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Functionality of Negotiation Agent on Value-based Design Decision

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***Abstract*—**This paper presents functionality of negotiation agent on value-based design decision. The functionality is based on the characteristics of the system and goal specification. A Prometheus Design Tool model was used for developing the system. Group functionality will be the attribute for negotiation agents, which comprises a coordinator agent and decision- maker agent. The results of the testing of the system to a building system selection on value-based decision environment are also presented.

***Keywords*—**Functionality, negotiation agent, value-based decision

I. INTRODUCTION

FRAGMENTATION is one of the major problems in construction [1]. Often geographically distributed, different project participants need to collaborate and negotiate to perform various activities [2]. Collaboration needs negotiation especially in conflict resolution and decision making [3], [4]. Agent negotiation Multi-Agent Systems (MAS) is useful for negotiation process. A key benefit for the application of MAS in value-based decision is that MAS provides a decentralized approach to model fragmented construction decision problems. One example application is in the field of design decision management using a value analysis tool. As a process of multi disciplines and teamwork, negotiation becomes an important role in the process of value-based decision.

The negotiation support for value-based decision is a very complicated system. Agent-based methods can significantly contribute to the efficiency of system. In this system, a negotiation consists of an exchange of proposals between agents. The greater the number of people involved in the hierarchy construction, the greater is the range of the ideas. Computer-mediated work increases the comprehension, the readability and, the objectivity of the decision-making. This system provides additional functionality to negotiate a joint representation of the problem. This paper aims to investigate the functionality of negotiation agent on value based-decision based on the characteristics of the specification. A testing of the system on a building system selection is also presented.

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II. THEORETICAL BACKGROUND

A. Value-Based Decision

Kirk et al [5] describes value-based approach as new approach and methodology that involves using a multidisciplinary team including representatives of the owner, user, facility manager, and constructor. Thomas and Thomas [6] and Kelly [7] wrote that value analysis is an integrated full team approach. In the natural characteristic of construction, it means that a tool for decision team is necessary. Negotiation will be appropriate for that aims.

Value analysis identifies the criteria for decision. Each criterion then needs to be weighted according to its importance to purpose. Clemen [8] argued that decision analysis techniques can then be applied to determine the relative value of the alternative solutions for performing the function. Weighting and scoring technique are relevant in value analyses exercise [9], [10] where a decision needs to be made in selecting an option. A paired comparison is held to determine the weighing to be given to each attribute [11]. Many studies in value-based decision apply multi criteria decision making, such as Al-Hammad and Hassanain [12] in assessment of exterior building wall, Qingan et al [13] in material design of concrete and Fisher [14] in a modification of value engineering in petrochemical industry. There have been two types of approaches to computerizing decision in value-based decision process. They consist of database, knowledge based system, expert system and internet-based computer application.

B. Negotiation Agent

Agents can be understood as an incremental extension of previous software technologies. Agents can be applied to filter data, interpret information, decision support provider , etc. There are various applications of agent technologies reported in many engineering fields in recent years. Negotiation is the interactive communication among agents to facilitate a distributed search process. It can be used to effectively coordinate the behavior of agents in multi agent system [15], [16]. In automated negotiation, all parties involved are software agents while most current negotiation online still depends on human activities. Game theory based negotiation and multi-attribute utilizing theory based negotiation [17],

[18] are theoretical approaches for automated negotiation. Morge and Beaune [19] wrote that a negotiation support system provides three kinds of functionality. Firstly, it facilitates the exchange of information among users. Secondly, it provides decision modeling or group-decision techniques. Thirdly, it provides negotiation support. All agents are registered by a middle agent transmitting proposals and counter proposals to other agents.

C. Introducing Prometheus Methodology for Model

A methodology is a body of methods employed by a discipline. A method is a procedure to attain something. While some developers employ a handful of methods to develop agent-based systems, few have methodology. Most developers of agent-based systems use an *ad-hoc* approach. There are eleven most prominent methodologies for developing agent-based system: Tropos, MAS-CommonKADS, PASSI, Prometheus, Gaia, ADELFE, MESSAGE, INGENIAS, RAP, MaSE, ROADMAP [20], [21].

D. Reason for Prometheus

A comparison analysis on different methodologies done by [21], concluded that Prometheus methodology [22] is suitable for automated negotiation in value-based decision of building system because:

1) It provides a toolkit for the development (only Prometheus, MaSe, ROADMAP have)
2) It is the best methodology if we need intelligent agent.
3) It is the most complete methodology in every phase of MAS development (system specification, analysis, architectural design, and detailed design)

Prometheus is an intelligent agent development methodology [22]. A key feature of this methodology is that it covers all phases of development. The Prometheus methodology contains three main phases: (i) system specification, (ii) architectural design and (iii) detailed design. Each of these contains a number of structured processes and results in specified design artifacts. The Prometheus Design Tool (PDT) is developed to support the Prometheus methodology. The tool provides the system developer with a graphical user interface that supports the development the various artifacts.

