Research on Urban River Spatial Continuity Design Based on RSC Model

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Abstract. In order to solve the problem of river spatial fragmentation and heterogeneity caused by urban expansion, a River Spatial Continuity (RSC) analysis model is proposed to explore the design strategy of spatial continuity, and alleviating the problem of uneven urban space construction. The river spatial continuity includes macroscopic spatial continuity and microscopic spatial continuity. This article takes the river microspace as the main object, and use the section from Mudugang to West qiujiang River in Putuo District, Shanghai as an example. The analysis results show that the spatial continuity index of the site is low (c₁=0.33) and the visual continuity is poor (C₂=0.26). In the industrial and commercial gathering areas (upstream and middle reaches), the river space has varied spatial changes and uneven quality distribution. However, in the residential areas (downstream) have similar types and densely distributed functions. The mixing of various types of surrounding environments leads to the fragmentation of the river space and heterogeneity. Because of this, the strategy has been proposed to optimizing land use space and improving the quality of details in the upper and middle reaches, while implementing standardized design in the downstream areas. In this way can promote the formation of regional linkage and coordinated development of the city.

1. Introduction
Due to the rapid urbanization, cities are presenting fragmentation and islanding characters [1-2], as a result, how to connect these “fragments” and build the green network have become the important subjects for the current cities. As a linear connection, the urban river space not only plays an important role in building the ecological connection for green urban infrastructure, but also serves as an effective spatial carrier in terms of urban visual intention and use function [3]. Therefore, the connected urban river space can be conducive to mitigating conflicts in ecology, function and aesthetics during the urbanization, stimulate the linkage effect of urban space, and arouse the urban vitality [4].

The study on urban river, based on the objective parameter analysis at a macro level, focuses on reflecting the evaluation of river water quality and ecological pattern, while based on the subjective parameter analysis at a micro level, centers on comprehensive reflection of differences in river space. By refining the spatial continuity and visual continuity and branching out to the living environment closely linked to users, it is of practical significance to connecting fragmented city and improving the quality of river corridor space [5-6].

Based on the foregoing, this paper developed the river spatial continuity (RSC) analysis model, a more applicable continuity evaluation system established by centering on the micro-scale spatial continuity and visual continuity of rivers and then stretching out to space connected with nodes, with the aim to accelerate the urban river continuity construction process.
2. Construction of RSC Model

2.1. Methods and procedures to build RSC model
Urban river spatial continuity analysis model mainly focuses on the quantitative research on landscape details (as shown in Figure 1), with spatial continuity and visual continuity as main criteria, while spatial connectivity index, real landscape continuity index and potential landscape continuity index as main evaluation indexes.

![Fig.1 RSC Model Structure](image1.png)

2.2. Analysis of RSC model indexes

2.2.1. Spatial connectivity index.
This paper puts forward the spatial connectivity index of landscape from three aspects, with its formed size as the final results, as shown in Figure 2, at the same time, it fully considers the impact of river banks and riverside structures on the site. In the y direction, the values are general evaluation results $y_i=0.5, 1$, representing the dis-connectivity and connectivity respectively; the values in the x direction represent the ratio of the passable width in the river bank space to the total landscape width, wherein, $0\leq x_i \leq 1$; the values in the z direction are the ratio of landscape width at the river bank to the height of the nearest building, as shown in Figure 2, reflecting the sensitivity to the openness and narrowness of the landscape site.

![Fig.2 Schematic representation of spatial connectivity in 3D space](image2.png)

Wherein, the value of spatial connectivity is shown with the volume of cubic constituted with their three dimensional coordinates, the expression being

$$V_{xyz} = x_i \times \left( \frac{w_{yiz}}{w_{yiz}} \right) \times \left( \frac{w_{ziz}}{h_{ziz}} \right)$$  \hspace{1cm} (1)
In which, \( V_{xyz} \) means the spatial connectivity index, \( w_{yi1} \) is the width of passable river landscape road, \( w_{yi2} \) is the width of landscape, \( w_{zi} \) is the distance from the river bank to the nearest building, and \( h_{zi} \) means the height of nearest building. The spatial connectivity index is calculated with the result of standard deviation, since the standard deviation reflects the dispersion degree of the value, while subtracting this value from the fixed value (1 set in this paper) comes to be non-dispersion degree, namely the spatial continuity.

