Capability Maturity Model of Software Requirements Process and Integration (SRP^{CMMI})

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ABSTRACT

Software requirement engineering (RE) process is one of the most important phases of the software development life cycle (SDLC) that affect its overall success, since it has a significant role in determining the software quality and software development process effectiveness, due to the increased consideration for Software requirement engineering process and process improvements at the SDLC life cycle. Several standards and RE improvements model were constructed on the aim at helping organizations in improving and assessing their RE process, however they suffer from several problems that limits their acceptance by the organization that are interest in the RE process improvement.

The paper proposed a new requirement engineering process capability maturity model based on the capability maturity model integration for development (CMMI-DEV). The intention is to provide a generic maturity model that based on international standards and literature on software RE to help developing the area of RE process improvement.

Categories and Subject Descriptors

D.2.1 [**Requirements/Specifications**]: Elicitation methods, analysis, specification, validation, and requirement management.

General Terms

Design, Measurement, Standardization.

Keywords

Requirement engineering; Process improvement; CMMI; Maturity model.

1. INTRODUCTION

Software requirement engineering process is a set of activities which are followed to define , evaluate, document, manage and maintain software requirements, it is one of the most important phases of the software development life cycle (SDLC) that affect its overall success, since it has a significant role in improving the software productivity, reducing software errors at the early stage of the development of software, and producing a high quality software .through delivering a clear, consistent, complete, modifiable and traceable set of requirements. Several standards, guidance and requirement engineering improvements model were constructed in order to help organizations in improving and assessing the REP such as Software Process Improvement (SPI) standards, IEEE for developing system requirements specifications [1] and IEEE recommended practise for software requirements specifications [2], however these standards didn't help organizations to choose the appropriate methods or design their own requirement engineering process.

Moreover, due to the increased importance of the Software requirement engineering process and process improvements at the SDLC life cycle, several specialized RE process improvement models were constructed, such as Requirements Engineering Good Practice Guide [3]; the Requirements Capability Maturity Model [4,5]; the Requirements Engineering Process Maturity Model [6], the Market-Driven Requirements Engineering Process Model [7], RE process improvement and assessment model [8], however these improvements model suffer from several problems that could prevent organization from adopting them ,for example they are too complex ,developed based on an old or unsupported versions of the capability maturity model (CMM) , support limited type of RE process and some of them are in drafts and not yet completed and validated .

Motivated by these improvements models and in order to solve the previous problems and to contributes in improving a new standard based maturity model of software requirements we propose a new Capability Maturity Model of Software Requirements Process and Integration (SRP^{CMMI}) the main goal of our model is to help organizations in improving and assessing their requirement engineering process. More specifically, to help practitioners to better define, understand and apply of their requirement engineering process activities in an efficiently with the CMMI phases.

The proposed model is based on the capability maturity model integration for development (CMMI-DEV) version 1.3 [9] developed by the Software Engineering Institute (SEI), we based our model on this maturity model because of the following:

1. It is a well-known framework that has been used widely and it is one of the few process models that attempts to define maturity levels of IT-related processes [10].

IPAC '15, November 23 - 25, 2015, Batna, Algeria.
© 2015 ACM. ISBN 978-1-4503-3458-7/15/11…$15.00
DOI: http://dx.doi.org/10.1145/2816839.2816856

2. It is based on best practices and contains guidelines for RE practices, it defines two process areas relating to RE process: Requirements Management (REQM) and Requirements Development (RD).

The rest of the paper is organized as follow: section 2 presents the related works, section 3 presents an overview of the CMMI-DEV model, while an overview of the SRPCMMI model covering its structure and maturity levels is presented in section 4, finally a brief conclusion and future work are pointed-out in section 5.

2. RELATED WORK

In the past several years' capability maturity model and capability maturity model integration are widely used for improving and assessing the organization software process. The great success of using the CMMI in software process improvement has triggered the world wide to use them as a base for developing and adapting wide range of software process maturity models in different domains including but not limited to requirements, testing, security, quality assurance and project management as shown in a systematic literature review of software process capability/maturity models proposed by Wangenheim et al [11].

Several CMM/CMMI based models were proposed in the requirement domain such as R-CMM a requirement process improvement model that was proposed by Beecham et al [4] ,the model was built by identifying and defining recommended RE sub-processes that meet maturity goals in order to assess the capability of these sub processes that combine to make up the RE process . The whole R-CMM model was then redefined based on the characteristics of the Capability Maturity Model for Integration for Development (CMMI-DEV) by Solemon et al [12].