III. Goal and System Specification

The goal specification is to develop an automated negotiation system for building system selection on value-based decision process. This system will offer an evaluation system for a technical solution, a FAST, an LCC analysis, an elicitation preference of stakeholders, a system to analyze Pareto optimum payoff, a system to determine the best-fit technical solution option a system to accommodate trade-off analysis. The system must facilitate personalized and collaborative, fast and reliable negotiation (group decision) at all stage of negotiation on NSVM (Negotiation Support on Value Management) process, from the search for technical solution to evaluation. The system should have valid information and better than other method on practice, and gives better satisfaction.

The system goals and sub goals are as follow:

1) Geographically distributed negotiation process
   a. Online system
   b. Delivers geographical distribution (international)
   c. Receives individual information
   d. Sending group information
2) Technical Solution Information Online
   a. Finds technical solution product specification on the world wide web (www) and database
   b. Finds technical solution product price on the www and database
3) Building the system selection
   a. Provides various building system selection
4) Evaluation of technical solution options
   a. Provides basic value for technical solution
   b. Estimates the value of function
   c. Calculates LCC
5) Function Analysis System Technique
   a. Provides database of technical solution function
   b. Finds basic function
   c. Interactive discovering function
   d. Opens diagram and line of communication
   e. Why-How logic thinking
6) Life Cycle Cost Analysis
   a. Calculates initial cost
   b. Calculates Operation and Maintenance cost
   c. Calculates replacement cost
   d. Calculates salvage value
   e. Provides sensitivity analysis
   f. Provides Time Value of Money analysis
7) Elicitation preferences of stakeholder
   a. Provides pair wise comparison
   b. Storing historical preference
   c. Suggest~~ion~~s preference from past
   d. Interactive consistency
8) Pareto payoff optimum
   a. Calculates Pareto payoff optimum each coalition
   b. Calculates Pareto payoff function
   c. Calculates Pareto payoff function
   d. Calculates Pareto payoff value
9) Best-fit of technical solution options
   a. Calculation for best-fit
   b. Interactive best-fit information
10) Accommodating trade-off analysis
   a. Changes function of technical solution
   b. Changes cost preference of technical solution
   c. Changes value platform optimum
   d. Provides interactive made off information
11) Personalized full information and collaboration
   a. Personalized welcoming
   b. Decisions are based on stakeholder profile
   c. Information is available about all process in negotiation
   d. Anonymous negotiation results, such as opt out, reject, accept, stop, new round.

12) Fast and reliable group decision
    a. Arrange supply decision result
    b. Provides estimate for negotiation result
    c. Tracks trade-off problems
    d. Have various scenario stakeholders' characteristics.
13) Accepted best-fit option
    a. Provides the adjustment from individual best options to group best options
    b. Provides full information on the technical solution best-fit option
    c. Provides acceptance to an option
14) Validation of information
    a. Provides similarity index information
    b. Provides comparison of results from different decision assumption
15) Satisfy all stakeholder
    a. Have the option to change preferences
    b. Provides dead lock anticipation

IV. Functionality

This functionality is determined from refining goals and sub-goals by applying "how" and "why" questions method.

1) Online Interactions
    a. Obtains user input
    b. Presents information
2) Individual-Group Information Processing Online
    a. Receives individual stakeholder input
    b. Presents group information
3) Building System Product Information
    a. Finds and updates product specification database
    b. Finds and updates product price database
4) Basic Value of Technical Solution Products
    a. Provides basic value of a product
5) Function Database Management
    a. Provides database of technical solution function
    b. Finding basic function
6) Creativity in building function
    a. Interactive discovering function
    b. Opens diagram and lines of communication
    c. Why-How logic thinking
7) Life-Cycle Cost Calculation
    a. Calculation of Life Cycle Cost
    b. Provides sensitivity
8) Individual Preferences
    a. Provides pair-wise comparison input
    b. Provides refining input as consistency
9) Knowledge Management
    a. Storing historical preference from the past
    b. Suggestion of preference from the past
10) Value of Pareto Payoff Optimum
    a. Calculates Pareto payoff optimum for function
    b. Calculates Pareto payoff optimum for cost
    c. Provides coalition formation information
11) Best-Fit Centre Information
    a. Calculates best-fit options
    b. Interactive best-fit information
12) Trade-off and Value Change
    a. Accommodates trade-off analysis
13) Welcoming
    a. Provides personalized welcome
14) Profile Monitor
    a. Provides personalized recommendation and user option
15) Negotiation Process Monitor
    a. Provides building system selection options menu
    b. Provides negotiation process information
    c. Provides anonymous negotiation result
16) Group Coordination Management
    a. Arrange supply decision result
    b. Provides estimates for negotiation result
    c. Tracks trade-off problems
    d. Have scenario stakeholder characteristics
17) Agreement Management
    a. Provides full information on best-fit option and comparison result
18) Validation
    a. Provides similarity index and comparison result
19) Deadlock Management
    a. Options to change preference
20) Provides dead lock anticipations

