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Modeling Lateral Communication in Holonic Multi Agent Systems

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ABSTRACT

Agents, in a multi agent system, communicate with each other through the process of exchanging messages which is called dialogue. Multi agent organization is generally used to optimize agents' communications. Holonic organization demonstrates a self-similar recursive and hierarchical structure in which each holon may include some other holons. In a holonic system, lateral communication occurs between members of a determined holon and vertical communications are inter-level ones between different holons. When agents start a dialogue, according to their beliefs, they follow some rules that define the permissive speech acts called dialogue protocol. The dialogue strategy is the policy of agents to choose a particular speech act among the allowed ones by the protocol in order to achieve the common goals of holon. In this paper a formal model for dialogue strategy for lateral communication in a holon is proposed. This model tries to choose the most preferable speech acts considering at the same time local beliefs and goals along with public knowledge obtained from holonic organization. Moreover, the argumentation theory is applied to rank and define the values of speech acts. The proposed model finds the most preferable option to utter and it also decreases the number of exchanging messages. The proposed model of dialogue strategy is illustrated via a deliberation dialogue example in a holon. The example showed a significant efficiency in decreasing the number of exchanged messages and the effectiveness of deliberation.

KEYWORDS

Holonic Multi Agent Systems; Lateral Communication; Dialogue Strategy; Argumentation.

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1. INTRODUCTION

Multi agent systems (MAS) are composed of some agents communicating with each other to achieve common goals [1]. Various models have been introduced for organization of MAS. The organizational structures can be classified in three main categories: heterarchy, hierarchy and holarchy (holonic). Heterarchical organizations have only one level of organization. In a hierarchy, agents are structured in multiple levels. The holarchy is composed of a hierarchy of autonomous self reliant units which may be composed of some autonomous agents. These units are called holons. Communications in MAS are based on agents' assumptions, beliefs and preferences in order to achieve their personal or shared goals. The organization of MAS can force fully influence some aspects like decision making, agent communications, etc [2]. It specifies the interactions between the agents in a group and may limit the ways of communication. Also multi agent organization is a way to optimize agents' communications. Although organizations affect communication overhead, they can limit the scope of interactions.

The interactions between autonomous agents participating in a MAS organization have been studied in some works. In [3] a message passing protocol is presented for dialogue based teamwork. They consider the sequence transmission problem of one agent to a group of agents. In [4] in order to reduce the number of passed messages between agents, the authors have proposed some rules to adapt a MAS organization. When an agent wants to send a message, it concerns these rules. In [5] they have analyzed the communication topology of MAS in order to reduce the number of exchanged messages. They propose the topology setting based on a redirecting probability in the communication. The aim of their algorithm is to search for an optimal communication topology to avoid a high message passing. In another work [6], a specification of agents' interaction models within an organization has been proposed. The proposed model is a model for multi party communications between the defined roles and groups of agents. This model is very simple and it does not actually consider the communications between groups. In [7], a hierarchical interaction model with two levels is introduced. The problem's space is divided into some partitions and the situated agent in each part form the team related to that part. Each team has a supervisor which manages the agents of its team and dictates the required commands to its team.

Each step of a dialogue is called "move". A typical move contains a speech act and a proper content (if needed). For example in an Auction problem, agent decides whether to Offer or Withdraw. Then if the Offer is selected, the proper content like a price must be presented. Note that Withdraw does not need any content. For making dialogue, agents need dialogue protocol that consists of a set of probable agents' conversations and defines the possible replies for a presented speech act [8]. The protocol that governs an agent typically depends on the role of the agent engaged in a dialogue. Also, in a MAS dialogue, agents choose their proper speech acts among permitted ones by the protocol according to their strategies. A strategy is a set of rules that specify the proper moves to utter according to the agents' goals and characteristics in each step of dialogue [9]. In a MAS dialogue, the agent chooses the appropriate moves among the legal ones defined by the protocol and according to the strategy.

