Towards a \{(Process Capability Profile) - Driven (Process Engineering)\} as an Evolution of Software Process Improvement

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Abstract

This article presents an innovative proposal towards a process engineering, driven by process capability profile, for software and any other knowledge intensive human work as an evolution of the current software process improvement. The proposed process engineering is based on a critical view on the current state of the practice and state of the art presented as seven issues and opportunities. An exemplar approach, named PRO2PI, for the proposed process engineering is also presented. The PRO2PI approach has been constructed using an industry-as-laboratory approach in 200 process improvement projects since 1999. The proposed process engineering and the PRO2PI approach aim to guide the software intensive industry, specially small software intensive organizations, in the establishment of relevant, feasible, opportunistic, systemic, representative, traceable, specific and dynamic process capability profiles to drive more innovative and successful business oriented process improvements cycles, as an evolution of the current process improvement approaches composed by the implementation of the fixed “one size fits all” maturity levels of SW-CMM and CMMI models.

Keywords

process improvement, process engineering, process capability profile, process capability model, ISO/IEC 15504, small software organizations
1 Introduction

The software industry has been using software process improvement approaches, based on the maturity levels of SW-CMM and CMMI staged models, to improve its business. However, in practice, most organizations are, usually in an informal basis, doing more than just implement the maturity levels. They are using multiple models and other references for process improvement, and they are using additional process areas. They are also using process improvement in other areas related to software processes. This article presents a proposal towards a Process Capability Profile Driven Process Engineering (PCDE) as an evolution of the current Software Process Improvement based on Process Capability (and Maturity) Models. This proposal has been constructed since 1999 using experiences from many process improvement projects in software industry. An industry-as-laboratory approach [Potts 1993] was used, instead of the traditional research-then-transfer approach. This proposal aims to formalize what software intensive organizations are already doing, in an informal way.

The article is organized in six sections. This introduction is the first section. The second section presents a critical view on the current scenario as seven issues and opportunities that oriented this research. The third section presents a proposal for a process engineering as an evolution of the current software process improvement. The fourth section presents an approach for the proposed process engineering. The fifth section presents experiences in software industry. Finally, the sixth section presents a conclusion.

2 Seven issues and opportunities

As a synthesis of a critical view on the issues and opportunities from the current state of the art and state of the practice of software process improvement area and related areas, seven views are presented.

• **Fixed maturity levels:** The software process improvement area was established based on the fixed “one size fits all” maturity levels of SW-CMM model [Paulk et al. 1994] from around 1993 until its retirement around 2002 and of CMMI staged representation models [Chrissis et al. 2003] since 2000. These maturity levels guided the software industry on the improvement of the process for software development projects. As all good pioneer work, the maturity levels established an area based on “one size fits all” approach, as, for example, Henry Ford established the car industry with his “T model” black car. After the establishment, there is a need for more flexibility to cope with the diversity. Most of the problems of software process improvement identified by the community, as, for example, the ones from Conradi and Fuggetta [2002] and Rifkin [2002], are due to the fixed maturity levels of SW-CMM and CMMI models.

• **Flexibility of continuous architecture:** The ISO/IEC 15504, also known as SPICE (Software Process Improvement and Capability dEtermination) proposed the continuous architecture as a more flexible alternative to the fixed maturity levels of staged models. The continuous architecture defines two dimensions for process capability models: one with a set of processes and another with process capability levels. An organization can choose a process capability profile, which is a subset of processes, each one in at a process capability level, to guide the improvement of its more relevant processes. Examples of continuous models are the ISO/IEC 15504-5 [2006], FAA iCMM model [Ibrahim 2000] and the continuous representation of CMMI models [Chrissis et al. 2003]. In order to be more used by software industry, the continuous models need an evolution of the current approaches for software process improvement. There a need for methodological support to use the flexibility to define process capability profiles.

