A Set of Support Tools to Software Process Appraisal and Improvement in Adherence to CMMI-DEV

Leonardo Possamai Mezzomo, Sandro Ronaldo Bezerra Oliveira
Graduate Program in Computer Science
Federal University of Pará
Belém, Pará, Brazil
e-mail: leopossamai@gmail.com, srbo@ufpa.br

Alexandre Marcos Lins de Vasconcelos
Informatics Center
Federal University of Pernambuco
Recife, Pernambuco, Brazil
e-mail: amlv@cin.ufpe.br

Abstract—**Adopting standards and reference models for quality software processes is essential to ensure a competitive software industry. However, despite the increasing number of standards and models, only a small proportion of software organizations adopt them. This paper presents a set of support tools for software process appraisal and improvement through their adherence to the CMMI-DEV (Capability Maturity Model Integration for Development) model. The purpose of this set of support tools is to assist software organizations in the implementation of the CMMI-DEV model. It is expected that these tools will be readily adopted by software organizations because they are based on models and standards that are generally accepted. Furthermore, this set of support tools employs free (non-proprietary) technologies to reduce costs.**

Keywords-software engineering; software quality; process appraisal; process improvement; software tool.

I. Introduction

Currently, there is a much greater need to develop software than design or create a tool or use a particular programming language. There have also been collective, complex and creative endeavors in this area since the quality of a software product relies heavily on the people, organizations and procedures needed to create it and make it available [1].

Quality is not only a question of market differentiation that can enable an organization to sell more and increase its profits, but also a prerequisite that the organization must meet to be able to put its product on the global market. In the domain of software development, quality can be defined as a set of characteristics that must be satisfied to ensure the software product caters for the needs of its users [2]. Thus, before the quality of the product can be achieved, a software development team must find a solution to guide them about what, how and when to do something. It is believed that the key to software quality lies in the quality-based process that is used to achieve it [3].

According to Humphrey [4], a software process consists of a set of software engineering tasks required to transform a user's requirements into software. In defining this process, some information is necessary about areas such as: activities, resources, consumed and generated work-products, procedures, paradigms and technology, and a software life cycle model [5]. Thus, a software process can be regarded as a set of tasks or activities that must be performed by a team to ensure a good product or service.

While the organizations have been implementing their processes, they have also carried out an appraisal as a means of improving them [6]. A software process cannot stay immutable in time, and as a result, reflects the "critical points" that lead to unwanted problems in product development. The processes must constantly undergo refinements and modifications so that they can increase their ability and flexibility during the projects. This means that they need to be continuously improved [1].

The aim of the Organizational Process Appraisal and Improvement process is to determine how the organization's processes help it to achieve its business goals and to support, implement and deploy measures that will lead to continuous improvement [6]. Although it is an independent process, it is essential that the process definition stage is deployed.

As there has been a good deal of discussion about the appraisals and continuous improvements of the processes, software engineers and organizations still have difficulties in defining their processes, because there is no software process that can be generically used by different organizations [7]. However, the process must be improved and continuously refined with each new project to enable it to deal with the requirements and expectations of the market and the organization. In this way, the process can increase the efficiency and productivity of the organization as a whole. These observations have driven a large number of studies on the creation of quality models and methods for improving processes [1] [8].

To make improvements in these processes, it is important to appraise them. The appraisal process addresses many factors, such as their assets (tasks, activities, procedures, tools, etc) and the products that are the outcome of the projects. Thus, providing support for the adoption of continuous improvement strategies is essential [1].

At present, Organizational Process Appraisal and Improvement process are employed in the quality models. The purpose of these models, guidelines and standards is to guide organizations about the use of good practices and the implementation of these processes. The main guidelines include the following: the Capability Maturity Model Integration (CMMI) [6], the Brazilian Software Process Improvement program (MPS.BR) [9] and the International

Organization for Standardization / International Electrotechnical Commission (ISO / IEC) 12207 [10].

The purpose of this paper is to define an approach about the Organizational Process Appraisal and Improvement process that is aligned with the Capability Maturity Model Integration for the Development (CMMI-DEV) quality model. This approach consists of: a) process mapping between the assets included in the quality models, b) a process framework for mapping and c) free tools of systemic support for the activities defined in the framework. Thus, it is expected to simplify the implementation of the appraisal process and assist organizations that are seeking to improve, standardize and institutionalize their software development processes, through the application of organizational assets for their software projects. These tools are based on free standards and technologies and are the outcome of the Software Process Improvement: Development and Research (SPIDER) project [11], carried out at the Federal University of Pará (UFPA).

As well as this introductory part, Section II discusses the software process appraisal and improvement stages, and it also examines related works. Section III sets out the appraisal and improvement tools. Section IV discusses the analysis of the tools and their application in industry and their adherence to the CMMI-DEV model. Section V analyzes the results obtained from this. Finally, Section VI summarizes the conclusions and makes recommendations for future work.

