2014 7th International Symposium on Telecommunications (IST'2014)

Agent Dialogue Strategy Based on Priority of Goals

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***Abstract*—In multi agent systems, agents interact with each other through a dialogue protocol to inform each other the relevant facts in order to reach the common goals. In a dialogue the protocol defines the possible replies for a presented speech act and the strategy specifies which speech act is premier. The strategy defines how to achieve the agents' goals by choosing the best one among all choices. Compared with researches on dialogue protocol, there are few works on dialogue strategy. We proposed a formal model for dialogue strategy in order to select the best speech act and the proper content. This model in each step of dialogue can decide the appropriate act and content allowed by the dialogue protocol in order to satisfy the agents' goals. This model computes the priority of possible acts and contents using argumentation theory. The proposed model is illustrated through a common example of deliberation dialogue.**

Keywords— multi agent systems; dialogue strategy; argumentation

I. INTRODUCTION

Multi agent systems (MAS) are formed of a number of agents interacting with each other through communications [1]. Agents communicate with each other based on their beliefs to achieve their personal or common goals through exchanging some messages. A dialogue is a sequence of messages that are exchanged between the members of MAS with a specific subject. Each step of dialogue which contains a speech act with a proper content is called move. The dialogue types have different categories listed as follows: persuasion, negotiation, inquiry, deliberation and information seeking [2]. Many researchers have presented their dialogue model based on these types of inter-agent dialogue [3]. Each type has different initial situation and different aims. Figure 1 shows the key of arriving at these types of dialogue.

To follow these dialogue types, we need a dialogue protocol. A dialogue protocol contains some rules governing high level behaviors of interacting agents. Dialogue protocol determines the possible replies for a presented speech act while the dialogue strategy includes rules that specify the uttering of a specific action in respond to the presented speech act according to the objectives. Indeed the strategy selects dialogue moves among the legal ones determined by the protocol. It can be said that the protocol is a public notion, while the strategy is an individualistic matter [1, 4].

In recent researches argumentation theory are applied to model interaction between agents in MAS dialogues [5-7]. The abstract model of argumentation, called Dung model, is defined as a set of elements (arguments) and binary relations (attacks) defined over them. In each attack relation, acceptance of an argument leads to reject the other. In another model [4] these attack relations have the preference values. This means that a specific argument may be stronger than others due to a higher priority.

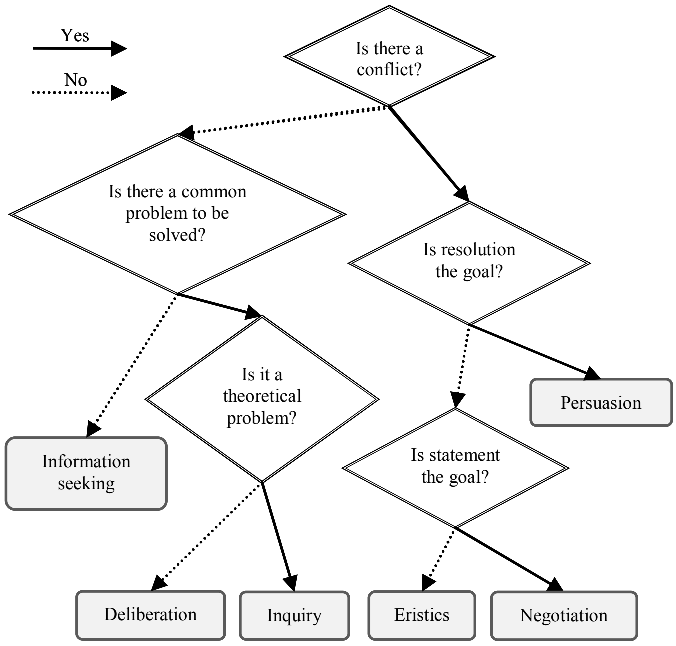

Fig. 1. Determining type of dialogue based on the nature of problem (from [8])

In Argumentation based dialogues, the agents present both the statements of what they believe or want and the reason of the statements. For example in a persuasion dialogue, when agent A wants to persuade agent B that p is true, it states the fact p is true and also gives a proof of p based on information (grounds) that it believes to be true. B can only disagree with p if it disputes the truth of some of the grounds or if it has an alternative proof that p is false [9].

