of: human resources, domain-specific software development standards, generic process capability/maturity models, or reports/papers which identify e.g. important quality / performance aspects. The identification of human sources requires the definition of profile of knowledge agents which in this context means to describe the software development domain experts. It is also necessary to identify which generic SPCMM will be customized for the specific domain. The choice depends on how important each generic SPCMM is for the domain sector in terms of reliability, applicability and market impact.

Activity 1.3 - Define scope and goals: of the model to be developed. The scope of the customized SPCMM must precisely define the limits of the application domain, and define without ambiguity the subject of the model and the aspects covered, thereby indicating the limits of its applicability or particular parts of it. It is important that to identifying the specific goals that must be achieved by the SPCMM to be customized, determining the aims and the interests that may be affected.

Activity 1.4 - Analyze existing related models: once specified the scope of the SPCMM has to be customized, relevant source models are defined and analyzed. This typically involves a mapping of the related models and/or a harmonization effort integrating the existing models into a unified model.

Activity 1.5 - Formalize the working group: for the development of the model. This includes the definition of the allocation of a sponsor/coordinator, working rules and procedures that will be used during the development of the new model. It also includes the invitation of relevant stakeholders to participate and defines who has the rights to vote to approve the model within the working group, who can make change requests and who has the capability to contribute with the model development.

Phase 2: Knowledge Specification

During this central phase, a first version of the customized model is developed, following these proposed activities:

Activity 2.1 - Develop the design/architecture of the model: identifying the main elements of the model. The standard ISO/IEC 15504 establishes a general structure for model design. This structure includes a Process Reference Model and a Process Assessment Model. Typically, within customizations, the structure of one of the principal source models is adopted. Therefore, the structure of those models has to be analyzed and if necessary, modified appropriately.

Activity 2.2 - Develop a draft model – process dimension: in this core activity the process dimension of the SPCMM is developed. Defining a process dimension of the SPCMM implies on identify relevant processes that contain best practices for the specific domain. To identify relevant processes, it is necessary to identify which are important software quality/performance needs within the specific domain. This can be done by extracting this knowledge from the domain knowledge agents (identified in phase 1) using various techniques, such as: interviews, surveys, ontology engineering, focus groups, nominal group technique, etc. either individually or by combining any of those techniques in an iterative and incremental way. Then, in a next step, it is necessary to relate these identified quality attributes to relevant processes. An adapted version of QFD – Quality Function Deployment, involving also SPI experts, can be used to systematically map quality/performance needs with processes and required outcomes/best practices and typical work products. The mapping of related source models produced in activity 1.4 can be used to support the development of the customized SPCMM as a basis by re-using an appropriate process description (as is or by modifying them appropriately) completed by new processes when necessary.

Activity 2.3 - Develop a draft model – capability/maturity dimension: in order to produce a model that can serve as a reference for process assessment, a capability/maturity dimension is developed. Therefore, it is necessary to define attributes and group them into capability levels. This means to define attributes applicable to all processes that describe a facet of the overall capability of achieving process purpose and can be evaluated on a scale of achievement, providing a measure of the capability of the process [3]. Capability levels can be defined as sets of attribute(s) that work together to provide a major enhancement in the capability to perform a process. If it is suitable, processes can also be grouped in levels in order to define a Maturity dimension, following the priority order defined by the quality /performance needs prioritization. Again, the capability/maturity dimension of the underlying source models can be used as a basis, and being adapted when necessary. As result of this phase a draft model is developed.

Phase 3: Knowledge Refinement

In this phase, the draft model is validated, balloted and refined to develop a model approved by a majority of respective community.

Activity 3.1 - Validate draft model: the draft model itself is then validated in order to demonstrate that the draft SPCMM fulfils the general characteristics required of SPCMMs (table 1). In this step, such a validation is typically based on a consensus of relevant stakeholders reviewing the model. Various techniques can be used, including Expert Panel, Delphi etc.

Activity 3.2 - Consolidate draft model: Based on feedback obtained, the draft model is iteratively evolved, until consensus is achieved among the members of the working group. This requires: the discussion, negotiation and resolution of significant technical disagreements in order to prepare a model that will be accepted and widely used.

