Agent Based Task Specific Team Formation for Effective Distributed Decision Making

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***Abstract*—Getting solution of a problem by group discussion is more reliable than getting solution from a single entity. To increase reliability of the solution, efficient group of experts should be formed. Here in this paper we have proposed a methodology for finding efficient team of experts for solution of a given problem collaboratively. The methodology is conceptualized with the notion of Multiagent system. We have considered several factors like Cardinality of team, ability, willingness, trust and reciprocality of an agent in order to construct the team. We have also proposed an optimization function which will be used to choose most eligible agents to form the team of experts.**

$Keywords:$ Multi agent system, Expert agents, Team formation, Ability, Willingness, Trust, Reciprocality, Group Cardinality.

I. Introduction

An agent [20], [21] is a computer system or software that can act autonomously in any environment, makes its own decisions about what activities to do, when to do, which type of information should be communicated with whom, and how to assimilate the information received. Multi-agent systems (MAS) are computational systems in which two or more agents interact or work together to perform a set of tasks or to satisfy a set of goals.

Decision making is a cognitive process in which a course of action is choosen among several alternative scenarios. This decision making process can be centralised or distributed in nature. In centralised decision mechanism, decision is taken by a single entity whereas in distributed decision mechanism [23], a number of team members collaboratively take the decision. A decision support system is a computer based information system that supports decision making process.

Multi agent system(MAS) based distributed decision support system [22] is a system where number of software agents which are physically distributed in nature take a decision of a given problem collaboratively. Here each agent plays role of a human entity in human-based group discussion methodology. Like human based discussion method each agent communicate with each other via message passing through a network i.e. share their opinions or decisions regarding to a given problem for its solution.

In order to get an effective solution of a given problem, a team of expert agents should be formed in which all the members are very much capable and willing as well as highly trustable. If the number of team members is very large, then the cost of decision making increases as large number of message passing is required but reliability of solution increases however if number of team member is less, then cost decreases but reliability also decreases. So to form a team with maximum reliability of solution and minimum cost, an optimum team size should be choosen.

Rest of the paper is organised as follows, Section II surveys some of the related works, Section III describes scope of work. In section IV we present our problem. In Section V some of the metrics are discussed for analysing an agent's behaviour. Section VI discuss about the solution we propose. In Section VII a case study and simulation of our proposed algorithm is described and finally Section VIII presents our conclusion and future works.

II. Related Work

There have been a significant amount of contributions in the reasearch area regarding team formation or coalition formation in Multi Agent Systems or in social network. We surveyed some of it. In[1], [5], [8], [9] Authors discuss regarding team formation dynamically based on resources available to an agent, also on the feasibility of Inter-agent network and in [10] author discuss about team formation from game theoretic approach, however to form an efficient team and to make it function effectively, it is very much important to consider the individual behaviour of agents, but [1], [5], [8], [9], [10] lacked behaviours like willingness of an agent towards the task, how much trustable an agent is and so on. In[2] Authors include a parameter called "attitude" of an agent to measure the trust of other agents and in[12] author introduces the concept of clan formation : agents who trust other agents and have similar objectives, in[13] authors discuss coalition formation based on trust and satisfaction among agents, however [2], [12], [13] missed one fact, that even if an agent is very much trustable, it may not have the required skill set for the task, it may not be willing to do the task. In[3], [4], [6], [11], [14] Authors consider regarding individual's skill set or capability of each agent for the task, also collaboration among team members but it lacked to include the trust factor of individual agents. In [7] Author discuss about, each agents knowing the capability of other agents for forming a coalition but it lacked to discuss on skills that each agent need to have, to solve a task.

III. Scope of Work

There have been a lot of contribution in the area of Team formation. In brief, some [1], [5], [8], [9] have concentrated on agent newtork topology, [3], [4], [6], [11], [14] on capability and collaboration of agents and [2], [12], [13] on trust among agents to form a team. But there is very little work on team formation by considering all neccessary factors like willingness, ability, trust value of an agent. In our work we have proposed a system for team formation by taking minimum number of agents having maximum ability, willingness, trust value and reciprocality. We have also simulated our proposed system by JADE(Java Agent Development Framework) tool with a case study.

