A Study on Innovation Diffusion Understanding with Multi-Agent Simulation

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***Abstract*—This paper describes the Innovation diffusions with Multi Agent Simulation. Among the Innovation diffusion theory, there are classified with five types such as innovator, early adopter, early majority, late majority, and laggard, so far. Among each classification, there are cracks in the innovation adaptation. Especially, in the high-tech industries, a big slot called Chasm is made between early adopter and early majority that proposed by Moore. These adaptations are based on human homogeneous behavior in social contacts from the results of observation in real world. This theory is even heuristics intelligence and we cannot capture the condition for the crack is made. Based on the innovation diffusion backgrounds, we made a simulator for Chasm observation. From the results of simulation, Chasm crack was made in the industry with Multi-Agent Simulation. We have attempted to acquire new knowledge for the industry.**

Keywords-component; Innovation; Innovation Diffusion; Multi-Agent Simulation; Simulation; Chasm

I. INTRODUCTION

According to Matsuoka [1], the products diffused generally lose the competitive power for catching up from newly emerging countries, such as China, South Korea, and Taiwan. As a result, the domestic industry is forced to severe market competition for losing their global competitiveness. For example, they are household electrical appliance and high tech products such as cell phone and television which the Japanese companies are good at. Therefore, in Japan, making an innovation prosperous the high-tech industry is advocated.

Although many policies for future industry generation have been made by the Japanese Government, They have not contributed to the recovery from the long term recession in Japan. It is one of the reasons it could not identify on what kind of conditions an innovation starts, so far. Then, the diffusion process of an innovation is considered with the multi-agent simulation that reproduces Chasm based on the diffusion theory of the innovation by Moore [2].

According to the survey about mid- and long-term research and development of company in our country that contributes to innovation creation by the Ministry of Economy Trade and Industry Japan [3], mid- and long-term research and development of the company in Japan contributes to innovation creation. In this survey report, it is necessary for Japanese companies not to consider Business plan focusing on short-term profits. And future vision plans to create venture new business is needed for Japanese companies.

Hasegawa [4] mentioned as follow: There is a need to emphasize the existing market for large companies. Therefore, the creation of new markets is difficult for large companies. Although in these domains there is also a view that a venture business is suitable depending on a type of industry. But a venture business does not grow up easily in our country. As it became clear from this investigation, suppose that it is required to challenge to a new domain with the concerted efforts of industrial, administrative and academic sectors from investment in these domains fully not being performed in minor and leading companies.

Also, supposing that the advance expansion to oversea markets, such as newly emerging country correspondence, is also included in new market creation. Why venture's leading research-does not grow, is the length of time dissemination of technology. Because, it is considered the body in which stagnation and a slot (it is called as Chasm) are in spread. Since there are the stagnation and slot, it is supposed by the destructive innovation that the whole industry of one country has damage. Therefore, in order to venture succeeds, a method of shortening the time for diffusion of innovation is required. It is necessary to give the suggestion about stagnation and chasm of innovation to the companies that include a venture about the stagnation and the slot in the spread of innovations, or the entrepreneurs of those.

Suppose that five adoption person types, an "innovator", an "early adopter", an "early majority", a "late majority", and a "laggard", have classification in the spread theory of an innovation. There are cracks among the five-adopter classifications. And it is supposed that a big slot, it is call as Chasm is between an early adopter and an early majority. In this paper, five adoption persons' type is based on observation of Moore [2]. Therefore, it is realized to be the difference between the homogeneous behavior to which it comes from adoption behavior of the same kind type, and two strategic behavior of differentiation action to classify an adoption person's type. We try to reproduces chasm phenomenon in a simulation. The simulation was made with the multi-agent simulation (MAS). We consider that whether Chasm exists, what frequency Chasm generates and it is born in what kind of case by the experiment with MAS.

This paper provides following components; Section 2 presents related work, Section 3 gives experimental setup for the simulation, Section 4 gives a discussion of result, and Section 5 gives concluding remarks and future work.

II. PREVIOUS RESEARCH

In this section, we review the previous research of the innovation at first. Then, we referred to the Chasm concept of Moore [2] to create MAS. Therefore, in this chapter, the research on the Chasm is surveyed. Next, we review the previous research that tried the development and experiment of MAS about the diffusion of innovations.

