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FUZZY BASED EVALUATION FOR AGENT ORIENTED MODELING TOOLS

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ABSTRACT

The importance of agent oriented system is expected to be more significant with the emergence of Industry 4.0. As the agent oriented system becomes more complex, the task of system architecture design would be more complicated and the modeling tools play an important role at that stage. To date, a great number of agent modeling tools have been introduced but to choose the best tool for different features and functions is also difficult. This paper summarizes some important criteria of an agent oriented modeling tooland introduces fuzzy based evaluation to rank the three popular tools of agent oriented modeling. The fuzzy based evaluation technique is able to objectivelyrank the available modeling tools based on specified criteria.

Keywords: agent oriented system; modeling; fuzzy ranking; evaluation.

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1. INTRODUCTION

Object-oriented systems have been around for more than a decade and recently agent paradigms have become increasingly popular [1-2]. Some of the reasons for the popularity of agents-oriented system are their flexibility, modularity and general capability to a very wide range of problems. Nowadays, a vast range of agent-oriented methodologies is available for agent-based systems designers as for examplesMaSE[3], Gaia[4]and Tropos[5].These agent-oriented methodologies provide rules and standard for the implementation of multi-agent systems through a set of phases.

Employment of those agent-oriented methodologies is dependent on the type of applications and designer needs. Designers need to consider many aspects supported by the methodologies especially in terms of agent-oriented attributes. Therefore, some research has been carried to evaluate the agent-oriented methodologies. Nevertheless, the evaluations were mostly based on qualitative perception only. We believe that to show the superiority criteria of an agent-oriented modeling, quantitative measurements on the qualitative criteria should be implemented.

The objective of this paper is two-fold. The first objective is to describe the criteria or requirement metrics of an agent-oriented in a distributed system. The second objective is to evaluate an agent-oriented methodology with quantitative measurement by using fuzzy technique.This information may help the agent-oriented system designer in selecting the most appropriate agent-oriented modeling technique.

2. BACKGROUND OF THE STUDY

Due to the complexity of software development process, various types of software engineering paradigms have been introduced. Started from procedural and structured programming in many years, object-oriented paradigm then gradually faces over, and recently, agent based system development has become so much popular. The agent-orientation seems to be a potentially powerful new paradigm in programming and system development [6-7].

An agent in agent-based system is sometimes called as software agent or intelligent agent. In agent-based system, it is normally utilizing various type of software agent with each one has different function and characteristic. These agents are referred as multi-agents with certain level of capabilities like communicating and negotiating each other. As reported in [5], the word intelligent was used to agents because it can have certain types of behavior ("Intelligent behavior is the selection of actions based on knowledge") and the term agent is about the act of it in representing others like human. On the other hand, multi-agents system consists of a collection of agents, act on behalf of human (users), do a certain tasks based on users preferences, automatically when it is activated. Once it is activated, it will run the tasks in no matters time although users are not connected to the system. Then, after completing and achieving goals, agents will come back to the end system at users' site and provide the desired results or reports needed by users. So, to perform these operations, the common classification scheme of agents can be autonomy, social ability, reactivity, pro-activity, mobility and rationality [8].

2.1. Agent Oriented Methodologies

In recent years, more and more effort has been made to propose and provide methodologies for the development of agent-based systems. There is awareness among agent based system developer to follow certain agent based system development methodology as to realize high quality agent systems[8]. A methodology provides guidance through the life cycle process, a set of predefined techniques and allows modeling process from the suitable notation. Those elements comprised from each methodology would be different suitability for certain type of agent based system. There are some criterions and sub criterions needed for consideration when choosing the right methodology for agent based system development in specific application domain. It is sometime difficult for developer to decide which one to use. In next section of this report, we will briefly describe the specifications of three commons agent based methodology namely as MaSE, Gaia and Tropos.

2.2. Multi-agent Systems Engineering Methodology (MaSE)

MaSE has been introduced by [3]. The MaSE methodology are divided into seven phases in the system development life cycle as in the following:

a. The first phase in MaSE is capturing goal involved the transformation of initial system specification into a structured hierarchy of system goal.
b. The second phase is applying use cases that creates use cases and sequence diagrams suit to the system specification. In the use cases, the logical interaction path between various agent

roles used in system will be identified while the sequence diagram can be used to determine the number of minimum number of messages among agent roles in the system.

c. During the refining roles, the tasks or role for each goal defined in the first phase will be determined. All roles together will have its own set of tasks which are represented in state diagram.

d. The fourth phase, creating agent classes, produced an agent class diagram. Agent class diagram resemble object class diagram, but the relationship semantic is high level communication as opposite to the object class diagrams. In object class diagrams, the inheritance of structure can be clearly represented.

e. Constructing conversation in the fifth phase involved the defining of coordination protocol in the form of state diagrams. The conversation state of interacting agents can be illustrated in the state diagrams.

f. In the sixth phase, the internal functionality of agent classes will be created. This phase is called is assembling agent classes.

g. The final phase, system design is to develop agent instances based on agent classes. Deployment diagram can be used to represent the overall architecture of the system design.