In an argumentation based dialogue, a protocol determines a set of possible moves that agents can make at each point and the agents put forward the arguments that support these moves. In every step, supporting arguments of presented moves typically attack the supporting arguments of the

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presented moves in the previous dialogue step. The presented arguments are evaluated and then conflicts are resolved [10].

The dialogue strategy is similar to a decision making process which selects the best act that an agent can utter according to its beliefs to satisfy the goal. Therefore it can be said that the strategy is a two phased decision making as follows: (1) to choose the move to play among all of the possible replies allowed by the protocol, (2) to select the content of the move if it is needed. For example, agent decides whether to ask a question or to offer it proposal and then selects the proper content if it is needed. Note that for some acts such as “Withdraw”, there is no need to choose the content.

In [11], it is supposed that the act “offer” is implicitly chosen by the agent therefore the proposed algorithm chooses the proper content. Based on argumentation framework, there are some proposed dialogue strategies for different types of dialogue like inquiry and persuasion dialogue [12, 13].

Argumentation based dialogue mechanism follows these steps: (1) constructing arguments in favor of or against each possible choice, (2) evaluating the strength of each argument, (3) comparing decisions on the basis of their arguments, (4) defining the priority of the choices. Therefore a decision making model is needed for taking a proper selection between presented arguments. In such framework the arguments can be built in favor of or against a possible choice and then arguments can be compared based on their quality or strengths [1].

This paper proposes a model for dialogue move selection using Dung model argumentation. Based on this model, an algorithm for computing the next move having the current state is introduced. The algorithm considers all allowed replies by the protocol and finally returns the move (act + content) with the highest priority.

In next section we brief dialogues strategy modeling and some definitions in this field. The proposed method of move selection is described in section 3. In section 4 we illustrate our model via an example of dialogue between agents. Finally some concluding remarks are presented in section 5.

II. Formal Definitions

Agents communicate with each other based on their beliefs in order to achieve their goals. The goals of agents can be divided into two sets: strategic and functional. These goals correspond to strategic beliefs and basic beliefs of agents respectively.

The strategic goals are the high-level and long term goals of the agents which describe what agents are aiming for. They are based on the strategic beliefs and they are independent of the subject of the dialogue and can help the agents to select the type of the act to utter. The strategic beliefs are the meta-level beliefs about both the dialogue and the agents involved in the conversation. In a dialogue, the agents choose their speech act based on their strategic goals.

The functional goals support the strategic goals and express that what an agent wants to achieve and how will achieve them. The functional goals are based on basic beliefs of the agents and can be used to select the appropriate content for a chosen action and they are directly related to the subject of the dialogue. Basic beliefs of an agent are about the subject of the dialogue and the environment. The functional goals express what an agent wants to achieve.

For example, in problem of determining a place for a meeting, the agents are trying to find a common agreement. The strategic goal is minimizing the discussion time. Therefore the agents would choose to offer instead of spending more time to ask questions. The strategic belief of each agent is: knowing the goals and beliefs of other agents is important in simulating the reasoning of the others. Consider that the functional goal of the agents is to offer a not warm and not expensive place. Hence the contents of the presented offers are based on satisfying such goals. The basic beliefs of the agent may include: “London is not warm”, “Tunisia is hot”, “London is very expensive”, etc. Also the basic beliefs may contain some facts related to the dialogue subject such as “the meeting cannot be at the same time in different places”. Dialogue strategy can be defined using these categories of goals and beliefs [14].

In this paper we proposed a dialogue strategy for selecting the rational next moves. In this way, we need to specify some definitions.

Definition 1 (Beliefs and Goals). Suppose that $\mathcal{L}$ is a propositional language. $Wff(\mathcal{L})$ is the set of well-formed formulas built from $\mathcal{L}$. The set of beliefs and goals of agent can be written in the following form:

$B_s = \{(bs_i, \delta_i), i = 1, ..., m \mid bs_i \in Wff(\mathcal{L})$ *is a strategic belief and* $\delta_i \in [0, 1]$ *is its certainty level*$\}$

$B_b = \{(bb_j, \rho_j), j = 1, ..., n \mid bb_j \in Wff(\mathcal{L})$ *is a basic belief and* $\rho_j \in [0, 1]$ *is its certainty level*$\}$

$G_s = \{(gs_k, \lambda_k), k = 1, ..., p \mid gs_k \in Wff(\mathcal{L})$ *is a strategic goal and* $\lambda_k \in [0, 1]$ *is its priority degree*$\}$

$G_f = \{(gf_l, \gamma_l), l = 1, ..., q \mid gf_l \in Wff(\mathcal{L})$ *is a functional goal and* $\gamma_l \in [0, 1]$ *is its priority degree*$\}$

Each individual in the above mentioned sets has different preferences. The values of certainty levels or priority degrees in Definition 1, are linearly scaled between 0 (corresponding to the complete absence of certainty or priority) and 1 (corresponding to total certainty or full priority).