A major decision to be made during the architectural design is which agent types should exist. This is done by grouping functionalities into agent types. Each agent type consists of one or more functionalities. The decision for a reasonable grouping is guided by considerations of coupling and cohesion. Once a grouping is chosen, each agent type is described using an agent descriptor form. The detailed design process is split into two parts, which are (1) the refinement of agents in terms of their capabilities, giving the agent an overview diagram and capability descriptors, and (2) the development of process specifications.

V. Testing

The negotiation support was tested for solving group choice decision-making problems to reduce the impact of mud volcano disaster in Sidoarjo, Indonesia [23]. Five stakeholders were involved and each gives their own preference (Fig. 1). Here, SH1 is the stakeholder in community domain, SH2 is the stakeholder in government domain, SH3 is the stakeholder in expert engineer domain, SH4 is the stakeholder in sponsor domain, and SH5 is the stakeholder in NGO (Non Government Organization) domain. Stakeholders present different side of preference. Nevertheless, the protocol of negotiation in this group decision is developed as a cooperative environment.

To obtain a good representation of a problem, it has to be structured into different components called activities. As the negotiation progresses, the agents user preferences on the evaluation criteria change, leading to the change in score of the alternative civil engineering solution for reducing impact disaster, and the change of membership and size of the set of agreement options. Five stages are conducted to determine agreement options, which are:

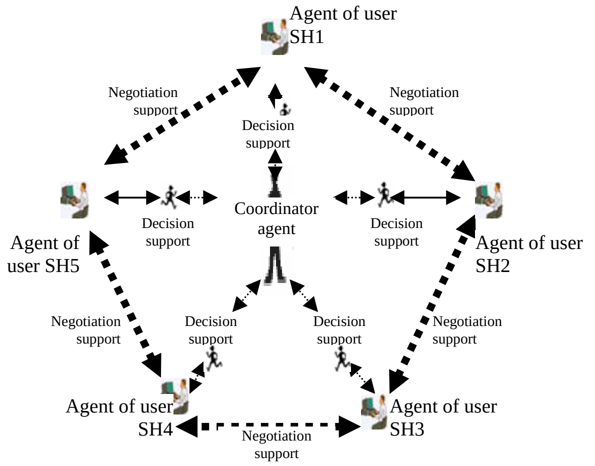

Fig. 1 System Architecture Negotiations (Adapted from [19])

1) Determining the weighting factor (weight of preferences) of criteria for each decision-maker. Fig. 2 reveals different preferences between stakeholders

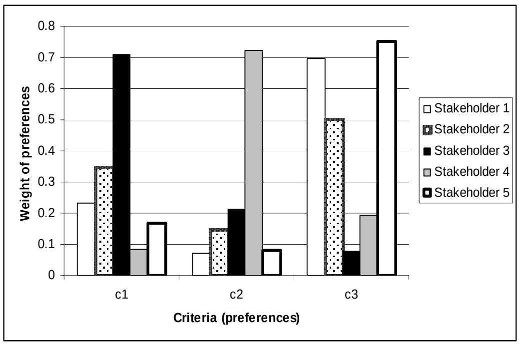

Fig. 2 Weight of Preferences for Each Stakeholder

2) Grading the alternative for each evaluation criteria. Fig. 3 shows that on the criteria of technical sustainability, alternatives 1 and 5 are the best. The results is different for economical and social environmental criteria, in which alternative 2 and alternative 4 are best for economical and social environmental considerations, respectively.

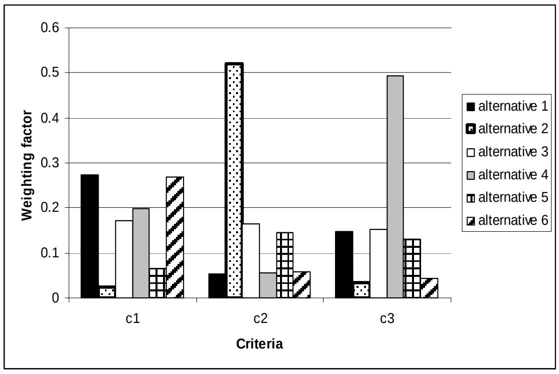

Fig. 3 Weighting Factor of Every Alternative for Each Criteria

3) Scoring every alternative for every decision-maker. Fig. 3 shows that stakeholders have different best options as a solution alternative. But only three alternatives are considered as the best options, which are a1, a2, a4.