A. Inovatinon

Schumpeter [5] defined the innovation as “Producing the existing thing by a new method, or producing a new thing." Utterback and Abernathy [6] divided the innovation roughly into product innovation that destroys the existing technical concept, and the process innovation elaborated at best more at a low price.

Rosenberg [7] insisted that the long-term ripple effect does not exist, without the cumulative and continuous innovation, and the qualitative development does not exist, without the epoch-making innovation. Abernathy et al. [8] and Abernathy and Clark [9] described four innovation types based on both the technical and the market condition. Those types are defined as follows:

- Architectural innovation; the innovation that sets a base to the systematized techniques that destroy the existing systematized techniques, and reclaims a completely new market.
- Revolutionary innovation; the innovation which reclaims the existing market while it is in the systematized techniques which destroy the same existing systematized techniques.
- Niche creation; the innovation that reclaims a completely new market while aiming to strengthen the existing systematized techniques technically.
- Regular innovation; the innovation that strengthens the existing systematized techniques and moreover cultivates the existing market.

Christensen [10] mentioned as follows: The big company thought that the market of innovation is small and not attractive compared with the conventional large-scale business. Since there is a risk of destroying the conventional primary business, the adoption of innovation is overdue. Therefore, the big company will lag behind the new companies. Then he named the dilemma of the innovation.

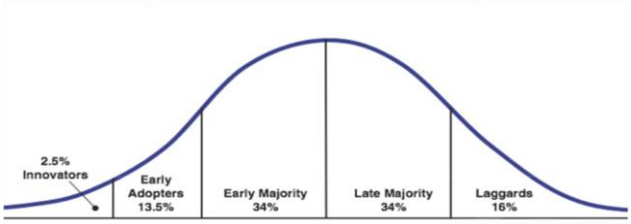
B. Chasm

It is said that there is a deep slot which checks the shift to the leading market from the initial market in the diffusion of the innovations that make new product and new technology permeate a market in the high-tech industry.

Moore [2] advocates the chasm concept. The strategy of overcoming the chasm from the concept of the chasm is named the chasm theory.

Rogers [11] classified the customer into five adoption types as innovator, early adopter, early majority, late majority, and laggard, in the innovation diffusion model. In this theory, among the new technology and the new fashion presuppose that it spreads rapidly in the stage (more than 16% of diffusion rate) that spread through the layer that united the early adopter with the innovator.

Fig. 1. Technology Life Cycle by Roger



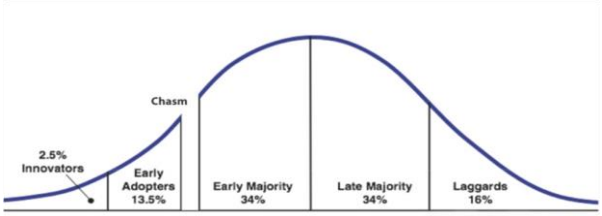


Fig. 2. Chasm by Moore [2]

Then, it is supposed that it is what is advertised to an innovator and an early adopter a key to new product spread.

Fig. 1 indicates the Rogers innovation spread model. And in the high-tech product that forces a user's behavioral pattern a change, Moore [2] discovered a crack among five-adopter classification. Especially he named chasm this it was presupposed that a deep big slot is between early adopter and early majority also in it. The slot in Fig. 2 indicates the image of Chasm.

An early adopter layer adopts new technology positively. An early majority layer tends to think stability and relief as important to it. Therefore, the uneasiness of an early majority layer is not canceled in the place that the early adopter layer that is a part of only market adopted. That is, both demands differ fundamentally, and in order to shift to a leading market from an initial market exceeding Chasm, suppose that it is necessary to change the approach of marketing according to the spread stage of an in-house product. Moore [2] observed the rate with five-adopter classification as follows:

- Innovator: (2.5%) people and the company that adopt it as technology aiming at differentiation from novelty.
- Early adopter: (13.5%) people and the company that adopt the first stage aiming at differentiation not from technology but from an actual profit side.
- Early majority: (34%) people and the companies that check a preceding person's success example and adopt from imitation.
- Late majority: (34%) prudent people and the company that copy after a large majority uses.
- Laggard: (16%) also technically and practically, they are people and a company who hate a new thing.

