

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 theories, there are five classification types such as Innovator, Early adopter, Early majority, Late majority, and Laggard, so far. Among each classification, there are cracks in the innovation adaptation. In particular, in the high-tech industries, a big slot called Chasm, proposed by Moor, is made between Early adopter and Early majority. These adaptations are based on human homogeneous behavior in social contacts from the results of observation in the real world. This theory is even heuristics intelligence and one cannot capture the conditions for the crack made. Based on the innovation diffusion backgrounds, we made a simulator for Chasm observation. The simulation results confirmed that a Chasm crack was made in the industry with Multi-Agent Simulation. We have attempted to acquire new knowledge for the industry.

Keywords—Innovation; Innovation Diffusion; Multi-Agent Simulation; Simulation; Chasm.

I. INTRODUCTION

According to Matsuoka [1], the products diffused generally a lose competitive power for catching up with newly emerging countries, such as China, South Korea, and Taiwan. As a result, the domestic industry is forced to severe market competition by losing their global competitiveness. For example, there are household electrical appliances and high tech products, such as cell phone and television, which the Japanese companies are good at making. Therefore, in Japan, producing an innovation that will be prosperous for 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 is not possible to identify under what kind of conditions 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 companies 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 companies in Japan contribute to innovation creation. In this survey report, it is necessary for Japanese companies not to consider business plans focusing on short-term profits. In addition,

future vision plans to create new venture business are needed for Japanese companies.

Hasegawa [4] mentioned that there is a need to emphasize the existing market for large companies. Therefore, the creation of new markets is difficult for large companies. Also, in these domains, there is a view that a venture business is suitable depending on the industry type. However, a venture business does not develop easily in our country. As it became clear from this investigation, it may be necessary to challenge to enter into a new domain. Concentrated effort and investment by industry, and administrative and academic sectors in these domains are not being fully performed by either minor or leading companies.

The advanced expansion to overseas markets that correspond to an emerging country is also included in new market creation. The reason why venture company's leading research does not develop is because of the duration it takes to disseminate the technology. This is because the body of knowledge stagnates and a gap (called Chasm) opens. Since this stagnation exists and a gap develops, destructive innovation is assumed and the entire industry of one country is damaged. Therefore, in order to be successful in venture businesses, a time reduction method for diffusion of innovation is required. Suggestions should be given to companies, including venture companies, regarding stagnation and the gap in the spread of innovation.

Suppose there are five adoptive type individuals, an "Innovator," an "Early adopter," an "Early majority," a "Late majority," and a "Laggard." These classification types are seen in the spread theory of an innovation. There are cracks among the five-adopter classifications. It is also assumed that a big gap, which is called Chasm, exists between an Early adopter and an Early majority. In this paper, five adoptive type individuals are based on the observation by Moore [2]. Therefore, differences among five adoptive type behaviors can be realized by the homogeneous behavior and the differentiation behavior with the same kind adoptive type and the diffusion preceded type. We tried to reproduce the Chasm phenomenon in a simulation, by using a Multi-Agent Simulation (MAS). We considered whether Chasm existed, at what frequency Chasm was generated, and what kind of case brings rise to Chasm generated by performing simulation experiments using MAS.

This paper consists of the following components: Section 2 presents the related work. Section 3 gives the experimental setup for the simulation. Section 4 discusses

the results. Section 5 concludes the paper and describes future work.

II. PREVIOUS RESEARCH

This section, firstly, reviews the previous research of the innovation. We referred to the Chasm concept of Moore [2] in order to create MAS. Therefore, this section surveys the research regarding Chasm. Next, we review the previous research that tried the development and experiment using MAS regarding the diffusion of innovations.

A. *Inovatinon*

Schumpeter [5] defined innovation as "Producing something that already exists by a new method, or producing a new thing." Utterback and Abernathy [6] divided innovations broadly into the product innovation that destroys the existing technical concept, and the process innovation that elaborates on the best at the lowest price.

