Fuzzy Emotional COCOMO II Software Cost Estimation (FECSCE) Using Multi-Agent Systems

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Abstract

Software development cost estimation is important for effective project management. Many models have been introduced to predict software development cost. In this paper, a novel emotional Constructive Cost Model II (COCOMO II) has been proposed for software cost estimation. In COCOMO II only the project characteristics are considered, whereas the characteristics of team members are also important factors. This paper presents a model, namely FECSCE, which in addition to project characteristics considers the communication skills, personality, mood and capabilities of team members. In FECSCE, we have used a Multi-Agent System (MAS) in order to simulate team communications.

Keywords— COCOMO II, Emotion, Personality, Mood, Fuzzy Agent, Multi-Agent System (MAS).

1 INTRODUCTION

One of the most critical tasks in managing software projects is software cost estimation [1]. The software industry is very competitive to establish the market with accurate cost estimation [2]. It can help industries to better analyze the feasibility of a project and to effectively manage the software development process [3]. There is no approach proven to have effectively and consistently predicted software output metrics [3]. There are a number of methods used to estimate the cost of various projects. COCOMO is known as a popular method in this respect.

Having an agile team is a significant element for the success of a complex software project. A project is the same as a social system where personal and cooperative characteristics play a key role in achieving goals. The members of any projects have emotions such as anger, fear, joy, sadness and surprise [4]. These emotions are positive or negative at the start of the project [4]. The positive emotion is related to the joy of having an interesting assignment, meeting new people and working in a new team. The negative emotion is related to the fear of a new challenge in a new work and new responsibility in a team. Emotions, the degree of

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cooperation and the suitability of the assigned tasks with the capability of team members are parameters affecting project properties (e.g. cost) [5]. By using simulation tools, we can simulate the operations of a team in a given project to estimate its cost [6].

In the previous cost estimations, only the project characteristics have been considered. In this paper a novel emotional COCOMO II model has been proposed. We present the FECSCE, Fuzzy Emotional COCOMO II Software Cost Estimation. The major difference between this model and previous ones is that the FECSCE incorporates characteristics of team members (i.e. communication skills, personality, mood and capabilities) into the COCOMO II model. In this study, fuzzy agents and Multi-Agent Systems have been used to simulate personal characteristics and interactions in a team.

This study has been inspired from a web-based digital library project in which all team members were students and the authors were involved in. The authors could view the effect of personality and emotional factors in the productivity of team members. Since the data of this project was available, we used it as the pilot test for the configuration of fuzzy sets and membership functions, and the definition of the internal variables of a team member.

Section 2 of the paper, describes the background of the study including the COCOMO model, fuzzy systems, software agents, personality, mood, and emotion, and related work; section 3 describes the FECSCE model. In sections 4, the design of the FECSCE is discussed. Section 5 presents the implementation and evaluation of the FECSCE and finally section 6 presents the conclusion and the perspective of future works.

2 BACKGROUND

2.1 The COCOMO

The COnstructive COst Model, COCOMO, was introduced by Barry Boehm [7]. It has become one of the most widely used software cost estimation models in the industry. To support new life cycles and capability, it has evolved into a more comprehensive estimation model, called COCOMO II [8, 9].

For the COCOMO II models, three different sizing options are available: object points, function points, and lines of source code. The COCOMO II application composition model uses object points. Object Point estimation is a relatively new software sizing approach. It is well matched with “prototyping efforts, based on the use of a rapid-composition Integrated Computer Aided Software Environment (ICASE) providing graphic user interface builders, software development tools, and large, composable infrastructure and applications components” [10].

The object point is computed using counts of the number of (1) screens (at the user interface), (2) reports, and (3) 3GL components (components likely to be required for building the application). Each object instance (a screen, report or 3GL component) is classified into simple, medium, or difficult using criteria suggested by Boehm [10].

Then, the number of screens, reports, and components are weighted according to a weight-table in [8]. The total Number of Object Points (NOP) is determined by the sum of the multiplications of the original number of object instances by the weighting factors. The NOP is adjusted by the reusing factor as follows (Eq. 1) [9]:

$$\text{NOP} = (\text{object points}) \times [(100 - \%\text{reuse})/100] \qquad (1)$$

The productivity rate is determined from Table 1. Hence, the person-month parameter is computed by Eq. 2.

$$\text{Person-month} = \text{NOP} / \text{PROD} \tag{2}$$

Table 1: Productivity rates for object points [8]

Developer's experience/capability ICASE maturity/capability	Very low	Low	Nominal	High	Very high
PROD	4	7	13	25	50

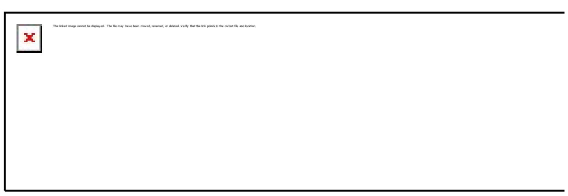
2.2 Fuzzy Systems

The term *fuzzy logic* emerged in the development of the theory of *fuzzy sets* by Lotfi Zadeh [11]. Fuzzy set theory provides a natural method for dealing with linguistic terms (i.e. beginner, intermediate, and expert) of the linguistic variables (i.e. skill). A general *fuzzy system* includes the following elements:

1. Fuzzification process, in which the membership functions (MF) are applied to the numerical value of input variables, to determine how much the input variables fit the linguistic terms.
2. A *knowledge base,* which is the set of the expert control rules (knowledge) needed to achieve the goal. The knowledge base is usually expressed as a number of 'IF-THEN' rules based on the domain expert's knowledge.
3. A *fuzzy inference* mechanism, which performs various fuzzy logic operations by using knowledge base to convert fuzzy inputs to fuzzy outputs.
4. Defuzzification process, in which if the conclusions of the fuzzy rule set are fuzzy subsets themselves, then it is necessary to translate these subsets into a crisp number before the results can be used in practice.

There are three widely used fuzzy inference system types: Mamdani [12], Sugeno [13, 14], and Tsukamoto [15] that are different in the fuzzy inference mechanism and the defuzzication. A good survey about these fuzzy inference systems exists in [16].

In this paper, we have used three kinds of MF: triangular (Figure **1**), trapezoidal (Figure **2**), and Gaussian (Figure **3**). The triangular MF is specified by a triplet (a, b, c) as follow (Eq. 3):



(3)

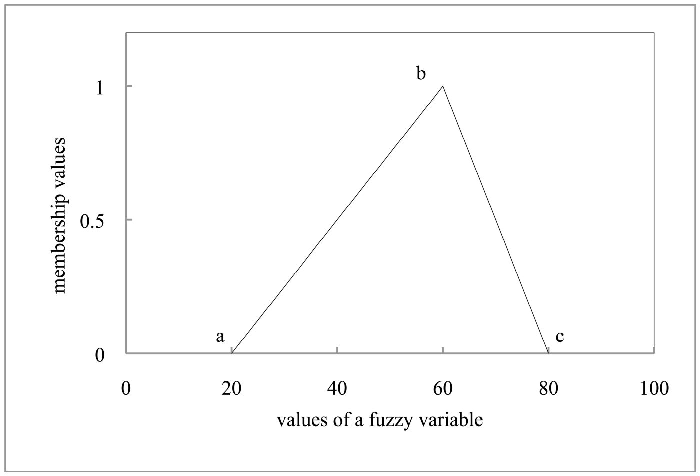


Figure 1: A triangular membership function specified by (20, 60, 80)

The trapezoidal MF is specified by four parameters (a, b, c, d) as follow (Eq. 4):

(4)

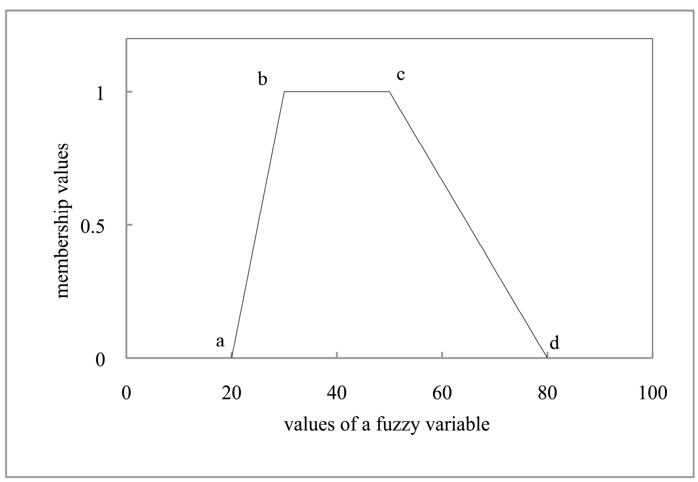


Figure 2: A trapezoidal membership function specified by (20, 30, 50, 80)

The Gaussian MF is specified by two parameters (m, σ) as follow (Eq. 5):

(5)

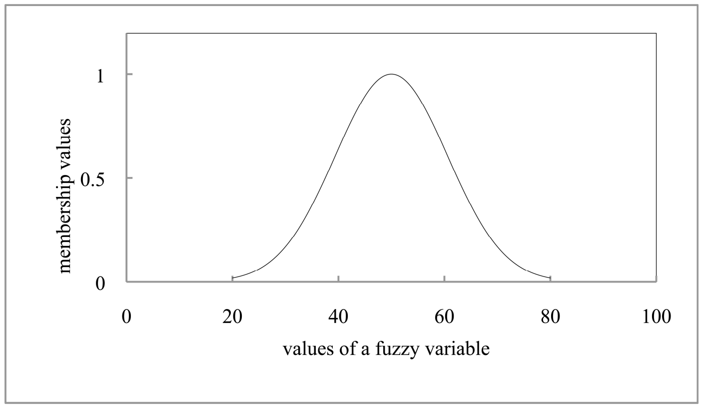


Figure 3: A Gaussian membership function specified by (50, 15)

2.3 Software Agents

Software agents are autonomous software modules which have the perception and social ability to perform goal-directed knowledge processing, reasoning, motivation, planning, and decision making, on behalf of humans or other agents in software and physical environments [17]. Ghasem-Aghaee and Ören [17] defined *Fuzzy agents* as agents that can perform qualitative uncertainty reasoning with *incomplete* and *fuzzy knowledge* in environments that contain linguistic variables.