Suppose B_b^*, B_s^*, G_s^* and G_f^* are the corresponding sets of propositional formulas in Definition 1 without weights (levels or degrees). In other words, these sets are the same sets of beliefs and goals. The functions *Replies:* $D \rightarrow 2^D$, and *Content:* $D \rightarrow 2^{Wff(\mathcal{L}) \cup \{null\}}$ return all the legal replies for each act and the possible contents for a given act respectively ,where D is the set of speech acts allowed by the protocol.

In a dialogue a move can be defined as the following form:

$$Moves = \{(a,x) \mid a \in D,\ x \in Content(a),\ a,x \therefore Protocol(p)\} \quad (1)$$

Definition 2 (Strategy). In respond to the current move (a, x), the strategy is choosing the next move (a', x') to utter such that a' ∈ Replies(a) and x' ∈ Content(a'), where a' satisfies at least one member of G_s^* *according to* B_s^**, and x' satisfies at least one member of* G_f^* *according to* B_b^**.*

Let X is the set of possible choices (acts/contents).

Definition 3 (Argument). An argument in favor of a choice $d \in X$ *is a triple A = <S, g, d> such that:*

$S \subseteq B_b^* \cup B_s^*$

$g \in G_s^* \cup G_f^*$

$S \cup \{d\}$ *is consistent*

$S \cup \{d\} \rightarrow g$

S is minimal with the above conditions.

S is the support of the argument, g is the goal which is reached by the choice d, and d is the conclusion of the argument. Considering Definition 1, *Levels(A)* and *Weights(A)* are defined as the certainty level and the degree of satisfaction of an argument:

$$Levels(A) = \begin{cases} \min\{\alpha_i \mid k_i \in S \text{ and } (k_i, \alpha_i) \in B_b \cup B_s\}, & S \neq \emptyset \\ 1 & S = \emptyset \end{cases} \quad (2)$$

$$Weights(A) = \beta \qquad \text{with } (g, \beta) \in G_s \cup G_f \quad (3)$$

Definition 4 (Argument's Strength). The Pair <Levels(A), Weights(A)> is defined as the strength of an argument A.

$$A \geq B, \quad (4)$$

iff min {Levels(A), Weights(A)} • min {Levels(B), Weights(B)}

Definition 5 (Arguments Comparing). A ≥ B (means A is preferred to B), iff min {Levels(A), Weights(A)} • min {Levels(B), Weights(B)}.

$A \geq B$ means A is preferred to B. The relation ≥ is reflexive and transitive. Let X be the set of possible decisions:

Definition 6 (Decision Model). An argumentation based decision model is a tuple $<X, A, \geq, \nabla_P>$ *where ≥ and* ∇_P *are the pre-order relations on A and X (respectively), based on the arguments which are used to support the decisions.*

The output of Argumentation based decision model is a pre-ordering ∇_P (complete or partial) on X. This order specifies the preference of X's individuals Let $x_1, x_2 \in X$ and *Arg(x)* denotes the set of arguments in A which are in favor of x:

$$x_1 \nabla_P x_2, \quad (5)$$

$$\text{iff } \exists A \in Arg(x_1) \text{ such that } \forall B \in Arg(x_2), A \geq B$$

Let S_R the support of the argument in favor of *Replies(a)* and S_C the support of the argument in favor of *Content(a')*. To find the next move *(a', x')*, the set X may contain all of the pairs of *Replies(a)* and *Content(a')*. Let $(d_1, d_2) \in$ *(Replies(a), Content(a'))* suppose $S_R \subseteq B^*_s$, $g \in G^*_s$, $S_C \subseteq B^*_b$, $g \in G^*_f$. This means that the argument in favor of *Replies(a)* are built from the strategic beliefs and strategic goals G_s and similarly argument in favor of *Content(a')* are built from the basic beliefs and functional goals G_f.

