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An Invitation to Cellular Geography

Iwao KANEYASU

1 Introduction

Sufficient time has passed since the significance of theoretical approach was stressed by several commentators in the field of human geography. The theme of duality is often picked up. The recent entrance examination for the graduate course of geography in some Japanese university shows such a situation. One of the questions is as follows[1].

Explain the duality of human geography by combining following five viewpoints; 1) idiographic vs. nomothetic, 2) physical vs. human, 3) systematic vs. inductive, 4) deductive vs. inductive, and 5) science vs. art.

Most of the current studies in human geography are done through the inductive approaches and the deductive approaches are few in Japan. This paper aims at the introduction to the scope for the theoretical approach in human geography through the concept of cellular geography proposed by Tobler (1979) and other specialists.

2 Quantitative revolution and theoretical geography

Ian Burton's phrase of 'Quantitative revolution is over' is well known, but the latter part of the title of his paper was often overlooked hehind the shocking words 'revolution'. Burton stated after the introduction of the publication of Theoretical geography by William Bunge (1962);

'—— This volume[2] will help to focus the attention of geographers on the need for theory. Perhaps a rash of attempts to develop geographic theory will begin. Such a development seems unlikely, however. For while the use of quantitative methods is a technique that can be learned by most, few seem to have that gift of insight which leads to new theory. North comments that a difficult problem is "the development of the theoretical hypotheses necessary for shaping the direction of quantitative research." ——' (Burton 1963).

Allan G. Wilson, who is known as a researcher on the development of spatial interaction models, delivered the following statement to the meetings of the Institute of British Geographers, the Geographical Association and the Royal Geographical Society;

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'—— Geography has had its so-called quantitative revolution and I believe that there is often a confusion between 'quantitative' and 'theoretical'. I should like to try to resolve the confusion and to indicate that theoretical development is much more important than quantification. ——' (Wilson 1972).

Wilson also defined in the same lecture that '—— a theory is a set of propositions which purports to explain the structure of some system and/or how the system develops. —— a theory does not have to be quantitative or mathematical by definition ——'. Let's pick up some phrases from his paper.

'a division of labour may appear between theoreticians and 'experimentalists' (for want of a better word)'.

'Good new ideas result from excercises of creative imagination of the highest order'.

'I suggest that the researcher has to explore an abstract space of possible ideas'.

The present author thinks that the comments by two prominent figures are enough to look at the theoretical aspects of geography. Looking into the current state of the geographical society in Japan, theoretical (deductive) approach is few. However, the study of the theory of occupance by Junjiro Takahashi is attractive. He proposed the problem setting from the standpoint of deductive approach at the Human Geographical Society of Japan in the 1977 conference (Ishimizu 1978 and Takahashi's papers on the list of references).

'Let's suppose that the surface of the earth is generated by following rule. What kind of pattern is formed?'

That is, he proposed the deductive approach such as 'What kind of rule the surface follows by?', instead of the inductive approach such as 'what kind of pattern can be found on the surface?' His idea suggests that a geographer does not find his own calculus, *i.e.*, rules as premises for the logical reasoning.

3 What is cellular geography?

The concept of cellular geography is introduced here as an example of the deductive approaches in human geography. W.R. Tobler proposed the idea of cellular geography at the seminar in Wien in 1975 (Tobler 1979).

The space of grid cell as in matrix algebra is considered. The cell in the ith row and jth column becomes the cell i, j. Geographical data to the cell is written as g_{ij}. If you wish to add the temporal dimension, you can write g_{ij}^{t} and g_{ij}^{t+dt}. According to Tobler, the classification of models of land use is shown as follows:

1) The independent model: The land use g_{ij}^{t+dt} does not depend on the previous state of g_{ij}^{t}.

2) The functionally dependent model: g_{ij}^{t+dt} depends on the previous land use at that location. *eg.* Markov chain model

$$g_{ij}^{t+dt}=F(g_{ij}^{t})$$

3) The historical model: g_{ij}^{t-dt} depends on the several previous land use at that location. *eg.* time series model

$$g_{ij}^{t+dt}=F(g_{ij}^{t},\ g_{ij}^{t-dt},\ g_{ij}^{t-2dt},\ \cdots\cdots,\ g_{ij}^{t-kdt})$$

4) the multivariate model: g_{ij}^{t+dt} is dependent on several other variables at that location. *eg.* simultaneous equations model

$$g_{ij}^{t+dt}=F(u_{ij}^{t},\ v_{ij}^{t},\ w_{ij}^{t},\ \cdots\cdots,\ z_{ij}^{t})$$

5) The geographical model: The land use at location i, j is dependent on the land use at other locations.

$$g_{ij}^{t+dt}=F(g_{i+p,\ j+q}^{t}).$$

The geographical model includes two models.