Recently, Distributed Artificial Intelligence (DAI) techniques have been evolved towards using Multi-Agent Systems (MAS) [5]. A Multi-Agent System is a system, which consists of multiple interacting agents, that is, the agents which communicate, collaborate, and negotiate to achieve a common goal. "Multi-Agent Systems have the capacity to play an important role in developing and analyzing models and theories of interactivity in human societies" [5].

2.4 Personality, mood, and emotion

Personality can be defined as “that pattern of characteristics thoughts, feelings and behaviors that distinguish one person from another and that persist over time and situation” [18]. In this study, the OCEAN personality model [19] has been used. This model includes five factors each having six facets. The five factors are Openness to experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. In this study, we have only used the factors related to team performance and productivity [20]: openness, conscientiousness, and extraversion. They will be defined in detail in the following sections. We have used “consolidation” instead of “conscientiousness” on the basis of the definition in [21] and we have renamed “extraversion” with “communication skills”. NEO PI-R[1] questionnaire [22] can measure the five factors of personality and consists of 240 personality items, 48 items for each factor. The questionnaire uses a five-scale (from strongly disagree to strongly agree) Likert response format. Ören and Ghasem-Aghaee formulated– based on the OCEAN model –personality representation processable in fuzzy logic for human behavior simulation [17, 23].

Mood is a less static than personality and a more global and longer lasting emotional state [24, 25]. “Moods are important to model because they have been shown to impact a range of cognitive, perceptual and behavioral processes, such as memory recall (mood-congruent

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[1] NEO Personality Inventory-Revised

recall), learning, psychological disorders (depression) and decision-making" [25].

The studies of recent years have proved that emotions are one of the key elements of the adaptive nature of human beings especially when considering decision-making [26]. Hence, both the social and computational sciences have seen an explosion of interest in emotions in the last decade [27]. There are several models to analyze the emotional states that an agent would be encountered with [28]. We have used the OCC model [29] which indicates a standard computational model for analyzing emotions. This model denotes eleven positive/negative pairs of emotions. In this study, we have used two pairs of emotions, joy/distress and gratitude/anger, to initialize only the mood of a team member. We have selected these pairs for mood initialization on the basis of our evidence in the pilot test. These pairs were dominant in our pilot test. We have used mood to aggregate the emotions of a team member in a more permanent variable.

2.5 Related work

Most of the recent studies in software cost estimation focused on the improvement and calibration of the COCOMO II. Dillibabu and Krishnaiah [2] calibrated the COCOMO II by the curve fitting approach. Huang et al. [3] used a neuro-fuzzy approach to deal with imprecision inputs (i.e size of software, cost drivers, and scale factors) and enhances the reliability of software cost estimation. Ahmeda et al. [30] dealt with the imprecision and uncertainty in the inputs of effort prediction. There are many studies that utilized the fuzzy systems to deal with the imprecise and linguistic inputs of software cost estimation [1, 30-33]. Reddy and Raju also compared the results of Gaussian, trapezoidal, and triangular MFs in COCOMO's effort estimation [31, 32]. Their comparison showed that Gaussian achieved the closest results to actual effort and after Gaussian came trapezoidal and finally triangular. Xu et al. [1] presented a fuzzy identification cost estimation modeling technique to deal with linguistic data in which fuzzy rules and MFs are constructed from data automatically.

A few studies used simulation environments for cost estimation. Choi and Bae [34] proposed a simulation method for dynamic project performance in which changes occur in the user requirements or project personnel to estimate effort, schedule, and defect density. They combined COCOMO II with system dynamics. Miranda et al. [5, 6] proposed a Multi-Agent System simulation tool to provide information about the behavior of a team. This simulation tool helps the project managers to integrate a team in terms of cost and time. Al-Sakran [35] proposed an improved Case-Based Reasoning (CBR) approach integrated with Multi-Agent technology to retrieve similar projects from a comparable domain in multi-organizational distributed datasets. Ping et al. [36] built an architecture of Multi-Agent Systems for cost estimation in which each agent represents a kind of cost estimation method. The architecture uses a fuzzy classification to classify the user's request to fulfill the task by expert agents.

One of the most important inputs to software cost estimation models is Capability Maturity Model Integration[1] (CMMI) [38] that reduces the human efforts and the costs of the project [39]. Yahya et al. [38, 40] investigated the benefits of CMMI based software process maturity and the effect of process maturity on software development effort to improve the COCOMO II. Wang et al. [41] proposed an ontology-based fuzzy agent for CMMI project planning to estimate the total project cost. Lee and Wang [42] presented an ontology-based computational intelligent Multi-Agent System for CMMI assessment. Lee et al. [39]

[1] "CMMI (Capability Maturity Model Integration) consists of best practices that address the development and maintenance of products and services covering the product life cycle from conception through delivery and maintenance. … By integrating these bodies of knowledge, CMMI provides a comprehensive solution for developing and maintaining products and services" [37].

presented an ontology-based intelligent decision support agent (OIDSA) for project monitoring and control of CMMI. Lee et al. [43] also presented an ontology-based intelligent estimation agent for total project cost estimation, including a CMMI-based project planning ontology containing the information predefined by domain experts and a fuzzy cost estimation mechanism to infer the total project cost.

3 FECSCE: FUZZY EMOTIONAL COCOMO II SOFTWARE COST ESTIMATION MODEL

The main goal of the FECSCE model considers team characteristics in such a way as to render the COCOMO II project cost estimation more accurate. There are two kinds of agent in FECSCE: "Team Member Agent" (TMA) and "Simulator Agent" (SA). TMA is a fuzzy agent for the simulation of a team member. Multi TMAs can simulate a team and TMAs communications can reflect intra communication of the team. In this model, only the direction of communications is considered not the quality of the communications or the role of the members. Figure 4 shows a communications graph of a team with four members: TMA_1 simulates a project manager; TMA_2 simulates an analyzer; TMA_3 and TMA_4 simulate two programmers: programmer_1 and programmer_2. The team's communications is showed as a directed graph in which the links show the communications. With respect to this graph, the project manager communicates with the analyzer, the programmer_1, and the programmer_2; the analyzer communicates with the project manager and the programmer_2; the programmer_1 communicates with the programmer_2; and the programmer_2 communicates with the programmer_1 and the analyzer. The TMA sends two kinds of message to other agents in each cycle of simulation: an "adjusted prod message" to the SA and an "affect message" to the linked TMAs. The "adjusted prod message" is the adjusted value of the prod and the "affect message" is the affect of a member on the teammates. A sample communication between TMA_1 and the other agents with FIPA-ACL[1] in one cycle of the simulation is as follow:

```
(inform
        : sender TMA_1
        : receiver SA
        : content (prod is 13.2
                  mood is 49
                  type is result
                  id is 1)
        : language sl
)
(inform
        : sender TMA_1
        : receivers TMA_2, TMA_3, TMA_4
        : content (affect is 30
                  type is affect)
        : language sl
)
```

[1] Foundation for Intelligent Physical Agents (FIPA) works on developing standards for agent systems and Agent Communication Language (ACL) specifications. We used a semantic language (sl) to explain the messages between agents. It is not the real language used in the FIPA-ACL.

"type" is used to indentify one message from other messages in the system; SA uses "id" to store the "prod" and "mood" of each agent separately for diagram display only. SA stores the "prod" of each TMA in each cycle of the simulation to aggregate them at the end of the simulation. It collects the adjusted prods and produces the final adjusted prod by averaging the adjusted prods through simulation. The communication schema of FECSCE is shown in Figure 4.

