LOWLAND TECHNOLOGY INTERNATIONAL Vol. 13, No.2, 35-39, December 2011
International Association of Lowland Technology (IALT), ISSN 1344-9656

THE QUANTITATIVE RESEARCH ON 3-DIMENSIONAL SIMILARITY OF URBAN TEXTURE

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ABSTRACT: Urban texture represents the city's characteristics abstractly. Based on the study of city in three dimensional orientations and the figure-ground relation theory, an evaluation system on the building form in the city has been set up by bringing forward the conception of regional 3-dimensional (3D) density, 3D similarity, 3D contrast and regional spatial complexity. This paper is about 3D similarity as a part of the research series. The evaluation system describes the morphological distribution and the differences of scale between buildings in 6 sample sites through rational analysis using qualitative figures and quantitative calculations, verifying the consistency of quantitative calculation and experience.

Keywords: Urban texture, 3D orientations, regional similarity, regional dispersion.

1. BACKGROUND

Urban texture is a description of urban spatial patterns and urban characteristics; it varies according to time, geography and city type. These differences are reflected in the structure of roads, patterns of layout, building density, height and volume, etc., which make urban texture rough or fine, homogeneous or heterogeneous. Most traditional descriptions and expressions of urban texture are based on the two-dimensional level such as figure-ground relation figure, which neglected the height of buildings and failed to transmit the integrated information of dimensions. For example, even if the building density and FAR equal to each other (as a traditional description), people's spatial feeling is quite different between regions constituted mainly by public buildings and those constituted mainly by residential buildings. However, with the concept of 3D density and 3D similarity, the difference of the issues will emerge objectively. The city we touch, experience and apperceive everyday is a three-dimensional or even four-dimensional (the dimension of time) space. Without the impact of height, deviations would emerge during the reconstruction of the basic image of city by making use of those figures and data, and would bring an increasing number of misunderstandings of virtual space. As a strategy to resolve this situation and problem, it is important to set up a three-dimensional evaluation system to describe the urban texture.

It can be traced to Kevin Lynch, who described the urban texture with size, clarity and roughness in his book "Good City Form" in 1980, and pointed out that these characters can be quantitative, although he did not put forward the way on calculation. In order to polishing the parametric way of reverting city image by figures, an evaluation system in 3D orientation has been put forward, which is constituted with 3D density, 3D similarity, 3D contrast, and regional spatial complexity. With this system, it is possible to make a quantitative description of urban texture based on related researches.

Regional similarity research deals with the relations of configurations between repetitive elements. Compared with organic and self-contained ancient cities, contemporary cities, although being carefully planned and designed, appear to be more chaotic and disordered on many aspects. Satellites indicate situations of the city clearly: the staggered junction of old and new in different volumes, buildings in city center with different height, the barracks-like residential communities arranged neatly. So what should the ideal city model be like? Should the forms of buildings be similar or different? Should the volumes change gradually or suddenly? Should the building styles be duplication or multiple? Formulate laws and regulations can only be a mere formality because qualitative description can not be taken as a unified standard. As Kevin Lynch has pointed out that the methods describing the city can not be limited to text and graphics： "the mathematic thoughts

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Note: Discussion on this paper is open until June 2012

become more and more important ... ... to show the spatial distribution digitally... ... is a valuable research data." The concept of Regional similarity is proposed to set up connections of forms among buildings in certain districts, and to describe the city buildings or the degree of the modulus of their configuration through combination of qualitative and quantitative research so as to provide a quantitative frame of reference for city government officers and urban designers.

2. REGIONAL SIMILARITY

2.1 Definition

Regional similarity is the extent of similarity among buildings in a certain district, which is also the extent of modularization among monomers. Similarity can be interpreted as the approximate extent among monomers in a selection of the study area and describe this in a type of system constituted with relevant parameters. The similarity is denoted with the discrete degree of the monomers' data distributed in the district.

