A General Pattern of Town Streets on Map Spaces

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***Abstract*—This paper presents a town street model which is a natural model to describe general borders of residential sections/blocks in town streets, and discusses the features of the model. This paper takes the typical residential blocks in Tokyo, presents the features of the blocks, and reproduces future general block borders which are taking into the updates in temporal borders based on Schelling model. We employ two features in this paper: one is the lengths of borders in sections/blocks, and the other is the angles between two borders in sections/blocks, where the boarders are represented by the piecewise linear. Then, we show that we can find the human features in the general town street patterns based on a boundary effect and a fluctuation.**

***Index Terms*—autonomous moving multi-agents, Schelling model, and segregation**

I. Introduction

A town street model is a model of life's aspect to daily activities. The mode can describe a street section/block which has the similar characteristics of areas, sizes and forms of sections/blocks in towns.

We are interested in the general characteristics of town streets, and our goal is to reproduce future general borders which have the same characteristic to real town streets, while the characteristics heavy depend on their countries, races, national characters, and areas we live in. Furthermore, the general borders will be updated over time gradually every times, just a little bit. But, it is for a long time. We take the typical blocks of a town in Tokyo, present the characteristics of the blocks, and reproduce future general blocks which are taking into the updates in temporal borders based on Schelling model [1]. We use two features to describe the town streets in this paper: one is the lengths of borders in sections/blocks, and the other is the angles between two borders in sections/blocks, where their boarders are represented by the piecewise linear. Then, we show that we can find the human characteristics in the town street general patterns based on a boundary effect and a fluctuation [2].

A lot of different kinds of patterns have been studied in the nature world, and they are sometimes discussed in *complex systems* [3], and most of them have exponential features since they are based on physical characteristics. On the other hand, it is point out that the distinct features of human activities in he/her life follow a power law, which corresponds to a kind of Boltzmann distribution, rather than an exponential law. It is well known that the characteristics of networks and others also have a power law [4]-[6]. In human activities, the streets which are made by human activities in a town are what human beings have made, while also studying patterns. It is also different from complex networks based on a graph showing relationships of things. Although river patterns can be based on invasion percolation, movement of wealth and humans is not fitted with fluid ideas from the viewpoint of land and living, that is a fluid passes through the porous body [3].

Our motivation is to generate a lot of slightly different patterns with similar or identical features for printing slightly different figures on furniture. They are similar feature patterns, but their patterns are slightly different. So, all the furniture printing figures are different. May be, some furniture can be fixed the patterns when ordering by generating a lot of patterns, choosing some, and fixing it. Then, a lot of different kinds of patterns are requested when ordering. This kind of works gives us relaxing and healing effects. In this work, we focus on the features of the street patterns created by artificial, and the purpose of this research is automatically to generate a street having the same characteristics as a real street in a certain sense. So, we propose a street model and evaluate it by simulation.

Those spontaneously produced have less external forces, and the main cause is interaction in the vicinity. By external force acting on neighboring interactions, it is thought that it will be possible to have regular characteristics as well.

When cities are formed to some extent, the influence on interaction becomes important. An Ising model is known as a model of interaction, and it is based on an entropy. Let P be an external force, and Delta characteristics of town streets. Then, we suppose that Px Delta has a lower bound like the uncertainty principle, and it represents one characteristic of human activity. We are trying to examine its characteristics on map spaces. The approach of this study is to simulate how the streets change under the assumption that the difference between rich and poor acts as the pressure of boundary updates, assuming that adjacent boundary updates arise due to the difference between rich and poor. The difference between rich and poor is modeled, and it's based on Schelling. Then, it is assumed that the adjacent boundary moves by

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pressure or power according to the difference of rich and poor, and a street is formed. We will examine how much the generated street is compared with the data on the map.

Application of this research can reproduce nature's healing effect easily by artificially reproducing naturalness and it can be applied to printing and display to furniture and home appliances.

II. A Town Street Model

A town street is a set of pairs $\{<o_i,p_i>\}$, where o_i are residence areas, p_i are the wealth of owners o_i. We assume a dynamic model such as the town streets reflect the relationship on economic powers, so that the model is suitable to Schelling model [1].