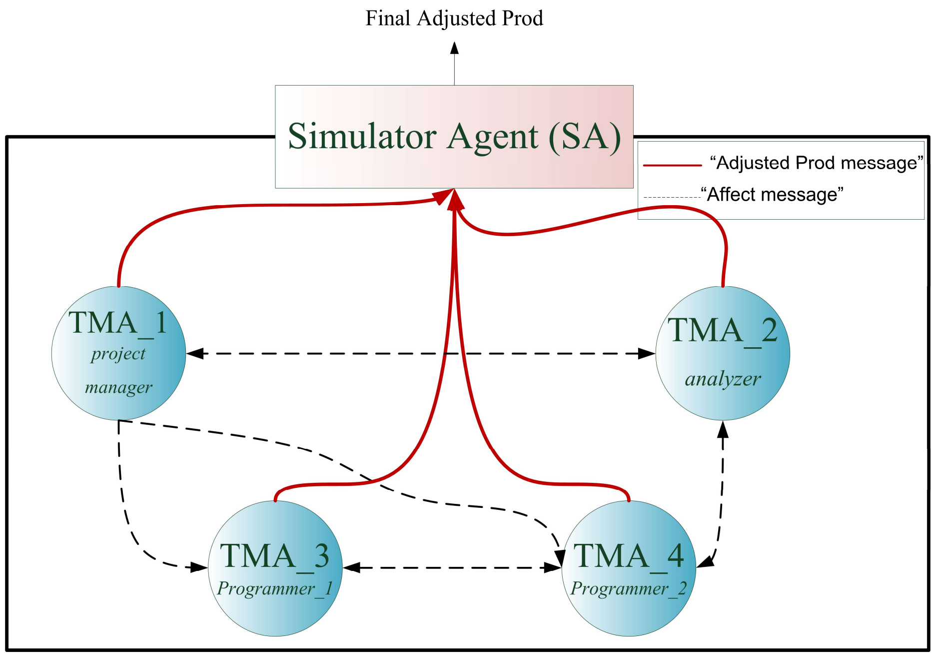

Figure 4: The communication schema of FECSCE
shows the communication between TMAs and SA. The team contains four members: a project manager, an analyzer, and two programmers. They are simulated by TMAs. The thick lines indicate the communications between TMAs and SA; the broken lines indicate the communications between the TMAs.

The intra architecture of a TMA is illustrated in Figure 5.

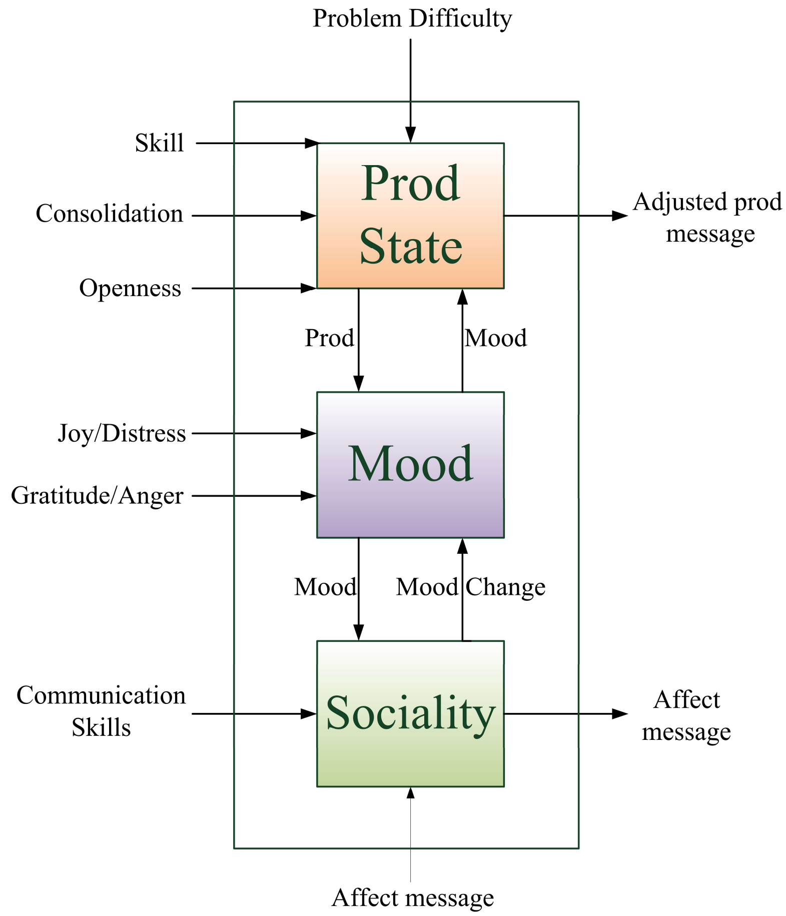

Figure 5: The intra TMA structure

A software agent needs three basic aspects in order to match with a real person [5]: cognition, emotion and personality, and social characteristics. To match a TMA with a team member, we have considered skill in the cognition aspect to represent the technical knowledge of the team member; joy/distress and gratitude/anger in the emotion aspect to represent the mood and emotional state of the team member; openness and consolidation in personality aspect to represent the personality of the team member; and communication skills in the social characteristics to represent the interaction among team members. Hence, the TMA includes six internal variables: skill, joy/distress, gratitude/anger, consolidation, openness, and communication skills. At the beginning of the simulation, a message form SA initializes the internal variables of each TMA, assigns an "id" to each TMA, and send the information that TMA needs for its computation (problem difficulty and linked TMAs). A sample initialization message between SA and TMA_1 is as follow:

```
(inform
        : sender SA
        : receiver TMA_1
        : content (joy/distress is 50
                   gratitude/anger is 50
                   openness is 80
                   consolidation is 80
                   communication skills is 85
                   skill is 85
                   problem difficulty is 55
                   linked TMAs are TMA_2, TMA_3, TMA_4
                   type is init
                   id is 1)
        : language sl
)
```

Based on the FECSE model, the TMA's internal variables organize in to three elements:

1. Prod State element
2. Mood element
3. Sociality element

The "mood", "prod", and "moodchange" are variables by which the elements communicate with each other. In the Prod State element, the original COCOMO II's prod value is adjusted. The inputs of this element are skill, consolidation, openness, problem difficulty and mood that they affect the productivity of a team member and the output is the adjusted prod. The first three inputs are team member characteristics and the fourth is the project characteristics needed to produce the initial prod according to COCOMO II.

The inputs for the Mood element are joy/distress and gratitude/anger. It is also affected by the output of the Prod State element. Besides, the Sociality element influences the Mood element. The Sociality element simulates the communication between team members. Its inputs are communication skills, mood states, and affect message. These inputs are exploited by the Sociality element to compute how a member influences others.

4 FECSCE FUZZY INFERENCE

We have utilized the Tsukamoto fuzzy inference system in the three elements of each TMA. Tsukamoto aggregates each rule's output by the method of weighted average and the output is always crisp even when the inputs are fuzzy [16]. Considering that the transition of Gaussian MF in the intervals is smoother and more natural than triangular MF, we have utilized Gaussian MF in the variables of COCOMO [31] (prod and problem difficulty). For the variables, which need superior transition, we have utilized the triangular MF (prodChange, moodChange, and affect message). We have utilized the trapezoidal MF for the emotion and personality characteristics [17, 23, 44] (skill, openness, consolidation, joy/distress, gratitude/anger, mood, and communication skills). In addition, the fuzzy sets were configured and refined in the pilot test (i.e. the "problem difficulty" changed from triangular to Gaussian).

4.1 Prod State

This element contains five fuzzy variables as inputs and two fuzzy variables as outputs (Figure 6).

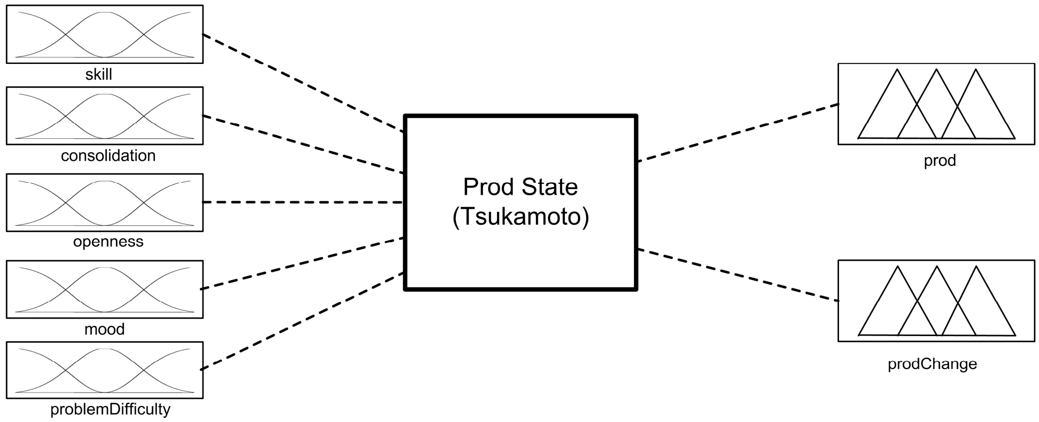

Figure 6: Fuzzy variables of the Prod State element

The inputs:

Skill, is the capability and experience of developers [5, 9] (Figure 7).

Consolidation, is the tendency to push toward the goals in the work and set high goals [17, 21, 23] (Figure 8).

Openness, is the tendency to new experience, a new way of doing things, and being intellectual [17, 21, 23]. Openness has a direct relation with problem solving [44] (Figure 9).

Problem Difficulty, is related to environment maturity and team capability [9]. The fuzzy values are obtained from [5, 9] (Figure 10).

