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Using a Data Mining Method to Explore Strategies for Improving the Social Interaction Environment Quality of Urban Neighborhood Open Spaces

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Abstract: With the intensification of population aging and the increasing awareness of public health protection in the post-epidemic era, the renewal of the old urban community neighborhood space is facing many new challenges and problems. Neighborhood Public Open Space (POS) is the main place for people to carry out various social activities in community life. The quality of the social interaction environment that a neighborhood POS can provide can have a vital impact on people's well-being, as well as their physical and mental health. Therefore, the purpose of this research is to identify and clarify the key physical environmental design attributes/features of the old urban community neighborhood POS, and to explore the relationship between them from the perspective of creating a high-quality social environment. Through the investigation of relevant cases in Shenzhen and Guangzhou, China, the classification performance of each case on the key physical and environmental elements is used as the conditional attribute, and the quality of the social interaction environment in the current situation of each case is used as the decision making attribute to conduct a data mining analysis. Using rough set theory, this study screened out four important elements: greenbelt form planning (C_1); ped and bike system (C_2); space organization and zoning planning (C_6); Public facilities (C_8). Moreover, this study also presents a set of hierarchical decision rules to describe the classification status of the matching physical environmental design elements when the social interaction environment reaches a high quality in the neighborhood POS. This study provides local policy makers with key current situation assessment and diagnostic tools in urban-built environmental renewal projects. The results of this study can help designers draw up the renovation design plans of neighborhood POS on the basis of efficiently obtaining the practical experience of relevant cases, and then create a high-quality social interaction environment.

Keywords: urban neighborhood open spaces; data mining method; physical environment design elements; rough set theory

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1. Introduction

With the improvement of construction technology, population growth and urban congestion, high-density compact urban forms and mixed development strategies are getting more and more support and promotion in many areas. Scholars argue that this is a more sustainable housing solution than urban sprawl [1]. As one of the main local features of the high-density development strategy, the public open space is the most closely related space component of the building and the city. It plays an important role in creating a good place for public activities and cultural exchanges in the city, and for promoting the formation of a harmonious, beautiful, and energetic urban atmosphere [2,3]. In recent years, more and more studies have shown that the quality and environmental characteristics of open spaces or public green spaces in urban neighborhoods has an important impact on people's health, happiness, and the establishment of a sense of place [4]. Neighborhood

open spaces in urban communities provide opportunities for people to engage with and share the natural landscape, which can have positive effects on the intra- and interpersonal levels [5]. Zhu et al. [6] found that the social environment that urban public open spaces can provide is the most important factor in promoting the health and well-being of the elderly in their later years. In a study that looked at using and maximizing green spaces and the benefits to be obtained from them, van Dinter et al. [7] found that the aesthetic quality of facilities in urban green open spaces and the reduction of distractions can have a positive impact on the use of open space and the establishment of a sense of place, which in turn can have a positive impact on people's life satisfaction.

It is undeniable that since the outbreak of the epidemic at the end of 2019, COVID-19 has changed the way people live and work to varying degrees, and it has also brought new challenges to the planning and designing of urban spaces. After a special epidemic prevention period, the potential of the social environment provided by urban POS in supporting positive emotions and mental health has been widely recognized [8]. Luo et al. [9] pointed out that the current strong motivations for people to visit urban public green spaces can be grouped into four themes: "healthy places", "escape", "social support", and "safety in outdoor activities". It is not difficult to speculate that before and after the epidemic, the social suitability of neighborhood POS scattered throughout cities will also undergo significant changes [10]. In reality, a large number of neighborhood POS with different characteristics need to be improved urgently. They follow the old planning and design guidelines, which has seriously affected the usability of a large number of POS and the social and environmental benefits thereof. In particular, China, after rapid urbanization, has now entered the era of stock planning. Many large- and medium-sized cities have a large number of old blocks/neighborhoods, neighborhoods, and villages. These old communities often live with local residents who are more dependent on the social environment of neighborhood POS and have higher demands. Therefore, we urgently need to re-evaluate and examine the neighborhood POS in these urban communities, investigate those POS that can still meet people's social interaction needs in the post-pandemic era, and further identify their physical environment's attributes/characteristics. It is worth emphasizing that the creation of a POS social environment must be realized under the synergistic effect of multiple associated material environment attributes/characteristics. However, previous studies often only focus on the influence of a certain type of environmental attribute/characteristic in urban public green spaces, namely those which promote people's safety and high-quality social interaction behaviors [11]. The supporting combination relationship among the influencing factors in Neighborhood POS and the new rules and knowledge composed of various attribute conditions have not been clarified yet.