2.3. Gaia

The Gaia methodology has been introduced by [4], which applied the terminology and notations from the object-oriented analysis and design. Gaia supports micro level (agent structure) and macro level (agent society and organization structure) of agent's development. The all five phases of system development life cycle are supported in Gaia methodology. During the first or analysis phase, the roles in the system will be identified. Then, the model interaction between roles will be created in the second phase. Roles in Gaia can have four attributes namely as responsibilities, permissions, activities and protocols. Gaia has formal operators and templates for representing roles and their belonging attributes. Furthermore, there is schemas can be used for representing roles interaction. The third phase involved design process which initially map roles into agent types and then create the right number of agent instances. The next phase is to determine the service model that representing the entire services requirement in one or several agents. The last phase in Gaia is acquaintance model that can be used to represent the communication scenario between agents.

2.4. Tropos

Tropos [5] provide concepts of actors, goals, model social structures in dependencies intended. The relationship between these elements can be described in detailed including its societal communication and corporation.

The phases involved in Tropos consist of four steps. The first step is the early requirements analysis for identifying basic stakeholders. During the analysis phase which is the second phase, potential actors in system will be analyzed. Dependency analysis plays an important role in the analysis phase. The operational and functional aspects of each potential actor will be then identified in the third phase. In the fourth phase, detailed illustration of actor role and functions will be developed in more explicit scenarios of agents.

2.5. Evaluation of Agent Oriented Methodologies

An increasing number of methodologies and modeling methods are being proposed in the area of agent-oriented software engineering. However, depending to the applications domain and developers' needs, not all agent-oriented modeling uses every aspects or characteristics requirement as an agent-based system. To overcome this problem, some research has been carried out to perform evaluation on agent-oriented modeling techniques. Nevertheless, the evaluations were mostly based on qualitative perception only. We believe that in order to show the superiority of an agent-oriented modeling criteria, quantitative measurements on qualitative evaluation should be considered as done by researchers in [9-10].

2.6. The Concept of Fuzzy Numbers

The concepts of fuzzy sets have been introduced by [11]. It is very suitable to solve any problem that are related with imprecise linguistic. In this research, we use the following definitions of fuzzy numbers.

Definition 1:

A fuzzy subset in the universe of discourse X that is both convex and normal. Here, "Normal" implies that $\exists x \in R, \vee_x \mu_{\bar{A}}(x) = 1$ and "Convex" means that $\forall x_1 \in \mathrm{X}, x_2 \in \mathrm{X}, \forall \propto \in [0,1]$

$\mu_{\bar{\mathrm{A}}}(\propto x_1 \div (1-\propto)x_2) \geq \min \left(\mu_{\bar{\mathrm{A}}}(x_1), \mu\overline{\mathrm{A}}(x_2)\right)$[11].

Definition 2:

A trapezoidal fuzzy number A of the universe of discourse X can be characterized by a trapezoidal membership function parameterized by a quadruple (a, b, c, d) as shown in Fig. 1 where a, b, c and d are real values[12].

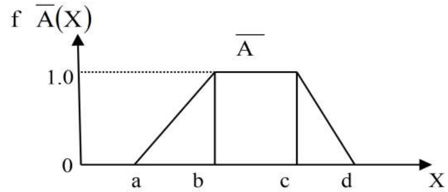

Fig.1. A triangular fuzzy number

In Fig. 1, if b=c, then $\bar{A}$ becomes a triangular fuzzy number and it parameter can be a triplet (a,b,d).