Urban texture is constituted with substantial buildings and the vacancy, the similarity among monomers reflects the strength of repetitive elements of these entities. The regional similarity can reflect the distribution of building styles to some extent: the higher similarity in the district, the higher modulus monomers are. In districts with higher similarity, the building style and from is relatively uniform, such as the district of multi-storey residential communities developed in China in 1990's. To the contrary, the lower similarity in the district, the more difference could be found among monomers. In districts with lower similarity, there are various form styles of buildings, such as the area mixed with commercial and residential facilities or comprehensive educational facilities.

2.2. Related Factors

There are large quantities of parameters related with regional similarity, which can be generally divided into two categories: building configurations and building styles. The factors of building configurations include the buildings' projected area, height, block construction way, etc. And the factors of building styles include forms of the roofs, style of doors and windows, materials, colors, year of construction, the complexity of the decoration, etc. The building configurations and styles affect the composition of urban texture together, the building configurations affect the experience of urban space and the composition (entity and vacancy) of urban texture directly, while the building styles impact the urban texture much more microscopically. Therefore, on the study of texture in the city level, we concerned more about the building configurations——like the situation in city planning model, buildings existed in the form of blocks without specific styles. Restricted to the limited time and resources, the quantitative study of regional similarity at this stage is limited to the similarity on building configurations. And the qualitative description of similarity on building style will be further improved in future research.

2.3 The object of calculation

As mentioned above, there are many different factors affecting the regional similarity of the buildings, while the integrate calculation of regional similarity is a complicated and cumbersome project. From the research point of view, the parametric study take the configurations, which affect the texture pattern mostly as the basis for quantitative calculation, regardless of the factors like materials, colors or building styles. Among those parameters which impact the building configurations, the building area ***s*** and building height ***h*** are quantitative parameters that can easily be measured, while block construction can neither be measured nor quantified with figures. The parametric factor is made as follows:

1) Every monomer is considered as a cylindrical body with the projection plane as its bottom and the height of building as its height. (Measured from the outside ground floor to the roof level, the partial difference of height is ignored, such as staircase and elevator machine room above roof.);
2) Disintegrate buildings into separate units, such as various parts with integrated functions of a multifunctional building, or parts clearly different with stories, types (form, structure, etc). For example: a hotel's main building and accessorial building, or the main tower and annex of a high-rise, etc.
3) Buildings connected by elements such as skywalks are regarded as different monomers.
4) Regardless of the morphological characteristics of abnormities, we simplified them as single shapes according to the principle of equal projection area and equal volume.

2.4 Algorithm

The concept of similarity comes from geometry: two geometrical objects are called similar if they both have the same shape. Equivalently and more precisely, one is congruent to the result of a uniform scaling (enlarging or shrinking) of the other. And they are congruent if they are isometric – roughly, if they are of the same size and shape. Further more, the "similarity" of plane graphics in

geometry can also be deduced to three-dimensional graphics. In the calculation of regional similarity, we consider similarity as the similarity of volume, such as similar bottom area and height. How to calculate two orientations' indexes of bottom area and height is the key point of the calculation. The comparison of the results of the indexes may prompt the difference of the configurations in the region, which is regional dispersion. On the contrary, the similarity of the configurations can also be prompted.

The calculation progress of regional similarity combined charts and computer programs.

1) Data collecting: Collect the basic parameters for each monomer building: the projected area ***s***, building height ***h***, and the length of ideal hemline $l = \sqrt{s}$. (by measurements or from the Planning Department)
2) Data organization: Set up a plan rectangular coordinate system, figures in x-axis show the length of Ideal Hemline ***l***, figures in y-axis show the height ***h*** of buildings, the point A_j (l_j , h_j) ($j = 0,1,2,\cdots,n$) records every single monomer in sample district, and the formation of points set is A. The concentration and dispersion of the points reflect the similarity of single building unit. The size of the enclosing circle including the points set is the key indicator which determines the level of concentration and dispersion.
3) Input the data of points set A into the computer, using computational geometry process to achieve radius ***r*** of the circle surrounds the points set A.

