Interrelation Between Micro-Blog Hotspots And Urban Spatial Network: An Empirical Analysis Of Tongji-Rim Intellectual-Economic-Zone, Shanghai, Based On Sina Weibo

Jing HAN, Lingyu KONG, Tongji University, China

Abstract

In the society with highly developed information technology, interaction of virtual world and physical space has become a hot topic for urban planners and architects. This paper tries to explore the mutual relation between information technology and physical space from a micro perspective of a small-scale urban area. We take the intellectual-economic-zone around Tongji University as target area. We propose a three-step methodology. First, we collect all the micro-blogs published on the Sina platform within Tongji-Rim during a week and create the hotspots density graph (heat map). Second, by Urban Network Analysis (UNA) toolbox of ArcGIS, we measure the five spatial network centrality indices of Tongji-Rim. Third, we overlay the heat map on the UNA graphs and compare the similarity. The outcome shows that there obviously exits interrelation between social network and urban spatial network. The order of the five indices' explanatory power for micro-blog heat map is: Reach, Straightness, Betweenness, Closeness and Gravity. Higher reach and straightness lead to more opportunities of arriving and micro-blogging. Betweenness represents necessity of passing by but not staying or more worthy news. The weak explanation of Closeness is the evidence that, although the virtual social network must be based on real individuals and space, information technology has already broken the geographic barriers. Location and distance are not the most significant factors for urban development.

1. Introduction

Information technology has been making dramatic impacts on the traditional space geography. It changed the way people understanding place and time, and built a new form of organization of space and objects in it. Many scholars have studied this variation from different aspects. Manuel Castells (1996) distinguished space of flow and space of place. He argued that the space of flow consists of the technical infrastructure network, the node and hub network, the dominant elite network and websites. This thought provided an important theoretical frame for physical and virtual space research.

After the traditional one-to-many and one-to-one media, the emergence of social networking services has brought human society into to a new many-to-many media era. Among various social networking services, micro-blogging has noticeably revolutionized the way information is consumed. Just as Nagarajan et al. (2009) pointed out, micro-blog has empowered citizens themselves to act as sensors or sources of information that could lead to consequences and influence, or even cause media coverage.

What's more, according to Liu Yang (2010) and Zhan Zihua (2011), by the end of June, 2011, the total number of netizens in China has amounted to 485 million and Internet penetration rate has reached 36.2%. The number of micro-blog users has increased to 195 million, while netizen utilization rate has been expanded to 40.2% from 13.8%. From the world's first micro-blog, Twitter, to Sina Micro-blog and Tencent Micro-blog in China, micro-blog has gradually become the fastest-growing Internet application and an influential social media.

Thousands of billions of micro-blogs are generated every day from all over the world, which makes micro-blog not only a platform for developing interpersonal relationship, but also a valuable huge database for studies. In this context, many experts mined the big data from different dimensions like space, time, theme, sentiment, impact, network structure, spreading mechanism etc. As for urban researchers and planners, does virtual factor have any relation with the physical space, what kind of interrelation is between them, and how do they interact with each other, are the questions they concerned most. To understand this, foreign scholars graphed and animated the heat map of Twitter. They proved that Twitter users can be considered as sensors that react to spatial static events or moving patterns (Sakaki *et al.* 2010), and it is possible to reliably detect relevant spatial changes (Eduardo Ruiz and Vagelis Hristidis 2013). Domestic scholars Zhen Feng *et al.* (2013) analyzed China's city network characteristics on Sina Micro-blog. The result shows a clear hierarchical structure and level distinction which are consistent with the real ones. They believed that the spatial "flow" and "viscosity" brought by this powerful new media will have a positive impact on urban systems.

Above all, scholars both at home and abroad have answered the questions from a national and regional macro view. But researches on the urban micro level are really rare. As a result, based on the previous theories and related works, this paper tries to explore the interrelation between micro-blog hotspots and urban spatial network from a relatively microscopic perspective of small-scale urban area. We take China's most popular social networking service site Sina Weibo as platform, and the intellectual-economic-zone around Tongji University as target area.

Figure 1: The location of Tongji-Rim Intellectual-Economic-Zone
Source: Author's self-drawn

The Tongji-Rim Intellectual-Economic-Zone (Figure 1) is currently China's largest design industrial cluster. Located in Yangpu District, Shanghai, reaching North Zhongshan No.2 Road on the north, Jiangpu Road on the east, Dalian Road and Kongjiang Road on the south, Miyun Road on the west, it occupies an area of 2.68 square kilometers. It mainly homes architectural design studios and urban planning offices, and is supplemented by various types of knowledge-based service enterprises such as education and training, landscape

design, art and media design, environmental engineering design, automobile design, software design and engineering consulting. There are tens of thousands of high-quality talents, who are the majority users of micro-blog, making it an ideal area to study the interrelation between micro-blog and urban spatial network.

This paper is organized as follows: After introducing the background and related studies in this section, we construct an innovative research methodology in Section 2. Section 3 presents the detailed research process in which a weekly micro-blog heat map of target area is drawn, a series of spatial traits are tested and the comparison of their similarity is made. Section 4 gives the ranking results of the spatial traits' explanatory power for micro-blog hotspots distribution and respectively analyzes the reasons. We discuss the meaning of results and conclude the paper in Section 5.

