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A Flexible Multi-agent System Model in System Simulation

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Abstract: The flexibility of process, rules and scope in modern command and control systems raises some new demands for the simulation of the command and control system. In this study a Multi-Agent System (MAS) framework model is proposed by introducing the Agent technology into the simulation of command and control systems. The structural model and process model of the MAS frame are presented. And strategies of extending the MAS frame application, modifying rules dynamically and changing cooperative relationship smoothly are given in accordance with the model's flexibility mechanisms. Then an Agent-based Command and Control Simulation Platform is implemented. Finally, the flexibility mechanisms of the framework model are verified by the application and experimental results in the anti-missile and air-defense command and control systems.

Key words: MAS, simulation, flexibility mechanisms, command and control systems

INTRODUCTION

In joint operation military systems, process and results of the command and control systems determine the operational efficiency of the whole combat system. And the effect depends on several key factors which always need immediate adjustment according to constant environment changes. So how to adjust these factors quickly and effectively is a problem that needs to be solved.

Command and control simulation is an effective means to test and improve the ways, styles and operational plans of command and control simulation systems. The Agent-based method introduces Agent's characteristics (Jennings and Wooldridge, 2001) into the simulation of command and control simulation systems, providing a novel idea and solution.

In recent years, many scholars have done plenty of research on the Agent Platform and Multi-Agent framework models. Xu *et al*. (2007), together with other people, studied a role-based open multi-Agent model, RADE (Role-based Agent Development Environment) which realized dynamically adding and removing Agents in running multi-agent systems. The CABLE, proposed by Dee *et al*. (1998), was a multi-Agent framework for the simulation of military command and control systems. Mason and Moffat (2001) proposed OACIS (Object Architecture for C2 In Simulations) model which made a clearly division and an effective description of the entities and their relationships in command and control simulation. However, all the achievements above give only a lukewarm support to the simulation of command and control systems. This study synthesizes the advantages of the relevant domestic and foreign research achievements and proposes a MAS framework model with some flexibility mechanisms that can be applied to the command and control simulation.

THE MAS FRAME MODEL

The structural model: Referring to the FIPA platform specification (http://www.fipa.org/specs/fipa00001/SC00001L.html) and on the background of command and control, we designed an Agent Based Command and Control Simulation MAS framework model shown in Fig. 1. The model consists of development module, configuration module, management module, command and control module, etc. In addition, two types of interfaces are given, one for development users and the other for management users.

In the model, Agent = <F, R, T>, in which F represents the function of an Agent. R represents the cooperation relationship of Agents. T records the type information of an Agent. Command and Control Module CCM = <Agent-1, Agent-2, …, Agent-m,…>, in which Agent-m represents an running Agent. In this module, each Agent can receive external messages, process them and then cooperate with each other and simulate the holistic command and control process. Management Module, providing various management functions, is defined as: MM=<ASM, ACM, ABM>. TheASM (Agent State Management) manages the state information of the

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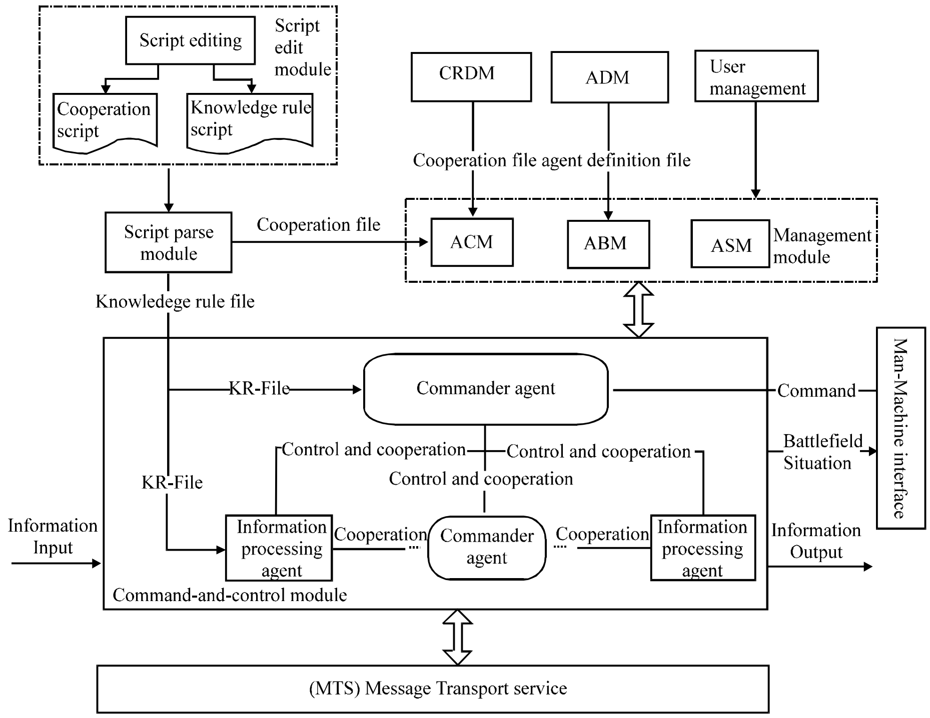