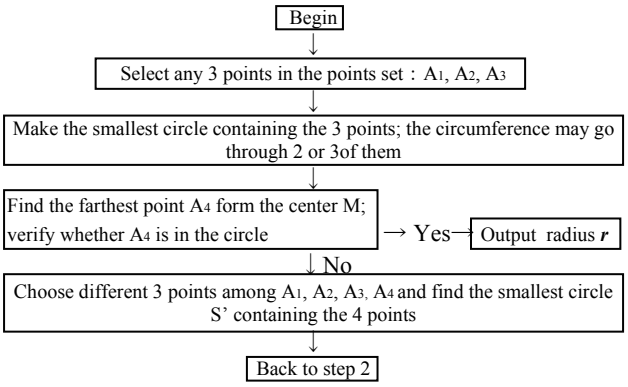


Table 1: Algorithm of the smallest enclosing circle of points set

4) The length of radius ***r*** reflects the size of area over which the points distributed. In another word, it reflects the degree of the differences among configuration of monomers. The longer radius of the enclosing cycle is and the broader the scope of the distribution of points is, the lower similarity buildings have. Conversely, the smaller the enclosing cycle is, the higher regional similarity there is. We describe the regional dispersion with the length of radius ***r*** of enclosing cycle.
5) Regional similarity and dispersion are of reverse relationship. In order to show the differences of the results clearly, take the square root of the reciprocal of the regional dispersion as regional similarity index, then it comes to regional similarity $\delta = \sqrt{\frac{1}{r}}$
6) The images bellowing indicate the analysis diagram and the block model of a college and a residential community. As showed in Fig. 1, the points which on behalf of the mass of college are relatively wide distributed, while Fig. 2 shows an intensive distribution of residential buildings. It can be inferred that the volumes and sizes of school buildings are much more different from each other, while in residential communities they are much more similar, which coincides with the situation demonstrated in Fig. 3.

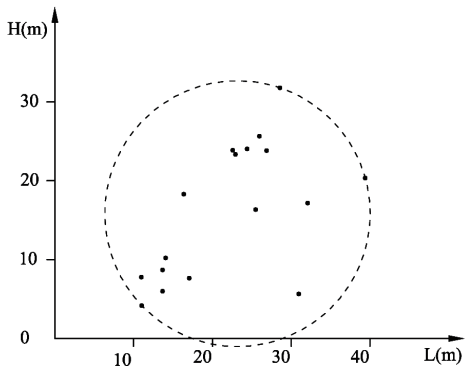


Fig. 1 Coordinates diagram of a college

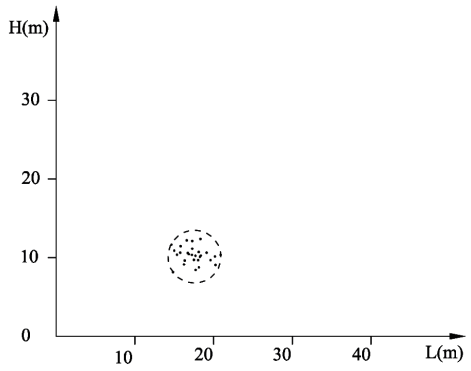


Fig. 2 Coordinates diagram of a peasant's residential community

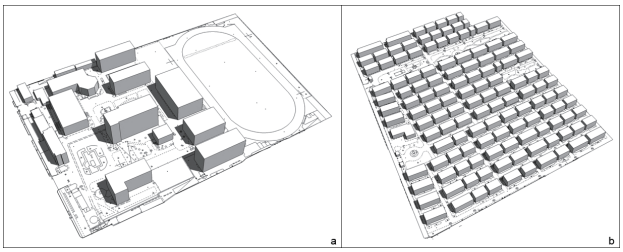


Fig. 3 Volume models, a: a college; b: a peasant's residential community

3. SAMPLES

On the basis of theoretical research, a district of 1.5 square km in the west part of Hangzhou was selected to be investigated for the further research. Qualitative diagram and quantitative calculations are taken in each block of this district to further demonstrate the necessity and feasibility to introduce the concept of regional similarity into the study of urban texture.

