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Author(s)	Murata, Shotaro; Kijima, Kyoichi
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Landscape Model with Dynamic Parameters
- Alliance Formation of Enterprises influenced by the Consumer Behavior -

Shotaro Murata and Kyoichi Kijima
Graduate School of Decision and Technology, Tokyo Institute of Technology
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8522, Japan
{murata,kijima}@valdes.titech.ac.jp

ABSTRACT

Landscape Model [1] simulates how the alliances of agents formed based on their decisions. The purpose of this paper is two-fold. The first is to generalize The landscape model in such a way that the parameters used for decision making of the agents change dynamically with the alliance structure. The second is to apply the model for analyzing alliance formation in the airline industry. Since we assume that the customers evaluate airline companies by the alliance to which they belong, we include the consumers' evaluation in our dynamic model. By conducting simulation by using the model, we discuss stability and justification of the present alliance structure of the industry. We further try to predict the future alliance structure.

Keywords: Landscape Model, alliance, configuration, dynamic parameters, Reputation quotient (RQ)

1. LANDSCAPE THEORY

1. 1. Basic Concepts

Landscape Theory, proposed by R.Axelrod [1] is a theory for simulating the formation process of alliances. Agents can switch from one coalition to another. They move to a coalition in which the frustration (disutility) she feels decreases most. The simulation is run by letting the agents move one by one in the order that the agent with highest frustration moves first.
The Landscape Theory makes two basic assumptions, both drawn from the recognition that it is difficult for a agent to assess the value of each potential alliances.

Assumption1: Each agent has a myopic viewpoint.
Assumption2: Each agent tries to change the alliance to join gradually.

Assumption1 means that an agent avoids the difficult problem of evaluating all combinations of agents simultaneously by making only pairwise evaluations. Assumption2 means that it does not happen that an agent transfers to another alliance in conspiracy with other agents.

1. 2. Parameters

An agent is characterized by following three parameters. The *size* of an agent means a reflection of the importance of the agent to others. We express the size of the agent i as $s_i > 0$.
The *propensity* shows the closeness between two agents. We express the propensity from agent i to agent j as p_{ij}.
The propensity number is positive if agent i wants to get along well together with agent j and negative if they have many sources of potential conflict.
The *distance* between two agents is defined by an alliance structure which is called as *configuration*. A configuration is a partition of the agents, that is, a placement of each agent into one and only one groups. A specific configuration, X, determine the distance $d_{ij}(X)$ between two agents, i and j. In the simplest version of the theory, all agents are assumed to be in one of two possible groups, so we describe $d_{ij}(X) = 0$ if two agents belong to the same alliance and if they belong to the different alliance, $d_{ij}(X) = 1$.

1. 3. Frustration and Energy

Based on these parameters, it is now possible to define a measure of *frustration*: how poorly or well a given configuration satisfies the propensities of a given agents to be near or far from each other agent. A agent, i, wants to switch its alliance so as to decrease its frustration. The frustration of agent i in a configuration X is defined as follows.

$$F_i(X) = \sum_{j \neq i} s_j p_{ij} d_{ij}(X)$$

In this equation, s_j is the size of j, p_{ij} is the propensity from i to j, and $d_{ij}(X)$ is the distance from i to j in configuration X. Note that the definition of frustration weights propensities to work with or against another agent by the size of the other agent. This takes the account that a source of conflict with a small agent is not as important for determining alignments as an equivalent source of conflict with a large agent. Notice that an agent's frustration will be minimized if it is:

A) in the same alliance as those agents with which it has a positive propensity to align, because otherwise $p_{ij} > 0$ and $d_{ij}(X) > 0$, and

B) in the different alliance from those agents with which it has a negative propensity to align, because this would make $d_{ij}(X) > 0$ when $p_{ij} < 0$.