II. Background and Related Works

This section provides an overview of the CMMI-DEV model, the fundamental concepts of the software process with regard to improvement and appraisal, and some related works.

A. The CMMI-DEV Model

The CMMI is a maturity model for process improvement, created by the Software Engineering Institute (SEI) to integrate areas of knowledge in a single model, such as Systems Engineering (SE), Software Engineering (SW), Integrated Products and Process Development (IPPD) and Supplier Sourcing (SS) [6].

Currently, the CMMI is in version 1.3 and is composed of three models, which are as follows: CMMI-DEV, which is concerned with development processes, CMMI for Acquisition (CMMI-ACQ), which deals with acquisition processes, as well as product and / or sourcing services, and CMMI for Services (CMMI-SVC), which focuses on service processes such as maintenance and evolution.

The CMMI structure consists of many elements that are grouped into three categories, which are: a) required components (Specific and Generic Goals), b) expected components (Specific and Generic Practices) and c) informative components (Subpractices, Examples of Work Products, and others). These components assist in the interpretation of the model requirements. Thus, the CMMI-DEV comprises twenty-two process areas, each of which has its own purpose and specific goals supplemented by generic goals, since they are related to all the process areas. The specific goal is to define the characteristics, which are unique for each process area, while the generic goals define the characteristics that are common to all the process areas. Each specific goal has a set of specific practices, which are activities that must be carried out to accomplish the goal. The generic goals have generic practices as well.

B. Software Process Appraisal and Improvement

To determine how the standard processes can assist the organization, the disciplined process appraisals must be performed by means of a process appraisal model, which is employed for assessing the process capability based on a reference model [12]. It is possible to determine the way that the processes can be assessed for a specific project in the organizational unit by analyzing the results obtained of the strengths and weaknesses of these appraisals and the risks involved. As a result, improvements can be made on the basis of information obtained in the standard processes of the organization and this can be applied to the standard processes by making changes in their existing capabilities or by replacing them with subprocesses that are more efficient or effective [13].

According to CMMI [6], the purpose of the Organizational Appraisal and Improvement process, called the Organizational Process Focus (OPF) process area, is to determine how the standard processes of the organization can a) assist an organization in achieving its business goals and b) support the organization by helping it to plan, implement and deploy continuous improvement in processes based on an awareness of its strengths and weaknesses. The main objective of the OPF process area is to conduct systematic appraisals, plan and implement the improvements that are found necessary by these appraisals and provide experience in the use of the standard processes of the organization.

The main goals of business process improvement are: (i) to understand the characteristics and factors that affect process capability, (ii) to plan and implement the activities that modify the process in response to business needs, and (iii) to assess the effects and benefits obtained and compare them with the cost of making changes in the processes [13].

Once the potential improvements in the standard processes of the organization have been identified, they are analyzed and transformed into action items that must be realistic and aligned to the roles and responsibilities defined in the organization. These action items should be planned and implemented, and not only take account of the resources available, but also the risks inherent in the changes that have to be implemented in the organization’s standard processes [14].

An efficient way to identify possible areas of improvement in future projects would be to conduct “post-mortem appraisals”, which entail making an appraisal after the execution of all aspects of a project, including its products, processes and resources [15]. Collier *et al.* [16] propose an appraisal process that follows 5 stages: (i) establishing a mechanism for collecting information for the project (usually by a survey), (ii) collecting objective information about the project (usually by measures related to the execution of the project), (iii) conducting an in-depth meeting (a structured meeting involving members of the project with the aim of collecting information that was not obtained in the first attempt to do this), (iv) leading the project that traces the activities of a single day (a meeting, where key players come together to evaluate the main events that have taken place during the project and the information obtained and thus assess the main problems and their possible associated causes), and (v) publishing the results.

After the improvements in the standard processes have been implemented, it is important to support the appropriate use of processes and other organizational process assets in the organization's projects and monitor their use to ensure that the implemented improvements have the desired effect and avoid having asny adverse effects on the projects [14].

C. *Related Works*

In [17], WebAPAEE was proposed for a process management environment based on free software. It was designed between 2004 and 2005 as a cooperative venture between academic and scientific institutions, in particular the Software Engineering Laboratory (LabES) at UFPA.

With regard to the process appraisal, the scope of the project is still limited. Currently, the environment is suitable for the definition of metrics and the collection of estimates and measurements, but there is no mechanism in the environment to enable an appraisal of the task of collecting that has been carried out. Furthermore, currently there is an ongoing project in the software environment to provide a more complete and integrated support for the measurement and analytical procedures. It is clear that there is not yet an integration of this kind. Although the process improvement, is discussed in [18] in an implementation strategy based on the Initiating, Diagnosing, Establishing, Acting and Learning (IDEAL) model [19], the project is only able to support the improvement, but lacks a tool that is integrated in the environment.