Mood, (which will be discussed in the next section.)

The outputs:

Prod, is the productivity rate parameter of COCOMO II model [9, 10] (Figure 11). The MF was configured in the basis of Table 1.

ProdChange, adjusts the initial value of the prod at each cycle of simulation (Figure 12).

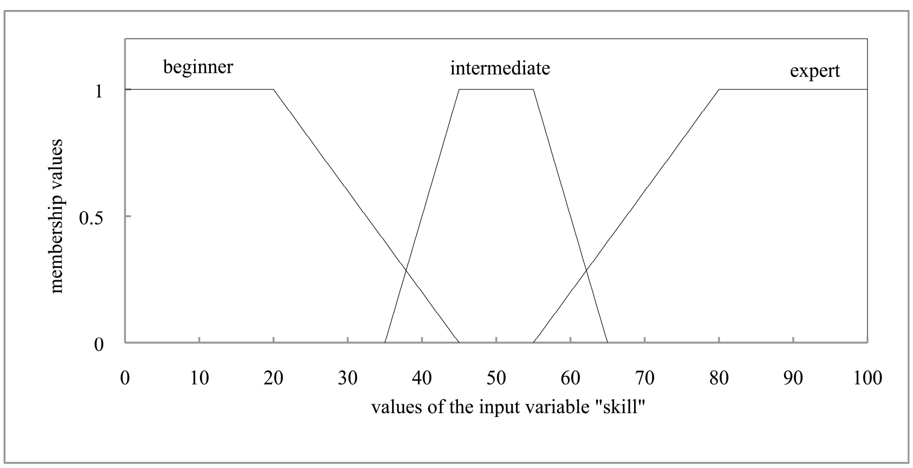

Figure 7: Fuzzy membership function of the skill

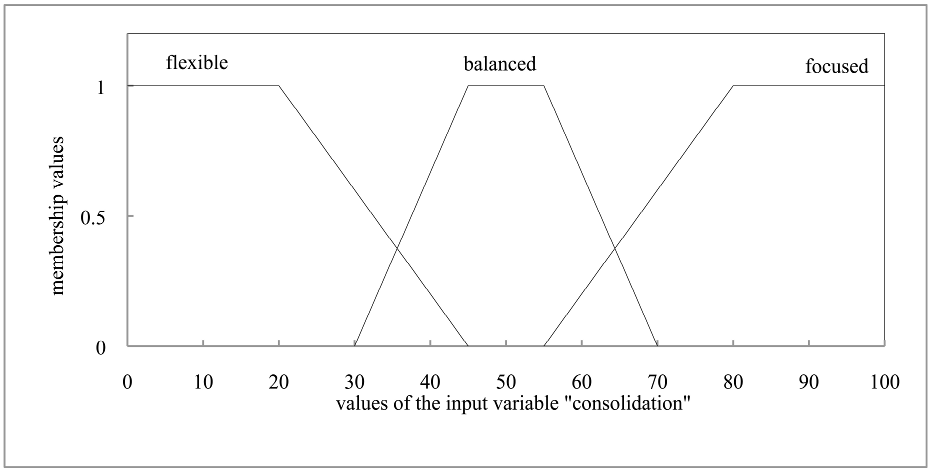

Figure 8: Fuzzy membership function of the consolidation

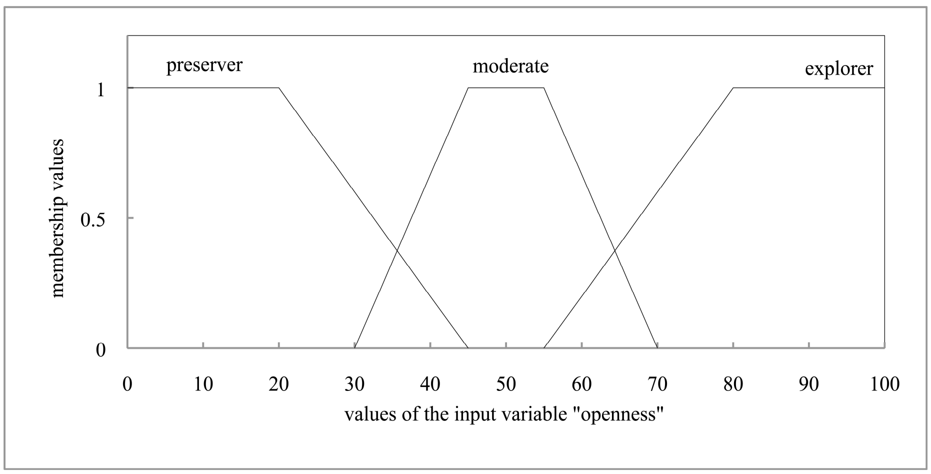

Figure 9: Fuzzy membership function of the openness

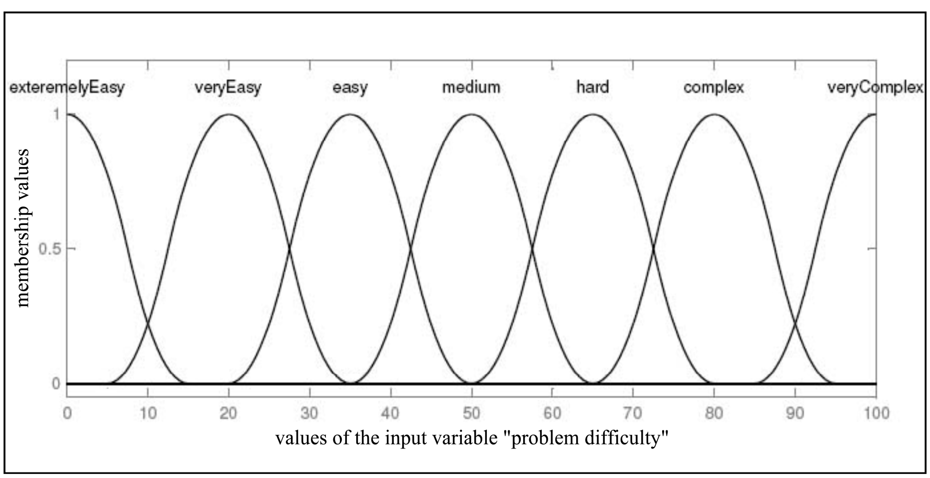

Figure 10: Fuzzy membership function of the problem difficulty

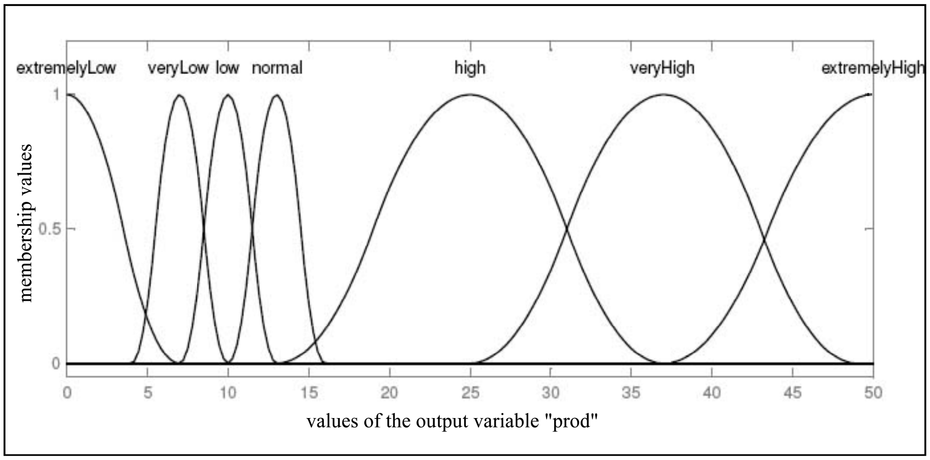

Figure 11: Fuzzy membership function of the prod

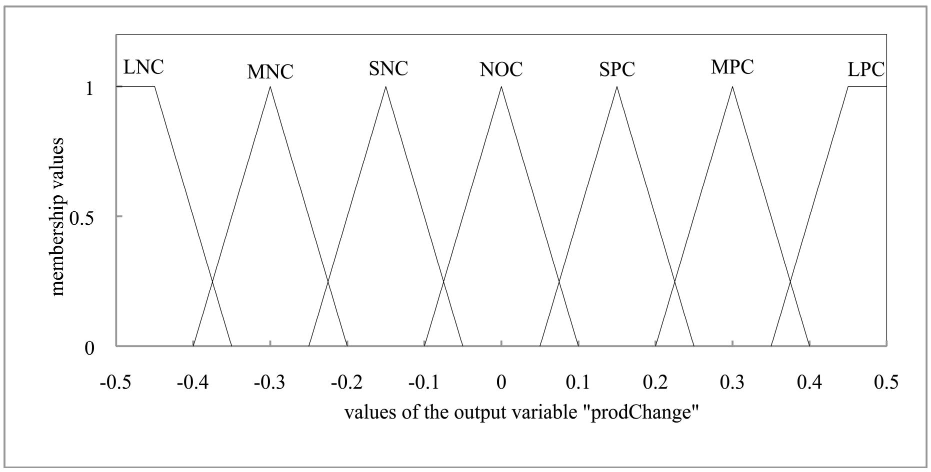

Figure 12: Fuzzy membership function of the prodChange

(L=Large, M=Medium, S=Small, P=Positive, N=Negative, C=Change, NOC=NOChange

i.e. LNC=Large Negative Change)

