EFFECTS OF EXPERT SYSTEMS IN COMPUTER BASED SUPPORT FOR CMMI IMPLEMENTATIONS

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Abstract: Computing systems are becoming more complex in very dynamic and uncertain situations. Due to this complexity, the importance of process focused quality approaches is increasing. Capability Maturity Model Integration (CMMI) standards and implementation practices were developed to simplify the software project management and to assure expected quality of the respective software. Realizing the CMMI systems, building and monitoring the implementation practices require an extensive knowledge and experience. Organizations receive these mainly through consultants which may become too costly in most of the cases. Although there have been some computer based support tools available in the market, those still require human experts to justify the related artifacts. In this study a knowledge-based assistant system so called "CMMI Assistant" is introduced. The main aim of this tool is to support CMMI implementations through utilising expert system methodology.

1 INTRODUCTION

Today, companies want to deliver their products faster, cheaper and more efficiently. They must ensure the reliability of their products and meet their customers' expectation. So they must be able to manage and control their processes in the best way. CMMI model is capable of handling customer requirements in this way especially for software products. This makes it very popular and surely increases the demand to implement respective processes.

CMMI is a reference model that covers the software development and maintenance activities applied to both products and services. This model outlines clear definition of processes with respective roles and responsibilities, and makes sure that the software development projects are carried out without any problem. It has a positive influence on cost, schedule and quality performance (Hollenbach, 2003). It can provide a path for organizations to achieve their performance goals.

Besides so many advantages, implementing CMMI is not easy. It requires extensive knowledge as well as organizational endurance. A Standard CMMI Appraisal Method for Process Improvement (SCAMPI) has been developed to support the companies to improve and prove that they posses respective capabilities.

Note that the model includes 22 process areas at different levels. Each process is defined through a set of specific and generic goals as well as some practices. The model requires that all processes for respective levels to be satisfied. Understanding how those processes are satisfied requires CMMI knowledge. This clearly indicates the need for the experts to be employed for the sake of proper implementation. But, hiring experts to prepare the organization is a timely and costly activity.

Literature survey indicates that there are some studies developing questionnaires to measure CMMI levels of an organization (Yücalar, 2006). But, the questions designed for this purpose are mainly superficial and there is usually no set of recommendations to yield respective improvements. Similarly, on the market, there are several computer-aided assistant systems as discussed in the following sections of this paper. Although they are beneficial to understand the model and to perform self CMMI evaluation, those still requires human experts to justify the respective artifacts of the processes.

Since knowledge based systems are proven to be capable of storing and utilizing expert knowledge in certain domains (MacKinnon, 2009), they may be

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very well utilized for assisting staff of the organization intending to implement CMMI processes. There have been some researches along this line as well. An intelligent fuzzy agent based on process and product quality assurance (PPQA) is one of them (Wang and Lee, 2007). It introduces ontology for supporting CMMI assessment. Similarly a methodology system for CMMI diagnosis and analysis is being developed and patented by Dagnino (2005).

The paper introduces CMMI Assistant which is a knowledge based system capable of defining the CMMI areas where lack of implementation exist and recommend remedies to overcome the respective gaps.

2 BRIEF OVERVIEW OF CMMI

Upon request of Department of Defence, CMMI was developed by several dedicated teams in Software Engineering Institute (SEI) of Carnegie Mellon University (CMMI Product Team, 2006).

CMMI Assistant which is the subject of this study mainly covers “CMMI for Development” model. It is a reference model that covers the development and maintenance activities applied to both software products and services. Note that all activities are carried out by a set of processes with respective goals and practices. Each process area includes three types of components such as *required components* (specific and generic goals), *expected components* (specific and generic practices), *informative components* (sub practices, typical work products...etc.).

For the sake of better process improvement, these components are handled on the bases of two different representations mainly: *The continuous representation* and *the staged representation*.

The continuous representation enables an organization to select a process area (or group of process areas) and improve the respective processes. This representation uses capability levels (CLs) numbered from 0 to 5 to characterize improvements.

As a starting point, if the organization does not know where to start and which processes to choose to improve, the staged representation will be a good choice as it gives a specific set of processes to improve at each stage and is mainly used for certification. Due to this, the staged representation with maturity levels (MLs) numbered from 1 to 5 to characterize improvements is considered to be the main focus of the system proposed in this paper.

The SCAMPI is a well defined and accepted method used for conducting appraisals. The SCAMPI family of appraisals includes Class A, Class B, and Class C appraisal methods. SCAMPI A is the most rigorous method and the only method that can result in a rating. In SCAMPI A, the organization should show that all specific and general practices for the intended maturity level are implemented correctly.

In this study, all *Direct Artifacts (D)* and *Indirect Artifacts (I)* for process areas were identified and used for rating the maturity level of the organization under assessment.