In [3], there is a software process implementation for the environment, called ImPProS, which is involved with Process Definition, Simulation, Implementation, Evaluation and Improvement through the use of tools that support the software process and software development. Among the approaches that form the environment, it is worth highlighting the ProEvaluator and ProImprove, which carry out the process evaluation and improvement activities respectively. However, this environment has some drawbacks: with regard to evaluation, the ProEvaluator supports the automation of only a few activities included in the MPS.BR Assessment Method [20], and on the question of improvement, the support tool only implements the activities of the IDEAL model, but does not integrate these activities with the results of the evaluation, and thus does not provide a cycle for process improvement.

Finally, Montoni *et al.* [21] present a Software Development Environment (SDE), called TABA Station that supports project management activities, improvements in software product quality and increased productivity. The TABA Station [22], which has been operating since 1990, is a meta-environment that seeks to generate a software development environment that is suited to organizational features, software processes and specific projects. The main dsriving-force behind this is the fact that the application domains and specific projects have their own characteristics, and it is essential that these features are present in a customized way in the environments used by software engineers for the application development.

In this environment, there are tools intended for process evaluation and improvement, called AvalPro and Pilot. The former supports the Processes and Product Quality Assurance team [23], while the latter is designed to carry out an evaluation of the improvement proposals of a process in a systematic, planned and controlled way by carrying out pilot schemes [24]. It was not found that the tools are based on quality models and unclear what their relationship is with other tools embedded in the environmental domain.

Finally, in [33] Portela *et al.* present a tool focused on software process enactment, which has been previously appraised and improved, called Spider-PE. It should be pointed out that this work differs from the paper on the Spider-PE tool in some respects. For example, the tools discussed in this work are concerned with generating and implementing the results of the software process appraisal and improvement, while Spider-PE receives as input the process has already been appraised and improved, i.e. these tools are dependent and are used in sequence during the implementation of process lifecycle.

The selection criteria of the tools described in this section are that they should be available for download and further analysis. Also, it must be possible to use them in the development scenario of Brazilian software organizations that adopt a software process improvement program using CMMI-DEV or another model.

The weaknesses of these tools are as follows: they do not provide different ways of conducting software process appraisals (objective criteria or metrics), they do not record the results of appraisals carried out over a period of time, they do not keep a historical record of improvement items generated from the results of the appraisal, they do not make full use of all the activities, principles and techniques suggested by the IDEAL model, and they do not evaluate the results of the improvements implemented in the software processes. All these features are suggested in the adherence of the OPF process area included in the CMMI-DEV.

Unlike these other environments, the proposal, set out in detail in this paper, is an appraisal tool integrated into the process for the modeling and definition tool, called Spider-PM, and a tool for process improvement, called Spider-PI, defined by the mapping of the appraisal and improvement process found in the Brazilian Reference Model of SPI for Software (MR-MPS-SW) and CMMI-DEV models and ISO/IEC 12207 standard.

III. A Set of Support Tools FOR Process Appraisal and Improvement

The set of supporting concepts adopted in this paper defines a set of technologies that can be integrated and thus assist in the software process appraisal and improvement. In this domain, there are tools, techniques, procedures, processes, roles, methodologies, frameworks, languages, standards, patterns, and so on.

A. A Framework for Software Process Appraisal and Improvement

A process framework was designed to make the organization concerned about the quality of its appraisal and improvement processes, not only adherent to the MR-MPS-SW model but also the other model and standard. All the activities in the framework originate from the assets (activities, practices, expected results) included in CMMI-DEV, MR-MPS-SW and ISO / IEC 12207.

Three flows were used to prepare the framework. One of them is called a macro-flow and contains macro-activities and two of them are formed of specific activities. The macro-activities are called Process Appraisal and Process Improvement; each of them consists of a set of other activities that structure the specific flows. The framework was modeled by means of the Business Process Modeling Notation (BPMN).

Fig. 1 shows a general flow between the macro-activities. In this flow, there is a need to appraise and improve a process. The exclusive gateways help to clarify the possible steps that can be followed. The first exclusive gateway determines the existence of a process, and allows it to be further assessed or improved by specific activities. Thus, it is important that there is already a process (as defined above), and that there is input to the macro-activity "Appraising Process". There is also another exclusive gateway that allows a process to be improved, if it can find opportunities for improvement at the end of the appraisal.

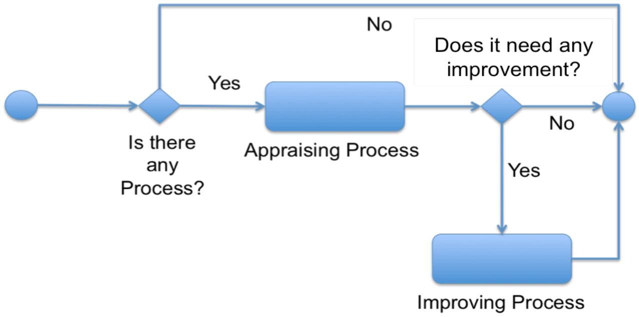


Figure 1. FlowChart showing the Macro-Activities of the Framework

The activities that form the flows that are directed at the process appraisal and improvement goals are included in the macro-activities. These activities are as follows: the Appraising Process, activities related to appraisal based on objective criteria or metrics, and the Improving Process, activities related to the implementation of improvements from the IDEAL model.