The problem difficulty is used to initiate prod value according to Table 2. This table contains seven rules to compute the initial prod. For example, the first row of the table is interpreted as follow:

IF	Problem Difficulty	IS	Extremely easy
THEN	Prod	IS	Extremely high

Table 2: Initial prod rules

Input	**Output**
Problem Difficulty	**Prod**
Extremely easy	Extremely high
Very easy	Very High
Easy	High
Medium	Normal
Hard	Low
Complex	Very low
Very complex	Extremely low

The initial prod of each TMA is adjusted by the prodChange variable. After each cycle of the simulation, the defuzzified value of the prodChange will be added to the previous value of its prod. The new value of the prod is sent to the SA by the “adjusted prod message”. The prodChange rules are shown in Table 3. This table contains nineteen rules for the computation of the value of prodChange in each cycle of the simulation. For example, the first row of the table is interpreted as follow:

IF	Skill	IS	Beginner
THEN	ProdChange	IS	Large Negative Change (LNC)

Table 3: The prodChange rules

Input	**Output**
Skill	**ProdChange**
Beginner	LNC
Intermediate	NOC
Expert	LPC
Consolidation	
Flexible	LNC
Balanced	NOC
Focused	LPC
Openness	
Preserver	LNC
Moderate	NOC
Explorer	LPC
Mood	
Bad	MNC
Neutral	NOC
Good	MPC
Problem Difficulty	
Extreme easy	LPC
Very easy	MPC
Easy	SPC
Medium	NOC
Hard	SNC
Complex	MNC
Very complex	LNC

4.2 Mood

This element contains four fuzzy variables as inputs and two fuzzy variables as outputs (Figure 13).

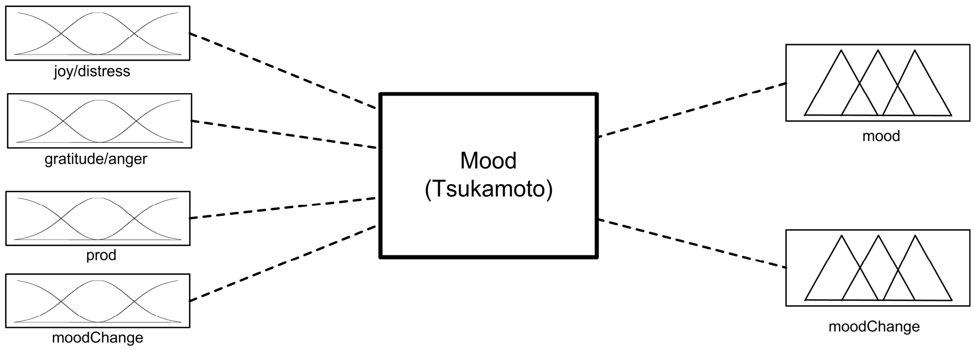

Figure 13: Fuzzy variables of the Mood element

The inputs:

Joy/Distress and Gratitude/Anger, are a pair of positive-negative emotions which affects the mood (Figure 14 and Figure 15).

Prod, (which was discussed in the former section.)

MoodChange, is the affect of other TMAs on the mood. It will be discussed in the next section.

The outputs are:

Mood, can be one-dimensional (good or bad mood) or multi-dimensional (feeling in love, feeling depressed)[45] (Figure 16). The one-dimensional mood has been considered in this study.

MoodChange, adjusts the initial value of mood at the end of each cycle of simulation (Figure 17).

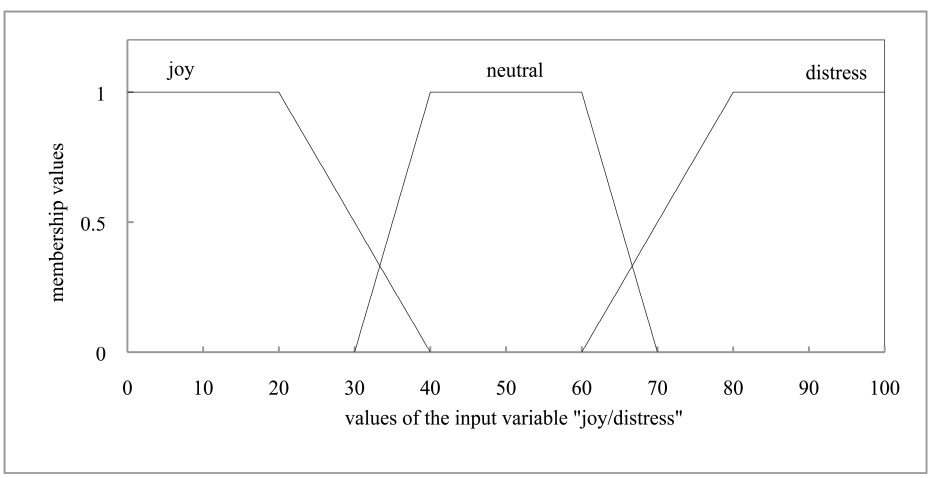

Figure 14: Fuzzy membership function of joy/distress

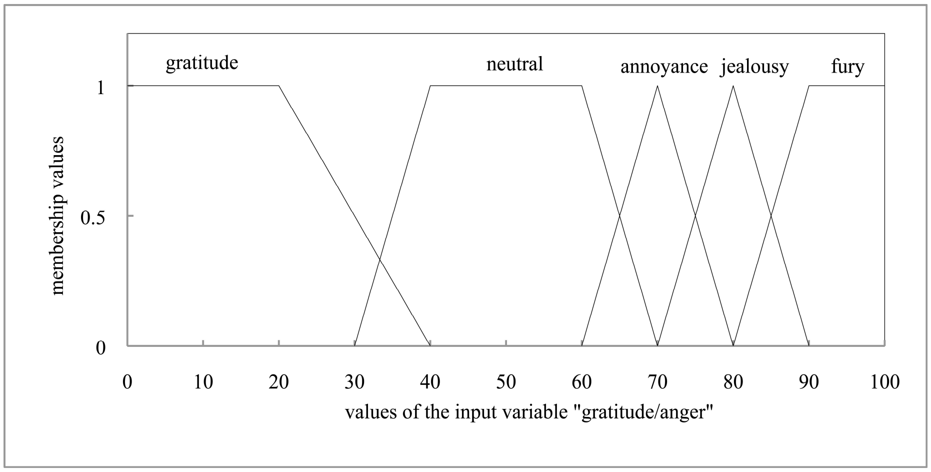

Figure 15: Fuzzy membership function of gratitude/anger
(The annoyance, jealousy, and fury are three values of anger [46])

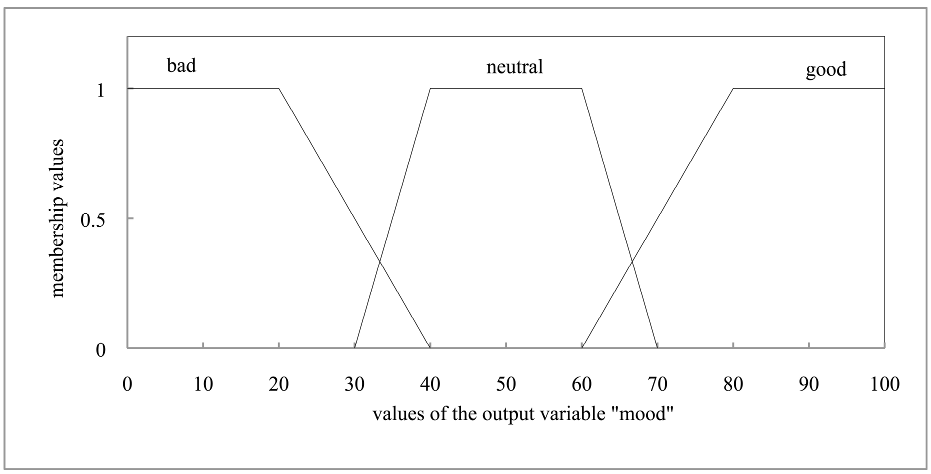

Figure 16: Fuzzy membership function of mood

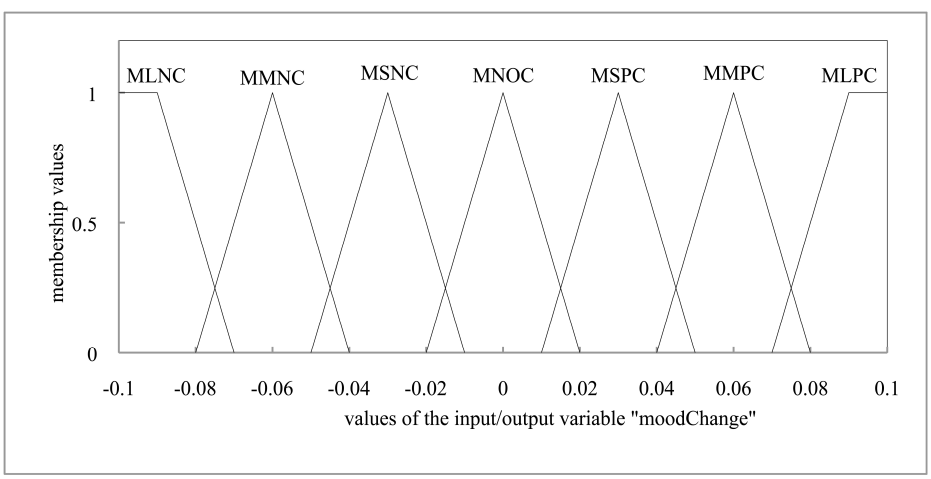

Figure 17: Fuzzy membership function of the moodChange
(The fuzzy value labels are similar to prodChange. The character 'M' at the first of the labels is acronym of mood. i.e. MLNC=Mood Large Negative Change)