Activity 3.3 - Ballot on the consolidated model: During this activity, the developed model is distributed, and interested parties vote on the approval or rejection of the model.

Activity 3.4 - Approve the model: Clear criteria for approval must be defined as well as procedures for what happens upon approval or non approval. If necessary, reviews of the model are repeated until the model is approved.

Activity 3.5 – Publish: the resultant model is then made available in an accessible place for the respective domain community.

Phase 4: Knowledge Usage

After its publication, the model is been put in use and results of its usage are collected and analyzed.

Activity 4.1 - Support model usage: it is necessary to define which kind of support will be provided for the model usage, such as, training, user forums, etc. For example, the establishment of a web forum is important to keep the SPCMM development community active.

Activity 4.2 - Validate model in use: in order to validate the model based on its usage in practice, a framework for its validation has to be defined, data collected and analyzed. Such a framework can be developed, using for example, the GQM method. The results will complement the results of the earlier expert validation that was performed and this may be used to develop future new versions of the model.

Phase 5: Knowledge Evolution

Due to various reasons, SPCMMs evolve constantly (maturing of the domain knowledge, technological advances, etc.). Therefore it is necessary to also provide methodological support for the continuous evolution of the model once the model has been implemented in the target domain.

Activity 5.1 - Change request management: it is necessary to define how change requests from different stakeholders are collected in a systematic way and how they are managed.

Activity 5.2 - Confirmation, revision or withdrawal: the process model development group defines which changes will be accepted and how new versions of the model will be published. Each group of changes must follow phase 3 to provide validation of the changes. This process must be supported by a regular configuration management process.

In this way, the proposed approach presents a first proposal for the systematic customization of SPCMMs. In the next section, we show first results and lessons learned we obtained by piloting the proposed approach in the development of a customized SPCMM.

4 First Results and Discussion

The proposed approach for SPCMM customization has been developed in parallel with the customization of a SPCMM for the Software as a Service (SaaS) domain [19].

SaaS is a software solution offered as a service and is developed using SOA. As the SaaS scenario requires specific quality needs, such as, security, availability and service continuation, due to its characteristics of distributed software products as services, a customization of SPCMMs has been done. The SaaS SPCMM has been developed by a group of researchers at the UFSC – Federal University of Santa Catarina/Brazil, involving experts from the SaaS domain and SPI experts. We developed the model through adopting the proposed approach, covering the phases 1 to 3. At present, phases 4 and 5 have not been performed.