In this paper, we model a communication strategy for interaction between peer members of a holon that are homogenous agents. In other words, in the holonic organization MAS we introduce a strategy which causes sibling agents to have the minimum needed conversations based on their common beliefs and goals. For this aim we apply the argumentation concept to supply this strategy. The main contributions of this paper are as follows:

- Formal modeling of dialogue strategy for a group of agents which have common goals in a holon,
- Introducing and applying the definition of public beliefs of a group of agents that have commitments to satisfy the joint goals of a holon,
- Using preference based argumentation concept to evaluate the possible choices to utter in a dialogue and select the best one.

The remaining of this paper is organized as follows. Section 2 is a brief review on holonic interactions. Section 3 focuses on argumentation based communication. The main idea and the proposed algorithm are described in section 4. In section 5 the proposed method is discussed through a common example of deliberation dialogue. Finally conclusion of the paper is presented in section 6.

2. HOLONIC INTERCTIONS

The structure of holonic organization consists of several holons as sub-structures while it could be a part of greater whole at the same time. In a holarchy, a holon can be seen either as an autonomous, atomic entity, or as an organization of holons [2]. Holons are autonomous, cooperative and re-cursive. Holons demonstrate self-similar recursive structure as shown in Fig. 1. Each holon is an autonomous actor with its defined principles and goals. However, its goals and strategies are also restricted by its head. The head of each holon manages inter-holon activities and represents the holon to the agent society.

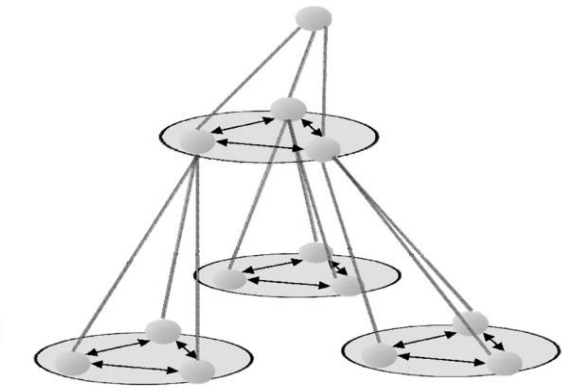

Fig. 1. Organization of holons in a holarchy with lateral and vertical interaction schema

There are two types of communications in a holarchy: lateral, when holons of the same levels communicate (the black arrows in Fig. 1), and vertical, when holons of different levels interact [10]. In the first case only the member of a holon can communicate with each other according to their defined goals. In the second type, the head of each holon can interface with other holons. In other words, only the head can communicate with outside of the holon. In this paper, we focus on lateral communication in holonic organization.

In each holon as a part of a MAS organization, dialogue is the flow of exchanged messages with a specific subject directly without engaging several parties of other holons [11]. As shown in Fig. 2, agents in a holon can communicate with each member of its holon laterally. They interact to reach particular objectives of the holon. When an agent wants to interact with others, it chooses a proper speech act according to the protocol and its strategy. Indeed an agent decides to select the best act that can be uttered according to its beliefs to satisfy the defined goals. It can be said that among all allowed speech acts by the dialogue protocol an agent chooses the move to utter and also selects the content of the move if it is needed, based on the dialogue strategy [12].

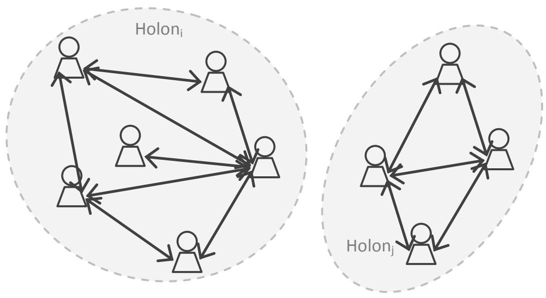

Fig. 2. Lateral interactions between agents in the separated holons in a HMAS

Agents in holonic MAS (HMAS) have implicit or explicit knowledge about their environment as their beliefs. This knowledge might be represented explicitly within a specific agent as the head of holon, or it may be provided implicitly by the local knowledge of each individual agent. Due to the availability of the public knowledge of a holon to all members, we can reduce the volume of message exchanging between communicating agents. The idea is: there is no need to repeat the common information in message passing.

In organized multi agent system, we can separate shared knowledge among agents from the private beliefs. On the other hand, autonomous agents may perceive environments in different ways and despite of being structured in an organization, they have their own beliefs. Argumentation based communication is an adequate approach to resolve the inconsistencies of beliefs [13].

