Study on Applying Optimal Path to Land Valuation

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ABSTRACT As an important role in the urban land price system, the basic land price appraisal directs and reflects all kinds of land price in the real estate market. Using geographic information systems (GIS) with algorithms and powerful analysis functions to valuate land will improve the rationality and convenience of land valuation. The objective of the study on basic land price using the optimal path algorithm is to decrease the man-made error, enhance automatization, avoid make inconvenience by roadblock object.

KEYWORDS GIS; optimal path; shortest path; land price appraisal; land valuation; basic land price

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Introduction

The basic land price is the average price of every equal parcel or every land class specified by the government, according to different use of land such as commerce, industry, residence, etc. As an important role playing in the urban land price system, the basic land price instructs and reflects all kinds of land price in the real estate market.

Lately, with the great development of real estate market in China, the market of land transaction is becoming more active. The technique that acquires land grades by multi-factor classifying method and then computes the basic land price by sample price in land transaction has been adopted in some cities. Supported by this technique, the efficiency and result of land valuation have made an immense improvement. However, there are some defects in the process of land valuation, mainly expressed as follows.

1) The subjectively man-made factors and the experts’ experience have a big effect on the land valuation, especially on the land classification. The appraisal process is at a low automation level. Those factors and the like disturb the daily update of land valuation.

2) No relationship between factors’ scores and the land price has been built. Therefore, it is impossible to test accuracy of the land valuation result. The traditional algorithms are inefficient and difficult to operate, while the result of land valuation is not accurate enough. To a certain extent, the index function of basic land price is weakened and manpower and material resources are wasted. Therefore, it is significant for us to study how to model basic land price appraisal rationally and scientifically.

1 Applying optimal path to basic land price appraisal

Recently, with the development of computer technology and other related techniques, GIS technology is also developing rapidly. The excellent spatial analyzing and processing capabilities in GIS can offer land valuation technical support. And using GIS technology to land valuation will have a good result. For instance, the optimal path, a frequently used algorithm in GIS...
will effectively solve the problems as mentioned above as used in basic land price appraisal. This study will try to elaborate on the application of optimal path to two current algorithms of basic land price appraisal: sample-interpolation method and multi-factor fitting method.

The sample-interpolation method has three steps. Firstly, choose a certain number of samples according to their uses. Then calculate or correct their prices. Finally calculate the basic land price by using some models. This method considers only the samples' prices but not the land unit grade or score. This is to say you need not consider any factor affecting land price. It is inaccurate to some extent and not so stable because of the influence of market change on the land price samples. However, in those cities where the land market develops well, wealthy samples will ensure good result of the basic land price appraisal. As the land unit grade and score need not to be considered, the analytical model of the method is relatively simple. For those cities where land market is very active and samples are abundant, the method is appropriate for the basic land price appraisal.

Traditional spatial interpolation is based on straight distance, such as spatial interpolation by triangulation net and dynamic region, etc. These interpolation models are founded on the premise that the interpolated space is continuous. However, blocked by roadblock object, the interpolation space of land price samples is discontinuous. As a result, traditional spatial interpolation method is unsuitable for land price interpolation.

Dynamic regional spatial interpolation based on optimal path (hereafter referred to as simplified optimal path interpolation method) is proposed to solve the above mentioned problems. This interpolation method inherits advantages of the traditional dynamic regional spatial interpolation. According to the characteristics of land price interpolation, we apply optimal path to spatial interpolation model. The kernel of optimal path interpolation method lies in how to choose the land price samples to be calculated in the interpolation. The process is as follows: take the interpolated point as the center, and then choose some land price samples whose optimal paths are the shortest to calculate the basic interpolated land price. Using this method can succeed in removing the influence of roadblock object.

As Fig. 1 shows, we assume that at least four samples are needed in the interpolated calculation of land unit G. There is a river between samples S1, S4 and land unit G. And we suppose that there is no bridge nearby on the river. Obstructed by the river, the land prices of both sides of the river have no influence on each other. So the land price is not continuous and we can not use samples S5, S6 to compute interpolated price of land unit G although their straight distances to land unit G are short enough. However, if we choose samples by comparing their optimal path, samples S5, S6 will not be chosen while samples S1, S3, S4 and S7 will. The merits of optimal path interpolation method are obvious.

