Analysis of Urban Distribution Pattern with Satellite Imagery

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ABSTRACT:

Nowadays, urbanized area expands its boundary, and distribution of urbanized area is gradually transformed into more complicated pattern. In Korea, SMA(Seoul Metropolitan Area) has outstanding urbanized area since 1950s. But it is ambiguous whether urban distribution is clustered or dispersed.

This study aims to show the way in which expansion of urbanized area impacts on spatial distribution pattern of urbanized area. We use quadrat analysis, nearest-neighbor analysis and fractal analysis to know distribution pattern of urbanized area in time-series urban growth. The quadrat analysis indicates that distribution pattern of urbanized area is clustered but the cohesion is gradually weakened. And the nearest-neighbor analysis shows that point patterns are changed that urbanized area distribution pattern is progressively changed from clustered pattern into dispersed pattern. The fractal dimension analysis shows that 1972's distribution dimension is 1.428 and 2000's dimension is 1.777. Therefore, as time goes by, the complexity of urbanized area is more increased through the years. As a result, we can show that the cohesion of the urbanized area is weakened and complicated.

Key words: Satellite imagery, GIS, Point pattern, Quadrat analysis, Nearest-neighborhood analysis, Fractal dimension.

1. INTRODUCTION

1.1 Purpose

Seoul metropolitan area has developed in quality and quantity since 1950s. Large number of people from the rural areas has been drifted into SMA. So boundary of SMA has been expanded. And people have got together over again, the boundary has been expanded again too. In this way, urbanized area has gone through changes. But it is difficult to make a decision whether cohesion of urbanized area distribution is stronger or not. The cohesion of urbanized area is not just increased by expansions of urbanized area. For the accurate decision of urbanized area's distribution patterns, we use quadrat analysis, nearest-neighbor analysis and fractal analysis.

1.2 Data processing

The data were processed as Figure 1. Landsat MSS(Multi spectral scanner) and TM(Thematic mapper) imagery were used in judgment of cohesion. Images were re-sampled into 80m×80m and Seoul metropolitan area is covered with 1000×1000 pixels. The images were classified into five classes; urban, forest, cultivated land, water, tideland (Jeong, 2001). And then, data was reclassified three areas to non-urbanized area, urbanized area and water (Figure 2). Next, we extracted urbanized area from classified data.