2. Methodology

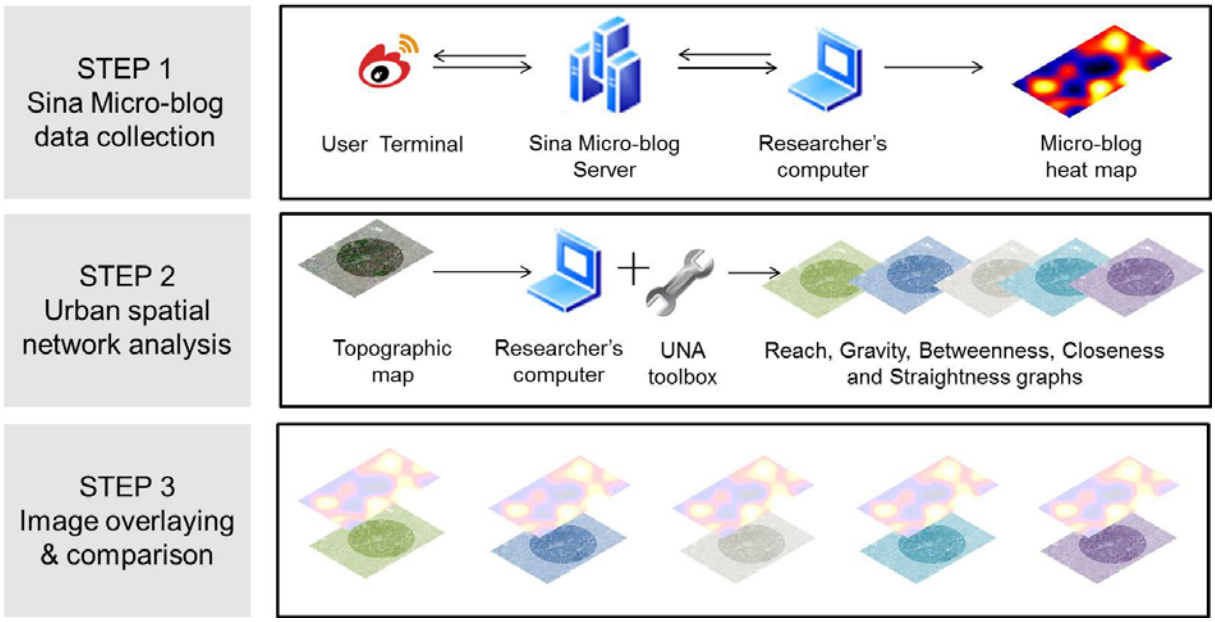

Figure 2: Framework of the research
Source: Author's self-drawn

This paper proposes a three-step methodology (Figure 2). The first step is data collection and visualization. We collect all the micro-blogs published on the Sina Weibo micro-blogging platform within Tongji-Rim for a certain period (a week). Then we extract time and geographic location information from every micro-blog posts, and organize them into a table. To create the hotspots density graph/heat map, we import the table into ArcGIS, and show it in a time-split way.

The second step is urban spatial network analysis. With the open-source software plug-in extension, Urban Network Analysis (UNA) toolbox for ArcGIS (developed by City Form Lab at the Singapore University of Technology & Design in collaboration with the School of Architecture & Planning at MIT), we compute five types of network centrality measures on spatial networks in the target area: Reach, Gravity, Betweenness, Closeness and Straightness. This toolkit applies to small-scale and detailed networks of dense urban areas, like Tongji-Rim.

The third step is image overlaying and comparison. We overlay the spatial network analysis results, Reach, Gravity, Betweenness, Closeness and Straightness images, respectively on the micro-blog heat map, to match the distribution of the micro-blog hotspots, and find out the spatial traits which best explain the visualized Sina Weibo data.

3. Research Process

3.1 Micro-Blog Data Collection

Sina Weibo Open Platform provides Application Program Interface (API) for developers. We choose "place/nearby_timeline" port to capture the dynamic information surrounding a particular location. To cover the whole Tongji-Rim area, we draw a circle with 1200-meter-radium and centered in the point of Shanghai No.1 International Design Square, whose specific latitude and longitude coordinates are 31°16'53.50" N, 121°30'10.21" E. The time range is the latest 7 days, from Jun 23 00:00:00 +0800 2013 to Jun 30 00:00:00 +0800 2013. By running the self-designed code, all the micro-blog containing users' personal information and post content are read one by one and output in the text form.

The statistical result shows that 6211 Sina micro-blogs were published altogether in the past 7 days around Tongji-Rim, 887 posts on average a day and 74 posts every two hours (Table 1). Every day there were two peaks, from 10:00 to 14:00 and 16:00 to 22:00, and two valleys, from 14:00 to 16:00 and 2:00 to 6:00 (Figure 3).

	Jun23	Jun24	Jun25	Jun26	Jun27	Jun28	Jun29	Total	Aver
00:00-02:00	63	54	54	54	67	45	52	389	56
02:00-04:00	16	13	17	18	27	22	31	144	21
04:00-06:00	14	7	19	13	19	10	12	94	13
06:00-08:00	38	39	51	37	38	43	24	270	39
08:00-10:00	70	79	194	85	58	85	90	661	94
10:00-12:00	106	98	108	80	72	87	106	657	94
12:00-14:00	119	83	125	75	100	92	115	709	101
14:00-16:00	92	65	103	78	75	108	122	643	92
16:00-18:00	117	68	112	95	87	73	87	639	91
18:00-20:00	100	77	133	107	95	95	95	702	100
20:00-22:00	104	95	66	102	99	103	92	661	94
22:00-24:00	92	96	94	101	87	75	97	642	92
Total	931	774	1076	845	824	838	921	6211	887
Aver	78	65	90	70	69	70	77	887	74

Table 1: The number of Sina Micro-Blogs around Tongji-Rim in every 2 hours of 7 days
Source: Sina Weibo Open Platform and the author's own study

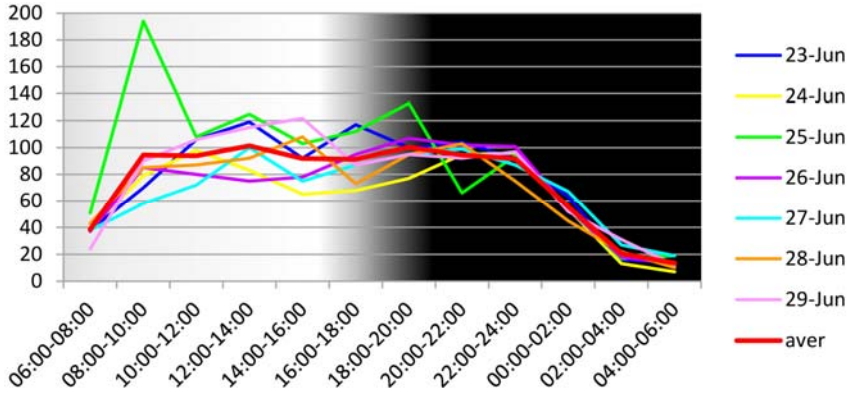

Figure 3: The line chart of Sina Micro-Blogs around Tongji-Rim in every 2 hours of 7 days
Source: Sina Weibo Open Platform and the author's own study

Table 1 and Figure 3 only tell the distribution characteristics of micro-blog publication from date and time dimension. To make comparative study with real space, what is more important is to find out the exact places where micro-bloggers release every post, then we can analyze the relevancy. Therefore, we import the processed data into ArcGIS, align the coordinate system, and achieve the spatial-temporal graphs.