Multi-factor fitting method utilizes both trade instances and influencing factors. The process is as follows. Using the multi-factor classifying method, land prices of land trade instances, and linear fitting algorithm, we build a relation model between land score affected by factors and land price, and then calculate the basic land price of every land grade. This complex method solves the instability of land price samples, so it meets the needs of micro-management of land price.

While the distance between a land unit and an instance of these factors increases, the score that
the instance acting on the land unit is getting lower. So we should find out attenuating types, models and overlaid types of factors' scores, according to the action law of the factors. Whether the selection for attenuating type and model is scientific or not will affect the validity of land units' scores.

For most factors, attenuating along the optimal path is a good attenuating type that conforms to the effects of human activity. Therefore, in the whole model of basic land price appraisal, the inerrancy and efficiency of optimal path algorithm will assure the accuracy and feasibility of basic land price appraisal. However, usually, the optimal path algorithms are based on abstract network model. We have to extract what we need from map and apply them to the algorithm of optimal path.

2 Analyzing algorithm of optimal path

Optimal path is often expressed in three different aspects: the optimal path between two given vertices, from a given vertex to all the others and of every pair of vertices in a graph. Their algorithms are also different[7]. The optimal path of every pair of vertices is necessary in this study, thus, we can adopt Floyd’s algorithm. Floyd’s algorithm is also known as all pairs of shortest path algorithm. It will compute the shortest path between all possible pairs of vertices in a (possibly weighted) graph or digraph (directed graph). The principle is as follows: in a graph (or a directed graph) \( G = (V, E, A) \), for \( k \) from 1 to \( n \) (\( n \) is the number of vertices in the graph), we compute the distance from \( V_i \) to \( V_j \) including the vertices whose number is not larger than \( k \).

Optimal path in GIS is often used in urban road network. In recent years, new types of roads, such as underground, light rail, etc., have been developing rapidly. How to connect them with conventional roads? A land unit to be appraised or a land price sample probably is not on a road or is beside a road, and how to compute their optimal paths? All the instances of land price factors are not only points but also lines or areas. How to compute the score acted by linear or surface instances? We have to make a specific analysis of the specific problem that appraises the basic land price.

2.1 Optimal path between two random road nodes

To get optimal path of two random points, at first we should get the optimal path between two random nodes on the road. Before we compute the optimal path of these nodes, we have to extract and generalize all types of road and build road network model. For special roads (underground, light rail, etc.), we can deliberately connect their nodes (or station) to the nearest road. Actually, these stations are usually built beside a road or more.

2.2 Optimal path between two random points

2.2.1 Random point linked to road node

To compute the optimal path between two random points, it’s possible that neither point is on the road net. So we need to consider how to link a random point to the nearest road node. As Fig. 2 shows, \( P \) is a random point in a block, and \( S \) is a river. Blocked by the river, \( P \) can on-
ly be linked to the nodes on $R_1$, $R_2$ and $R_3$ but not $R_4$ on the other side of river $S$. And which one to be chosen depends on that the optimal path passing this node is the shortest or not. We can construct a surface to get a set of polygons (hereafter called block's boundary) bounded by map margin, centerline of road and boundary of roadblock object. When we compute the optimal path from a random point $P$ to other points, we can find out the node where $P$ links to the road on the boundary of block $P$.

2.2.2 Distance between a random point and the nearest road of the point

As Fig. 3 shows, the block’s boundary of a random point $P$ has 4 nodes $A$, $B$, $C$ and $D$. We know that the optimal path from $P$ surely passes one of the 4 nodes. Assuming that the optimal path passes node $A$, the distance from $P$ to $A$ can be computed as follows.

Method 1 $R_1$ and $R_2$ are roads passing node $A$. Draw vertical lines from $P$ to $R_1$ and $R_2$ respectively at $T_1$ and $T_2$. Compute the distance of $S_i$ (from $P$ to $T_1$), $S_2$ (from $P$ to $T_2$), $S_1'$ (from $T_1$ to $A$) and $S_2'$ (from $T_2$ to $A$). The distance from $P$ to node $A$ is $\min(S_1 + S_1', S_2 + S_2')$.