IV. Problem Formulation

Let A = { A_i | i $\in$ [1,n] } is a pool of agent.
And S_{univ} = { S_j | j $\in$ [1,m] } be the universal set of skills which are required to perform any task in a particular domian.

Each agent A_i where i$\in$ [1,n] has it's own skill set $S_{Ai} \subseteq S_{univ}$ in their Knowledge Base(*KB*).

Now suppose from a user U, a problem *P* comes to an agent $A_i \in A$ and suppose A_i identifies the required skill set to solve the problem. As it doesn't have the identified skill set in it's *KB*, it cannot solve it. Thus it forward the skill set to it's neighbouring agents for a collaborative solution and initiate the request for Team Formation.

Now we have to build a group of expert agents $G_f \subseteq A$ which will collaboratively provide an effective solution of the given problem *P*.
In rest of the paper we are using the term problem and task interchangeably.

V. Metric Definition

Here we consider some of the metrics to analyse the individual behaviour of agents in order to form an effective task specific team.

A. Skill set of an Agent

Skill set of an agent is defined as the various skills that an agent possess or develops in due course of time in it's knowledge base for solving any problem. Skill set of agent A_i is represented as S_{Ai}.

B. Ability of an Agent

Ability(Ab_i) of an Agent measures, how much the agent is capable of doing the task. Ability of an Agent A_i is represented as Ab_i
$Ab_i = \mid S_{Ai} \cap SP \mid / \mid SP \mid$
where SP is the skill set required to solve a task.

C. Reasoning Capability of Agent

Reasoning capability(RC_i) of an agent A_i is defined as the capability of that agent to perform correct reasoning in order to get solution of a given problem.
$RC_i = C_i \ / \ C_n$
C_n = Total number of problems in which agent A_i was involved for solving it along with other agents
C_i = Total number of problems in which agent A_i's initial assumption was same to the final solution obtained after discussion among agents.

D. Confidence of task provider on an Agent

Confidence of task provider on an agent A_i is task provider's impression on agent A_i's capability of performing any task in a particular domain. The task provider builds it's confidence on A_i from the output of predefined questionaries test. Let L={ L_i | i $\in$ [1,v] } is the set of linguistic levels to quantify the performance of an expert agent. Here *L*={*High(.9), Medium(.5), Low(.2)*}.

DM={ D_{m1},D_{m2},.,D_{mk} } is the set of different domains.

Task provider's confidence on agent A_i in domain D_{mi} will be mathematically defined as,
$Cf(A_i, D_{mi}, Low) = Cf_i = 0.2$
Cf_i : Confidence of task provider on an agent A_i is calculated using Algorithm 4

E. Known fraction of a group by an Agent

Known fraction of a group by an agent A_i is defined w.r.t to a Group say G_n is,
$K_i = \mid Gk_i \mid / \mid G_n \mid, \ Gk_i \subseteq G_n$
where Gk_i = Number of agents in G_n which are known to A_i, as in past each of them participated in atleast one discussion with A_i.

F. Past History Success Rate

Past History Success Rate(PS_i) of an agent A_i is similar to Reasoning Capability(RC_i) but w.r.t to a Group say G_n
$PS_i = PC_i \ / \ PC_n$
PC_n = Total number of problems in which agent A_i was involved for solving it with the agents of Group G_n.
PC_i = Total number of problems in which agent A_i's initial assumption was same to the final solution obtained after discussion among the group members of Group G_n.

G. Reputation of an Agent

Reputaion(R_i) of an agent A_i measures how much the agent is reputed in the agent society. It depends upon two factors Ability(Ab_i) and Reasoning Capability(RC_i) of an agent A_i.

$R_i = \alpha * Ab_i + (1 - \alpha) * RC_i$, where α is Reputation constant and $\alpha \in (0 , 1)$

H. Willingness of an Agent

Willingness (W_i) of an Agent A_i measures, how much the agent is willing to do the task assigned to it. It depends upon two factors Ability(Ab_i) and Reputation(R_i) of agent A_i.

