Model-Driven Process Capability Engineering for Knowledge Working Intensive Organization

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Abstract

This article presents a definition, rationality and an exemplar methodology for a proposed evolution of the current Software (and System) Process Improvement (SPI) area. This proposed evolution is a {(Process Capability Profile) Model-Driven (Process Capability Engineering) for (Software, System and other Knowledge Working) Intensive Organization} (MDPEK). This proposal is important because the forces around the successful current SPI demand a revision of the current area towards a more generic area in order to allow these forces to resolve themselves. The ISO/IEC 15504 vision for process improvement and assessment is one of these forces.

1. Introduction

Software (and System) Process Improvement (SPI) is established as a successful area for the needed improvement of software and systems intensive organizations. SPI “has become a driving force in the global software industry” [1]. The definition and utilization of SW-CMM (Capability Maturity Model for Software) [2] during the 1980s established SPI. Nowadays, the models of CMMI (Capability Maturity Model Integration) [3], successors of SW-CMM, and the ISO/IEC 15504 [4] compatible models are the predominant models for SPI. Basically the current SPI area continues the same as it was established around SW-CMM. There are, however, forces around the successful current SPI that urge for a revision and evolution of SPI area. The ISO/IEC 15504 vision for process improvement and assessment [4, 5, 6, 7, 8, and 9] is one of them. This article presents a definition, rationality and an exemplar methodology for a proposed evolution of the current SPI area. This proposed evolution is named MDPEK for a {(Process Capability Profile) Model-Driven (Process Capability Engineering) for (Software, System and other Knowledge Working) Intensive Organization}.

The article is organized as follows. This first section provides an introduction to the article. The second section presents the research methodology and process. The third section presents a view for the consolidated current SPI. The fourth section describes groups of forces for the evolution of SPI. The fifth section introduces a proposal for the definition of MDPEK. The sixth section comments an exemplar methodology for MDPEK. The seventh section describes related, current and further work. Finally, the eighth section presents some conclusions.

2. Research methodology and process

MDPEK has been conceived during many cycles of exploration, application and consolidation of already nine years research effort following the industry-as-laboratory approach proposed by Potts [10]. He argues that the traditional research-then-transfer approach has problems because it treats research and its application by industry as separate, sequential activities.

The MDPEK version introduced in this article is a result of the third phase of a project in this research effort. The first phase, from 1999 to 2004, was focused in a methodology for process improvement using ISO/IEC 15504-5 continuous model, composed by a method for performing a process improvement cycle (AMP1) and a method for defining a process capability profile (MEP1) [11]. The second phase, from 2004 to 2007, was focused in the revision of AMP1 and MEP1 methods. It produced the initial version of an exemplar methodology for an emergent evolution of SPI [12, 13, and 14]. During phase 2, another methodology was also produced [15]. The third phase, from 2007 to 2008, is been focusing in establishing MDPEK. The main goal of this article is to introduce MDPEK as a useful and convinced proposal for the evolution of SPI.

As an additional methodology support, the structure and organization of three main sections of this article,
which are sections 3 to 5, resembles the three-part rule used by the pattern community [16, 17]. “Each pattern is a three-part rule, which expresses a relation between a certain context, a certain system of forces which occurs repeatedly in that context, and a certain software configuration [a solution] which allows these forces to resolve themselves” [17]. The characterization of the current SPI in section 3 is analog to the certain context, the groups of forces in section 4 are similar to the system of forces, and, the proposed MDPEK in section 5 is similar to a solution.

3. The Current SPI

The concept of process has been extensively used in many human intensive areas, including software and system development. A balance and a roadmap for software process research in general are presented by Fuggetta [18]. Process is about what a group of people do to achieve some objective. In order to deal with process, the community has been using its abstraction as a process description. A process description abstracts a process as a representation model about what a group of people is doing (a descriptive model) or about what a group of people is supposed to do (a specification model).