• **Using multiple models:** Many organizations are using simultaneously elements of multiple models as reference for process improvement. Some of these models are capability maturity models, other are certification models, other generic process models and any other kind of model that represents best practices. Maybe the most common combination nowadays is the combined usage of CMMI-SE/SW staged representation, ISO 9001, RUP and PMBOK.
The definition or use models: Nowadays there is a clear cut separation between groups that define process capability models and the ones that only use these models. Examples of groups that define models include SEI groups, in the development of SW-CMM and CMMI models, ISO/IEC JTC1 SC7 WG10 group, in the development of ISO/IEC 15504-5 model, FAA groups, in the development of iCMM model, and MPS-BR group, in the development of MR-MPS model [Weber et al. 2005]. Examples of groups that only use one of these models are the SEPG groups of software intensive organizations.

More specific models: There is a tendency for more specific process capability models for technological segment or domain under the ISO/IEC 15504-2 framework. ISO/IEC 15504-2 [2003] defines six process capability levels as a measurement framework, the requirements for process reference models and process assessment process, and other orientations and requirements. In addition to the ISO/IEC 15504-5 model, CMMI models, iCMM model, MR-MPS model, there already other models under ISO/IEC 15504-2 framework, including the OOSPICE model for component-based software engineering [Stallinger et al. 2002] and automotive SPICE model for car’s software supplies for the automobile industry [Automotive SIG 2005].

Model-driven engineering: Model-driven engineering is an emergent area that put model in the center of an engineering. Favre concludes a model-driven engineering overview with the definition of two terms. “Model engineering is the disciplined and rationalized production of models. Model-driven engineering is a subset of system engineering in which the process heavily relies on the use of models and model engineering” [Favre 2005, p. 26].

Fundamental concepts: David Card observed that the process improvement approaches are “all based on very similar concepts and techniques”. However, because these approaches “have evolved or been adapted to software engineering largely without the participation of the academic research community”, “they are considered competitors”. “The packaging obscures the underlying principles. Eliciting and refining underlying principles is the role of science” [Card 2004].

An evolution of the current software process improvement should extend the fixed maturity levels using the flexibility of continuous models, supporting the usage of multiple models, including the development of more specific models, allowing an organization to define and use models as in model-driven engineering, by eliciting and refining the fundamental concepts and underlying principles of the current state of the practice and state of the art of software process improvement.

3 The basis and a proposal for a process engineering

Process can be considered as virtually any granularity. Given an organization unit, the complete view about what people do in that organizational unit can be seen as a process, in this case, the organization unit process. Any subset of the organizational unit process can be considered also as process, as, for example, the process for unit testing. An appropriate granularity for process is related what the ISO/IEC 15504-5 defines as “process” and what the CMMI models define as “process area”. In spite of the difference in name, both concepts are similar. ISO/IEC 15504-5:2006 defines 48 processes and CMMI-SE/SW v1.1 defines 22 process areas. The term “process area” is used in this research to mean both concepts. Therefore, a process is a set of actions that people do that could be represented by a process area, from any model.

The six process capability levels as defined by ISO/IEC 15504-2 are the best candidate for the fundamental law of process improvement. The performance of any process at an organization unit can be estimated by a characterization of the process in one of the six capability levels from level 0, incomplete, to level 5, optimizing, given that the process is abstracted as a process (area).

Process capability profile as a combination process capability level and process area, is the best candidate for the basic unified concept of a reference for a process improvement. Each element of a process capability profile represents a process, in the granularity of, and represented by, a process area, at a process capability level. Therefore a process capability profile represents a process at a granularity of the aggregation of the processes in each element. The Figure 1 illustrates a candidate for the basic relationship for process engineering.

Using the M0-M1 hierarchy [Bézivin 2003, slides 62 and 66], a process is a part of the world (M0)
represented by a model, in the modeling space (M1). In this case the model is a process capability profile that represents the process, under the process capability aspect. Note that a process description also can represent a process, in this case under the process description aspect. A process capability profile can be a prescriptive or descriptive model. As a prescriptive model a process capability profile drives the improvement of a process towards a better process using the requirements and orientations from the process capability profile. As a descriptive model the process is represented by a process capability profile that is a result from a process assessment process.

The short term “{(Process Capability Profile)-Driven (Process Engineering)}” and a long term “{(Process Capability Profile)-Driven [Software and any other Knowledge Intensive Human Work] (Process Engineering)}”, both with the same meaning and with the same initials (PCDE), are proposed as an evolution of the current software process improvement. A more complete definition for the proposed process engineering is presented at Figure 2.