Joy/distress and gratitude/anger are two pairs of emotions used to produce initial mood. These rules are shown in Table 4. The defuzzification of moodChange will be added by 50 (normal person) to produce the initial mood. This table contains eight rules to compute the initial value of moodChange at the start of the simulation. For example, the first row of the table is interpreted as follow:

IF	Joy/distress	IS	Distress
THEN	MoodChange	IS	Mood Medium Negative Change (MMNC)

Table 4: Initial mood rules

Input	**Output**
Joy/Distress	**MoodChange**
Distress	MMNC
Neutral	MNOC
Joyful	MMPC
Gratitude/Anger	
Gratitude	MMPC
Neutral	MNOC
Annoyance	MMNC
Jealousy	MMNC
Fury	MLNC

The initial mood is adjusted by the moodChange variable. After each cycle, the defuzzified value of moodChange will be added to the previous mood. The moodChange rules are shown in Table 5. This table contains seven rules to compute the value of moodChange in each cycle of the simulation. For example, the first row of the table is interpreted as follow:

IF	Prod	IS	Extremely low
THEN	MoodChange	IS	Mood Large Negative Change (MLNC)

Table 5: Mood Change Rules

Input	**Output**
prod	**MoodChange**
Extremely low	MLNC
Very low	MMNC
Low	MSNC
Normal	MNOC
High	MSPC
Very high	MMPC
Extremely high	MLPC

4.3 Sociality

This element contains three fuzzy variables as input and a fuzzy variable as output (Figure 18).

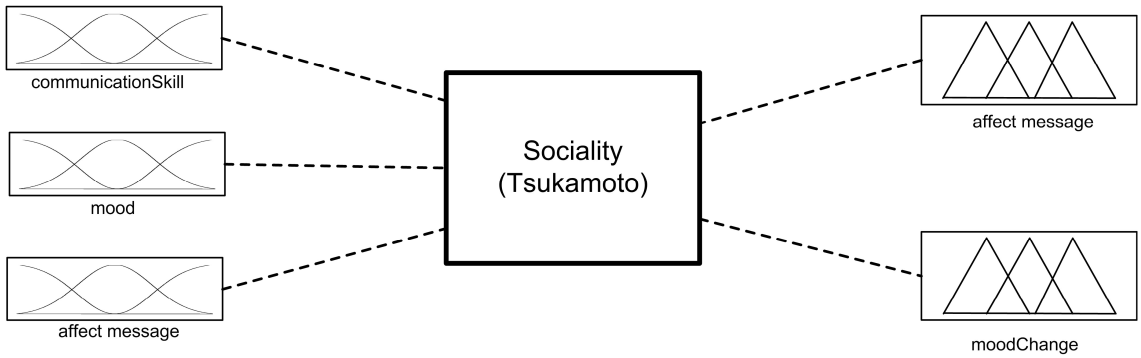

Figure 18: Fuzzy variables of the Sociality element

The inputs:

Communication skill, is a trait associated with sociability and sensory stimulation tolerance related to people and situations[21, 23]. The fuzzy values are obtained from [17] (Figure 19).

Mood, (which was discussed in the former section.)

Affect message, is the affect received from other TMAs (the teammates) which affects mood and the output (Figure 20).

The outputs are:

Affect message, is the affect to other TMAs (the teammates) on the basis of its internal state.

MoodChange, is the affect of the Sociality element on mood which was discussed in the former section.

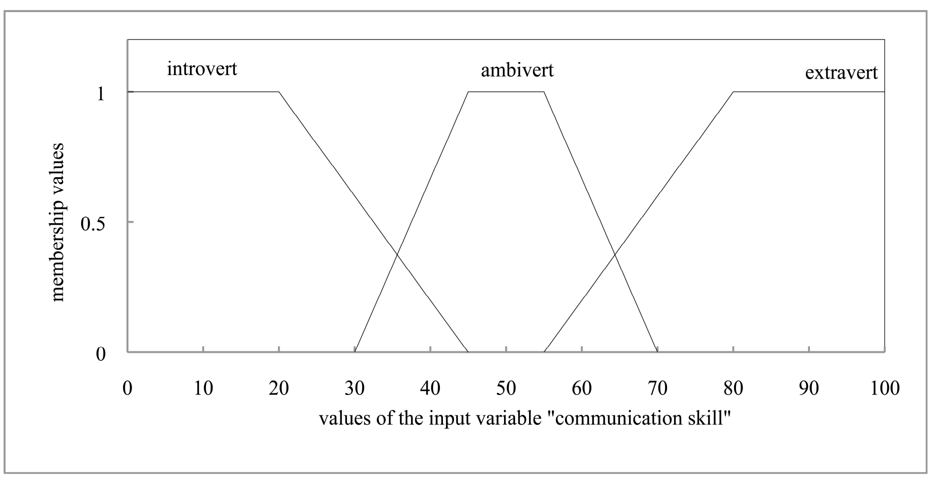

Figure 19: Fuzzy membership function of the communication skills

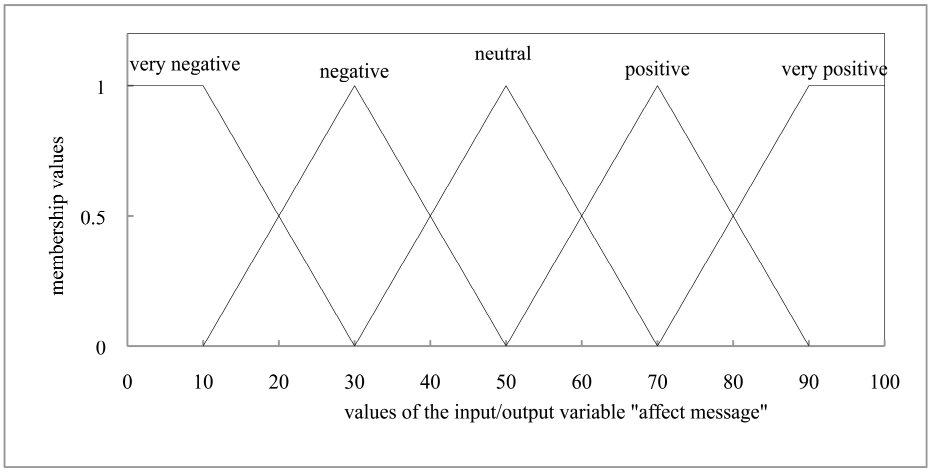

Figure 20: Fuzzy membership function of the affect message

As we discussed in Figure 5, the mood is affected by parameters of the Sociality element. The rules, which change mood, are shown in Table 6. This table contains fifteen rules to compute the value of moodChange in each cycle of the simulation. For example, the first row of the table is interpreted as follow:

IF	Communication Skills	IS	Introvert
AND	Affect Message	IS	Very negative
THEN	MoodChange	IS	Mood Medium Negative Change (MMNC)

Table 6: The mood change rules

Inputs		**Output**
Communication Skills	**Affect Message**	**Mood Change**
Introvert	Very Negative	MSNC
Introvert	Negative	MNOC
Introvert	Neutral	MNOC
Introvert	Positive	MNOC
Introvert	Very Positive	MSPC
Ambivert	Very Negative	MMNC
Ambivert	Negative	MSNC
Ambivert	Neutral	MNOC
Ambivert	Positive	MSPC
Ambivert	Very Positive	MMPC
Extravert	Very Negative	MLNC
Extravert	Negative	MMNC
Extravert	Neutral	MNOC
Extravert	Positive	MMPC
Extravert	Very Positive	MLPC

The communication skills and mood of the agents affect the mood of the other agents by an affect message. The affect message includes very positive, positive, neutral, negative and very negative values. The rules, which produce the agent affect message, are shown in Table 7. This table contains nine rules to compute the value of the affect message in each cycle of the simulation. For example, the first row of the table is interpreted as follow:

IF	Communication Skills	IS	Introvert
AND	Mood	IS	Good
THEN	Affect Message	IS	Neutral

Table 7: The affect message rules

Inputs		**Output**
Communication Skills	**Mood**	**Affect Message**
Introvert	Good	Neutral
Introvert	Neutral	Neutral
Introvert	Bad	Neutral
Ambivert	Good	Positive
Ambivert	Neutral	Neutral
Ambivert	Bad	Negative
Extravert	Good	Very Positive
Extravert	Neutral	Neutral
Extravert	Bad	Very Negative

5 FECSCE SIMULATOR

The FECSCE simulator uses FuzzyJ package [47] to implement the fuzzy inference system and JADE[1] [48] to implement the Multi Agent System (MAS). The developed software includes screens for team members' characteristics, project information, simulation results, and the team relationship graph. A sample screen shot of team members' characteristics is shown in Figure 21.

