ISSN : 0974 - 7435 Volume 10 Issue 18

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(18), 2014 [10291-10297]

A mental state-based extended contract net model for agents' coordination

Zhangli[1,]*, Zhaochunjiang[2], Jiangdali[1], Zenyoujun[3], Wangqianzhu[4]
[1]The Institute of Modern Logistics, Logistical Engineering University, Chongqing, 401311, (CHINA)
[2]Department of Fundamental Studies, Logistical Engineering University, Chongqing, 401311, (CHINA)
[3]Department of Foreign Training, Logistical Engineering University, Chongqing, 401311, (CHINA)
[4]School of Software Engineering, Chongqing University of Posts and Telecommunications, Chongqing, 400065, (CHINA)
E-mail : zhangli_zju@163.com

ABSTRACT

To meet the specific requirements of Multi-Agent Systemtask allocation coordination, this paper puts forward an extended contract net model based on mental state constraints. The suggested mental state includes mental factors such as trust degree, loyal degree, active degree, risk tolerance degree, busy degree and urgency degree. By setting rational mental state parameters, it narrows down bidder agents to a rational and limited number, reducing significantly system communication cost. The mental state is applied from both the perspective of the manager agent and that of the bidder agents and it is more rational by employing different adjustment coefficients according to the property of the task. The system control employs a mixed structure of centralized and distributed control to reduce complexity. The overall task allocation coordination enjoys finer granularity by using ability and resource required by the task, instead of the whole task, as the basis of operation. Finally, the example of emergency relief support task allocation is descripted to validate the effectiveness of the suggested model.

KEYWORDS

Agent; Coordination; Contract net,mental factor; optimized method.

INTRODUCTION

Coordination is a process that ensures the concerted action of multiple agents[1]. Agents' coordination can prevent the MAS from being in anarchy, enable them to meet the requirements of overall restraints, and undertake and execute the task allocated. Multi-Agent System (MAS) coordination can be achieved with various techniques, such as blackboard mechanism, organization formation, contract net and intelligent planning, etc.

Coordination, as a basic technique in MAS, can be divided into two categories, namely centralized control and distributed control. Centralized-control coordination, which employs a traditional master/slave structure with the master agent allocating tasks and resources for the slave agent, is appropriate for a multi-agent environment with a clear organizational structure. The master agent is completely autonomous, while the slave agent is semi-autonomous. See references[2-4] for those relevant studies. However, centralized-control coordination has a default precondition that the master agent must know all the actual task requirements, environment information and the abilities and the resources of the slave agent. As it is very difficult to meet this precondition in most cases, centralized coordination cannot guarantee the willingness of the slave agent to undertake the task allocated, which lowers the efficiency of the overall system. Another strategy for MAS coordination is distributed coordination where there is no centralized-control master agent and all the agents negotiate and coordinate with each other on an equal footing. Contract net[5] is the basic technique in MAS task allocation coordination. The contract net protocol can guarantee the rationality of the task and the willingness of the contractor agent through the process of request for tender and submission of proposals. It also avoids communication bottleneck through equal and distributed control instead of limiting the message to one or a group of agents.

Although it can solve the problem of MAS distributed coordination, the traditional contact net protocol has various defects such as complex distributed control, heavy communication traffic, large resource consumption, uncertainty, and the inability to describe the dependency between tasks. Therefore, extension study based on contract net protocol has become a hot spot in MAS research. In recent years, many novel ideas and methods have come forth in the extension study of contract net protocol and been applied to practice. For example, Hsieh et al[6] puts forward the bi-layer contract net protocol and applies it to the workflow planning in HMS systems. Billington et al[7] extends the contract net protocol by employing the colored petri nets technology to support concurrent control based on multiple manager agents. Raza et al[8] establishes the Q-Contract Net by adding quality assessment factors to contract net protocol and applies it to digital business ecosystem. Similar studies include Luo's KEMNADmethod[9], Wong's multiple task-supported agents' negotiation protocol[10], Zhang's dynamic contract net protocol[11], Yen's shared mental model[12], etc. Among them, it is an important improvement to introduce mental concepts to contract net protocol so as to speed up coordination and reduce communication cost, which is discussed in references[11,12]. However, the above mentality-based contract net protocols are mainly focused on those basic mental state parameters such as acquaintance coalition and trust degree. Without considering mental state parameters fit for different scenarios such as loyal degree and risk tolerance degree, the discussion on mental states is not systematic. Besides, there are very few studies on how to apply the mental model to task allocation coordination, and research on task allocation usually remains on the prototype stage in most cases.