### 2.2.2. Real visual continuity index and potential visual continuity index.

Visual continuity index refers to the “visible” continuity process, the results of which can be divided into real one and potential one. The real one is the real space screen, while the potential one refers to the ideal spatial space environment after eliminating human reference factors, both of which can be represented by the variation of screen occupancy [7]. The user can have certain environment cognition during the sightseeing, while, the image occupancy’s calculation aims to simplify the complicated language in the vision. According to Kevin Lynch (1960), urban cognition is summarized into several elements: roads, districts, boundaries, nodes and landmarks [8], while Jane Jacobs (1961) believes that streets are formed due to enclosure of buildings along streets [9], and river landscape can be divided into five parts, sky, ground, buildings, plants and water area, as shown in Figure 3. The changing relation of these five parts can be available by measuring at different points of different reaches. The value of visual continuity of the site can be shown with the recognition area ratio of green space, and their continuity indexes can be calculated with standard deviation.

![Fig.3](image)

**Fig.3** Comparison of existing spatial analysis based on image cognition and future potential analysis based on model cognition

### 3. Application of RSC Model in the Reach from Mudugang River to West Qiujiang River, Putuo District, Shanghai

#### 3.1. Overview on the survey area

The survey area, coordinates being W121°42955’, N31°24809’, E121°35646’, and S31°21220’, is located at the south of Putuo District, adjacent to Suzhou River in the south, north to Meichuan Road, bordering on the west by the Zhonghuan Road and on the east by community proximate to Yangliuqing Road, and mainly covers Changfeng Community and Changzheng Community. The survey area is 8.62km long in total, and covers a total area of 30.5 hectares.
3.2. Data sources and image processing

(1) Data sources
Since it’s a small area, there are two ways for collecting data, one from the network and the other from measurement, with the data sources as shown in Table 1.

| Source classification | Data Sources         | application                                      |
|-----------------------|----------------------|--------------------------------------------------|
| Network data          | Google Satellite Map | Location analysis, green space analysis, length measurement, area measurement |
|                       | Baidu Street Map     | Road node analysis                               |
| Actual data           | Field measurement    | Riverside landscape size and digital model making |
|                       | Take photos in the field | Screen share analysis                           |

(2) Picture processing
Considering the manual measurement errors caused by weather, light and photographing angle, pictures should be, upon completing the shooting, partially retouched or refined in details by virtue of PS, AI and other image processing software. For pictures used for visual continuity analysis, the resolution of landscape green infrastructure shall be well guaranteed in the screen, and the exploitable above-ground space of riverside landscape should also be clearly identified in the pictures based on digital model technology.

3.3. Landscape continuity analysis

3.3.1. Continuity analysis on landscape under the influence of continuity in three-dimensional space.
During the measurement, point locations can be determined according to the following principles: ① Evenness. Each point location to be selected within the measurement area should be regularly distributed, which can avoid the one-sided evaluation due to excessive concentration or decentralization of point locations, in order to reflect the current situation of site more realistic. ② Superiority. Since the two parallel riverside landscape spaces are formed on the base of river existence, two measurement points should be selected in each space to finally determine which point is closer to the building, aiming to fully consider the influence of building height on the landscape space. ③ Typicality. The digital model technology makes it convenient to conduct spatial analysis, and also makes it possible to proceed virtual analysis on those spaces unapproachable in reality. When studying the distribution of point locations, typical unapproachable spaces are preferred, in order to predict the development potential of the site in the future. Total 20 measurements points are selected for the landscape space continuity index, with the specific distribution of these point locations as shown in Figure 4.