Process improvement, as a specific area, started with the work of Shewhart in the 1930’s with his principles of statistical quality control. These principles were refined by many others authors, including, Deming, Phillip and Duran [3, p. 5]. As mention before, Software Process Improvement (SPI) was established in the 1980’s with the development and successful usage of the four cumulative fixed SW-CMM maturity levels.

There are many definitions for SPI. This research effort introduces and uses the following definition:

Software Process Improvement (SPI) is an approach for improving a software and system intensive organization acting in some given relevant processes based on the concept of process capability aligned with the organization strategy aiming better business results using as a reference one Process Capability Model (most of the cases a CMM/CMMI maturity level or similar)

A relevant aspect for the success of SPI is its business model. Figure 1 shows the main elements, some examples and the business model of the current SPI.

![Figure 1 – Elements and examples of current SPI](image)
models (the software and system intensive organizations).

4. Groups of forces

This section presents seven groups of forces that urge for an evolution of the current SPI. Each one of these forces is a combination of industry demand and improvement opportunity. Although these forces have been somehow used in practical process improvement, most of the time in an informal way, they have not been used in their full potential.

4.1. Multiple and integrated models

There are many best practices models used as reference for SPI. Some of them are structured using process capability and/or maturity concepts. This research effort classifies them as Process Capability Models (PCM). A partial list of relevant PCMs includes CMMI-DEV, ISO/IEC 15504-5, iCMM, eSCM-SP, COBIT, MR-MPS (the Reference Model for the Brazilian MPS-BR Program), COMPETISOFT (the Reference Model of Competisoft Ibero American Project) and Automotive SPICE [12, 19, 20]. Other models are structured using different concepts. A partial list of them that have been used for SPI includes ISO 9001, PMBOK, EFQM, SWEBOK and RUP [12].

Many organizations are using more than one model as reference for a process improvement cycle. The number of organizations using elements from, for example, CMMI-DEV, ISO 9001 and PMBOK models in a process improvement cycle is significant. Sometimes there are different teams using each model without a proper integration of them.

The current SPI provides appropriate support for using a given single model. There is a need for appropriate support for using relevant set of selected multiple models.

4.2. ISO/IEC 15504 vision

ISO/IEC 15504, also known as SPICE (Software Process Improvement and Capability Determination), is a standard for process assessment. The vision of ISO/IEC 15504, however, is beyond process assessment and also covers process capability models and process improvement. ISO/IEC 15504 introduced and consolidated many relevant concepts, including the continuous architecture, the framework of models and the generalization from software to system.

These three concepts allow more flexibility in a process improvement cycle. Although they have been used in SPI, they are not been used in their full potential. There is a need of methods to support the definition of process capability profile for process improvement from multiple models in different domains. The current SPI do not provide appropriate support for this flexibility.

3.3. Generalization of software

The term software was created as the complement of hardware. Dijkstra defined, in his ACM Turing Award speech in 1972, the humbler programmer [21] as what is now named as software worker. SPI has generalized the software focus to system focus.

Software, however, should be generalized as explicit knowledge and therefore software process should be generalized as knowledge working process, including software and system processes. Knowledge worker and knowledge working are used in the sense defined first by Drucker [22] (“anyone who works for a living at the tasks of developing or using knowledge”). Knowledge working is the activity of the knowledge worker. Drucker also contextualized knowledge working in a post-capitalism knowledge society [23]. Davenport [24] explored the Drucker’s knowledge working vision. “Knowledge workers have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the creation, distribution, or application of knowledge. Knowledge workers think for a living” [24].

The vision by Armour [25] that “probably the biggest mistake that has been consistently made since the invention of software is the view that software is some kind of a product... it is not … software is a medium in which we store knowledge. It is the fifth of such medium that has existed since the world began”.

The current SPI provides appropriate support for software processes to develop products. There is a need for expanding the appropriate support to knowledge working processes.

4.4. Underlying principles

In a panel on research directions in SPI, Card pointed out that SPI “approaches have evolved or been adapted to software engineering largely without the participation of the academic research community. Does this pose a problem? My response is yes. One issue that inhibits the deployment of these approaches today is that [they] are considered competitors. In reality they are all based on very similar concepts and
techniques. The packaging obscures the underlying principles. Eliciting and refining underlying principles is the role of science” [1].

