Proceedings of the Ninth International Space Syntax Symposium
Edited by Y O Kim, H T Park and K W Seo, Seoul: Sejong University, 2013

APPLICATION OF SPACE SYNTAX THEORY IN STUDY OF URBAN PARKS AND WALKING

032

Yujia Zhai
North Carolina State University
e-mail: yujia.zhai85@gmail.com

Perver Baran
North Carolina State University
e-mail: kperver@ncsu.ed

Abstract

Urban parks are important open spaces that encourage people's physical activity (McCormack, Rock, Toohey, & Hignell, 2010), and social interaction (Matsuoka & Kaplan, 2008). They can bring tremendous physical and psychological health benefits to users (Bedimo-Rung, Mowen, & Cohen, 2005). People experience park environment through walking, which is the most popular leisure-time physical activity among US adults (DHHS, 1996). Theory of experiential landscape (Thwaites & Simkins, 2007) proposes that human experience has spatial dimensions, and certain spatial configurations may be beneficial to human experience of the external environment. Theory of space syntax provides efficient tools to examine configurational characteristics of environment, and their potential influences on people's activity and perception. Space syntax has been widely used in study of urban environment and people's movement, however, its use in examining urban open space, especially urban parks has been limited.

This study responds to such a gap and aims at offering a model of applying space syntax methodology in interpretation of urban park configuration characteristics, specifically in relation to users' walking behavior. Findings of this study are expected to provide frameworks for understanding configuration of urban parks and other urban open spaces. They could also offer basis for future explorations of urban park environment and people's perception and behavior, and help evaluate park design scenarios in practice.

Urban parks include activity areas and pathways. These elements are similar to main components of urban environment. Activity area is designed for people to stay and engage in activity, which is similar to buildings in an urban environment; while pathway is designed for circulation, having a similar purpose as a city street. Although space and movement are extensively addressed in landscape architecture (Loidl, 2003), complex natural elements in urban park give rise to many theoretical and methodological issues when applying space syntax. First, it is difficult to clearly define boundaries of individual spaces, since spaces are not separated by solid walls and accessibility is not controlled by doors. For instance, a pathway may directly connect to an activity zone, with fuzzy boundaries between them. Problems in defining boundaries give rise to the second concern in determining configurational relations among spaces (i.e., adjacency or permeability). Third, urban park environment allows for considerable visual connection and visual continuity. In urban environment, people's sight lines are mainly blocked by buildings; in contrast, in urban parks, users can look through branches of trees and shrubs. Fourth, incongruence exists between people's visual accessibility and spatial accessibility. Users can look through creeks even no bridge exists across the creek for physical access. Finally, whether to consider activity areas and pathways equally in the system presents another issue. Overall, these problems bring concerns in the application of space syntax both through convex map and axial map.

This paper is intended to address indicated concerns, and generate general principles for application of space syntax to study of urban parks and walking behavior. These principles will be developed and illustrated through examination of two real large urban parks in Beijing, China.

Keywords: *Space syntax, Urban park, Walking, Case study, Methodology*

Theme: *Green Urbanism and Sustainable Developments*

1. Introduction

Urban parks are important open spaces that encourage people’s physical activity (McCormack et al. 2010), and social interaction (Matsuoka and Kaplan 2008). They can bring vast physical and psychological health benefits to users (Bedimo-Rung, Mowen , and Cohen 2005). People experience park environment through walking, and walking is the most popular leisure-time physical activity among US adults (DHHS 1996). Walking is also important means by which users could explore a park. It is through walking that users get access to park sceneries and experience the whole park. Users' movement and route choices can significantly influence spatial sequences they experience, therefore impact overall experience and satisfaction. Empirical findings indicate that some park features are closely related to people’s walking within park (Corti, Donovan, and Holman 1996).

Theory of experiential landscape (Thwaites and Simkins 2007) proposes that human experience has spatial dimensions, and that certain spatial configurations may be beneficial to human experience of the external environment. Theory of space syntax provides valuable tools to examine configurational characteristics of environment, and their potential influences on people’s activity and perception. Space syntax has been widely used in examining urban environment and people’s movement. Research in this area indicates that configurational measurements are correlated with number of leisure walking trips (Baran, Rodríguez, and Khattak 2008), pedestrian movement rates (Hillier et al. 1993; Zampieri, Rigatti, and Ugalde 2009; Ozer and Kubat 2007) and route choice (Chang 2002). However, use of space syntax theory in examining urban park use has been limited.