In this paper we propose an argumentation based dialogue strategy for communication between involved agents in a holon which have the same role in an organization. We consider the shared beliefs of the agents and try to remove the needless message passing. In the next section we brief some primary definitions and concepts of argumentation based communication that is applied in our method.

3. ARGUMENTATION-BASED COMMUNICATION

Argumentation is the sequence of putting forward the arguments for or against the propositions by the involved agents and investigating the acceptability results. In this way, each agent represents the statements of what it believes or wants and also the reason of the statements. When an agent wants to utter that the proposition P is true, it states P is true and it also represents a proof of P based on the knowledge that it believes to be true. One justification method is Dung-style argumentation system. In this system the argument A_i attacks argument A_j means that accepting A_i would mean rejecting A_j [13]. In Dung-style argumentation all attacks have the same equal strength whereas in real-world problems some arguments are stronger than others [14]. In preference based argumentation systems a preference measure is defined that may be specified in various ways like having a higher probability or certainty of corresponding beliefs. Hence, each presented argument has a priority value [15].Argumentation has been considered to model the dialogue between agents. In an argumentation based dialogue, agents exchange both the statements of what they believe or want and the reason of the statements. They construct arguments for and against a particular claim and present those to others [14].

Applying the argumentation to MAS dialogues improves the efficiency of communication [16]. In argumentation based dialogue when an agent presents its argument, the other agents may attack the current argument. Also, a decision making model for taking a proper choice among the presented arguments is needed. Argumentation based dialogue follows these steps: (I) Constructing arguments in favor of or against the presented choices, (II) Determining the strength of the arguments, (III) Comparing decisions on the basis of their arguments, (IV) Specifying the preferences of the choices. A finite dialogue between two agents contains a sequence of dialogue steps (moves) and can be defined as:

$$(m_0, m_1, \ldots, m_n) \tag{1}$$

In Eq. 1, m_i represents an uttered move on the i^{th} turn. The moves contain a speech act and the supporting arguments. For example, in a dialogue between two agents, the moves with even indices belong to the starter of dialogue and the odd ones are related to the other agent. The current move tries to attack the previous move. When it is not possible to present another move to attack the previous one, the dialogue ends. The winner is the speaker of the last move [1].

Suppose that D is the set of all speech acts allowed by the protocol:

$$Moves= \{(a,c) | a \in D \text{ and } c \in Content(a),\ a,c \therefore Protocol(pr)\} \tag{2}$$

In Eq. 2, $a,c \therefore Protocol(pr)$ means that a and c are allowed by the protocol pr.

The agent selects each move based on specified goals and beliefs. The agents have two types of goals: strategic goals and functional goals which correspond to two groups of beliefs: strategic beliefs and basic beliefs of agents, respectively.

The strategic goals are high-level and long term goals which describe the targets of agent and the functional goals support the strategic goals and describe how the agent will achieve them. The strategic beliefs are the meta-level beliefs about dialogue in which the agents are involved. The basic beliefs are about the subject of dialogue and the environment [17]. Agents can select the suitable speech act and the related content according to strategic and functional goals respectively. In the preference based argumentation, the aforementioned goals and beliefs can be presented as weighted propositions. These weights can specify the preferences of so-called goals and beliefs. In the remaining of this section we have presented some essential definitions borrowed from [18] in this regard. Then we introduced our proposed method and some related definitions. It is worth mentioning that, to the best of our knowledge, almost all the previous works including [18] focus on individual utility for each agent in a dialogue while the present work deals not only with individual utility for each agent but also with the utility of a holon. It means that each agent tries to consider its own utility and teammate utilities at the same time. Team utility is a dynamic function determined independently by holonic organization in the form of public knowledge.