Rosenberg [7] insisted that a long-term ripple effect does not exist without cumulative and continuous innovation, and the qualitative development does not exist, without an 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: Big companies think that the market for innovation is small and not attractive when 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 gap which checks the shift to the leading market from the initial market in the diffusion of the innovations that makes new products 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 called the Chasm theory.

Rogers [11] classified the customer into five adoptive types as Innovator, Early adopter, Early majority, Late

majority, and Laggard, in the innovation diffusion model. In this theory, it is supposed that innovation spreads rapidly from the Innovator to the Early adopter (more than 16% of diffusion rate).



Fig. 1. Technology Life Cycle by Rogers



Fig. 2. Chasm by Moore [2]

Then, it is assumed that the key to new product spread is what is advertised to an innovator and an Early adopter.

Fig. 1 indicates the Rogers innovation spread model. In the high-tech product that forces a user's behavioral pattern change, Moore [2] discovered a crack among the five-adopter classifications. He named this Chasm, and it supposes that there is a deep gap between the Early adopter and the Early majority. The gap in Fig. 2 indicates the image of Chasm.

The Early adopter layer adopts new technology positively. The Early majority layer tends to think about stability and relief as important. Therefore, the uneasiness of an Early majority layer is not canceled in the place where the Early adopter layer is only a part of the adopted market. Both demands differ fundamentally, and in order to shift to a leading market from an initial market exceeding Chasm, it is necessary to change the approach of marketing according to the spread stage of an in-house product. Moore [2] observed the following rates within the five-adopter classifications:

- Innovator: (2.5%) People and companies that adopt technology aiming for differentiation from novelty.
- Early adopter: (13.5%) People and companies that adopt technology in the first stage aiming at differentiation not from technology but from an actual profit position.
- Early majority: (34%) People and companies that check a preceding person's success example and adopt by imitation.
- Late majority: (34%) Prudent people and companies that copy large majority uses.
- Laggard: (16%) People and companies that hate new things technically and practically.

An Early adopter tends to adopt new technology as a "means of change". They aim at the action of a

differentiation strategy by staying ahead of their competitor and adopting new technology.

They introduce new technology with the determination to overlook the risk, in order to obtain a competitive advantage by differentiation. They also often make excessive demands on previously trusted vendor.

On the other hand, the Early majority (utilitarian) positions the product as a "means of an operational efficiency improvement." This is the situation where a trial-and-error method with unripe technology is avoided. They also copy the example of the usage of the new technology of the other companies in the same industry. They want to take action with a 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 the Chasm theory, there are different demands for the Early adopter and the Early majority, and in order to shift to a leading market exceeding Chasm, the marketing approach needs to be changed according to the diffusion stage of an in-house product.

The differences among these five-adopter classes are what is derived 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]. This paper examines the conditions of generating Chasm based on two strategic behaviors such as differentiation behavior and homogeneous behavior as agents activities. Meaning of homogeneous behavior is that of action to mimic the behavior of others. The snob effect definition is as follows: People do not want the same product others bought, and want something different from the product others bought. The bandwagon effect definition is as follows: More people support certain products and services, and the effect of satisfaction and sense of security that the customer obtained by the products and services will increase.

Moreover, they mention that the technologies that could not exceed Chasm are Video conference systems, Artificial Intelligence, Pen computing system and so on. Regarding music devices, Compact Discs (CDs) and Digital Versatile Discs (DVDs) have exceeded Chasm, but Laser disc and Mini Disc (MDs) have not. Chasm is a big gap that exists before the diffusion of a 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 the 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 in one area. It is important to complete the perfect product quickly toward a certain specific customer segment.

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

He insists on that the Early adopter who is constitution of the initial market expects and dreams product usefulness in the future.

This approach is explained by the lane of a bowling alley metaphor. Each customer segment is also equivalent to knocking over one pin. Knocking down one pin causes all others to also fall.

In other words, success with one customer segment is used as a springboard, and success with a new customer segments is then gained.

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

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

1. Though it is small, a positive foothold is made somewhere in one mainstream market as soon as possible.
2. When innovation diffuses in the mainstream market, the strategy that was conscious in the overall market is promoted, and it should be remade to spread widely as a standard product.
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 to individual specification in large quantities.