The left side of Figure 4 is the scatter plot of all 7 days. Each red spot corresponds to one micro-blog. The transformed heat map, which reflects the density of micro-blogs, lays on the right side. (The transformation method is to enumerate the dots in a circle with given radius. Here we use 100-meter radius for best image effect.) From it, 2 red super hotspots in the northwest and southeast can clearly be seen. Their real addresses are the Music Square near the College Students' Activity Center of Tongji University, and the commercial area around Xinhua Hospital, respectively. On the periphery of them, as well as at the intersection of two thoroughfares (in the southwest corner) -- Dalian Road and Siping Road, there are some yellow secondary hotspots forming a triangle structure. Along the sides the heat falls off gradually with distance, and in the center very few micro-blogs are produced. Figure 5 illustrates the initial daily scatter plots from Jun 23 to 29, 2013.

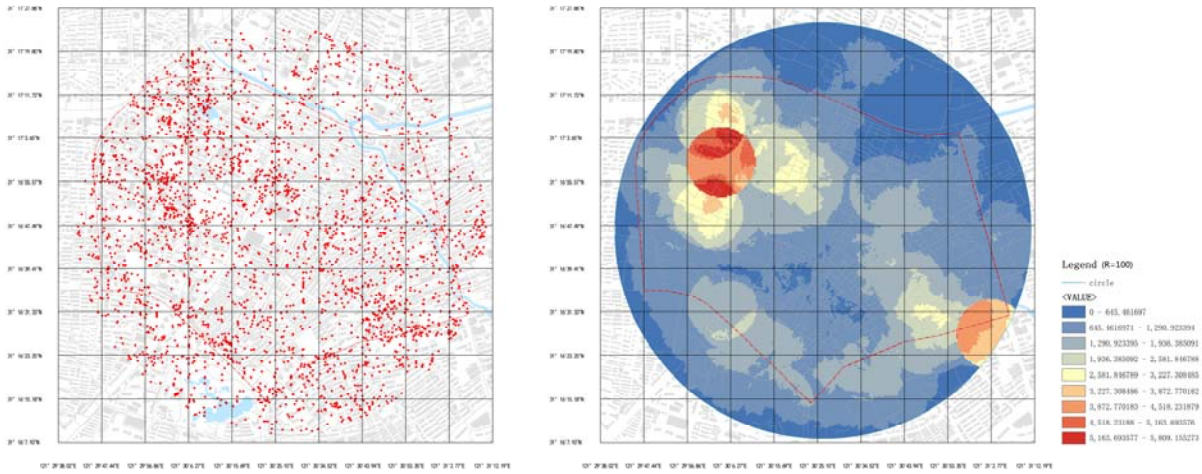

Figure 4: Left: Scatter plot of Sina micro-blog in all 7 Days
Right: Heat Map of Sina micro-blog in all 7 Days with 100-meter radius
Source: Author's self-drawn in ArcGIS environment