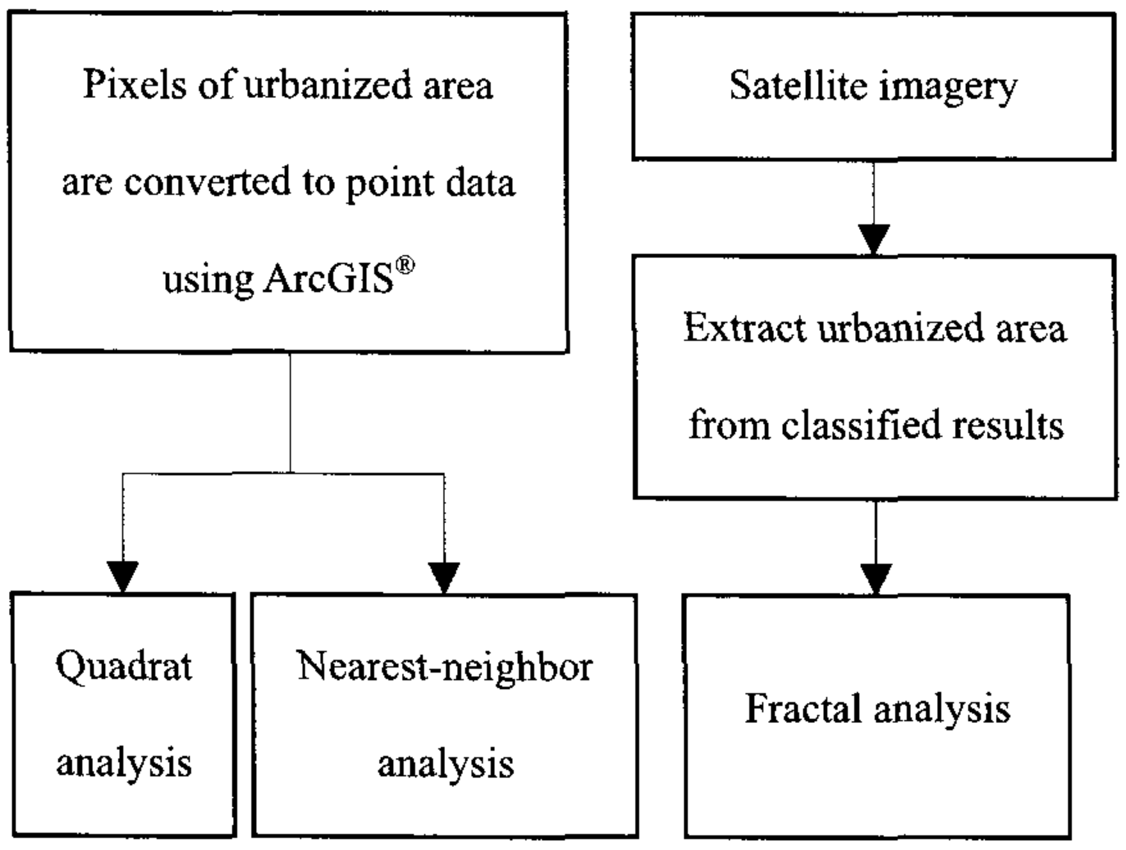

Figure 1. Process of data processing

For the quantitative analysis, we converted pixels of urbanized area to points of urbanized area through raster to vector conversion function. In this process, for the convenience of calculation, we re-sampled data in 500m×500m. After this, we conduct quadrat analysis and nearest-neighbor analysis over 25000(160×160) points.

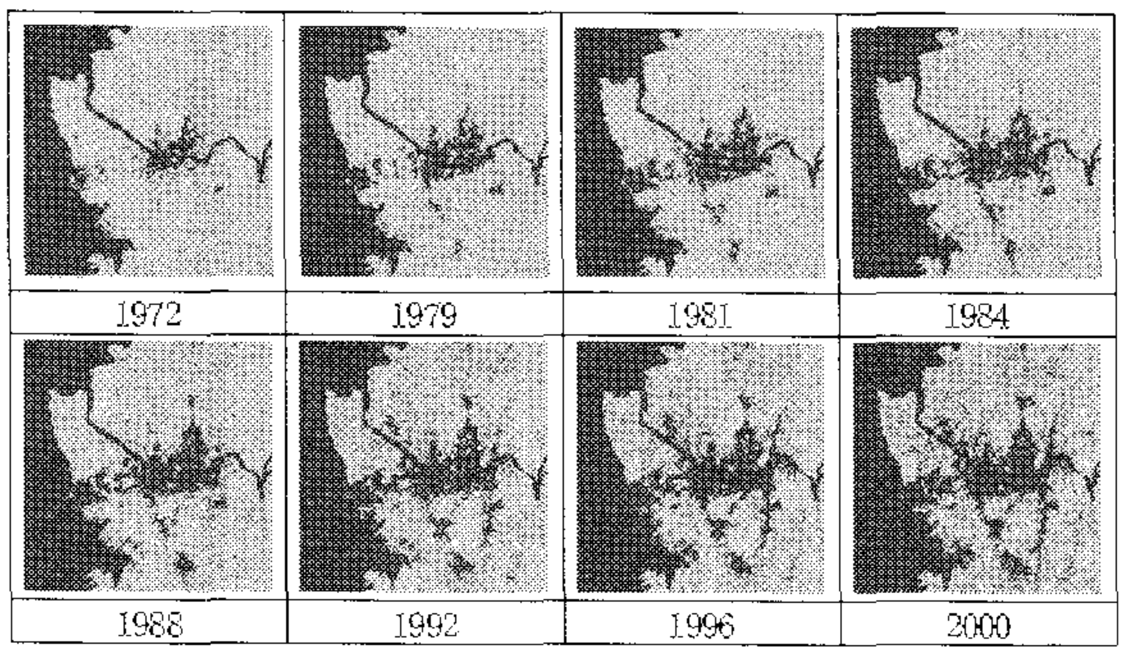

Figure 2. Satellite image data

2. ANALYSIS OF DATA

2.1 Quadrat analysis

A method for detecting spatial patterns from a point distribution is quadrat analysis. A study area is overlaid with regular grids, and the numbers of points included in each grid are counted.