Type I

$$g_{ij}^{t}=F(g_{i+p,\ j+q}^{t})$$

This type shows that the state at time t depends on the states of neighbors.

Type II

$$g_{ij}^{t+dt}=F(g_{ij}^{t},\ n_{ij})$$

This is a dynamical type model and means that the state at time $t+dt$ is dependent on the previous state at that location and the states in the neighborhood of the location i, j.

The concept of the neighborhood

The concept of the neighborhood in the grid-cell space is introduced here. The simple definition of a neighborhood in a square lattice is to include all cells in a box around the cell of interest; n_{ij}=cells $i+p$, $j+q$. Therefore the number of whole cell is equal to $(2p+1)(2n+1)$. Other popular definition are Neumann neighborhood and Moore neighborhood (Fig. 1).

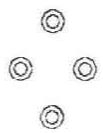


Fig. 1-a Neumann neighborhood

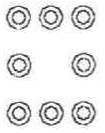


Fig. 1-b Moore neighborhood

The transition rule

It is important to specify the function F in the Tobler's geographical model. He introduced the case of transition from agricultural landuse to commercial landuse in the following example (Fig. 2). Symbols of areas are as follows; A: Agricultural, C: Commercial, R: Residential, and I: Industrial.

Tobler's idea is applicable to the problem to estimate the geographical transition

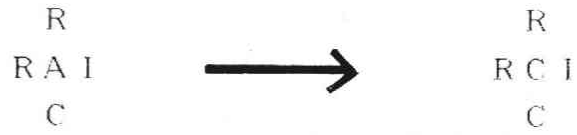


Fig. 2 A transition rule in the case of landuse change

rules given geographical maps of one area but different times. In the case of geographical planning, given an initial state, a desired state, and a set of transition rules, we can ask what changes need be made to the rules so that the objective is realizable.

4 Conway's Life game

Simplicity comes from principle through abstraction of the real world. Life game introduced here was originated by John Horton Conway, a mathematician at the University of Cambridge. Conway's game fascinated lots of system scientists through the introduction by Martin Gardner in the journal of Scientific American around 1970 (Gardner 1970-1971).

Life is a simulation game to show the birth, death, survival of living creatures and the change of society. 'The basic idea is to strart with a simple configulation of counters, one to cell, then observe how it changes as you apply Conway's "genetic laws" for births, deaths and survivals.' (Gardner 1970). To implement Conway's life game, following preparation is needed.

— Tool : checkerboard and stones with black and white.

— Neighborhood : Checkerboard has eight neiboring cells, four adjacent orthogonally, four adjacent diagonally, *i.e.*, Moore-type neighborhood (Fig. 3).

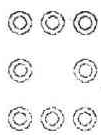


Fig. 3 Neighboring cells
(Moore-type neighborhood)

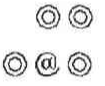
— Participant : one. After initial setting, the results can be automatically gotten. It might be called a 'no-player game' after Conway.

— States : occupied or vacant.

— Transition rule (genetic laws) :

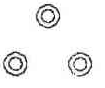
(a) Survival : A cell that was live at time t will remain live at $t+1$ if and only it had just 2 or 3 live neighbors at time t.

(b) Death by overcrowding: A cell that's live at t and has four or more of its eight neighbors live at t will be dead by time $t+1$.



(c) Death by exposure: A cell that has only one live neighbor, or none at all, at time t, will also be dead at $t+1$.

(d) Birth: A cell that's dead at time t becomes live at $t+1$ only if exactly three of its eight neibors were live at t.



Let's see the transition of the initial states by the genetic laws in the case of a simple line of three live cells (Fig. 4).

It is very hard to see what goes on in future in Life game. For instance, a simple straight line of n live cells shows a variety of future life.