Definition 3:

The fuzzy number arithmetic operations [11-12] between two triangular fuzzy numbers $\bar{A}_1$ and $\bar{A}_2$ are as follows:

Fuzzy number Addition $\oplus$:

$(a_1,b_1,c_1) \oplus (a_1,b_2,c_2) = (a_1+ a_1, b_1 + b_2, c_1+c_2)$

Fuzzy number Multiplication $\otimes$:

$(a_1,b_1,c_1) \otimes (a_1,b_2,c_2) = (a_1 * a_1, b_1 * b_2, c_1 * c_2)$

Fuzzy number Division $\div$

$(a_1,b_1,c_1) \div (a_1,b_2,c_2) = (a_1/ a_1, b_1/ b_2, c_1 /c_2)$

Definition 4:

According to [13]for ranking fuzzy numbers, the ranking value Rank($\bar{A}$) of a generalized trapezoidal fuzzy number $\bar{A}$, $\bar{A}$=(a_1,a_2,a_3, a_4) can be calculated as follow:

$$\text{Rank}(\bar{A}) = x^*_{\bar{A}} + (1 - y^*_{\bar{A}})^{S_{\bar{A}}}$$

$$x^* = \frac{y^*_{\bar{A}}((a_3 + a_2) + (a_4 + a_1)(1 - y^*_{\bar{A}})}{2}$$

$$S_{\bar{A}} = \sqrt{\frac{\sum_{i=1}^{4}(a_i - \bar{a})}{3}}$$

$$y^{*}_{\bar{A}} = \begin{cases} \dfrac{1 \text{ x } \left[\dfrac{a_3 - a_2}{a_4 - a_1} + 2\right]}{} , & if\ a_1 \neq a_4 \\ \dfrac{1}{2} , & if\ a_1 = a_4 \end{cases}$$

where $\bar{a} = \dfrac{a_1 + a_2 + a_3 + a_4}{4}$

The ranking of $\bar{A}q$ would be better if it has larger value than the ranking of $\bar{A}_p$, q and p are the index of fuzzy number.

3. EVALUATION FRAMEWORK

In this part, we will explain the evaluation framework used for evaluating agent oriented modeling tools quantitatively as in the following.

3.1. Questionnaire Development

In the questionnaire, the evaluators have been explained about the criterion and sub-criterion that need to be evaluated. Table 1 lists all the criterion and sub-criterion used in this evaluation.

Table 1. The criterion for appraising the performance of agent oriented modeling tools

Criteria	Sub-Criteria	Contents
	X_{11}	Autonomy
	X_{12}	Mental attitudes
X_1	X_{13}	Proactive
(Concept and	X_{14}	Reactive
Properties)	X_{15}	Concurrency
	X_{16}	Teamwork
	X_{17}	Protocols
X_2	X_{21}	Static + Dynamic
(Notation and	X_{22}	Syntax defined
Modeling)	X_{23}	Semantics defined
	X_{24}	Expressiveness
	X_{25}	Traceability
X_3	X_{31}	Life-cycle coverage
(Process)	X_{32}	Specification
	X_{33}	Architecture design
	X_{34}	Deployment
X_4	X_{41}	Tools available
(Pragmatics)	X_{42}	Expertise requirement
	X_{43}	Domain applicability
	X_{44}	Scalability

These set of criteria was developed from the generalization of evaluation framework proposed by [10, 14-15]. In this evaluation framework, two sets of fuzzy linguistic questionnaires have been developed that comprising the important levels of each criteria as presented in Fig. 2 and the satisfaction level of evaluators to the sub-criterion as presented in Fig. 3.

Fuzzy Linguistic Questionnaire				
Important Levels of the Criterion Xi				
Low ←				→ High
VL	L	M	H	VH

Fig.2. A fuzzy linguistic questionnaire for appraising the performance of a modeling tool

Fuzzy Linguistic Questionnaire				
Satisfaction Levels of the Sub Criterion Xij				
Low ←				→ High
VL	L	M	H	VH

Fig.3.A fuzzy linguistic questionnaire for determining the weight of the criterion

The questionnaires were distributed to three evaluators who involved in the design phase of the agent based system used to develop an automated marking system.During the design phase, they were required to explore the three agent methodologies namely as Gaia, Tropos and MasE.

3.2. Calculate Fuzzy Weight

The fuzzy weight of the criterion (x_i) Xi is calculated with the followingformula:

$$W(\overrightarrow{X_i}) = \frac{\sum_{k=1}^{5} \overrightarrow{(X_{ik})} \overrightarrow{f(X_{ik})}}{\sum_{k=1}^{5} \overrightarrow{f(X_{ik})}}$$

where i denotes the index of the criterion, k denotes the index of linguistic levels, $\overrightarrow{(X_{ik})}$ denotes the kth linguistic important level of the criterion Xi, $1 \le k \le 5$, $\overrightarrow{f(X_{ik})}$ denotes the degree of percentage that the criterion Xi satisfies the kth important level and $\sum_{k=1}^{5} \overrightarrow{f(X_{ik})} = 1$ as given in [13].As for example, some of the results after the three evaluators full filled questionnaire is shown in Table 2.