This study responds to such a gap and aims at generating general principles for applying space syntax methodology in interpretation of urban park configuration characteristics, especially in relation to people’s walking within parks. These principles will be developed and illustrated through examination of two real urban parks in Beijing, China. Findings of this study are expected to provide frameworks for understanding characteristics of urban parks and other urban open spaces. They could also offer basis for future explorations of urban park environment and people’s perception and behavior, and shed light on the park design development and evaluation in practice.

2. Space Syntax Theory and Justification of Its Application to Urban Park and Walking

Theory of space syntax posits that the system structure of space in which various activities occur can influence movement, encounter, and avoidance, as well as generates social relations (Hillier and Hanson 1984). Space is considered as a discrete system, which follows certain logical rules in form of configurations. Concept of configuration works as an important base of space syntax theory, which is defined as a set of independent relations in which each is determined by its relation to all the others (Hillier 1996, p. 35). Such a concept points to the essential nature of space, therefore could be applied to interpreting buildings, urban environments and all other built or natural environments. Configurational relations are identified as adjacency or permeability between any pair of elements in a system. Concept of configuration offers possibility of studying architecture and other kinds of spaces in an objective and rigorous way.

According to Peponis and Wineman (2002), space syntax theory has two main focuses: 1. Examination of linear space and the paths of movement along these spaces; and 2. Study of spaces in building and how they contribute to the reproduction of social schemas. Movement and prolonged occupation are fundamental poles of our experience of space (Peponis and Wineman 2002). Likewise, space and movement are addressed in landscape architecture (Loidl

2003).Urban parks include activity zones and pathways connecting them. These elements are similar to main components of urban environment. Activity zones are designed for people to stay and engage in activity, which are similar to buildings; while pathways are designed for circulation, with a similar purpose of city streets. As indicated earlier, theory of space syntax addresses configurational characteristics of space, which is the underlying structure of any space. Based on such an emphasis and these similarities, there is a justification to apply space syntax theory in analysis of urban park environment, particularly in the context of walking.

3. General Theoretical Issues in Applying Space Syntax Theory in Urban Park and Walking

Complex and diverse natural elements in urban park give rise to many problems in application of space syntax methodology. At general level, these problems include boundaries of analysis, and scale of analysis. These problems will be discussed by examining two example parks. They are Rendinghu Park (9.6 Hectares) and Yuetan Park (8.12 Hectares) (Figure 1) in Beijing, China. Rendinghu Park has a big water body in the northern part, and a more enclosed spaces in the southern part. Yuetan Park was originally a royal garden for worship, and it has traditional courtyards and straight pathways in the northern part. Also, the northwest part of Yuetan Park is a preservation area that is closed to public. Consequently, these areas will not be considered in the present study.