Fig. 1: MAS frame model applied to command and control simulation

running agents. The ACM (Agent Cooperation Management) distributes and manages the cooperation information of Agents. ABM (Agent Base Management) supports the generation, canceling, addition, deletion and collaboration of agents for the whole framework.

The MAS frame model is formally defined as: MAS=<SEM, SPM, CRDM, ADM, UM, MM, CCM, MTS, MMI>, in which SEM (Script Edit Module) describes the knowledge of Agents by using the script language. SPM (Script Parse Module) is capable of parsing scripts generated in SEM to do some troubleshooting and correction. Using CRDM (Cooperative Relationship Define Module) module, development users allocate and define the Agents' cooperation relationships. Development users use ADM (Agent Develop Module) module to develop required Agents. UM (User Management) offers interfaces for management users to manage the cooperation relationship, the states of Agents and the Agent base. MM (Management Module) is responsible for Agent State Management, Agent Cooperation Management and Agent Base Management. CCM (Command and Control Module) is in charge of simulating the holistic command and control behaviors. MTS (Message Transport Service) provides communication services and routes messages for Agents and modules in the frame. MMI (Man Machine Interface) provides interfaces for the commanders if necessary.

The process model: The whole working process of MAS framework module proposed in this study is divided into three stages, including development process, configuration process and simulation process. The concrete work in each process is described as follows:

Development process: As shown in Fig. 2, development users generate the required simulation resources with the developing and configuring tools by analyzing the simulation field. The specific Command and Control field and simulation factors should be analyzed. The process is divided into the business analyzing layer and the model functioning layer. Developers analyze the simulation fields and abstract the more independent function modules. They also abstract Agents with the corresponding abilities according to the characteristics of the function modules and then develop agents of the corresponding module. According to the Agent cooperation relationship developers define the cooperation relationships of Agents. Based on the logical description of Agent processing rules, developers describe Agent knowledge rules and the internal processing flows with Script Languages.

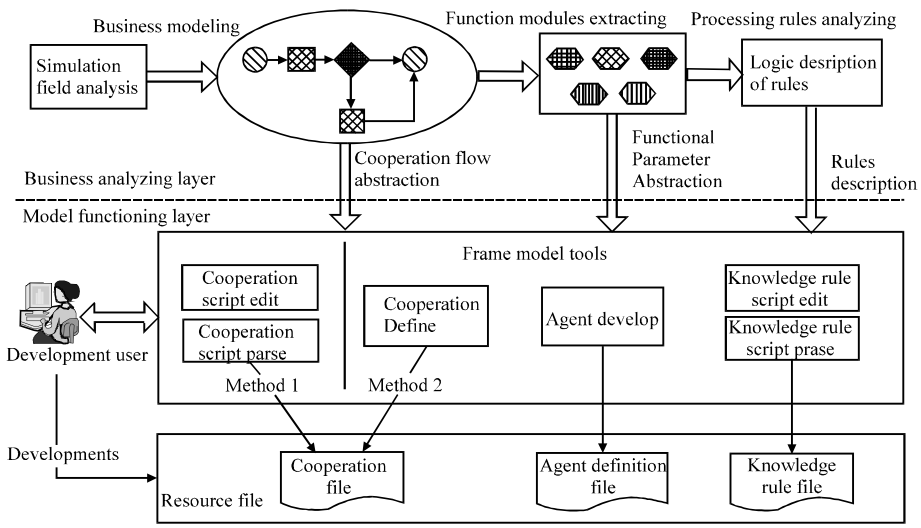

Fig. 2: The development process of MAS frame model

Configuration process: The main task of developers in this process is to choose the source files for simulation and set the relevant simulation parameters. Developers address the specific simulation requirements and add the needed Agents to Agent Base and then select the corresponding cooperation files to control the cooperation of Agents according to the scheduled command and control process. The Agents' behaviors are controlled by setting the Agent knowledge rules file. After setting the simulation parameters of the MAS frame, developers will get a simulation system meeting the specific requirements.