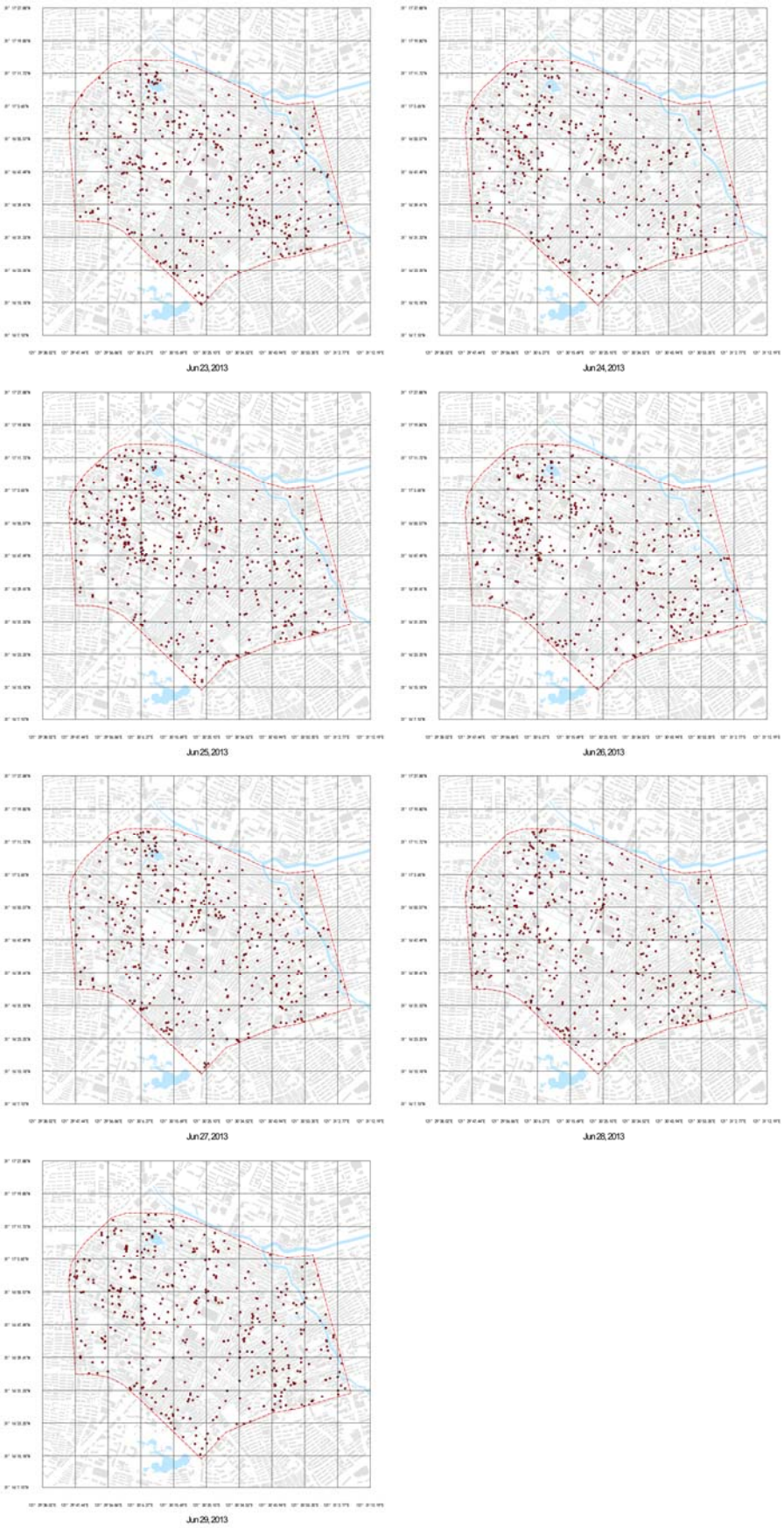

Figure 5: Daily scatter plots of Sina micro-blog, from Jun23 to 29, 2013
Source: Author's self-drawn in ArcGIS environment

3.2 Urban Spatial Network Analysis

As a mathematical method of quantifying how centrally each graph element is located with respect to the surrounding elements, the UNA toolbox abstract and simplify the topographic map of Tongji-Rim into a framework to represent the built environment before computation, which is illustrated in Figure 6. The left side of the figure presents a fragment of Tongji-Rim in topographic map. The same plan drawing is shown in abstracted graph form on the right. Analysis results of the five metrics are illustrated in Figure 7 and described each in detail below.

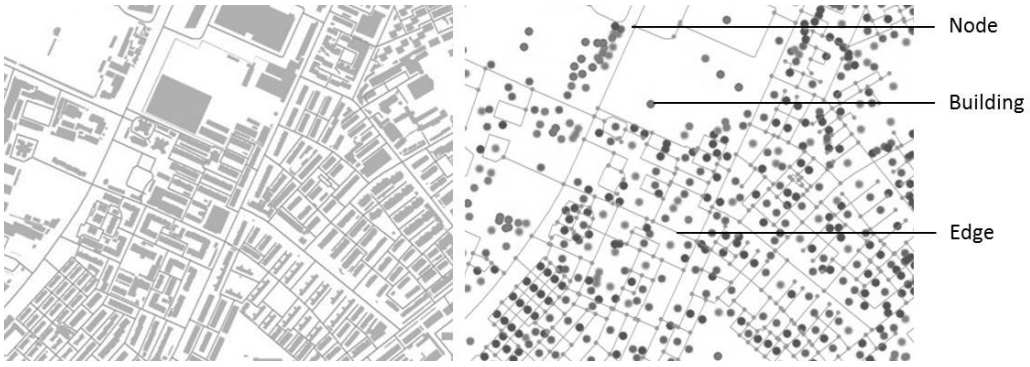

Figure 6: Left: Detail Topographic Map of Tongji-Rim.
Right: a graph representation of the same plan drawing
Source: Shanghai Surveying & Mapping Institute and author's self-drawn

To eliminate the edge effect, we use a larger network that represents the metropolitan environment as a whole (see Figure 7, Row 1, Left). Then we clip off the surroundings from the analysis and only focus on our case study area.

The reach centrality of a node describes the number of other nodes in the network that are reachable from it at a shortest path distance of at most radius input by researcher (here we adopt 500-meter radius). The right graph in row 1 of Figure 7 illustrates the Reach measure applied to buildings in Tongji-Rim. We see that areas with higher Reach values result in areas, where buildings are repeated with nearly the same volumes, more densely spaced, or where the street network is denser. Along Fuxin Road, Jinxi Road and Anshan Road, a typical building reaches roughly 300 other buildings in a 500-meter walking radius. To the contrary, in a campus area around Tongji, ten times less buildings can be reached during the same walk.

The gravity centrality of a node in the network is based on the intuition that centrality is inversely proportional to the shortest path distance between itself and each of the other nodes in the network that are reachable from this node within a radius. Whereas the Reach measure simply counts the number of destinations around each building within a given search radius, the gravity measure additionally factors in the spatial impedance required to reach each of the destinations. First introduced by Hansen (1959), the gravity remains one of the most popular spatial accessibility measures in transportation research (Sevtsuk 2012). Gravity can be seen as a revised version of Reach, introducing the effect of the distance decay on each shortest path. The left graph in row 2 of Figure 7 shows how Gravity is applied to the same dataset in Tongji-Rim as above. Since the index is sensitive to distance, we see how the values are less spread out than in the case of Reach.

The betweenness centrality of a node in the network estimates the number of times lies on shortest paths between pairs of other reachable nodes within the network radius (Freeman 1977). If more than one shortest path is found between two nodes, as is frequently the case