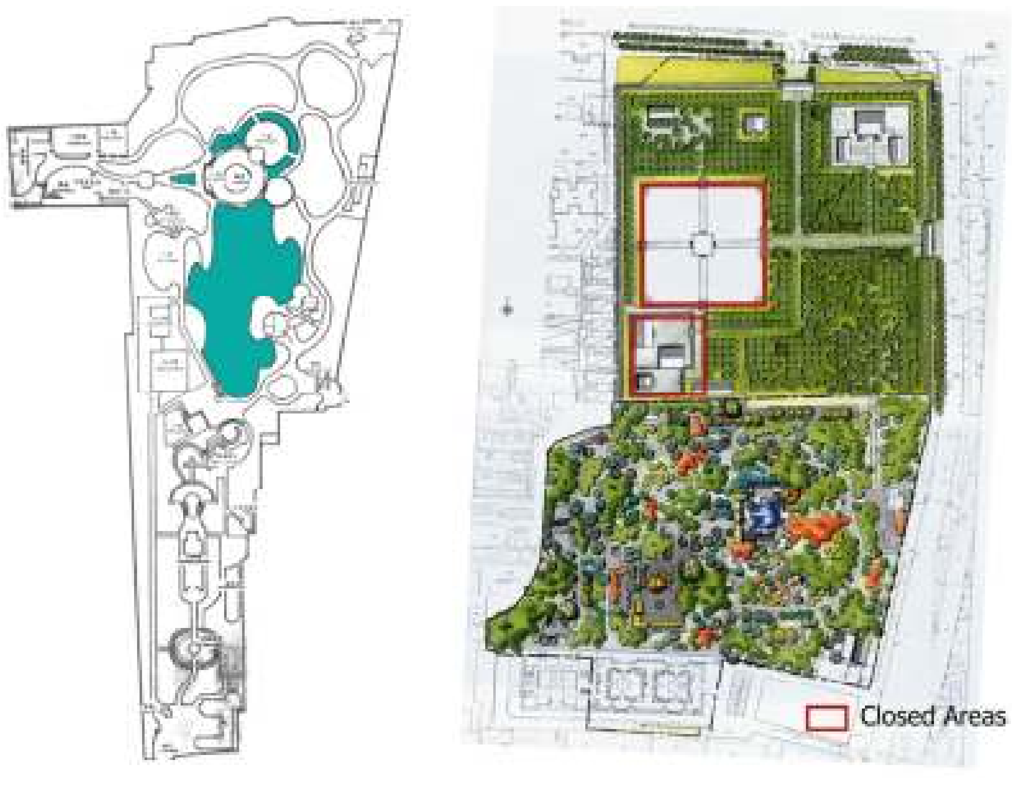

Figure 1 Rendinghu Park (Left) and Yuetan Park (Right) in Beijing, China

3.1 Boundaries of Analysis

Different from architecture or urban environment, urban parks include complex natural elements. Although these elements serve as objects to define spaces, they only define fuzzy boundaries. For instance, even there are tall trees along a pathway or an activity zone, people still could walk through these trees to go to other places. These boundaries are not solid, but more flexible and blurred. Such a situation brings problems in defining boundaries of spaces for analysis. If research purpose is to explore how urban park's configurational characteristics may affect people's walking, focus should be placed on the space that people have access to, or spaces which are designed to accommodate people's circulation and stay. As to the above example, although people could walk through trees, pathways are areas which are designed for people to walk on, and under most circumstances people walk on pathways. So the boundaries for analysis should follow functions of space, and should be limited to areas where people have spatial access to. For the example parks, these areas of analysis include activity zones and pathways (Figure 2).

Figure 2 Boundaries of Analysis in Example Parks

3.2 Scale of Analysis

Urban parks comprise various activity zones and pathways, and these spaces vary vastly in their size. For the purpose of this study, a pathway segment refers to a pathway that has no crossings on it. In other words, when people walk on a pathway segment, they have to follow the direction of the pathway without other choices. Activity zones refer to "blocky" spaces that are designed for people to stay and engage in activities; activity zones may have some facilities or structures. Activity zones include spaces such as playground, lawn, court, square, and open spaces. Scale of analysis can influence how individual spaces are defined, which ultimately will impact spatial relations between spaces. For instance, the square in northern part of Yuetan Park has tall shrubs and feature walls on it. These objects could be considered together as parts of the big square; however, at the same time they could be viewed as partitions that divide the square into sub-spaces (Figure 3).

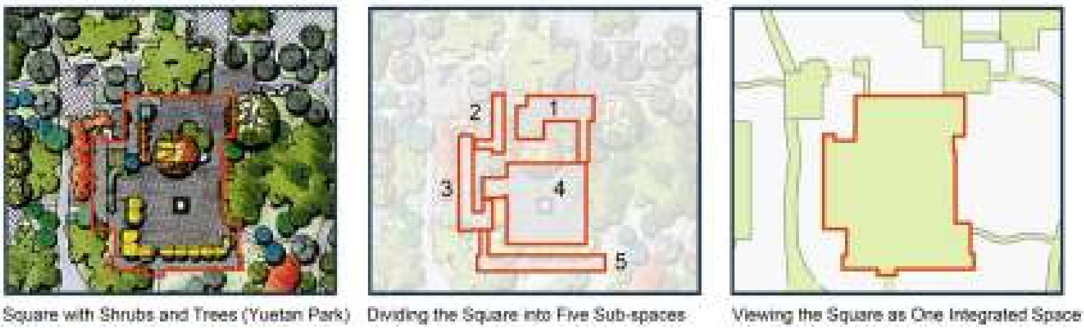

Figure 3 Scale of Analysis

Scale of analysis should be based on purpose of the study and functions of spaces. If the study aims at examining people’s walking over the whole park, and if comparison of usage will be made between different pathway segments, pathway segment should be viewed as individual space for analysis. Regarding function, activity zones are designed to accommodate people’s stay and activities, rather than walking. Therefore they should be viewed as spaces that connect pathway segments. In this case, each activity zone will be viewed as a unit of space, while sub-areas in the activity zone will not be considered. In contrast, if the study's purpose is to explore how people use an activity zone, especially the sequence of walking across sub-areas, items on the activity zone and sub-areas defined by these items should be carefully examined. In this example, sub-area will be regarded as a unit of space for analysis.