$n=1$ or 2 fades immediately,
$n=3$ is the Blinker;
$n=4$ becomes a Beehive at time 2,
$n=5$ gave Traffic Light at time 6,
$n=6$ fades at $t=12$
$n=7$ makes a beautifully symmetric display before terminating in the Honey Farm at $t=14$;
$n=8$ gives 4 blocks and 4 beehives,
$n=9$ makes two sets of Traffic Lights,
$n=10$ turns into the pentadecathlon, with a life cycle of 15,
$n=11$ becomes two blinkers,
$n=12$ makes two beehives,
$n=13$ turns into two blinkers,

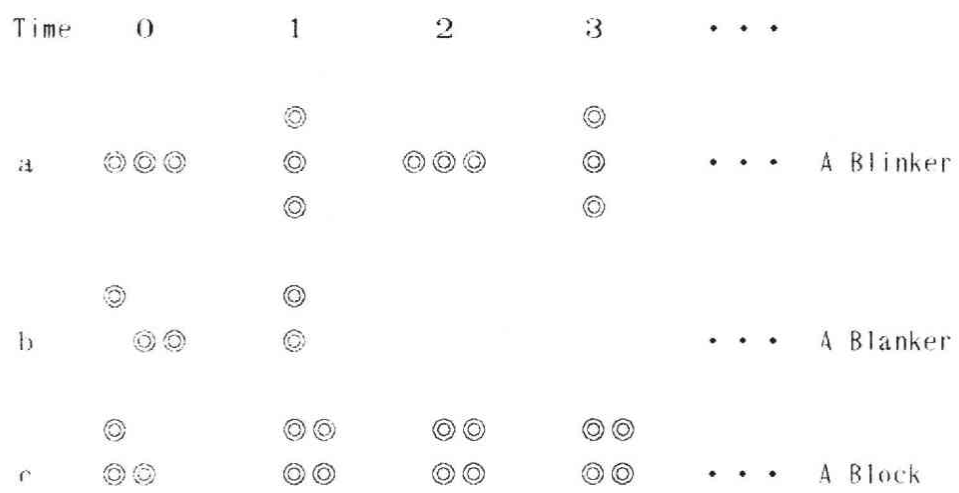


Fig. 4 Life of a line of three cells

$n=14$ vanish completely,
& $n=15$
$n=16$ makes a big set of Traffic Lights with 8 blinkers,
$n=17$ becomes 4 blocks,
$n=18$ fade away entirely,
& $n=19$
$n=20$ makes just 2 blocks,
and so on (Berlekamp, Conway and Guy 1982).

As typical examples, still life (stable configulation) and life cycles are shown in Fig. 5 & 6 respectively.

Can the population of a Life configulation grow without limit ? The $50 prize was offered and a group at M.I.T. headed by R.W. Gosper won the prize in November 1970. They found the so-called Grider. The Grider appears every five steps (Fig. 7).

Other interesting cases are reported by Conway ; When grider meets grider, the eater's behavior, grider vs. block, grider vs. pond, grider vs. ship, kickback reaction of the grider, sidetracking, when the eater is eaten, when the gun is guned down, *etc.*

Life game tells us how the complicated real world is generated by the simple basic rule. This game is based on the deterministic process, therefore the case by chance cannot contribute to the final results. The charming point of the life game is that the change is unpredictable even though the final output is determined by the very simple transition rule and the initial condition.

The background of this game is related to the theory of cellular automaton. A.M. Turing set up the problem whether there exists the automatic machine of thinking