Simulation process: The working process of the framework model is divided into several steps. The ACM sub-module analyzes the cooperation relationship files to get the information of required Agent instances; Agent instances are generated by Agent Base; Agents register in the ASM sub-module; Agents send a request of cooperative Information to ACM sub-module; The ACM distributes Agents' cooperation information.

The agent model: Agent is the major running part in the Frame Model. The structure of the Agent provides the constructional support for Agent's cognitive approaches and business process flow. And it determines the working process and operation features of the Agent to a great extent. In the foreign related research, the Reactive Agent Model (Brooks, 1991) advanced by Brooks are representatives. The domestic representative research is the expanded and improved BDI Model based on formal language reasoning by Yi-Chuan and Chun-Yi (2003) and Kai *et al.* (2004).

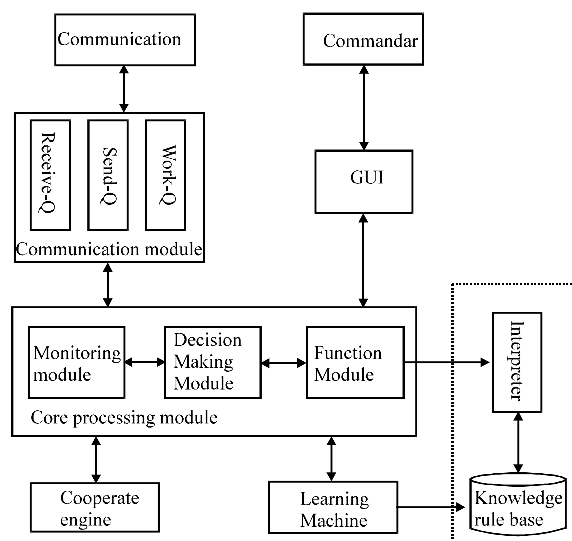

Fig. 3: Simulation process of MAS frame model

Based on the BDI Model theories, an Agent model is presented in the study, with its structure shown in Fig. 3. In the Agent structure, communication module is responsible for transmitting, receiving and storing Agent's messages. GUI is an interface between Agents and external commanders. Core processing module consists of the monitoring module, the decision-making module and the function module. Knowledge rule base is used to store the Agents' internal processing rules. Interpreter loads corresponding knowledge rule files according to the invoking information of the Function Module and completes the whole reasoning process. Cooperate Engine records, manages and updates

Agents' cooperation information. When Agents want to send a message, Cooperate Engine will work out the best receiver and support the Agents' communication. Learning Machine is able to learn the Agents' decision and internal rules, for instance, the battle plan learning.

THE FLEXIBILITY MECHANISMS OF FRAME MODEL

In order to solve the problems about the difficulties of model extension and the changeability of knowledge and cooperative processes, the MAS frame model provides flexibility supporting mechanisms so that the model can be extended to different command and control fields, realizing the dynamic modification of Agent knowledge and the smooth transition of cooperative relationship.

Extended application of the framework: The business and operations change greatly for different military command and control fields. Based on the framework model, script language is used to define and describe the business in the command and control process. Under different simulation requirements, factors, such as the abilities and characteristics of Agents, the Agents' knowledge, the cooperative relationship among Agents and so on, will change dramatically. The MAS frame model enables users to develop and define these factors quickly to meet different demands.

The extended application layers of the MAS frame model is shown in Fig. 4. It consists of the general command and control field layer, the specific command and control field layer and the specific application system layer.

Most of the components and functions in the MAS frame model work on the general command and control field layer. The specific command and control field layer can be formed from the general command and control field layer through configuring the script language and extending the interpreter functions. In the specific application system layer, configuration of simulation resources and parameters such as Agents resources, knowledge resources and cooperative relationship resources is required to generate a simulation system meeting the specific requirements. This layer works for specific simulation application systems.

Smooth transition of agents' cooperative relationship: The cooperation logic among Agents changes frequently in the command and control simulation. To adjust the change, the MAS frame model provides control mechanism for Agent cooperation which can alter the pre cooperation logic to a new one quickly and smoothly. The cooperation control process is shown in Fig. 5.