The current SPI uses different terms and definitions for similar concepts. There is a need for eliciting and refining underlying principles of SPI.

4.5. Process and model relationship

Current SPI uses a process capability model as a reference to improve processes. Although a process assessment can demonstrate that a process implements a process capability model, there is not a full model relationship between the model and the process, as the process often involves more activities than the ones abstracted by the model.

Model-Driven Engineering (MDE) is a subset of system (and knowledge) engineering in which the process heavily relies on the use of models and model engineering. Model engineering is the disciplined and rationalized production of models. Therefore MDE implies the systematic use of models as primary engineering artifacts throughout the engineering lifecycle. MDE can be applied to software, system, and knowledge engineering, and in MDE, models are considered as first class entities [26, 27, 28].

The current SPI provides appropriate support for using a maturity level or a process profile as a partial reference for improvement. There is a need for appropriate support for establishing a full relation of a process capability profile as a model for processes and process improvements, as defined by MDE.

4.6. Commoditization of process

Davenport said that “business processes are being analyzed, standardized, and quality checked. That work, as it progresses, will lead to commoditization and outsourcing on a massive scale” [29]. Among the business processes, most of them are knowledge work processes. As the globalization is increasing, as pointed out by Friedman [30], the global commoditization of process is also increasing.

The current SPI provides appropriate support for using the already consolidated generic CMMI-based maturity levels as reference for process improvement. There is a need for appropriate support for defining more specific process areas to be included in the generic maturity levels.

4.7. Diversity and importance of strategy

Rifkin [31] investigated the fit between the current CMMI-based SPI and the corporate strategy. Using the three generic strategy identified by Treacy and Wiesema [32], Rifkin concluded that CMMI-based SPI is appropriate for organizations using operational excellence strategy, but not for the ones using product innovativeness or customer intimacy strategies. The diversity and importance of strategy definition and execution have been pointed out by Kaplan and Norton [33] among others.

The current SPI provides appropriate support for perform a process improvement aligned with a strategy. There is a need for appropriate support for performing process improvement integrated with any strategy.

5. Proposed MDPEK

Most of the groups of forces described in the previous section have been partially identified. For some of them, partial proposals have been presented. These partial proposals are not well disseminated yet, because they cannot be satisfactorily applied in the current SPI. Actually, these forces, which are there already, demand a revision of current SPI towards a more generic area.

This section introduces MDPEK as a proposed evolution with a balance of the group of forces. Table 1 repeats the definition for the current SPI and presents a definition for MDPEK in a similar structure.

The current SPI does not have a precise classification; therefore the term approach is used to classify it. MDPEK, in the order hand, has a very precise classification: it is a MDE. While SPI uses as a reference one Process Capability Model, that in most cases is a fixed maturity level of SW-CMM, CMMI or similar model, MDPEK is driven (driven in the sense of MDE) by a Process Capability Profile. SPI acts in some given relevant process, the ones that implements the fixed maturity level. MDPEK allows the acting in any relevant process because any relevant and useful Process Capability Profile can be established. For the same reason a SPI is aligned with the organizational strategy while MDPEK is integrated with the organization strategy. MDPEK supports the integrated co-evolution of strategy and process improvement. The objective of SPI is to improve a software and system intensive organization while the objective of MDPEK is to improve a knowledge working intensive organization.
Table 1 – Definitions for SPI and MDPEK

