

A Study on the Innovator’s Dilemma based on Multi-Agent Simulation

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Abstract—According to the dilemma theory of Christensen about innovation, large companies are not attracted to innovation on a small scale when compared to a smaller business that wants to use innovation. Large companies recognize that getting involved in innovation might eliminate their existing business. Therefore, entry into activities that involve innovation is often delayed. Accordingly, large companies lag behind emerging companies when it comes to innovation. In this study, we attempted to conduct multi-agent simulation in order to consider the conditions under which the dilemma of innovation occurs.

Keywords—Innovation Diffusion, Chasm Theory, Differentiation Behavior, Homogenous Behavior

I. Introduction

There were 11 mobile phone manufacturers in Japan in 2001; however, only four companies remain. In 2011 they were Sony, Fujitsu, Kyocera, and Sharp. Therefore, it is said that the mobile phone industry in Japan collapsed. Sony announced a deficit for the current fiscal year would reach more than 230 billion yen on September 17 of 2014. The majority of the deficit is due to sluggish achievements in the mobile phone business. Table 1 below shows the smart phone market share in the world in 2011. Mobile phone manufacturers in Japan did not remain in the top 5. The mobile phone business of Sony is in a slump, and this represents the collapse of the mobile phone industry in Japan.

TABLE I. 2014 SMART PHONE GLOBAL MARKET SHARE

Maker	2014 Q2 Volume of shipment Units	2014 Q2 Share
Samsung	74.3 million	25.20%
Apple	35.1 million	11.90%
Huawei	20.3 million	6.90%
Lenovo	15.8 million	5.40%
LG	14.5 million	4.90%
Other	135.3 million	45.80%
Total	295.3 million	100%

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The cause that disrupted the mobile phone industry in Japan is the effect of the innovator’s dilemma. Disruptive innovation of the mobile phone industry, which has been a dilemma for Japan, was the advent of the smart phones. For the collapse of Japan’s mobile phone industry, it is necessary

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to consider whether there exist strategies to avoid such a collapse. The main motivation of this paper is to present the awareness of this problem.

To do this, we developed a multi-agent simulation based on the innovation diffusion theory. We then attempted to show a new disruptive innovation into this simulation. The purpose of this paper is to confirm the simulation and what strategic behavior can be used to quickly respond at the time of appearance of the disruptive innovations in the industry.

II. PREVIOUS RESEARCH

Christensen [2] mentioned the following: Big companies think that the market for innovation is small and not very attractive when compared with a conventional large-scale business. Since there is the risk of destroying the primary conventional business, the adoption of innovation is overdue. Therefore, the big company will lag behind the new companies. Then he described the dilemma regarding the innovation.

It is said that there is a deep gap which stops or delays the shift to a leading market from the initial conventional market by the diffusion of the innovations that makes new products and new technology permeate the high-tech industrial marketing.

Moore [3] advocates the Chasm concept. The strategy of overcoming the Chasm from the concept of the Chasm is called the Chasm theory.

Rogers [4] 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 (at a more than 16% diffusion rate).



Figure 1. Figure1. Technology Life Cycle by Rogers [4]

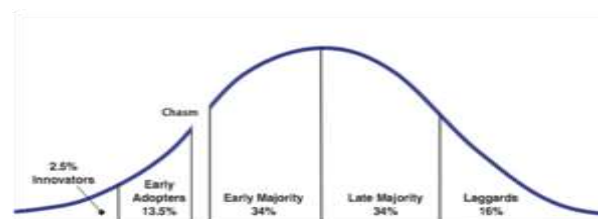


Figure 2. Figure2. Chasm by Moore [3]

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. With the high-tech product that forces a user's behavioral pattern change, Moore^[3] 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 the 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^[3] observed the following rates within the five-adopter classifications:

- Innovator: (2.5%) People and companies that adopt technology aiming for differentiation from the norm.
- 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 successful 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 vendors.

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 undeveloped 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^[5], Porter^[6], Porter et al.^[7], and

Asaba^[8]. This paper examines the conditions of generating Chasm based on two strategic behaviors such as differentiation behavior and homogeneous behavior as agent activities. The meaning of homogeneous behavior is the action of mimicking 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 obtains by the products and services will increase.