In the MAS frame model, users develop cooperation relationship files during the Agent cooperative definition and development stage. ACM loads and analyzes the cooperation relationship files and then distributes

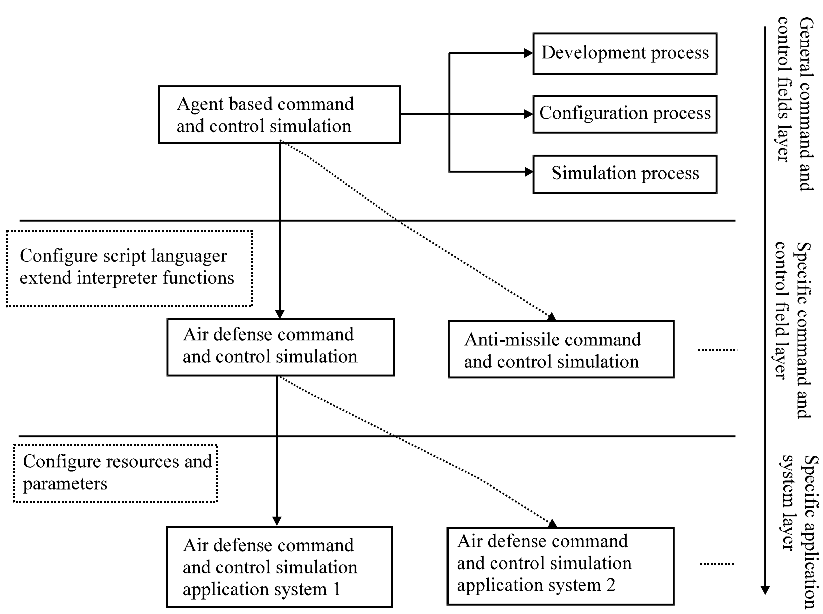

Fig. 4: The extended application layers of the MAS frame model

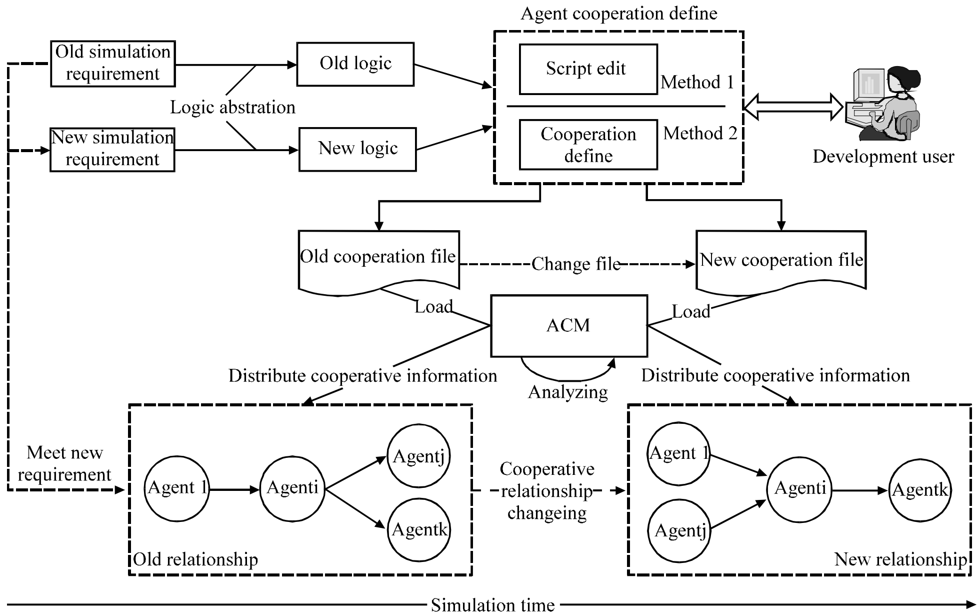

Fig. 5: The control process of Agent cooperation in the frame model

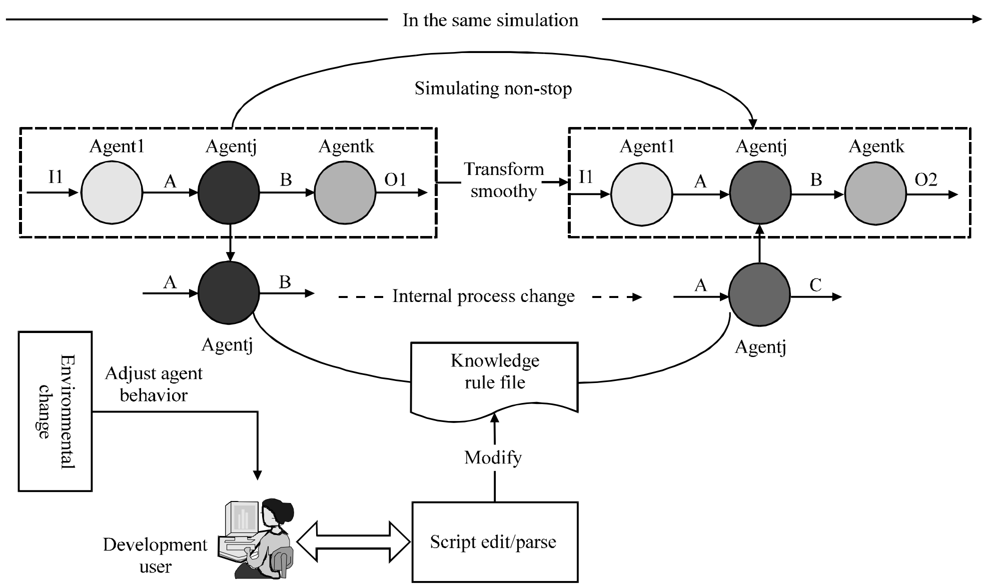

Fig. 6: The process to modify Agent's rules

collaboration information to Agents to complete the control process of Agent cooperation.

Under a new simulation requirement, users firstly get the new cooperate logic through business analysis and logical abstraction and then define the Agent cooperation relationship according to the new logic and develop a cooperation relationship file. At last, ACM analyzes the new file and distributes new collaboration information to Agents. The Agents update their cooperation logic. Then the pre cooperation relationship is changed to the new one. In the following simulation process, every Agent completes its work in the new cooperation logic.

Dynamic modification of agents' rules: In the command and control field, the internal process and behavior rules of command entity need adjustment with the changes of the environment factors to meet new war-fighting needs. The internal knowledge rules and process flows of Agents also need to be updated for an effective and realistic command and control simulation.

The MAS frame model provides a strategy to modify the Agents' rules dynamically. As shown in Fig. 6, each Agent obeys the established cooperation logic and its internal rules in the simulation process. When the simulation environment changes, it is necessary for users to modify some of the Agents' internal rules. With the support of MAS frame model, there is no need to stop the current simulation process. The user can analyze, modify and update Agent's rule files by using Script Edit Module. Once Agents detect that the rule file has changed, they use the latest one and then continue the simulation process. The whole process achieves a dynamic modification of the Agent rules and a smooth transition between different processes.