It is as "a means of change" that an early adopter tends to adopt new technology. They aim at action of a differentiation strategy by preceding competitor and adopting new technology.

They introduce new technology with the determination to take over a risk in person, in order to obtain the competitive advantage by differentiation. And they often claim an excessive demand to a vendor that may be thrust before.

On the other hand, the early majority (utilitarian) has positioned the product as "a means of an operational efficiency improvement." The situation where self will apply a trial-and-error method with unripe technology is avoided. And they copy the example of the usage of the new technology of the other company in the same industry. They want to take action of the strategy of homogeneous behavior. However, since an early majority specifies the product and technology that were introduced as a company standard in many cases, technology vendors can expect a high profit ratio. Therefore, Early majority is an important customer for vendors. In Chasm theory, in the early adopter and the early majority, demands differ, and in order to shift to a leading market exceeding Chasm, according to the diffusion stage of an in-house product, it is being explained that it is required to change marketing approach.

The difference among these five-adopter differences is the difference, which comes from the strategic activity principle in a management strategy theory called differentiation behavior (behavior by the snob effect), and homogeneous behavior (behavior by the bandwagon effect). Strategic behavior was mentioned by Leibenstein [12], Porter [13], Porter et al. [14] ,and Asaba [15]. Then, this paper examines based on two strategic behaviors such as differentiation and homogeneous as agents' activities. The snob effect definition is: people do not want the same product others bought, and want something different from product others bought. The bandwagon effect definition is: More people to support the certain products and services, the effect of satisfaction and sense of security that the customer obtained by the products and services will increase.

Moreover, they mention the technologies that could not exceed Chasm are Video conference system, Artificial Intelligence, Pen computing system and so on. Especially, in the music devices, CD and DVD have exceeded Chasm, but Laser disc and MD could not. Chasm is a big slot that exists before the diffusion of high-tech product through the mainstream market. In order to exceed Chasm, the basic strategy that Moore [2] asserts is responding to the utilitarianism of the early majority who is a customer segment of the beginning of a mainstream market. However, he suggests that the innovation vendor must not provide all early majorities with a product. The concrete method exceeding Chasm is concentrating the best on one place. It is important to complete the perfect product quickly towards the certain specific customer segment.

The greatest reason against the overall market is that demand level of early majority who is a utilitarian wants 100% of solution.

He insists on that it should be recognized that the early adopter that constitutes the initial market before that expects what "will be become useful in the future", and bears a dream against a product that there is a difference.

This approach is explained to the lane of the bowling alley by the metaphor. And each customer segment is equivalent to the pin of drilling, and then makes it. Pushing down one pin pushes down other pins.

In other words, a success in one customer segment is used as a spring, and a new customer segment's success is gained.

Eventually a "strike" is taken out and it can create rapid growth in whole market. The analogy of the lane of this bowling alley serves as reference when developing MAS.

Moreover, the approaches for exceeding Chasm are the following three steps.

1. Though it is small, build a positive foothold in somewhere in one mainstream market as soon as possible.
2. When innovation diffuses in mainstream market, the strategy that was conscious of the overall market is promoted, and it should be remade to spread widely as standard goods.
3. Return to the approach of a client centered again and append added value to a product through mass customization. Mass customization is building the product of individual specification in large quantities.

Moreover, Markides and Geroski (2004) [16] mentioned as follows: If it is not a second runner that is called "Fast Second", it cannot generate "radical innovation". The reason has a big rupture called "Chasm" between soliciting to some innovators, and being accepted in the public as a market, and presupposed that it is because the second runner is more advantageous to exceeding Chasm.

The second runner who has made the market expand raises business that shakes existence of a customer's custom and existing company, such as a mobile phone and an online bookstore. It can be said that strategic behavior called homogeneous behavior and differentiation behavior show also that the second runner has taken in the innovation advantageously.