The specific measurement refers to apply SigmaPlot software to conduct comprehensive analysis on the continuity of 3D space (Figure 4), wherein, data at Z axis, in order to highlight the extent of changes in results, is not a real value, but an estimated value based on the extent of changes in data, expressed in figures. According to the formed area, the blue part is quite steep slope, with obvious changes; orange part is a gentle slope, with stationary curve; and the green part is the medium level. Since the sequence of measurement point locations coincide with the direction of X-axis, Y-axis and Z-axis, we can come up with the preliminary judgment from the figure that the value in the middle area is slight, while the value at both ends change significantly. After calculating the standard deviation of the final measurement results, the spatial connectivity index value comes out to be $c_1=0.33$. 
3.3.2. Visual continuity analysis under the influence of varying screen occupancy

(1) Real visual continuity index

When determining the point locations for measuring the visual continuity, in addition to ensure its evenness same to that of landscape spatial continuity, the following principles should also be observed: (1) accessibility. It's preferred to select the real spatial connectivity point locations. During the analysis, users' visual perception in the space should be fully taken into consideration, and the screen should be analyzed from the first perspective, thus ensuring the more accuracy of the results. (2) Try to avoid all traffic nodes. This study focuses on the riverside landscape spatial analysis, which means that the measured locations should be able to directly reflect the landscape content, so as to minimize the impact of external factors. Total 16 point locations are selected to be measured, with the specific distribution as shown in Figure 5:

- Considering the randomness of shooting angle and height during the measurement, in order to ensure the accuracy of screen, the following contents have been uniformly specified: (1) the pictures should be shot from the landscape road; (2) the shooting direction should be aligned with the direction of the flowing water, and it’s preferred to select the right river band along the direction of flowing water; (3) pictures should be shot at the height of 1.6m. When analyzing pictures, the screen ratio should be calculated. In this paper, the area calculation tool in the AUTO CAD software should be used. The measurement results focuses on, rather than the size of the area, but their proportional relation. The specific measurement process, variation trend of screen occupancy and measurement results is as shown in Figure 5. The study on the landscape space along the river mainly focuses on the study of green landscape along the river, therefore, the final evaluation results of visual continuity index can be calculated on the base of varying ratio of green recognition screen, with the calculation result expressed in standard deviation, and the final result is \( c_2 = 0.26 \).
(2) Potential visual continuity index

The principles of shooting should also be following in the process of selecting model images, in order to ensure the height, angle and direction, and it’s better to have the same shooting point location as the real pictures, as shown in Figure 6, namely, the recognition screen used in the model space. The measurement results are shown in Figure 6. The value of potential visual continuity index will be used to compare with the real continuity index, and the utilization conditions of the current site will be analyzed on the base of the relationship between the potential continuity index and real continuity index.

Along with the change of sequence of measurement points at the river bank, the potential landscape area changed significantly. However, from the perspective of overall tendency, compared with the change of real screen occupancy, the potential landscape land area gradually declines, which means that the real landscape visual perception is limited by the site.

Based on the average deviation, we come up with the potential landscape visual continuity index, $c_3=0.91$. Finally, we conduct the correlation analysis on the real landscape continuity index and potential landscape visual continuity index of the screen, with the correlation index being 0.33, a weak correlation.
4. Analysis of results and updated spatial strategies

4.1. Analysis of results

In terms of spatial continuity, as shown in the figures, the space at z axis changes obviously, especially in the midstream and the upstream area; while the space at x axis remains relatively stable, with slight changes in the downstream; meanwhile, the spatial variation at these three dimensions shares the basically same trend and becomes stable after passing Point Location 13, which means that the spatial composition at this area is similar, and can be the standardized design of riverside bank. According to the research results on comprehensive spatial continuity index ($c_1=0.33$), the site is with poor spatial continuity. To be specific, the spatial continuity index in the upstream area of the site is at large, with relatively stable fluctuation in value, single sensitivity passing the space; the spatial continuity in the midstream area is relatively good, but the values fluctuate largely, with varying sensitivity passing the space; the spatial continuity in the downstream area is relatively good, but the values fluctuate largely, with varying sensitivity passing the space is relatively poor, with stable values and single sensitivity to the space. The landscape at the site within the study area has just been developed at the initial level, and the potential of landscape has not been fully exploited.