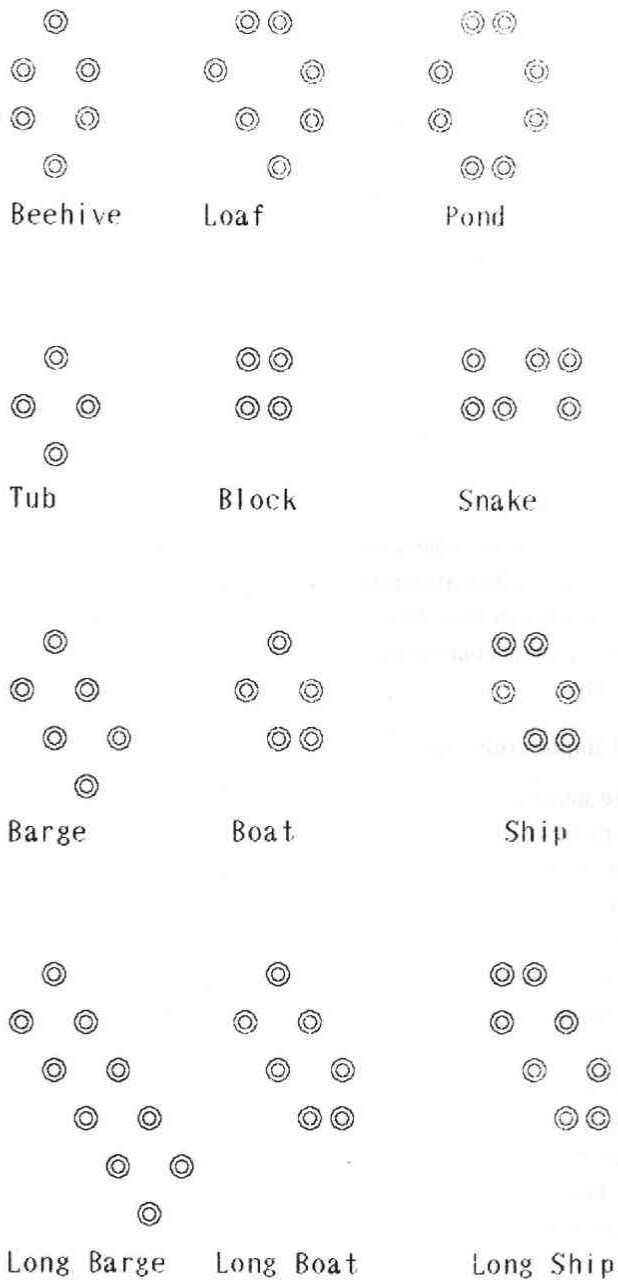


Fig. 5 Still life (stable configulation)

Fig. 6 Life cycles

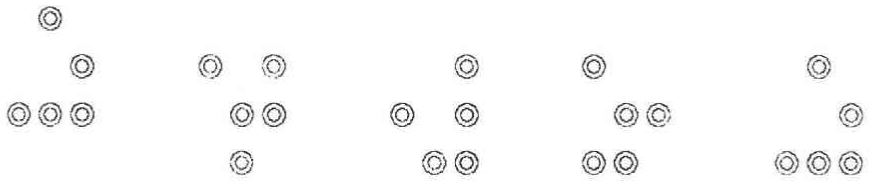


Fig. 7 Grider

(Turing machine). Later on, 'John von Neumann set himself the task of provoking the possibility of self-duplicating automata. —— Neumann, applying transition rules to a space in which each cell has 29 states and four orthogonally adjacent neighbors, proved the existence of a configulation of about 200,000 cells that would self-reproduce.' (Gardner 1970).

5 Geographical implications by Takahashi's theory of occupance

Conway's life game is an example of cellular automaton. Now it's our turn to think about the meanings of the application of the life-game-type thinking to geographical phenomenon.

Geography is generally recognized as a science of the surface of the earth. Geographer's primal concerns are referred to the surface of the earth as the home of human beings, spatial variation, temporal change, some structure and process. We are interested in the structured body of knowledge and the procedures to produce such knowledge. According to Junjiro Takahashi, geographers are interested in 'the generation and control of the tempo-spatial variations as the basic characteristics of the surface of the earth. It is our final goal to find out several theorems and present the conceptual framework including these theorems, that is to form the theory of geography.' (Takahashi 1986). He presented a stimulating sense of problem at the Human Geographical Society of Japan in 1977. His early papers appeared in the Mita Journal of Economics in 1976. Following phrases can be found in his papers.

'The reason why the geographical theory was not developed sufficiently should not be attached to the special nature of the study subject of geography, but comes from the attitudes of geographers.'

'Geographers are not interested in the meanings of theory and are not familiar with the theory construction'.

Then his problem setting can be summarized as follows;

'Let's suppose that the surface of the earth is generated by following rule. What kind of pattern is formed?'