C. MAS of Innovation diffusion

Washida [17], Washida et. al [18], and Matsuka et. al (2013) [19] developed MAS of the innovation emergence in innovation diffusion processes. They are referring to the diffusion model of the innovations from Rogers (1986) [8], the Chasm from Moore [2], the small-world network structure from Watts [20] and the scale-free network structure from Barabsi [21]. Small-world network structure is a small world character network structure that appears in both of a network natural or artificial (a nervous system and a transmission network). Moreover, small-world network structure follows "A power distribution." "A power distribution" is network structure without a specific type value. They reproduced that the innovation that exist really is not necessarily based on development of a supplier's technology, and many innovations in which emergence was carried out by consumers' value conversion phenomenon in the multi-agent simulation.

They developed exploratively the multi-agent model that used the network about the innovation generation by such a value conversion phenomenon. The developed multi-agent model assumes that the case of the mobile phone which carried out conversion to e-mail and a ringtone use subject from a telephone call subject, and the case of the wagon type passenger car converted into the mainstream vehicle type which exceeds a sedan from the special vehicle for niche demand are reproduced.

Kitanaka [22] set up four kinds of agents, such as maker, wholesale, retail store, and consumer. It was stretched three diffusion course networks among each agent with MAS. Three spread courses are a distribution channel network, an advertising and promotional network, and a word-of-mouth network. The distribution channel network is made into the tree structure. The advertising and promotional route is made into emanated type network structure. And the word-of-mouth network is made into the scale-free network. A distribution channel network and an advertising and promotional network spread an innovation through a consumer agent according to dropping resources. In the word-of-mouth network, it has set up so that the consumer agent recognized as the hub by the number of links may diffuse an innovation. And they reproduced that a difference appears in the diffusion of innovations by the difference in the active degree of a word-of-mouth network (the number of hub consumer agents) by experiment.

Morioka [23] is developing MAS of brand value. He set up that an agent gave one of a bandwagon effect (effect which makes it take homogeneous behavior), and the snob effects (effect which makes it take differentiation action) by communication of market share information. As the result, the change of the market share is reproduced with MAS. A market share becomes high, so that the threshold value of a market shares when giving a bandwagon effect is high according to it. However, it found out that a market share is balanced with a fixed value.

D. Suggestions from previous works

We considered that Moore [2] classified five-adopter classification of spread of an innovation depending on how to take homogeneous behavior and differentiation behavior called strategic behavior. Therefore, after giving a definition as an agent from whom how to take strategic behavior for these five-adopter classifications are different, you should develop MAS about the diffusion of innovations. This paper aimed at obtaining the suggestion about Chasm by the experiment with MAS.

III. CONFIGURATIONS OF CHASM IN MAS

In this paper, we take the Artisoc3.0 as Multi-Agent simulator. We focus on consumer market as simulation market that the company group of a certain industry is targeted for the diffusion of innovations. The case where an innovation spread through industry is assumed in this paper. The setups becomes as follows:

- Space Industry (as default setups) was added to Universe.
- Agent High Tech1, which expresses an innovation to Space Industry, was added.
- As an agent showing a company, Innovator, Early adopter, early majority, late majority, and Laggard were added.
- It enabled it to set the number of each company agents from 0 to 200 in control panel.
- The real type variable, which expresses each agent's diffusion rate to Universe, was added. INDiffusion was added to Innovator and EADiffusion to Early adopter, EMDiffusion was added to early majority, LMDiffusion was added to late majority, and LADiffusion was added to Laggard.
- As an output setup, the real type variable Diffusion showing the whole diffusion rate was added.
- The real type variable speed which specifies the speed that flies to each company agent was added.
- We added a real type variable SHIYA to specify the size of the field of view to observe the movement of intra-industry competitors in each company agent.
- We added a real type variable NAKAMA to specify the number of others to observe as a condition of taking the homogeneous behavior by the bandwagon effect in each company agent.
- We added a real type variable KYOGO to specify the number of conflicts within the field of view as a condition to take behavior by differentiation snob effect on each company agent.
- Set to map the output space Industry, was added as an element each company agent on the map.

About the diffusion from HighTech1 agent to each company agent, it set up as follows.

