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An Modeling of Urban Land-use Changes by transportation Improvement using Voronoi Concepts

Tohoku Univ. student ○Mossa. Anisa Khatun
Tohoku Univ. member Hajime Inamura

1. Introduction

It is important to analyze land prices and its demand considering the land-use changes and the land use zoning in urban areas. To avoid computational difficulties, a previous urban simulation model SUSTAIN (Sustainable Urban Structure and Interaction Networks)[1] considered employment subcentres to be located one or more circumferential ring roads which are symmetric about the central business district (CBD). But in real urban systems, employment subcentres may be located at arbitrary locations outside of the CBD. Voronoi concepts is very attractive "which can deal an arbitrary configuration of urban development", to analyze such systems. This paper aims to design an urban simulation model using Voronoi concepts[2].

2. Voronoi Concepts in Urban Simulation Model

Given a set of two or more but a finite number of distinct points in the two dimensional Euclidean space, we associate all locations in that space with the closest member(s) of the point set with respect to the Euclidean distance. The result is a tessellation of the plane into a set of the areas associated with members of the point set.

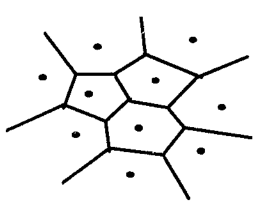

Fig. 1 Voronoi diagram with ten points.

We call the tessellation the planar *ordinary Voronoi diagram* generated by the point set, and the areas composing the Voronoi diagram ordinary *Voronoi polygons*. An illustration of Voronoi diagram is shown in fig. 1.

A city consists of a CBD and multiple employment subcentres around the CBD is considered in our urban system.. If assume that the CBD and employment subcentres are a point set of Voronoi diagram, then it gives a tessellation of the city into a set of zones associate with the CBD and the employment subcentres. The CBD and the employment subcentres, and the zones constitute the Voronoi diagram and Voronoi polygons respectively. We consider each of the zones as a monocentric city having corresponding CBD or employment subcentre as the center of that monocentric city. Therefore by analyzing each of the zones as a monocentric city, we can obtain a complete analysis of the whole city with CBD and a multiple employment subcentres.

The ordinary Voronoi diagram is based on Euclidean distance only. But in real situation it may happen that a subcentre has more importance and influence (in terms of population, shopping etc. in our urban simulation model) than its nearest subcentres. In that case the boundary between the two zones is not equidistant from each other but it should be more far from the important subcentre and closer to the other subcenter. To handle this type of situation we use a special version of Voronoi diagram called *weighted Voronoi diagram*.. In weighted Voronoi diagram we consider a set of distinct points, $P=\{p_i,\dots p_n\}$ in the Euclidean plane, and assign a weight w_i to each p_i which measures the importance and influence (in population, shopping etc. in our urban simulation model) of p_i. Considering this weight w_i a distance $d_w(p,p_i)$ from a point p to p_i is defined in equation 1., called the *weighted distance* .

$$d_w(p,p_i)=\frac{d(p,p_i)}{w_i} \qquad (1)$$

where $d(p,p_i)$ is the Euclidean distance from point p to p_i.

Weighted Voronoi diagram is constructed considering weighted distance instead of Euclidean distance.

3. Land price and urban land use pattern in a monocentric city

As we consider each zone as a monocentric city, we now study the different aspects of a monocentric city, such as, location of employment, estimation of the land-price function, estimation of the population density, income and household demand etc.

3.1. ***Location of employment:*** In a monocentric city, all employments (manufactures, office, firm) and all shopping services are concentrated with CBD. If distance from the centre of the city increases, commuting cost will increase. For decreasing commuting cost people will move closer to the city centre for employment and shopping. As a result housing demand as well as land prices will increase towards the CBD.

3.2. ***Estimation of the land-price function:*** A number of researchers have estimated the relationship between land price and distance to the city center. Mills[3] assumed the following relationship between land value and distance:

$$P(u) = Ae^{-cu}$$

where $P(u)$=Price of land u miles from the city center;

A= Price of land at the city center;
e= Base of the natural logarithm;
c is a parameter.

3.3. ***Estimation of the population density function:*** The density function describes the relationship between the population density and distance to the city center. Mills assumed the following relationship between density and distance:

$$D(u) = d_0 e^{-gu}$$

where $D(u)$= population density u miles from the city center(population per square mile);

d_0 = population density at the city center;
e= Base of the natural logarithm;
g is a parameter.

3.4. ***Income and household demand [4]:*** In the simple monocentric model, if we consider the demand side, households maximize utility, which is a function of a composite goods and quantity of land, subject to a budget constraint that includes commuting cost. With a Cobb-douglas utility function and constant per mile commuting costs, the household problem is to

$$\text{maximize } U\{z,q\} = z^{1-\alpha} q^{\alpha}$$

$$\text{Subject to } Y = z + P(u)q + ku$$

The first order conditions of this problem lead to the following demand function for q and an analogous one for z.

$$q(u) = \frac{\alpha(Y - ku)}{P(u)}$$

where U= utility;
z= quantity of the composite good, which has a price unity,
q= quantity of land,
α = utility function parameter;
Y= household income
u= distance from employment;
$P(u)$= price of land at location
k= round trip commuting cost per mile.

4. Conclusion

In this paper, it has been shown that (a) using the Voronoi concepts a city can be analyzed with more than one employment subcentres which are located at arbitrary locations outside of the CBD. And (b) also considering transportation networks land-prices and land-use changes may be analyzed. Now I am engaged in developing different program modules of simulation model. Output of one of such program module shows the land-price pattern of a city. In put of this program module is land-prices in the CBD and in the employment subcentres.

5. References

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[3]. Mills, Edwin S. *Studies in the Structure of the Urban Economy*, Baltimore: Johns Hopkins, 1972.

[4][4]. J. Yinger, *City and Suburban: Urban Models with More than one Employment Center*, Journal of Urban Economics 31, 1992.