To solve the problems above, this paper takes task allocation coordination as the object of study and establishes a multi-agent extended contract net coordination model based on mental states. Some mental factors are introduced to narrow down the scope to request for tender and reduce communication traffic. Other mental factors are introduced to accurately describe the actual willingness of the bidder agents to submit proposals and to project the willingness as competitive tender price. The overall task allocation coordination is designed to meet the actual requirements of emergency command and networked manufacturing by combining centralized and distributed control, which lowers system implementation costs at the same time. The overall task allocation coordination takes ability and resource as the basic unit of a contract which has finer granularity and more rationality.

MODEL DEFINITION

Definition 1: The MAS extended contract net model based on mental states is defined as: *MS_CNP=<Mental_factor,Call_for_bidder, Bidding,Winner_selection>*. In this definition, *Mental_factor*meansthe agent's mental states at the time of task allocation; *Call_for_bidder=<Cfb_function, Cfb_algorithm, Cfb_letter>*, stands for, respectively, the bidder fitness degree assessment function, the bidder agent selection algorithm and the request for tender; *Bidding=<Bidding_function, Bidding_algorithm>*, stands for, respectively, the competitive tender decision function and the algorithm; *Winner_selection*stands for the winner selection algorithm, the valid tender proposal with the lowest price and the corresponding agent will be selected to be awarded the contract. $agent_m$stands for the manager agent; $agent_p$stands for the task candidate agents; $agent_b$stands for the bidder agents; and $agent_c$stands for the task contractor agent.

Definition 2: The mental states are defined as:*Mental_factor =<B,L,A,RT,BD,UD>*, which stands for, respectively, factors of the agent's mental states such as trust degree, loyal degree, active degree, risk tolerance degree, busy degree and urgency degree. The detailed description is shown in TABLE 1, in which, the $agent_p$ means the manager agent and the $agent_m$refers to the bidder agent.

TABLE 1 : The mental states of extended contract net model

Label	Name	Usage	Meaning
B	Trust degree	$B(agent_p, t_i)\ B \in [0,1]$	The trust degree of *agent*$_m$is an overall reflection of the performance of *agent*$_p$in completing tasks in history.
L	Loyal degree	$L(agent_p, agent_m)\ L \in [0,1]$	Loyal degree reflects the subordination of *agent*$_{p,}$ the task candidate agent, towards *agent*$_m$, and the closer the subordination, the higher the loyal degree.
A	Active degree	$A(agent_p, t_i)\ A \in [0,1]$	Active degree reflects the enthusiasm of participating tasks of *agent*$_{p,}$.
RT	Risk tolerance degree	$T(agent_p, t_i)\ R \in [0,1]$	Risk tolerance degree reflects the capacity of *agent*$_p$to take risks.
BD	Busy degree	$BD(agent_p, t_i)\ BD \in [0,1]$	Busy degree reflects how busy *agent*$_p$is at present.
UD	Urgency degree	$UD(agent_p, t_i)\ UD \in [0,1]$	Urgency degree reflects how *agent*$_p$assesses the urgency in performing the task.

CALLING FOR BIDDER

Calling for bidder refers to the process during which the manager agent selects the optimum task candidate agents to form the set of bidder agents and sends them the request for tender. The selection process includes three elements, namely the bidder fitness degree assessment function, the bidder agent selection algorithm and the request for tender.

Bidder fitness degree assessment function

Definition 3: When task$t_i$is to be allocated, bidder fitness degree is the comprehensive assessment value given by the manager agent concerning whether *agent*$_p$is fit for competitive tender. *Cfb_function*, its assessment function, is described as $Cf\_Bidder\_fitness(agent_p, t_i)$. The property of t_i, the task to be allocated, is classified into three categories, namely normal task, important task and urgent task. The value of $t_i.property$is a constant, namely *NOR, IMP,* and *ARD* respectively. Therefore, the bidder fitness degree is calculated as shown in Formula (1):

$$Cf\_Bidder\_fitness(agent_p, t_i) = \begin{cases} \alpha \times B + \beta \times A + \gamma \times L \\ t_i.\mathrm{property} = \mathrm{NOR}, 1 \geq \alpha > \beta > \gamma \geq 0, \alpha + \beta + \gamma = 1; \\ \mu \times B + \sigma \times L \\ t_i.\mathrm{property} = \mathrm{IMP}, 1 \geq \mu > \sigma \geq 0, \mu + \sigma = 1; \\ \varphi \times L + \rho \times B \\ t_i.\mathrm{property} = \mathrm{ARD}, 1 \geq \varphi > \rho \geq 0, \rho + \varphi = 1; \end{cases} \quad \textbf{(1)}$$