$W_i = \beta * Ab_i + (1 - \beta) * R_i$, where β is Willingness constant and $\beta \in (0 , 1)$

I. Trust of an Agent

Trust (T_i) of an agent A_i measures how much the agent is trustable. It depends upon two factors Confidence of task provider on the agent(Cf_i) and Reputation(R_i) of agent A_i.

$T_i = \gamma * Cf_i + (1 - \gamma) * R_i$, where γ is Trust constant and $\gamma \in (0 , 1)$

J. Reciprocality of an Agent

Reciprocality (RP_i) of an agent A_i measures how much an agent is comfortable to work with other members of a group say G_n. It depends upon two factors (K_i) and Reputation(R_i) of agent A_i.

$RP_i = \delta * K_i + (1 - \delta) * PS_i$, where δ is Reciprocality constant and $\delta \in (0 , 1)$

K. Optimal Index of an Agent

Optimal index (O_i) of an agent A_i is defined as overall acceptability of the agent for performing a task. It can be represented as,

$O_i = \lambda_W * W_i + \lambda_T * T_i + \lambda_{RP} * RP_i - \lambda_{WT} * (\mid W_i - T_i \mid) - \lambda_{WRp} * (\mid W_i - RP_i \mid) - \lambda_{TRp} * (\mid T_i - RP_i \mid)$

where λ_W = Optimal willingness constant.
λ_T= Optimal trust constant.
λ_{RP}= Optimal reciprocality constant.
λ_{WT}= Optimal willingness trust constant.
λ_{WR_p}= Optimal willingness reciprocality constant.
λ_{TR_p}= Optimal trust reciprocality constant.

Every constants satisfy following relations,
$\lambda_W = \lambda_T > \lambda_{WT}$, $\lambda_{WT} > \lambda_{WRp} > \lambda_{TRp}$,$\lambda_W > \lambda_{RP}$ and λ_W, λ_T , λ_{RP} , λ_{WT}, λ_{WRp} , $\lambda_{TRp} \in (0 , 1)$

L. Average Index of a Group

Average index(GV_i) of a Group G_i can be defined by considering three factors Average Willingness $W_{av}(G_i)$ of the group, Average Trust $T_{av}(G_i)$ of the group, Average Reciprocality $RP_{av}(G_i)$ of the group. So it can be represented as,

$GV_i(G_i) = \lambda_W * W_{av}(G_i) + \lambda_T * T_{av}(G_i) + \lambda_{RP} * RP_{av}(G_i)$,

Where $W_{av}(G_i) = \Sigma_{\forall i, i \in Gi}\ W_i \ / \mid G_i \mid$
$T_{av}(G_i) = \Sigma_{\forall i, i \in Gi}\ T_i \ / \mid G_i \mid$
$RP_{av}(G_i) = \Sigma_{\forall i, i \in Gi}\ RP_i \ / \mid G_i \mid$

VI. Proposed Solution

Suppose from a user U a problem P of domain d_{mi} comes to an agent A_i for solution. Let A_i is not capable of finding the solution as required skill sets are not in it's knowledge base(*KB*). So agent A_i as a task provider starts finding a team of expert agents who can collaboratively make the solution from pool of agents in domain d_{mi}. Finding a team of experts can be done in two phases,

- Phase 1 : Initial Group Formation
- Phase 2 : Final Group Formation

A. Phase 1 : Initial Group Formation

Initially from pool of agents number of expert agents are selected to form a group G_i. The group should satisfy the following criterias:-

1) W_{av} is maximum : Average Willingness of the Group should be maximum. It can only be possible if the group contains agent with maximum willingness value.