The next step is to define the *energy*, E , of an entire configuration, X , as the weighted sum of the frustrations of in that configuration, where the weights are just the size of the agents. The energy of a configuration X is given as:

$$E(X) = \sum_i s_i F_i(X)$$

Substituting the definition of frustration into this equation allows the calculation of the energy of a configuration in terms of size of the agents, their propensities to work together, and their distances in a particular configuration:

$$E(X) = \sum_{i,j} s_i s_j p_{ij} d_{ij}(X)$$

The formula for the energy of a configuration captures the idea that energy is lower (and the configuration is better) when agents that want to work together are in the same alliance, and those that want to work against each other are in different alliances. Size plays a role because having proper relationship with a large agent is more important than having a proper relationship with a small agent.

Given the energy of each configuration, it is possible to construct an energy *landscape*. The landscape is simply a graph that has a point for each possible configuration and a height above this point for the energy of that configuration. Figure1-1 shows an example of a landscape where each point in the plane at the bottom of the figure indicates a specific configuration and the surface above the plane represents the energy of that configuration. Adjacent points on the landscape are those that differ in the alignment of a single agent. The landscape has a dimention for each agent indicating which alignment it is in. Because it is not possible to draw a large-dimentional hypercube, in Figure1-1 we have provided a conceptial (two-dimentional) surface instead.

An alliance structure attains to the state in equilibrium that has no room for decreasing energy as a consequence of agents' behavior. The state of alliance and rupture of agents represents final state of alliance structure.

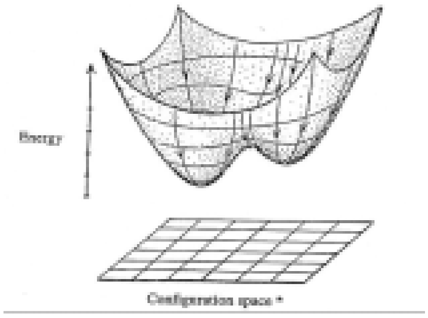

Figure1-1. A Landscape with Two Local Optima [1]

2. APPLICATION TO AIRLINE INDUSTRY

2. 1. Our interest

We apply this model to *alliance strategy* in airline industry. An airline alliance is an agreement between two or more airlines to cooperate for the foreseeable future on a substantial level. Though the degree of cooperation differs between alliances, this strategy plays an important role in the present airline industry. Therefore, the industry provides an appropriate case for demonstrating validity of the methods proposed above.

Some extensions and generalizations of the landscape model which deal with airline industry have been proposed so far. In these researches, however, the parameters shown above are defined staticially fixed. It is because their main focus is on dealing with "evaluation of the stability of configurations", "exclusion of individual rationality of each agent" and "proposal of algorism for discovering new equilibrium configuration" [2][3].

The model proposed previously also only considered correlation between airline companies. But in an actual decision situation, the airlines are influenced by consumers' behavior as well as competition between companies (growth of sales or expansion of air lines, for example). In this paper, we take consumer's behavior into consideration in our modeling (Figure2-1.).

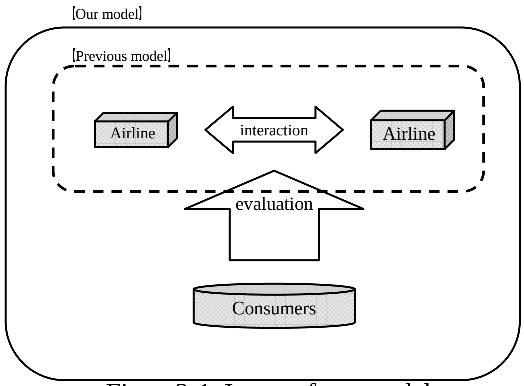

Figure2-1. Intent of our model

3. DYNAMIC MODEL

3. 1. Basic Idea

To achieve our purpose, we assume that value of the parameters shown above varies from stage to stage. So we construct a new type of landscape model with *dynamic parameters*.

When proposing a dynamic model, we do not take a myopic viewpoint of agents anymore (Remember Assumption1). In the original landscape model as well as in the past extensions, neither 1) dynamic change of parameters nor 2) synergetic value of the alliance is considered.

Our new dynamic model assumes an agent respects structure of membership in its alliance and re-evaluates its parameters every stage.

The image of our model is shown by Figre3-1. An alliance structure at a stage yields new parameters and lead to a new alliance structure of the next stage. Each parameter is not only defined by the independent value of each agent but also by the attractiveness of the alliance (the function of the structure of alliance members). Therefore, these parameters are not dealt with statically but dynamically.