Moreover, Markides and Geroski [16] stated: If the second runner is not called the "Fast Second," then it cannot generate "radical innovation." This is the reason why there is this big gap called "Chasm" between soliciting some Innovators, and public acceptance in a market. This is also presupposed, because the second runner has the advantage to exceed Chasm.

The second runner who has made the market expand raises business that disturbs the existence of a customer's customs and the existing company, such as in the 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 advantage of innovation.

C. MAS of Innovation diffusion

Washida [17], Washida et al. [18], and Matsuka et al. [19] developed MAS of innovation emergence in the 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 Barabasi [21]. Small-world network structure is a small world character network structure that appears in both a network natural and artificial (a nervous system and a transmission network). Moreover, small-world network structure follows "A power law Distribution." [17] [18] [19] "A "power law Distribution" is a network structure without a specific type value. They stated that the innovation is not based on the development of a supplier's technology, but the

discovery of the utility value by the consumer from the experimental results of multi-agent simulation.

They develop the multi-agent model of innovation that was generated by consumer user's conversion value phenomenon. The developed multi-agent model assumes that the case of the mobile phone which carried out conversion to e-mail and a ringtone to identify a specific caller and the case of the development of the station wagon type car from a regular sedan. However these two products were developed for a niche of the market, these became mainstream goods in high demand.

Kitanaka [22] set up four kinds of agents, namely, maker, wholesale, retail store, and consumer. Three diffusion course networks were stretched for each agent with MAS. Three spread courses were a distribution channel network, an advertising and promotional network, and a word-of-mouth network. The distribution channel network was made into a tree structure. The advertising and promotional route was made into an emanated type network structure. The word-of-mouth network was also made into the scale-free network. A distribution channel network and an advertising and promotional network spread innovation through a consumer agent according to dropping resources. In the word-of-mouth network, it was set up so that the consumer agent was recognized as a hub because of the number of links it could use to dispense innovation. By experimenting, the researchers were able to reproduce the difference that appears between the diffusion of innovations and the active degree of a word-of-mouth network (the number of hub consumer agents) by experiment.

Morioka [23] developed MAS of brand value. He set up that an agent gave with the bandwagon effect (effect which makes it take homogeneous behavior), and the snob effects (effect which makes it take differentiation action) by communicating market share information. As the result, the change of the market share is reproduced with MAS. A market share became higher, so that the threshold value of a market share when giving the bandwagon effect is higher as a result. However, it was found that the market share is balanced with a fixed value.

D. Suggestions from previous works

We considered that Moore [2] proposed a five-adopter classification for the spread of an innovation. This spread depends on how to take homogeneous behavior and differentiation behavior into behavior called strategic behavior. Therefore, after giving a definition to an agent as to how to use strategic behavior differently with all five-adopter classifications, MAS should be developed with regard to diffusion of innovations. The purpose of this paper was to obtain implications about the conditions for generating Chasm from the experiment of MAS.

III. CONFIGURATIONS OF CHASM IN MAS

In this paper, we used Artisoc3.0 (<http://mas.kke.co.jp/index.php>) as Multi-Agent simulator. Artisoc3.0 is a software simulator of the MAS that
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(<http://www.kke.co.jp/en/>) provides. We focused on the consumer market as the simulation market for a group of companies in a certain industry targeted for the diffusion of innovations. The case where an innovation spread through industry is assumed in this paper. The setup was as follows:

- Space Industry (as default setups) was added to the Universe.
- Agent High Tech1, which expresses as an innovation of the Space Industry, was added.
- As an agent showing a company as an Innovator, Early adopter, Early majority, Late majority, and Laggard were added.
- The number of agents for each company could be set from 0 to 200 in the control panel.
- The real type variable, which expresses each agent's diffusion rate in the 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.
- The output setup was the real type variable Diffusion showing the entire diffusion rate was added.
- The real type variable speed which specifies the speed that corresponds 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 by each company agent. SHIYA means a field of view company agent to look for other company agents.
- 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 by each company agent. NAKAMA means the number of peer company to be homogenized by company agents.
- We added a real type variable KYOGO to specify the number of conflicts within the field of view as a condition by taking the behavior by differentiation, the snob effect on each company agent. KYOGO means the number of competitors that is the subject of differentiation by company agents.
- An output map of the Space Industry was added as an element for each company agent on the map. The diffusion from HighTech1 agent to each company agent was set up as follows.
- We have defined the state of Innovation diffusion as the analogy that the company agent is facing the direction of 0 degree the same as the high-tech 1 agent.
- Agent High Tech1 acted in the direction of 0° , and it added the function that made Innovator to 0° direction as a function to transmit an innovation to the Innovator in the field of view within less than 15.
- Agent Innovator has the capability to make the 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 to make the 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 to make the 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 to make Laggard to 0° direction in the field of view within 1, as a function of diffusing the innovation.

Fig. 3 illustrates the innovation diffusion.

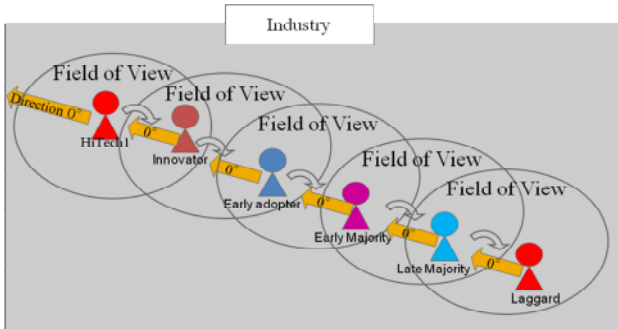


Fig. 3. Innovation Diffusion Model

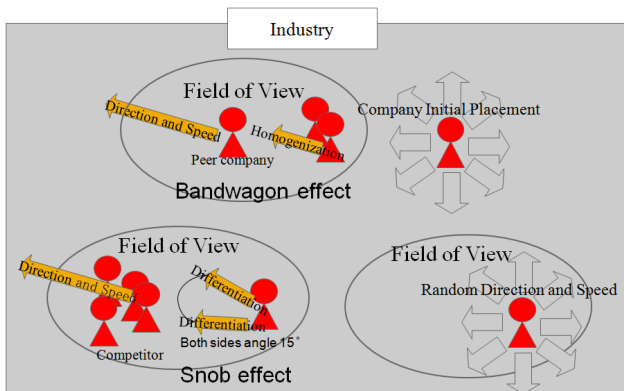


Fig. 4. Homogeneous Behavior with MAS

Each company agent shall take homogeneous behavior or differentiation depending on the following configuration.

- As analogy that takes the homogeneous behavior by the bandwagon effect, with every agent set up as follows.
- When number of company agents of the same kind within a view size was more than the NAKAMA number, it was made to progress at 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 turned to and followed the same direction behavior according to the snob effect, it was set up as follows for every agent. When the number of agents of the same kind within a view size was more than the KYOGO number, it was made to progress in a different direction in a range of 15 on both sides.

Fig. 4 indicates homogeneous behavior with MAS.

The flow of the company agents contains the following configurations.

1. At first, random position, direction, and speed was used.
2. If more than the fixed number (the number is the Variable NAKAMA), of the other agents of the same kind are within the surroundings (width of a view), the company agents take the same direction and speed as the other agents of the same kind, because of the 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 (the number is the Variable NAKAMA).
4. If more than the number (Variable KYOGO) whose agents of the same kind are in the surroundings (width variable SHIYA of the view) , the company agents take the different direction and speed as the other agents of the same kind because of the snob effect.
5. Change the direction in the direction of another company of the differentiation partners (the number is the Variable KYOGO) to the direction of 15 on both sides. However, the present Speed is not changed.
6. There is neither a homogeneous partner nor a differentiation partner, change of direction or speed suitably.
7. If there is an affecting target agent in the view, it will turn in the direction of 0.