4. Application of Convex Map Analysis, Axial Map Analysis, and Visibility Graph Analysis

According to Penn et al. (1997), the first step in application of space syntax theory is to construct a representation, a map which reduces continuous open space to a finite number of discrete ‘elements’ or ‘spaces’ which can somehow be considered to be equivalent to each other. Natural elements in urban parks bring complexity in generating such a representation, hence neither axial map nor convex map fits urban park environment perfectly. Regarding convex map, the challenge is to define clear boundaries of individual park spaces, and their relations; as to an axial map, natural elements in urban parks provide large degree of visual connections, unlike buildings in urban area, which may conflict with actual spatial accessibility; for visibility graph analysis, natural elements in the park bring numerous problems in identifying objects that could block line of sight. The following section will discuss these problems by examining the two example parks.

4.1 Application of Convex Map Analysis

Spaces in urban parks are defined by natural elements, and these spaces have large degree of permeability. These characteristics bring challenges in defining individual spaces and relations between them. This section addresses these issues and discusses how to apply convex map analysis in urban park environment.

Units of Space

As noted earlier, different spaces in urban parks are designed for different functions. An activity zone is a unit of space for activity, and a pathway segment is a unit of space for circulation. Such characteristics distinguish park settings from other open spaces, such as urban streets. Urban streets are designed mainly for the single purpose of circulation, thus they could be viewed as homogenous spaces. In contrast, park settings could be classified into pathway segments and activity zones. Each pathway segment is a unit space for walking, and each activity zone is a unit space for staying and performing various activities. For the two example parks, pathway segments and activity zones are identified as individual spaces (Figure 4).

Figure 4 Units of Spaces in the Sample Parks

Boundaries between Individual Spaces

Boundaries are used to create relations of enclosure, contiguity, containment, subdivision, accessibility, and visibility; this complexity requires an effort in interpretation when defining the boundaries in a particular space (Peponis and Wineman 2002). In architecture spaces, boundaries between spaces are defined by walls, and permeability between them is controlled by doors. However, in urban parks, spaces have a large degree of permeability, and adjacent spaces tend to have direct spatial connections. For instance, if a pathway directly links to an activity zone, people can enter the activity zone by going along the pathway. Such a large degree of permeability brings challenges in defining boundaries between spaces.

We propose that boundaries between spaces are interpreted based on space function and design intentions. Pathways and activity zones have distinct functions, therefore they should be viewed as different spaces and with boundaries between them (Figure 5). For adjacent pathways, boundaries between them should be defined at the location of conjunction. For instance, if three pathway segments join together at the same conjunction, this conjunction should be viewed as a boundary among these segments. When standing at this conjunction, park users have three different pathways choices to follow, which will lead them to three different spaces.

For adjacent activity zones, features on them and the access between them could help in defining these boundaries. For instance, a square may be filled with benches for sitting, while its adjacent square may have huge sculptures and good views, however, no sitting places. These two squares have distinct features and are designed for different purposes. Thus they should be viewed as two individual spaces with boundaries between them, even though they are adjacent to each other. Similarly, access controlled by steps between activity zones may reflect designers' intention, and imply that these zones are designed as different spaces. It is worth noting that, such a division between individual spaces involves certain subjectivity, and its appropriateness should be evaluated based on whether study purpose is well served.

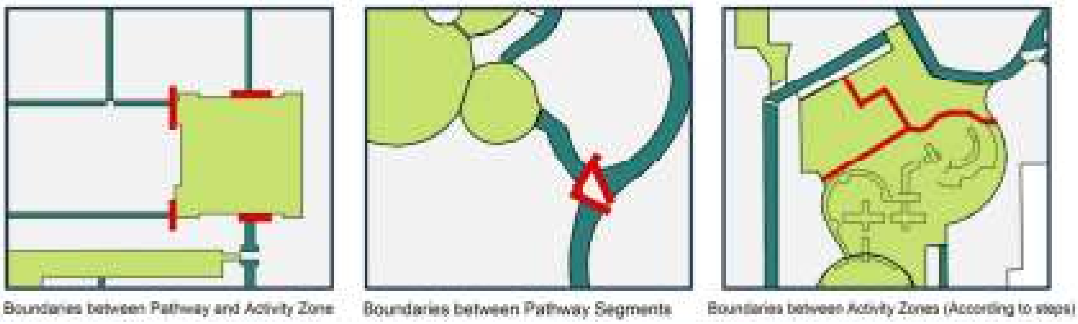

Figure 5 Boundaries between Individual Spaces

Applications of Convex Map Analysis in the Example Parks

Based on arguments and the approach presented above, individual spaces in the two example parks are identified and convex map analysis is applied to these spaces using Depthmap (Figure 6) (Table 1). The analysis indicates that in Rendinghu Park, there are 48 individual spaces, and that the northwest part is the most integrated part in the park. On the other hand, in Yuetan Park, there are 74 spaces, and the middle central part is the most integrated area. It is worth noting that even though these pathways and activity zones have distinct spatial characteristics