In order to exceed Chasm, the basic strategy that Moore^[3] 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 the early majorities with a product. The concrete method for exceeding Chasm is concentrating on the best one in an area. It is important to complete the perfect product quickly and direct it toward a certain specific customer segment. The greatest reason against the overall market is that the demand level of Early majority who utilitarianly wants 100% of the solution. He insists on that the Early adopter who constitutes the initial market expects and dreams about product usefulness in the future.

This approach is explained using the bowling alley lane 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 the entire market. The analogy of the bowling alley lane serves as a 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 modified to spread widely as a standard product.
- (3) Return to the approach of being client centered again and append added value to a product through mass customization. Mass customization is the building of the product to individual specifications in large quantities.

Moreover, Markides and Geroski^[9] 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 promotes a 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.

By developing a multi-agent simulation based on Christensen [2] and Moor [3], it can be made to appear that innovation can be Disruptive to the mature stage of a saturated market. It is thought to be able to perform experiments in a multi-agent simulation regarding Disruptive Innovation, it is necessary to obtain suggestions about the strategic behavior of the high-tech industry about the innovator's dilemma.

III. Simulation Development

In this paper, we used Artisoc3.0 (<http://mas.kke.co.jp/index.php>) as the Multi-Agent simulator. Artisoc3.0 is the software simulator that the KOZOKEIKAKU Engineering Institute (<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 spreads through industry is assumed in this paper. The setup was as follows:

- Space Industry (as the default setup) was added to the Universe.
- Agent Current Innovation (High Tech1), which expresses as an innovation of the Space Industry, was added.
- As disruptive innovation of mutation, agent Disruptive Innovation (High Tech2) was set up so that it could be added in the middle of the simulation.
- 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 companies 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 Current Innovation (HighTech1) agent and Disruptive Innovation (High Tech2) 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 Current Innovation (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 Disruptive Innovation (High Tech2) 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. Disruptive Innovation can be added during the simulation.
- 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.

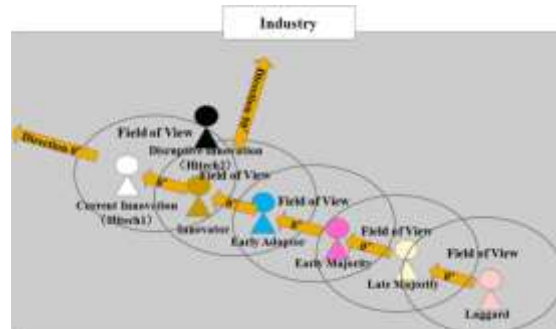


Figure 3. Figure3. The emergence of the Disruptive Innovation

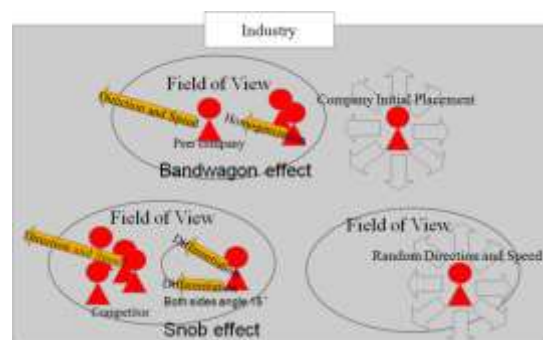


Figure 4. Figure4. Strategic Behavior with MAS

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 Strategic 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.