- It was considered as the analogy which considers that the situation which turns to and follows the 0°, in the same direction as agent High Tech1 is the state of Innovation diffusion.
- Agent High Tech1 acted in the direction of 0°, and it added the function made Innovator to 0° direction as a function to transmit an innovation to Innovator in the field of view within less than 15.
- Agent Innovator has the capability that made Early adopter to 0° direction in the field of view within 3, as a function of diffusing the innovation.
- Agent Early adopter has the capability that made Early majority to 0° direction in the field of view within 1, as a function of diffusing the innovation.
- Agent Early majority has the capability that made Late majority to 0° direction in the field of view within 1, as a function of diffusing the innovation.
- Agent Late majority has the capability that made Laggard to 0° direction in the field of view within 1, as a function of diffusing the innovation.

Fig. 3 indicates the illustration for innovation diffusion.

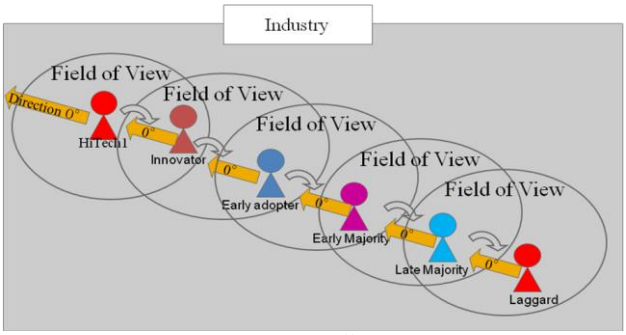


Fig. 3. Innovation Diffusion Model

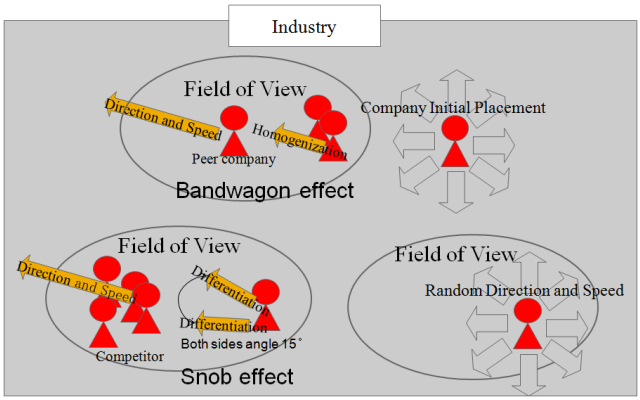


Fig. 4. Homogeneous Behavior with MAS

Each company agent shall take homogeneous behavior or differentiation one depends on following configuration.

- As analogy that takes the homogeneous behavior by bandwagon effect, every agent was set up as follows.
- When number of company agent of the same kind within a view size was more than NAKAMA number, it was made to progress with the same speed and the same direction as a company agent of the same kind.
- When there were many agents of the same kind who turn to and follow the same direction, as analogy that takes differentiation behavior according to the snob effect, it set up as follows for every agent. When number of an agent of the same kind within a view size was more KYOGO number, it was made to progress in the different direction in the range of 15 both sides.

Fig. 4. indicates homogeneous behavior with MAS.

The flows of the company agents contains following configurations.

1. Use random position, direction, and speed at first.
2. In more than fixed numbers (a number is Variable NAKAMA), the agent of the same kind which is in the surroundings (width of a view) takes the same direction as a partner, and speed by a bandwagon effect. This action was defined as homogeneous behavior.
3. Unite the direction and speed of your company with the direction and speed of one company of the homogeneous partners (a number is Variable NAKAMA).
4. In more than a number (Variable KYOGO) whose agent of the same kind which is in the surroundings (width variable SHIYA of a view) is fixed, consider that it is the other company of the differentiated partner from the snob effect.
5. Change its direction in the direction of one company of the differentiation partners (a number is Variable KYOGO) to the direction of 15 both sides. But Speed is not changed as at present.
6. If there is neither a homogeneous partner nor a differentiation partner, change a direction and speed suitably.
7. If there is the affecting target agent in a view, it will turn in the direction of 0.