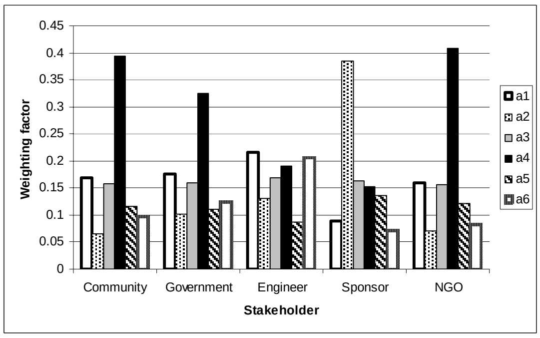

Fig. 4 Weighting Factor of Every Alternative for Each Stakeholder

4) Determining the payoff optimum, based on the coalition algorithm and analyzing the best-fit options for every coalition and grand coalition. The result is presented in TABLE 1, which shows the priorities that follow the best-fit options process and the coalition algorithm. It also presents the result on the priorities of technical solution in the first negotiation round.

TABLE I
WEIGHTING FACTOR OF EACH ALTERNATIVE AND COALITION

Alternative ranking and coalition	Alternatives					
	a1	a2	a3	a4	a5	a6
SH 1 (Community)	2^{nd}	6^{th}	3^{rd}	1^{st}	4^{th}	5^{th}
SH 2 (Government)	2^{nd}	6^{th}	3^{rd}	1^{st}	5^{th}	4^{th}
SH 3 (Engineer)	1^{st}	5^{th}	4^{th}	3^{rd}	6^{h}	2^{nd}
SH 4 (Sponsor)	5^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}	6^{h}
SH 5 (NGO)	2^{nd}	6^{h}	3^{rd}	1^{st}	4^{th}	5^{th}
Coalition SH1 and SH2	1^{st}	6^{th}	2^{nd}	4^{th}	3^{rd}	5^{th}
Coalition SH1 and SH3	3^{rd}	4^{th}	1^{st}	2^{nd}	6^{th}	5^{th}
Coalition SH1 and SH4	4^{th}	5^{th}	1^{st}	2^{nd}	6^{th}	3^{rd}
Coalition SH1 and SH5	3^{rd}	4^{th}	2^{nd}	1^{st}	5^{th}	6^{th}
Coalition SH2 and SH3	3^{rd}	2^{nd}	1^{st}	5^{th}	4^{th}	6^{th}
Coalition SH2 and SH4	3^{rd}	6^{th}	1^{st}	5^{th}	2^{nd}	4^{th}
Coalition SH2 and SH5	3^{rd}	6^{th}	1^{st}	5^{th}	2^{nd}	4^{th}

Coalition SH3 and SH4	3rd	6th	1st	2nd	4th	5th
Coalition SH3 and SH5	3rd	6th	1st	5th	2nd	4th
Coalition SH4 and SH5	4th	6th	1st	5th	3rd	2nd
Coalition SH1, SH2, and SH3	2nd	4th	1st	5th	3rd	6th
Coalition SH1, SH2, and SH4	4th	5th	1st	6th	2nd	3rd
Coalition SH1, SH2, and SH5	2nd	5th	3rd	1st	4th	6th
Coalition SH1, SH3, and SH4	3rd	5th	1st	6th	2nd	4th
Coalition SH1, SH3, and SH5	4th	3rd	1st	6th	2nd	5th
Coalition SH1, SH4, and SH5	4th	5th	1st	6th	2nd	3rd
Coalition SH1,2,3,4	4th	5th	1st	6th	2nd	3rd
Coalition SH1,2,3,5	6th	3rd	1st	5th	2nd	4th
Coalition SH1,2,3,4,5	2nd	5th	1st	6th	4th	3rd
RESULT	3rd	4th	1st	2nd	-	-

The coalition table (TABLE 1) reveals the start of the first negotiation round. Some solutions are not an option if no individual stakeholder or coalition of stakeholders desires to select it. In this case, alternative solution a5 and a6 are not options. The table also indicates the alternative solution that will be determined the best fit solution. In this problem, in the first negotiation round, a3 is the 'best-fit' solution.

VI. Conclusion

Functionality of negotiation agent on value-based design decision has been described, including **t**he results of testing done on a building system selection in value-based decision environment.

Future work is on Prometheus model development using JACK® Agent Language ™ (JACK®). JACK® is a programming language and a development environment for building, running and integrating commercial-grade multi-agent systems using a component-based approach. Since the final stage of the Prometheus Development Tools are in a detail design, not all of design entities are carried through to implementation, therefore it is necessary to implement the model to the BDI (belief, desire, intention) system such as JACK®. This means that the conceptual model will be implemented using an agent-oriented programming language and be presented using a GUI.

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