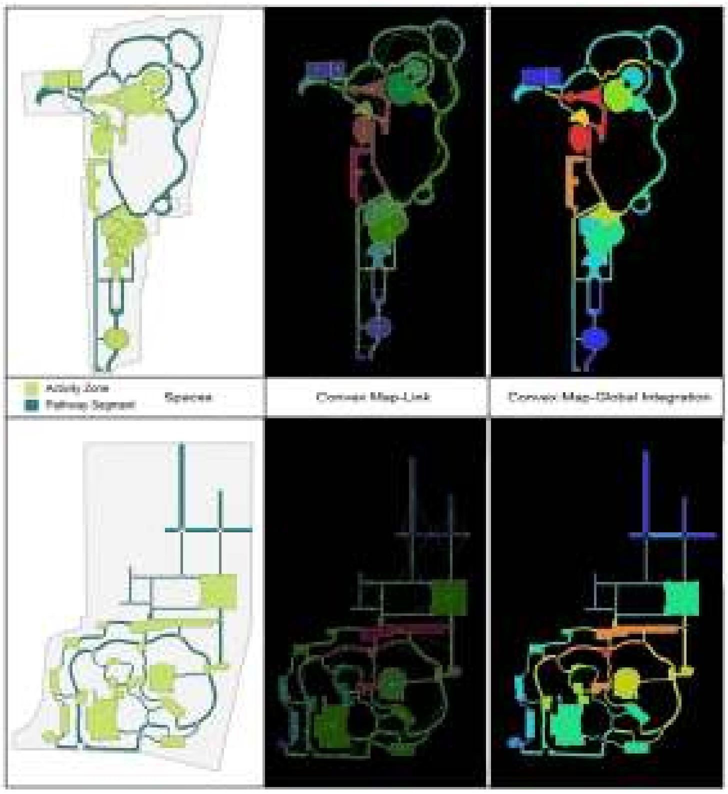

Figure 6 Convex Map Analysis of Rendinghu Park (top) and Yuetan Park (bottom)

and functions, their spatial characteristics do not have much impact on their configurational relations. Thus in the present study, equal weights are assigned to pathways and activity zones.

Table 1 Summary of Attributes of Convex Maps

		Minimum	Maximum	Average
Rendinghu Park	Connectivity	1	7	3.542
	Integration	0.584	1.274	0.883
	Mean Depth	3.468	6.383	4.708
	Node Count	48	48	48
Yutan Park	Connectivity	1	6	3.297
	Integration	0.537	1.134	0.814
	Mean Depth	4.288	7.945	5.723
	Node Count	74	74	74

4.2 Application of Axial Map Analysis

Conflicts between visual accessibility and spatial accessibility and open space in urban parks give rise to considerable theoretical issues in application of axial map analysis. This section will address these issues and propose method to apply axial map analysis in interpretation of urban park environment.

Drawing Axial Map within Areas Where People Have Spatial Access

Compared with architectural and urban environment, urban parks provide much wider fields of view and larger visual accessibility. Such characteristics lead to incongruence between people's line of sight and their actual spatial accessibility. For instance, people could see buildings across the water, however, they may not have spatial accessibility to directly approach the building (Figure 7). Under such a circumstance, these visual connections may not influence their movements directly, for people are unable to follow their lines of sight. At the same time, seasonal changes of flora or tree growth bring more complexity in visibility of park environment. If the purpose of the study is to explore how people walk around parks, axial lines should be drawn within the areas that people could access spatially, rather than purely following lines of sight.

Figure 7 Conflict between Line of Sight and Spatial Accessibility

Axial lines in Activity Zone

There are mixed arguments about reliability and comparability of fewest line axial map (Desyllas and Duxbury 2001; Hillier and Penn 2004). In open spaces, there is a potential to identify a large number of axial lines, which brings problem in selecting a subset to represent the space. If the study aims at exploring people's walking behaviors, park activity zones should be viewed as connections that link pathway segments, and their own configurational characteristics should be ignored, since activity zones are designed for activity. Activity zones are usually connected with several pathway segments, and people enter these open spaces by moving along pathways. Axial lines could be first drawn along the directions of pathway segments that connect with the activity zones (Figure 8). Then new axial lines are added to make the system connected. It is worth noting that the structures and facilities on activity zones could influence the generation of axial lines, since they may interrupt axial lines.