In Formula (1), $\mathrm{B, L, A}$ stands for three mental state factors, namely trust degree, loyal degree and active degree respectively, and $\alpha, \beta, \gamma, \mu, \sigma, \rho, \varphi$ is the weight coefficient. When t_i is a normal task, the mental state factors referred to in tender decision are trust degree, active degree and loyal degree in descending order of weight. When t_i is an important task, the mental state factors referred to in tender decision are trust degree and loyal degree in descending order of weight. When t_i is an urgent task, the mental state factors are loyal degree and trust degree in descending order of weight.

Bidder agent selection algorithm

Definition 4: Define the 0-1 matrix*TC, TR, AC, AR, TCA and TRA*. *TC*=[t_ic_j], where t_ic_j=1 stands for c_j, the ability required byt_i; *TR*=[t_ir_j], where t_ir_j=1 stands for r_j, the resource required byt_i; *AC*=[a_ic_j], where a_ic_j=1 stands for c_j, the available ability of agent a_i; *AR*=[a_ir_j], where a_ir_j=1 stands for r_j, the available resource of agent a_i; *TCA*=[$t_ic_ja_k$], where $t_ic_ja_k$=1 means that it needs to invite Agent $a_k$to participate in the competitive tender when t_i, the task to be allocated, requires ability c_j; *TRA*=[$t_ir_ja_k$], where $t_ir_ja_k$=1 means that it needs to invite Agent $a_k$to participate in the competitive tender when $t_i$requires resource r_j. Define the array TR_{letter}=[$t_ir_j.letter$], which stands for the request for tender corresponding to r_j, the resource required by task t_i. Define the array $T_{property}$=[$t_i.property$], which stands for the property of each task to be solved. Define *BD_limit*, which stands for tender quota. In other words, for a certain ability $c_j$or resource $r_j$required, the number of bidder agents to be invited in the competitive tender is no more than *BD_limit*.

Algorithm 1: Call_for_bidder ( )
Step 1: //Initialize *TCA*={0}, *TRA*={0}, *max_amount, BD_limit*. Input *TC, TR, AC, AR* and $T_{property}$. Define the variables amount_t, amount_c, amount_r and amount_a, which store the numbers of the tasks, abilities, resources and agents respectively.

Step2: // Set up the matrix *TCA*, and get the set of bidder agents for each ability of task.

```
for (inti=1; i<=amount_t; i++)
for (int j=1; i<=amount_c; j++)
if (TC[i][j]==1) { /*if t_i needs c_j*/
max_amount= 0;
for (int k=1; k<=amount_a; k++)
if (AC[k][j]==1) { /*if agent_k has c_j*/
TCA[i][j][k] = 1; max_amount++;
 }
}
for (inti=1; i<=amount_t; i++)
for (int j=1; i<=amount_c; j++)
if(max_amount>BD_limit) Operation_Cf_bidder_fitness(TCA[i][j][], BD_limit);
```

Step3: // Set up the matrix TRA with the specific process, similar to that in Step 2, omitted here.

Step4: // Produce the request for tender and send it.

```
/* Produce the task-ablity request for tender and send it*/
for (i=1; i<=amount_t; i++)
for (j=1; i<=amount_c; j++) {
TC_letter[i][j]= {agent_name, agent_addr, tc_des, bid_deadline, win_deadline, achieved_deadline, reward, penalty
};
Send(TC_letter[i][j], TCA[i][j][]);
 }
/* Produce the task-resource request for tender and send it, omitted here.*/
```

Algorithm 2: Operation_Cf_bidder_fitness(*TCA*[i][j][], *BD_limit*)

Step1: // Initialize the array position[*BD_limit*]={0}.