The appraisal framework, in which the activities are described as features in Section B, begins with an activity that provides information about the use of the process and can be checked before the process is used. After this, the appraisal needs and goals are defined and the type of appraisal is chosen from the metrics (metrically – using the Spider-MSControl tool [31]) or objective criteria (objectively - using the Spider-CL tool [32]). The activities, included in the appraisals that are based on metrics, follow a simple flow from the definition of goals and measurements, and then the collection and analysis of the measurements. The other type of appraisal includes a set of activities that involve the definition of questions and the application of surveys, which are later drawn on to conduct the data collection and analysis. However, the two types of appraisal generate a report, which serves as input for process improvement.

The report on the generated improvements at the end of the appraisal is considered to be critical for the improvement activities. In this domain, the framework is formed of seventeen activities, which are described in Section C as features that are based on an improvement model called IDEAL. The IDEAL model is an organizational improvement pattern that serves as a guide for initiates. It plans and implements the improvement actions and provides a usable and easy approach to understand the stages that are needed to establish a successful process improvement program [19].

The evaluation of the prepared framework was submited to the judgment of experts in software process appraisal and improvement (included in the MR-MPS-SW, CMMI-DEV and ISO / IEC 12207) through the completion of a questionnaire. These experts were contacted by email, and were sent the framework documents and survey with objective questions about the work proposed. The purpose of the survey was primarily to evaluate the correctness and suitability of the framework to support people and organizations when they use the solution that supports the quality models and standards.

The survey had sixteen objective questions, divided into two parts:

- (i) Expert Profile - this was designed to characterize the expert's level of knowledge, regarding the process models and appraisal methods, time of experience, and the role/function of the software process appraisal, and
- (ii) Approach Evaluation - this concerns the correctness and completeness of the mapping and the framework, and determines whether the process framework can serve as a reference-point for software process appraisals and improvements in an organization or if it adheres to the designed mapping.

In addition to objective questions, the survey also had a space for comments so the expert could provide any additional information that needed to be reviewed.

The expert had considerable knowledge of quality models and software process appraisal and improvement, as well as five years' practical experience of making appraisals and improvements in the processes included in MPS.BR, CMMI-DEV and ISO / IEC 12207 models. Thus, the need for the expert to have sufficient knowledge and experience in both quality models and standards was an ideal condition that had been achieved.

With regard to the results of the evaluation, the framework was considered to be suitable, and was able to address a few of the suggestions made for corrections.

B. The Software Process Appraisal Tool

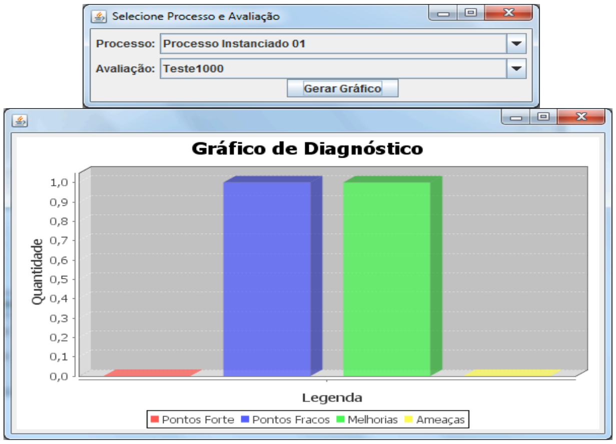
The Spider-PM tool is a General Public License (GPL) tool that supports the process modeling and definition, by means of the Software & Systems Process Engineering Metamodel Specification (SPEM) standard. The Spider-PM tool also supports the software process appraisal.

Since the software process appraisal is a crucial skill, it should be noted that the use of tools to support the appraisal process is of great importance, as confirmed by Hunter, Robinson and Woodman [25] “Tools to visualise software assessment data are therefore of value both to software producers who wish to improve their processes compared with their competitors, and for software procurers who wish the assess the processes of potential contractors against those used in the industrial sector involved.”.

Currently, most process appraisals only involve recording the information in documents and spreadsheets. This means it takes more time to write the work manual, since it is more difficult to handle the appraisal information [26].