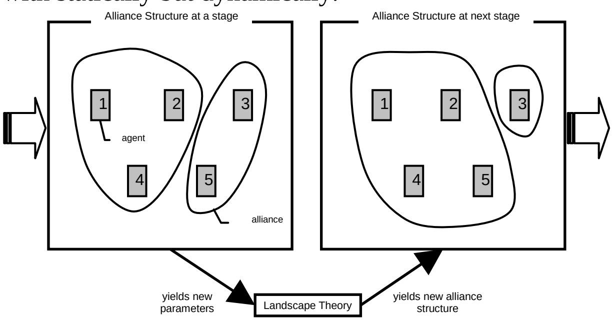

Figure3-1. Image of dynamic model

3. 2. Dynamic Parameters

To help keep the terminology as simple as possible, the language of airline alliance will be used. So, after this, we regard agents as airline careers.

3.2.1. External Parameters

To define the parameters of an agent dynamically, we prepare some external values. All the values are available from published data objectively.

The *reptutation* of an agent means attractiveness toward other agents. This value is determined mainly by outsiders (consumers or investers, for example). The higher reputation value an agent has, the more attractive it is toward other agents. We express the reputation of agent i as $r_i > 0$.

The *value* of the agent means economic value of the agent. We express the value of the agent i as $v_i > 0$.

The *line-propensity* indicates the one-to-one relationship between two agents by complemental relation of air line between company. We express the line-propensity from agent i to agent j as l_{ij} .

3.2.2. Simulation Parameters

Based on the external parameters provided avobe, we define new parameters used in our landscape simulation. First of all, we define the *alliance reputations*.

Let X be a configuration and suppose agent i belongs to an alliance $k_i(X)$. Then, the alliance reputation of alliance $k_i(X)$ is defined as:

$$R(k_i(X)) = \sum_{i \in k_i} r_i \frac{v_i}{\sum_{i \in k_i} v_i}$$

The alliance reputation represents attractiveness as a group. If there are many attractive members, the alliance reputation value should be high. The value of alliance reputation leans toward reputation of an agent which has high value. This means a large agent tends to become a representative of its alliance.

By using $R(k_i(X))$, we can define two parameters, i.e., size and propensity, which depend on configuration X . In our model, we assume that each agent considers not only the one-to-one relation between two agents but also co-relation with alliance members. In other words, we do not suppose any more that each agent has a myopic viewpoint nesessarily (See Assumption1).

Then, we define the parameter *size* used in our simulation. Suppose agent i belongs to alliance $k_i(X)$. Then the size of agent i is defined as:

$$s_i(X) = \alpha \cdot R(k_i(X)) \cdot v_i$$

In our model, we define size not only by the value of the agent but also by alliance reputation of the agent. Then, even if the value of the agent is small, the size of the agent can be calculated high because of the other alliance members. We think the agent doesn't consider the one-to-one relation with the other agent but the co-relation with other agents in the real decision situation, so that it is realistic to define size by the form depended on configuration X . The parameter alpha is a conversion parameter.

Finally, we define *propensity* from agent i to agent j as:

$$p_{ij}(X) = l_{ij} + \beta(r_j - R(k_j(X)))$$

By the same reason with size, we define the propensity in such a way that depends on configuration X . In this equation, the term $r_j - R(k_j(X))$ means the value of contribution to its alliance by alliance j. If the value of $r_j - R(k_j(X))$ is high, agent j is more attractive to agent i because agent j probably can contribute to other agents. The parameter beta is a figure for conversion. The original model proposed by Axelrod assumes that propensity is symmetric, so that $p_{ij} = p_{ji}$. But some extensions have been proposed about $p_{ij} \neq p_{ji}$ [2]. In our paper, we follow the latter line because we think it is more realistic.

Distance between two airlines is defined as the same as the original model proposed by Axelrod.

3.3. Frustration and Energy

We follow the original concept of Landscape Theory to calculate frustration and energy basically. Each airline wants to decrease its frustration. Consequently, we attain equilibria that have no room for decreasing energy. But the most important interest of our model is not only to seek the equilibria but also to express the dynamic transition of configurations. Therefore, the most essential expansion in this model is that agents estimates the configuration and re-calculate the parameters after the configuration is decided.