Suppose $\mathcal{L}$ is a propositional language and the set of well-formed formulas built from $\mathcal{L}$ is Wff($\mathcal{L}$). The sets of goals and beliefs can be presented in the following forms:

$$B_s= \{(bs_i, \delta_i),\ i= 1, \ldots, m \mid bs_i \in Wff(\mathcal{L}) \text{ is a strategic belief and } \delta_i \in [0, 1] \text{ is its certainty level}\} \tag{3}$$

$$B_b= \{(bb_j, \rho_j),\ j= 1, \ldots, n \mid bb_j \in Wff(\mathcal{L}) \text{ is a basic belief and } \rho_j \in [0, 1] \text{ is its certainty level}\} \tag{4}$$

$$G_s= \{(gs_k, \lambda_k),\ k= 1,\ldots, p \mid gs_k \in Wff(\mathcal{L}) \text{ is a strategic goal and } \lambda_k \in [0, 1] \text{ is its priority degree}\} \tag{5}$$

$$G_f= \{(gf_l, \gamma_l),\ l= 1, \ldots, q \mid gf_l \in Wff(\mathcal{L}) \text{ is a functional goal and } \gamma_l \in [0, 1] \text{ is its priority degree}\} \tag{6}$$

In Eq. 3 to Eq. 6, each item has a specific preference which may be different from others. These preference values are linearly scaled between 0 (minimum preference) and 1 (maximum preference). Suppose B_s^*, B_b^*,$G_s^*$and $G_f^*$are the sets corresponding to Eq. 3to Eq. 6, when the preference values are omitted.

As mentioned before, the dialogue strategy is selecting one move among allowed moves and it can be formalized as follows:

Definition 1. Considering the current move (a, c), the strategy is choosing the next move (a', c') to utter where a' ∈ Replies(a) and c' ∈ Content(a').

Let *X* be a set of choices (acts/contents), then an argument in favor of each individual can be written as follows:

Definition 2. An argument in favor of a choice $x \in X$ is a triple A = <S, g, x> such that:

- $S \subseteq B_b^* \cup B_s^*$,
- $g \in G_s^* \cup G_f^*$
- $S \cup \{x\}$ is consistent
- $S \cup \{x\} \rightarrow g$
- S is minimal with the above conditions.

In Definition 2, *S* is the support of the argument, *x* is the conclusion of the argument and *g* is the goal that the choice *x* is aiming for it. The certainty level and the degree of satisfaction of an argument $A = <S, g, d>$ are defined in Eq. 7 and Eq. 8. Also the strength of a given argument is according to Eq. (9).

$$Levels(A)=\begin{cases} \min\{\alpha_i \mid k_i \in S \text{ and } (k_i,\alpha_i) \in B_b \cup B_s\}, & S \neq \emptyset \\ 1 & S = \emptyset \end{cases} \quad (7)$$

$$Weights(A)=\beta \quad \text{with } (g, \beta) \in G_s \cup G_f \quad (8)$$

$$Strength(A)=<Levels(A), Weights(A)> \quad (9)$$

The concept of strength of arguments is used to compare them with each other. One way to define the comparison relation is as the following definition:

Definition 3. If A and B are two arguments, we can define the preference relation ≥ on them, whereas A ≥ B (means A is preferred to B), iff min {Levels(A), Weights(A)} ≥ min {Levels(B), Weights(B)}.

The relation ≥ is reflexive and transitive. Also we can define the preference relation on the conclusion of the arguments (set of choices) as:

Definition 4. If X be the set of possible decisions, $x_1, x_2 \in X$ and Arg(x) denoting the set of arguments which are in favor of x, then the relation ∇ can be defined on X, where $x_1 \nabla x_2$ iff $\exists A \in Arg(x_1)$ such that $\forall B \in Arg(x_2)$, $A \geq B$.

The relation ∇ is reflexive and transitive and it is used to define a pre-order (complete or partial) arrangement on the set of possible choices. Also we define the priority of a move as follows:

$$priority(move) = \min\{ priority(act) , priority(content)\} \quad (10)$$

4. PROPOSED DIALOGUE STRATEGY

In HMAS, an agent commits itself to accept the holon goals and accept constraints of its capabilities to act or to communicate according to the capabilities of the holon [10]. Agents choose the speech acts to utter based on their knowledge and the preferences in order to achieve their goals and optimize their benefits [19]. The agent's information of its state and the environment are defined by the belief model. In a holon, some knowledge and the public beliefs of agents are shared and are accessible to all members of the holon [2].Through a dialogue between agents of a holon, there is no need to exchange lots of these shared knowledge. While in the common dialogue strategy, this public knowledge may be exchanged between members frequently.