SIMULATION VERIFICATION AND RESULT ANALYSIS

The processing rules of the air-defense command and control system change continuously, so high real time ability is very significant for the system. The main procedure of the system is to process radar information and infer the battle space situation information and then calculate the threat level of enemy targets and the targets that should be intercepted and finally distribute weapons and intercept the enemy targets according to the rules of deploying weapons.

Relying on the framework model, an Agent-based command and control simulation platform is developed, on which the simulation of the air-defense command and control system is carried out.

The feasibility analysis of the MAS frame model: According to the analysis mentioned above, three function modules can be obtained in the simulation of the air-defense field, together with the cooperation flows and the internal processing rules. Based on the business analyzing layer, the information processing Agent, threat assessment Agent and weapons distribution Agent are developed with Agent Development Tools; The Agent cooperative relationship file is generated with cooperative-relationship define tools; agent knowledge rule files are generated with script develop Tools.

As soon as the simulation begins, Agents deal with the input plot messages with their own knowledge rules and then communicate and cooperate with each other according to the cooperative relationship. After that, an effective result is outputted. As shown in Fig. 7, the red is intercepting the blue raid-goal effectively. Both the analysis of simulation platform' processing procedure and the test result prove that the MAS framework model is feasible and effective.

The analysis of the flexibility mechanisms: It has been proved that the MAS frame model can make effective simulation in the air -defense command and control field.