The results of point distribution analysis show that the point pattern is clustered, random, or dispersed pattern (Figure3). In case of dispersed pattern, distribution of point is regular and variance of points in grid is close to 0 (Lee, 1989). So variation divided by mean is close to 0(zero) too. Considering a clustered pattern, variation is larger. So, variance of points in grid divides by mean become larger too.

A statistical test known as the Kolmogorov-Simirnov test(K-S test) can be used to test the statistical difference between an observed frequency distribution and a theoretical frequency distribution (Wong and Lee, 2005).

The formula is as follows:

$$D = \max\left|F_n(X) - S_n\right|, \quad D_{\alpha=0.05} = \frac{1.36}{\sqrt{n}} \qquad (1)$$

where,

F_n: Expected frequency

S_n: Observed frequency

n: number of quadrat

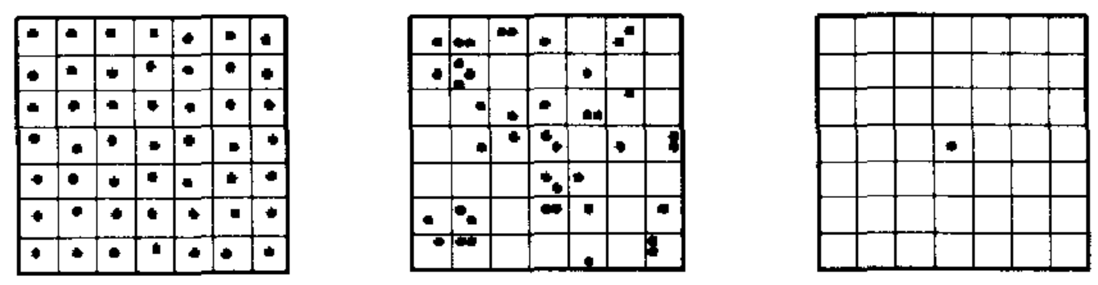

Figure 3. Types of Quadrat patterns

2.2 Nearest-neighbor analysis

Nearest-neighbor analysis is based on comparing the average distances ($\overline{r_a}$) between nearest neighboring points in observed points and the average distances ($\overline{r_e}$) between nearest-neighboring points in randomly dispersed points (Wong and Lee, 2005).

We can compute $\overline{r_a}$ and $\overline{r_e}$ as follows:

$$\overline{r_a} = \frac{\sum \min d_i}{n}, \quad \overline{r_e} = \frac{1}{2\sqrt{\lambda}}\left(= \frac{1}{2\sqrt{n/A}}\right) \qquad (2)$$

where,

d_i = nearest Euclidian distance from the point i

λ = assumption density of point per unit area

A = the unit area

The R statistic is calculated to determine whether the points are randomly distributed or not.

$$R = \frac{\overline{r_a}}{r_e} \qquad (3)$$

The R scale ranges from 0(completely clustered) to 2.149(completely dispersed). If the R value is 1, it means that points are randomly distributed. The R is 0 means, all points are found at the same location.

Z score is evaluated difference between observed value and expected value. If, Z>1.96 or Z<1.96, we conclude that the calculated difference between the observed patterns and random patterns is statistically significant. The R value is confirmed by Z score.

$$Z = \frac{\overline{r_a} - \overline{r_e}}{SE_d} \ , \ SE_d : \frac{0.26136}{\sqrt{n^2 / A}} \qquad (4)$$

where,

n: number of quadrat

A: the unit area

2.3 Fractal analysis

Fractals have been widely used in order to distinguish between different urban typologies (Frankhauser, 1998), measure the degree of urban sprawl and examine the way cities expand in space and time (Batty & Longley, 1994), the value of the dimensions is estimated in the range 1<D<2 (Batty, 2005). The basic models used to calculate the fractal dimension in our researches is box-counting method(DeCola, 1991 ; Ku, 2001).

