AN EXAMINATION OF A RULE-BASED EXPERT SYSTEM TO AID IN THE IMPLEMENTATION OF THE CMMI FRAMEWORK

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Abstract -- Implementing the Capability Maturity Model Integration (CMMI) framework in an organization can prove costly and daunting to an organization seeking to implement this framework for the first time. Complaints from organizations attempting this rigorous improvement program address the large overhead, implementation risks and lack of quantitative value compared to their present processes. However, using a simple rule-based expert system may address the implementation difficulties by suggesting a path of improvement incorporating the framework. This paper will examine the effects of applying an expert system as a process improvement management tool in the implementation of the CMMI model.

1. INTRODUCTION
The cost associated with implementing the Capability Maturity Model Integration (or CMMI) framework in an organization is significant, and without proper guidance and training, can prove to be daunting to an organization with process improvement goals [1]. Costs are associated with a number of activities including proper training of those involved in the process improvement effort, pre-assessments to determine the current state or condition of the organization, the actual implementation of the model itself, and appraisals which uncover the organization’s strengths and weaknesses after implementation of the framework. Both assessment and appraisals can be very costly, and this cost varies based on the size of the organization and the model level being obtained. For smaller software companies (which make up a large percentage of the industry), the large cost of implementing the CMMI models can prove too much and most companies are either reluctant to use it, or do not understand the value-added. Because the value of having effective processes and best practices within organizations has shown to be important, an alternative and possibly more cost-effective way of implementing the CMMI framework is needed. Additionally, because the model has proven itself as an asset in improving quality and processes within organizations, as well as streamlining businesses, it would be of interest to explore a possible software solution that could be used as a management tool. This tool would also help in keeping the organization on the right path to its process improvement goals.

Although expert systems have been widely used in many areas, little work has been done in the possible automation or expert system implementation of the CMMI model, an area that could possibly benefit by the utilization of an expert system. This paper will explore using a simple rule-based expert system to address the CMMI implementation difficulties by suggesting a path of improvement incorporating the framework. By applying an expert system to an existing software engineering process improvement model, this paper examines the use of an expert system as a process improvement management tool in the implementation of the CMMI model.

2. WHAT IS CMMI?
A process is defined as a particular course or set of actions that produce a result. The CMMI along with its predecessor CMM is a process improvement framework that seeks to provide guidance in the implementation and continuous improvement of an organization’s processes, as well as the management activities associated with the development process of an organization [2].

The goal of the SW-CMM was to help software development companies become more mature such that in terms of projects and processes, predictability will be high, while risk is low. A fully mature organization is characterized by development processes that are disciplined, predictable, and most importantly repeatable [3].

A. The Structure of the CMMI Framework
In using the CMMI model for process improvement, an organization must identify and clearly define their process improvement goals. There are three key elements that need to be chosen: the part of the organization to be used in process improvement, the model, and the representation. The CMMI model has two representations, the staged and continuous models, and although the goal of the models is the same, their approach to process improvement is different. Process area capability is the primary focus of the continuous representation while organizational maturity is the focus of the staged representation. The purpose of both representations is to take processes that are ill-defined or not defined at all, and turn them
into useful, quantifiable and well managed processes enabling the organization to reach their business objectives [4].

After implementation of either representation or successful process improvement, many organizations want to measure their progress and conduct an appraisal. Appraisals can be done for one or more reasons including informing external customers and suppliers of how well the organization measures up to the CMMI best practices, identifying areas where improvements can be made, and meeting contract requirements of one or more customers [4].

B. Model Implementation

The actual implementation and use of the CMMI framework into mainstream businesses has seen positive results in these organizations. While the precise results of CMMI model implementation vary, organizations that have implemented CMMI initiatives have seen results including: reduction in general costs and delivery associated with their products, improved budget estimation accuracy, reduction in variation in schedule, improved software production, and improvement investments [5].

In looking at the software industry today with respect to the CMMI framework, the software products available for use as management tools for the CMMI framework are limited [6,7,8]. Most products are geared toward individual process areas such as but not limited to: Measurement and Analysis, Project Planning, and Organizational Training. There are also a few software tools that cover limited parts of the CMMI models with the use of what is referred to as a Process Asset Library (PAL); these typically focus just on level three of the staged representation.

3. THE INTELLIGENT ASSISTANT

After careful analysis of the CMMI framework structure and its benefits, it is noted that there is a need for a management tool that would assist organizations in using the CMMI framework for their process improvement goals. After examining the different aspects of the CMMI framework and the different approaches that can be used for implementing the different models in an organization, it became clear that there is no simple algorithm that could utilize conventional programming to build a management tool that would serve as a “diagnostic intelligent assistant” for organizations seeking to use the CMMI framework for their process improvement goals. Therefore, we decided to use a simple rule-based expert system to implement the intelligent assistant. But to do this, we first had to decide what our tool needed to do.