3 COMPUTER-AIDED CMMI

In an organization, understanding conceptually the CMMI, mapping the software developing or operational processes to CMMI process areas and respective practices is a difficult activity which may not always produce expected results. This requires several internal assessment activities in order to trigger improvements and prevents respective gaps. However, conducting internal assessments before SCAMPI A is costly and necessitates extensive labour intensive tasks. Because of these reasons, several computer- aided CMMI assistant programs are developed in order to support and map the organizational processes to respective and expected CMMI capabilities easily. These programs mainly provide support for conducting internal assessments in the organization before SCAMPI A. However, they still require intervention of human experts or extensive CMMI and domain knowledge to make decisions on the available artifacts.

There are several computer-aided assistant systems such as CMM Quest (HM&S, 2009), Appraisal Assistant Tool (Griffith University, 2007), Compass (Vector Consulting, 2009), APEX (Milman and Joubert, 2009), CMMI Appraisal Recorder (SE-CURE AG, 2009) and QMIM Tool (Kelemen et al., 2007) for the implementation of CMMI. They are extremely important and beneficial to understand the model and to perform self evaluation on the process areas. However, it is important to note that those systems are not intelligent systems and they can only provide a road map for the developers to make implementations. Internal decisions are left to the user. There is still a need for a system to provide both a road map as well as set of recommendations for possible improvements.

These computer-aided systems have common specifications such as;

- Mapping the typical work products which should be demonstrated to the company artifacts is decided by user.
- The user decides whether the artifacts are direct or indirect, strong or weak.
- The user decides practices, goals and process areas characterizations according to the situation (strong or weak) of the respective artifacts.

These basic capabilities can be performed by the computer provided that the respective knowledge is stored within the knowledge base. Expert system technology presents related methodologies and background knowledge to create fully automated expert CMMI advisor so called "CMMI Assistant".

4 CMMI ASSISTANT

Expert systems are computer systems that are capable of solving problems as human experts of the same domain would do when they face the same problem. An expert system is composed of a *knowledge base*, *inference engine*, and a *user interface* which handles the communication between the user and the system (MacKinnon L. M., 2009).

The *knowledge base* contains the knowledge and the respective rules for the expert system. Expert systems generally represent knowledge in the form of "IF…. THEN……ELSE ….."

The inference engine draws conclusions through scanning, filtering and interpreting the knowledge already stored in the knowledge base. CMMI Assistant uses *Forward Chaining* (data-driven reasoning) (Pomykalski et al., 1999) inference mechanism. In this case, reasoning starts with certain facts and certain answer to a certain problem is sought based on the availability of the facts.

While this system is being developed, knowledge and experiences of experts, detailed model information, implementation framework (Kökten, 2007.*)*, some implementation questionnaires (Carnegie Mellon SEI, 2002), appraisal questions (Kalaycı, 2007), "lessons learned" of some firms and the documentation of the Practice Implementation Indicator Database (PIID) (Kneuper, 2009) are utilized.

Architecture of CMMI Assistant developed is shown in the Figure 1. As in traditional expert systems, the CMMI Assistant has a knowledge base, an inference engine, and a user interface.

4.1 Knowledge Base

There is a need for domain knowledge which was stored in so called the knowledge base. Since the proposed methodology is designed to assist CMMI ML2 implementation, the knowledge base is populated with the knowledge related to ML2. Weighted artifacts list, CMMI ML2 process and assessment information are placed in this knowledge base.

4.2 Inference Engine

The inference engine manages to make decisions on the status of CMMI implementations and provide directions. The system is mainly based on the understanding that there are two characterizations for the artifacts: *Strong* and *Weak.* These characterizations are used by CMMI Assistant to identify the gaps so that possible remedies can be recommended to overcome them.

There are five situations for CMMI practices:

- If *Direct Artifact (D)* and *Indirect Artifact (I)* are weak and the system gives a recommendation, then the practice is *not implemented*.
- If any of *D* and *I* is weak and the system gives a recommendation, then the practice is *partially implemented.*
- If *D* and *I* are strong and the system gives a recommendation, then the practice is *largely implemented.*
- If *D* and *I* are strong and the system gives no recommendation, then the practice is *fully implemented.*
- If any data is not given to the system, then the practice is *not yet implemented.*

If all of the related practices are largely or fully implemented, the goal is considered to be satisfied.

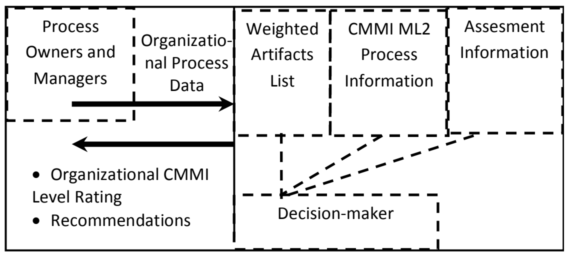

Figure 1: Components of CMMI Assistant.