Figure 8 Axial Lines in Activity Zone

Applications of Axial Map in the Example Parks

Based on above arguments and rules, axial map analysis is applied in the two example parks by using Depthmap (Figure 9) (Table 2). Following the above identified rules, the results suggest that Rendinghu Park could be represented by total of 89 axial lines, while the middle-west part is the most integrated area. On the other hand, in Yuetan Park 108 axial lines are identified, while the middle southern-west part is the most integrated area. Some objects and structures on the activity zones are taken into consideration in the process of generation of axial lines, thus they have an influence on the final axial line map.

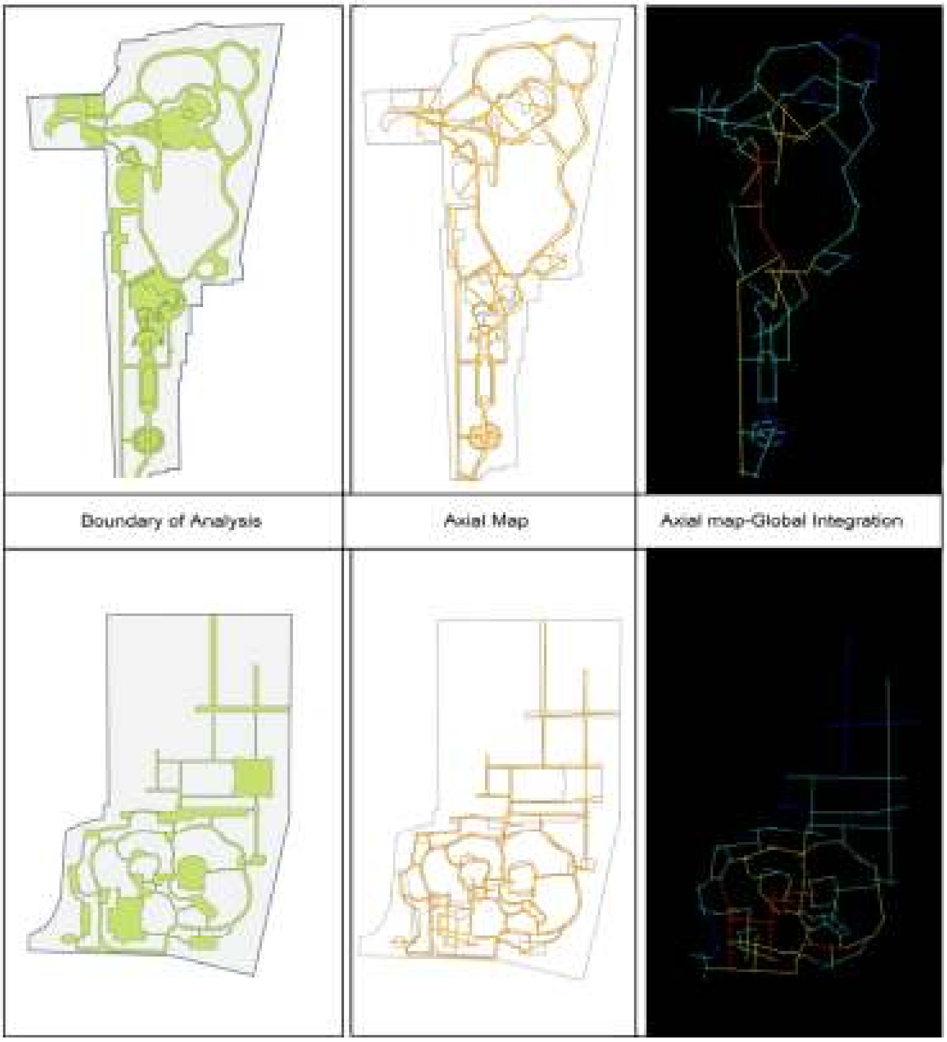

Figure 9 Axial Map Analysis of the Rendinghu Park (top) and Yuetan Park (bottom)

Table 2 Summary of Attributes of Axial Maps

		Minimum	Maximum	Average
Rendinghu Park	Connectivity	1	5	2.831
	Integration	0.500	1.108	0.723
	Mean Depth	4.591	8.955	6.690
	Node Count	89	89	89
Yutan Park	Connectivity	2	6	2.889
	Integration	0.570	0.968	0.765
	Mean Depth	5.383	8.449	6.643
	Node Count	108	108	108

4.3 Application of Visibility Graph Analysis

When visibility graph analysis is applied in an urban park, complex natural elements bring challenges in identifying objects that could block line of sight, while at the same time, incongruence between visual accessibility and spatial accessibility give rise to a problem in defining areas for analysis. For the first issue, objects that could block the line of sight at an eye level should be identified and examined. However, objects at other heights should not be considered, since it is very likely they do not block people's line of sight. For instance, if people could see through branches of trees, these trees should not be regarded as objects that block line of sight. For the second problem, since people usually engage in activity or walk mainly in activity zones and pathways, visibility of these areas has significant influences on people's experience. Thus these areas should be highly addressed in the analysis.