To sum up, the purpose of this research is to identify and clarify the key physical environmental design attributes/features in the old urban community neighborhood POS from the perspective of creating a high-quality social environment, and to discover the supporting combination relationship between them. After nearly 30 years of development, the use of "data mining" in urban spatial analysis has been very diverse. The concept can be understood as the examination of large data sets for the purpose of knowledge discovery [12]. Knowledge discovery is the discovery of new patterns in data, i.e., hitherto unknown forms of knowledge of this kind. Therefore, this study applies data mining technology (rough set theory), takes the environmental attributes/characteristics of POS in urban community neighborhoods as conditional attributes, and takes the social environment quality exhibited by POS in the status quo as decision attributes. Furthermore, through data mining and an analysis of a large number of related cases, the core physical environmental design attributes are identified and clarified, and the knowledge of relevant decision rules (i.e., If...Then...) is clarified.

2. The Influence of the Physical Environment on the Urban POS Social Environment

The performance of urban public space has long been considered a reliable tool for assessing the success of urban development in terms of civic recreation and cultural build-

ing [13]. Among its main benefits is the ability to enhance social interactions and enhancing people's sense of community and safety [14]. Neighborhood POS planning affects the quality and accessibility of urban public space, plays an important role in social cohesion and social network relations, and continues to affect people's health in the future [15]. Hao [16] found that part of the greening, public leisure and entertainment space, and communication behavior variables are positively correlated with neighborhood relations. In addition, some landscape design elements such as monuments, stairs, fountains, etc. are effective ways to develop an urban POS environment for social interaction [17]. Rasidi et al. [18] has found that vegetation density, animal populations, relief landforms, water bodies, and the diversity of subspaces in urban POS are the main factors affecting the environment of social interaction. Peters et al. [19] has pointed out that the presence of activities and amenities in neighborhood POS is an important factor triggering a wide range of social interaction behaviors. Based on the review of previous studies, Yung et al. [20] constructed a framework consisting of 27 environmental design criteria to meet the social interaction needs of the elderly in neighborhood POS, including 8 criteria in the category of physical environment. These guidelines relate to a clean and pleasant environment, proximity to nature, public service facilities, site connectivity, adequate lighting, imagery relevant to the local culture, safety, and routine maintenance, among others. This study summarizes the following eight elements of the physical environment in the POS of urban neighborhoods and collects and analyzes related cases based on these as conditional attributes (as shown in Table 1).

Table 1. Design elements of neighborhood POS physical environment (social aspects).

Design Elements	Description	Citations
Greenbelt form planning (C_1)	Organizational form and morphological characteristics of green space in urban public open space.	[18,20]
Ped and bike system (C_2)	Infrastructure, paths and grounds to support walking, jogging, and biking.	[21]
Waters-cape (C_3)	Area, shape, and positional relationship of the water body in the place.	[6,22]
Arbor shrub configuration (C_4)	Size, type, and collocation of trees and flowers	[20]
Interior to exterior linkages (C_5)	Connectivity and inter-linkages: layering and sequence from private zone to community gathering zone and neighborhood	[20]
Space organization and zoning planning (C_6)	Organizational distribution of subspaces or partitions	[23]
Relationship with urban neighborhood (C_7)	Spatial location relationship with neighboring neighborhoods	[24]
Public facilities (C_8)	Seating area for rest, communal spaces, special seating, talking spaces	[19]

3. Methodology and Data Collection

This study applies rough set theory from the field of operations research to explore the existing case data of urban built environments. Rough set theory is a mathematical tool proposed by Professor Pawlak in 1982 that can quantitatively analyze and deal with inaccurate, inconsistent, and incomplete information and knowledge [25]. The original prototype of rough set theory comes from a relatively simple information model. Its basic idea is to form concepts and rules through classification and induction of relational databases, and to realize knowledge discovery through the classification of equivalence relations and the approximation of classification to the target. The data analysis steps of rough set theory are shown in Figure 1.