We propose a method that reduces the volume of exchanged message using the intersection of public beliefs. In the proposed model for dialogue strategy, when an agent wants to utter a move, it also considers the supporting arguments which are in the set of public beliefs. A schema of a dialogue strategy model in a holon is depicted in Fig. 3.

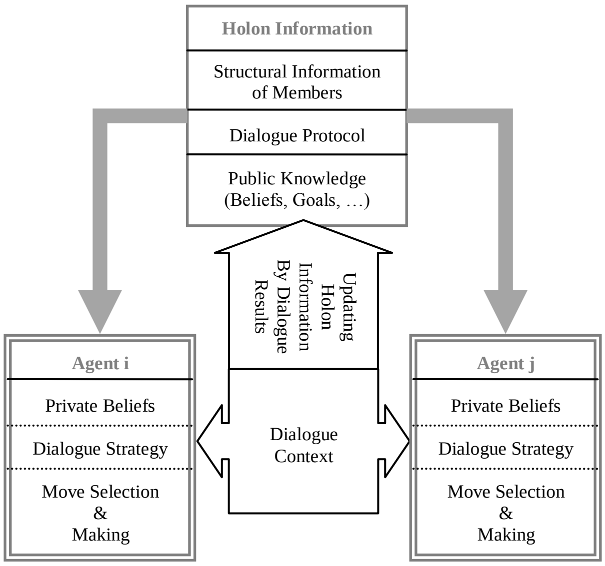

Fig. 3. Model of dialogue strategy in a holon

In the proposed model, when the agents want to communicate with each other, they choose the best move to utter according to Definition 1.

Consider the holon $H_i = <\mathcal{A}, C_i>$ that is the set of holon's commitments and $\mathcal{A} = \{A_1, A_2, \ldots, A_n\}$ is the set of members. The set of public beliefs of holon is defined as follows:

Definition 5. In holon H_i =<A, C_i> that contains n members, the set of public beliefs B_{ph} is:

- $B_{ph} = \{(bp_m, \mu_m), m=1, \ldots, z\}$

- $bph_m \in \bigcap_{1 \le i \le n} B_{Ai}^*$

- $\mu_m = \min\{\alpha_i \mid (bph_m, \alpha_i) \in B_{Ai}, i=1,\ldots, n\}$

- $B_{Ai} = B_b(A_i) \cup B_s(A_i)$

- $B_{Ai}^* = B_b^*(A_i) \cup B_s^*(A_i)$

In a dialogue, the beginner makes the first move according to its goals and preferences considering the dialogue protocol. Also other agents choose their replies according to the protocol and their preferences.

The members of a holon have some common goals (G_H) but each one of them may have different beliefs or the same beliefs with various certainty levels. Thus, when an agent wants to make a proper move, it focuses on strengths of the supporting arguments of the possible move.

According to argumentation based dialogue, each move tries to attack the previous ones. Also if an agent fails to dispute the truth proposition, it must accept it [1]. Therefore, if a move has been selected considering the public beliefs as supporting arguments, the next moves have less chance to attack it. In this way considering the public beliefs causes a reduction in the volume of needed communications. In other words, when the supporting arguments of current move are subsets of the public beliefs the chance of acceptance of it by the other agents will increase.

In the proposed model, some of plausible moves have a higher popularity compared to others. Suppose B_p^* defines the public beliefs of a holon without weights, we can define this popularity metric:

Definition 6. For A_i a member of the holon H, Let D be the collection of speech acts allowed by the dialogue protocol and S containing the supporting arguments in favor of the move m, we call m is popular if:

- m = (a, c), a ∈ D and c ∈ Content(a),

- $S \subseteq B_p^*$,

- S is minimal.

Based on Definition 6, we can rank the plausible moves at each step of a dialogue as follows.