Table 2. The result of the fuzzy linguistic questionnaires for Gaia methodology

Criteria	Evaluator 1					Evaluator 2					Evaluator 3				
	VL	L	M	H	VH	VL	L	M	H	VH	VL	L	M	H	VH
X_1			20	70	10			10	70	20			20	80	
X_2				80	20			5	85	10			20	70	10
X_3		20	80					20	80				45	55	
X_4			30	50	20			40	40	20			10	75	15

Then, the fuzzy weight for each criterion was calculated by using the above formula as shown in the following Table 3.

Table 3. The fuzzy weight of each criterion evaluated by each evaluator

Criteria	Evaluator 1	Evaluator 2	Evaluator 3
X_1	(2.9,3.9,4.9)	(3.1,4.1,5)	(2.8,3.8,4.8)
X_2	(3.2,4.2,5)	(3.05,4.05,5)	(2.9,3.9,4.9)
X_3	(1.8,2.8,3.8)	(1.8,2.8,3.8)	(2.55,3.55,4.55)
X_4	(2.9,3.9,4.9)	(2.8,3.8,4.8)	(3.05,4.05,5)

Finally, the fuzzy weighted vectorw_x,can be calculated at each criterion. We first drop the fuzzy weights of each criteria with the smallest ranking value and the largest ranking value, then calculate the average of the remaining fuzzy weights using the addition and division operations of fuzzy numbers. Therefore, the fuzzy weighted vector for each criterion is as in Table 4.

Table 4. The fuzzy weighted vector

Criteria	Fuzzy Weighted Vector
w_1	(2.9,3.9,4.9)
w_2	(2.8,3.8,4.8)
w_3	(1.8,2.8,3.8)
w_4	(2.8,3.8,4.8)

3.3. Calculate Fuzzy Grade

Data from the questionnaires in Fig. 2 and Fig. 3 will be used to establish the fuzzy grade matrix. Then, the fuzzy grade $G\overrightarrow{(X_{ijk})}$of sub-criterion $X_{ij}$is calculated as the following equation

$$G\overrightarrow{(X_{ijk})} = \frac{\sum_{k=1}^{5}\overrightarrow{(X_{ik})}\overrightarrow{f(X_{ijk})}}{\sum_{k=1}^{5}\overrightarrow{f(X_{ikj})}}$$

where i denotes the index of the criterion, j denotes the index of sub-criterion, k is index of linguistic levels, $\overrightarrow{(X_{ijk})}$ denotes the kth linguistic important level of the criterion Xij, 1≤k≤5, $\overrightarrow{f(X_{ijk})}$ denotes the degree of percentage that the evaluator satisfies the kth satisfaction level of the sub-criterion Xijkand $\sum_{k=1}^{5}\overrightarrow{f(X_{ijk})} = 1$as given in[13].

The average fuzzy grade for each evaluator came from the calculation steps as in finding average fuzzy weight. It is essential to drop the minimum and maximum fuzzy grade and perform addition and division fuzzy operations to the rest of fuzzy grade in each criterion. For example, the average fuzzy grades as in Table 4.

Table 4. The average fuzzy grade

Criteria	Sub-Criterion	MaSE	Gaia	Tropos
X_1	X_{11}	(2.33,3.33,4.33)	(2.23,3.23,4.23)	(2.2,3.2,4.2)
	X_{12}	(2.83,3.83,4.83)	(2.63,2.83,4.33)	(2.51,3.51,4.46)
	X_{13}	(2.23,3.23,4.23)	(2.3,3.3,4.3)	(3.06,4.06,4.8)
	X_{14}	(2.65,3.65,4.65)	(2.53,3.63,4.5)	(2.67,3.67,4.67)
	X_{15}	(2.46,3.46,4.46)	(1.87,2.87,3.87)	(2.02,3.02,4.02)
	X_{16}	(1.62,2.62,3.62)	(2.23,3.23,4.23)	(2.55,3.55,4.55)
	X_{17}	(2.42,3.42,4.33)	(1.88,2.88,3.88)	(1.67,2.67,3.67)
X_2	X_{21}	(3.03,4.03,4.82)	(2.48,3.48,4.48)	(3.75,4.75,5.75)
	X_{22}	(1.75,2.75,3.75)	(2.28,3.28,4.28)	(2.58,3.58,4.58)
	X_{23}	(2.73,3.73,4.73)	(2.78,3.78,4.72)	(2.32,3.32,4.27)
	X_{24}	(2.23,3.23,4.23)	(2.41,3.41,4.41)	(2.4,3.4,4.4)
	X_{25}	(2.17,3.17,4.17)	(2.1,3.1,4.1)	(2.03,3.03,4.03)
X_3	X_{31}	(2.61,3.61,4.61)	(2.95,3.95,4.9)	(2.36,3.36,4.36)
	X_{32}	(2.0,2.7,3.7)	(1.98,2.98,3.98)	(1.8,2.8,3.8)
	X_{33}	(2.33,3.33,4.33)	(2.42,3.42,4.42)	(2.27,3.27,4.27)
	X_{34}	(2.43,3.43,4.42)	(2.23,3.63,4.43)	(2.58,3.58,4.47)
X_4	X_{41}	(2.75,3.75,4.75)	(2.8,3.8,4.8)	(2.78,3.78,4.75)
	X_{42}	(2.41,3.41,4.41)	(2.47,3.47,4.47)	(2.4,3.4,4.4)
	X_{43}	(2.58,3.58,4.58)	(2.57,3.57,4.57)	(2.35,3.47,4.43)
	X_{44}	(2.76,3.76,4.76)	(2.67,3.67,4.67)	(2.73,3.73,4.6)