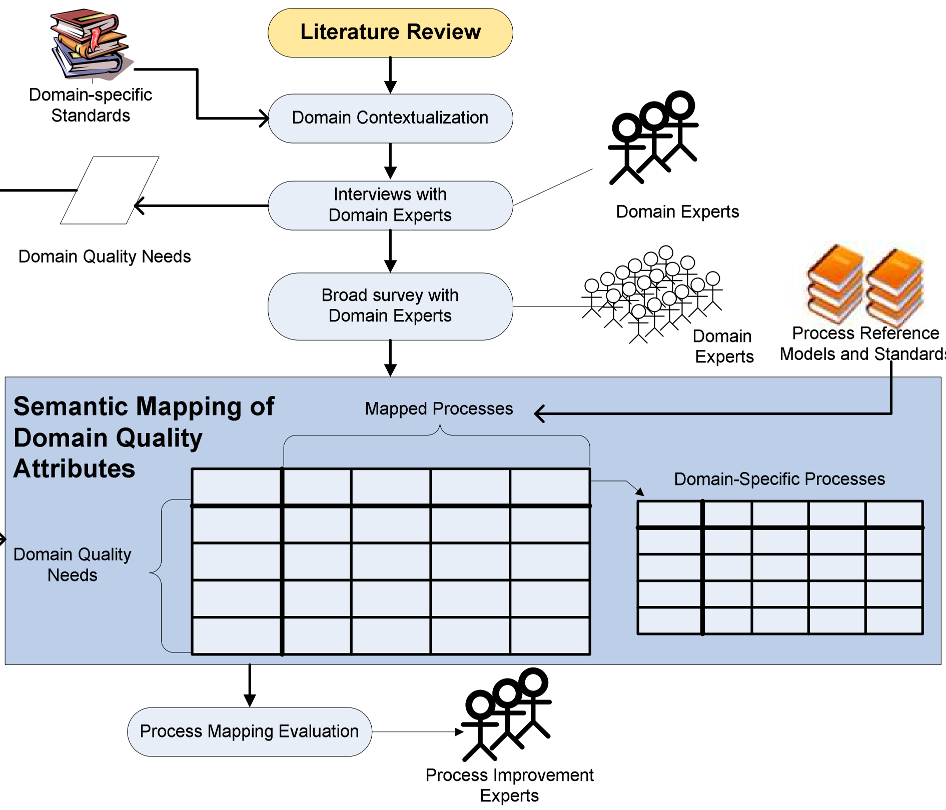

Fig 3. Process adopted for the development of SaaS SPCMM [19].

Following the process illustrated in figure 3, the domain has been contextualized and stakeholders have been identified and characterized. Generic SPCMMs (ISO/IEC15504-5, CMMI-DEV, MPS.BR and CMMI-SVC) have been analyzed and identified as a basis for the customized model. In addition, relevant quality and performance needs in the SaaS domain have been elicitated based on a literature review.

During phase 2, we decided to basically adopt the architecture of ISO/IEC 15504 as the structure of the customized model. Developing the process dimension, in a first step we interviewed 6 SaaS experts in order to complete the elicitated quality and performance needs. The results have then been validated in a second step through a survey, involving 84 SaaS experts, who reviewed and prioritized the identified needs.

Then, a group of 3 SPI experts identified relevant processes and basic practices with respect to the identified quality and performance needs by mapping them using an adapted version of the QFD approach [9]. The result was a draft version of the process model (figure 4). So far, no specific capability/maturity dimension has been developed, adopting simply the capability dimension from ISO/IEC 15504.

CORRELATION MATRIX

Legend:

Essential
Very Important
Important
Weakly Important
Unnecessary

ISO 15504

	ACQ					SPL			ENG											
	ACQ.1 Acquisition preparation	ACQ.2 Supplier selection	ACQ.3 Contract agreement	ACQ.4 Supplier monitoring	ACQ.5 Customer acceptance	SPL.1 Supplier tenDering	SPL.2 ProDuct release	SPL.3 ProDuct acceptance support	ENG.1 Requirements elicitation	ENG.2 System requirements analysis	ENG.3 System architectural Design	ENG.4 Software requirements analysis	ENG.5 Software Design	ENG.6 Software construction	ENG.7 Software integration	ENG.8 Software testing	ENG.9 System integration	ENG.10 System testing	ENG.11 Software installation	ENG.12 Software anD system maintenance
DUCTS Accessibility	U	U	U	U	U	U	U	U	I	V	U	I	U	U	U	U	U	U	U	U
Reliability	I	I	I	I	E	W	W	W	E	E	I	I	V	I	I	E	I	E	I	V
Performance	I	I	I	I	E	W	W	W	E	E	E	E	E	V	I	E	I	E	W	V
Availability	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

	OPE		MAN						PIM			RIN			
	OPE.1 Operational use	OPE.2 Customer support	MAN.1 Organizational alignment	MAN.2 Organizational management	MAN.3 Project management	MAN.4 Quality management	MAN.5 Risk management	MAN.6 Measurement	PIM.1 Process establishment	PIM.2 Process assessment	PIM.3 Process improvement	RIN.1 Human resource management	RIN.2 Training	RIN.3 KnowleDge management	RIN.4 Infrastructure
DUCTS Accessibility	E	U	U	U	U	U	U	U	U	U	U	U	U	U	E
Reliability	I	I	U	U	I	V	W	W	U	U	U	W	I	W	I
Performance	I	W	W	W	V	I	W	W	U	U	U	W	I	W	I
Availability	E	W	U	U	U	I	U	U	U	U	U	U	U	U	E

Fig 4. Extract of the mapping of quality and performance needs to relevant processes (The complete version of the matrix is available at http://www.gsigma.ufsc.br/~cancian/msc/mapping.pdf).