In the past few decades, under the high-density development policy in many large cities in the southeast coastal area of China, the quantity and quality of urban public open spaces have been significantly improved. These spaces have an important and ongoing impact on the daily life, health, and well-being of city dwellers. In the two core cities (Shenzhen and Guangzhou) of the Guangdong–Hong Kong–Macao Greater Bay Area in China, we conducted a long-term observation and investigation of the current situation of the neighborhood open spaces in the old urban areas. On the one hand, according to the 8 environmental design elements summarized in Table 1, we classified and logged the

investigated neighborhood POS cases. In brief, we documented the classification status of each case on different environmental design elements. On the other hand, based on the long-term observation and recording of each case, we evaluated the quality of the social interaction environment in each case according to certain indicators, such as the number of people gathering for social interaction activities in the place, as well as duration and activity diversity. The questionnaire is shown in Table 2. After nearly 10 months of investigation, we visited 55 neighborhood POS in old urban areas, out of which 30 were in Shenzhen and 25 in Guangzhou.

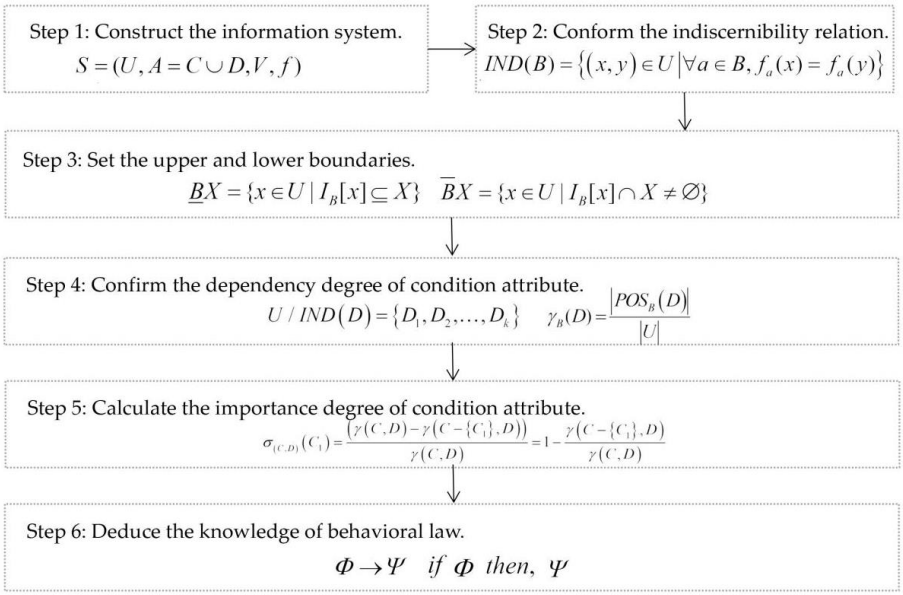

Figure 1. Computational steps for data mining.

Table 2. Conditional and decision attributes and semantic scale.

	Conditional Attributes (C)	**Decision Attributes (D)**
No.	**Semantic Scale**	**Likert Scale (5 Point)**
C_1	1. Fragmentation and scattered layout; 2. Large area, concentrated and complete arrangement; 3. Arranged in columns, arranged according to the path.	1: Extremely low-quality social interaction environment; 2: Low quality social interaction environment 3: Average quality social interaction environment; 4: Higher quality social interaction environment; 5: Excellent quality social interaction environment.
C_2	1. Fully equipped (exercise bike, spinning bike, etc.); 2. Greenway coverage for running (without supporting equipment); 3. No supporting facilities, no greenways.	
C_3	1. With large lakes and rivers; 2. Small lakes, fragmented bodies of water; 3. Anhydrous.	
C_4	1. Complete variety, including shrubs, flowers and large trees; 2. Fewer types of grass, small trees.	
C_5	1. Multiple forms of transportation paths (public transportation vehicles, bicycles, pedestrians) and the paths radiate to connect the community; 2. The path can only pass through (pedestrians, bicycles) and has a single path.	
C_6	1. Wrap-around space; 2. The open space; 3. Irregular spaces.	
C_7	1. Centralized layout in the center of the community; 2. Fragmented, inlaid in the neighborhoods of the community, distributed in a node-like manner.	
C_8	1. Complete facilities, benches, garbage cans, drinking pool; 2. Lack of facilities (fewer benches, no drinking pools); 3. The facilities are poor (most of them are unusable or damaged).	

4. Results and Discussion

Through the investigation of 55 POS cases in the neighborhoods of old urban areas in Shenzhen and Guangzhou, this study used Table 2 to log the data of condition attributes and decision attributes and made a classification description and evaluation of the current social interaction environment quality for each case. A summary of the results is shown in Table 3. In the current situation, the social interaction environment quality of these cases is relatively evenly distributed from extremely poor to excellent, and their classification status in terms of condition attributes also shows obvious differences.