Patel et al [13] proposed a process improvement model called Story card Maturity Model (SMM) based on the CMMI in order to solve the problems related to the story cards based requirement engineering process like requirements conflicts and missing requirements.

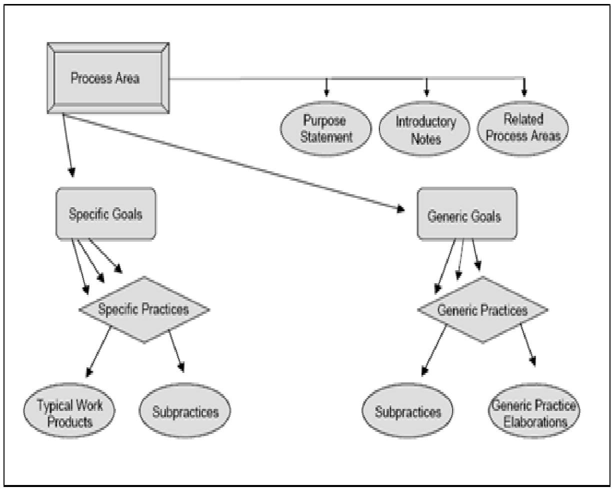
Moreover, based on adapting and expanding the structure of the continuous representation of the formal maturity framework Capability Maturity Model Integration for Development (CMMI-DEV), Solemon et al [8] proposed REPAIM a specialized RE process improvement and assessment model .

In addition to these CMM/CMMI based models there exists Several RE standards that provide general principles and guidance for performing the RE process. For examples the IEEE Guide for Developing System Requirements Specifications [1] that include the identification, organization, presentation and modification of the requirements in addition to the necessary characteristics and qualities of individual requirements, the IEEE Recommended Practice for Software Requirements Specifications [2] that describe the content and qualities of a good software requirements specification (SRS) and presented several sample SRS outlines, and the Requirements Engineering Good Practice Guide (REGPG) [3] that provide a guidance on the assessment and improvement of the RE process maturity through introducing a list of 66 guidelines to key good practises and a requirements improvement model called REAIMS .

3. OVERVIEW OF THE CAPABILITY MATURITY MODEL INTEGRATION

Capability maturity model integration for development (CMMI-DEV) is one of the most common used maturity framework that is developed by the Software Engineering Institute (SEI) in aim to help organizations in assessing and improving their process.

The CMMI defines 22 process areas – a set of related practices that are implemented together in order to satisfy a set of goals that are important for making improvement in a specific area – grouped in four categories Project Management, Process Management, Engineering and Support, each process area has a specific goal that represents a unique characteristic that is mandatory for satisfying the process area, and corresponding specific practices which is a description of an activity that is mandatory for achieving the associated specific goal. Figure 1 illustrates the CMMI components.



Figuer1: The CMMI model components

The CMMI also define two types of levels - an improvements path that must be followed by organizations that want to improve their processes – capability and maturity levels. Capability levels are those that are related to the path which helps organizations to apply an incremental improvement to processes that corresponding to a given process area and goes through 0 to 5 as follows:

0) Incomplete level: Process that either is not performed or partially performed.
1) Performed: A process that satisfies the specific goals of the process area.
2) Managed: A performed process that is planned and executed in accordance with organization policy.
3) Defined: A managed process that is tailored to the organization's set of standard processes.
4) Quantitatively Managed: A defined process that is controlled using statistical and other quantitative techniques.
5) Optimizing: A quantitatively managed process that focus on continually improvements.

Maturity levels are those that related to the path which helps organizations to apply improvements to a set of related processes by incrementally addressing successive sets of process areas and goes through 1 to5 as follows:

1) Initial: There is no formal process.
2) Managed: There is a minimal process and the status of projects is visible to management at major milestones
3) Defined: Processes are well characterized and understood, and are described in standards, procedures, tools, and methods.
4) Quantitatively Managed: The organization and projects establish quantitative objectives for quality and process performance and use them as criteria in managing processes.
5) Optimizing: All processes are already defined and managed. Goals for levels one to four are all achieve.