Fig. 7: Distribution result of weapons in simulation

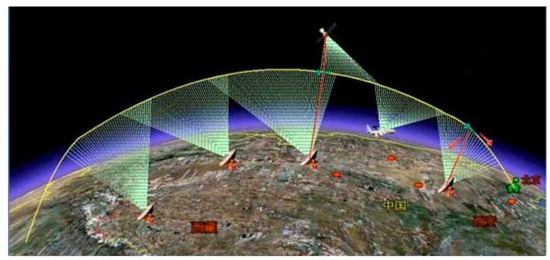

Fig. 8: Anti-missile command and control simulation process

In order to verify the frame model's extensive ability in different command and control fields, the Agent-based command and control simulation platform is applied to the anti-missile field. By configuring and updating the script language and the interpreter functions and developing Agent resources, knowledge rule resources and cooperative relationship resources, the simulation, shown in Fig. 8, is carried out after the configuration of the simulation parameters. Through the records and analysis of the process and the result, it proves that the application of MAS frame model in the anti-missile filed is effective. Meanwhile, the experiment also proves that the model has the ability to extend in different fields.

The MAS frame model realizes the dynamic modification of Agent knowledge and the smooth transition of cooperation relationship. In the traditional simulation way, the modification of rules and the transition of cooperation relationship are in a static way, carried out after stopping the simulation which is time-consuming. The MAS frame model provides flexibility mechanisms to solve the above problem with good timeliness.

As the modification of Agent knowledge and the transition of cooperative relationship have similar controlling mechanism, we only choose the efficiency comparison of modification of Agent knowledge for

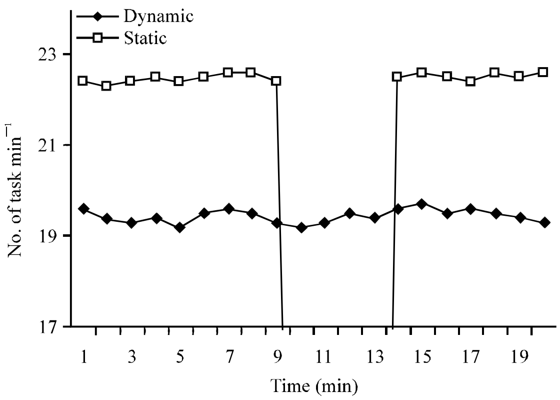

Fig. 9: Efficiency of dynamic modifications of Agent rules

analysis. We compared the efficiency of the dynamic modification way with the traditional static way. The Agent efficiency is represented by the number of accomplished tasks in unit time. In this study we only consider the number of successful tasks. The simulation begins after all Agents' initialization and continuously running for 20 min. We modified the knowledge rules of the weapon distributing Agent in both the traditional and MAS-based systems at the 5th min. As shown in Fig. 9, we can see the efficiency of the weapon distributing Agent working both in a dynamic way and in a static way.

As indicated in Fig. 9, the simulation system should be suspended in the traditional static way. Thus, in the suspended period, for example at the tenth minute, the efficiency is about zero, while in the dynamic way the efficiency keeps nearly unchanged which proves that it is effective for the MAS framework model to modify Agent knowledge rules dynamically.

CONCLUSION

The experimental results showed that the flexibility mechanisms can support quick application extension in simulation of different fields and flexible system building to meet different simulation requirements. However, an amount of developing and configuring work still needs to be done when the model extends its application to different fields and further research is required to improve the ability of extending its application.

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REFERENCES

Brooks, R.A., 1991. Intelligence without reason. Proceedings of the 12th International Joint Conference on Artificial Intelligence, Aug. 24, Sydney, Australia, pp: 569-595.

Dee, C., P. Millington, B. Walls and T. Ward, 1998. CABLE: A multi-Agent architecture to support military command and control. Proceedings of the 3rd International Conference on the Practical Applications of Agents and MultiAgent Systems, London.

Jennings, N.R. and M. Wooldridge, 2001. Agent-Oriented Software Engineering. In: Dans Handbook of Agent Technology, Bradshaw, J. (Ed.). AAAI/MIT Press, USA.

Kai, D.M., Z.H. Jun and S.Z. Zhi, 2004. An agent model based on dynamic description logic. J. Comput. Res. Dev., 41: 780-786.

Mason, C.R. and J. Moffat, 2001. An Agent architecture for implementing command and control in military simulations. Proceedings of the Winter Simulation Conference, Dec. 9-12, Arlington, VA., USA., pp: 721-729.

Xu, H., X. Zhang and R.J. Patel, 2007. Developing role-based open multi-agent software systems. Int. J. Comput. Intell. Theory Pract., 2: 39-56.

Yi-Chuan, W. and S. Chun-Yi, 2003. A concurrent BDI-agent model. J. Software, 14: 422-428.