To exemplify the issues addressed above, visibility graph analysis is applied to Rendinghu Park (Figure 10). First, objects that could block people's sight of line are identified based on satellite image and site observation. These objects include buildings, structures and dense shrubs. Trees that allow for visibility at eye level are not included. Then visibility graph analysis is run in Depthmap within the boundaries of the park. As noted earlier, people could only get spatial access to activity zones and pathways, thus it is assumed that visibility of inaccessible places will not influence people's experience. Therefore, visibility of pathways and activity zones are extracted from the visibility graph for the entire park. The result indicates that the three circle squares on the northern part of the park have the highest visibility from the surrounding pathways and activity zones.

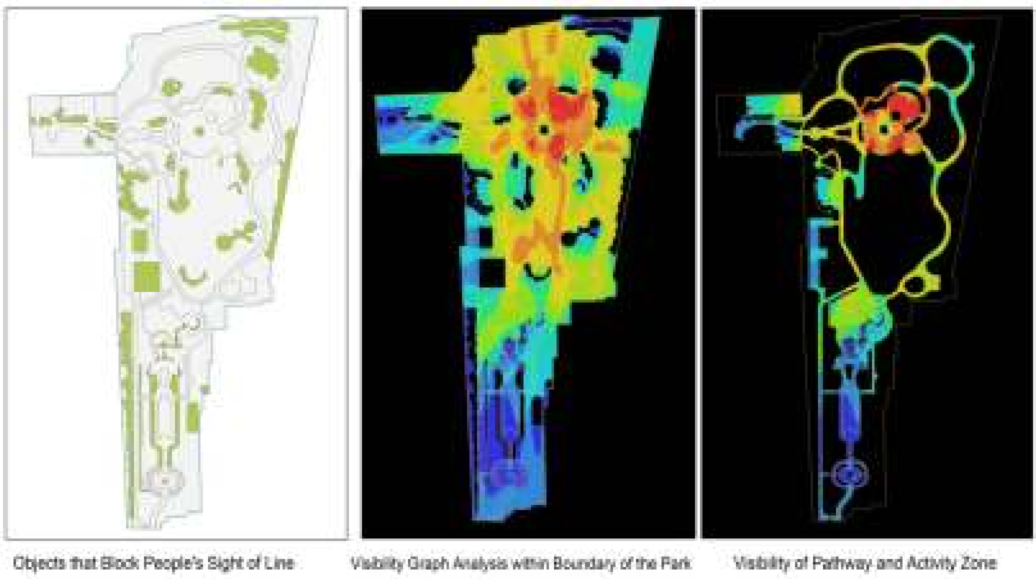

Figure 9 Visibility Graph of Rendinghu Park

5. Conclusions and Discussions

The overall purpose of this paper was to generate general principles for applying space syntax methodology in interpretation of urban park configuration characteristics, especially in relation to people's walking within parks. When applying space syntax theory in urban park environment, the scale of analysis and the unit of individual space play important role in influencing analysis output. For the example parks, some structures and objects on the activity zones, such as feature walls and raised flower beds, are taken into consideration in developing axial map analysis, however, they are ignored in convex map analysis. Overall, this approach results in a smaller scale and more node counts in axial map. Such a difference could partly explain why the most integrated areas are slightly different in the convex map analysis and axial map analysis for the same park.

For the convex map analysis, scale and unit of individual space should be decided based on research purpose and should be congruent with unit of analysis of the research. If the study aims at comparing use of different pathway segments, then each pathway segment will be considered as an individual space. Similarly, if usage of sub-areas of the activity zone is the research interest, units of individual spaces will be these sub-areas.

As to the axial map analysis, controversial issues are involved in drawing axial lines to represent activity zones. Different methods may result in different number of axial lines, and therefore influence configurational relations of the whole system. Objects on activity zones should be considered consistently across all settings, to ensure similar rules are followed. For instance, for activity zones whose objects are considered in generation of axial lines, more and shorter lines are likely to be produced. Since these objects tend to "block" long lines, more lines might be needed to connect the whole system. More work is needed to develop rules for generation of axial lines on activity zones in urban parks.