We randomly choose distinct two areas $<o_i,p_j>$ staying in a street town, and they do some transactions between the two. Some wealth moves between distinct two areas, repeatedly. Then, one p_i is increased, and the other one is decreased. This transactions are repeated in $\{<o_i, p_i>\}$. Schelling discovered that we can observe that the gap between rich and poor is expanded after some transactions. That is, the distribution of the wealth p_i, rich or poor, of areas o_i spreads. We examined the simulation. We initially employee the grid pattern shown in Fig. 1, and each cross is living a family. We randomly assign points to their families, 10,000 points in total. They make one point transaction once between two families. After 554,947 transactions, the points owned by each family are as shown in the Fig. 2. Then, the sizes of the circles show the points owned by each family member. The distribution of the initial points owned by family members in Fig. 1 is shown in Fig. 3. After the transactions, the distribution is expanding as shown in Fig. 4, and the families with rich point 0 are characteristically increasing. Also, a few wealthy families are increasing. Schelling, he uses the mechanism for segregating rich and poor. Actually, the simulation shows that the numbers of poor families are not only increased after the processing of many transactions, but also the numbers of rich families are increased.

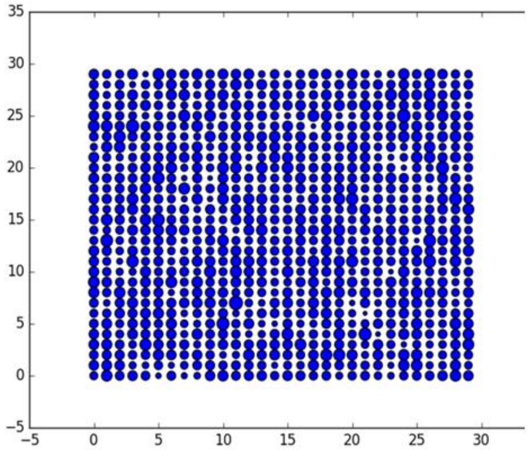


Figure 1. Initial status owned by families in Schelling model.

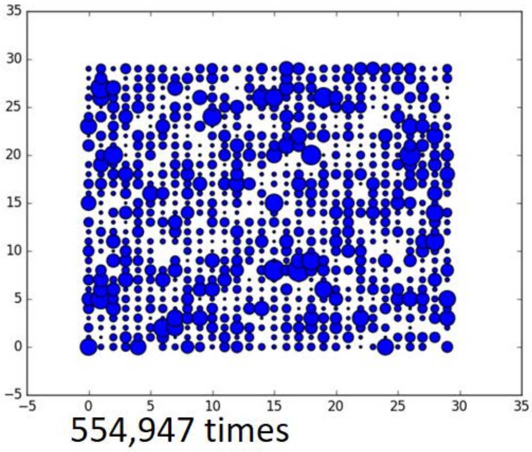


Figure 2. The simulation result after 554,947 transactions.

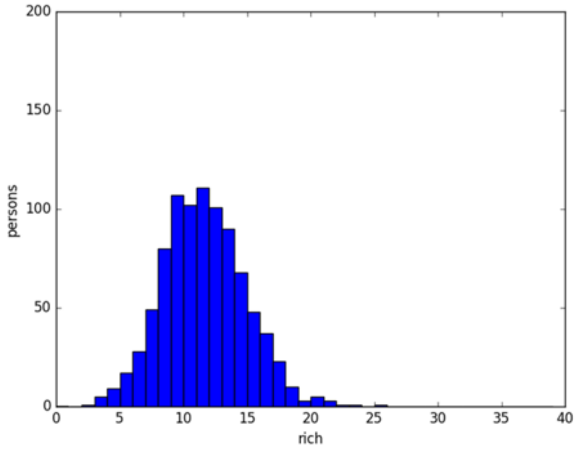


Figure 3. The distribution of initial wealth owned by the families.

