Multi-category Tempo-Spatial Pattern Analysis (McTSPA)

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1. Introduction

The authors recently developed Comparative Tempo-Spatial Pattern Analysis (CTSPA) statistics to describe the characteristics of urban growth pattern changes over different time periods (Xie and Ye, 2007). CTSPA, on the basis of vector geometry (paired centroids, shared boundary lines, and overlain polygons), formulated three indices, the Polygon Number Change Index, the Polygon Shape Change Index, and the Polygon Area Change Index, to quantify polygon feature changes in quantity, shape, and size. These statistics were used to analyze urban growth changes in metropolitan Detroit between 1990 and 2000. The findings indicated that the CTSPA statistics were effective in describing urban spatial pattern changes over the selected periods. Various combinations of these indices disclose distinctive patterns of land use development, including, fragmenting and declining, fragmenting but growing, in-fill-type growth, frog-leap-type growth, merging-type growth, and scattering-type growth.

In this ongoing research project, we will expand the CTSPA indices from a single land use (urban or non-urban) to Multi-category Tempo-Spatial Pattern Analysis (McTSPA). With McTSPA, we expect to quantify urban growth from the perspective of multiple economic sectors and to develop new spatial statistics to support pattern analysis of spatial socio-economic phenomena. In other words, it will generate greater insights about urban development processes and driving forces when urban growth could be investigated from socio-economic interactions and in a composite manner. In this research, we will first plan to provide a thorough literature review on quantifying urban growth patterns. Second, we will study statistical formulations of the Multi-Polygon Number Change Indices, the Multi-Polygon Shape Change Indices, and the Multi-Polygon Area Change Indices. Third, we will apply these McTSPA statistics to analyze land use changes in metropolitan Detroit between 1990 and 2000 and to explore the economic driving forces. Finally we will summarize what we will find out in the case study and point out future research directions.

2. The Main Design

Because this project is in progress, we are presenting the formations of the Multi-Polygon Number Change Indices in this abstract as an illustration of our research design. Let W_i be a moving window of a selected size, m is the total number of polygons at T_I, n is the total number of polygons at T_{II}, and $P_I[m]$ and $P_{II}[n]$ denote two sets of polygons respectively at two time points T_I and T_{II}.

$$P_{Ck} = \log\left(\frac{n_k - c_{IIk} + \varepsilon_c}{m_k - c_{Ik} + \varepsilon_c}\right) \subseteq W_i \quad (1)$$

Where P_{ck} is the Polygon Number Change Index for land use class k, m_k is the number of polygon of land use class k at T_I, n_k is the number of polygon of land use class k at T_{II}, c_{Ik} is the number of paired centroids of land use class k at T_I, and c_{IIk} is the number of paired centroids of land use class k at T_{II}. c_{Ik} does not necessarily equal to c_{IIk}. ε_c is the error term that is introduced to balance out abnormal conditions, such as, when the denominator equals to 0, or when either numerator or denominator has a very small value.

The Multi-Polygon Number Change Index for an urban landscape in study is formulated as,

$$P_c = \sum_{k=1}^{K} P_{ck} / K \quad (2)$$

Where P_c is the Multi-Polygon Number Change Index over a landscape, P_{ck} is the Polygon Number Change Index for a specific land use class k, and K is the total number of land use classes consisting of the landscape.

The Primary-Polygon Number Change Index for landscape,

P_{Pc} = the largest P_{ck} , when 1 <= k <= K (3)

The global forms of P_{ck} and P_c are formalized as,

$$G_{DR}\bar{P}_{Pc} = \bar{P}_{Pc}[\mathrm{D}, \mathrm{R}] \quad (4)$$

$$G_{DR}\bar{P}_{c} = \bar{P}_{c}[\mathrm{D}, \mathrm{R}] \quad (5)$$

Where D is an index of distance zones, R is an index of socio-economic (or political jurisdiction, or ecological) regions, $\bar{P}_{Pc}$ and $\bar{P}_c$ are the mean values of the P_{Pc} (the Primary-Polygon Number Change Index of a landscape) and P_c (the Multi-Polygon Number Change Index of a landscape) over a distance zone (D) and a region (R), respectively. If the study is conducted in a uniform region, Equation 4 and 5 will be reduced from 2-D arrays into a one-dimensional array,

$$G_{D}\bar{P}_{ck} = \bar{P}_{ck}[\mathrm{D}] \quad (6)$$

$$G_{D}\bar{P}_{c} = \bar{P}_{c}[\mathrm{D}] \quad (7)$$

3. References

Xie, Y., and Ye, X., 2007. Comparative Tempo-Spatial Pattern Analysis: CTSPA. *International Journal of Geographic Information Science*, 21(1): 49-69.