Related to the requirements field the CMMI define two requirements process areas Requirements Management (REQM) and Requirements Development (RD). Requirements management is a project management process area at maturity level 2 its purpose is to manage project's requirements and to ensure alignment between those requirements and the project's plans and work products. It has one specific goal Manage Requirements where Requirements are managed and inconsistencies with project plans and work products are identified. This specific goal has the following specific practices:

SG 1 Manage Requirements

SP 1.1 Understand Requirements

SP 1.2 Obtain Commitment to Requirements

SP 1.3 Manage Requirements Changes

SP 1.4 Maintain Bidirectional Traceability of Requirements

SP 1.5 Ensure Alignment between Project Work and Requirements.

Requirements development is An Engineering Process Area at Maturity Level 3 its purpose is to elicit, analyze, and establish customer, product, and product component requirements. The Requirements Development process area includes three specific goals. The first specific goal is the Develop Customer Requirements where customer requirements are defined and used in the development of product requirements. This specific goal has the following specific practices:

SG 1 Develop Customer Requirements

SP 1.1 Elicit Needs

SP 1.2 Transform Stakeholder Needs into Customer Requirements

The second specific goal is the Develop Product Requirements where a set of product or product component requirements are defined and used in the design of products and product components. This specific goal has the following specific practices:

SG 2 Develop Product Requirements

SP 2.1 Establish Product and Product Component Requirements

SP 2.2 Allocate Product Component Requirements

SP 2.3 Identify Interface Requirements

The third specific goal is the Analyze and Validate Requirements where the customer, product, and product component requirements are analyzed in order to define, derive, and understand the requirements. The specific practices of this specific goal are as following:

SG 3 Analyze and Validate Requirements

SP 3.1 Establish Operational Concepts and Scenarios

SP 3.2 Establish a Definition of Required Functionality and Quality Attributes

SP 3.3 Analyze Requirements

SP 3.4 Analyze Requirements to Achieve Balance

SP 3.5 Validate Requirements

4. CAPABILITY MATURITY MODEL OF SOFTWARE REQUIREMENTS PROCESS and Integration (SRP^{CMMI})

4.1 The SRP^{CMMI} Model Structure

The SRP^{CMMI} is a new standard based capability maturity model that is developed based on the CMMI-DEV; it is basically consist from three maturity levels which were adapted from the CMMI capability levels, numbered 0 through 2: Incomplete, Performed, and Managed.

Like the CMMI model, the SRP^{CMMI} define a number of process areas distributed over the maturity levels, each process area has a RE goal and its related RE practices which are descriptions of an activity that is mandatory for achieving the associated goals and for improving organizations' RE processes, Each RE practice in the SRP^{CMMI} consists of the following components (See Figure 2).

4.1.1 *Purpose:* A statement that explain the aim that the practices intend to attain.
4.1.2 *Sub-practies:* statements that provides a detailed description of how to interpret and implement a specific or generic practice.
4.1.3 *Technique:* a list of all techniques that were used to perform a RE practices.
4.1.4 *Work product:* a list of the outputs that resulted from an RE practice.
4.1.5 *Elaboration:* Extra details or information about the RE practices.

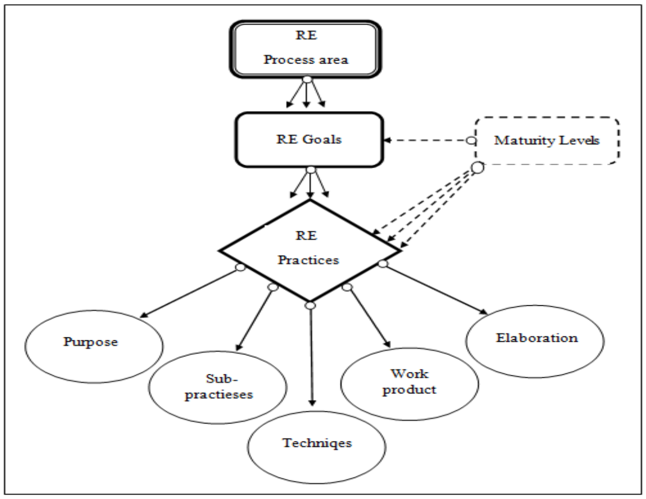


Figure 2: Components of the SRP^{CMMI}

4.2 SRP^{CMMI} Maturity Levels

Each RE maturity level of SRP^{CMMI} consist of a RE process area and its related RE goals and practices, reaching a particular RE maturity level depend on satisfying all of the targeted RE practices. The four RE maturity levels of our model provide a detailed description of how organization can measure and improve their RE process. The four maturity levels are as follow:

4.2.1 Level 0-Incomplete RE process:

An incomplete RE process is similar to the capability level 0 of the CMMI-DEV where it either is not performed or partially performed, in other words there is one or more of the RE practices are not implemented. Since there is no reason to institutionalize a partially performed RE process this level doesn't have a RE goal.

