Creating Sunshine Environments in Public Spaces of Residential Districts in the Colder Regions of China: A Digital Simulation

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Abstract

Taking full advantage of the natural light is a key element of eco-settlement design, and also an essential index of evaluating the quality of residential districts. The research of architectural interior lighting for residential districts is quite mature, but the research for sunshine environments of residential public spaces is still neglected, especially for the small towns in cold area of China, where the sunshine environment is even more important.[116]

Digital simulation technology based on computer science development has influenced the design of architecture and urban planning deeply. The development and use of digital simulation platforms make it possible that planning can compare, analyze and adjust design through the environmental performance-based assessment at any time.

In this paper, an analysis of the sunshine environment and its impact on the public spaces in cold regions is presented. It takes a typical small town in a residential district as the study object. It uses environmental and spatial simulation software such as Ecotect Analysis and Depthmap,, to simulate and study the solar radiation distribution at specific time periods in the residential district public spaces. Combined with the characteristic of residential activities, it adjusts the program and tests the results to ascertain the cold climate adaptability of the public space of small towns in order tobetter fit activity characteristics of cold regions.

Keywords: *Cold Area, China, Residential District, Public Space, Sunshine* Environment, Ecotect Analysis, Depthmap

Introduction

The design of ecological sustainablity is being increasingly identified as a core issue of architecture and planning. However, the complexity of present buildings and cities has already exceeded the extent that the architects are able to control just by their subjective judgments or personal experiences. Consequently, varieties of computer visualization & simulation technologies have been applied in the design of cities.

In evaluating the ecosystem of a residential area based on the quality of physical environments, the sunshine conditions affect most. Taking full advantage of the natural light has specified

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significance especially to the towns located in the cold areas in China. According to a study in Sweden, the temperature levels people can tolerate in sunshine is 11℃ when 20℃ in the shadow under the same conditions. The study indicates that people would require more time for outdoor activities when adequate sunshine is present.

At present, the design in China aims at evaluating quality of physical environment of residential areas only at the initial stages. There is hardly any analytical research of activities specific to physical environments. Bringing and applying digital simulation techniques into environmental design related to sunshine and using it flexibly has been a new way of thinking. This article begins with the characters of open spaces in the cold regions and summarizes the existing problems in order to obtain the core causes. It will examine these influences by applying the digital simulation techniques.

Literature review

Chen Ye (2009) has explored the use of Depthmap software in China for the first time. The research used software to build a special model, and step depth and integration is carried out on both walkable level and visible level. It showed the application of Depthmap software in spatial structure analysis of garden. Similarly, Yang Li (2010) researched the application of Ecotect in the residential district planning. The research made some useful explorations on ecological and energy saving measures in residential district planning by Ecotect software.

Both studies have discussed the problem of public space on spatial property or physical environment property, but the two parts influence each other. They have never been considered overall in a digital simulation method.

Research Method

This research uses survey data obtained POE, behavioral observation, and statistics of winter activities of inhabitants in a residential area. It analyses results according to different age levels, and summed up the characteristics of winter activities in the study area. Ecotect software uses meteorological data from the local weather bureau. However, it does not deal with time and cost considerations and this to some extent, limits the accuracy of the study. Nevertheless,it does not produce an error of principle.

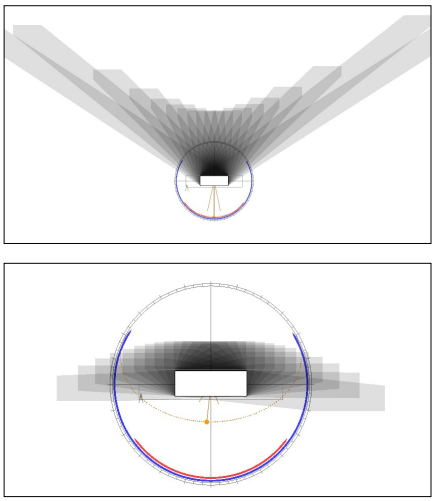


Fig.1: Greater cold days and the summer solstice continuous shadow figure of a same building（time range7:00-15:30, time interval is 30min）

1. The features of the Residential Public Space in Small-towns in Cold Area

1.1 Differences in Climatic Properties

Climate conditions of cold areas of China are important to this study: Winter lasts for five months (November to next March), cold and dry. Solar incident angle decreases, which enlarges the shadow area of buildings (Fig.1) and reduces the amount of solar radiation required by residential public spaces. Then it causes a huge climatic difference of the sunshine environment between winter and summer. Especially for outdoor spaces in the cold areas, it demands more climatic protection in winter rather than the aero-cooling in summer.

1.2 Physical space planning Properties

Compared to large cities, the population and density of small towns are small, and the construction area is adequate. The residential areas mainly contain multi-storey residential buildings and new ones, where it is not crowded. Therefore they enjoy larger minimum distances for sunlight but loose valuable residential public space.

Different from the residential areas in the South of China, the layout mode of residential buildings in small-towns of cold areas is simple and uncomplicated. Presently, such areas are composed mainly of enclosures and semi-enclosure modes. It is because such modes can take full use of land and makes better sunshine environments for most residential buildings.