The appraisal tool integrated to Spider-PM is designed to systematize the activities of the appraisal process by complying with quality models and standards. This tool was developed from preliminary studies, which included a preparation of process mapping based on quality models and standards and the design of a process framework. Hence, the input for this tool is the software process defined in the Spider-PM, which consists of activities, tasks, resources, work products, roles, and others assets that will be appraised in an automated way. This tool has the following features:

- Appraisal Creation: this enables a new appraisal to be recorded. In this feature, the user can create an appraisal, by filling some of the spaces,
- Appraisal of Reading: this shows the users all the process appraisals that have been created. It makes possible to list all the appraisals created or else it can deal with queries that are included in three filters,
- Appraisal Setup: this enables the appraisal to be initialized. The graphical interface of this feature has a component that lists all the appraisals with the “Created” status, so that they can be automatically initiated,
- Appraisal Storage: this enables the reports produced by the appraisal to be stored in the tool,
- Appraisal Diagnosis: this allows the appraisal to be diagnosed after the reports have been loaded in the repository (see Fig. 2). This means that the user can select the process and the appraisal is carried out in the dialogue box. Then the tool generates a diagnosis chart, which shows the number of strengths, weaknesses, opportunities and threats achieved as the result of an appraisal. The graphical interface of this feature has a component that lists all the appraisals with the “Finished” status,
- Diagnosis of Reading: this shows the users all the diagnosis items of the appraised processes that have been created,
- Appraisal Consolidation: this gathers together and disseminates the information generated by the appraisals.


Selecione Processo e Avaliação

Processo: Processo Instanciado 01

Avaliação: Teste1000

Figure 2. Screen for the Generation of the Diagnosis Chart

The following section describes the support tool that is employed to improve the software process on the basis of the appraisal results obtained.

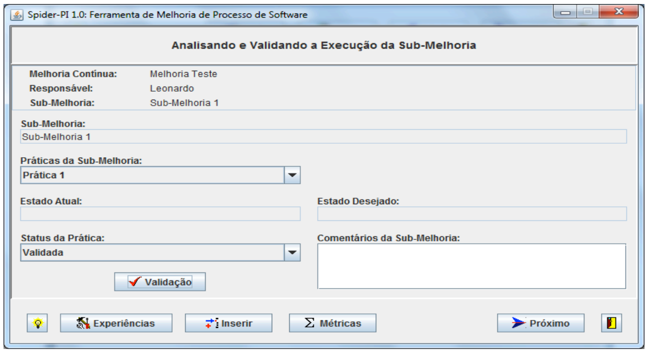
C. Spider-PI: The Software Process Improvement Tool

Spider-PI also has a General Public License (GPL) and is designed to systematize the business process improvement activities in compliance with quality models and standards. It was developed from preliminary studies, which included the preparation of process mapping based on quality models and standards, and the design of the process framework. The input for this tool comprises the results of the appraisal generated by the Software Process Appraisal Tool. This is formed of the strengths, weaknesses, opportunities and threats that will be addressed in an automated way. This tool has the following features:

- New Improvement Creation: this enables new improvements to be recorded. In this feature, the user can “create an improvement”, by filling some fields of the feature,
- Improvement Setup: this enables the improvement to be initialized. The graphical interface of this feature has a component that lists all the improvements with the “Created” status, which can be automatically initiated,
- Improvement Display: this shows users all the process improvements that have been created,
- Defining the Reason for Improvement: this enables the users to create the reason / goal of the improvement,
- Defining Improvement Practices: this allows the users to define the necessary practices required to make the improvement,
- Defining the Improvement Domain: this allows the

users to create the goals, existing works and benefits, which can be achieved / obtained by the improvement,

- Defining the Improvement Sponsorship: this enables the sponsor to give his / her approval of the improvement implementation and to give continuous support,
- Defining the Improvement Infrastructure: this provides the information about the infrastructure designed for the improvement, such as the human effort that must be expended to make the improvement,
- Characterizing Improvement Practices: this makes it possible to characterize the current practices and set out the goals for achieving the improvement implementation,
- Defining the Improvement Procedures: this enables the users to define the procedures that must be followed for the completion of the improvement,
- Defining the Priorities for the Implementation of Practices: this sets out the range of priorities for implementing the improvement in the practices,
- Defining the Improvement Plan: this allows the improvement implementation plan to be defined,
- Creating the "Improvement Solution": this prepares the improvement solution,
- Testing the "Improvement Solution": this tests the improvement solution that has been formulated,
- Deploying the "Improvement Solution": this enables the "improvement solution" to be deployed,
- Analysis and Validation of the Improvement: this validates the improvement, as shown in Fig. 3. The user selects the improvement practice that has been implemented in the process. After this, the system displays the planned state (both before and after the improvement has been made). Then, the user performs the validation of the practice implementation in the process on the basis of a set of criteria and metrics that have been previously defined. As a result, this user can report the experiences obtained from the improvement implementation. At the end of this feature, a status is defined to show the "improvement practice" that has been implemented by the user,



Spider-PI 1.0: Ferramenta de Melhoria de Processo de Software

Analisando e Validando a Execução da Sub-Melhoria

Melhoria Contínua: Melhoria Teste
Responsável: Leonardo
Sub-Melhoria: Sub-Melhoria 1

Sub-Melhoria: Sub-Melhoria 1

Práticas da Sub-Melhoria: Prática 1

Estado Atual:

Estado Desejado:

Status da Prática: Validada

Comentários da Sub-Melhoria:

Figure 3. Screen showing the Analysis and Validation of the Improvement Implementation

- Proposing Future Activities: this allows future activities to be carried out so that they can be performed with a view to bringing about an improvement.