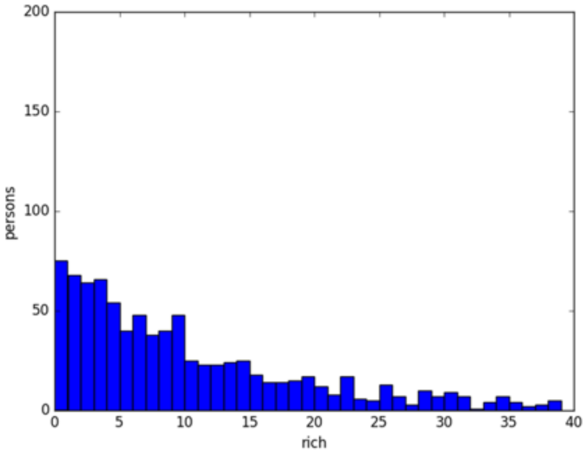


Figure 4. The distribution of wealth after 554,949 transactions.

Assume the areas are updated upon p_i, so o_i are increased or decreased by purchasing real estate. In this paper, the areas are updated to minimize the quadratic form centered on the center of gravity shown in Fig. 5. Then, the crossing point (x,y) moves to a new one which minimize the quadratic form.

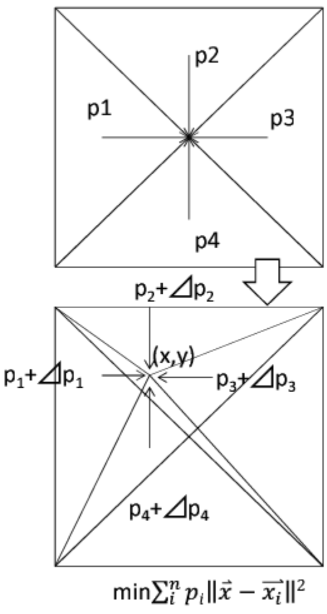


Figure 5. The area update method.

Fig. 6 shows an example of the updates after 10 transactions. That is, the borders move according to the updates of wealth as in Fig. 7, where the outer borders are fixed.

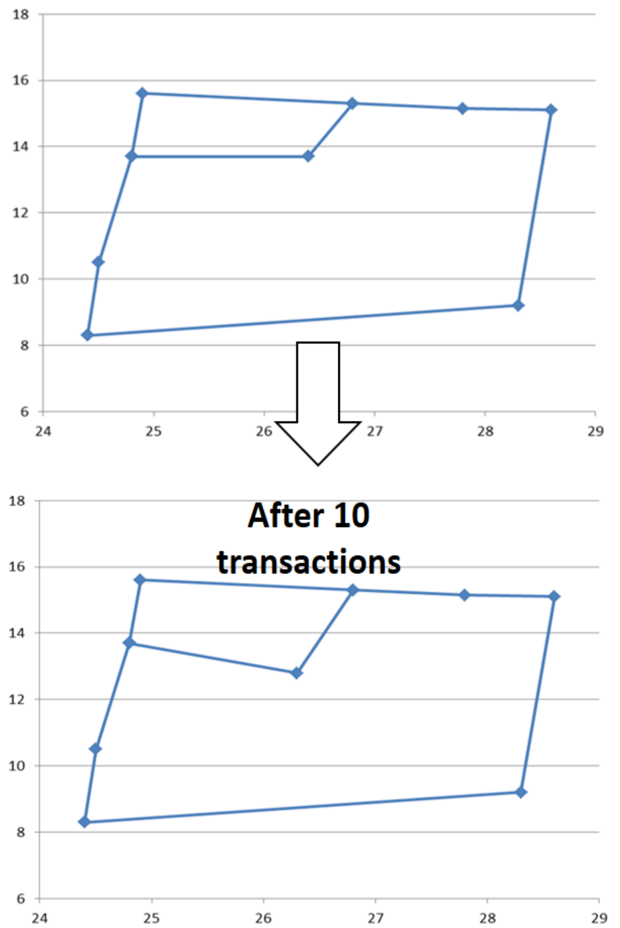


Figure 6. An example of the areas updated by 10 transactions.

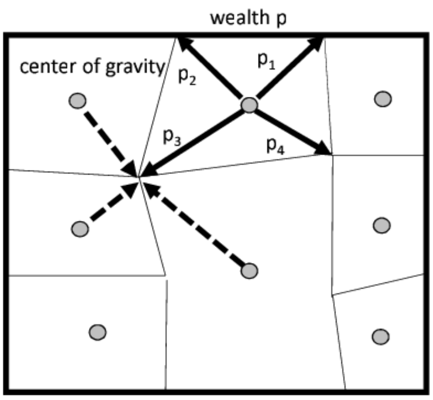


Figure 7. The border movement model along rich and poor.