Otherwise in turn it is unsatisfied. If all of the related goals are satisfied, the process area is supposed to be satisfied.

Forward chaining rules on how to decide "Configuration Management process area" is satisfied are given as an example below. Note that, "SP x.y" indicates x^{th} specific practice of y^{th} specific goal in a process area. Artifacts order is shown as a, b, c…etc. Also note that, x in "SG x" indicates x^{th} specific goal in a process area.

Example:
Required Direct Artifacts:
SP 1.1 a: Identified configuration items
SP 1.1 b: Specifications of configuration items
SP 1.1 b.1: unique identifier
SP 1.1 b.2: owner responsible
SP 1.1 c: Specifications of configuration items
SP 1.1 c.1: author
SP 1.1 c.2: document files type
SP 1.1 c.3: programming language
SP 1.1 d: Documented plan for keeping information about configuration items

These are represented as a rule such as the following.

Rule 1:
IF SP 1.1 b.1 AND SP 1.1 b.2
THEN SP 1.1 b
IF SP 1.1 c.1 OR SP 1.1 c.2 OR SP 1.1 c.3
THEN SP 1.1 c
IF SP 1.1 a AND SP 1.1 b AND SP 1.1 c
THEN D of SP 1.1 is Strong
ELSE D of SP 1.1 is Weak.

Similarly Indirect Artifacts Expected:
SP 1.1 d: Criteria for choosing configuration items
SP 1.1 d.1: Work products that may be used by two or more groups
SP 1.1 d.2: Work products that are expected to change over time either because of errors or change of requirements
SP 1.1 d.3: Work products that are dependent on each other in that a change in one mandates a change in the others
SP 1.1 d.4: Work products that are critical for the project
SP 1.1 e: Criteria for when placing an configuration item under Configuration Management System
SP 1.1 e.1: Stage of the project lifecycle
SP 1.1 e.2: When the work product is ready for test
SP 1.1 e.3: Degree of control desired on the work product
SP 1.1 e.4: Cost and schedule limitations
SP 1.1 e.5: Customer requirements

These can be coded as the following rule.

Rule 2:
IF SP 1.1 d.1 OR SP 1.1 d.2 OR SP 1.1 d.3 OR SP 1.1 d.4
THEN SP 1.1 d
IF SP 1.1 e.1 OR SP 1.1 e.2 OR SP 1.1 e.3 OR SP 1.1 e.4 OR SP 1.1 e.5
THEN SP 1.1 e
IF SP 1.1 d AND SP 1.1 e
THEN I of SP 1.1 is Strong
ELSE I of SP 1.1 is Weak

According to the artifacts characterizations respective recommendations are provided such as "*You must identify Plans, Process descriptions, Product specifications, Requirements, Interface description, Design data, Drawings as a configuration item in the Design stage"*.

Based on the availability of the artifacts, Rule 3, 4 and 5 can assure practices are implemented to a certain degree and related goal and process area are satisfied respectively.

Rule 3:
IF D of SP 1.1 is Weak AND I of SP 1.1 is Weak
THEN SP 1.1 is not implemented
ELSE IF D of SP 1.1 is Weak AND I of SP 1.1 is Strong OR D of SP 1.1 is Strong AND I of SP 1.1 is Weak
THEN SP 1.1 is partially implemented
ELSE IF D of SP 1.1 is Strong AND I of SP 1.1 is Strong
THEN SP 1.1 is largely implemented OR fully implemented.
All SPs and GPs are evaluated in the same way.

Rule 4:
IF SP 1.1 AND SP 1.2 AND SP 1.3 are largely OR fully implemented
THEN SG 1 is satisfied
ELSE SG 1 is unsatisfied.
All SGs and GGs are evaluated in the same way.

Rule 5:
IF SG 1 AND SG 2 AND SG 3 are satisfied
THEN CM is satisfied
ELSE CM is unsatisfied.
All process areas are evaluated in the same way.

4.3 User Interface

The user interface has two aspects:

a) Screen design: It is the interface of the program with the user in such a way that the user enters his organizational data and the system provides respective expert response.
b) Explanation: The user is informed about the reason behind the decisions. CMMI Assistant is designed in such a way that the recommendation to the user includes the reasons behind the