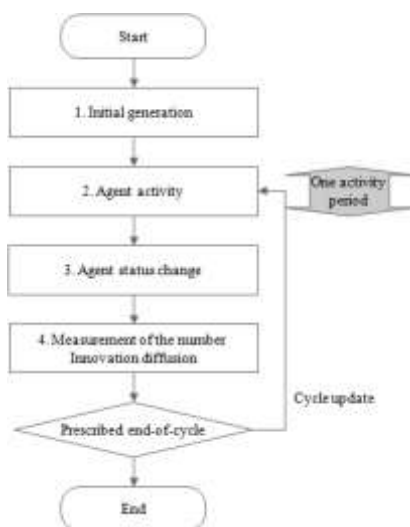


Figure 5. Figure5. Simulation Flow

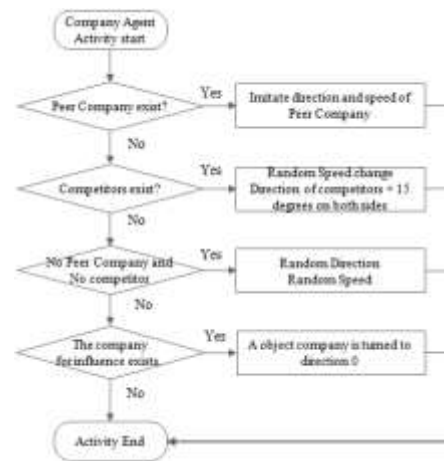


Figure 6. Figure6. Agent Activity Flow

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

iv. Experiment

The experimental setup is as follows: 200 companies are set 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 set-ups are shown in Table2. Based on the above configurations, 10 time trials each with 10,000 steps were performed. Figure 7 show the experimental results.

TABLE II. SET-UPS WITHIN DIFFERENTIATION BEHAVIOR

	Innovator	Early Adopter	Early Majority	Late Majority	Laggard	Total
SHIYA	6	6	6	6	6	
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 indicates the sum of diffusion of innovation in the industry. Fig. 7 indicates the result of trials without the Disruptive Innovation. Chasm can be seen where there is an ellipse.



Figure 7. Occurrences of chasm

As shown in the simulation results in Fig. 7, we succeeded in crack generation as in Moor's Chasm Theory.

Afterward, it was decided to make Disruptive Innovation appear at the 10,000th step. We changed the value of KYOGO, the variable of adopters of the Disruptive Innovation, to 10, 20, 30, 40, 50, 60, and 70. The Innovation Diffusion rate was measured in the experiment. Diffusion rate of the venture company is a diffusion rate sum of innovators and early adopters. Additionally, diffusion rate of corporate giants is the diffusion rate sum of early majority and late majority. In the experiment, 20,000 steps were carried out 10 times. Table 3 below shows the results of the experiment. The numerical values in the table indicates the average of the diffusion rates of up to 10,000 steps, after 20,000 steps, and after the disruptive innovation was turned on.

TABLE III. THE RESULTS OF THE EXPERIMENT

KYOGO	Hi Tech1 (Current Innovation)		Hi Tech2 (Disruptive Innovation)	
	Venture company	Giant	Venture company	Giant
10	25.40%	19.72%	19.98%	4.12%
20	28.56%	23.15%	25.69%	20.30%
30	33.66%	27.29%	25.99%	19.68%
40	29.91%	25.29%	27.27%	20.44%
50	28.66%	24.25%	27.18%	21.17%
60	27.11%	21.12%	33.09%	28.24%
70	21.20%	16.37%	36.89%	32.70%

According to Table 3, when the variable of differentiation behavior is large, the diffusion of HiTech1 decreases, while the diffusion of Hi Tech2 increases. In addition, if the variable differentiated behavior is small, the diffusion of Hi Tech2 does not increase and the diffusion of HiTech1 remains the same.

v. Conclusion

In this paper, through a multi-agent simulation based on Hi-tech Innovation, Disruptive Innovation was generated and brought to the mature stage in a saturated market. We were able to perform experiments in a multi-agent simulation of the Innovation's dilemma in order to obtain suggestions about the strategic behavior of the high-tech industry for the innovator's dilemma.

As suggested from the results of the experiment, differentiation behavior by fierce competition, from the small-scale innovation, within a narrow industry, it is better to keep the advantage of the existing technology of the industry. Differentiated behavior for such new entrants from other industries has a function to protect the industry. However, for disruptive innovation such as in the case of the smart phone in the differentiation behavior, we need recognize that there will be delays in response. In addition, the industry is often in the homogenization behavioral state, when a new innovation appears, causing destruction of the industry. At the stage of progress in the spread of innovation, it is necessary to take the strategy of homogenization action to search for large differentiation, namely the disruptive innovation.

The future issue of this study is to obtain suggestions from the simulation about what should be done to differentiate behavior and homogenization behavior to overcome the innovator's dilemma at any stage of the innovation diffusion. Furthermore, by designing the actual simulation, it has been found that it is necessary to consider the alignment of the innovator's dilemma and innovation diffusion theory. For example, there is a relation between early majority and huge corporate relations, and a relation between venture companies and the early majority. It is also the future object of this study to examine the theoretical consistency between the Innovator's Dilemma theory and the Chasm theory.

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