Step2: // Record the position of the first group of agents in *TCA*[i][j][] whose $Bid\_fitness$ is bigger and whose number is *BD_limit*in the array position[].

```
for (m=1; m<=BD_limit; m++) {
curr_max=1;
for (n= 1; n<= amount_a; n++)
if ((n not in position[]) && (TCA[i][j][n]==1))
if (Cf_Bidder_fitness(a_n,t_i)>Cf_Bidder_fitness(a_curr_max,t_i)) curr_max=n;
position[m]= curr_max;
 }
```

Step3: // Remove the corresponding relations which is not in matrixposition[].

```
for (m=1; m<=amount_a; m++) {
 if ((m not in position[] ) && (TCA[i][j][m]==1)) TCA[i][j][m]=0;
}
```

SUBMISSION OF PROPOSALS

Submission of proposalsrefers to the process during which the task candidate agents receives the request for tender and decides whether to bid. The key step is cost estimation, only when the cost is lower than the reward, the bidder agent will participate in bidding. The suggested process includes three elements, namely estimated cost, competitive tender decision function and tender price.

Estimated cost

Definition 5: When c_j, the ability required by the task t_i, is to be allocated, the estimated task-ability cost refers to the value of cost estimated by $agent_p$to perform the requirement, and it is described as $Cost(agent_p, t_i, c_j)$. As the property of t_i, the task to be allocated, is classified as normal task, important task and urgent task, the value of $t_i.property$ is constants *NOR, IMP* and *ARD* respectively. Therefore, the calculation of $Cost(agent_p, t_i, c_j)$ is as shown in Formula (2):

$$Cost(agent_p, t_i, c_j) = \alpha \times 1/RT + \beta \times BD + \gamma \times UD + \delta \times (penalty/reward) \begin{cases} t_i.property = NOR, 1 \geq \delta > \beta > \alpha > \gamma \geq 0, \alpha + \beta + \gamma + \delta = 1; \\ t_i.property = IMP, 1 \geq \alpha > \gamma > \delta > \beta \geq 0, \alpha + \beta + \gamma + \delta = 1; \\ t_i.property = ARD, 1 \geq \gamma > \alpha > \beta > \delta \geq 0, \alpha + \beta + \gamma + \delta = 1; \end{cases} \quad \textbf{(2)}$$

In Formula (2), RT, BD, UD are three mental state factors, namely risk tolerance degree, busy degree and urgency degree respectively; $penalty/reward$ refers to the penalty-reward ratio for task-ability/resource execution; $\alpha, \beta, \gamma, \delta$ is the weight coefficient. When $t_i$is a normal task, the estimated task cost assessment weights are penalty-reward ratio, busy degree, risk tolerance degree and urgency degree in descending order. When $t_i$is an important task, the weights are risk tolerance degree, urgency degree, penalty-reward ratio and busy degree in descending order. When $t_i$is an urgent task, the weights are urgency degree, risk tolerance degree, busy degree and penalty-reward ratio. Similarly, when resources are to be allocated, the estimated cost of task resource consumption is described as $Cost(agent_p, t_i, r_j)$ and the calculation refers to Formula (2).

Competitive Tender Decision Function

The decision function, which determines whether $agent_p$participates in competitive tender, is described in Formula (3).

$$Bid(agent_p, t_i, c_j) = \begin{cases} 1\ reward \geq Cost(agent_p, t_i, c_j) + \min\_profit; \\ 0\ reward < Cost(agent_p, t_i, c_j) + \min\_profit\ or \\ \qquad penalty > threshold\_num; \end{cases} \tag{3}$$

When $agent_p$receives the tender request for c_j, an ability required by t_i, whether it will participate in competitive tender depends on the value of the function $Bid(agent_p, t_i, c_j)$. When $reward$, the value of reward when the task is completed given in the request for tender, is greater than or equal to the sum of $Cost$, the cost of task execution, and $\min\_profit$, the minimum expected profit, the value of the function Bid is 1, which means it will participate in competitive tender. On the contrary, when $reward$ is less than the sum of $Cost$and $\min\_profit$, the value of Bid is 0, which means it will give up. Besides, when $penalty$ is greater than $threshold\_num$, the maximum value of penalty which $agent_p$can take, the value of the function Bid is 0, which means it will give up tender. Similarly, when it is r_j, a resource required by $t_i$that is for tender, the task-resource tender price is described as $Bid(agent_p, t_i, r_j)$, and its calculation refers to Formula (3).