The research area is located at Neighborhood of Cuiyuan and New Community of Gudang in Westlake District, Hangzhou, enclosed by Wenyi Road, Academic Road, Wensan Road and Yile Road. The construction of this area started from late 1980s, including all kinds of land-use pattern such as commercial, residential, official, medical and educational facilities. Now it is a developed district in Hangzhou with multifunctional urban form and superimposed urban texture.

Roads and walls are bounds in plot division, ensuring both the purity of each sample's land-use and the integrity of buildings within to make the valuation statistics more pertinently. The 6 samples included all kinds of land-use pattern mentioned above. Meanwhile, communities in different ages were selected as the sample of residential land-use to make the valuation statistics more universal. (Fig. 4) Through digital analysis and data statistics of maps of Cuiyuan residential area in Hangzhou in 2007, coordinate diagram of each sample is made. Moreover, the parameters of each sample (regional similarity) are figured up with the calculation method mentioned above (Fig. 5).

We can see:

1) Comparing the point sets of three different residential communities with the coordinate system of the same scale, it is found that: some points are assembled in A, which means this block is constituted with groups of buildings which are similar in volumes; points in B are more concentrated than A because it is full of multi-unit apartment community built in 1990s; the most assembled points appear in C, which have the most similarity of buildings. If the three graphs are superimposed in a unified coordinate system, it could also be seen the morphological differences among the three types of residential buildings.
2) Compared the residential community with the comprehensive function area: the points are more assembled in the sets of residential communities (such as D, B and C) or partly assembled (such as A). But the points in F are distributed dispersedly and equably in multi-function areas such as educational areas.
3) The radius of enclosing cycles in D, E is similar while the distributions of points are totally different. In points set D, the points are dispersed horizontally while in points set E, the points are dispersed vertically. It means that the difference in D is mainly about the floor space of buildings, while the difference in E is apparently about the heights of buildings.
4) ***r*** represents the distribution of points and $\delta = \sqrt{\frac{1}{r}}$ reflects the regional similarity. It is abstract and easy to compare, but cannot present the distribution of