4. Simulation

4.1. The way to model the Airline Industry (Input Data)

This section describes data required to establish the models.

Firstly, the present paper prepares nine airlines, consisting of each three airlines in the United States, Europe, and Asia (Table 4-1.).

Table4-1. Selected nine airlines

United States	Europe	Asia
American Airlines	British Airways	Japan Airlines
United Airlines	Lufthansa German Airlines	All Nippon Airways
Delta Airlines	KLM Royal Dutch Airlines	Korean Air

Next, to measure the *value* of airlines, Revenue Passenger Kilometers* is prepared as raw data (Table 3-2.). We got the data from each Annual Report of airlines.

Table4-2. Value of agents (raw data)

No	Airline	RPK (million)
1	American	209473
2	United	185388
3	Delta	182351
4	British	107892
5	Lufthansa	104100
6	KLM	64125
7	JAL	102354
8	ANA	57645
9	Korean	46000

*RPK is calculated by "(The number of valied seats)×(Flight distance)"

Next, we define the line-propensity of agents. We follow the idea of the previous model [2]. We obtained the air line data from the latest Timetable of each airline. The algorism is shown in Figure4-1. On the assumption that each airline feels attract to expand own air line network, we compare overlaps or connections of air lines. The result is shown below (Table4-3.).

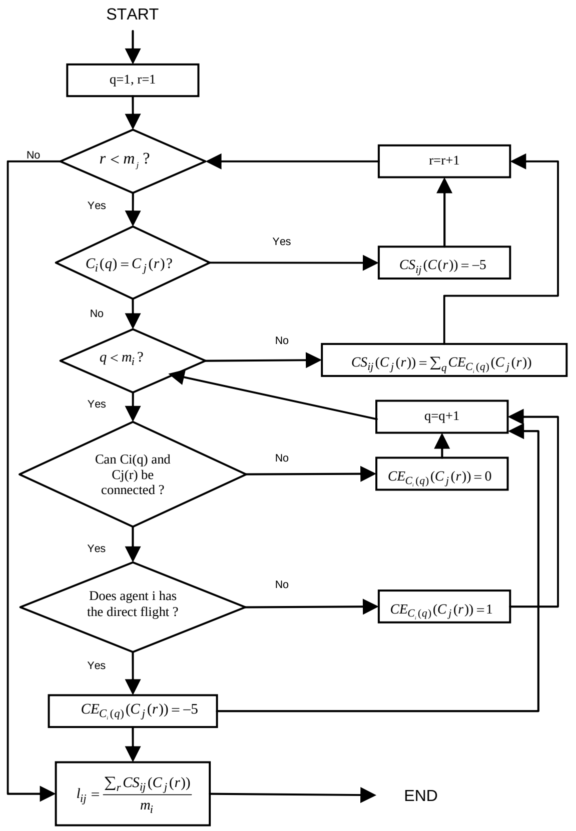

Figure4-1. Algorism to calculate the line-propensity

*Each formula express about as follows.

m_i :total number of the line of airline i

$C_i(q)$:each line of airline i

$C_j(r)$:each line of airline j

$CE_{C_i(q)}(C_j(r))$:evaluation from $C_i(q)$ to $C_j(r)$

$CS_{ij}(C_j(r))$:total evaluation from $C_i(q)$ to $C_j(r)$

Table4-3. line propensity of agents

No	1	2	3	4	5	6	7	8	9
1	-5.000	-7.618	-3.012	0.988	-1.708	-1.332	1.961	2.606	-0.523
2	-8.345	-5.000	-4.327	2.642	0.785	-0.546	5.336	6.386	-0.419
3	-8.225	-4.755	-5.000	-1.222	0.466	-1.902	0.405	0.674	-0.849
4	-0.340	-0.818	0.174	-5.000	-0.582	-1.158	-2.724	-1.712	-1.709
5	0.988	0.220	0.298	-0.469	-5.000	0.488	0.642	0.977	-0.244
6	-1.833	-2.529	1.947	-1.444	-1.517	-5.000	0.565	0.780	-0.802
7	0.228	-0.392	0.038	1.840	0.052	0.344	-5.000	16.121	-2.256
8	0.158	-0.240	0.133	1.259	0.200	-0.020	8.108	-5.000	-0.314
9	0.490	-0.517	0.535	1.265	0.079	0.063	-1.211	0.591	-5.000