Tender price

Definition 6: When $agent_p$bids for c_j, an ability required by t_i, task-ability tender price refers to the price expected by $agent_p$for performing c_j, and it is described as $Price(agent_p, t_i, c_j)$ whose calculation is shown in Formula (4).

$$Price(agent_p, t_i, c_j) = Cost(agent_p, t_i, c_j) \times (1 + \varphi)\ 1 \geq \varphi \geq 0 \tag{4}$$

In the Formula, φ is the profit coefficient, which is set in accordance with the property of $t_i$and the eager degree of $agent_p$towards the task. Similarly, when it is a certain resource required by the task that is for tender, the task-resource tender price is described as $Price(agent_p, t_i, r_j)$ whose calculation refers to Formula (4).

AN ILLUSTRATIVE EXAMPLE

Example setting

Suppose there is a problem concerned with emergency relief support decision-making: Set a normal emergency support task t, including the set of abilities required $C_t = \{c_1, c_3, c_5, c_8\}$, the set of resources required $R_t = \{r_2, r_3, r_6, r_8\}$, the set of Agents to be allocated the support tasks $A = \{a_1, a_3, a_4, a_5, a_6, a_8, a_9, a_{11}, a_{13}, a_{14}, a_{16}\}$. Randomly generate the Agentability relations: $A_{c_1} = \{a_1, a_3, a_6, a_9, a_{11}, a_{13}, a_{14}\}$; $A_{c_3} = \{a_1, a_4, a_6, a_8, a_{11}, a_{16}\}$; $A_{c_5} = \{a_1, a_3, a_4, a_9, a_{14}\}$; $A_{c_8} = \{a_9, a_{14}\}$. The Agent resource relations are: $A_{r_2} = \{a_1, a_3, a_4, a_6, a_{11}, a_{14}, a_{16}\}$; $A_{r_3} = \{a_1, a_5, a_8, a_9, a_{11}, a_{14}\}$; $A_{r_6} = \{a_4\}$; $A_{r_8} = \{a_4, a_5, a_8, a_{11}, a_{13}, a_{14}\}$. The result of allocation coordination for emergency support task t is sought.

Initial data

The initial data of the example refers to TABLE 2 and TABLE 3.

TABLE 2 : Mental states of candidate agents

Mental Index	a_1	a_3	a_4	a_5	a_6	a_8	a_9	a_{11}	a_{13}	a_{14}	a_{16}
Trust Degree B	0.3	0.8	0.1	0.6	0	0.4	0.7	0.4	0.5	0.3	0.9
Loyal Degree L	0.5	0.2	0.8	0.3	0.5	0.2	0.1	1	0.2	0.5	0.7
Active Degree A	0.1	0.5	0.3	0.1	0.4	0.2	0.9	0.5	0.2	0.7	0.9
Risk Tolerance Degree RT	0.2	0.6	0.3	0.5	0.1	0.7	0.8	0.3	0.2	0.5	0.7
Busy Degree BD	0.1	0.5	0.2	0.3	0.9	0.1	0.7	0	0.7	0.8	1
Urgency Degree UD	0.2	0.4	0.1	0.4	0.5	0.3	0.7	0.9	0.4	0.1	0.6

TABLE 3 : Relevant coefficients and constants

Name of Coefficients (Constants)	Value of Coefficients (Constants)
Bidder Fitness Degree Weight Coefficient	$\alpha : 0.55 \beta : 0.35 \gamma : 0.1$
Tender Quota	$BD\_limit : 4$
Estimated Cost Assessment Weight Coefficient	$\alpha : 0.15 \beta : 0.3 \gamma : 0.1 \delta : 0.45$
Penalty-reward Ratio ($penalty/reward$)	$c1$: 0.8; $c3$: 0.7; $c5$: 0.9; $c8$: 0.8; $r2$: 0.8; $r3$: 0.8; $r6$: 0.9; $r8$: 0.7
Profit Coefficient φ	a_1: 0.3; a_3: 0.4; a_4: 0.3; a_5: 0.5; a_6: 0.3; a_8: 0.4; a_9: 0.4; a_{11}: 0.5; a_{13}: 0.4; a_{14}: 0.3; a_{16}: 0.4

Result of task allocation

Suppose all the tender proposals are valid. Then the result of allocation coordination for emergency support task t is shown in TABLE 4 according to the processing of the suggested agents' coordination model.