Table 3. Results of data collection/summary.

Case No.	Conditional Attributes								Decision Attributes
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	
SZ01	3	2	2	2	2	2	2	1	3
SZ02	1	3	2	2	1	1	2	1	3
SZ03	3	1	3	2	1	1	2	1	3
SZ04	2	2	3	1	2	1	2	1	1
SZ05	3	1	1	2	1	2	1	1	3
SZ06	1	3	3	2	2	3	2	3	3
SZ07	1	2	3	2	2	2	2	1	1
...									
GZ01	3	2	3	1	1	1	2	2	3
GZ02	1	3	3	2	2	3	2	3	3
GZ03	1	2	3	2	1	3	2	1	3
GZ04	2	1	1	1	2	2	1	1	2
GZ05	1	3	3	1	2	3	1	2	3
GZ06	2	2	3	1	2	1	1	2	2
GZ07	3	2	3	1	1	1	2	2	3
...									

We applied the Rose.2 software to sequentially analyze the knowledge of hierarchical patterns between the design elements of neighborhood POS physical environments and the quality of social interactions. It was found that the classification quality of these data reached 0.700 (shown in Table 4). The results show that the classification boundary of the global decision has a high quality of approximation. In terms of approximation accuracy, the approximation boundary for each class of the three datasets is blurred, i.e., there is ambiguity and roughness. Furthermore, through data analysis, we screened out the four elements with the highest importance among the nine elements of the physical environment of the urban public (POS) listed in Table 2 (referred to in this study as the core condition attribute). The four elements are: greenbelt form planning (C_1); ped and bike system (C_2); space organization and zoning planning (C_6); Public facilities (C_8) (as shown in Table 4).

Table 4. Quality of classification and Extract core attributes.

Decision Attributes (D)	Core Attributes	Quality of Classification
Epidemic Prevention and Control Level	C_1, C_2, C_6, C_8	0.700

The data analysis results show that after three years of COVID-19, people's choices and preferences for social communication activities in urban neighborhood POS are mainly influenced by the shape and planning of green spaces in the site, the characteristics of slow traffic systems, the division of subspaces, and the configuration of basic service facilities. The extraction of core attributes confirms to a certain extent the speculation regarding which POS environmental elements affected the quality of social communication environments before the outbreak of the new crown epidemic [18]. During the lockdown caused by

the new crown pneumonia epidemic, urban public green spaces were one of the few places where people could still gather. We believe that new approaches to urban planning should incorporate holistic planning approaches for grey, green, and blue infrastructure, promoting public health improvements, and climate adaptation and mitigation strategies. Additionally, larger open spaces in urban systems can be used to assist emergency services and evacuation missions. Larcher et al. [26] pointed out that after the impact of the epidemic, people's interest in urban green spaces had strengthened, and green spaces and vegetation played a more important role in the well-being of citizens. This study argues that in the post-epidemic era, planning designers should increase and utilize the natural elements (such as lawns, hedges, flower beds, and trees) in neighborhood POS to provide resilience to maintain the well-being of the urban population. At the same time, it is also necessary to achieve an appropriate social interaction distance that is conducive to emergency epidemic prevention and evacuation through subspace division and path planning.

In this study, we evaluated the social interaction environment quality of neighborhood POS under the restrictions of epidemic prevention from "Good class" (D = 1) to "Poor class" (D = 5). In order to better promote the improvement of the social quality of urban neighborhoods in the post-pandemic era, this study only compared and discussed the "good class (D = 1)" and "bad class (D = 5)". As can be seen in Table 5, in the case of meeting the requirements of the conditional attributes, the first and second rules have a certain probability that the place will have a higher level of social interaction environment quality. The third and fourth rules have a certain probability that the social interaction environment quality in the place will be at a lower level.

Table 5. Minimal covering rules with strength exceeding 10% in Decision = 3.

