



A CMMI appraisal support system based on a fuzzy quantitative benchmarks model

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ABSTRACT

In Capability Maturity Model Integrated (CMMI), Lead Appraiser (LA) evaluates the processes of one company according to qualitative sources such as instrument, interview and document through direct artifacts, indirect artifacts and affirmation. Due to the subjective measurement and non-quantitative expression of LAs, this paper proposes a fuzzy quantitative integrated metric model (FQIMM) that combines Quantitative Software Metrics Set (QSMS), linguistic variables, interval of confidence and a new fuzzy number ranking method. It can help software companies to evaluate on quantitative approach and then know the status by their self more quickly and effectively. Moreover, a CMMI appraisal support system (CMMI-ASS) is developed to help self-assessment software companies to accomplish the appraisal process, which integrates a fuzzy number ranking method to rank the final result.

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1. Introduction

In recent years, software development companies and departments follow software process methodology (SPM) including ISO9000, Capability Maturity Model (CMM) and Capability Maturity Model Integrated (CMMI) for improving competitiveness and quality. Moreover, many researches investigate the impact of software process improvement on organizations performance and the situations (Ashrafi, 2003; Li Eldon, Chen, & Lee, 2002). Besides, the impact of software process improvement on organizations performance and the situations was investigated by many researches, such as Ashrafi (2003), Li Eldon et al. (2002), Jiang, Klein, Hwang, Huang, and Hung (2004), Osmundson, Michael, Machniak, and Grossman (2003).

In order to evaluate the maturity of the software development process in a software company, software measurements are needed and used to measure specific attributes of a software product or software process. This study area uses software measures to derive various objectives (Grady, 1987; Grady, 1990; Grady & Caswell, 1987). In CMMI, the Lead Appraisers can know the effects and the performance of institutionalized process in one company according to Specific and Generic Goals, and Generic and Specific Practices defined in Process Area. Lead Appraisers can also evaluate in qualitative description based on questionnaire, interview and document by appraisal requirements for CMMI, and standard CMMI appraisal method for process improvement (SCAMPI) (Mellon Software Engineering Institute, 2001).

The CMMI evaluation results are usually dependent on the Lead Appraiser's subjective judgment. Therefore, Chen and Huang (2003) built Quantitative Software Metrics Set by appraisal requirements for CMMI and function point analysis (Garmus & Herron, 2001) and chose one category of each process area in CMMI Continuous for Quantitative Software Metrics Set. In Quantitative Software Metrics Set, 'benchmark' means the computing unit is calculated by function point, but cannot benchmark with certificated company. Also, according to (APQC, 1993), 'benchmark' was defined as "evaluating the practices of best-in-class organizations and adapting processes to incorporate the best of these practices (APQC, 1993)". According to Kearns, the former CEO and Chairman of Xerox Corporation, says, "Benchmarking is the continuous process of measurement of products, services, and practices, related to the strongest competitors or the recognized companies that is leader in its field."

This paper accepts above definition and want to build a more feasible and flexible system for improving this process. However, in many decision-making situations, the values for the qualitative criteria are often imprecisely defined for the decision-makers (DMs) and the final scores of alternatives are represented in terms of fuzzy numbers. The evaluation of software maturity also must face this problem and we adopted the fuzzy numbers for describing Lead Appraiser's judgment and knowledge. For above reasons, a ranking fuzzy numbers method based on two-dimensions dominance (Chang, Cheng, & Kuo, 2006) is adopted into the CMMI appraisal support system (CMMI-ASS) developed in this paper for handling the benchmark problems.

In this paper, the preliminary will be introduced briefly in Section 2. FQIMM is proposed in Section 3. Then, the practical example

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and CMMI-ASS are introduced in Sections 4 and 5, respectively. The conclusion and future work will be presented in Section 6.

2. Preliminaries

2.1. Capability Maturity Model Integrated (CMMI)

In 1980, the researchers in Software Engineering Institute (SEI) have engaged in the research of software maturity in different software development organizations. At first, in order to evaluate the performance of contractors, Department of Defense (DOD) provides a set guideline of software process management (SPM). Therefore, many researchers develop model that describes the activities and models of software process called Capability Maturity Model® (CMM) (Paulk, Cutis, Curissis, & Weber, 1991; Paulk, Cutis, Curissis, & Weber, 1993).

From then on, SEI has published several modules of CMM, there are five kinds CMM so far. Although they are applied in many organizations, it exists a lot of problems that an organization uses more one model simultaneously. Because of different architectures, contexts and methods among several models, organizations must spend more resources to finish integrating the different models. In order to solve such a problem, SEI develops a set model, which can solve this problem and integrate training and appraisal models called Capability Maturity Model Integrated® (CMMI). Therefore, CMMI Version 1.02 was published in 2000, and CMMI Version 1.1 in 2001 (Carnegie Mellon Software Engineering Institute, 2001, 2002a, 2002b).

