Research on Urban entity boundary and virtual boundary based on GIS——Taking Dujiangyan City as an example

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Abstract. This paper uses the Point of Information (POI) point of interest and population distribution feature data in Dujiangyan City as the basic data, and uses spatial analysis methods, such as nuclear density analysis, contour analysis and standard deviation ellipse, to study the correlation between the entity and virtual boundaries of Dujiangyan. The results show that the urban entity and online activity intensity of Dujiangyan spreads around Xingfu, Guankou, and Puyang. The entity boundaries of the city and the virtual boundary in these three areas overlap basically, except for the city of Dujiangyan. The entity and online activities are not balanced in intensity, and there are obvious dividing lines in the area near Longchi. The entity and virtual boundaries of the city are quite different in Qingcheng Mountain and Juyuan.

1. Introduction
In the field of urban planning, the city is mainly divided into functional areas and the city’s regional boundaries by the city’s administration, transportation, economy, architecture, etc., but the most obvious regional boundary of a city is the administrative boundary, which is defined by the administrative functions of each region. However, the boundaries of administrative regions often can’t reflect the level of development and construction of the city’s regional buildings and the activity status of residents. The above four methods of defining urban boundaries have certain defects and can’t accurately reflect the correlations between human activities and geographic space. In order to better reflect the temporal and spatial relevance of people and regions, the geographic spatial location information in big data is used to study the entity and virtual boundaries of the city from the perspective of the temporal and spatial characteristics of the intensity of residents’ activities and the distribution of interest points in the research area [1]. The research results of this article are a supplement to the delineation of urban boundaries and provide a reasonable reference for the scientific development of cities.

2. Data sources
The basic data required for this research is mainly the Easygo travel heat map data and the POI data on Baidu map. The POI data need to be obtained through the corresponding code written in Java and Python on the open public platform interface of the corresponding websites [2]. Refer to five major systems of human settlements proposed by Wu Liangyong [3] (natural system, human system, social system, residential system, support system), combined with the actual conditions of Dujiangyan city, ten POI points of interests are selected, such as food, life services, tourist attractions, leisure and
entertainment, medical education, cultural media, transportation facilities, real estate, companies, enterprises, and government agencies in 2019, to extract the point data attributes of the three fields of name, longitude and latitude [4].

3. Research methods

3.1. Nuclear density analysis
The nuclear density analysis method is one of the main technical paths to analyze the density of point data or line data. It is a processing operation of non-parametric estimation density analysis method, which uses the regular area around any points in space as the spatial range of calculation density to analyze the spatial distribution situation of the point or line feature data in the area.

3.2. Contour analysis
According to the nuclear density analysis, the POI data distribution map and the population flow distribution map are obtained. The two types of distribution maps are used to extract the corresponding contours with GIS analysis tools, and the distance between the contours and the center point is used to determine the urban entity range and network activity intensity of Dujiangyan.

3.3. Standard deviation ellipse calculation
Use the standard deviation ellipse to judge the spatial distribution of the population in the studied area. It can present the central trend, dispersion and direction of geographic elements to better understand the densely populated areas of the studied area and reflect its population development trends and infrastructure construction to a certain extent.

![Figure 1. Standard deviation ellipse calculation.](image)

The standard deviation ellipse form is:

\[
SDE_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}}
\]

\[(1)\]

\[
SDE_y = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n}}
\]

\[(2)\]

Where \(x_i\) and \(y_i\) are the average center of element \(i\), and \(n\) is the total number of elements, the calculation method of the standard deviation ellipse rotation angle:

\[
tan \theta = \frac{A + B}{C}
\]

\[(3)\]

\[
A = (\sum x_i^2 - \sum y_i^2)
\]

\[
B = (\sum x_i y_i - \sum x_i \bar{y}_i)
\]

\[
C = \sqrt{(\sum x_i^2 - n \bar{x}^2)(\sum y_i^2 - n \bar{y}^2)}
\]
\[
B = \sqrt{\sum_{t} x_t^2 - \sum_{t} y_t^2 + 4\sum_{t} x_t y_t}^2 \\
C = \sum_{t} x_t y_t
\]

Where \( \bar{x} \) and \( \bar{y} \) represent the average center of the elements, and \( n \) is the total number of elements.