2) Cover(G_i,SP) = SP: Cover(G_i,*SP*) can be defined as, Cover(G_i,*SP*) = *SP* $\cap$ ($\cup_{\forall j, A_j \in Gi}\ S_{Aj}$). Now Cover(G_i,*SP*) = *SP* will be satisfied only if,

- I) Each member of G_i must have atleast one skill common with *SP* in it's skill set.
  i.e $\forall$ j , $A_j \in G_i$, $S_{Aj} \cap SP \neq \emptyset$
- II) *SP* $\cap$ ($\cup_{\forall j, A_j \in Gi}\ S_{Aj}$) = *SP*.
  i.e (*SP* $\cap S_{A1}$) $\cup$ (*SP* $\cap S_{A2}$) $\cup$ .... $\cup$(*SP* $\cap S_{Ak}$) = *SP*

3) $\mid G_i \mid \leq$ MAX : In initial group G_i there should be atmost *MAX* number of agents. *MAX* is defined as an upper limit.

Initial group of agents can be formed according to Algorithm 1.

B. Phase 2 : Final Group Formation

After getting Initial Group G_i, we move to next phase i.e to find Final Group $G_f \subseteq G_i$, We obtain final group with following criterias:-

i) W_{av} is maximum
ii) T_{av} is maximum
iii) RP_{av} is maximum
iv) $\mid G_f \mid$ is minimum : The average index value(refer to section *V.L*) of final group should be maximum with minimum number of agents. Adding or subtracting more agents decreases average index value of that group.

Final group of agents can be formed according to Algorithm 3.

VII. Case Study and Simulation

In order to simulate our proposed methodology, i.e to form a team of expert agents we are considering a Virtual Medical Board System as a Case Study. In conventional Medical Board System, number of expert physicians discuss over the

Algorithm 1 Find Initial Group (*SP* , *MAX*)

Assumptions-
TP $\#Task\ Provider$
AID $\#ID\ of\ the\ Agent$
SP[] *#Array containing skill sets required to solve a task*
IG[*MAX*] *# Array to hold Initial Group member's IDs*
Nbr[] *# Array containing neighbouring agent IDs*
W # Willingness W = {low(0.2),Medium(0.5),High(0.8)}

```
W ← 0.8
initiate(∀i∈[0,length(TP.Nbr)] Nbr[i],SP,W )
Wait() # Wait for all agents to reply back
if length(IG) ≤ MAX then
   W ← 0.5
   initiate(∀i∈[0,length(TP.Nbr)] Nbr[i],SP,W )
end if
Wait()
if length(IG) ≤ MAX then
   W ← 0.2
   initiate(∀i∈[0,length(TP.Nbr)] Nbr[i],SP,W )
end if
Wait()
```

initiate(*AID* , *SP* , *W*)
-It's a primitive that triggers Agent with id AID to start executing a sub-routine Agent(SP,W)
- for Agent(SP,W) refer Algorithm 2

Algorithm 2 Agent(*SP* , *W*)

```
w ← findWillingess(SP)
if w ≥ W and coverI(AID,SP) != 0 then
   IG[i++] = AID
else {length(IG) ≥ MAX}
   if coverII(IG,SP) == TRUE then
      return
   else
      remove(AID with minimim(Ab_i) from IG)
   end if
else
   initiate(∀i∈[0,length(A.Nbr)] Nbr[i],SP,W )
end if
```

diagnosis of a patient with critical diseases. But medical board formation is a costly method as well as it needs very good infrastructure in hospital. Good infrastructure means availbility of highly skilled physicians and all necessary medical equipments for diagnosis. But in rural side hospitals above mentioned resources are rarely available. In this situation to provide medical board like facility to rural side people, a virtual medical board can be formed. In virtual medical board system a number of software agents act on behalf of expert physicians. This software agents reside in different government

Algorithm 3 Final-Group(G_i)

```
GOpt ← GV(G_i)
for i = 1 to | G_i | do
   AID = get Agent ID with minimum(O_i) in G_i
   Gv = GV(G_i - AID)
   if GOpt ≥ Gv then
      break
   end if
   GOpt = Gv
   remove (AID from G_i)
end for
G_f = G_i
return G_f
```

Algorithm 4 Cf_i of A_i

Assumptions:-
n *#Total number of questions in questionaries test*
correct-answer *#Total number of correct answers given by agent A_i in questionaries test*

```
if n ≥ correct-answer ≥ (3/4)*n then
   Cf_i = High
else {(3/4)*n > correct-answer ≥ (1/2)*n }
   Cf_i = Medium
else
   Cf_i = Low
end if
```

hospitals and medical units which may be in geographically disparsed location. Each individual software agents have their associated knowledge base(*KB*) which is represented by a set of symptoms with possible diseases. Like conventional medical board, in virtual medical board also, number of software agents, each represents one physician, can discuss with each other via message passing to perform the diagnosis of a patient properly. In order to form a group of expert software agents which will provide an effictive diagnosis of the patient, we are using our proposed methodology of team formation.

