SIMULATION OF URBAN LAND-USE CHANGES: A CASE STUDY OF HIGASHI-HIROSHIMA CITY

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INTRODUCTION

In absence of centralized decision-making, urban spatial pattern can be assumed to be an accumulated result of land use changes in each small land lot. Because expected utility for using land for certain purpose depends on the present land use of surrounding area, there is a network of interaction among land use of land lots in a city. Spatial agglomeration or clustering structure can emerge due to the interaction among small scale land uses. In order to simulate the emergence of spatial pattern in macro level, Cellular Automata (CA) modeling have been studied. The development of remote sensing technique has provided enough empirical land cover data to stimulate the CA based simulation in the area of land use study. The CA methodology, however, has been much criticized that transition rules lacks rational reasoning and that relationship between policy measures and the transition rules is not clear. On the other hand, due to the development of random utility or random bid rent models, locators' preference or land owner's behavior have become possible to be reflected in land-use modeling, with help of statistical estimation procedure. To explain the city's spatial pattern, in this paper attempts have been made to construct bid-rent functions for different usage of a particular land percel using both geographic and land-price information in multinomial logit framework. Using mesh data of 100mX100m grid and considering each mesh's characteristics in terms of its land-use, topographic condition, planning restrictions, accessibility, and neighborhood's land-use, four different bid-rent functions, viz., industrial, commercial, residential and vacant land, for each mesh have been constructed. To generate different spatial pattern, CA like simulation method is applied; initial land-use assignment for any particular mesh has been made under assumed decision rules. Assignment of a particular type of land-use for any mesh changes the bid-rent structure for remaining meshes in the system. Bid rents of these cells have been recalculated for their subsequent assignment under same decision rules.

RELATING STUDIES

Geographic Data and Land Use Model

Projecting future land use of the cities with reasonable degree of accuracy is a daunting task for the city planners. The statistical land use models explaining land use by using the geographical conditions and infrastructure development levels as explanatory variable have been developed since long time ago. However, up to the 1980's, micro scale model building didn't proceed from being very difficult and expensive to obtain detailed data on the land condition. Due to the development of remote sensing technologies in 1990, land cover classification became easy to be done. Several researches were appeared that analyzed the land cover changing process by capturing it as a probabilistic changing process. At first, the explanatory variables for these statistical models were limited to the adjoining land covering given by remote sensing, or manually prepared data such as straight line distance to the principal facilities like railway station.

The performance improvement and cost reduction of the geography information system proceed, and the country information base data of 1:2,500 level were introduced to the public from the Geography Survey

Institute after 1990..

Simulation Modeling Using CA

With the increased availability of remotely sensed data and GIS technology recently renewed interests have been noticed among the urban researchers to use Cellular Automata (CA) as simulation technique to predict future urban pattern. CA, termed as artificial life approach in simulation modeling, depends on the interactions of the entities based on intuitively understandable behavioral rules, rather than performance functions. Such behavioral rules are often decided by the researchers. In CA global patterns are generated from very local elements and so has much to offer urban simulation (Sullivan and Torrens,2000)

The key of CA simulation is formulation of transition probabilities and updating those probabilities with the passage of time. Many authors have shown the ways to formulate such transition probabilities and their updating in their researches (Almeida et al., (2002) and M. Phipps, A. Langlois**).** It is completely wrong to assume that cities can be evolved with out intervention and interaction of some processes generated at macro level (regionally, outside the preview of local cells). These factors have been considered in terms of formulating constraints in some models. Basically they these constrains formulations violated another basic assumption regarding unconstrained nature of CA simulations. Till the date most of the GIS applications in CA are in the form of generating some indices, which can be used in formulating decision rules for the state transition of cells or storing the data and visualization (Sui and Zeng, 2001; R. White, G. Engelen,1997)

Finally it can be concluded that though CA has the potential to use as tool in simulation of urban patterns but it is very slow to adopt explicitly geographic or urban theory as a basis for transition rule formulation, which is the core of such kind of simulation.

Random Bid rent model

It was difficult to take in the effect of the policies such as land tax system, which works on the economic entity's behavior. It is therefore, became necessary to develop land use models based on the behavior of the economic entities. It proceeded with the application of the random utility model developed by McFadden in the field of the traffic demand prediction in 1980s. But, there are some difficulties in applying a random utility model to the land choice behavior, simply because it doesn't consider that a locator can compare very huge number of possible places at a time easily.