Then, we develop fuzzy grade matrix as presented in Fig. 4.

3.4. Calculate Total Fuzzy Grade Vector

The calculation of total fuzzy grade vector has been done through addition and multiplication process between fuzzy grade matrix and fuzzy weight.Result of calculation for the total fuzzy grade vector is given as in the following Fig. 5.

:

$$\tilde{G} = \begin{pmatrix} \tilde{A}_1 \\ \tilde{A}_2 \\ \tilde{A}_3 \end{pmatrix} = \begin{pmatrix} & X_1 & X_2 & X_3 & X_4 \\ & (2.42,3/42,4.4) & (2.34,3.38,4,38) & (2.38,3.38,4,38) & (2.67,3.67,4.7) \\ & (2.23,3.09,4.19) & (2.39,3.39,4.39) & (2.33,3.53,4.93) & (2.62,3,62,4.62) \\ & (2.39,3.39,4.38) & (2.43,3.43,4.42) & (2.32,3.32,4.32) & (2.57,3.57,4.5) \end{pmatrix}$$

Fig.4. fuzzy grade matrix

$$\tilde{R} = \begin{pmatrix} \tilde{A}_1 \\ \tilde{A}_2 \\ \tilde{A}_3 \end{pmatrix} = \begin{pmatrix} (24.67, 48.70\ 80.48) \\ (24.24, 47.43, 81.55) \\ (25.11,49.12, 80.75) \end{pmatrix}$$

Fig.5. Total fuzzy grade vector

3.5.Calculate Ranking Values

The reason for calculating ranking values is to get overall overview of each methodology ranking as shown in Table 5.

Table 5. Ranking for each agent oriented methodology

Total Fuzzy Grade	X*	Y*	Ranking value	Rank
Gaia	51.28400	0.3333	51.28400	2
Tropos	51.07567	0.3333	51.07567	3
MaSE	51.65967	0.3333	51.65967	1

Although the ranking formula introduced by Chen-and Chen's considering Y* and S value, in this evaluation, we have ignored the two values since the (1-Y*)S value is too small to be considered and will not affect so much different to the X* value. So, the ranking value used in this evaluation is directly came from the X*.Furthermore, the ranking criteria for each methodology is presented in Table 6.

Table 6. Ranking of criteria for each methodology

M	Properties		Notation		Process Flow		Pragmatic	
	RV	Rank	RV	Rank	RV	Rank	RV	Rank
MaSE	4.9452	1	4.7363	2	4.9234	1	4.6521	1
Gaia	4.8176	2	4.6213	3	4.6122	3	4.4534	3
Tropos	4.5134	3	4.9213	1	4. 8735	2	4.6213	2

*M=Methodology, RV=Ranking value

In general, the first rank was derived to MaSE followed with Tropos and Gaia. The MaSE got the first rank in term of properties, process flow and pragmatic but second rank for the notation criterion. However, Troposachieved the third rank for the property and was evaluated better than MaSE in term of the notation. The process flow and pragmatic criteria for Tropos are measured moderately in between MaSE and Gaia.

4. CONCLUSION

This paper attempts to describe the most important criteria of agent oriented modeling [16] tools namely properties, notation, process flow and pragmatic. The criteria then were evaluated qualitatively by a set of questionnaires form. From the input given by users, the qualitative data then were transform to quantitative measurement with fuzzy [17] technique. This is to get the general ranking of the modeling tools and the specific ranking of each criterion provided by the selected tool.

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