These tools are designed as desktop environments, using Java programming language and other free technologies, such as Eclipse 3.7 Integrated Development Environment (IDE), MySQL 5.5 Database Management System (DBMS), Hibernate 4.0 for object-relational mapping, XStream a simple library for serializing objects into eXtensible Markup Language (XML), and iText as the library for creating and manipulating the Protable Document Format (PDF). For a full description of the tools and each feature, see the work of Mezzomo [27].

It should be emphasized that these tools are used in sequence, and follow the management lifecycle of the software process: definition, execution, evaluation and improvement. These tools interoperate with each other as follows: (i) the definition tool generates a software process with the assets (Spider-PM), (ii) this process should be planned, executed and managed by the allocated staff (Spider-PE [33]). Then (iii) the process can be appraised by objective criteria and / or metrics to identify the strengths, weaknesses, opportunities and threats (Appraisal Tool), and (iv) the appraisal results are implemented by means of the improvement practices in the software process (Spider-PI).

IV. TOOLS EVALUATION

This section describes the evaluation of tools in the software industry and their adherence to CMMI-DEV.

A. *Application in the Software Industry*

The tools were used during the implementation of CMMI-DEV Maturity Level 3 in a Brazilian software development organization called Emprel, and gave support to the practices included in the Organizational Process Definition (OPD) and OPF process areas. The organization was assessed at this level and obtained a certificate issued by the CMMI Institute.

The users of the tools stated that their use facilitated the generation of historical data. As a result of the continuous appraisal process, there was a greater improvement in traceability made by the appraisals, together with the process versions that were established. This led to a more efficient and effective means of managing the implementation of the OPD and OPF process areas. It can be stated that the tool helped the organization in the following areas:

- Establishing organizational process needs,
- Appraising the business processes of the organization,
- Identifying the process improvements of the organization,
- Establishing process action plans,
- Implementing process action plans,
- Deploying organizational process assets,
- Adopting standard processes,
- Monitoring the implementation,

- Incorporating experiences into the assets of the organizational process.

B. *Adherence to CMMI-DEV*

The analysis of the adherence of the tools was conducted through the mapping of the features outlined in Section III with the specific practices included in the OPF process area that can be found in CMMI-DEV. A specific practice can be defined as "the description of an activity that is considered important in achieving the associated specific goal, i.e. it describes the activities that are expected to result in the achievement of the specific goals of a CMMI process area" [6]. In the OPF process area of CMMI-DEV, there are nine specific practices. The details of each of the recommendations for the specific practices listed in the first column of Table I, can be obtained by consulting the official guide of the CMMI-DEV model [6].

TABLE I. ADHERENCE BETWEEN THE APPRAISAL AND IMPROVEMENT TOOL TO CMMI-DEV

OPF Specific Practices	Process Tool Functionalities	Degree of Adherence
SP1.1 Establish Organizational Process Needs	Appraisal Creation	Fully Implemented
SP 1.2 Appraise the Organization's Processes	Appraisal Setrup	Fully Implemented
SP 1.3 Identify the Organization's Process Improvements	Appraisal Diagnosis, Appraisal Consolidation	Fully Implemented
SP 2.1 Establish Process Action Plans	Defining the Improvement Practices, Defining the Improvement Domain, Defining the Improvement Plan	Fully Implemented
SP 2.2 Implement Process Action Plans	Creating the Improvement Solution, Testing the Improvement Solution	Fully Implemented
SP 3.1 Deploy Organizational Process Assets	Deploying the Improvement Solution	Fully Implemented
SP 3.2 Deploy Standard Processes	Deploying the Improvement Solution	Fully Implemented
SP 3.3 Monitor the Implementation	Analysing and Validating the Improvement	Fully Implemented
SP 3.4 Incorporate Experiences into Organizational Process Assets	Proposing Future Actions	Fully Implemented

It can be seen that the features of the tools implement all the CMMI-DEV specific practices of the OPF process area, and hence it can be assumed that the tools are adherent to CMMI-DEV and support the process appraisal and improvement.

V. OBTAINED RESULTS

This section describes the obtained results of this work in both the academic world and industry.

A. *In the Academic World*

An initial version of this thesis proposal has been published and presented at a conference called Workshop of Theses and Dissertations in Software Quality (WTDQS) [28]. This research can be characterized as a subproject of the SPIDER Project, and was accepted in the 2011/2012 cycles of the Brazilian Program of Software Quality and Productivity. In 2011, the framework employed in the implementation of the tools was published in the Symposium of Computer Technology at Santarém (SIGES) [29] and Conference of the Peruvian Society of Computing (CSPC) [30] conferences. The framework and tools were the subject of a dissertation that was defended at the Federal University of Pará (Graduate Program in Computer Science) [27].