Therefore, random bid rent models have been developed to capture the competition between different locators. The model suggests that for a certain land lot, several numbers of the locators give different bid rent according to the expected utility or expected profit. The landowner who expects more profits selects the locator with the highest bid rent.

Here, bid-rent is the locator's willingness to pay for the land lot, reflecting the future expected profit or utility level to be gained by using that land for his desired use. On that occasion, locator cannot use perfect information about the land conditions and future economic trends. Bid rent is, then, thought to change around the most probable value (systematic part), and the random bid rent model was developed. It had the same form as the random utility model. If the random part is supposed to follow the mutually independent identical Gumbell distribution, the probability of the occurrence of one type land use can be given by the multinominal logit model.

MODEL AND THE ESTIMATION

In this research a logit model has been proposed to grasp the effects of monetary policies such as the land tax system, and land use regulations on the land use of the city. Geographic Information System has been used to prepare detail database for land-use and other land characteristics fro each 100m mesh of the study area. Land-usages in year of 1991 and 2000 have been reclassified in five different categories Viz., industrial, public use, residential, commercial and vacant. In fig.1, classified land use in 2000 is shown.

A random bid-rent model, describing the competitions between the various usages has been developed in the study. In developing such model meshes classified, as 'public use' have been excluded considering the fact that though some such mesh might be more suitable for other use but their public use should be conserved.

At first with the bid rent model using only real land use data bid rents for different land usage was estimated. Then the land values for different usage were estimated by the resulted those bid rents. But this sequential estimation gave poor result for our case study area in Higashi Hiroshima City.

So we proposed a compound likelihood function including both land use and observation land price and

estimated the model, which showed better fit between predicted land value and observed land value without any logical contradictions in the estimated parameters, seen in Table 1.

SIMULATIONS BY SEVERAL RULES

Deterministic Assignment

There are many ways to predict the future land use type based on the logit model. The simplest rule is based on deterministic comparison that the land use type offering the highest bid rent win the bargaining and get the land. Fig.2 shows the predicted land use pattern, which seems to be similar to the real situation shown in Fig.1, with exception that vacant land are mis-predicted to be developed as residential, or commercial use. Table 2 shows the cross counting of real and predicted land use.

In the model, bid rent function includes the effect of the surrounding land use, then we can update the surrounding situation by the first round predicted land use and repeated the simulation procedure again. This iterated simulation enable to take positive agglomeration effect into account. Fig.3 shows the change of fitting ratio of each type land use. Fit ratio of residential use increases along the iteration, but the others go down. This result seems natural, because the model was caribrated to reproduct the changes in 10 years (1991-2000). The first assignment was enough to predict the change in that 10 years.

Probabilistic Assignment

Logit model output the probabilities for each type of land use for each land lot, then we can take probabilistic assignment rule, instead. In the deterministic assignment, only the land use with the highest bid rent is considered to be realized but not for the following land uses, even when the probability of the next one is almost same as the first one. For the purpose of illustration, let us consider the situation when the probabilities of the four types are predicted as 26%, 25%, 25% and 24%. The deterministic assignment bases on probability of 26% and neglect the 74% of other possibilities. Probabilistic assignment can consider those possibilities by using randomly generated numbers. However, that feature also yields a problem of unstable result. The simulation result totally depends on the set of random values; if different random numbers are given, very different result are derived by other trials.

This dependency is stimulated when the assignment procedure is repeated. The succeeding developments will be attracted the previously developed location chosen by chance. Fig.4 shows the change of goodness of fit for each land use type along the iteration of the probabilistic assignments.

CONCLUSIONS

Write a CONCLUSIONS section at the end of the paper, followed by REFERENCES. References should be listed at the end of the paper in alphabetical order with the first author's last name and separated by one blank line between each other. Make sure all references are complete, including last names and initials of all authors, year of publication, title of paper or book, name of periodicals, volume number, issue number, publisher (in case of books), city and country of publication, and page number.

References should be cited in the text by indicating the last name of the first author and the year of publication, for instance, Kawashima et al. (1998). If there is more than one paper to be cited as mentioned, place letters a,b,… after the year to distinguish the references, for instance, Kawashima et al. (1998a).

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