For the purposes of this study, to better explore visibility of activity zones and pathways, visibility graph of inaccessible areas is excluded from analysis. Although remaining graph could show variation in visibility, the range of analysis output is based on the analysis of the entire park area, rather than the range of accessible areas. Namely, if visibility graph is only run within accessible spaces, different results will be produced; future work is needed to solve such a limitation.

References

Baran, K. Perver, Daniel A. Rodríguez, and Asad J. Khattak. 2008. "Space Syntax and Walking in a New Urbanist and Suburban Neighbourhoods." *Journal of Urban Design* 13 (1):5-28. doi: 10.1080/13574800701803498.

Bedimo-Rung, A. L., A. J. Mowen, and D. A. Cohen. 2005. "The significance of parks to physical activity and public health - A conceptual model." *American Journal of Preventive Medicine* 28 (2):159-168. doi: 10.1016/j.amepre.2004.10.024.

Chang, D. 2002. "Spatial choice and preference in multilevel movement networks." *Environment and Behavior* 34 (5):582-615. doi: 10.1177/0013916502034005002.

Corti, Billie , J. Robert Donovan, and J. C D' Arcy Holman. 1996. "Factors influencing the use of physical activity facilities: results from qualitative research." *Health promotion journal of Australia: official journal of the Australian Association of Health Promotion Professionals* 6 (1):16-21.

Desyllas, J, and E. Duxbury. 2001. "Axial maps and visibility analysis." *In Space syntax : 3rd International Symposium*, Georgia Institute of Technology, Atlanta, May 7-11: proceedings, edited by John Peponis, Jean D. Wineman, Sonit Bafna. Georgia Institute of Technology. College of Architecture. and University of Michigan. College of Architecture and City Planning. Ann Arbor, Mich.: A. Alfred Taubman College of Architecture and Urban Planning.

DHHS. 1996. "A Report of the Surgeon General:Physical Activity and Health." *U.S Department of Health and Human Services*, Centers for Disease Control and Prevention, Atlanta ,GA.

Hillier, B., A. Penn, J. Hanson, T. Grajewski, and J. Xu. 1993. "NATURAL MOVEMENT - OR, CONFIGURATION AND ATTRACTION IN URBAN PEDESTRIAN MOVEMENT." *Environment and Planning B-Planning & Design* 20 (1):29-66. doi: 10.1068/b200029.

Hillier, B., and A. Penn. 2004. "Rejoinder to Carlo Ratti." *Environment and Planning B-Planning & Design* 31 (4):501-511. doi: 10.1068/b3019a.

Hillier, B. 1996. *Space is the machine : a configurational theory of architecture*. Cambridge: Cambridge University Press.

Hillier, B., and J. Hanson. 1984. *The social logic of space*. Cambridge [Cambridgeshire]; New York: Cambridge University Press.

Loidl, Hans-Wolfgang. 2003. *Opening spaces*. design as landscape architecture, Boston, MA, Birkhäuser.

Matsuoka, H. Rodney. and Rachel Kaplan. 2008. "People needs in the urban landscape: Analysis of Landscape And Urban Planning contributions." *Landscape and Urban Planning* 84 (1):7-19. doi: 10.1016/j.landurbplan.2007.09.009.

McCormack, R. Gavin. Melanie Rock, Ann M. Toohey, and Danica Hignell. 2010. "Characteristics of urban parks associated with park use and physical activity: A review of qualitative research." *Health & place* 16 (4):712-726. doi: 10.1016/j.healthplace.2010.03.003.

Ozer, O., and A. S. Kubat. 2007. "Walking Initiatives: A Quantitative Movement Analysis." Paper read at 6th International Space Syntax Symposium, Istanbul.

Penn, Alan, Ruth Conroy, Nick Dalton, Laura Dekker, Chrion Mottram, and Alastair Turner. 1997. "Intelligent architecture: new tools for the three dimensional analysis of space and built form." In *Proceedings of the Space Syntax First International Symposium*, 30.1-30.19. UCL, London Space Syntax Laboratory, University College London, London.

Peponis, John, and Jean Wineman. 2002. "The Spatial Structure of Environment and Behavior: Space syntax." In *Handbook of Environmental Psychology,* edited by Bechtel Rober and Churchman Arza. New York: John Wiley.

Thwaites, Kevin, and Ian Simkins. 2007. *Experiential landscape : an approach to people, place and space*. Abingdon ; New York: Routledge.

Zampieri, F L., D. Rigatti, and C. Ugalde. 2009. “Evaluated Model of Pedestrian Movement Based on Space Syntax, Performance Measures and Artificial Neural Nets.” In *7th International Space Syntax Symposium*, edited by Daniel Koch, Lars Marcus, and Jesper Steen. Stockholm.