[1] Java Agent DEvelopment Framework (JADE) is a software framework for multi-agent systems. It complies with the FIPA specifications and uses FIPA-ACL communication language.

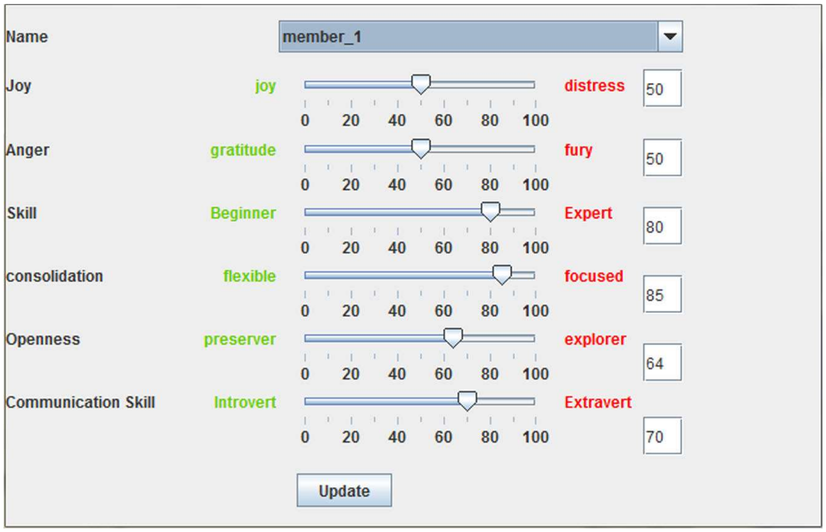

Figure 21: The "characteristics of team members" screen

(A range between 0 and 100 is considered for team members' characteristics)

Since teams' information in the standard COCOMO datasets [7, 9] is not available, we collected data of three teams from two different companies for the evaluation of this study. The team managers were asked about project information related to COCOMO II requirements (This information is indicated in Table 8) and the skill of team members. Other characteristics of team members, openness, consolidation, and communication skills, were extracted using the NEO PI-R questionnaire. The numerical value attributed to joy/distress and gratitude/anger has been considered to be 50 (which is attributed to a normal person). The information of the three projects is shown in Table 8. EPEDC is a MIS[1] for the Electronic Distribution Company; CRRS is a CRM[2] project for the Mobarakeh Steel Company; MECVX is a MIS project for the Seavolex Kala Company[3].

Table 8: The information of the three projects used in evaluation

Info. / Projects	Name	Screens			Reports			Reuse (%)	Difficulty
		Simple	Medium	Difficult	Simple	Medium	Difficult		
Project_1	EPEDC	60	25	66	25	15	46	10	56
Project_2	CRRS	9	25	14	20	55	25	15	41
Project_3	MECVX	300	130	160	49	150	50	10	55

A sample of project_1 team members' data is shown in Table 9 (The names of the members have not been disclosed).

[1] Management Information System

[2] Customer Relationship Management

[3] It provides a full range of commercial services including import, export, and the procurement of raw materials for steel plants and the distribution of steel products.

Table 9: Team members' data of project_1

(the range of values is between 0 and 100)

Member#	Joy/Anger	Gratitude/Anger	Skill	Consolidation	Openness	Communication skills
1	50	50	80	85	64	70
2	50	50	80	83	61	74
3	50	50	75	67	64	63
4	50	50	75	68	65	54
5	50	50	65	73	68	75
6	50	50	60	67	68	67
7	50	50	55	69	66	66
8	50	50	40	63	61	53
9	50	50	40	73	74	70

The simulation runs 500 cycles. After the simulation the person-month of COCOMO II, FECSCE are computed by SA. The person-month of the three projects is compared in Table 10. The FECSEC results are better than those of COCOMO II in all three projects. Team members' characteristics of project_1 (Table 9) and the difficulty of project_1 (fifty six) show that the project_1 team can do the project quicker than estimated by COCOMO II.

Table 10: The person-month of three projects

	COCOMO II	FECSCE	Actual
Project_1	59.4	57.2	55
Project_2	24.5	23.3	22.7
Project_3	169.6	160.5	162

At the end of the simulation, the diagrams of the prod and mood status of each team member are presented. These diagrams are very useful to understand how the FECSCE functions. Figure 22 shows the diagram and results of the project_1 simulation. The increasing/decreasing value of the prod/mood depends on team members' characteristics. The pattern for prod/mood change for competent members (with respect to the aforementioned characteristics) is seen as increasing (e.g. member_1), and for incompetent persons is seen as decreasing (e.g. member_7). The characteristics of the team members of project_1 are for the most part higher than average; hence, most value of the prods and the moods are increasing.

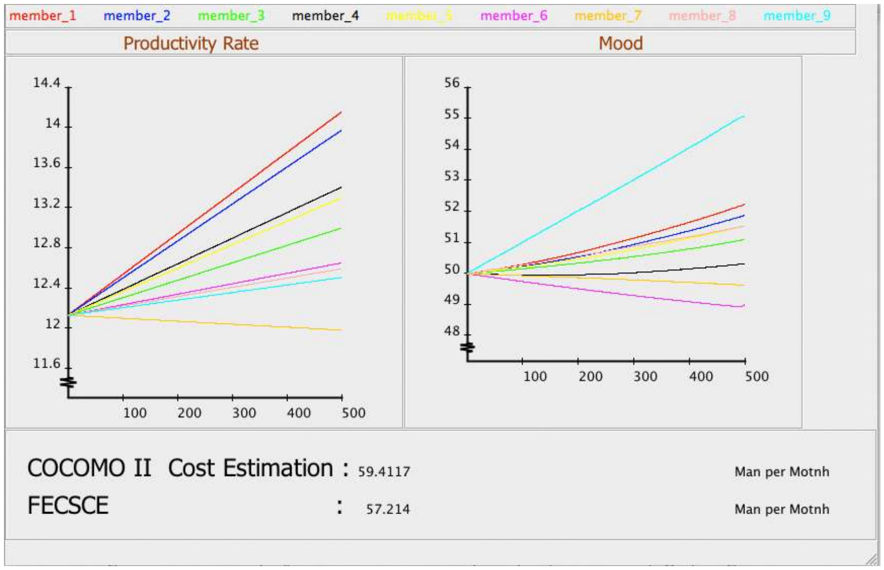

Figure 22: Result of project_1 simulation with prod (left) and mood (right) diagram

6 CONCLUSION

Accurate cost estimation is important for effective project management. Most of previous studies utilized fuzzy systems, Multi-Agent Systems and CMMI to improve cost estimation. One of the problems of the previous cost estimation studies is that they only considered project's characteristics not team members' characteristics. The FECSCE was discussed as a novel cost estimation model, which includes the team members' characteristics as another factor in project cost estimation. This novel model uses social characteristics, emotion and personality factors, and the capabilities of the team member in order to have a better simulation of a real team. There are two kinds of agent in FECSCE: "Team Member Agent" (TMA) and "Simulator Agent" (SA). TMA is a fuzzy agent for the simulation of a team member. A team can be simulated by Multi TMAs. Each TMA is characterized by six internal variables: skill, joy/distress, gratitude/anger, consolidation, openness, and communication skills. FECSCE structured these six variables in to three elements and utilized fuzzy systems in implementation of the elements. A Multi-Agent System has been used to simulate intra team communications. SA stores the "prod" of each TMA in each cycle of the simulation to aggregate them at the end of the simulation. The model was evaluated with three projects. The evaluation showed improvement of cost estimation.

In our future work, we aim to perform experiments on the other personality factors (agreeableness and neuroticism), other emotions of OCC, and other parameters of human modeling such as *culture* and *motivational state*s. Fixed values for emotions were considered in this study and they initialized the mood only without any affect during the simulation. Implementing a computational emotional model on the basis of OCC to compute the intensity of emotions with respect to the events and TMA's actions during the simulation is another work for future. In this study, the role of team members did not affect the computation. Roles only affect the direction of communications not the quality of the communications. Hence, the effect of the role assignment (i.e. Belbin model [49]) will be assessed in computations. The lack of data is one of the hindrances in our present work. We will be testing the FECSCE with more data in future.

In this study, project difficulty was considered without change during project execution time. When a project progresses, there are more developed CASE development tools which can be reused [50]; hence, the project difficulty may encounter change during the project progression. We want to consider this aspect also in future work.

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REFERENCES

[1] Z. Xu, T.M.Taghi, M. Khoshgoftaar, Identification of fuzzy models of software cost estimation Fuzzy Sets and Systems, 145 (2004) 141-163

[2] R. Dillibabu, K. Krishnaiah, Cost estimation of a software product using COCOMO II.2000 model – a case study, International Journal of Project Management, 23 (2004) 297-307

[3] X. Huang, D. Ho, J. Ren, L.F. Capretz, Improving the COCOMO model using a neuro-fuzzy approach, Applied Soft Computing, 7 (2007) 29-40.