Finally, in the consumer evaluation, we consider the reputation factor. *Corporate reputation quotient (RQ)* presented by Harris Interactive Inc. is popular as a total evaluation value of companies [4]. It is evaluated by taking consumer, stakeholder and employee into consideration. In this paper, we adopt RQ as the consumer's total evaluation index (Table4-4.). We obtained the raw data from research operated by Harris Interactive Inc. [5]. Though the research was operated a few years ago, we think RQ doesn't change within short-term.

Table4-4.Reputation Quotient of agents

No	Airline	RQ
1	American	69.5
2	United	67.2
3	Delta	70.0
4	British	72.5
5	Lufthansa	74.7
6	KLM	74.1
7	JAL	69.6
8	ANA	67.6
9	Korean	54.5

4.4. Simulation algorithm

The most important expansion of the algorism is that we suppose agents re-calculate the parameters after the alliance structure is decided. The alogorithm of our simuration is shown as follows (Figure4-2.).

By this algorithm, we could express a formation process of the present alliance structure in our model. And we could find parameters effective to describe the real situation. Furthermore, by using these parameters, we can try to predict a future alliance structure. Finally, we will challenge to develop the new parameters or algorithms to arrive at the optimal alliance structure. As a result, we will give a bit of advice to airline carrirs.

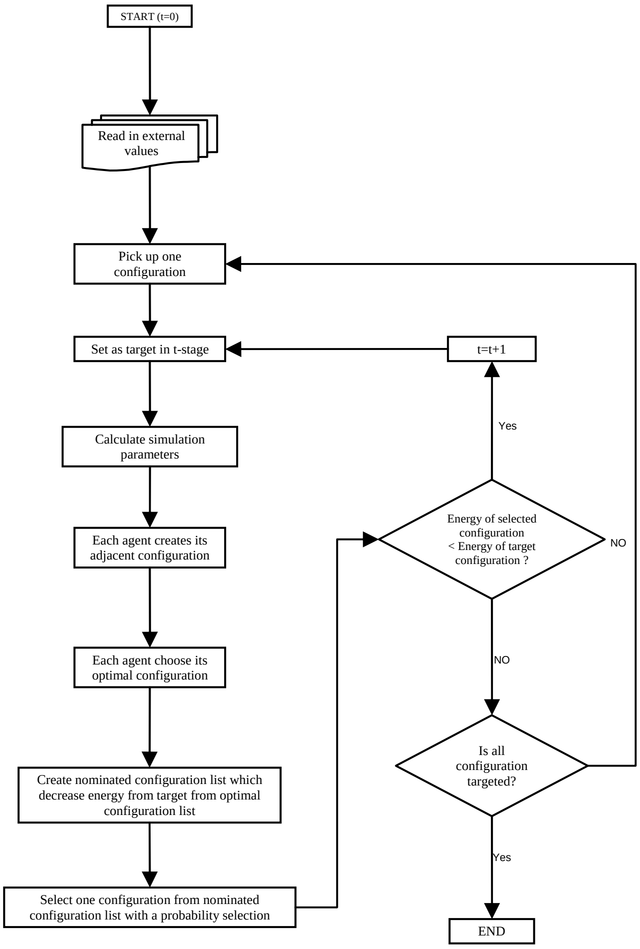

Figure4-2. Simulation process of our model

5. CONCLUSION

In this paper, we focused on ‘dynamic property of parameters’ which haven’t cousidered sufficiently in the model proposed past. We proposed a new type of landscape model in which the parameters change dynamically and we describe real decision situation faithfully.

Furthermore, we applied this model to ‘alliance strategy’ in the airline industry and discussed the stability and justification of the present alliance structure of the industry. We finally tried to predict future alliance structures.

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