3.4. Determination of urban boundary

3.4.1. Determination of urban entity boundary. Use nuclear density analysis and contour analysis to obtain the contour of a certain type of POI point, and use GIS to fit the contour of this type to obtain the city boundary of this type of POI point, then perform spatial analysis of 10 types of city boundaries superimpose and determine the preliminary urban entity boundary combined with the urban entity geographic scope of Dujiangyan city. The obtained preliminary urban entity boundary and linear urban elements, such as buses, subways, highways, and pipelines, are superposed again to get the urban entity boundary [5].

3.4.2. Determination of urban virtual boundary. The Easygo travel heat map data reflect the population distribution characteristics of Dujiangyan city. The standard deviation ellipse calculation and contour analysis of the heat map data at different periods are used to obtain the virtual city boundary of Dujiangyan at different periods. The space overlay analysis is performed to achieve the virtual city boundary of Dujiangyan city.

4. Results and analysis

4.1. Distribution characteristics of urban entities in Dujiangyan City

![Figure 2. Lifeservice](image)
![Figure 3. Real estate map.](image)
![Figure 4. Administrative organ map.](image)
![Figure 5. Scenic spot map.](image)

By analyzing the geographical distribution characteristics of the entity, it can be found that the urban entity activity area of Dujiangyan is mainly centered on the original old city area, which is close to the new central city area. Most areas of Dujiangyan city belong to rural areas, while these areas, such as Longchi, Daguan, and Chongyi, have relatively simple urban functions and do not undertake more urban functions. Due to the influence of these factors, the urban entity activities in these areas are also relatively weak, and urban construction is relatively poor.
4.2. Population distribution characteristics of Dujiangyan City

By analyzing the population density maps at four different moments, it can be concluded that the population distribution has not been changed so much over time and has the trends to be stable. The population gathering is mainly centered in the towns of Guankou, Xingfu and Puyang with better urban construction and relatively better infrastructure. Two sub-centers of population gathering are formed in Juyuan Town and Qingchengshan Town. The reason why Qingchengshan Town has formed a population gathering center is mainly because there are two scenic spots (Jiezi Ancient Town and Qingcheng Mountain) in this area. The development of cultural tourism industry is bound to bring a stable people flow to the local area. Juyuan Town is a key experimental town for the construction of small market towns in the province. Chengguan Expressway, 213 National Road, Guanwen Road and Tianfu Avenue pass through this town, and there are more characteristic agricultural economic parks within the town, which can attract more people flow to the town.

4.3. Spatial distribution of urban entity boundary and virtual boundary

Comparing the entity and virtual boundary of the city, it can be seen that the two boundaries are roughly the same in scope, and a large part of the boundary overlaps, but there are more obvious dividing lines in Longchi, Qingcheng Mountain and Juyuan areas. The specific analysis is as follows: Dujiangyan city takes Guankou and Xingfu as the center and expands to Puyang and Zhongxing. Guankou and Xingfu are the central urban areas of Dujiangyan. The economic construction, infrastructure and network facilities in this area are relatively perfect. Therefore, both two areas have strong network activity intensity and physical activity. Through field research, it can be found that places with dense populations and prominent urban physical activities are often economic and commercial centers, scenic spots, universities, and transportation hubs.

The distribution of the road network is closely related to the development of the city. By comparing the urban road networks, it is found that the entity and the virtual boundary of the city are consistent with the two main road network axes, namely, Puyang Main Road-Rainbow Avenue-213 National Road-Qingchengshan Avenue axis and Yingbin Avenue-Rongchang Expressway axis. Other roads extend along the two axes respectively, and two axes cover the area with abundant traffic routes,
which brings great convenience to traffic and attracts many people to gather into this area. Due to the underdeveloped road network system in Longchi and Liujie areas, the entity and virtual boundaries of the city are rarely covered.

5. Conclusion
This study compares 10 types of POI points of interest data and population heat map data in Dujiangyan city, also uses spatial analysis methods (nuclear density, contours and standard deviation ellipses) and GIS spatial analysis tools to complete the comparative analysis of entity and virtual boundary of Dujiangyan. Combined with the road networks and field investigation analysis, more accurate verification results are obtained, which can provid a certain decision basis for urban planning and development.

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