III. Experiments

We have been discussed what kind of characteristics human beings have built over a long time. In this section, we discuss the original map of a town in Tokyo shown in Fig. 8, and is a typical down town border in Tokyo area. Then, the distribution of the lengths of the sides (borders) is shown in Fig. 9, and also the distribution of angles between two sides is shown in Fig. 10. The both are having wider distribution rather than a exponential. This kind of distributions is a typical one which is characterized by power law [4]. Even, they are depending on a culture and a specific area whether a real estate is expensive. In the transactions, if two areas become neighbor, their borders actually move. So, the transactions is said to be performed in locally. Otherwise, a lot of strange areas are generated to evolve so that some boarders might disappear. Because the rich owners try to extent their areas without considering neighbor area shapes.

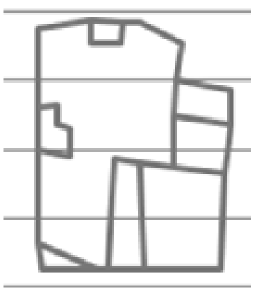


Figure 8. The original tow street map in Tokyo.

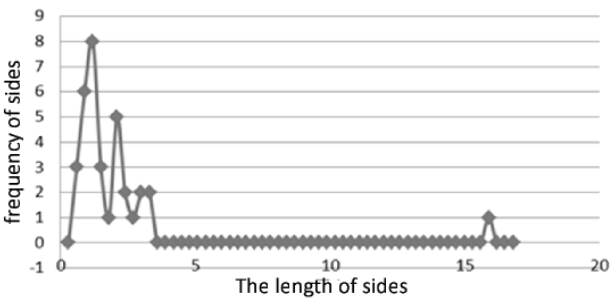


Figure 9. The original length distribution of Fig. 8.

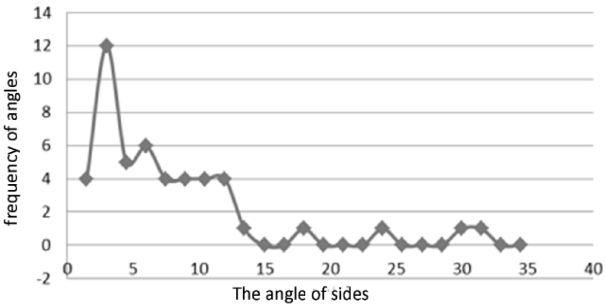


Figure 10. The original angle distribution of Fig. 8.

For the original map in Fig. 8, we generated five town street maps by repeating 10 transaction described in Section II. Then, we choose two areas in randomly, and the two perform the some transactions which buy or sell somethings alternatively, and they exchange some money, but their roles are selected randomly. And, if their become rich areas, then the owners expand the areas along quadratic evaluation shown in Fig. 5. On the other hand, if the areas become poor, then the areas are reduced. After 10 transactions, we obtain the future town streets, and they are illustrated in Fig. 11, and every town streets are different so that every areas are figured the different design on them. The left upper side case is redrawn in Fig. 12. Then, the distributions of side lengths and angles are shown in Fig. 13 and 14, respectively. They keep the similar features on the lengths of borders and the angles between two borders.

We note that the transactions are performed in locally. That is, if two areas are separated by other areas, then the owners of the areas become rich and poor. But, their borders could not move along their asset, because the two areas are separated by others.