4.2.2 Level 1-Performed RE process:

A performed RE process is a process that satisfies the RE goals and implements all the RE practices of the process area. At this maturity level, the SRP^{CMMI} defines five RE process areas: elicitation, analysis, specification, validation, and requirements management where the requirements are gathered, analyzed, prioritized, documented, validated, and requirements changes and traceability are managed, RE practices at this level are mostly developed based on the CMMI Managed each process area has RE goals and related RE practices as follow:

***A.* Elicitation:**

REG1: Establish an understanding about the problem, solutions and stakeholders**.**

REP1.1: Identify stakeholder and requirements resources.

REP 1.2: Elicit needs.

***B.* Analysis:**

REG1: Create an analysis model that identifies data, function, features, constraints and behavioral requirements using the information obtained during elicitation.

REP 1.1: Establish operational concepts and scenarios.

REP 1.2: Model requirements.

REG2: Resolve conflicts, prioritize requirements, and identify risks, in order to gain a win-win result before proceeding to subsequent software engineering activities.

REP1.1: Resolve conflicts.

REP1.2: Prioritize requirements.

REP1.3: Obtain commitment to requirements.

***C.* Specification:**

REG1: formalizes the informational, functional, and behavioral requirements.

REP1.1: Produce a document that can be systematically reviewed, evaluated, and approved.

***D.* Validation:**

REG1: Validate requirements to ensure the resulting product will perform as intended in the end user's environment.

RP1.1: Confirming that requirements are correct, complete, consistence, testable and satisfies customer needs.

***E.* Requirements management:**

REG1: Identifying, controlling and keeping track of all changes that occurs to the requirements.

REP1.1: Manage requirements changes.

REG2: Ensure that all source requirements are completely addressed.

REP2.1: Manage requirements traceability.

Level 2-Managed RE process:

A managed process is a process that is planned and executed in accordance with organization policy, the SRP^{CMMI} define the organizational support process areas to this maturity level where RE Policy is established; relevant stakeholders are involved; resources are allocated; people are trained; responsibilities are assigned; and RE process adherence is evaluated, the RE practices at these process area are constructed by referring to four of the CMMI process areas namely Project Planning, Organizational Training, Project Management and Control, and Process and Product Quality Assurance.

***A.* Organizational Support:**

REG1: Evaluate the amount of organizational support given to requirements engineering practices.

REP1.1: Establish an Organizational Requirements Engineering Policy.

REP1.2: Monitor Stakeholder Involvement.

REP1.3: Identify project resources.

REP1.4: Assign responsibility.

REG2: Develop skills and knowledge, and train people so they can perform their roles effectively and efficiently.

REP2.1: Define a training program(s).

REP2.2: Deliver training.

REP2.3: Establish training records.

REP2.4: Assess training effectiveness.

REG3: Objectively Evaluate Adherence against applicable process descriptions, standards, and procedures.

REP3.1: Objectively evaluate processes.

REP3.2: Objectively evaluate work products.

RP1.5: Provide adequate resources.

RP1.6: Establish a process to review allocated requirements within the project.

5. CONCLUSION AND FUTUER WORK

The paper proposed a new standard based capability maturity model of software requirements process and integration - called SRP^{CMMI} – at the aim of contributing in the improvement of the RE process.

The SRP^{CMMI} has three maturity levels that were developed and adapted based on the latest version of the CMMI-DEV model version 1.3. The model provides practitioners with a detailed guidance for improving and assessing their RE processes through a set of component (purpose, sub-practices, technique, work product and elaboration) that Presents a complete description of what, why and how to implement the RE practices in order to Achieve the RE goals and to obtain the required improvement.

For future work, we intend to conduct an experimental research in order to validate and evaluate the efficiency of our model in improving the RE process.

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