Multi-agent Simulation for the Adaptive IT Capability based on Swarm

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***Abstract*—In this paper we try to focus on the adaptive IT system's capability of an enterprise, which describes the organization's IT ability to support changes in firms' products, services, business processes, organizational structures and competences when necessary. Based on the multi-agent simulation methodology, this paper analyzes the evolution of adaptive IT capability and its influence on the enterprise performance. The results show that the evolution of adaptive IT capability has complexity and dynamic adaptability. These promote us a good perspective for the evolution of adaptive IT capability and the notions of adaptability and complexity.**

Keywords-multi-agent simulation; adaptive IT system; IT capability; competitive advantage; CAS

I. INTRODUCTION

The emergence of the complex adaptive systems (CAS) theory gives rise to study many IT capabilities in the of enterprise capability, and pushes many researchers to adopt this methodology to study, understand and control the enterprise capability (Stephen, 2003; Jason, 2007; John H, 1995) [1]~[3]. The combining of the CAS theory and the study of enterprise capability with other tools as the multi-agent modeling and the computer simulation give a better explanation of the evolution of the enterprises competitive capability (Xiuquan & haorun, 2008; John & Scott, 2007; Richard M & Mark A, 2000)[4]~[6], and many work has been done on this way for modeling the enterprise capability and the adaptive IT capability (Benedikt, 1997; Christoph, 2005; Haorun, 2009; Nigel & Pietro, 2000)[7]~[10]. In the way of explaining the enterprise competitive capability, the study of the adaptability characteristics of the enterprise and their components is necessarily recommended, and present one of the keys of the understanding of enterprise evolution.

Therefore, the combining of CAS theory and multi-agent simulation theory gives not just the possibility of studying and modeling the enterprise capability, but also the possibility of analyzing the evolution of these capabilities. Recent researches had tied to build a path for this field (Zott, 2003; MARITAN, 2004; Ane, Serra, Villani, & Ansaloni, 2004/2005)[11]~[13] by studying the dynamic side of the enterprise capability, contrary to many searches where the enterprise seen just as an affected entity by the environment (John & Scott, 2007; Haorun,2009)[5][9]. These recent studies focus on the adaptive capabilities of the enterprise as an entity, which can contribute to the evolution of the environment. Thus, in our study we focus on these aspects to study the adaptive IT capability and their competitive advantage in the evolution of the environment, and simplify the study to analyze the adaptive IT system where the result could be generalized in such way to similar adaptive IT capability.

II. THEORETICAL FOUNDATIONS

A. A Brief Introduction of CAS Theory

The theory of complex adaptive system is proposed by SFI School which is one of five schools of complex science (John H, 1995)[3]. Its core idea is "Adaptability creating Complexity" that the evolution of system benefited from the "living" agent. In order to adapt to the environment or to win the right to survive, agents will adjust their behaviors constantly according to the external environment and other agents (Guoling Lao, 2008)[14]. To use a resource, an agent must contact the agent that provides it (Desai D, 2005)[15]. Complex adaptive system theory provides a new perspective to explain the evolution of enterprise IT capability.

B. Multi-agent Simulation Platform-Swarm

Multi-agent modeling and simulation is a main tool to study complex adaptive system. Until now, there have been a few platforms for multi-agent modeling and simulation. Among them, Swarm is regarded as a popular one. The basic architecture of Swarm is the collection of concurrently interacting agents. With this architecture, a large variety of agent-based models can be implemented. Swarm provides abundant components and a program framework for researchers to create system models (Honglei Li,2007) [16].

III. IT CAPABILITIES AND ADAPTIVE IT CAPABILITY

IT capabilities refer to an organization's capacity to deploy IT resources, usually in combination with other organizational resources (Bharadwaj, 2000)[17]. They can result in improved IT performance (Wang & Ahmed, 2007) [18]when organizations utilize them to deploy IT resources together with other complementary organizational resources to form IT support for core competences (Zhang & Lado, 2001)[19]. In this research, three IT capabilities are identified: IT infrastructure capability, IT personnel capability and IT management capability. Some authors classify all of these three constructs as IT resources, and some only regard IT infrastructure as an IT resource and assign IT personnel skills to the higher order of an IT capability, while others regard both IT infrastructure and IT personnel skills as capabilities (Fink& Neumann 2007)[20].