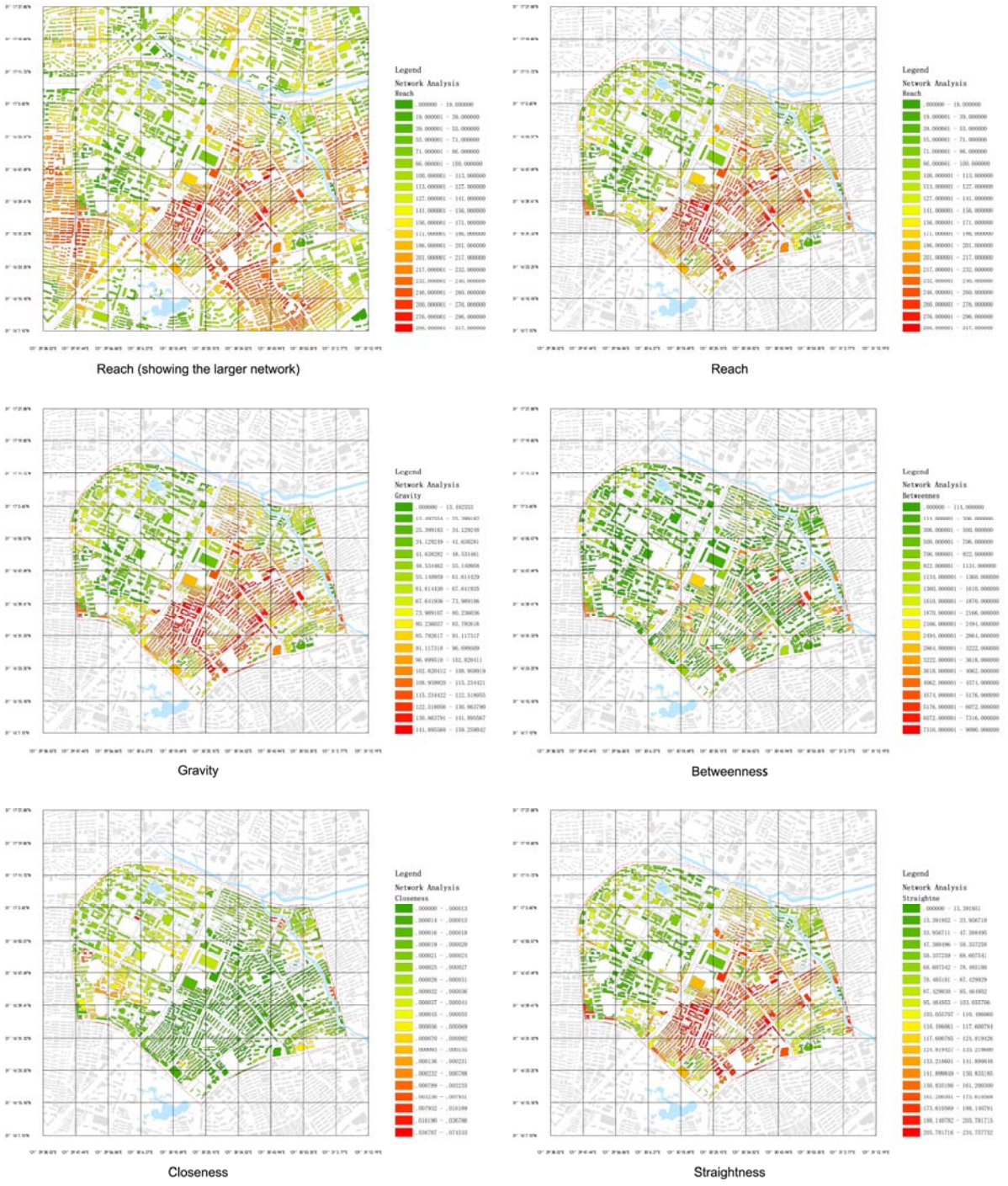

Figure 7: Reach, Gravity, Betweenness, Closeness and Straightness centrality in a 600-meter network radius in Tongji-Rim
Source: Author's self-drawn in ArcGIS environment

in a rectangular grid of streets, then each of the equidistant paths is given equal weight such that the weights sum to unity. As the name suggests, Betweenness may be used to estimate the potential of passersby at different locations of the network. The right graph in row 2 of Figure 7 shows the betweenness centrality of buildings in Tongji-Rim. Buildings that are located along the main thoroughfares, especially at the intersections, intuitively obtain higher Betweenness results, since such routes offer long and straight geodesic paths between numerous surrounding destinations.

The closeness centrality of a note in the network is the inverse of the total distance from itself to all other notes that are reachable within radius along shortest paths (Sabidussi 1966). Unlike Gravity, Closeness does not use the weights of destination buildings in the enumerator, effectively making the measure purely illustrative of how far a building is from its surrounding neighbors. The left graph in row 3 of Figure 7 illustrates how the values of campus area and some commercial office buildings are higher than residential districts, which is exactly the opposite of Reach and Gravity.

The straightness centrality of a node illustrates how closely the shortest network distances between this node and others which are reachable within a radius resembling Euclidean distances (Vragovic, Louis et al. 2005; Porta et al., 2005). Mathematically, it is a ratio between the as-a-crow-flies distance and the geodesic distance from each location to the surrounding locations. The right graph in row 3 of Figure 7 illustrates how Straightness, like Reach, picks up the buildings along some of the longest and straightest thoroughfares in the network. This is because such locations offer more direct travel routes to all their neighbors than buildings along less continuous streets.

3.3 Image Overlaying and Comparison

After graphication of micro-blog hotspots and visualization of the urban network attributes, we add them together to observe the matching degrees. Figure 8 to 12 demonstrate the overlaying of Sina micro-blog scatter plot (7 days) and each spatial centrality index analysis.