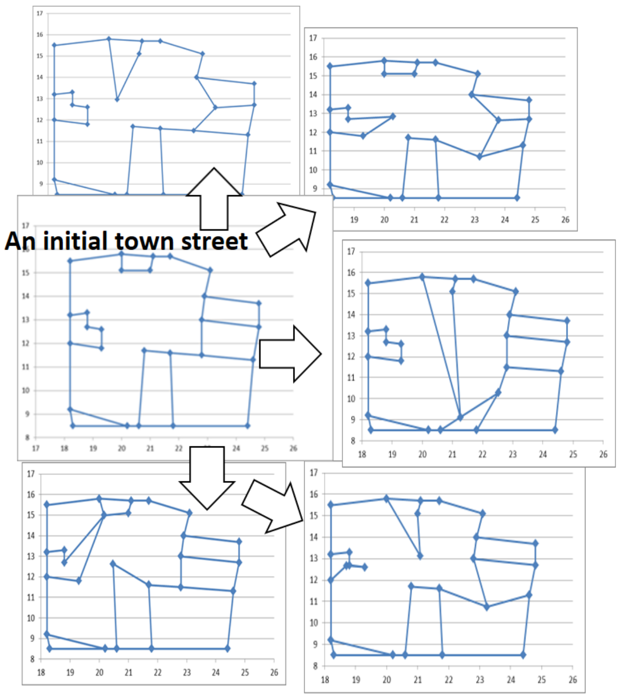


Figure 11. After 10 transactions.

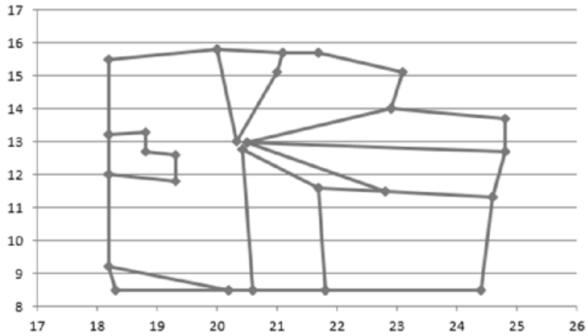


Figure 12. The generated town street map of Tokyo.

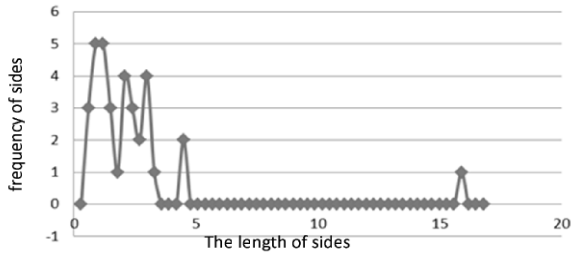


Figure 13. The length distribution of Fig. 12.

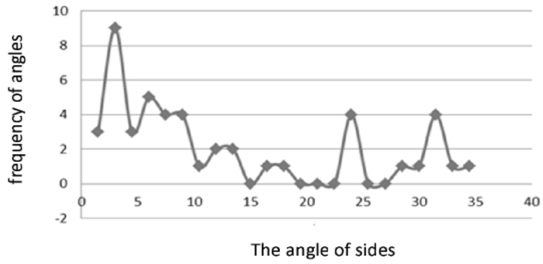


Figure 14. The angle distribution of Fig. 12.

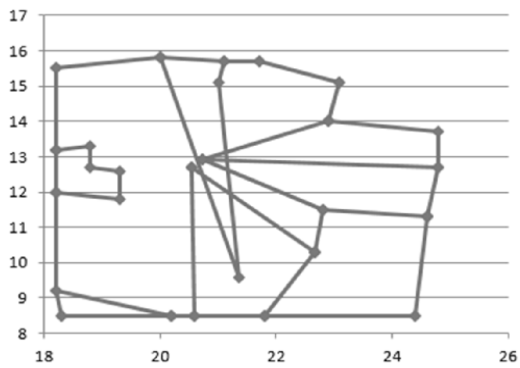


Figure 15. The generated town street map in Tokyo, but it is invalid.

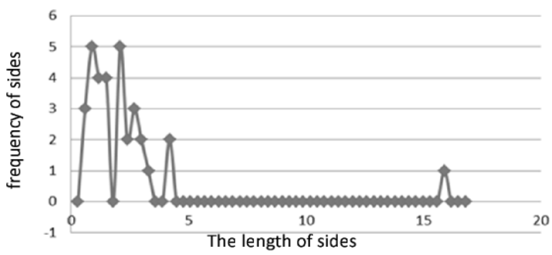


Figure 16. The length distribution of Fig. 15.