The main academic results were as follows: the training of one post-graduate student in Computer Science, the training of two students from a scientific background, and the dissemination of knowledge about process appraisal and improvement in subjects involving experimental software engineering applied to practical projects. Thus, the knowledge used for the development of software tools served to improve the practical understanding of the concepts defined by the quality models.

B. *In Industry*

The authors took part in consultation projects related to process improvement and made use of the technologies examined in this paper. First, the tools were used by organizations, which are partners of the SPIDER project, such as Jambu Tecnologia and GOL Software, both located in Belém city, and SWQuality and Emprel, located in Recife city. Basically, the tools assisted in the appraisal and improvement stages by defining and monitoring the projects. On the other hand, the activities carried out by the Framework are widely adopted in the implementation of the CMMI-DEV Maturity Level 3 in organizations in which the authors act as consultants; these are, located at Porto Digital (Recife city) and Farol Digital (João Pessoa city).

The main results for industry were as follows: the support given for the implementation of practices on software process appraisal and improvement that are included in the quality models, the systematic implementation of the appraisal and improvement process, and the training of business teams in software process appraisal and improvement. Thus, the tool can be seen as providing support for the implementation of quality models as well as for the education of personnel in the area of software process appraisal and improvement.

VI. CONCLUSION

The development of organizational process appraisal and improvement tools is intended to support the process appraisal and improvement activities that involve the good practices defined by the quality models and standards. However, our goal is to facilitate the adoption of these models and standards for software development organizations by means of these tools. A striking feature of this proposal is the fact that the tools are open source, and can thus enable the academic community and / or industry to assist in their development and evolution. The use of tools can also help the software organizations to achieve more satisfactory levels of discipline through the combination of techniques and methods that assist in the appraisal and improvement of its processes.

The main contribution to science made by this work concerns the automated application of practices in CMMI-DEV on organizational process appraisal and improvement, which involve tools and their integration with other management support tools. As well as this, the software process improvement programs continually benefit from the results that generate value to the organization.

In a future work, which is already in development, the integration of these tools with other tools will be made available in a SPIDER project. This entails a joint implementation of the other process areas included in CMMI-DEV, such as configuration management, measurement and analysis.

It should be stressed that this work has provided a set of basic support tools for the implementation of an organizational process improvement program. These tools are integrated with other tools that support different process areas included in the CMMI-DEV. Moreover, this work forms a part of a master's thesis for the Graduate Program in Computer Science and also a scientific research project at the Faculty of Computing, Federal University of Pará.

ACKNOWLEDGMENTS

The authors would like to thank the Dean of Research and Postgraduate Studies at the Federal University of Pará (PROPESP/UFPA) by the Qualified Publication Support Program (PAPQ), for the financial support.

REFERENCES

[1] A. Fuggetta, "Software Process: A Roadmap", In: Proceedings of The Future of Software Engineering, (ICSE'2000), Ireland, pp. 25-34, 2000.

[2] L. Morais, "Software Quality - Unraveling an essential requirement in the development process", Revista de Engenharia de Software, ed. 29, ano 3, pp. 34-38, 2010

[3] S. R. B. Oliveira, "ProDefiner: A Progressive Approach to Software Process Definition in a Process Centered Environment Domain", Tese de Doutorado, CIN/UFPE, Brazil, 2007.

[4] W. S. Humphrey, Managing the Software Process, The SEI Series in Software Engineering, Addison-Wesley, 1989.

[5] R. A. Falbo, "Knowledge Integration in a Software Development Environment", Tese de Doutorado, COPPE/UFRJ, Brazil, 1998.

[6] SEI – Software Engineering Institute, "CMMI for Development – V 1.3", 2010, Available: http://www.sei.cmu.edu/reports/10tr033.pdf, [retrieved: July, 2016].

[7] A. Koscianski and M. S. Soares, Software Quality - Learn the More Modern Methodologies and Techniques to Software Development, 2ed, São Paulo: Novatec, 2007.

[8] P. Kruchten, Introduction to RUP – Rational Unified Process, Rio de Janeiro: Ciência Moderna, 2003.

[9] SOFTEX – Associação para Promoção do Software Brasileiro, "MPS Software General Guide 2012", 2013, Avaiable: http://www.softex.br/wp-content/uploads/2016/04/MPS.BR_Guia_ Geral_Software_2016-com-ISBN.pdf, [retrieved: July, 2016].

[10] ISO/IEC, "ISO/IEC 12207: Systems and software engineering – Software life cycle processes", Geneve, 2008.

[11] S. Oliveira, M. Souza, W. Lira, E. Yoshidome, and J. Furtado, "A System Solution Proposal of a Free Software Tools SUITE to Support the Implementation of MPS.BR Model", Revista do Programa Brasileiro de Qualidade e Produtividade em Software, pp. 103-107, 2011.