In terms of real visual continuity, the site is with poor visual continuity ($c_2=0.26$), the landscape green visual ratio declines gradually, and the ratio of waters, sky, building facilities increases gradually. The different kinds of visual screen in the downstream area gradually become balanced, which means that there are explicit changes layer by layer in the visual screen in the upstream area, while such changes in the downstream area become slight, thus forming the discontinuity with explicit differences between the midstream and the downstream. At the same time, the green screen ratio of the site declines little by little, which is also another main cause of the discontinuity at the site. In terms of potential visual continuity, the overall changes are relatively large and even, without regular variation trend. Considering
c3=0.91, we can find that the full development of continuity potential of the site can promote the visual aesthetic feeling of the whole river.

4.2. Updated landscape strategies from Mudugang River to West Qiujiang River, Putuo District, Shanghai

As to the existing problems in the project, based on the landscape continuity indexes from different perspectives, the following update strategies are proposed:

Spatial continuity design strategies: ① For the river area from Point Location 1 to Point Location 12, by combining the usable site width, taking the influence of the surrounding building height into full consideration, new design criteria with relatively uniform road width and landscape width adapting to the topographical changes should be developed, aiming to enhance the spatial continuity of the site. From Point Location 13 to Point Location 20, by combining the reasonable zoning of the site, standard design should be developed to improve design efficiency. ② Enhance the river landscape infrastructure construction, update the design on landscape areas with incomplete function and obsolete facilities, and sound the functional demands of landscape green space. ③ Increase the continuity of the landscape space along the artificial channel in the city, connect the previously fragmented space blocked by other reasons, and form a complete pedestrian continuous space. ④ Make full use of the existing revetment form. When taking advantage of the natural revetment, the impact of river overflow should be taken into full consideration, the access to water should be ensure on the basis of not destroying the riverbank matrix; in terms of artificial revetment, the dam form should be optimized on the basis of ensuring the safety of river course, and the new space of landscape utilization should be expanded by means of landscape construction such as stretching out, hollowing and vertical means.

Visual continuity design strategies: ① When carrying out the space design of landscape, attention should be paid to the visual continuity of space, including the virtual continuity and real continuity, continuity between colors and materials, and element continuity. ② The rich level of landscape details should be fully used to form the enclosed vision, expand the sense of space, enhance the overall sense of the site, form the psychological hint, visual guidance and other functions, improve the quality of landscape space. ③ Planting density should be reasonably planned, attention should be paid to match different plants to form well-organized spatial variation, and ensure the growth continuity from season to season, as well as from year to year. Appropriate plants with aromatic characteristics should be applied to enhance the sense of smell of space. ④ The historical elements in the site should be retained, and properly applied into the space design to form the landscape spatial memory, and enhance the historical continuity of that time and space.

5. Conclusion

In this paper, RSC model has been applied to conduct the spatial continuity analysis on the reach from Mudugang River to West Qiujiang River, Putuo District, Shanghai, and the application of space syntax and vision field analysis method refines the spatial continuity study, which is of direct significance to improving the quality of specific river space. Meanwhile, the results are obtained by quantifying values, which is more visualized. According to the results, the river spatial continuity is limited by the surrounding functions, construction area of green space and height of neighbouring buildings. To be specific, the river space varies a lot, with uneven quality distribution in the commercial and industrial cluster districts (upstream and midstream), while the space types at the residential district (downstream) remains similar, with relatively dense function distribution. Therefore, the mixing of various types of surroundings contributes to the fragmentation and heterogeneity of channel space.

As to the existing problems concerned the river space, according to the RSC model analysis results, in terms of spatial continuity, the surroundings should be taken into the consideration of design, with the guiding role of macro control and the realistic means of micro adjustment integrated to flexibly adjust the river land space, form the special design criteria applicable to industrial and commercial districts and standard design applicable to residential districts; in terms of visual continuity, the quantity
and types of plants in the river space should be optimized to form the sight-seeing sequence mainly with green space, an even screen ratio between water, sky and buildings, and full of visual change rules; at the same time, attention should be paid to optimize the dam construction materials, enlarge the greening, hollowing and stretching-out space, increase the continuity of ecological network system. It’s necessary to establish the analysis from three aspects, centered on the node design, supplemented by district planning and district design, which is good for reconstructing the urban space and motivating the vigor of river area. Due to the limitation of cross-discipline, the research on ecological connectivity and spatial continuity in this article is not deep enough. The sustainability of landscape and its potential connection is the direction that can be studied in depth in the future.

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