In order to successfully “guide” an organization in its process improvement efforts with respect to the CMMI framework, the tool would need to complete several main activities. First the tool would need to effectively collect information about the organization. This organizational data should include: improvement goals, organizational goals and objectives, and any problems or potential problems (risks). This information would then need to be represented as relationships between important elements such as goals and problems, and the specifications of these elements must be detailed and prioritized. This specification when used with the inference rules in the inference engine would allow for association of these goals and/or problems to a particular process area, while also pinpointing the processes that either need to be improved or established within the organization. Further analysis of the process specifications would determine which process areas address the needs of the goals and problems, as well as determine which specific goals and practices within the process areas would address the needs of the process. The resulting output would provide a suggested path for improvement with completed steps outlined, and incomplete steps detailing proven practices that would directly address the improvement effort. Lastly the tool would have to be able to track the improvements that have been made.

The next section discusses the results of a survey indicating the need for such a tool and the implementation of our intelligent assistant.

A. Survey Results

As part of this study, 50 software engineering companies in the US were asked to participate in a telephone survey to gauge the use of the CMMI framework. Since we called them directly, we had 100% compliance; nevertheless, the results were disheartening. Forty-two percent of the respondents thought that the CMMI framework was too big and complicated, while others (14%) complained of the mass overhead associated with implementing such a hefty process improvement program. Another 14% stated that the use of the framework was just too costly and that it was not worth the time it would take to implement it. Eighteen percent of the respondents were agile-based, and believed that the framework was counteractive to their agile processes, while 8% knew nothing of the model at all. Only 4% used some version of CMMI: one company successfully implemented the CMMI framework at level three, and another was currently using the SW-CMM.

After speaking directly with a number of CMMI consultants [9,10], research revealed that the problem that most organizations face with the implementation
of this model despite its high overhead is in the implementation itself. Often times the drive behind implementing the CMMI framework is based on client requests, or organizations focusing more on the level to be achieved than the benefit the improvement program can bring to the organization. Other reasons that organizations fail are that the process improvement program does not directly address the goals or needs of the organization; the program is implemented in its entirety instead of in smaller manageable pieces; and people within the organization are resistant to change. Additionally, others reported a lack of understanding of the model being implemented, and how the model should be implemented to have an effective process improvement program. Ultimately the scope of the improvement program should be driven by the organization’s specific needs, and should be defined by the organization’s goals and problems.

In order to be considered a successful management tool, the intelligent assistant would need to deduce from the information collected (i.e., organizational goals and problems, risks, funding, and company culture) an appropriate improvement path, or action plan, that would link the organization’s problems to the appropriate goals, and map CMMI generic practices to the goals as possible solutions. The tool would also allow for actual process improvement to be tracked enabling the organization to see that the improvement plan is working. This would allow management to not only map the CMMI practices to their own which is what is required of the improvement program, but also would provide proven solutions to existing problems.

B. Expert System Construction

With the use of an expert system shell, an intelligent assistant that could serve as a guide for those seeking to implement the CMMI framework for process improvement was developed. The expert system shell being utilized was Jess, a rule engine written entirely in Java [11]. The structure of an expert system consists of the knowledge base, the working memory, and the inference engine that controls the system’s inner workings. Jess works by “matching” the facts found in the working memory to the rules found in the knowledge base through the use of the inference engine. This inference engine matches through the use of a pattern matcher that decides what rules are on the agenda. This schedules the activated rules that will fire. The “firing” of the rules is done by the execution engine. Jess uses a Rete algorithm for the pattern matching by building a network of nodes, each of which represents one or more tests found on a rule’s “IF” side [11].

Summarizing, the engine matches the facts and rules, prioritizes them and then applies those rules based on the facts stored in the working memory. The information stored in the working memory has a representation similar to that of frames. The information is stored as facts, and every fact has a template. The templates provide the name and list of slots to the fact. The slots hold data about the fact, and a template can have one slot or multiple slots.

C. Implementation

The goal of our intelligent assistant is to provide the user with a suggested path for process improvement that incorporates the proven practices within the CMMI framework. The assistant allows the user to implement improvement in smaller, more manageable pieces. The assistant receives company profile information from the user including the organization’s various business goals and objectives, problems keeping the organization from reaching those goals, company culture, project implementation styles and risks, as well as CMMI criteria (model, representation, capability or maturity level, and additional appraisal goals). Our tool’s output is a suggested process improvement path that maps the problems to related goals, prioritizes them based on importance, and allows the user to define metrics; it also maps the CMMI process areas (their specific goals and practices) to the problems and their goals, and tracks the progress of each area.