[12] ISO/IEC, "ISO/IEC 15504-1: Information Technology - Process Assessment - Part 1: Concepts and Vocabulary", Geneve, 2004.

[13] W. A. Florac and A. D. Carleton, Measuring the Software Process – Statistical Process Control for Software Process Improvement, Addison-Wesley, 1999.

[14] S. Zaharan, S. Software Process Improvement – Practical Guidelines for Business Success, Addison-Wesley, 1998.

[15] S. L. Pfleeger, Software Engineering: theory and practice, 2nd edition, Prentice-Hall, Inc., ISBN 0-13-029049-1, 2001.

[16] B. Collier, T. DeMarco, and P. Fearey, "A defined process for project post mortem reviews", IEEE Software, pp. 65-72, 1996.

[17] E. Sales, M. Sales, A. Costa, C. Reis, and R. Reis, "WebAPSEE Pro: An Environment to Support hte Software Process Management", In: VI WAMPS, Brazil, pp. 228-237, 2010.

[18] B. França, E. Sales, C. Reis, and R. Reis, "Using the WebAPSEE Environment in the Implementation of the MPS.BR level G at CTIC-UFPA", In: VIII SBQS, Brazil, pp. 310-317, 2009.

[19] B. Mcfeeley, "IDEALSM: A User's Guide for Software Process Improvement", Software Engineering Institute Handbook, Carnegie Mellon University, CMU/SEI-96-HB-001, 1996.

[20] J. M. C. Xavier, "ProEvaluator: A Tool for Software Process Assessment", Dissertação de Mestrado, UFPE, Brazil, 2007.

[21] M. Montoni, G. Santos, S. Figueiredo, R. Silva, R. Barcelos, A. Barreto, A. Barreto, C. Cerdeiral, P. Lupo, and A. Rocha, "A Software Process and Product Quality Assurance Approach to Support Knowledge Management in TABA Station", In: V SBQS, Brazil, pp. 87-99, 2006.

[22] G. H. Travassos, "The Tools Integration Model of TABA Station", Tese de Doutorado, COPPE/UFRJ, Brazil, 1994.

[23] J. Andrade, "Software Process Assessment in TABA Environment", Dissertação de Mestrado, COPPE-UFRJ, Brazil, 2005.

[24] R. C. Silva Filho, A. R. C. Rocha, and G. H. Travassos, "An Approach for Improvement Proposal Evaluation in Software Processes", In: VI SBQS, Brazil, pp. 485-499, 2007.

[25] R. Hunter, G. Robinson, and I. Woodman, "Tool Support for Software Process Assessment and Improvement", University if Strathclyde, Department of Computer Science, 1997.

[26] J. Neiva, "The Proposal for a Framework and Systemic Support for Process Assessment Based on MA-MPS, SCAMPI and ISO/IEC 15504", PBQP Software, SEPIN/MCTI, pp. 121-127, 2010.

[27] L. P. Mezzomo, "A Framework for Software Process Assessment and Improvement Adhering CMMI, MR-MPS-SW and ISO/IEC 12207", Dissertação de Mestrado, UFPA, Brazil, 2015.

[28] L. P. Mezzomo and S. R. B. Oliveira, "A Proposal of Tools to Support the Organizational Process Evaluation and Improvement Process in Software Quality Models and Standards Domain", WTDQS - SBQS, Brazil, pp. 35-42, 2012.

[29] L. P. Mezzomo and S. R. B. Oliveira, "Framework for Organizational Process Definition, Evaluation and Based on Quality Models", I SIGES, Brazil, pp. 56-66, 2011.

[30] L. P. Mezzomo and S R. B. Oliveira, "An Approach to Software Process Definition, Evaluation and Improvement in the Software Quality Models and Standards Domain", X CSPC, Peru, pp. 97-106, 2011.

[31] T. S. A. Costa, B. W. F. V. Silva, D. J. S. Teixeira, G. P. Silva, P. J. S. Souza, A. I. X. M. Batista, S. R. B. Oliveira, and A. M. L. Vasconcelos, "Spider-MSControl: A Tool for Support to the Measurement Process using GQIM Approach", In: Software

Engineering and Applications, USA, pp. 55-62, 2015, Avaiable: http://www.spider.ufpa.br, [retrieved: July, 2016].

[32] R. S. Barros and S. R. B. Oliveira, "Spider-CL: A Tool for Support to use Objective Criteria in the Software Quality Domain", In: ERIN, Brazil, pp. 112-120, 2010, Avaiable: http://www.spider.ufpa.br, [retrieved: July, 2016].

[33] C. Portela, A. Vasconcelos, S. Oliveira, A. Silva, and E. Silva, "Spider-PE: A Set of Support Tools to Sotware Process Enactement", In: The Ninth International Conference on Software Engineering Advances, France, pp. 539-544, 2014.