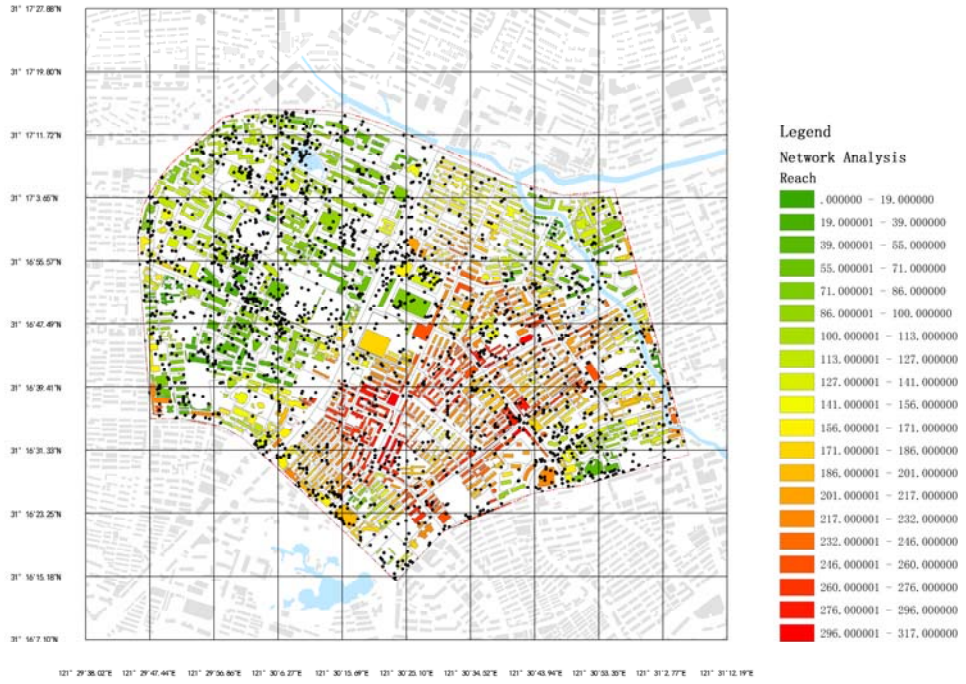

Figure 8: Overlaying of Sina micro-blog scatter plot and Reach centrality analysis
Source: Author's self-drawn in ArcGIS environment

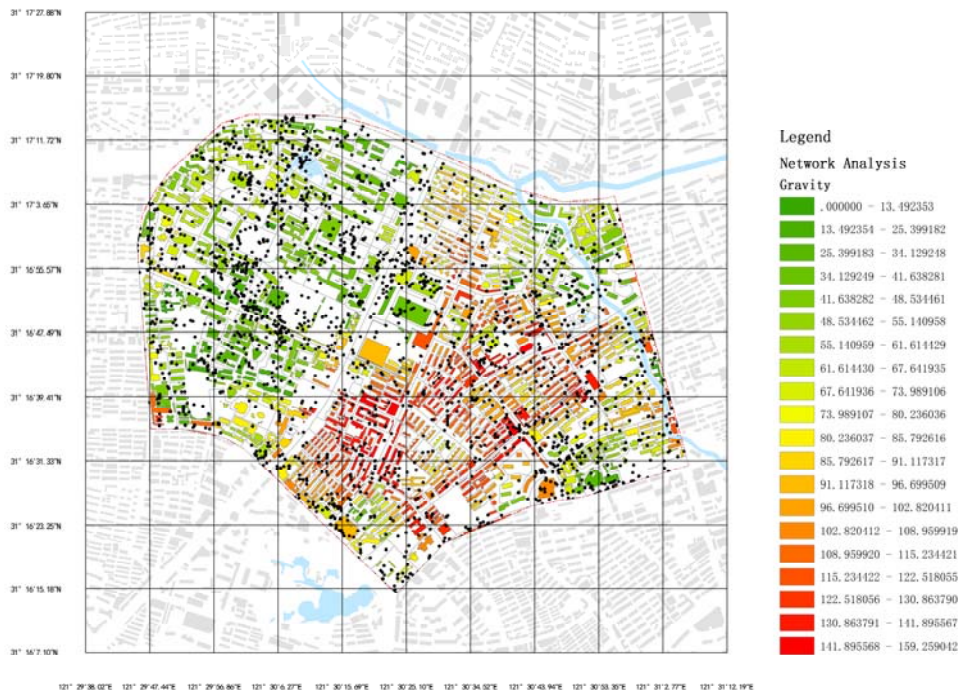

Figure 9: Overlaying of Sina micro-blog scatter plot and Gravity centrality analysis
Source: Author's self-drawn in ArcGIS environment

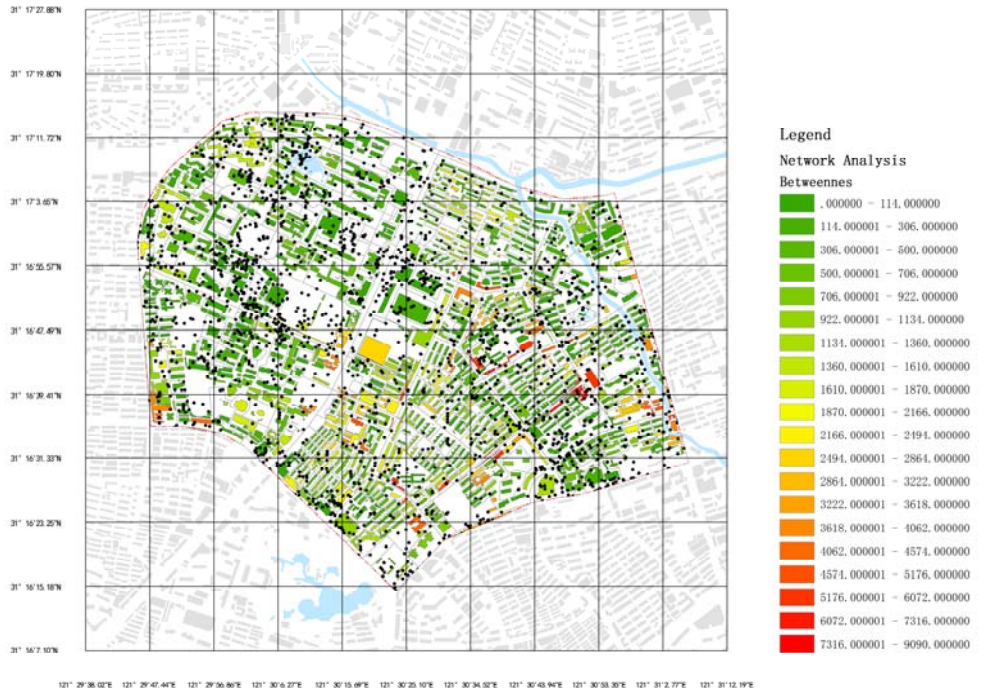

Figure 10: Overlaying of Sina micro-blog scatter plot and Betweenness centrality analysis
Source: Author's self-drawn in ArcGIS environment

