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Quantifying the spatiality of urban leisure venues in Wuhan, Central China – GIS-based spatial pattern metrics

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ABSTRACT

Due to the rapid socio-economic development, citizens are approaching a leisure era during which they are pursuing more psychological needs towards lifting the quality of life. Leisure venues act as the spatial carriers of leisure activities. The spatiality of leisure venues is closely linked with both cities' intelligent growth and citizens' life quality. We highlight the need for quantifying the leisure spatial configuration to guide citizens' healthy leisure lifestyle, to optimize urban planning and to promote people-centered urbanization transition. This article aims to quantitatively characterize the spatiality of leisure venues via a series of geospatial techniques for leisure spatial pattern metrics. The Metropolitan Development Zone (MDZ) of Wuhan City is selected as the study site. Research findings are concluded that: 1) A three-level urban polycentric structure is identified. 2) The gradient variation of leisure venues is found. That is, leisure venue gradient density decreases with the distance from urban centers increasing. 3) The gradient effects of the four sub-types of leisure venues (i.e., tourist, cultural, sportive and recreational sites) are all highly fitted to the power function. 4) A significant correlation exists between the leisure spatiality and the demographic distribution. The research facilitates political strategies-making of sustainable urban spatial development.

1. Introduction

Leisure is one of four urban basic functions (besides dwelling, work and transportation) according to Charter of Athens (1933) (Le et al., 1973; Gold, 1998). Owing to the rapid socio-economic progress, we are approaching a leisure era during which people's psychological needs are constantly increasing, and people's life styles are shifting to better quality of life (Veal, 2012; Goodale & Ellis, 1985; Molitor, 2000; Molitor, 2008; Yang & Kim, 2016). Leisure essentially serves as the linkage for human-environment interaction and is a people-centered issue (Liu et al., 2017). The leisure industry is important for citizens' happiness and well-being (Isoaholo & Weissinger, 1984; Yang et al., 2012), improving residents' quality of life (Yang & Kim, 2016), raising urban interaction and cohesion (Peters, 2010), triggering urban vitality (Ravenscroft, 2000) and enhancing social justice and equity via promoting positive social changes (García, 2013; Floyd & Stewart, 2014; Morpeth, 2014).

Characterizing the spatial characters facilitates better understanding urban form (Liu et al., 2016). Detecting spatial regularities assists in solving certain real social problems (e.g., social justice, urban segregation, public health etc.) (Jerrett et al., 2010; Kwan et al., 2015), given the leisure spatiality. Leisure venues act as the spatial carriers of leisure activities, possessing multiple spatial characters (incl. the spatial pattern) (Li et al., 2015; Wang, 2015), spatial accessibility (Devine & Mobily, 2017; Hansen, 2017), spatial optimization (Son & Janke, 2015) and so forth. Intelligent spatial planning of leisure sites is believed to greatly boost urban competitiveness, urban vitality (Chen et al., 2014) and social justice (Henderson & Stewart, 2014; Stewart, 2014). Hence, it is highly desirable to address the leisure spatial features and further explore the formative mechanism of urban fabrics.

The boom of leisure industry is promising to reveal social issues (e.g., public health and social justice). In terms of public health, the inequality of leisure distribution may lead to health inequality. Evidence-based science on park access and human health is increasing. Specifically, the ratio of obese children tends to be lower in communities providing more areas of parks and other recreational amenities (García, 2013). It is inferred that inferior access to certain type of leisure sites could reduce physical activities and then result in children's obesity and further health inequality. Additionally, the perspective of social justice is becoming a common framework for various leisure

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issues (Morpeth, 2014). In the domain of leisure amenities' spatiality, the research focus shifts from simply depicting their spatial disparities to further elaborating practical issues (e.g., social justice) (Floyd & Stewart, 2014). The research domain of leisure has underscored the essentiality of social change for improving livelihood and reducing barriers to leisure opportunities (Henderson & Stewart, 2014; Stewart, 2014). Leisure justice is a basis for social action and that we must "move toward ascertaining how leisure can be a force for positive social change" (Wei, Qu, & Ma, 2016). The aforementioned publications indicate that the rational distribution and development of leisure venues could facilitate environmental, social and health justice.

Accordingly the challenge is how we address the leisure spatiality to remedy social problems (Fang & Wang, 2015; Jiao, 2015). Research on the spatiality of multiple kinds of leisure venues from the perspective of geospatial analysis start to emerge (Liu et al., 2017), involving parks (Sugimoto, 2013), gardens (Bechet et al., 2017), museums (Choi, 1991), karaoke (Cui et al., 2016), cinemas (Chen, 2009; Fan et al., 2015), and so forth. Quantitatively characterizing the spatiality of leisure venues could provide more scientific reference for further monitoring, assessing and predicting. Despite the abovementioned studies concerning spatial analysis, quantifying the leisure sites' spatial pattern is still insufficient. The density analysis or pattern metrics is the core of deep understanding urban system (Jiao, 2015), involving the spatiality of all these venues. To better demonstrate the spatial pattern, gradient analysis is a widely-used tool for quantifying spatial pattern in urban studies (Dai et al., 2017; Freitas et al., 2010; Sun et al., 2014; Wang et al., 2014). This gradient analysis integrating GIS-techniques (kernel density analysis), the curve fitting analysis and the correlation analysis are likewise adopted in this study.