Definition 7. A_i a member of the holon H, If M is the set of plausible moves, $m_1, m_2 \in M$, and Arg(m) denotes the set of arguments which are in favor of m, then the relation "◄" can be defined on M, where m_1◄ m_2 means the priority of m_1 is greater than or equal to m_2, iff any of the following conditions are satisfied:

- m_1, m_2 are popular, and $\exists$ A $\in$ Arg(m_1) such that$\forall$ B $\in$ Arg(m_2), A $\geq$B

- m_1, m_2 are not popular and $\exists$ A $\in$ Arg(m_1) such that$\forall$ B $\in$ Arg(m_2), A $\geq$B

- m_1 is popular and m_2 is not popular.

According to Definition 7, an agent is willing to select the move with high preference (in terms of certainty level or priority degree of supporting arguments and beliefs). The move with supporting arguments that are approved by other agents has more priority. Hence, the property "*popularity*" has a significant role in dialogue strategy in a holon of agents. The following definition determines the preference:

Definition 8. The best response to a given move (a,c) is move m =(a',c') whereas$\forall m_i \in$ M, m◄ m_i.

Based on these definitions, we propose dialogue move strategy in a holon which is shown in Fig. 4. This algorithm is introduced to compute the proper move in each step of a dialogue.

```
Algorithm. Computing the next move (DialogueHistory, CurrentMove (a, x), B_ph, A_k, B_Ak, G_P)
begin
ACT_set= ComputeReplies(a, B_ph*)
ifACT_set = Ø then
ACT_set= ComputeReplies(a, B_Ak*)
ifACT_set = Ø then
return(error)
for each act_i∈ACT_set do
begin
CONT_i_set = ComputeContents (act_i, B_ph*)
ifCONT_i_set = Ø then
CONT_i_set = ComputeContents (act_i, B_Ak*)
ifCONT_i_set = Ø then
begin
Move_i= ( act_i, ? )
preference(Move_i)= ComputePreference( act_i, 1)
end
else
begin
Move_i= (act_i, Best(CONT_i_set) )
preference(Move_i)=ComputePreference( act_i, Best(CONT_i_set))
end
ifMove_i ∉DialogueHistory
MOVES_set=Add(Move_i)
end
DialogueHistory=Add(Best(MOVES_set))
return Best(MOVES_set)
```

Fig. 4. The proposed algorithm for holonic next move computation

In the proposed model considering the history of current dialogue in a holon, we compute the next move selection with popular supporting arguments in each step of dialogue. Considering the dialogue protocol and the defined goals and beliefs of agents the model evaluates the preferences of allowed acts and their proper contents and returns the more preferable.

When an agent in a holon takes the turn to respond a given current move, the algorithm searches for speech acts which are allowed by the protocol and are supported by public beliefs in order to satisfy the defined goals of the holon and not rejected in a history of dialogue. In other words, the algorithm lists the possible options which have some supporting arguments among the public beliefs of the holon. If there is not a proper move, the algorithm searches for the allowed replies supported by own private beliefs of the agent.

The model evaluates every item in the list of possible moves and returns the most preferable move to utter using a preference based selection method. The preference of each pair of act and content is computed according to the priority degrees and certainty levels of the defined goals and their related beliefs. In the proposed model, the function *Best()* computes the preference of a move according to Eq. 10 and returns the proper one.

Note that, when the strategic and functional goals are not compatible, the model returns no valid item. It means that there is no rational choice.

5. ILLUSTRATION THROUGH AN EXAMPLE

In this section, we study a common example of deliberation dialogue in a holon to illustrate the effectiveness of the proposed model [20]. Deliberation is a kind of cooperative dialogue between agents. It occurs when agents need to reach an agreement on a specified subject or make a joint decision [21]. Through the dialogue, one agent proposes the option that it believes in. Other agents may have different interests and beliefs. Thus, if the option is desirable to others, they can support it and when the option is undesirable, they can reject or ask about the support of the presented option. An agreement is reached when an option wins.

We apply a deliberation example [22] between agents of a holon. In a holon, agents have some common beliefs and goals. Also they may have some private and different beliefs and aims. But in the holonic organization all the member of a holon must be committed to the holon's goal.