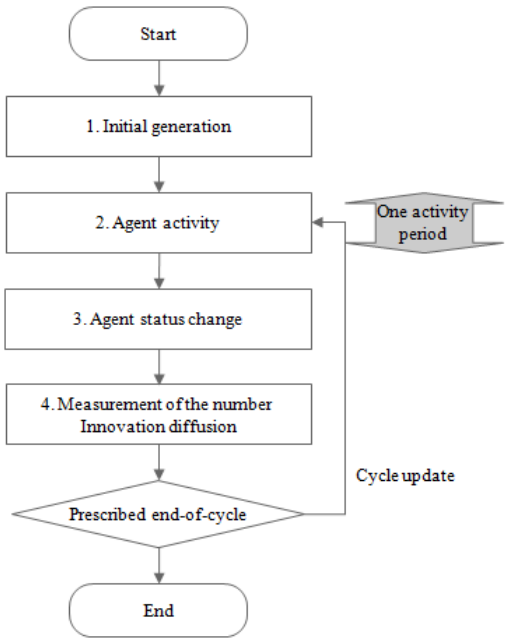


Fig. 5. Simulation Flow

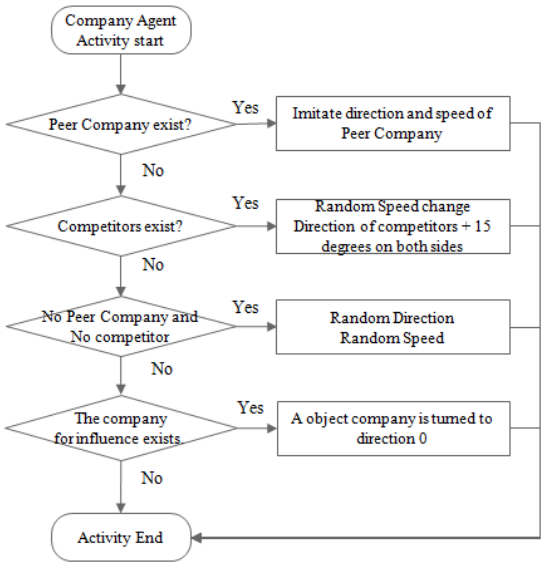


Fig. 6. Company Agent Activity Flow

The simulation flow is shown in Fig. 5. And the flow of the company agent activity flow is shown in Fig. 6, respectively.

IV. EXPERIMENT

We set 200 companies in the same industry with two variables of KYOGO as the competitor and of NAKAMA as another company and generate agents with the ratio that Moore [2] proposed. Each agent takes homogeneous behavior or not in judgment as agent's sight variables in agent's decision. Experimental set-ups are shown in Table 1.

Based on the above configurations, 10 times trials in each 10,000 steps were operated. The experimental results are shown from Fig. 7. to Fig. 9., respectively.

TABLE I. Experimental Set-ups

	Innovator	Early Adopter	Early Majority	Late Majority	Laggard	Sum total
SHIYA	2	2	2	2	2	
NAKAMA	1	1	2	3	3	
KYOGO	10	10	10	10	10	
Existing ratio	0.025	0.135	0.340	0.340	0.160	1.000
Number of existence	5	27	68	68	32	200

The top line in gray color indicates sum of diffusion of innovation in the industry. Following figure from Fig. 7. to Fig. 17 indicates the result of ten trials. Only one trial was not observed the crack in Fig. 11.

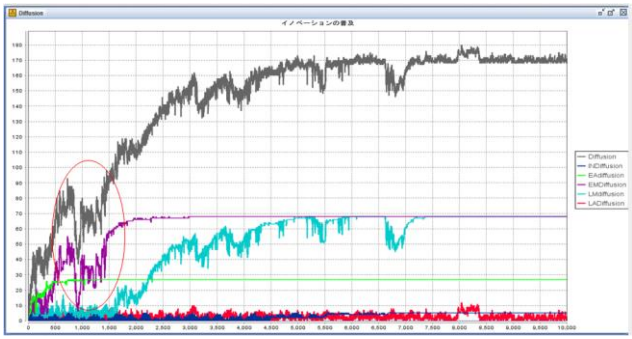


Fig. 8 Simulation Result (1st trials)