The decision model will select the best act and its content to utter. For each option, the decision model considers the certainty levels of a reply and priority degree of its content simultaneously and finally returns the best one. In the presented argumentation based approach, each argument may be defined in favor of each $d \in$ *(Replies(a), Content(a'))*. Then the decision model is applied. Finally, all possible choices are compared and the best one will be selected with the following definitions:

Definition 7. (Move Preference) Let $d = (d_1, d2) \in X$, $d_1 \in$ *Replies(a),* $d_2 \in$ *Content(a'), the Preference(d) = min {certainty level(*d_1*), priority degree(*d_2*)}.*

$$Best(Replies(a), content(a')) = \quad (6)$$

$$\{d=(d1,d2) \in X,\ d1 \in Replies(a),\ d2 \in Content(a') \mid \forall d' \in X,\ Preference(d) \geq Preference(d')\}$$

In the next section, we discuss about preparing the alternative choices for the act and content in a multi agent system's dialogue.

III. The Proposed Method for Move Selection

In this paper we propose a strategy to choose dialogue move using argumentation. In our method for a current move, we study all supporting and opposing arguments and then select the best move. We propose an algorithm to define the priority of each choice and to select the best one. This algorithm considers all of the possible acts and their relevant contents and returns the best move (act + content). This algorithm is a kind of rational decision making (RDM).

In RDM the aim of agents is selecting the best possible options. This approach maximizes the possibility of achieving the defined goals. Agents can grade the desires and priorities based on their utility and usefulness in a logical sequence. Agents know their goals and find all different solutions and evaluate each of them carefully [15]. Generally RDM consists of these steps: (1) outlining the goal, (2) gathering data to develop options, (3) listing pros and cons of each option and considering all possible options, (4) grading each option and choosing the best one, (5) computing the optimal decision and taking action to implement it. Considering RDM, when the decision problems are decomposable to some independent sub-decisions by some proper measures, the hierarchical decision making framework is a rational approach. But if eligible conditions are not existent, this framework cannot help to make the rational decisions [16]. In dialogue move selection because of the nature of problem and dependency existence between the acts and the related contents, applying the hierarchical decision making would not be helpful.

In a research [14] a strategy has been introduced for move selection which it chooses the act with higher priority and then pays attention to content selection. The hierarchical structure and sequential manner of that model may cause to lose the possibility to review all of the valuable options. Although that model has less complexity compared to the method presented here, it is susceptible to lose the possibility to review all of the valuable options and it is not a kind of rational decision making.

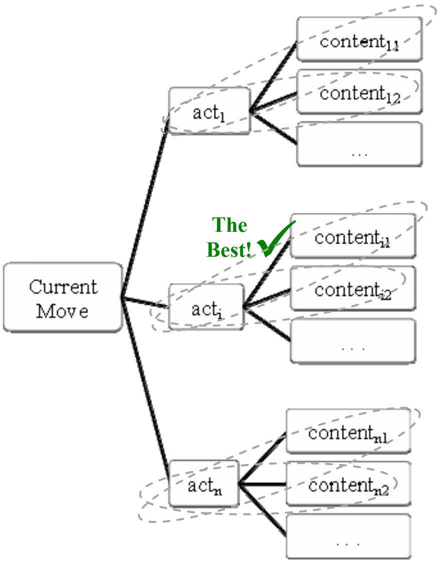

Fig. 2. The Schema for the selection of pairs of acts and their possible contents

Figure 2 shows the grouping for the pairs of the allowed acts and their possible contents. The preference of a move *m=(a, x)* is computed by Equation 7.

$$priority(m) = min\{priority(a), priority(x)\} \qquad (7)$$

The proposed algorithm receives the current move, beliefs and goals of agents and returns the preferred allowed move. When no valid response is returned from the algorithm, it means that there is no rational response. The algorithm is shown in Figure 3. The function *Best( )* is defined according to Equation 6.