For example, suppose three agents $\{A_1, A_2, A_3\}$ in a holon need to decide where to go for dinner. They cooperate to aggregate on a joint decision while they have different beliefs and also different food desires. The agents can propose their proposals or consider other agents' proposals according to their goals and beliefs until reaching an agreement. Agents can assert their arguments in favor/against an action or pass their turn with no action. The dialogue protocol and the set of replies for each speech act can be stated by the following:

- ***propose*:** to assert an action or positive argument in favor of an action. The set of its replies contains: *refuse*, *pass.*
- ***refuse*:** to assert a negative argument against the last proposed action. The set of its replies contains: *propose*, *pass*.
- ***pass*:** to pass the turn without saying anything (also this means agreeing with the last proposed action). The set of its replies contains: *propose*, *refuse*, *pass*.
- Suppose A_1 is the beginner of the dialogue then A_2 and A_3 have the next turns, respectively. Therefore, the dialogue starts with assert of an action by A_1 then A_2 and A_3 present their replies alternatively until reaching an agreement or when the dialogue ends.
- The holon's strategic goals are to minimize the deliberation time and also to respect the food tastes of members. While the agents want to enjoy the food, they cooperate to select a no restricted one. Therefore, the strategic beliefs are uttering the '*propose*' instead of '*refuse*' which leads to less waste of time for deliberation. Thus, in response to a presented proposal, other agents will '*refuse*' if only they have some arguments against the presented option. If they have some arguments in favour of it or they have no arguments in favour/against, they will choose '*pass*' to utter. The strategic goal and the strategic belief are written in formal as:

G_s = {(min-time, 0.8), (selfishness, 0.7)}

B_s = {(propose → min-time, 1), (pass → min-time, 0.8), (refuse → selfishness, 0.8)}

Agents want their foods to be tasty and healthy to enjoy their dinner, but they have various preferences in choosing tasty or healthy or both. The functional goals and basic beliefs are as follow:

G_f = {(enjoy, 0.8), (healthy, 0.6)}

B_{b1} = {(Pizzeria (pizza pepperoni) → tasty, 1), (TGI Friday's (lasagna) → ¬low-calories, 1), (TGI Friday's (soup) → low-calories, 1), (TGI Friday's (soup) → tasty, 0.6), (tasty→ enjoy, 1), (low-calories → healthy, 0.8)}

B_{b2} = {(Pizzeria (pizza pepperoni) ∧ topping (dull) → ¬ tasty, 1), (TGI Friday's (salmon) → tasty, 1)), (TGI Friday's (vegetable plate) → healthy, 0.9), (tasty→ enjoy, 1)}

B_{b3} = {(TGI Friday's (lasagna) → tasty, 1), (TGI Friday's (salmon) → low-calories, 0.8), (tasty→ enjoy, 1), (low-calories → healthy, 0.8)}

According to Definition 5, the public beliefs of agents are:

B_p = {(propose → min-time, 1), (pass → min-time, 0.8), (refuse → selfishness, 0.8), (tasty→ enjoy, 1)}

Consider the following scenario in dialogue between these agents:

According to the beliefs and goals the possible acts for A_1 are '*propose*' and '*pass*'. '*pass*' does not need a content. If we don't consider the public beliefs, based on basic beliefs of A_1, there are two proper contents for '*propose*': '*Pizzeria (pizza pepperoni)*' and '*TGI Friday's (soup)*'. Therefore, three moves are probable to present and the preferences of these moves are computed by Eq. 10:

M_1= pass

Preference (M_1) = 0.8

M_2= propose (Pizzeria (pizza pepperoni))

Preference (M_2) = min {1, 1} = 1

M_3= propose (TGI Friday's (soup))

Preference (M_3) = min {1, 0.8} = 0.8

Therefore, the most preferable move to utter is M_2. Now according to the proposed method which is depicted in Fig. 3, the reply set contains only M_1 and M_2. This is because the algorithm at first searches for acts or contents which are supported by public beliefs. If an option does not exist, the algorithm searches in all beliefs of the agent. Therefore our algorithm reduces the search space of possible acts and contents effectively. In this state, there is no argument in support of the '*low-calories*' in public beliefs. Hence at the beginning of this deliberation example, A_1 compares only M_1 and M_2 and selects M_2 to put forward:

- *A_1 → propose (Pizzeria (pizza pepperoni) → tasty*

According to the protocol and in response to the previous move, A_2 has a counter argument against '*Pizzeria (pizza pepperoni)*'. Therefore, it can choose among '*pass*' and '*refuse*'. In the same way, '*refuse*' is more preferable and A_2 utters:

- A_2 → refuse (Pizzeria (pizza pepperoni) ∧ topping (dull)) → ¬ tasty

According to the dialogue protocol A_3 can pass its turn or assert an option. The possible contents for selecting are '*TGI Friday's (lasagna)*' and '*TGI Friday's (salmon)*'. But in a similar way as mentioned before, the algorithm adds only '*TGI Friday's (lasagna)*' to the list of contents. The algorithm decreases the number of choices in a well manner. Thus we have:

M_1= pass

Preference (M_1) = 0.8

M_2= propose (TGI Friday's (lasagna))

Preference (M_2) = min {1, 1} = 1

Therefore A_3 selects M_2:

- A_3 → propose (TGI Friday's (lasagna)) → tasty

Now A_1 has an argument against the previous move. Thus, it has two options '*pass*' and '*refuse*'. It computes the preferences similarly and then selects its move:

- A_1 → refuse (TGI Friday's (lasagna)) → ¬low-calories

A_2 can choose among '*pass*' and '*propose*'. It has arguments in favor of '*TGI Friday's (salmon)*' and '*TGI Friday's (vegetable plate)*'. The plausible moves are:

M_1= pass

M_2= propose (TGI Friday's (salmon))

M_3= propose (TGI Friday's (vegetable plate))

Preference (M_1) = 0.8

Preference (M_2) = min {1, 1} = 1

Preference (M_3) = min {1, 0.9} = 0.9

And then we have:

- A_2 → propose (TGI Friday's (salmon)) → tasty

A_3 has no argument against the last presented option, therefore passes its turn:

- A_3 → Pass

And A_1 has no argument against the uttered move by A_2 and its choices are the following moves:

M_1= pass

M_2= propose(TGI Friday's (soup))

Preference (M_1) = 0.8

Preference (M_2) = min {1, 0.6} = 0.6

And its selection is:

- $A_1 \rightarrow$ Pass

Finally, the agents' agreement is 'TGI Friday's (salmon)' and the dialogue is ended. Note that if we don't consider the public beliefs, in the last step A1 has another argument in favor of '*TGI Friday's (soup)*' which is '*TGI Friday's (soup) → low-calories*' with preference value of 0.8. Therefore ignoring the public beliefs may cause to present the move '*TGI Friday's (soup)*'. This means that the dialogue does not end and the volume of exchanged messages will increase.

6. CONCLUSIONS

A MAS organization model defines the structure of agents, their groups, their roles and interaction patterns. Holonic organization is a hierarchical structure of some recursive parts named holons. In a holon, the group of agents cooperate together to reach common objectives of the holon. Agents in a holonic system can communicate laterally between their teammates in a holon or can send their messages to other holons through a head of the holon. In this paper, we focused on lateral communication between agents in a holon. All members of a holon must be committed to the defined common goals of the holon. Also in a holon, agents pass their messages according to some rules called dialogue protocol. The protocol defines which speech acts are plausible for replying a presented speech act. Using dialogue strategy, agent can select the most preferable speech act among allowed ones by the protocol.

In this paper, we introduced a dialogue strategy for a group of homogenous agents in a holon based on argumentation concepts. We apply argumentation concepts to define the preferences of allowed speech acts and make decisions to select the most preferable move. The main idea is to determine the public beliefs of holon which are the base of making decision about which speech act is the best. Applying the agents' public beliefs in dialogue strategy decreases the volume of exchanged messages. We have used the argumentation theory to determine the priority of dialogue moves, and making decision for selecting the best one.

The proposed method can be applied in various dialogue types. In this paper, we have illustrated our algorithm through an example of deliberation dialogue in a group of agents in a holonic organization. Via this example we saw that the proposed method has significant efficiency in decreasing the number of exchanged messages.

In this work, it is assumed that all agents have the same role in a holon. As a future work, we will apply the proposed method in vertical dialogue in holonic multi agent systems. In that case the priority of the goals, beliefs and supporting arguments and also the autonomy of members of holons are different according to their roles and levels.

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