<table>
<thead>
<tr>
<th>Current SPI</th>
<th>Proposed MDPEK</th>
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<tbody>
<tr>
<td>is an approach</td>
<td>is a model driven engineering</td>
</tr>
<tr>
<td>for improving a software and system intensive organization</td>
<td>for improving a knowledge work (including software and system) intensive organizations</td>
</tr>
<tr>
<td>acting in some given relevant processes</td>
<td>identifying and acting in any selected relevant processes</td>
</tr>
<tr>
<td>based on the concept of process capability</td>
<td>founded upon the concept of process capability</td>
</tr>
<tr>
<td>aligned with the organization strategy</td>
<td>integrated with the organization strategy</td>
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<tr>
<td>aiming better business results</td>
<td>aiming better business results</td>
</tr>
<tr>
<td>using as a reference one Process Capability Model (most of the cases a CMM/CMMI maturity level or similar)</td>
<td>driven by a Process Capability Profile defined with elements from one or more Process Capability Models and other types of models and references</td>
</tr>
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</table>

Process can be abstracted in terms of process description, using elements as, for example, role, activity and work product. Process can be also abstracted in terms of process capability, using elements as, for example, process capability area, process capability level and process capability profile. Process description is more disseminated. SPI introduced a different abstraction, under the aspect of capability.


Process worker, which is another type of knowledge worker, performs process engineering cycle processes driven by a Process Capability Profile. Therefore, a process engineering cycle can (and should) also use MDPEK. Process engineering cycle includes all kind of activities already used by SPI with a significant addition: establishing a process capability profile.

Process description guides software, system, process and other knowledge worker to perform process.

While process workers perform process engineering cycle activities, including establishing Process Capability Profile and process definition, knowledge workers perform processes.

Process Capability Profile is a model in process capability. Process Capability Profile predicts process performance. Process Capability Profile is built from one or more Process Capability Model (PCM) or other type of reference model (No PCM).

Process capability is the general conceptual reference for MDPEK. Process Capability Profile is a model of a process under the aspect of process capability.

MDPEK is a specialization of MDE by the usage of Process Capability Profile model. The focus of the engineering is knowledge working processes, as defined by Drucker [22].

Process can be abstracted in terms of process description and Process Capability Profile.
Process Capability Area is defined in this research effort as unified term for CMMI process area and ISO/IEC 15504 process.

**Figure 2 - Concept Map for MDPEK**

Process Capability Model (PCM) is composed by a set of good practices. Process Capability Model (PCM) uses PCM’s architecture.

The architecture of a PCM defines how its elements are structured.

PCM’s architecture defines the organization of good practices. PCM’s architecture is from a Closed Staged, Closed Continuous and Open Continuous generation. Closed Staged is a specific usage of a Closed Continuous. Closed Continuous is a specific usage of Open Continuous.

Current SPI consider two alternative architectures (or representations) for process capability models: staged and continuous. This research effort defends that they are not alternatives, but generations. There are three generations: closed staged, closed continuous and open continuous [13, 46]. Closed staged is the current staged architecture. It is closed because the maturity levels are predefined and they cannot be changed, as for example, the staged representation of CMMI-DEV.

Closed continuous is the current continuous architecture, when the set of process areas from which a process capability profile can be defined, are predefined, as for example the continuous representation of CMMI-DEV.

Note that a maturity level is an example of a process capability profile. Therefore Closed continuous is the following generation for closed staged. Open continuous is a continuous architecture with any set of process areas, as for example, the ISO/IEC 15504-5.

In terms of business model, there is a need for a sustainable model for MDPEK. Such sustainable model must allow decoupling a process assessment from the model owner. In this way, one assessment may satisfy multiple assessment methods in relation with elements from multiples models. Knowledge working intensive organizations may also define new process capability areas.

MDPEK vision includes a future with:
- a market for sets of process capability areas, where each set provides a codification of knowledge of specific “what to do good practices” for a domain;
- a metamodel for process capability models and process capability profiles;
- methodologies for establishing process capability profiles; and
- a sustainable model for defining and using process capability profiles.
6. Exemplar methodology for MDPEK

Following the industry-as-laboratory research approach, an exemplar methodology for MDPEK is been defined and used. This methodology is named PRO2PI (Process Capability Profile to Process Improvement). Figure 3 illustrates an overview of PRO2PI methodology.

A more specific model can be defined or improved for a segment or domain, using selected good practices from more generic models and/or from any other source. This definition or evolution is represented by the DefineModel function in Figure 3. This more specific model can be a staged model, with a hierarchy of process capability profiles, or a continuous model, with a set of process areas and process capability levels.