TABLE 4 : Result of allocation coordination

t	$c1$	$c3$	$c5$	$c8$	$r2$	$r3$	$r6$	$r8$
$agent$	a_3	a_8	a_3	a_9	a_3	a_9	a_4	a_5

CONCLUSIONS

Based on the classical literature in the field plus improvement and extension aimed at actual requirements, the mental model put forward in this paper includes mental factors such as trust degree, loyal degree, active degree, risk tolerance degree, busy degree, and urgency degree. From the perspectives of the manager agent and the bidder agent, it employs different adjustment coefficients according to the property of the task, which makes the mental model more systematic and practical, and supports MAS task allocation more efficiently. Besides, this research uses a mixed structure to design MAS task allocation coordination by combining both centralized and distributed control. The manager agent selects the optimum bidder agent by employing the mental model and issues request for tender according to the task's requirements for ability and resource. With the mental model, the bidder agent does computation according to the requirements for ability and resource to get the tender price and submits its proposal. Then, the manager agent allocates the task according to the tender prices. The overall task allocation coordination uses ability and resource required by the task instead of the whole task as the basis of operation, achieving finer granularity and more rationality. Finally, the effectiveness of the MAS task allocation coordination model and its algorithm is verified by the example of emergency relief support task allocation.

ACKNOWLEDGEMENT

This work is supported by the National ScienceFoundation of China (Grant# 71101152). This workis also supported in partby the Natural Science Foundation Project of CQ CSTC(Grant2011jjA00008, 2011BB0045, 2010BB9200).

REFERENCES

[1] N.R.Jennings; Commitments and Conventions: The Foundation of Coordination in Multi-agent Systems. The Knowledge Engineering Review, **8(3)**, 223-250 **(1993)**.

[2] K.H.Chang, W.B.Day, S.Phiphobmongkol; An Agent-oriented MultiagentPlanning System. Proceedings of the 1993 ACM Conference on Computer Science: ACM, 107-114 **(1993)**.

[3] R.W.Quadrel, R.F.Woodbury, S.J.Fenves, S.N.Talukdar; Controlling Asynchronous Team Design Environments by Simulated Annealing.Research in Engineering Design, **5(2)**, 88-104 **(1993)**.

[4] Y.C.Jiang, J.Jiang; A Multi-agent Coordination Model for the Variation of Underlying Network Topology.Expert systems with applications, **29(2)**, 372-382 **(2005)**.

[5] F.S.Hsieh; Analysis of Contract Net in Multi-agent Systems. Automatica, **42(5)**, 733-740 **(2006)**.

[6] F.S.Hsieh, C.Y.Chiang; Workflow Planning in HolonicManufacturing Systems withExtended Contract Net Protocol. Proceedings of the 22nd InternationalConference on Industrial Engineering and Other Applications of Applied Intelligent Systems: Springer, 701-710 **(2009)**.

[7] J.Billington, A.K.Gupta, G.E.Gallasch; Modelling and Analysing the Contract Net Protocol-extension Using ColouredPetri Nets. Proceedings of 28th IFIP WG 6.1 International Conference: Springer, 169-184 **(2008)**.

[8] M.Raza, F.K.Hussain, O.K.Hussain, E.Chang; Q-Contract Net: A Negotiation Protocol to Enable Quality-based Negotiation in Digital Business Ecosystems. Proceedings of the Complex, Intelligent and Software Intensive Systems (CISIS)2010: IEEE, 161-167 **(2010)**.

[9] X.Luo, C.Miao, N.R.Jennings, M.He, Z.Shen, M.Zhang; KEMNAD: A Knowledge Engineering Methodology for Negotiating Agent Development. Computational Intelligence, **28(1)**, 51-105 **(2012)**.

[10] T.Wong, C.Leung, K.Mak, R.Fung; An Agent-based Negotiation Approach to Integrate Process Planning and Scheduling. International Journal of Production Research, **44(7)**, 1331-1351 **(2006)**.

[11] H.Zhang, Z.Shi; Dynamic Contract Net Protocol. Computer Engineering, **30(21)**, 44-47 **(2004)**.

[12] J.Yen, X.Fan, S.Sun, T.Hanratty, J.Dumer; Agents with Shared Mental Models for Enhancing Team Decision Makings. Decision Support Systems, **41(3)**, 634-653 **(2006)**.