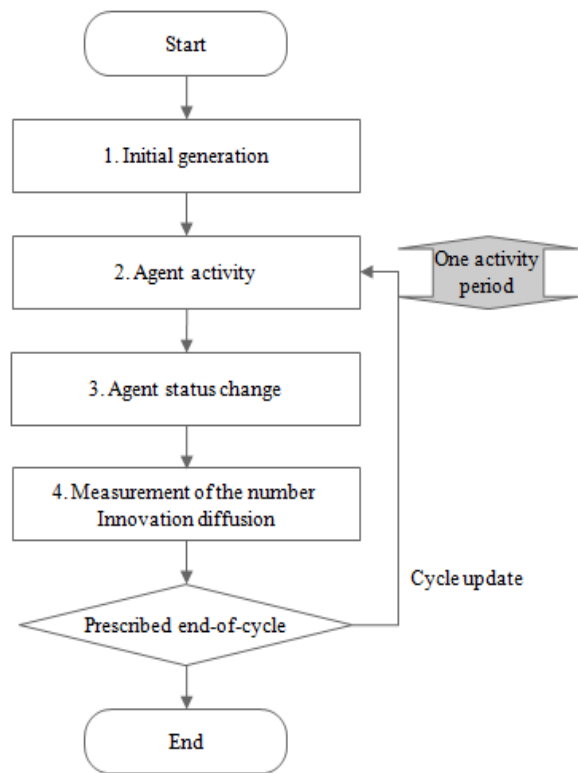


Fig. 5. Simulation Flow

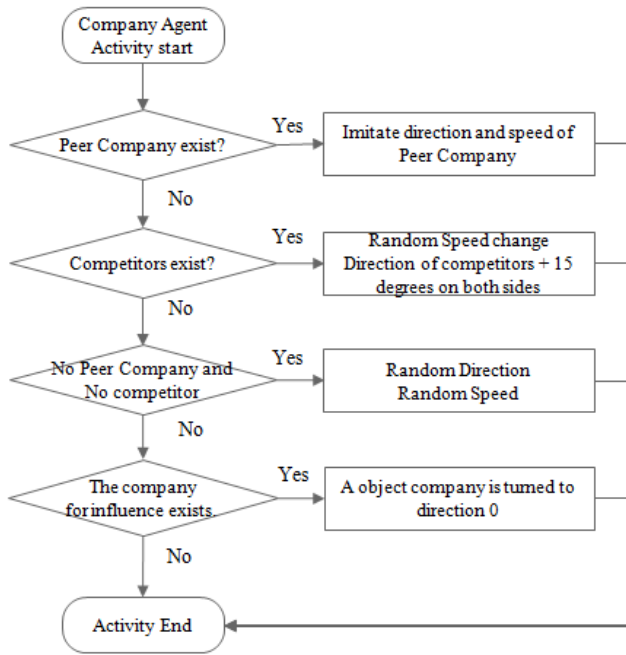


Fig. 6. Company Agent Activity Flow

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

IV. EXPERIMENTS

We set 200 companies in the same industry with two variables of KYOGO as the competitor and of NAKAMA as another company and generated agents with the ratio that Moore [2] proposed. Each agent takes homogeneous behavior or without the judgment of agent's sight variables used in agent's decision. The experimental setups are shown in Table I.

Based on the above configurations, 10 times trials within each 10,000 steps were operated. Figures 7 to 16 show the experimental results.

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 the sum of diffusion of innovation in the industry. Figures 7 to 16 indicate the result of ten trials. Only one trial was not observed in the crack in Fig. 11.