A process capability profile to process improvement, also named as PRO2PI, can be defined or improved integrated with the organization and organizational unit's business goals, using selected good practices from more specific models, more generic models and/or from any other source. A PRO2PI may also be defined using elements from a single model. 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 or evolution does not need to be done at once. Rather, it is better to do it in an incremental way. It is represented by the DefineProfile function in Figure 3.

A process improvement cycle uses a PRO2PI, again integrated 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 UseProfile 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 AssessProcess function in Figure 3. These four functions represent an overview of the PRO2PI methodology.

PRO2PI methodology has been developed and used with the support of seven set of elements:

a) a set of eight properties for a useful and effective PRO2PI (relevant, feasible, opportunistic, systemic, representative, traceable, specific and dynamic),

b) a metamodel for process capability profiles,

c) a model for an unified view of elements from the most relevant process capability models,

d) a set of measures to qualify a PRO2PI,

e) phases for a process improvement cycles including a function to define, update or use a PRO2PI,

f) a method for the initial phases of this cycle for a workshop to establish a process capability profile to process improvement, and

g) a method for defining more specific domain process capability models.

7. Related, current and further work

There are already some considerations about issues and forces for current SPI. Some of them are commented in this section as related work.
Conradi and Fuggetta [35] reported challenging issues with existing SPI approaches and proposed theses as initial attempts to provide directions and indications on how to address these challenging issues. The International Process Research Consortium (IPRC) identified nine forces driving the Process Research Framework: (1) value add, (2) business diversification, (3) technology change, (4) system complexity, (5) product quality, (6) product turnaround, (7) regulation, (8) security and safety, and (9) globalization [36]. MDPEK considers most of these issues and forces.

There are already efforts to integrate models and methods for process improvement, as for example, the CMMI, ISO/IEC 15504, and iCMM themselves, the harmonization of ISO/IEC 15504 and CMMI [37], and initiatives to understand and integrate selected models and methods, as, for example, the Integrated System Framework for Excellence [38], Enterprise SPI [39], the Integrated Approaches to Six Sigma and Domain Practices [40], and the Unified Process Improvement Approach for Multi-Model Improvement Environments [41]. MDPEK provides a new generic area to improve SPI and considers most aspects of these integrations efforts as examples.

ISO/IEC 15504-4 [8] and Van Loon [42] provide guidelines to define process capability profiles. MDPEK goes beyond that and again these guidelines are examples.

There is also a proposal for Model-Driven Process Engineering by Breton and Bézevin [43]. This proposal, however, uses the term process engineering as related with process description, while MDPEK uses the term process capability engineering.

MDPEK is part of an ongoing research effort. Among the current activities are the development and utilization of a process capability model for university laboratory processes [45] and a proposal for unifying basic concepts [46]. A previous version of MDPEK was presented as a tutorial [44].

8. Conclusion

Peter Drucker said that in the knowledge society (also named as post-capitalism society) people need to learn how to learn. Actually, the subjects to be learned may be less important than the student’s capacity to identify the subject to be learned, continuously learning and the motivation to do so. The knowledge society demands lifelong continuous learning that needs discipline [29, p. 193]. MDPEK vision is that in the knowledge society, organizations need to learn how to improve their processes (which is how they learn). Actually, the processes to be improved (and the process capability areas used as reference for improvement) may be less important than the organization’s capacity for identify the processes to be improved (and identify or create process capability areas to be used as reference for improvement), continuously improving their relevant process integrated with the strategy, and the motivation to do so. The knowledge society demands lifelong continuous learning that needs discipline. MDPEK in general and the process capability levels supports such discipline.

The proposed MDPEK introduced in this article intended to be a useful attempt to address the necessary evolution of current SPI. As results of a research effort, MDPEK and its exemplar methodology PRO2PI are not ready to be fully used by industry. The industry however must be aware and involved in such research effort in order to help the establishment of both MDPEK and PRO2PI.

References