That is, he proposed the deductive approach such as 'what kind of rule the surface follows by?', instead of the inductive approach such as 'what kind of pattern can be found on the surface?' Deductive approach stresses a set of definitions of terms and premises, process of logical reasoning, and the results. It is the output from the intense thinking, and observation is not necessarilly included in deductive approach.

His idea suggests that a geographer does not find his own calculus, *i.e.*, rules as premises for the logical reasoning. Takahashi's argument goes into the abstract space. The statement on the tempo-spatial variation of the earth surface is equivalent to the statement on the spatial arrangement of the objects and events. The earth surface is the space filled with various objects and events. The study on the tempo-spatial variation of the earth surface is equal to the study on the spatial arrangement of the objects and events occurred on the surface. We can point out four basic principles referred to the objects and events occurred on the surface.

Principle of occupance: Two different things cannot occupy one place at the same time.

Principle of exclusion: When one object occupies a place, the others are automatically excluded from that place.

Principle of filling up: The surface is filled up by some occupants.

Principle of replacement: Occupance is usually limited in time and the replacement of occupance occurres.

Our primal concern is the generalization of abstract space based on the new categorization, *i.e.*, spatial arrangement. Occupance is a function of state category and location category. The pattern of the spatial arrangement differs depending on the ways of extraction. So, the first step is to show the possible number of patterns of spatial arrangement from the theoretical viewpoints. Then we can introduce the regulation rule (Ross Ashby 1956) to reduce the number. Takahashi (1989) discusses the possibility of reduction of the number of possible pattern of spatial arrangement through the introduction of the principle of occupance as one of the regulation rule in geography. He also tries to develop his theory by the combinatorial theory since the combinatorial theory deals with the problem of counting the number of setting.

6 Application of cellular geography idea to Hägerstrand-type diffusion studies

The description above touches upon the introduction to the various aspects of cellular geography. Let's look at the application of cellular geography idea to

Hägerstrand-type diffusion studies as an example from abstract to concrete cases (Hägerstrand 1953 & 1965).

Although Hägerstrand model is originally an inductive one, it is important to reinterpret Hägerstrand-type diffusion studies from the context of our discussion in this paper. Hägerstrand simulation model is composed of four types from simple assumptions to realistic premises. Folowing discussion deals with the model with realistic assumptions.

a) Initial setting: Simulation starts with 22 adopters of innovation on the square grid.

b) Rule of regulation:
   - Geographical condition: Barrier effect is introduced. *eg.* mountains, rivers, *etc.*
   - Level of resistance: People accept some innovative ideas or things after they receive several messages. The resistance level used by Hägerstrand implicitly contains the idea that repeatendness makes people easier to adopt.
   - Mean information field: This concept is one of the most important ideas in Hägerstrand model. We discuss it below.
   - Communication: Information is transmitted by the personal contact at some time interval.

c) Output: Simulated pattern is generated by the simulation model.

Hägerstarand invented his model based on both inductive and deductive approaches. Let's look at the concept of the mean information field (MIF).

Three basic characteristics show the hypotheses of the MIF.

1) It is the same for all senders of messages.
2) It reflects a spatially symmetrical distance decay function.
3) It is bounded by an effective distance beyond which the probability of interaction may, for operation purpose, be regarded as zero.

There are nine steps to form the MIF.

1) Origin and destination of movement (1935-1939).
2) Centered migration field (Direction and distance of movement).
3) Grid with figures.
4) Table of moving units.
5) Distance and moving density.
6) Estimation.
7) Estimated number of movement.
8) MIF.
9) Floating grid with sequential number.

The MIF comes from the neighborhood effects. The diffusion of private informa-

tion depends on the movements of local population. The private information field has the stable spatial distribution just as the population movement field has.

7 Concluding remarks

This paper tries to point out the importance of deductive approach in human geography through cellular geography coined by Tobler. Conway's life game is suggestive to our concerns and Takahashi's discussion is challenging one. Cellular geography idea is applicable to the re-interpretation of Hägerstrand-type diffusion studies.

There still remain several tasks for cellular geographers; Stochastic situation, variety of transition rules, subdivision of area of occupance, *etc.* Every task is related to the fruitful conceptualization and applicability of the concept to the real world.

Notes

1) The content is not necessarilly precise because of the hearing from my student who got the entrance examination.
2) Bunge's book entitled *Theoretical Geography.*

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