[4] R. Gareis, Emotional Project Management, in: U. Darby (Ed.) PMI Research Conference, PA: Project Management Institute, Londen, 2004, pp. 1-7.

[5] J.M. Miranda, A. Aldea, Emotions in human and artificial intelligence, Computers in Human Behavior, 21 (2005) 323-341.

[6] J.M. Miranda, A. Aldea, R.B. Alcántara, Simulation of Work Teams Using a Multi-Agent System, in: The Second International Joint Conference on Autonomous Agents & Multi Agent Systems, Melbourne, Australia, 2003, pp. 1064-1065.

[7] B.W. Boehm, Software Engineering Economics, Prentice-Hall, Upper Saddle River, NJ, 1981.

[8] B.W. Boehm, Anchoring the Software Process, IEEE Software, 13 (1996) 73–82.

[9] B.W. Boehm, C. Abts, A.W. Brown, S. Chulani, B.K. Clark, E. Horowitz, R. Madachy, D.J. Reifer, B. Steece, Software Cost Estimation in COCOMO II, Prentice-Hall, Upper Saddle River, NJ, 2000.

[10] COCOMO II Model Definition Manual. Center for Software Engineering, University of Southern California 2000; Available from: http://sunset.usc.edu/research/COCOMOII.

[11] L.A. Zadeh, Fuzzy Sets, Information and Control, 8 (1965) 338-353.

[12] E.H. Mamdani, S. Assilian, An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller, International Journal of Man-Machine Studies, 7 (1975) 1-13.

[13] M. Sugeno, G.T. Kang, Structure Identification of Fuzzy Model, Fuzzy Sets and Systems, 28 (1988) 15-33.

[14] T. Takagi, M. Sugeno, Fuzzy Identification of Systems and its Application to Modeling and Control, IEEE Transactions on Systems, Man, and Cybernetics, 15 (1985) 116–132.

[15] Y. Tsukamoto, An Approach to Fuzzy Reasoning Method, in: M. Gupta, R. Ragade, R. Yager (Eds.) Advances in Fuzzy Set Theory, Hrsg, North-Holland, Amsterdam, 1979.

[16] P. Melin, O. Castillo, Type-1 Fuzzy Logic, in: Hybrid Intelligent Systems for Pattern Recognition Using Soft Computing, Springer-Verlag Berlin Heidelberg, 2005, pp. 7-32.

[17] N. Ghasem-Aghaee, T.I. Ören, Towards Fuzzy Agents with Dynamic Personality for Human Behavior Simulation, in: 2003 Summer Computer Simulation Conference, Montreal, PQ, Canada, 2003, pp. 3-10.

[18] E.J. Phares, Introduction to Psychology, 3rd ed., Harper Collins Publishers, New York, 1991.

[19] P.T. Costa, Jr., R.R. McCrae, Normal Personality Assessment in Clinical Practice: The NEO Personality Inventory, Psychological Assessment, 4 (1992) 5-13.

[20] M.R. Barrick, M.K. Mount, The Big Five Personality Dimensions and Job Performance: a Meta-Analysis, Personnel Psychology, 44 (1991) 1-26.

[21] P.J. Howard, J.M. Howard. An Introduction to the Five-Factor Model of Personality for Human Resource Professionals. 2004 [cited 2009, 15 March]; Available from: http://www.centacs.com/quickstart.htm.

[22] P.T.J. Costa, R.R. McCrae, Revised NEO Personality Inventory (NEO PI-R) and NEO Five-Factor Inventory (NEO-FFI): Professional Manual, Psychological Assessment Resources, Odessa, FL, 1992.

[23] T.I. Ören, N. Ghasem-Aghaee, Personality Representation Processable in Fuzzy Logic for Human Behavior Simulation, in: 2003 Summer Computer Simulation Conference, Montreal, PQ, Canada, 2003, pp. 11-18.

[24] S. Kshirsagar, N. Magnenat-Thalmann, A Multilayer Personality Model, in: 2nd International Symposium on Smart Graphics, ACM Press, 2002, pp. 107–115.

[25] J. Gratch, S. Marsella, A Domain-independent framework for modeling emotion, Cognitive Systems Research, 5 (2004) 269-306.

[26] A. Damasio, Descartes' Error: Emotion, Reason and the Human Brain, Picador, New York, 1994.

[27] J. Gratch, S. Marsella, P. Petta, Modeling the cognitive antecedents and consequences of emotion, Cognitive Systems Research, 10 (2009) 1-5.

[28] M. Kazemifard, N. Ghasem-Aghaee, T.I. Ören, An Event-based Implementation of Emotional Agents, in: Summer Simulation Conference, Calgary, Canada, 2006, pp. 63-67.

[29] A. Ortony, G.L. Clore, A. Collins, The Cognitive Structure of Emotions, Cambridge University Press, Cambridge, UK, 1988.

[30] M.A. Ahmeda, Z. Muzaffar, Handling imprecision and uncertainty in software development effort prediction: A type-2 fuzzy logic based framework, Information and Software Technology, 51 (2009) 640-654.

[31] C.S. Reddy, K. Raju, An Improved Fuzzy Approach for COCOMO's Effort Estimation using Gaussian Membership Function, Journal of software, 4 (2009) 452-459.

[32] C.S. Reddy, K. Raju, Improving the Accuracy of Effort Estimation through Fuzzy Set Representation of Size, Journal of Computer Science, 5 (2009) 451-455.

[33] I. Attarzadeh, S.H. Ow, Improving the Accuracy of Software Cost Estimation Model Based on a New Fuzzy Logic Model, 8 (2010) 177-184.

[34] K. Choi, D.-H. Bae, Dynamic project performance estimation by combining static estimation models with system dynamics, Information and Software Technology, 51 (2008) 162-172

[35] H. Al-Sakran, Software Cost Estimation Model Based on Integration of Multi-agent and Case-Based Reasoning, Journal of Computer Science, 2 (2006) 276-282.

[36] L. Ping, H. Yongtong, J. Bode, R. shouju, Multi-agent system for cost estimation, Computers & Industrial Engineering, 3 (1996) 731-735

[37] M.B. Chrissis, M. Konrad, S. Shrum, CMMI: guidelines for process integration and product improvement, Addison-Wesley, New York, 2003.

[38] M.A. Yahya, R. Ahmad, S. Lee, Impact of CMMI Based Software Process Maturity on COCOMO II's Effort Estimation, The International Arab Journal of Information Technology, 7 (2010) 129-138.

[39] C.S. Lee, M.H. Wang, J.J. Chen, Ontology-based intelligent decision support agent for CMMI project monitoring and control, International Journal of Approximate Reasoning, 48 (2008) 62-76

[40] M.A. Yahya, R. Ahmad, S.P. Lee, Effects of software process maturity on COCOMO II's effort estimation from CMMI perspective, in: International Conference on Research, Innovation and Vision for the Future, 2008. RIVF 2008. IEEE, Ho Chi Minh City, 2008, pp. 255-262.

[41] M.-H. Wang, C.-S. Lee, Z.-R. Yan, H.-H. Chuang, C.-F. Lo, Y.-C. Lin, A Novel Fuzzy CMMI Ontology and its Application to Project Estimation, Journal of Internet Technology, 9 (2008) 317-325.

[42] C.-S. Lee, M.-H. Wang, Ontology-based computational intelligent multi-agent and its application to CMMI assessment Applied Intelligence, 30 (2009) 203-219.

[43] C.-S. Lee, M.-H. Wang, Z.-R. Yan, C.-F. Lo, H.-H. Chuang, Y.-C. Lin, Intelligent estimation agent based on CMMI ontology for project planning, in: IEEE International Conference on Systems, Man and Cybernetics, 2008. SMC 2008 Singapore, 2008, pp. 228-233.

[44] N. Ghasem-Aghaee, T.I. Ören, Cognitive complexity and dynamic personality in agent simulation, Computers in Human Behavior, 23 (2007) 2983-2997.

[45] A. Egges, S. Kshirsagar, Generic Personality and Emotion Simulation for Conversational Agents, Computer Animation and Virtual Worlds, 15 (2004) 1-13.

[46] N. Ghasem-Aghaee, L. PoorMohamadBagher, M. Kaedi, T.I. Ören, Anger filter in agent simulation of human behavior, in: the 18th IASTED International Conference: modelling and simulation ACTA Press Montreal, Canada, 2007, pp. 44 - 46

[47] FuzzyJ ToolKit [cited 2010, June 20]; Available from: http://www.iit.nrc.ca/IR_public/fuzzy/fuzzyJToolkit2.html.

[48] Java Agent Development Framwork. [cited 2010, June 20]; Available from: http://jade.tilab.com/.

[49] R. Belbin, Team Roles at Work, Oxford, Butterworth-Heinemann, 1983.

[50] R. Banker, R. Kauffman, R. Kumar, An Empirical Test of Object-Based Output Measurement Metrics in a Computer Aided Software Engineering (CASE) Environment, Journal of Management Information Systems, 8 (1994) 127-150.