Process improvement is not anymore only for software processes. The current versions of SEI CMMI and ISO/IEC 15504 use the term “system” as a more generic boundary that includes software. A boundary line related with the term “knowledge worker” seems to be more appropriate. This term was used by Peter Drucker in his 1959 book, Landmarks of Tomorrow as “a knowledge worker is anyone
who works for a living at the tasks of developing or using knowledge”. “For example, a knowledge worker might be someone who works at any of the tasks of planning, acquiring, searching, analyzing, organizing, storing, programming, distributing, marketing, or otherwise contributing to the transformation and commerce of information and those (often the same people) who work at using the knowledge so produced” [searchCRM 2006]. The knowledge worker includes those in the information technology fields, such as programmers, system analysts, technical writers, academic professionals, researchers, and so forth”. Knowledge workers include people outside of information technology, such as lawyers, doctors, diplomats, lawmakers, marketers, managers, bankers, teachers, scientists of all kinds and students of all kinds.

This PCDE definition is based on a combination of definitions for engineering, software engineering, software process engineering, software process improvement, process capability model engineering and model-driven engineering.

4 An exemplar approach for the proposed process engineering

The proposed process engineering was conceived during the many cycles of exploration, application and consolidation of a six years research following the industry-as-laboratory approach. During these six years an exemplar approach has been developed for the proposed process engineering. This approach, presented for the first time in Salviano et al. [2004], is named PRO2PI (Process Capability Profile to Process Improvement). Figure 3 illustrates an overview of PRO2PI approach.

A process capability profile to process improvement, also named as PRO2PI, can be defined in alignment with the organization and organizational unit's business goals, using selected good practices from a more specific model, from process capability models (SW-CMM, ISO/IEC 15504-5, iCMM, CMMI-SE/SW, OPM3, COBIT, eSCM-SP, MR-MPS, ...), from other types of reference models (ISO 9001, PMBOK, ISO/IEC 12207, SWEBOK, EFQM, PNQ, RUP, ...) and/or from any other source.

The definition of this PRO2PI can use also analyses from the process capability results of a process assessment and from the process performance results of the current process. This definition, which can be also an update, does not need to be done at once. Rather it is better to do it in an incremental way. This definition or update is represented by the defineP (define or update a PRO2PI) function in Figure 3.

A process improvement cycle uses a PRO2PI, again in alignment with the organization and organizational unit's business goals, to plan and realize process improvement actions to change the organization unit process towards a process driven by the PRO2PI. This usage of PRO2PI is represented by the useP (use PRO2PI) function in Figure 3.

The organizational unit process can be examined using a process assessment oriented by a PRO2PI. This process assessment produces a process capability results. This assessment is represented by the assessPr (assess process) function in Figure 3. These four functions (defineM, defineP, useP and assessPr) represent an overview of the PRO2PI approach. The ISO/IEC 15504 is the conceptual base for PRO2PI approach.

PRO2PI approach has been used with the support of four elements: a set of eight properties for a good PRO2PI (relevant, feasible, opportunistic, systemic, representative, traceable, specific and dynamic), a model that unified the elements from the most relevant process capability models, a set of measures and phases for a process improvement cycle including a function to define, update or use a PRO2PI. The initial phases of this cycle are support by a method for a workshop to establish a process capability profile to process improvement (PRO2PI-WORK). The current versions of these elements are defined in Salviano [2006] and previous versions of PRO2PI are presented in Salviano and Jino [2004] and Salviano et al. [2004].

The PRO2PI-WORK method is composed by activities to achieve the following objectives:
- to capacitate members of the organization in process engineering fundaments and the most relevant process capability models;
- to consolidate information about the organization and the organization unit;
- to consolidate information about the business goals for a process improvement;
- to model the current relevant processes of the organizational unit;
- to define a process capability profile to process improvement;
- to understand the current capability of the organizational unit process;
- to define orientations for process improvement actions; and
- to reinforce the motivation and commitment to process improvement.

The definition of the process capability is based on an analyses of the results of a set of activities including: an identification of major current problems, a view on the strengths, weakness, opportunities and threats of the organizational unit; an identification of relevant for the organization for each selected process area; an identification of the current process capability for each selected process area; an identification of the risk for the business in case of each selected process area still be performed at the current process capability.