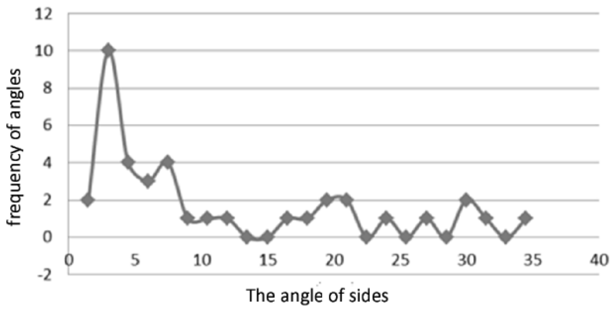


Figure 17. The angle distribution of Fig. 15.

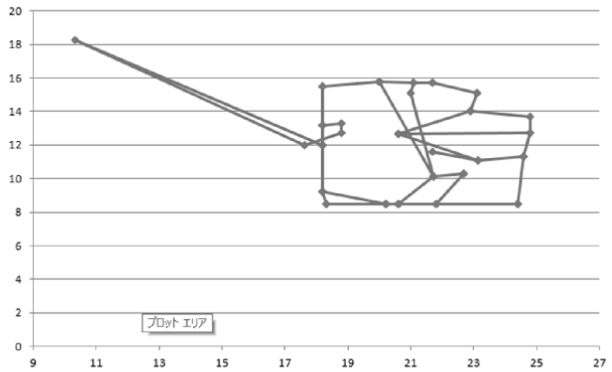


Figure 18. The generated town street map in Tokyo, but it is invalid.

Some generated town streets are not realistic and they are not allowed in actual. Fig. 15 is also generated the other town street, and the lengths and angles are shown in Fig. 16 and 17, respectively. Their characteristics are said to be a fluctuation shown in [2], and their distributions become like Chi-square around lower values 0. In upper areas, the distribution (Fig. 16) on the lengths of sides is approximated by power law density function, and the distribution (Fig. 17) on the angles of sides is also too. But, the town map in Fig. 15 is invalid, because their borders are crossed in different directions. Fig. 18 is also an invalid case. However, the features of their distributions keep power law [4].

To escape the invalid town cases such as Fig. 15, we need the constrains not to overlap areas by crossing borders. Further, we require to update the borders drastically as a mechanism of phase transition, while the distributions of borders lengths and angles do not have big variations. We have performed the experiments by taking a town street in Tokyo, and generate some town streets performed by the transactions based on Schelling model. Then, two features, the lengths and angles of borders, are keeping, but the wealth of residences are evolved, and the rich and poor residences are separated. This is a natural mechanism to live in towns, and the future towns might be expected. We took a specific town in Tokyo, but the mechanism is natural to live in towns. Quantitative evaluation is necessary by adding the constraints not to overlap. This problem is formalized in the constraint optimization framework. If there are no constraints, the solutions are given by linear equations.

IV. Conclusions

We examined whether the street model assuming that the streets change in proportion to the ownership of the land by the economic activity gap between rich and poor can produce something with the same characteristics as our familiar streets. We need more evaluations whether the generated town streets actually give a healing and a relaxing to us. This point depends on the race, culture, areas, etc.

References

[1] T. Schelling, "Dynamic models of segregation," *Journal of Mathematical Sociology*, vol. 1, pp. 143-186, 1971.

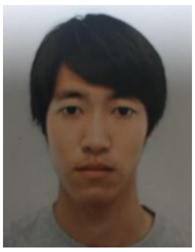
[2] T. Suzuki, S. Tanabe, and I. Shioya, "Accelerated traffic model based on psychological effects," *International Journal of Digital Information and Wireless Communications*, vol. 7, no. 1, pp. 26-34, 2017.

[3] P. Ball, *Nature's Patterns: A Tapestry in Three Parts*, Oxford, 2009.

[4] K. Ara, *et al.*, "Sensible organizations: Changing our business and work styles through sensor data," *Journal of Information Processing*, vol. 16, pp. 1-12, 2008.

[5] D. J. Watts and S. H. Strogatz, "Collective dynamics of 'small-world' networks," *Nature*, vol. 393, pp. 440-442, 1998.

[6] A. L. Barabási and R. Albert, "Emergence of scaling in random networks," *Science*, vol. 286, pp. 509-512, 1999.



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