In our scenario, we are representing skill set(S_{Ai}) of an expert software agent A_i as set of symptoms which are in it's knowledge base. For a given skill set *SP* (here patient's symptom set) agent A_i can find possible disease name if those symptoms of *SP* are also present in it's *KB*.

Our problem here is to form a team of expert software agents which are best suited to perform diagnosis(finding possible diasease) of a patient with set of symptoms(*SP*). Now suppose the patient has following symptoms:-{ $Headache(A), BodyPain(B), JointPain(C), Chills(E),$ $PoorAppetite(F)$ } Each symptom is mapped with an alphabetic letter, here $Headache$ is represented as '*A*', $Bodypain$ as 'B' and similarly others thus *SP* = $\{A, B, C, E, F\}$
Suppose universal skill set(here symptom set) contains all possible symptoms of diaseases named from *A* to Z represented as

S_{univ}. So cardinality of universal skill set is 26. Each software agents also have symptom set in their *KB* which is subset of universal skill set. For example suppose agent A_i has skill set $S_{A1} = \{P, R, B, E, A\} \subseteq S_{univ}$ and so on $\forall$ i$\in$ [1,$|A|$].

Assumtions :-

- We have a special agent called Local Physician Agent(*LPA*), *LPA* is the agent to which, a patient reports about his illness and it determines the patient's symptoms (*SP*). Now LPA as a task provider forwards *SP* to the system and initaite the request for team formation.
- In our scenario in order to create the *KB* of software agents, we have randomised the symptom set(S_{Ai}) of each software agents between A to Z with $|S_{Ai}|$ equal to 4 or 5.
- We assume our system has 17 agents as Fig1 shows the network topology and out of this 17 agents, a team of experts will be formed.
- We are randomly calculating the values of various features of an agent such as Reasoning capability (RC_i), Confidence(Cf_i), Known fraction of a group(K_i) and Past Success Rate (PS_i). As this features are something that an agent develops in due course of time since inception of the system.

We are simulating this case study of virtual medical board using JADE tool. We randomly created the skill sets of each expert agent present in their respective knowledge bases. The network of created agents are shown in Fig1. Now *LPA* initiate the team formation request using $Algorithm1$ with *MAX* = 15 i.e initial group(G_i) with 15 members is formed. Fig2 represents Willingness, Trust and Reciprocality values of those 15 agents. Fig3 represents Optimal index values(O_i) of each agents in initial group. Next depending on optimal index value of agents in G_i *LPA* starts phase 2 i.e final group formation using $Algorithm3$. Fig4 represents number of iterations required to get the optimum number of members in the final group depending on average index value of the group $GV_i(G_i)$ in each iteration. In Fig4 Average index value at 0^{th} iteration is $GV(G_i)$, we can see that *GV* value after removing an agent(with minimum value of O_i) is more than the previous value and it goes like this till 4^{th} iteration. At 5^{th} iteration *GV* value decreases, so algorithm stops here and remaining agents in the Initial Group(G_i) are considered as the final members of the group. Hence we get the final group G_f which are best suited to perform the diagnosis of the patient. Fig 5 represents optimal index value of agents in the final group.

VIII. Conclusion and Future Work

In this paper we propose a multi agent based team formation mechanism for a task considering parameters like cardinality of team, willingness , ability, trust and reciprocality of the agent. We also propose an optimization function which evaluates the final team members.

We simulate our proposed system with a case study of virtual medical board formation using JADE and we are able to get the results which shows, our proposed algorithm produces an effective team of expert agent from an agent community which are best suited for the task. And effectivness of the team is determined by the average willingness, trust and reciprocality of the team as a whole.