For the sake of simplicity, information gathered from the GUI was done through the use of radio buttons, Yes or No answers, and check boxes. This was done to avoid parsing large volumes of text that could be entered by the user, and also to avoid the errors that could arise with having to match so many different keywords. The templates stored in the working memory hold information on every single element: framework holds multiple slot information about the CMMI constellation, model, representation and level; level has multiple slot information about process areas; process areas hold information about the specific goals; and company templates hold information about goals, objectives and additional information.

The GUI for the assistant allows the user to create a new user profile or open an existing profile. The user is then guided through a series of questions specific to the user’s organization. As the user completes each section of the diagnostic tool beginning with profile information, the information gathered is asserted in the corresponding fact template. At the end of the diagnostic, the rule engine fires all the rules that have been satisfied and presents the findings. The user is given a suggested improvement
shown the groupings of problems to their related goals; presented the appropriate parts of the maturity level process areas that can provide solutions to their problems; and extensions to new windows that will help define metrics and store data for appropriate tracking of improvement. The improvement plan will be based on the user’s stated priority of the goals and problems, and pressing issues are suggested first.

In order to know whether or not the prototype would be successful, the prototype was used by the Chief Operating Officer (COO) of Organization X. Based on previous attempts at process improvement, the COO logged his results in a short survey created along with the prototype. The results obtained from the prototype are found in Figures 1 and 2.

Organization X is an agile-based software engineering firm with approximately 30 employees, whose primary business is software solutions. A new contract requires them to be rated at least at level two of the SEI’s CMMI framework. Funding for the process improvement effort has been secured, and the appropriate team leaders have been trained by SEI. The company’s main goal is to meet all scheduled commitments, with intermediate goals being improvement of software quality and increase in profits. The problems that Organization X faces are that employees feel that documentation takes too much time, and would rather just code the project; deadlines are often missed because of lack of a proper project management plan causing unforeseen project escalation, and because there is no real time allotted for proper design activities, customer requirements are sometimes missed, and the lack of testing tools forces more rework, risking budget excess.

While we are aware that having our prototype beta-tested by only one company is definitely too small of a sample size to claim success, we simply wanted to get some real feedback from a client experienced with the CMMI framework. Based on his answers, he felt that the tool was a helpful starting point for those seeking to implement the CMMI framework. He found that the question and answer format forced him to sit down with management and determine each individual goal and objective, as well as possible problems that prevent the achievement of these goals. This encouraged management and employees alike to find a purpose for the improvement effort and not to just implement the framework because the client requested it. Additionally the COO felt that the proven processes mapped to his existing problems were good starting points and considered them “plausible solutions” to some of the existing problems that the organization was challenged with. On the negative side, he felt that the tool was very limited in addressing the needs of all companies considering that individual goals and problems had to be chosen from predetermined lists.

![Figure 1: Suggested Improvement Path Screen 1](image)

4. SUMMARY AND RESULTS

This study revealed that issues such as implementation methods play a large role in the success of a process improvement effort. A prototype was built using an expert system shell to help companies trying to implement the CMMI model. The tool provides help in the definition and documentation of a company’s process goals and objectives; and also provides some guidance on the path towards a rational approach to attain a specific CMMI level.

Our limited results show that the intelligent assistant proves helpful because during the question and answer methods, the organization is forced to specify and adhere to their set goals and objectives. This makes the process improvement effort reflect the needs of the organization, and employees are more willing to accept a process improvement effort that has a compelling purpose [10]. The results also show that
the CMMI framework can not only be used for improvement of process, but also to identify plausible solutions to existing problems. Because the framework consists of a group of proven processes, knowing that these processes can work to solve a company’s problem is half the battle. The other half lies in the implementation and tracking of the process.

However, our client found our tool to be limited in its use due to the type of expert system logic chosen and the limited representation technique. We realize that our implementation did not allow for the processing of all the infinite combinations and variations of elements that are involved in a process improvement effort. That would require a much more complex system, one that would allow for better collection and representation of the user information. This future implementation would allow the user to input their own individual goals, objectives, problems and improvement goals, while still allowing them to be weighted for priority, and would result in a more detailed improvement program. This future solution would have to parse through the user input for keywords that would associate the component to a process area, which would require each component to be well-defined, and well-represented. Thus better collection and representation techniques would allow for better associative relationships between the information collected and appropriate process areas; it would also allow for the tool to pinpoint which process within the organization needs to be improved or even established, and which specific practices within associated process areas would work to improve an existing process.

This study revealed that while the CMMI framework has been beneficial to the software engineering industry, businesses trying to implement the CMMI are faced with massive associated costs. Considering the benefits that the framework can bring to an organization, we are suggesting that perhaps a tool like our intelligent assistant, while weaker in power than the future system proposed in the previous paragraph, may be exactly what the software industry needs to get organizations to more easily adopt CMMI, where the complexity burden currently keeps a lot of prospective software companies away.

References