論文の内容の要旨

論文題目　Development of Methods for Analyzing Urban Phenomena Represented by Surfaces
（ 連続分布として表される都市現象に関する一連の分析手法の開発 ）

氏 名　李 廷 恩

(本文)

1. Backgrounds

For describing spatial phenomena, various types of spatial objects such as point, line, polygon and surface are used. These spatial objects are used on GIS and provide easier understanding of spatial phenomena. In explaining spatial phenomena especially, urban phenomena, points indicate the location of facilities including stores, schools, offices and so forth, lines are for describing road network, river that are connected to each other. Polygons are often used to represent the land use of regions. For surfaces, various geographical or urban phenomena are often represented in the format of TIN when used on GIS. For instance, population density, CO_2 emission, temperature of a region and etc. showing continuous distribution are described by surfaces. Such approach is useful since it helps us to understand the distribution of geographical or urban phenomena in terms of their spatial meaning that provides information from the data that are not easily found by visualization. Moreover, considering the situation that series of data describing spatial phenomena get digitalized and are given in complex form quantitatively and qualitatively, it is important that we should make full use of given such spatial data by means of effective techniques such as GIS and other methods for analysis. Among various spatial objects mentioned above, we focus on surface analysis in this study in various aspects, because the methodology of analyzing surfaces is not fully developed. In addition, surface is used to represent urban phenomena such as population density which shows the status of urban growth. From such aspect, methods of analyzing surface are required to understand the change of urban structure.

In terms of types of spatial objects to be treated in surface analysis, the study fields of surface analysis can be divided into three categories. First, it includes analysis of one surface which is the simplest case. Second, it is required to analyze the relationship between two surfaces if there exist multiple of them. Third, surface analysis on the relationship between one surface and other spatial objects where they have mutual effect can be treated as well. There are some approaches previously studied for surface analysis so far concerning study fields described above, however, more generalized and effective approaches are still required for resolving problems such as analysis approach from different aspect from previous ones or limitation on data availability.

Concerning the methods for one surface analysis, there are trend surface analysis, geostatistics and surface network. Trend surface analysis is one of the oldest mathematical techniques that have been used consistently by geologists for the analysis of geological data. The technique represents a methodology for manipulating map data and it produces a smooth approximation of a 3-D surface. Trend surface is the result of trend surface equation that is a linear polynomial and it is the graphical representation of the mathematical equation. This method separates a mapped variable into two components, the trend and the residuals from the trend. The trend corresponds to the concept of "regional features," while residuals represent "local features." Used in this manner, trend surface analysis is a global method for filtering spatial data. Geostatistics is a collection of statistical methods which were traditionally used in geo-sciences, mathematics and statistics. In statistical point of view, this approach models both spatial trend and spatial correlation dealing with spatial process indexed over continuous space. Geostatistics changes the entire methodology of sampling. Traditional sampling methods don't work with autocorrelated data and therefore, the main purpose of sampling plans is to avoid spatial correlations. Also, geostatistics changes the emphasis from estimation of averages to mapping of spatially-distributed populations. Surface network is usefully used to describe the topological structure of a surface. This concept is developed to visualize the structure of geographic surfaces which are recognized as functions of three or more variables. Therefore, surface network describes a surface by connection of pits, cols and peaks which consisting a surface. This concept is modified and developed for its various uses.

The second approach of surface analysis is relationship analysis between two surfaces. In this approach, quantitative methods and qualitative method are applied for the analysis. Different from one surface analysis, the method is focused on finding the difference between two surfaces which is able to describe the relationship between two surfaces. Quantitative methods distinguish the difference between two surfaces by statistical measures. Pearson's correlation coefficient is often used to evaluate similarity of two surfaces whose values at each point are in linear relationship. For Kappa index of agreement, it is often used for accuracy assessment in the remote sensing fields which is a mean to test two images whether their differences are due to chance or real agreement or disagreement. It is also used for comparison of general surface data as well. Kullback-Leibler information number is used for comparing probability density functions where the value of each function should not be zero. For this measure, it can be applied to generalized surface if total surface volume is standardized to 1. As for qualitative approach, surface network is representatively used to describe the topology of a surface.

For surface analysis between two surfaces, for instance, previous approaches focus on surface comparison at global scale by statistical measures or topology description while there are few studies on comparison from spatial difference of surfaces. For quantitative methods, it is difficult to distinguish surface difference occurred by surface transformation, and for surface network, it is not effective to distinguish surface difference when given surfaces have the same topology. The result of comparison would be the same. Thus, better description of analysis results that provides findings which are not understood from previous approaches is necessary.