In this paper, a combinational preference decision making method is used to decide the optimal move step. All the possible options are considered and ranked at once and an option with the highest rank is selected for the next decision. Using a simultaneous preference determination mechanism, the best allowed move and content are selected. We consider both of the act and its content to define the overall preference of a move. Thus overall preference of the move is computed based on the preferences of act and its content. Also, we introduce a method for comparing the preferences of the presented choices and selection the best move to play. In the proposed algorithm, for a given current move, first the allowed replies by the protocol are defined and then for each reply the probable contents are listed. Finally the best reply and its content will be determined using a preference based selection method.

```
(a', x') Next_Move_Computing ((a, x), B_s, B_b, G_s, G_f)
{
for each act_i ∈ Replies(a)
    if (act_i satisfies G_s^* according to B_s^*)
        add act_i to ACTS
if (ACTS = Ø)
    return(Null)
for each act_i ∈ ACTS
    for each cont_ij ∈ Content(act_i)
        if (cont_ij satisfies G_f^* according to B_b^*)
            add cont_ij to CONTS_i
    if (CONT_i = Ø)
        {add ( act_i, ? ) to CHOIS_i
        preference( CHOIS_i) =  preference(act_i) }
    else
        {add ( act_i, Best( CONT_i)) to CHOIS_i
        priority(CHOIS_i) =  min (preference(act_i), preference(Best(CONT_i)))}
    add CHOIS_i to CHOISES
return Best(CHOIS_i)
}
```

Fig. 3. The Proposed Algorithm for Dialogue Move Selection

IV. Illustrative Example

In this section we have illustrated the proposed model with a familiar deliberation dialogue between agents [17, 18]. To demonstrate the capabilities of the proposed method the example is slightly modified. This example considers a dialogue between three agents that need to find a restaurant for dinner quickly and all enjoy the food. They have different food tastes. In every step of dialogue, they can propose their options or consider other agents' options according to their goals and beliefs until reaching agreement [19]. The allowed moves to utter in this protocol are stated in table 1 .

TABLE I. The Allowed Moves by The Protocol in the Delibration Example

Moves	Description	The set of Replies
assert-pos	Agent proposes its option	assert-neg, pass
assert-neg	Agent defeats the last proposed option	assert-pos, pass
pass	Agent pass its turn by saying nothing	assert-pos, assert-neg, pass

In mentioned deliberation dialogue, an agent asserts an option when it has an argument in favour of it. The other agents can defeat the presented option or pass their turn if they have no contrariety.

The strategic goals of the agents are minimizing the deliberation time and also to respect their food tastes. Based on these goals, they believe that uttering the '*assert-positive*' or '*pass*' is more preferable instead of '*assert-negative*'. This means that if an agent has a good offer will present it or pass its turn which means it has no opposition to the presented offer before. If an agent does not agree with the presented offer, it states its counter arguments with '*assert-negative*'. In other words, if they don't '*assert-negative*' as much as possible, the deliberation time will be decreased. The strategic goal and belief are written in formal form as follows:

$$G_s = \{(min\text{-}time, 0.8), (selfishness, 0.7)\} \tag{8}$$

$$B_s = \tag{9}$$

$\{(assert\text{-}pos \bullet min\text{-}time, 1), (pass \bullet min\text{-}time, 0.8), (assert\text{-}neg \bullet \neg min\text{-}time, 1), (assert\text{-}neg \bullet selfishness, 0.8)\}$

The functional goals of agents are to order the delicious and healthy foods. On the other hand, they have different preferences to choose tasty or healthy or both of them. Their functional goal and basic beliefs of these three agents are as follows:

$$G_f = \{(enjoy\text{-}food, 0.8), (healthy\text{-}food, 0.6)\} \tag{10}$$

$$B_{b1} = \tag{11}$$

$\{(Pizzeria\ (pizza\ quattro\ formaggi) \wedge topping\ (gorgonzola) \rightarrow tasty\text{-}food, 1), (Bistro\ (steak) \rightarrow \neg low\text{-}calories, 1), (Pizzeria\ (pizza\ verdure) \rightarrow low\text{-}calories, 1), (tasty\text{-}food \rightarrow enjoy\text{-}food, 1), (low\text{-}calories \rightarrow healthy\text{-}food, 0.8)\}$

$$B_{b2} = \tag{12}$$

$\{(Bistro\ (seafood) \rightarrow tasty\text{-}food, 1)), (Pizzeria\ (pizza\ quattro\ formaggi) \wedge topping\ (dull) \rightarrow \neg\ tasty\text{-}food, 1), (Bistro\ (salad) \rightarrow low\text{-}calories, 1), (Pizzeria\ (pizza\ verdure) \rightarrow low\text{-}calories, 1), (tasty\text{-}food \rightarrow enjoy\text{-}food, 1), (low\text{-}calories \rightarrow healthy\text{-}food, 0.8)\}$