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The adaptive IT capability refers to the ability of IT to support firms' dynamic capability in general, and firms' adaptive capability in particular. Hence, the concept of adaptive IT capability reflects the ability of organization's IT to support changes in firms' products, services, business processes, organizational structures and competences when necessary in order to deal with different situations.

In this paper, we take adaptive IT capability as a kind of IT dynamic capability, and analyze the evolution of IT dynamic capability from CAS and routine perspective.

IV. A Routines-Based Approach to Study Capabilities

Routines have been defined for many years. Nelson and Winter (Nelson & Winter, 1982)[21] defined organizational routines from the evolutionary perspective as "the ways of doing things". Teece described routines as "the way things are done or patterns of activities" (Teece et al., 1997)[22]. According to the above definitions of routines, we take routines as the vector of organizational capabilities. The organizational routines are the bridge that connects organizational resources and capabilities. This routines-based approach to capabilities allows disentangling them into specific and identifiable routines, thereby outlining possible pathways to capability building and evolution (David, Roger & Rachna, 2008)[23].

V. Model Design

A. The Adaptive IT Capability Design

In the stage of design, we inspired from the structure ERA (Environment Rules Agents) developed by Pietro Terna (Nigel & Pietro, 2000)[10] and also from the model developed by Xiuquan et al in (Xiuquan & haorun, 2008) [4]based on Terna's ERA. The structure scheme of the simulation model is based on ERA. The environment in this model is the market or the space where the adaptive IT capability capabilities evolve. The agents of the simulation model are enterprises, which have attributes of *EnterprisesType*, *IT Infrastructure capability*, *IT Human Resource capability*, *adaptive IT capability*, and so on. The rules of the simulation model are according to the genetic algorithm theory, which has long been known as variation, selection, and retention.

B. Setting up The Model and Initializing Variables

To set the model in motion and to make the simulation results easily replicable, we need to assign numerical values to all the parameters, initialize all the state variables, and select appropriate forms for those functional relations about which there is no clear theoretical indication(Erik Larsen, Alessandro Lomi,2002)[24].In order to simulate the model, the initial values of variables and parameters need to be initialized firstly.

- Initializing parameters. We set the market space of in the simulation as "*worldXSize=100*, *worldYSize=100*", the paramenters of *seedProb* is 0.4, the paramenters of *enterpriseDensity* is 0.03, the paramenters of *ConfigSucessRate*, *LearnSucessRate*, *InnovaSucessRate* set 0.6,0.7,0.4 respectively. The following figure is shown the specific parameters setting:

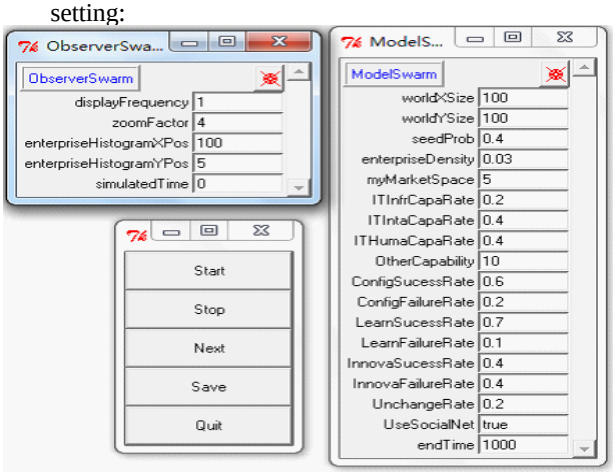

Figure 1. Initializing parameters

- Creating the market space. Market space is composed of by the X*Y two-dimensional grid. The initial space sets 100*100. Market share is scattered by 0.4 probabilities(*seedProb*). If the grid value is "1", it indicates that there is 1 unit space to share. If the grid value is "0", it indicates that this grid has been occupied (Bing Bai , Xiuquan Deng & Dehua Gao,2011)[25].
- Creating the agents. The agents are created by 0.03 probabilities (*enterpriseDensity=0.03*) in the market space.