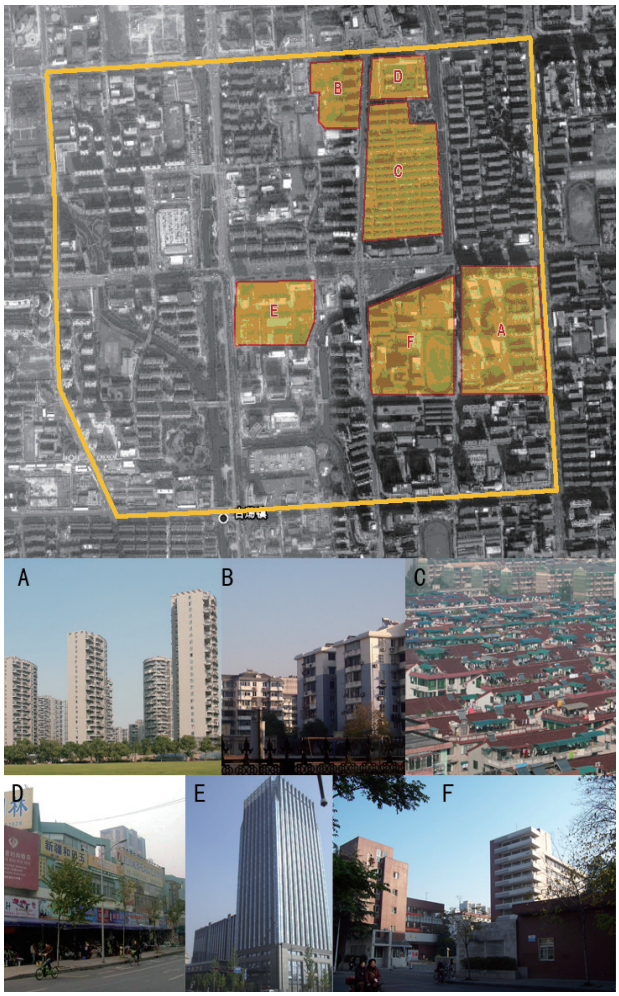


Fig. 4 The 6 sample research sites

5 points visually. In points set D, E, deviation of one point will lead to several times expansion of the radius of the enclosing circle. Therefore, in order to express regional similarity more intuitively and more accurately, we recommend making use of quantitative coordinate's illustration to interpret the urban characteristics more accurately.

4. MEANINGS AND APPLICATIONS

The index of similarity breaks the original model in which people estimate city space and architectural environment with intuitive and emotional cognitive. Through the introduction of mathematical methods, our perception of configurationally similarity will be improved to a new level. Databases of regional similarity can be established after calculation and collection of regional similarity in different cities or districts. This huge parametric database can be the foundations of further development or rehabilitation of old districts. The regional similarity system can be used not only to control configuration of buildings to be built but also to inspect whether the relationship between old buildings and new buildings is harmonious.

The study of regional 3D similarity is a sub-topic of the study on urban texture in three-dimensional orientation and a path to recognize and quantify the urban space. And it is necessary to combine the study of 3D similarity with concepts such as 3D density, 3D contrast and regional spatial complexity to lead to an integrated and comprehensive evaluation system to provide more rational and objective references for government decision-makers and urban planners.

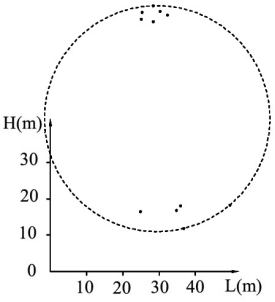
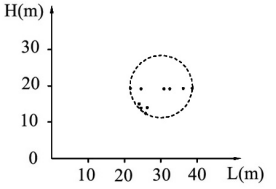
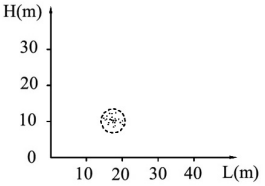
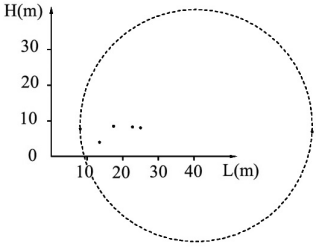
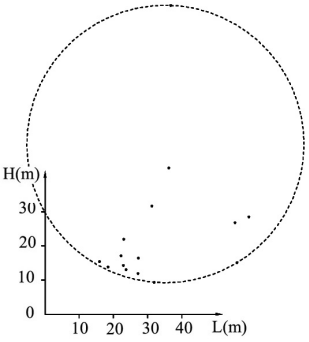
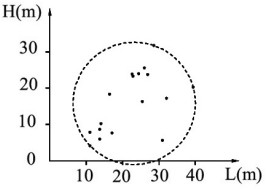
A: Fenghua Community	B: Cuiyuan Community
Regional dispersion：31.1 Regional similarity：0.179	Regional dispersion：6.15 Regional similarity：0.403
	
C: New Community of Gudang (a peasant's residential community)	D: Cuiyuan Maket
Regional dispersion ：1.4 Regional similarity ：0.845	Regional dispersion ：41.4 Regional similarity ：0.155
	
E: Energy Company	F: Arts Academy of Hangzhou Normal University
Regional dispersion ：45.45 Regional similarity ：0.148	Regional dispersion ：16.8 Regional similarity ：0.244
	

Fig. 5 Regional similarity of 6 sample sites

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