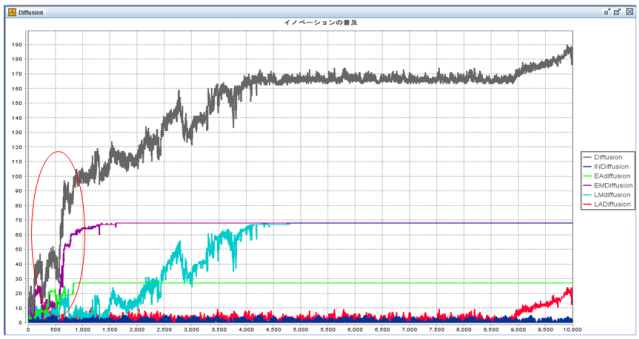


Fig. 9 Simulation Result (2nd trials)

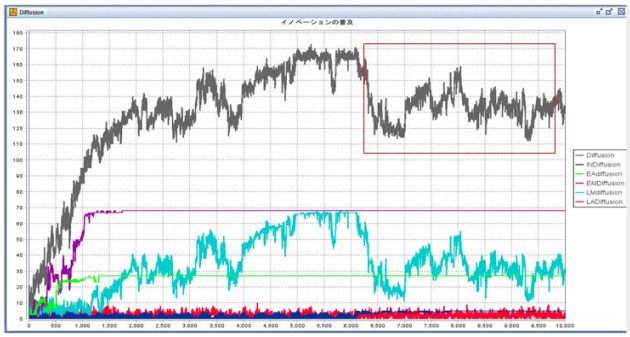


Fig. 10 Simulation Result (3rd trials)

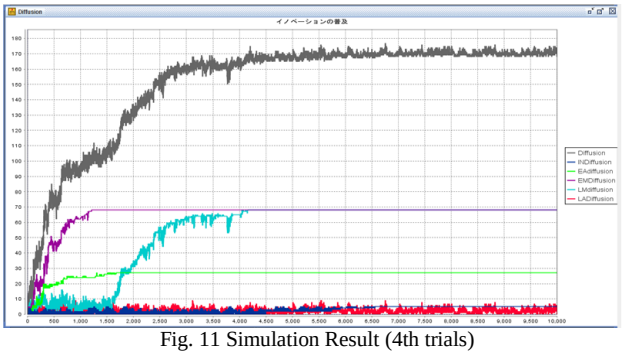


Fig. 11 Simulation Result (4th trials)

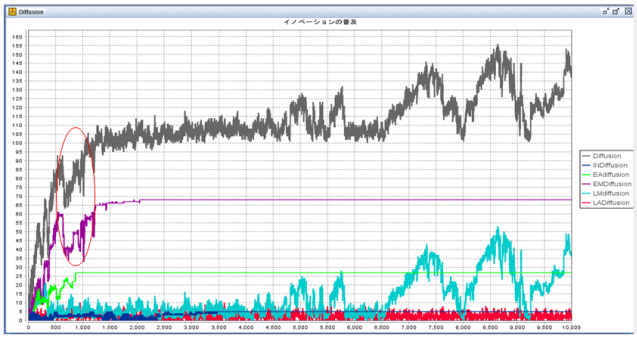


Fig. 12 Simulation Result (5th trials)

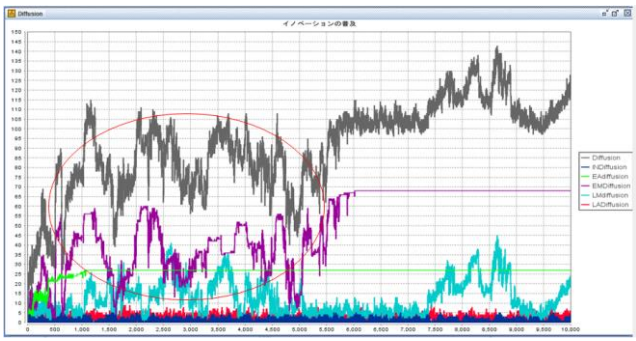


Fig. 13 Simulation Result (6th trials)

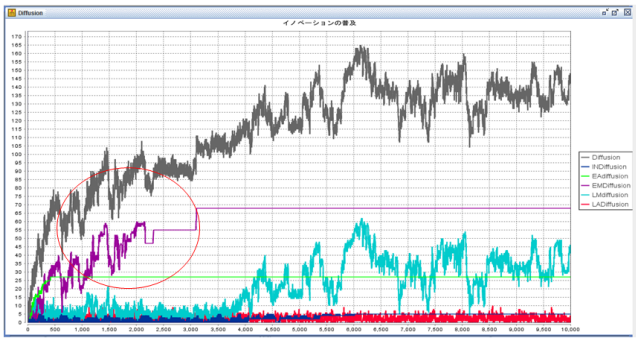


Fig. 14 Simulation Result (7th trials)