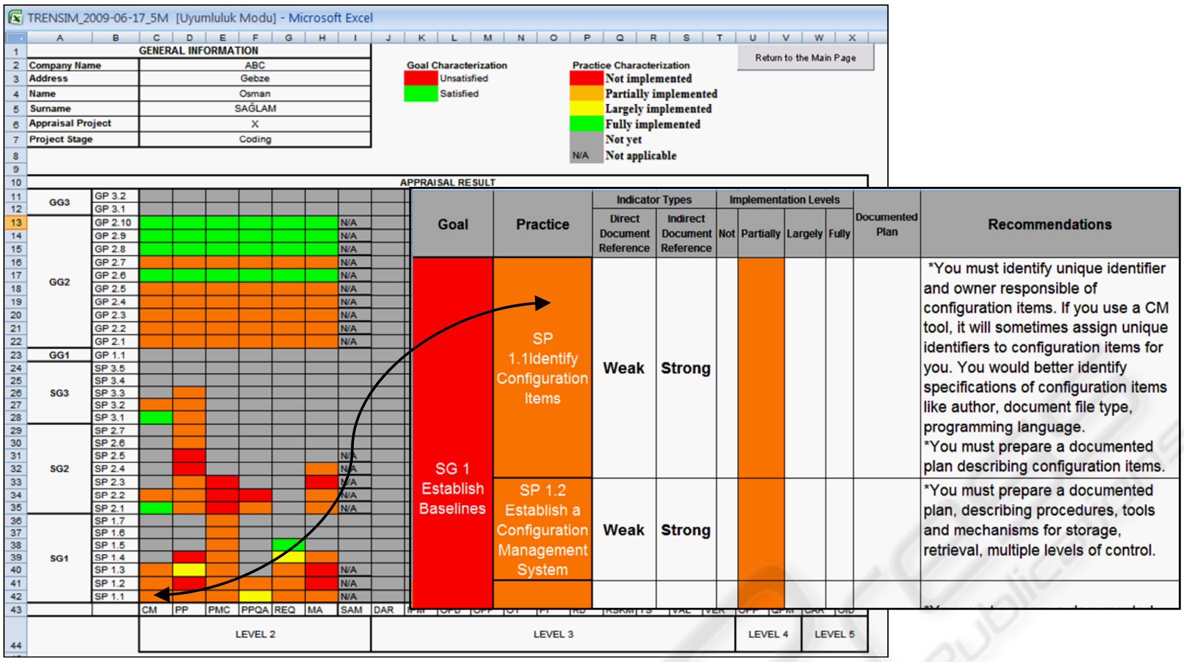

Figure 2: CMMI Assistant ABC Organization appraisal result page.

decisions in any case. This would definitely decrease the complexity of the system design.

5 CASE STUDIES

Two case studies are designed in order to show the proof of concept for CMMI Assistant. In the first case, the program developed was implemented in TUBITAK Marmara Research Center (MRC), Information Technology Institute (ITI) where several software projects (small, medium and big size) are carried out. The program was tested mainly using the process information from the project called “TRENSIM” which is a driving simulator project developed for Turkish Railways.

All required knowledge about ML2 process areas were collected from the MRC ITI process owners. Specific forms are designed to acquire the knowledge expected.

Results show that TRENSIM Project satisfies ML2 of CMMI model. Performing the respective analysis for the overall organization on some other projects, CMMI Assistant decided that the institution is complying with CMMI ML2 standards. This was also proved through real life implementation and TUBİTAK MRC ITI, after successful completion of a SCAMPI Class A Appraisal on 19 December 2008, attained CMMI-DEV v1.2 Staged Representation ML 3. (ITI, 2008) This is an indicator that proves accuracy of CMMI Assistant appraisal results.

Second case study is carried out in a software developing company ABC which is located in TUBITAK technopark. All questions about ML2 process areas were collected from company ABC and knowledge base of CMMI Assistant is populated with company specific knowledge as well. After data and knowledge acquisition process CMMI Assistant decided that the organization is having several gaps in complying with the required level of CMMI implementations of the respected processes. The organization has to improve itself especially in terms of creating baselines. The CMMI Assistant provided several reasons for this possible gap and recommended some actions for improvements.

The result of organizational appraisal for company ABC is shown in the Figure 2. Note that SAM Process area is not applicable in ABC. It is clearly seen that the organization does not satisfy ML 2. They have to improve their processes by taking into account all recommendations provided by CMMI assistants. The program provided both a road map and recommended areas to be improved.

6 CONCLUSIONS AND FUTURE WORK

In this study, CMMI Assistant which is an expert system based computer program was developed in order to provide required expertise to organizations willing to go for SCAMPI A. The system proposed is capable of defining the areas where lack of implementation exist and recommend actions to overcome those gaps. The case studies clearly proved the concept and showed the potential benefits of the proposed approach.

The study for improving the capabilities of CMMI Assistant continues. It will be extended to be able to handle MLs 3, 4 and 5 as well. It is also considered to add some statistical analysis capabilities to the system to be able to asses the improvement level of the respective organization. Note that, it can also be enriched with the capability of performing appraisals for continuous representation in any category.

Further study can also be carried out to embed learning ability to the system in order to create high degree of flexibility to the system. With the help of artificial intelligence technologies, agent-based systems this may seem to be possible but still needs further research on defining possible implementations.

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