The third approach of surface analysis is treating a surface in relation to a set of other spatial objects. This analysis takes approaches including visual analysis on GIS or modeling by mathematical measures. This case handles, for instance, extracting a subset of a spatial object whose distribution is related to that of a surface. The method to be applied in each case changes depending on the characteristics and availability of given data since there exist various combinations between a surface and other spatial objects such as surface-points, surface-lines, surface-polygons and surface-multiple spatial objects. Therefore, it is necessary to determine the range of analysis clearly. In this study, we focus on micro scale retail marketing environment since marketing analysis with the help of GIS plays an important role in the field of urban analysis where the information of location is a key factor to understand consumers' purchase behavior. From such background, the study topic is to detect a subset of points that has much effect on the surface distribution with limited data availability. For a set of points, the location data of competing stores are used and sales distribution of a store is treated as a surface.

2. Goal of this paper

Based upon research background described in previous section, brief explanation of study goal concerning study topics of relationship analysis between two surfaces and that of between a surface and a set of points are described in following subsections.

2.1 Analysis of the relationship between two surfaces: 1. Development of minimum transformation approach

This study theme treats surface analysis in the context of surface comparison between two surfaces. By surface comparison, it is able to distinguish the difference between two surfaces that represents various urban phenomena such as population density, industrial production, accessibility and so forth is understood. The result of surface comparison is expected to provide useful information that is not known from the visualization of given data.

As for previous approaches of surface comparison, the simplest one is comparison by visualization. This approach is useful if the difference is obvious, however if the given data has enormous amount of records and the shape is complex then this approach is not effective. Concerning another approach for surface comparison, quantitative measures such as Pearson's correlation coefficient, Kappa index of agreement and Kullback-Leibler information number are applied to evaluate global similarity of surfaces in statistical aspect. In addition, where the focus of comparison is on the structural perspective of surfaces, surface network is used for comparison which is a qualitative approach by describing the topology of each surface by connecting peaks, pits and cols of it for surface comparison. Both quantitative and qualitative measures are effective for surface comparison in limited occasions as mentioned above. Furthermore, these methods are not able to evaluate structural difference obtained by surface transformation such as shift or rotation and so forth even though these measures are useful to describe the surface difference by statistical approach or by comparing topology of each surface at global scale. Thus, in this study, surface comparison by surface transformation is introduced. The method is defined by the concept of earth moving problem and named minimum transformation in this study. By using this method, it is expected that structural difference between surfaces can be understood which explains the tendency of surface volume transformation both in local and global aspect which cannot be explained with previous approaches.

2.2 Analysis of the relationship between two surfaces: 2. Extension of minimum transformation approach

From the result of minimum transformation in the first step, it is found that convergence or divergence points of surface volume which indicates the tendency of surface transformation is specifically evaluated than the distribution of subtraction in surface volume between two surfaces. However, the extension of minimum transformation approach is necessary for more detailed comparison results other than divergence or convergence of surface volume such as structural difference in terms of the shape of surfaces. In the extended version, two types of surface transformation depending on the transformation direction of surface volume are defined. The transformation of movement is the transformation in horizontal direction and that of add/remove indicates a type of transformation in vertical direction. In addition, weight parameter controls the portion of each transformation type in the process of surface transformation. By combining these two types of surface transformation, it is expected that surface difference is evaluated from various aspects such as the shape of surfaces at global scale by comparing transformation cost of each transformation type with different value of weight parameter including the findings understood from the result of minimum transformation in the first step.

2.3 Analysis of a surface in relation to a set of points

This research topic treats surface analysis of extracting a subset of points that strongly affects the distribution of a surface. Since this study topic deals both a surface and a set of points that interactively affect each other, it is not enough to apply methods of analyzing one surface. For possible examples related to this topic, there are facility location problem of choosing better location among many candidates based on the information of population density, evaluating the usefulness of existing stores with sales status in a certain market area and so forth.

Extracting strong competitors of a store by its sales history can be a special example of relationship analysis between a surface and a set of points since this case have to deal with limited data availability since there is no information of competitors except their location. For such problem, if required data including questionnaire surveys, the data of consumers' store choice behavior are available, it can be easily solved by using disaggregate spatial choice models such as the logit model. From the proposed method, due to the limit of data availability, we are trying to get as accurate result from logit model estimation as possible that describes the real world situation in a reasonable manner.