In this paper we have not taken any real life data set to test and simulate our proposed system. Our future work will be to consider some real life data set of a specific domain and simulate our system to see whether it provides expected output. We also want to incorporate this system as a module of another system like Multi-agent based virtual discussion

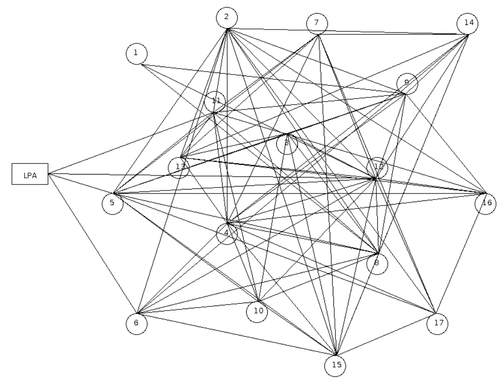

Fig. 1: Inter-Agent Network Topology

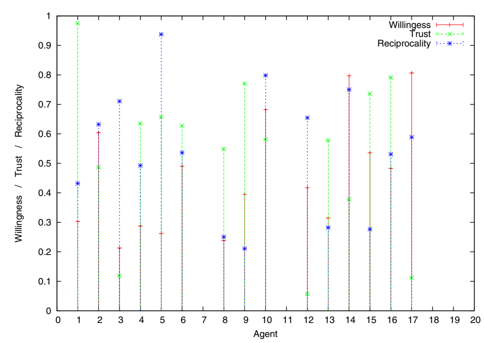

Fig. 2: Willingness, Trust and Reciprocality values of Initial Group members

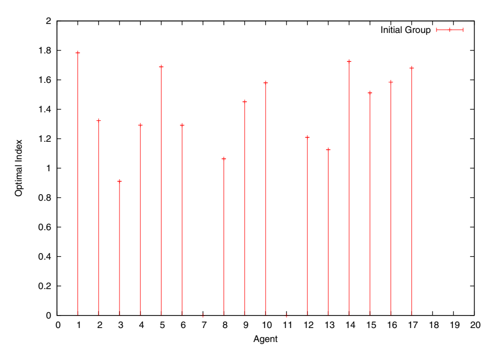

Fig. 3: Optimal index values of Initial Group members

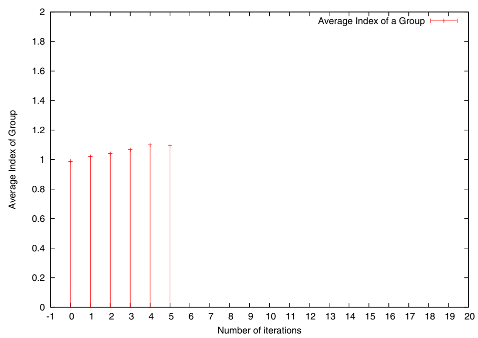

Fig. 4: Average Index value of Groups

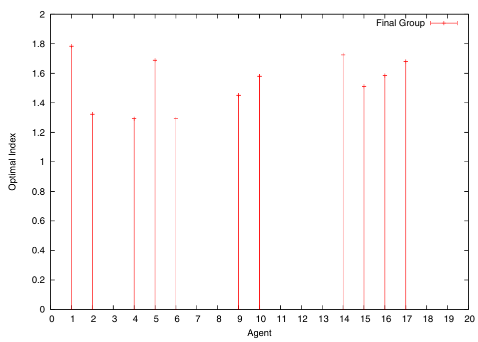

Fig. 5: Optimal index values of Final Group members

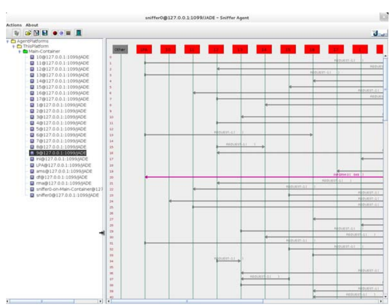

Fig. 6: Message passing among agents in JADE

mechanism where our proposed system can acts as starting module.

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