Rule No.	Conditions	Decision	Number of Objects
1	$(C_2 = 2)$, $(C_3 = 3)$, $(C_5 = 2)$	Good class (D = 1)	80%
2	$(C_7 = 2)$, $(C_8 = 1)$	Good class (D = 1)	40%
3	$(C_5 = 2)$, $(C_6 = 1)$, $(C_8 = 2)$	Poor class (D = 5)	28%
4	$(C_8 = 3)$	Poor class (D = 5)	71%

The results of our data analysis show that when people conduct social interaction activities at outdoor POS, they try to avoid being in relatively private and closed subspaces for a long time and dislike them in places with single paths and insufficient supporting facilities. The previous POS planning and design methods are no longer reasonable under the current demand. Many urban furniture are mechanically and evenly distributed on people's activities. At present, people realize the risks they face when using these urban furniture, consequently, there are a large number of recreational facilities, seats, and other urban furniture that are left idle and abandoned. Therefore, we suggest that the future urban neighborhood POS needs a refined and targeted design, rather than solidifying standards and following unit patterns to create a social interaction environment. For reference, Spennemann [27] proposed a feasible design plan: designers can use the change of soft and hard materials on the ground to distinguish sub-spaces that maintain social distance. This depends on people's voluntary compliance, and the visual patterns and characters are only indicative.

In addition, the analysis results suggest that we need to consider the organization and connectivity of various slow-moving paths in the neighborhood POS. The visual identification system in the neighborhood POS is particularly important. It should not only play a role in public health science popularization, but also assist people in the passage of traffic and avoid crowding. Surface lane markings, whether by paint or physical means (miniature green bars), may need to be considered, as well as the creation of a dedicated run/bike lane to make slower pedestrian traffic feel safe, according to rule 1 in Table 5. We found that when there is no waterscape in the neighborhood POS; hence, designers should adhere to the planning method of "greenway", pay attention to the creation of local

ecological environments, and use tall trees and shrubs to create a comfortable walking and cycling environments. This could also maintain a high-quality social interaction environment. In conjunction with rule 2, this study recommends that local policymakers focus on neighborhood POS embedded in aging urban communities. These spaces may be small in scale, but they are often highly permeable to the surrounding environment. It is necessary to enhance the visual permeability of these pocket parks and improve their infrastructure and related urban furniture on the basis of public health and safety.

On the other hand, through the investigation of a large number of cases, it can be seen that the population of elderly people in high-density urban and old areas is relatively dense, and they often need to be guardians for children. Therefore, the influence of neighborhood POS within the scope of their residential area on their well-being in later life is more important. In addition to the above-mentioned rules, the communication with elderly residents in the field survey shows that a safe, comfortable, and accessible environment is the main requirement of elderly residents. The specific requirements include avoiding fast-moving motor vehicles and non-motor vehicles, being leeward, having sufficient sunshine and shade, and being close to their place of residence. This study suggests that the planning of neighborhood POS in elderly residential areas should focus on the safety and recognizability of the environment, enhance environmental assistance, encourage the elderly to rely on themselves to carry out activities, reduce manual care, and enhance self-confidence. This study recommends that planners focus on creating a sense of belonging and a positive atmosphere and encourage older people to engage in social and physical activities and participate in public affairs. Through the active design, the elderly can observe crowd activities more conveniently and relax with beautiful scenery.

5. Conclusions

This study develops a conceptual framework to summarize the relevant physical environmental design elements that influence the social interaction environment of urban neighborhood POS. The framework is composed of eight elements of physical environmental design. After a case collection and investigation in the old urban areas of Shenzhen and Guangzhou, China, we conducted data exploration based on rough set theory. We discovered four core conditional attributes and constructed a set of hierarchical decision rules to describe the classification status of the matching physical environmental design elements when the social interaction environment reaches a high quality in the neighborhood POS. This study provides new knowledge for the design of urban open spaces in the post-epidemic era. From the perspective of creating a public social communication environment, this knowledge clarifies the combination relationship and classification status of different physical environmental design elements. The results of this study provide key references for local governments and planners in project decision making. Moreover, landscape architects can follow the recommendations of this study and the clear rules outlined to formulate specific design strategies in design practice.

A limitation of this study was that all the empirical cases were distributed in the Shenzhen and Guangzhou area, resulting in less diverse data. In future, more extensive environmental data on the current status of urban public green spaces in China should be collected and then analyzed to classify and evaluate a large number of real-world cases. The efficiency of case data collection should also be improved. This study evaluated the quality of the social interaction environment based on three observation points: the number of people conducting social interaction activities in the neighborhood POS, the activity duration, and the diversity of social interaction behaviors recorded throughout the observation. In future, empirical research can be conducted using this study to evaluate the quality of the social interaction environment for neighborhood POS cases and formulate specific improvement strategies. Using this study, factor analyses can be conducted to further clarify the specific design indicators included in each core condition attribute, and hence quantitatively evaluate a large number of POS cases in urban neighborhoods to determine their ability to create social communication environments.

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