There are lots of researches about the improvement and discussion for CMMI. For example, Huang and Han (2006) proposed a decision support model that assists managers in determining the priorities of the CMMI process areas based on the characteristics of the is being developed. Jung and Goldenson (2009) think that higher process maturity is associated with improved project performance and product quality, so they provides a empirical evidence to support this proposition. Their results indicate that organizational size does not influence the relationship, while geographical region is deemed to be an independent variable. Lee, Wang, and Chen (2008) develop an ontology based intelligent decision support agent (OIDSA) to apply to project monitoring and control of CMMI. It is composed of a natural language processing agent, a fuzzy inference agent, and a performance decision support agent.

This research has two reasons to use CMMI to be our research model. One is tendency, in order to keep pace with other countries and become a globalization country; the institute for information industry in Taiwan has engaged moving this worldwide standard of the software process. The other is that SEI says that it will engage in CMMI and would not update CMM.

2.2. Fuzzy set theory

Zadeh originally describes Fuzzy as fuzzy set, which is a technique that is designed to cope with imprecise linguistic concepts or fuzzy terms. It allows users to provide inputs in imprecise terms and receive either fuzzy or precise advice (Zadeh, 1965).

2.2.1. Arithmetic operations of fuzzy numbers

In this section, the definition and arithmetic operations of fuzzy number described by Zimmermann (1991) will be introduced.

Definition 1. Let X be a universe of discourse corresponding to an object whose current status is fuzzy, and the status value is characterized by a fuzzy set \tilde{A} in X . A membership function $\mu_{\tilde{A}}(x) : X \rightarrow [0, 1]$ is called the membership function of \tilde{A} .

Definition 2. A fuzzy number \tilde{A} is a normal and convex fuzzy subset of X , which is described as follows (Zimmermann, 1991).

$$\sup_x \mu_{\tilde{A}}(x) = 1, \tag{1}$$

$$\mu_{\tilde{A}}(x)[\lambda x_1 + (1 - \lambda)x_2] \geq \min [\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)]. \tag{2}$$

A fuzzy numbers can be described as triplet $\tilde{A} = (a_1, a_2, a_3)$, and the arithmetic operations of fuzzy numbers depends on the arithmetic operations of the interval. Some main operations for fuzzy numbers described are as follows (Kaufmann & Gupta, 1991):

$$\forall a_1, a_3, b_1, b_3 \in R : \tilde{A}_x = [a_1^{(x)}, a_3^{(x)}], \tilde{B} = [b_1^{(x)}, b_3^{(x)}], \alpha \in [0, 1].$$

(1) Addition: \oplus

$$\begin{aligned} \tilde{A} \oplus \tilde{B} &= [a_1^{(x)}, a_3^{(x)}] \oplus [b_1^{(x)}, b_3^{(x)}] \\ &= [a_1^{(x)} + b_1^{(x)}, a_3^{(x)} + b_3^{(x)}]. \end{aligned} \tag{3}$$

(2) Subtraction: \ominus

$$\begin{aligned} \tilde{A} \ominus \tilde{B} &= [a_1^{(x)}, a_3^{(x)}] \ominus [b_1^{(x)}, b_3^{(x)}] \\ &= [a_1^{(x)} - b_3^{(x)}, a_3^{(x)} - b_1^{(x)}]. \end{aligned} \tag{4}$$

(3) Multiplication: \otimes

$$\tilde{A} \otimes \tilde{B} = [a_1^{(x)}, a_3^{(x)}] \otimes [b_1^{(x)}, b_3^{(x)}] = [a_1^{(x)} * b_1^{(x)}, a_3^{(x)} * b_3^{(x)}]. \tag{5}$$

(4) Division: \oslash

$$\tilde{A} \oslash \tilde{B} = [a_1^{(x)}, a_3^{(x)}] \oslash [b_1^{(x)}, b_3^{(x)}] = [a_1^{(x)} / b_3^{(x)}, a_3^{(x)} / b_1^{(x)}]. \tag{6}$$

2.2.2. Linguistic variable

A linguistic variable is “a variable whose values are words or sentences in a natural or artificial language” (Zadeh, 1975). For instance, some matters are characterized by linguistic term in nature, such as ‘good’, ‘medium’, and ‘bad. Each linguistic variable may be assigned one or more linguistic values, which are in turn connected to a numeric value through the mechanism of membership functions. From Miller (1956), the number of terms that a person is able to discriminate is 7 ± 2 . Therefore, this paper adopts five fuzzy linguistic terms by triangular fuzzy numbers to express un-quantified matters. Fig. 1 shows the membership function of linguistic valuables. Table 1 explains the numeric values of the membership functions.

2.3. A ranking fuzzy numbers method

Many ranking methods have been proposed so far. However, there is yet no method that can always give a satisfactory solution to every situation. The existing ranking fuzzy numbers methods all have their advantages and some shortcomings. They may valuable in solving some types of fuzzy numbers (i.e. normal, non-nor-

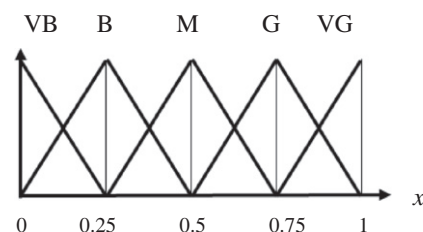


Fig. 1. The MF of linguistic valuables.

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