3. RESULTS

3.1 Quadrat analysis

In quadrat analysis, the results may be different by quadrat size. Generally, the quadrat size is determined by 2A/N but A/N is often assumed as appropriate size in geographic analysis (Lee, 1989). So, we execute two types of quadrat analysis; one has 6000 quadrats (approximately N/A) and the other has 10000 quadrats (approximately 2N/A). The results are shown in Table 1 and Table 2.

Throughout 1972 to 2000, variances were reduced and variance/mean ratio was also reduced. K-S D test shows that the points are not randomly distributed. The test shows that the points are clustered. But the cohesion of the points is weakened since middle 1980s.

Table 1. Results of quadrat analysis (square 6000)

years	Number of point	Z statistics (Critical value 2.58)				K-S D	
		Variance	mean	Variance /Mean	Z stat.	D	Cri.
1972	1695	0.771	0.281	2.744	95.814	0.130	0.018
1979	2580	1.217	0.429	2.840	100.947	0.185	
1981	3532	1.809	0.590	3.065	112.966	0.228	
1984	5026	2.255	0.840	2.685	92.192	0.245	
1988	5991	2.522	1.001	2.520	83.170	0.252	
1992	8294	3.152	1.386	2.275	69.737	0.264	
1996	10097	3.528	1.687	2.092	59.727	0.262	
2000	11772	3.895	1.967	1.981	53.641	0.254	

Table 2. Results of quadrat analysis (square 10000)

years	Number of point	Z statistics (Critical value 2.58)				K-S D	
		Variance	mean	Variance /Mean	Z stat.	D	Cri.
1972	1695	0.354	0.169	2.090	77.100	0.059	0.014
1979	2580	0.565	0.258	2.188	83.937	0.091	
1981	3532	0.767	0.351	2.187	84.212	0.117	
1984	5026	0.982	0.499	1.968	68.674	0.129	
1988	5991	1.126	0.595	1.892	63.325	0.137	
1992	8294	1.431	0.824	1.738	52.358	0.150	
1996	10097	1.658	1.012	1.638	45.022	0.155	
2000	11772	1.783	1.169	1.525	37.286	0.145	

3.2 Nearest-neighbor analysis

Table 3 shows the results of nearest-neighbor analysis. From 1972 to 1981, R value is smaller a 1, but 1984 to 2000 is larger than 1. And Z values jump to positive number from negative number. So now we can explain that point patterns are changed from clustered pattern to dispersed pattern. Finally, urbanized area has been changed its pattern into gradually dispersed pattern (or decreased cohesion).

Table 3. Results of Nearest-Neighborhood analysis

Years	1972	1979	1981	1984	1988	1992	1996	2000
R	0.67	0.77	0.87	1.02	1.09	1.25	1.36	1.46
Z score	-25.9	-21.6	-14.1	3.5	14.7	44.1	69.6	96

3.3 Fractal analysis

Fractal dimensions have increased 1972s 1.43 to 2000s 1.78. Dimension becomes 2 means that all of study area is urbanized. In Table 4, the dimensions have gradually increased. From that we can realize that urbanized area will expand gradually and be distributed more complicatedly.

Table 4. Fractal dimension

year	1972	1979	1981	1984	1988	1992	1996	2000
Fractal dimension	1.43	1.48	1.53	1.61	1.64	1.70	1.74	1.78

4. CONCLUSION

We use quadrat analysis, nearest neighbor analysis and fractal dimension analysis to know distribution pattern of urbanized area in time-series urban growth. Experiments show that cohesion of SMA's urbanized area had increased to the early 1980s, but has decreased from the middle 1980s. Also, urban growth of SMA has been characterized not by spillover growth but by leapfrogging growth and road-influenced growth since the middle 1980s.

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