5 PRO2PI experiences in software intensive organizations

The Table 1 summarizes experiences with PRO2PI utilizations from 1999 to 2005.
Table 1 – Summary of PRO2PI utilizations

<table>
<thead>
<tr>
<th>Characteristic and year interval of the utilization</th>
<th># of projects</th>
<th># of uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software process improvement cycle in an organization [1999-2002]</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Software process improvement cycle in another organization [2002-2003]</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Establishment of process capability profiles to improvement [2000-2005]</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>15504MPE Project [2003-2004]</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Process improvement in groups of organizations [2004-2005]</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Development of more specific process capability models [2004-2005]</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Students projects in professional SPI courses [2004-2005]</td>
<td>10</td>
<td>164</td>
</tr>
<tr>
<td>TOTAL</td>
<td>32</td>
<td>200</td>
</tr>
</tbody>
</table>

The fundamentals and elements of PRO2PI has been used from 1999 to 2005 in at least 32 (thirty-two) projects. In these projects, the defineP (define or update a PRO2PI) function has been used at least 200 (two hundred) times [Salviano 2006], as summarized in Table 1. In 2006, about 20 (twenty) new utilizations are on the way.

The first utilization in Table 1 is a process improvement project, based on ISO/IEC TR 15504-5 and ISO 9001:2000 models in a low maturity product-oriented organization, without previous experience in software process improvement, performed from 1999 to 2002 [Nicoletti and Salviano 2003]. In this cycle a process capability profile with five process areas (CUS.4.2 Customer Support, SUP.3 Quality Assurance, MAN.2 Project Management, ORG.1 Organizational Alignment and ORG.2.1 Process Establishment), at capability level 2, was established after a careful study of the organization context and business goals. The engineering processes were considered as in a capability level 1 due to 10 years history of software development with four products in 100 of clients. A formal ISO/IEC 15504 conformant process assessment was performed in 1999, before the improvement. The result was a capability level 0, with process attribute PA1.1 partially achieved and PA2.1 and PA2.2 not achieved. A process improvement plan was established. The process improvement actions were performed by the organization, without external consultancy. In the middle of the project, the profile was updated to include the requirements of ISO 9001:2000. In 2002, after the improvement cycle, another formal ISO/IEC 15504 conformant assessment were performed for an extended process capability profile, with the inclusion of ENG.1.2 Software Requirement Analysis and ORG.5 Measurement processes. The result was a capability level 2 for most of the processes. An ISO 9001 certification was also achieved by the organization. An initial version of PRO2PI was used for this process improvement cycle. The major result from the organization perspective was the establishment of a management system to control the relevant processes. At the time of the second assessment, twelve sets of data related with software development, customization and maintenance processes and four sets related with customer support has been collected, analyzed and used to manage the organization.

The second utilization in Table 1 is a process improvement project based on ISO/IEC TR 15504-5 model in a very small project-oriented software organization [Silva et al. 2003]. After an elicitation and analysis of the organization business context, strategy and goals, the improvement focus was driven to the organization software factory process, composed by five phases: prospect, contract, development, deliver and close. Five 15504-5 process were selected as a process capability profile to guide the process improvement: CUS.2 Supply process (at capability level 2), to cover a macro view of the whole organization software factory process, ORG.5 Measurement process (at level 3), to consolidate measurement as the support given that the organization already have an unusual good foundation on using measurement, and a set with CUS.3 Requirement Elicitation process (at level 2), MAN.2 Project Management process (at level 2) and ENG.1.6 Software test process (at level 3) to cover a more detailed view of the organization software factory process. In addition to ISO/IEC TR 15504-5 model, three more references were selected for the improvement: RUP generic process, because the organization already uses it, ProGer generic software project management process model for small organization [Roullier 2001], and the IEEE Std 829 [1998] for software test documentation. A formal ISO/IEC 15504 conformant process assessment was performed before the improvement actions. The result was a capability level 2 for measurement process and a strong
capability level 1 for the other four processes. A process improvement plan was established. The process improvement actions were performed by the organization with external consultancy.