$$B_{b3} = \tag{13}$$

$\{(Bistro\ (steak) \rightarrow tasty\text{-}food, 1), (Pizzeria\ (pizza\ quattro\ formaggi) \rightarrow \neg low\text{-}calories, 1), (Bistro\ (seafood) \rightarrow low\text{-}calories, 0.7), (tasty\text{-}food \rightarrow enjoy\text{-}food, 1), (low\text{-}calories \rightarrow healthy\text{-}food, 1)\}$

In the remaining of this section a sample dialogue is presented in form of a scenario which can be occurred between these agents. This scenario is according to our proposed method depicted in Figure 3.

Suppose that agent A_1 starts the dialogue and other agents have their turn respectively. For the first move, A_1 has an argument in favour of '*Pizzeria (pizza quattro formaggi)*' which satisfies the *min-time* and *enjoy-food* goals. In this move the agent chooses the '*assert-positive*' as an act and '*pizza quattro formaggi*' of '*Pizzeria*' as a related content. Therefore its move is:

- $A_1 \rightarrow assert\text{-}pos\ (Pizzeria\ (pizza\ quattro\ formaggi) \wedge topping\ (gorgonzola)) \rightarrow tasty\text{-}food$

According to the protocol, agent A_2 can choose *pass* or *assert-neg*. because it has an argument against the previous move, therefore it utters its move as follow:

- $A_2 \rightarrow assert\text{-}neg\ (Pizzeria\ (pizza\ quattro\ formaggi) \wedge topping\ (dull)) \rightarrow \neg\ tasty\text{-}food$

In this state, the A_3 has two choices for move selection. It can select *pass* or *assert-pos*. Therefore these moves are available for A_3:

$M_1 = pass$
$M_2 = assert\text{-}pos(Bistro\ (steak))$

In this case the preferences of these options are computed according to Definition 7. The act '*pass*' does not need a content, thus its preference is only equal to the preference of the act. But the preference of M_2 is computed based on both of the act and the content:

$Preference\ (M_1): 0.8$
$Preference\ (M_2): min\ \{1, 1\} = 1$

Therefore A_3 selects M_2:

- $A_3 \rightarrow assert\text{-}pos\ (Bistro\ (steak)) \rightarrow tasty\text{-}food$

Similarly we have:

- $A_1 \rightarrow assert\text{-}neg\ (Bistro\ (steak)) \rightarrow \neg low\text{-}calories$
- $A_2 \rightarrow assert\text{-}pos\ (Bistro\ (seafood)) \rightarrow tasty\text{-}food$

In this step, A_3 has no argument against the previous move and also has an argument in favour of *Bistro (seafood)* which says it also satisfies *healthy-food* goal. Therefore choose *pass*.

- $A_3 \rightarrow Pass$

Then A_1 and A_2 have arguments in favour of *healthy-food* goal and also they choose *pass* and the dialogue will terminate:

- $A_1 \rightarrow Pass$
- $A_2 \rightarrow Pass$

As mentioned above, the proposed algorithm considers all plausible choices and finally returns the rational action to move.

V. Concluding Remarks

In multi agent systems, agents interact to inform their teammates some relevant facts about each other. Agents make dialogue according to their defined protocol and to follow their strategies for speech act selection. The dialogue strategy specifies the uttering of a specific action among the different existent choices in a given step of dialogue between agents.

In this paper we have proposed a formal model for dialogue strategy. At each step of the dialogue in our model, the strategy determines the proper next move to utter in order to satisfy the agents' goals. In proposed method we apply argumentation concepts in order to preference determination of each possible act and content to utter. This model considers the constructed arguments that have been achieved from goals and beliefs and computes the strength of each argument. Then the results are applied to define the preferences of possible acts and contents. In the end the pairs of acts and contents are compared based on the values of their supporting arguments and finally the preferable one will be returned.

The proposed model can be applied in various dialogue types and we have illustrated our proposed model through the example of deliberation dialogue.

ACKNOWLEDGMENT

The first author thanks Iran Telecommunication Research Center, Tehran, Iran, for their supports.

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