This research has threefold contributions: 1) Theoretically, the spatial regularity of urban leisure venues' gradient variations is identified, as well as its significant correlation with demographic distribution; 2) Methodologically, a GIS-based integrated gradient analysis method is constructed, that can be generalizable to other regions or geographical phenomena; 3) Practically, case studies are enriched in the Metropolitan Development Zone (MDZ) of Wuhan, Central China.

2. Case study and data sources

2.1. Case study

Wuhan is the capital of Hubei Province (Central China), consisting of 13 administrative districts and covering a total area of 8494 km^2 with the population of approximate 10.02 million (the largest population of permanent inhabitants among cities in central China). Wuhan plays a strategically important role due to its geographical location. This city locates at the intersection of the middle reaches of the Yangtze River (the length of which ranks the 3rd globally) and the Han River (the largest branch of the Yangtze River) in the northeast of the Jianghan Plain along the Yangtze River Economic Zone (113°41′–115°05′E and 29°58′–31°22′N).

The central urban areas of Wuhan consist of three townships containing 7 administrative districts. They are: 1) Great Hankou Township, covering Jianghan district, Jiang'an district and Qiaokou district; 2) Great Wuchang Township, covering Hongshan district, Wuchang district and Qingshan district; 3) Great Hanyang Township, covering merely Hanyang district. Wuhan is abundant in water resources, with one quarter of the city area took up by waterbody. Wuhan is named "the City of Hundreds of Lakes", with 900,000 stere of water resources per capita (ranking the 1st in the world) (Tu & Liu, 2010). Moreover, Wuhan functions as the internationally-acclaimed transport hub due to its advanced and diversified transport modes - aviation flight, high-speed railway, normal-speed railway, roads, public transport (metro, bus, bicycles etc.) and waterway.

According to Wuhan Master Plan (2010–2020): The Metropolitan Development Zone (MDZ) of Wuhan is demarcated by the administrative boundaries of the counties along the fourth road loop, with a total area of 3261 km^2. It is planned to possess 802 km^2 construction land and 8.8 millions' population (i.e., 91.1 m^2 construction land per capita) in 2020. The MDZ covers the urban center downtown (within the third road loop). MDZ is defined as the key urban spatial development zone or the centralized urbanization development zone with the main agglomeration urban functions.

2.2. Data sources

This study involves four categories of data sources: 1) district boundaries of the study site, the four road loops and the geographical features (e.g., the Yangtze River, the Han River, the lakes etc.) are from the First National General Survey of Geographical Conditions (2013–2015); 2) POIs of the entire Wuhan city with the number of around 510,000 amenities from Baidu Map (similar to Google Map) in 2017. Tag 1 (one field of the data attribute table) includes 20 general categories - beauty, car service, company, education, entertainment, exercise, finance, food, government, hotel, life service, media, medical care, nature, real estate, scenic spot, shopping, wedding, traffic facilities and 'other' type; 3) leisure POIs are specifically extracted according (Liu et al., 2017); 4) Demographic data at community scale (population distribution in each residential unit): obtained from the Land Management and Planning Department of Wuhan.

2.2.1. The taxonomy of leisure venues

According to China's Classification and Requirements of Cities' Public Leisure Space (GB/T31171-2014), issued in 3th September 2014, leisure space has been divided into two categories: 1) leisure venues with only one specific function (e.g., gyms, cultural palace, recreational trails etc.); 2) leisure complex (e.g., parks, residential communities' leisure centers, etc.). This taxonomy covers all types of leisure venues based on the diversity of leisure sites' leisure function, yet the detailed taxonomy is necessary for further academic researches. In Australia Cultural and Leisure Classifications (ACLC), leisure sites are divided into four categories. They are: 1) Heritage type (i.e., museums, natural heritage sites, etc.); 2) Arts type (i.e., libraries, theatres, museums, etc.); 3) Sportive type (fitness centers, stadiums, etc.); 4) Others (i.e., open camping area.). This taxonomy provides a reference for detailed leisure taxonomy. Yet, leisure sites are not uniformly classified.

This study takes ACLC for reference, and selects the tags of scenic spot (e.g., museums, zoos, churches etc.), food (e.g., restaurant, tea houses, cafes etc.), entertainment (cinemas, theatres, cultural palace etc.) and exercises (e.g., gyms, stadiums etc.) among Tag 1 of the Baidu POIs. Then 82,120 leisure sites are selected after removing the duplicated within the MDZ of Wuhan, Central China. On this basis, these sites are reclassified into cultural, sportive, and recreational and tourist sub-types (shown in Table 1).

3. Methods

This study applies a GIS-based gradient analysis integrating kernel density estimation, curve-fitting analysis and correlation analysis, demonstrated as below:

3.1. Spatial interpolation - kernel density estimation (KDE)

Spatial interpolation estimates the values of un-sampled zones in the study site (Lam, 2009). KDE is one universally harnessed technique of interpolating values via evaluating a random variable's probability density (Deveaux, 2004).Kernel density estimation (KDE) is capitalized on to show a smooth and continuous surface of probability density via normally a Gaussian kernel (i.e., a weighted distance function to measure Euclidean distances) (Bailey & Gatrell, 1995; Levine, 2002; Parzen, 1962; Rosenblatt, 1956; Silverman, 1986). KDE typically visualizes the clusters of certain events. Peak values mean clusters or hot