The third utilization in Table 1 is a set of nine projects to establish process capability profile for process improvement in nine different organizations, from 2000 to 2005. For each organization, a specific process capability profile, based on the specific business goals and context of each organization, was established using elements of four reference models: SW-CMM (projects 2 and 5), ISO/IEC TR 15504-5 (projects 1, 2, 3, 5, 6, 7, 8 and 9), CMMI-SE/SW (projects 4 and 9) and ISO 9001 (project 4). In five of these projects, the author of PRO2PI method participated in the establishment, and in four of them, the author did not participated. These experiences are described in Salviano [2006].

The fourth utilization in Table 1 is the development of 15504MPE Project from 2003 to 2004 [von Wangenheim et al. 2006]. In 15504MPE, a process capability model and a process assessment method were developed to using ISO/IEC 15504 for process improvement in small software organization. Based on PRO2PI, a contextualization phase is performed to study the overall situation of the organization’s business and improvement goals and its software processes. As a result of this phase, a process capability profile to process improvement is defined. From 2003 to 2004, five projects, in five different organizations, were performed, with the establishment of five different profiles.

The fifth utilization in Table 1 is in process improvement in groups of organizations from 2004 to 2005. In two different projects, eight organizations shared activities for process improvement actions oriented by CMMI-SE/SW’s maturity level 2. PRO2PI-WORK was used to study the eighteen process areas from maturity levels 2 and 3 as a mean to introduce them to each organization and to prioritize the process improvement actions from an analysis of the importance and risk for each process area to each organization business.

The sixth utilization in Table 1 is the development of seven more specific process capability models from 2004 to 2005. One project was the development of a process capability maturity model for Brazilian small and medium software organization in the MPS-BR initiative [Weber et al. 2005]. In addition to the main idea to developed a more specific model, the utilization of PRO2PI oriented three suggestions: (i) to use the maturity levels of CMMI as the basis for the model, (ii) to include additional maturity levels between level 1 and 2 and between levels 2 and 3 in the model, and (ii) to define the model as an ISO/IEC 15504-conformant model. The first suggestion was based on the dissemination and domination of SW-CMM and CMMI staged models in Brazilian software industry, the second suggestion was based on the opportunity to give smaller steps for small and medium organizations, and the third one was to be aligned with an international framework for the development of process capability models and process assessment processes.

The seventh utilization in Table 1 is the development of 164 articles, each one describing the establishment of a process capability profile for a specific organizational unit, as a course project in 10 editions of 40 hours of a software process improvement course by 261 students from 2004 to 2005. Each group of one to three students used the PRO2PI-WORK method to guide the development of an article covering the identification a an organizational unit and a suggestion of a process capability profile to process improvement, using references from CMMI-SE/SW, ISO/IEC 15504-5 and/or MPS.BR models.

### 6 Conclusion

This article presented a proposal towards a Process Capability Profile Driven Process Engineering (PCDE) as an evolution of the current Software Process Improved based on Process Capability (and Maturity) Models and an exemplar approach for this process engineering. Many versions of what is now the PRO2PI approach has been used in 200 projects since 1999 [Salviano 2006]. These experiences are related with full process improvement cycle, only with the initiation and preparation of an improvement cycle, and the definition of more specific models. PCDE and PRO2PI have been formalized recently [Salviano 2006].

From the best of our knowledge the proposed process engineering PCDE and PRO2PI approach are

innovative work. The closest related works to PRO2PI are the methodology SEI Toolkit for using CMMI continuous in small setting [Garcia et al. 2004], the Olson orientation for using staged and continuous representation of CMMI models [Olson 2003] and the “constagdeous” approach [Kasse 2004] to use a combination of staged and continuous CMMI models. PRO2PI goes beyond that using references from any model and supporting a process capability profile as a model for a process.

The proposed process engineering and the PRO2PI approach aim to guide the software intensive industry, especially small software intensive organizations, in the establishment of relevant, feasible, opportunistic, systemic, representative, traceable, specific and dynamic process capability profiles to drive more innovative and successful business oriented process improvements cycles, as an evolution of the current process improvement approaches composed by the implementation of the fixed “one size fits all” maturity levels of SW-CMM and CMMI models.

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Literature


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