C. Implementation of Simulation

This program realizes under the Swarm-2.2-java and the jdk1.6.0_10 development package. The main program documents include *Enterprise.java*, *MarketSpace.java*, *AdaptionMechanism.java*, *ConfigurationMechanism.java*, *InnovationMechanism.java*, *ITRoutineGene.java*, *Model Swarm.java*, *ObserverSwarm.java*, *StartSimulation.java*, and so on.

VI. Analysis of the Simulation Result

From 1 schedule to 100 schedules, the process of changes about the distribution of market share and the social net structure in the market space is followed:

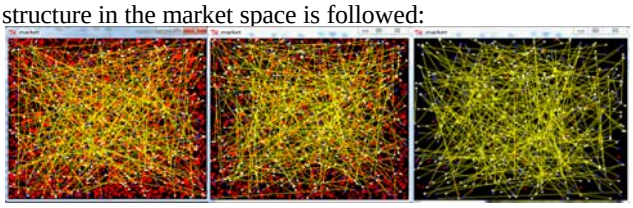

Figure 1. The Evolution Process of the market share and learning network

The red grids represent that there is one unit market share in the market space. The white grids are the agents whose *EnterprisesType* equal "0". In other words, the white grids are the conserve enterprises. On the Contrary, the blue grids represent the agents whose *EnterprisesType* equal "1". The

linkage of agents is the learning network. It stands for the learning relationship among the agents.

As you can see from the figure 1, they show that the amount of market shares(red grids) is decreasing steadily. The main reason is that the agent occupied gradually the market share through constantly searching and competing. The learning network reflects the complex relationship of study among agents each other.

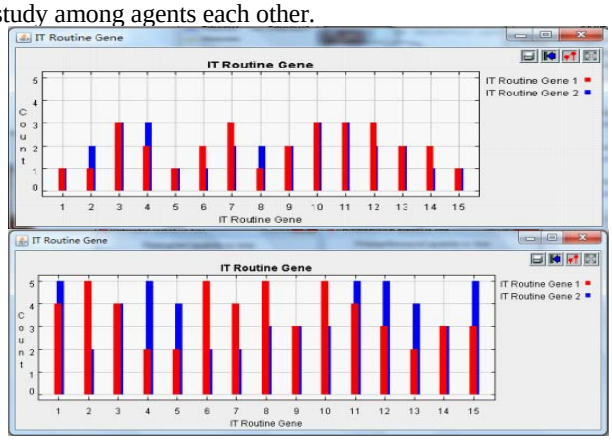

Figure 2. The changes of IT routine gene

As is shown in the graph 2, the each accession of IT routine gene is changing in the simulation experiment. The evolution of 2,6,7,8,10 gene accessions of enterprise1's IT routines are better than others, and superior to the enterprise2's in the end. While the 1,4,5,11,12,13,15 gene accessions of enterprise2's have an advantage over the enterprise1's.

VII. CONCLUSION

Using the Swarm simulation platform, from the perspective of complex adaptive system, this paper studied the adaptive IT capability improvement and its influence on the evolution of adaptive enterprise, especially on the enterprise IT system. We analyzed the process of adaptation, and drew the following conclusions:

- The evolution of enterprise IT capability has complexity, and is a dynamic adaption and learning process. The adaptive complex agents' behavior is the result of agents that can self-organize into an evolving process structure capable of executing an effective sequence of decisions to respond to incoming requests.
- From the routine-based perspective, the evolution of adaptive IT capability is indeed the process of variation, selection, and retention for IT routines. The adaptive IT capability is composed of a series of IT routines.

These conclusions are advantageous for us to make a more reasonable explanation for the evolution of adaptive IT capability. But the agent-based simulation model also has insufficiencies to be improved. For example, the accurate Verification and Validation of the Simulation model, the reasonable expression of IT routines gene, and the evolution mechanism of IT capability, all of these need to further study in the coming research work.

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