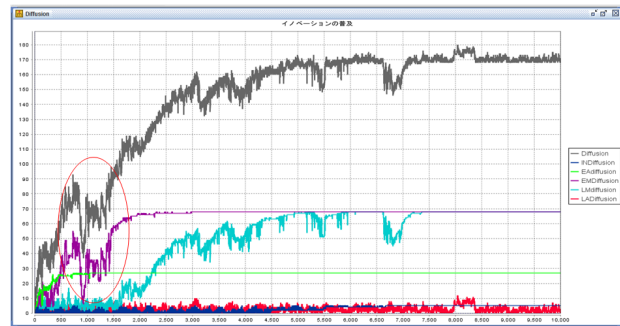


Fig. 7 Simulation Result (1st trial)

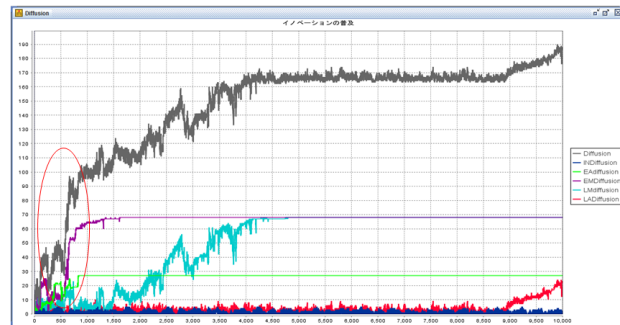


Fig. 8 Simulation Result (2nd trial)

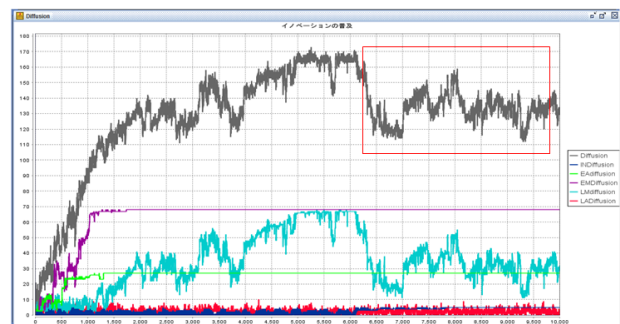


Fig. 9 Simulation Result (3rd trial)

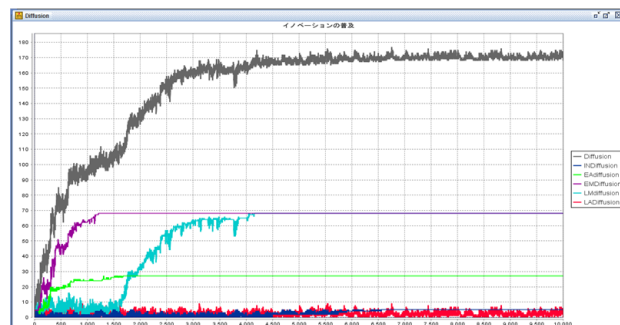


Fig. 10 Simulation Result (4th trial)

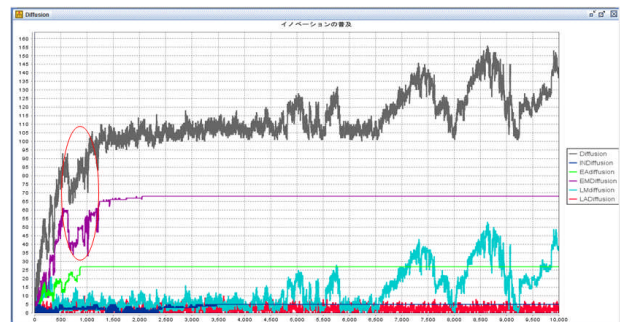


Fig. 11 Simulation Result (5th trial)

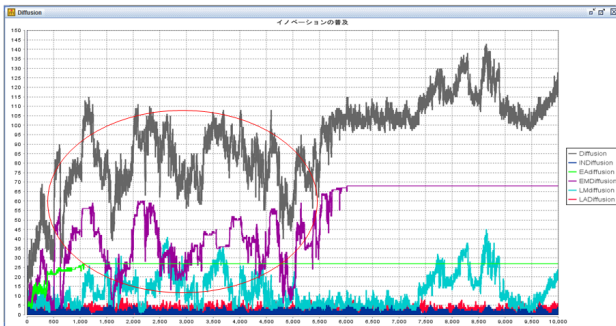


Fig. 12 Simulation Result (6th trial)