During phase 3, the draft model has been reviewed by different SPI experts and the model has been improved based on the obtained feedback.

This experience allowed us to identify strengths and weaknesses of the proposed approach in practice. One of its strengths is the involvement of specialists, although we also identified that in order to stimulate a wide adoption of the model, a much stronger involvement of the community is also required. Another strength is the methodological support which typically, for standard developments, is not available. Using for example, a modified version of the QFD allowed systematic mapping and also allowed explicit derivation of the model. We also observed several improvement opportunities:

- Support for a systematic mapping and harmonization of existing models;
- Better methodological support for consensus building among community representatives throughout the models development and not just elicitation of their knowledge;
- More systematical and formal support for the validation of the models.
- Integration of data-based input to the models if available in the specific domain in order to complete the expert's knowledge.

5 Conclusions

In this paper, we outline an approach for SPCMM customization by integrating a KE perspective, customization experiences from literature and standard development processes. A first application of the proposed approach for the customization of a SaaS SPCMM provides a first indication that the approach can be useful for the customization of such models as well as enabling the identification strengths and weaknesses. Based on the feedback, we are currently evolving and refining the proposed approach as well as continuing its application in parallel for the customization of SPCMMs, such as, for medical devices as well as digital convergence.

Acknowledgements

Authors would like to thank Maiara H. Cancian for sharing experiences on the development of the SaaS Process Reference model.

This work was supported by the CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) and CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), entities of the Brazilian government focused on scientific and technological development. This research is also supported in part by Science Foundation Ireland (SFI) through the Stokes Lectureship Programme, grant number 07/SK/I1299, and the SFI Principal Investigator Programme, grant number 08/IN.1/I2030.

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Author CVs

Jean Carlo R. Hauck

Jean Carlo Rossa Hauck is visitor researcher at Dundalk Institute of Technology (DkIT) and SEPG manager of the CYCLOPS Research Group at the Federal University of Santa Catarina (UFSC). His research interests are in software process improvement and project management. He received his M.Sc. in Computer Science from the UFSC and he is PhD student of Knowledge Engineering and Management at the Federal University of Santa Catarina. Contact him at UFSC - EGC, Campus Universitário 88049-200 Florianópolis/SC, Brazil; jean-hauck@incod.ufsc.br

Christiane Gresse von Wangenheim

Christiane Gresse von Wangenheim is a professor at the Federal University of Santa Catarina (UFSC). Her research interests are software process improvement, including project management. Previously, she worked at the Fraunhofer Institute for Experimental Software Engineering and the UNIVALI. She received a PhD in Production Engineering at the Federal University of Santa Catarina (Brazil) and a PhD in Computer Science at the University of Kaiserslautern (Germany). She's also a PMP - Project Management Professional and Assessor of the Brazilian Process Improvement Model MPS.BR. She's a member of the IEEE Computer Society, the Project Management Institute, and the Working Group ISO/IEC JTC1/SC7/WG24—SE Life-Cycle Profiles for Very Small Enterprises. Contact her at UFSC, Campus Universitário 88049-200 Florianópolis/SC, Brazil; gresse@gmail.com

Fergal McCaffery

Fergal Mc Caffery is a Lecturer with Dundalk Institute of Technology. He is leader of the Regulated Software Research Group in Dundalk Institute of Technology and a member of Lero. He has been awarded Science Foundation Ireland funding through the Stokes Lectureship and Principal Investigator Programmes to research the area of software process improvement for the medical device domain. Additionally, he has received EU FP7 research funding to improve the effectiveness of embedded software development environments for the medical device industry. Contact him at fergal.mccaffery@dkit.ie.

Aldo von Wangenheim

Aldo von Wangenheim is a professor in medical informatics and telemedicine at the Federal University of Santa Catarina's University Hospital. His research interests include medical image analysis for diagnosis support and large-scale telemedicine frameworks for public health and healthcare education. von Wangenheim received his PhD in computer sciences from the University of Kaiserslautern, Germany. He has been nominated to coordinate the newly created Brazilian National Research Institute for Digital Convergence in Health. Contact him at awangenh@inf.ufsc.br.