Method 2 Computing the straight distance from $P$ to $A$.

Because the block’s boundary is short the difference between the results of Method 1 and Method 2 is little. Straight distance is better visually oriented and easier to be calculated. So it is a good choice to solve this problem by Method 2.

2.2.3 The shortest distance between two random points

$P_1$ is in the boundary of block $A$, and $P_2$ is in the boundary of block $B$. Assuming that $S_i$ is the distance from $P_1$ to $A_i$ (the $i$-th node on boundary of block $A$), $S_j$ is the distance from $P_1$ to $B_j$ (the $j$-th node on the boundary of block $B$) and $S_o$ is the shortest distance from $A_i$ to $B_j$. The distance from $P_1$ to $P_2$ is $S_i + S_o + S_j$, while the shortest distance of $S_i + S_o + S_j$ is $\min(S_i + S_o + S_j)$.

However, it is not suitable to consider $\min(S_i + S_o + S_j)$ as the shortest distance from $P_1$ to $P_2$. As Fig. 4 shows, $L$ is a road within the boundary of block $A$. The length of $L$ is $S_L$. $S_{st}$ is the straight distance from $P_1$ to $L$. Obviously, if $S_{st}$ is very short, it’s more convenient for the optimal path to pass through $L$ than that straight from $P_1$ to $A_i$. So the distance which is not on the road should be multiplied by a weight $K$ (larger than 1). The shortest distance from $P_1$ to $P_2$ is $\min(K_1 \times S_i + S_o + K_2 \times S_j)$. According to our experience, the range of $K$ is better to be 1.4 to 2.0.

Fig. 3 Distance between point and road

Fig. 4 Shortest distance between two random points
Particular case: when $P_1$ and $P_2$ are in a same block or their blocks are neighboring to each other, they need not to be linked to the road. The distance between them is $K \times S$, while $S$ is the straight distance between them.

2.3 Optimal path from a random point to a line

Linear objects are generalized as lines in the digital map. Distance from a land unit to a linear factor is the distance from a point to a line in the digital map. How to compute can be described as follows.

As Fig. 5 shows, marking a point every a given distance on the line $L$ will come to $n$ points. According to the characteristics of human events, the minimum value of the distance from point $P$ to these marked points can be considered as the distance from point $P$ to line $L$. So the shortest distance from Point $P$ to line $L$ is $S = \min (S_i)$ (is the shortest distance from point $P$ to the $i$-th marked point on the line $L$).

![Fig. 5 Optimal path from point to line](image)

Because these marked points is just a part of a line, this method may bring some errors. We should set the distance of two neighboring marked points so short that the error need not to be counted.

2.4 Optimal path from a random point to a surface

For surface objects, the geometric center can be taken as its characteristic point. If the area of the surface object is small, we can use the shortest distance from a random point to the characteristic point instead of the distance from the random point to the surface. But if the surface is broad or irregular, we can not generalize a point from the surface. The shortest path can be computed as follows.

As Fig. 6 shows, get the blocks where the surface factor $M$ crosses and combine them into a total as $N$. We can replace the shortest distance from a random point $P$ to $M$ by the minimum value of the shortest distance from $P$ to the nodes of $N$.

3 Conclusions and future study

Without any doubt, applying optimal path to basic land price appraisal makes the algorithm more convenient and feasible. However, geographic data is so large and complicated that it’s difficult to compute. In real applications, we need to optimize and generalize the algorithm and data. And this study also supports comprehensive applications of GIS. Our study should focus on not only GIS itself but also the relationship with other related subjects, actualizing the worth of GIS to a greater extent.

![Fig. 6 Optimal path from a random point to a surface](image)
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(Continue from Page 31)

it is difficult to retrieve the wind speed when the sea surface wind exceeds this range.

4) Due to performing the complete integration for each point would be computationally intensive, it is necessary to create a modeled waveform database with respect to different receiver height and GPS satellite elevations for real time retrieving.

5) The investigation in spaceborne situations and LEO-experiments must be carried on in immediate future.

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