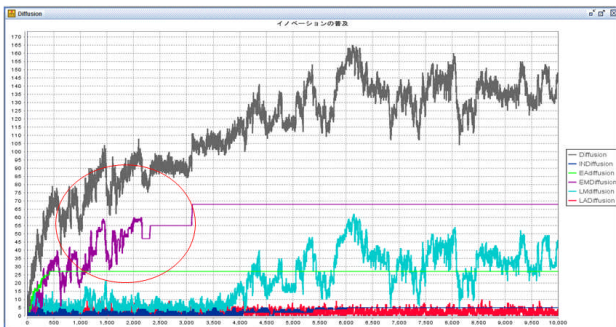


Fig. 13 Simulation Result (7th trial)

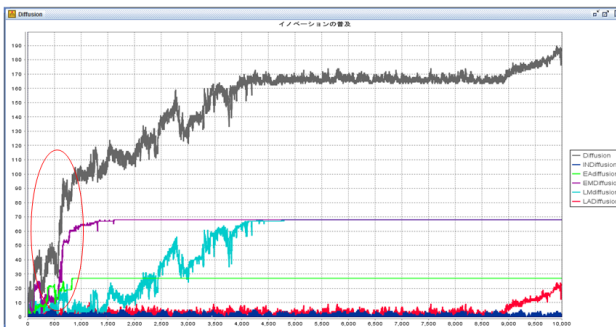


Fig. 14 Simulation Result (8th trial)

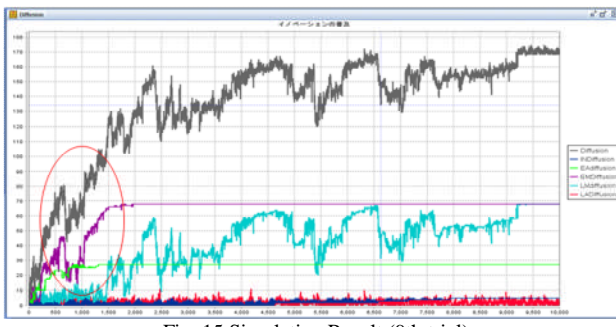


Fig. 15 Simulation Result (9th trial)

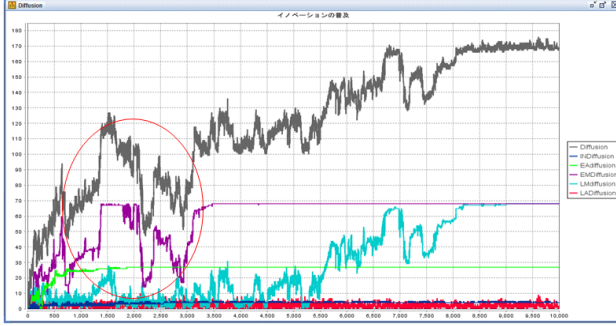


Fig. 16 Simulation Result (10th trial)

As seen in the simulation results in Figures 7 to 9 and Figures 11 to 16 (except Fig. 10), we succeeded in crack generation.

V. CONCLUDING REMARKS

This paper described the Innovation diffusion with MAS. In the Innovation diffusion theory, the market is classified in five types, namely: 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 gap called Chasm is made between Early adopter and Early majority that were proposed by Moore (1991) [2]. Since this paper proposes the innovation diffusion model with MAS as a preliminary trial, we translated the heuristic knowledge into a computer simulation model.

At first, we recounted the related work. Based on the innovation diffusion theory, we defined parameters and made a simulator for Chasm observation. From the results of the simulation, we succeeded in crack generation. By statistical analysis and by case, we identified the conditions for generating the Chasm within the spread of innovation. In contrast, by utilizing MAS, the possibility of identifying the condition is confirmed. As an example of the Chasm in recent years, the mobile phone standard is unique to Japan, but did not spread to the global market while gaining the function of an Internet connection terminal and the like. Currently, the mobile phones of Japan's own standard are called Galapagos mobile phones. We were able to recognize that Galapagos mobile phones have fallen into a Chasm of innovation diffusion. We believe that we reproduced such phenomena as the 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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