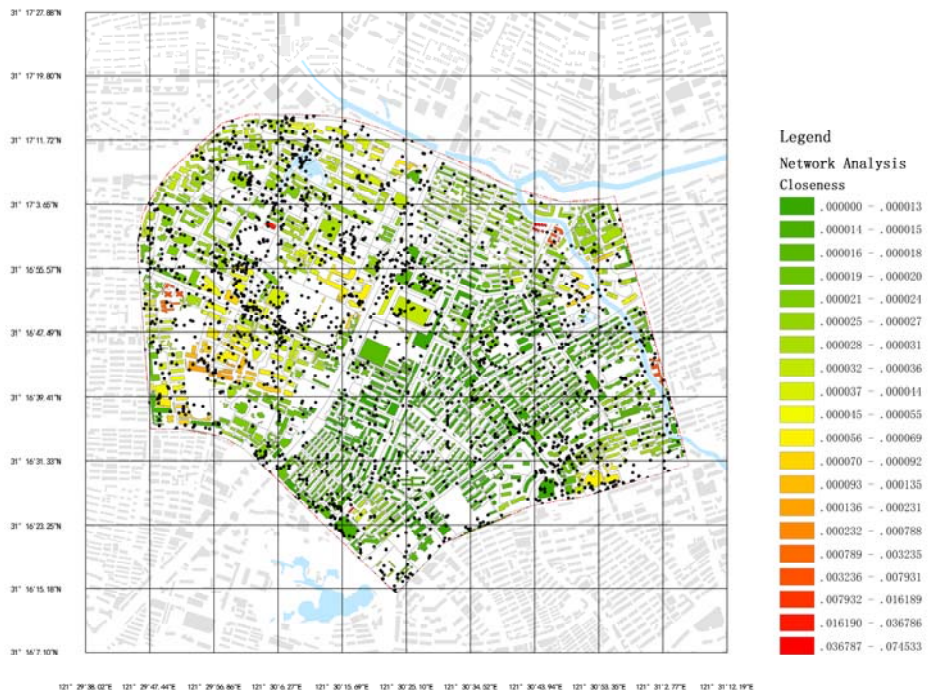

Figure 11: Overlaying of Sina micro-blog scatter plot and Closeness centrality analysis
Source: Author's self-drawn in ArcGIS environment

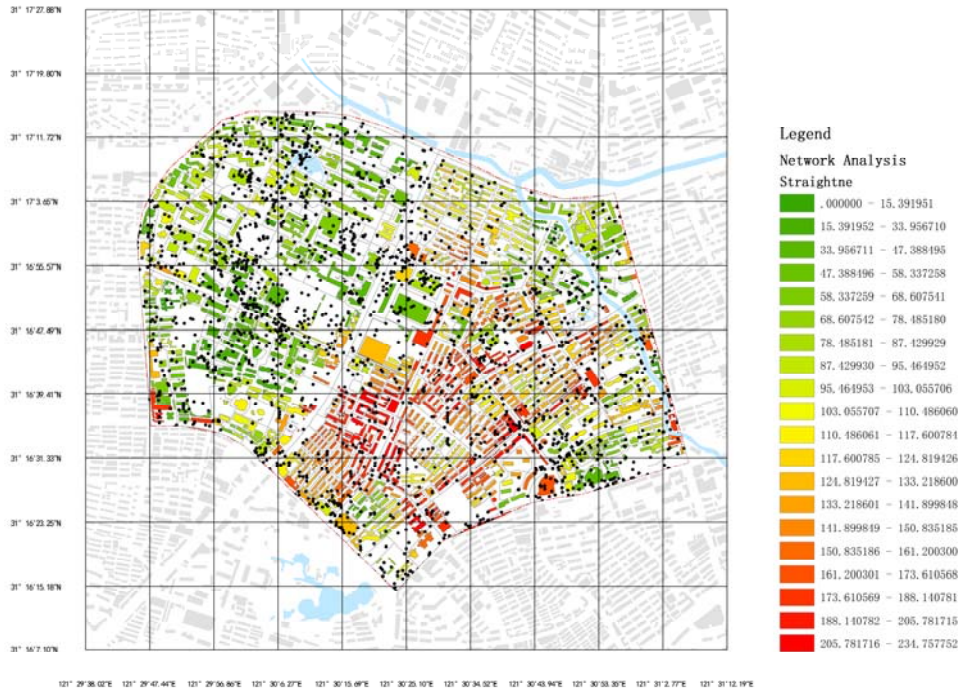

Figure 12: Overlaying of Sina micro-blog scatter plot and Straightness centrality analysis
Source: Author's self-drawn in ArcGIS environment

In Figure 8, the residential buildings in the southeast, especially some large public buildings at the gateway of the communities, have relatively higher reach values. However, the micro-blogs are not correspondingly denser in these areas. Obviously, more micro-blog dots emerge on Tongji campus, in the Tongji Union Square and the commercial area around Xinhua Hospital, where the building colors are green and yellow indicating lower reach levels. As a result, there is a negative correlation between micro-blog distributions and Reach centrality.

In Figure 9, like Reach, Gravity shows the same type of interrelation with micro-blog, just in different degrees.

Betweenness estimates the potential traffic passing by each location in the spatial network. In Figure 10, a small number of buildings with higher betweenness value, which look red and orange, are all situated in hubs or must-go-ways. There are micro-blogs showing up in these places, but more spots are also found in other greener region. Therefore, the interrelation of Betweenness and micro-blog appears more negative than Reach and Gravity.

Closeness indicates how close each of these locations is to all other surrounding locations within a given distance threshold. In Figure11, most buildings with higher closeness values lie on the places where micro-bog spots are much denser and concentrated. Thus, contrary to Reach, Gravity and Betweenness, Closeness has a positive correlation with micro-blog distributions. This result can also be inferred through math deduction.

As in the above case of Reach and Gravity, Figure 12 shows that Straightness has the similar variation trend with them and resembles their correlations with micro-blog distributions as well.

4. Results

According to the three-step research methodology, we get the results as follows:

Firstly, in Tongji-Rim, the campus of Tongji University, the commercial area around Xinhua Hospital, and the intersection of the two thoroughfares -- Dalian Road and Siping Road are the hotspots of Sina micro-blog. Around these hotspots are the radiation areas, and the heat falls off gradually with distance.