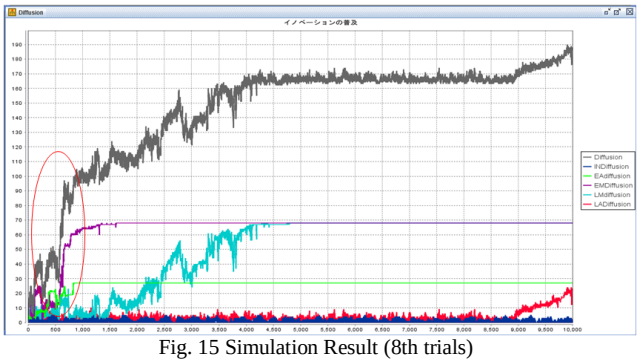


Fig. 15 Simulation Result (8th trials)

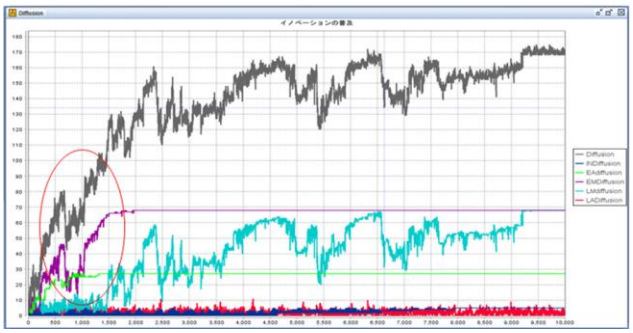


Fig. 16 Simulation Result (9th trials)

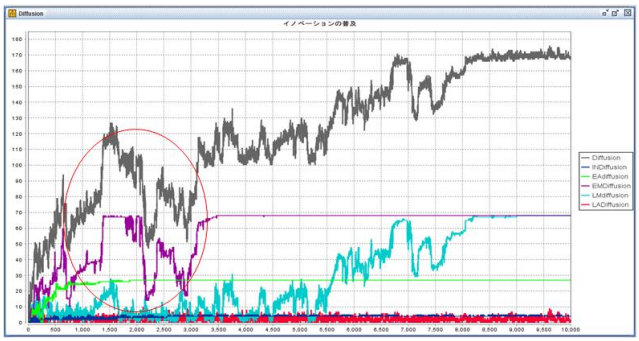


Fig. 17 Simulation Result (10th trials)

From the simulation results of Fig.8-10 and Fig.12-18(Fig. 11 except), we succeeded in crack generation.

V. Concluding Remarks

This paper describes the Innovation diffusions with Multi Agent Simulation. In the Innovation diffusion theory, there are classified with five types such as innovator, early adopter, early majority, late majority, and laggard, so far. Among each classification, there are cracks in the innovation adaptation. Especially in High-tech industries, a big slot called Chasm is made between early adopter and early majority that proposed by Moore (1991) [2]. Since this paper proposes the innovation diffusion model with MAS as a preliminary trial, we translate the heuristic knowledge into computer simulation model.

At first, we indicate related work. Based on the innovation diffusion theory, we defined parameters and made a simulator for Chasm observation. From the results of simulation, we succeeded in crack generation. By statistical analysis and case, to identify the conditions for generating the chasm in the spread of innovation is difficult. In contrast, by utilizing the MAS, the possibility of identifying the condition is confirmed. As an example of the chasm in recent years, the mobile phone standard unique to Japan, but did not spread to the global market while having the function of the Internet connection terminal and the like. Mobile phone of Japan's own standard is called the Galapagos mobile at present time. We will be able to recognize that Galapagos mobile had fallen into a chasm of innovation diffusion. We believe that it was reproduced such phenomena as Galapagos mobile's Chasm by MAS.

Our future work is as follows: a) Capture the conditions for the crack generation, b) Parameter tunings of corporate indicators such as sales, costs, assets, and capital and so on. and c) Compose simulation for a new technology as Innovation goes into the industry.

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