Secondly, urban network centrality indices of Reach, Gravity and Straightness have the similar analytical outcomes that the multi-storey residential houses are the main objects with higher measuring values. Closeness performs oppositely, and Betweenness becomes more significant when buildings are located along the main thoroughfares, especially at the intersections.

Reach, Gravity, Betweenness and Straightness all have negative correlations with micro-blog distributions, but in different degrees. On the contrast, there is a positive correlation between Closeness and micro-blogs.

5. Discussion and Conclusion

The starting point of this paper is to make an exploration of the mutual relation between information technology and physical space, from a micro perspective of a small-scale urban area. The most interesting and challenging thing is that the former is unreal and the latter is real. To make the research more feasible, we choose China's widely popular social networking tools, Sina micro-blog as representative of information technology, and adopt the

spatial network centrality indices as measurement of physical space. After the three-step research above, we prove that there obviously exits interrelation between social network and urban spatial network. The former cannot exist isolated. It must take the latter as the support. In other words, any kind of information technology could not play its role without the material existence. While people utilize virtual social network tools, they must depend on the real space carriers. However, the reliance just means that virtual tools need a place for their users' existence. The place may overlap with everywhere of the users' lives. Information technology does not care about how far the place locates, and gradually takes away people's concept about distance. We can imagine that in the future a city's location or a building's site will become less and less important. The negative correlations between the four urban network centrality indices (Reach, Gravity, Straightness and Betweenness) and micro-blog distributions are explicit evidences. Meanwhile, the mathematically negative correlations of Closeness and Reach lead to the positive performance which exactly supports our points before.

To discuss in another way, people now share what they observe in their surroundings and their opinions about topics from a wide range of fields through micro-blog. Every piece of micro-blog they broadcast always is the thing they most concern about and want to show to others. Thus, in a sense, micro-blogging is a mirror that reflects people's real behaviors and preferences, or a filtered window through which we can see the most meaningful and significant parts of their daily life. Consequently, virtual network might be a digital attachment of the real world and their interrelation is reality and projection.

In addition, the residential communities where buildings have higher Reach, Gravity and Straightness values are actually the "model workers' villages", which are the special products of China's Planned Economy Era. These villages are characterized by the high-dense, multi-storey and same-looking buildings, as well as the large-scale parallel layouts, which provide a full explanation for the high level of Reach, Gravity and Straightness. Since last century the living condition of the "model workers' village" has deteriorated with the aging of the infrastructure, but there are lots of families who cannot afford a better habitant still abiding in it. The "model workers' village" falls into a gathering nest of the poor people, who are scarcely possible to use the micro-blog or other social networking service tools. By contrast, there are more chances that the college students, the white collars and the other upper-middle class micro-blog on campus, in the commercial offices or the apartments, where the building density is lower and the volume is larger. Hence, the correlations of the urban network centrality indices and the micro-blog distributions reveal the social rules and the meanings behind the appearances.

Admittedly, as a newly emerging social networking service tool, micro-blog is still in its infancy. Its interaction with the geographic entity space remains to be verified from various dimensions. But undoubtedly, the new urban spatial form brought by this powerful social dynamics will strongly change people's life styles and ideas.

References:

Castells, M (1996) The Rise of the Network Society: The Information Age, Economy, Society and Culture Volume I, Cambridge, MA: Wiley-Blackwell.
Eduardo, R. and Vagelis, H. (2013) "Measuring and Summarizing Movement in Micro-blog Postings", the 7th International AAAI Conference on Weblogs and Social Media, 8-10 July 2013, Boston, USA.
Freeman, L.C. (1977) "A Set of Measures of Centrality Based on Betweenness", Sociometry, 40, pp.35-41.
Hansen W.G. (1959) "How Accessibility Shapes Land Use", Journal of the American Planning Association, Vol. 25, No. 2, pp.73-76.

Liu, Yang (2010) “Micro-blog: Happy Words from Media Age”, Today’s Massmedia, Vol. 1, pp.34-35.
Nagarajan, M., Gomadam, K., Sheth, A., Ranabahu, A., Mutharaju, R. and Jadhav, A. (2009) “Spatio-Temporal-Thematic Analysis of Citizen-Sensor Data -- Challenges and Experiences”, Tenth International Conference on Web Information Systems Engineering, 5-7 October 2009, Poznan, Poland, pp.539-553.
Porta S., Crucitti P., Latora V. (2005) “The Network Analysis of Urban Streets: A Primal Approach”, Environment and Planning B, Vol. 35, No. 5, pp.705-725.
Porta S., Crucitti P., Latora V. (2008) “Multiple Centrality Assessment in Parma: A Network Analysis of Paths and Open Spaces”, Urban Design International, 13, pp.41-50.
Porta S., Strano E., Iacoviello V., Messora R., Latora V., Cardillo A., Wang F. et al. (2009) “Street Centrality and Densities of Retail and Services in Bologna, Italy”, Environment and Planning B: Planning and Design, 36, pp.450-465.
Sabidussi G. (1966) “The Centrality Index of A Graph”, Psychmetrika, 31, pp.581-603.
Sakaki, T., Okazaki, M. and Matsuo, Y. (2010) “Earthquake Shakes Twitter Users: Real-time Event Detection by Social Sensors”, the 19th International Conference on World Wide Web, pp.851-860.
Sevtsuk, A., Mekonnen, M. (2012) “Urban Network Analysis Toolbox,” International Journal of Geomatics and Spatial Analysis, Vol. 22, No. 2, pp.287–305.
Vragovic I., Louis, E. Diaz-Guilera, A. (2005) “Efficiency of Information Transfer in Regular and Complex Networks”, Physics Review E., 71(026122).
Zhan, Z. (2011) “Research Review on Micro-blog”, Journal Of University Of Ji’nan (Social Science Edition), Vol. 21, No.1, pp.34-37.
Zhen, F., Wang, B., Xi, G. and Chen, Y. (2013) “Research on China’s Urban Network Based on the Relations between Micro-Blog Users: a Case Study of Sina Micro-Blog”, Proceedings REAL CORP 2013 Tagungsband. 20-23 May 2013, Rome, Italy. pp.779-792.