1.3 Distribution of using time

In winter in cold areas, the residential public spaces are desolate. According to the living features of residents in small-towns, they are used mainly between 8 am to 10 am and 12 am to 16 pm. (Fig.2)

1.4 Users diversity features

Most users of open spaces of residential areas are senior citizens. Based on the reasons of great labor force immigrating to the cities, elderly stay back while the young move to towns. Open spaces thus turn out to be the main “living circle” and “social circle” for the people who stay behind; the seniors.

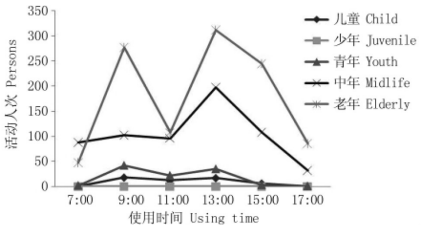


Fig.2: Public space usage survey in winter

2. Problems of public space sunshine environmental design in cold area small town residential area

2.1 Lack of active applicable design in cold area

Research on residential sunshine environments mostly focus on the utility of sun radiation of buildings, also known as interior sunshine environment, and ignores the importance of public space sunshine environment, and even suppose that the public space does not have much or even does not have the value of being used in design. In fact, the abundant sunlight can greatly decrease the bad feeling of depression and emotional feeling and upgrade the living quality.

2.2 The lack of consideration of landscape and public facilities planning layout in sunlight utility.

Currently, the landscape planning is usually too simple and barely considers the features of cold area sunlight, and the layout of facilities does not combine with the sunshine environment. We can often see the squares and benches that are covered in year-long shadow zone, or the situation that the accumulated snow on the roads does not melt. These affect the willingness and time of outdoor activities of residents. On the other hand, people have few activities, and the senior citizens and children's active time and methods are both relatively fixed. If these are taken into account, sunshine environment design can be focused on their activities.

2.3 The uncertainty of designing standards cause the hardness of quantify

The current sunlight related standards rarely involve outdoor public space sunshine management, and there is only "standards of urban residential area design" (GB50180-93). It requires that a "kindergarten and nursery has to have no less than 1/2 activity space that is outside the standard building sunlight shadow line, and the residential area should have no less than 1/3 green area that is outside the standard building sunlight shadow line." [5]The standards do not limit the conditions such as location and seasons, and numbers of changeable factors make it difficult to quantify. This leads to a lack of scientific base and examination methods during the spatial planning management of residential public spaces.

3. Introduction of Digital Simulation technology

3.1 The techniques of solving the sunshine environment design issue

There are many reasons for the issue discussed above about the sunshine environment design in public spaces of cold areas in small towns. However, the solution must include enough consideration and analysis of the following aspects.

(1) Producing and making available information about the particular time and spaces of sunshine environments. Accurate information on any space and at any time or a period of time is necessary. Describe the particular conditions of sunlight information more accurately with direct or indirect sun radiation information instead of only giving the ration of shadow and shade.

(2) Designing the public spaces based on human activity. The layout of residential public spaces can directly influence the daily outdoor life of residents, and the quality of sunshine

environment eventually is based on human activities. The design of public spaces has to fit human requirements; not contrary to the sunshine environment. And the key to this kind of design is to predict the common usage of people in the particular outer public space of buildings in order to reasonably create public spaces with different functions and shapes in the site.

(3) The real-time interactive design of both points above.

3.2 The selection of relative digital simulation programs

Currently, there are different kinds of planning related design aid software to fit the requirement mentioned above. In this article, we select Ecotect Analysis and Depthmap separately for the simulation of environment and space, and the operability, visibility, and sharing ability all provides a very good software environment for the interactivity.

3.2.1 Ecotect Analysis

Ecotect Analysis, the ecological architectural modeling software is capable of overall technological performance analysis design aid. The idea is based on the analyzing methods of architectural climate designing system, which has benefitted from the computing field. [6]This software has been widely accepted and is applied in architectural design, although it is still under exploration in urban planning area.

The sunshine environmental analyzing/computing/simulating technology is relatively developed, and can accurately simulate the track of sun movement and sun position at any particular time. The

Fig.3: Typical site plan and researching range

features are easy to operate visually. It can not only calculate the sunshine time of buildings, but also accurately count the sun radiation intensity of sites.

3.2.2 Depthmap

Depthmap is a space syntax program developed by UCL in Britain, is still not widely used in China. The fundamental principle is to demonstrate space with mathematic models, and to represent with visual methods. [7] to predict and judge the impact from space towards people. Thus Depthmap can be classified in the digital simulation software category.

Depthmap has an extensive researching range, from as small as detailed layout of interior space to as huge as city or national level space. And the function of it in residential area space level is to simulate the general pattern of space to people through digital expressions in order to avoid long period behavior observations.

4 Sunshine Environmental analysis and simulation optimize of common residential area in winter – a town in Harbin as example.

4.1 The selection of research object

The object is a partial area of some residential area in a suburb near Harbin, built in 2012. The public space is relatively abundant, and there are small squares in each group, and public space spreads throughout the whole area. Yet the rationality is to be evaluated (Fig.3). According to the features of cold area climate, we set up the research period from Nov 1 to March 31.

4.2 Public space sunshine environment analysis

4.2.1 Research the properties of public space with Depthmap

The first task is to simplify the plan of the researching range, and keep the buildings and outer boundaries only. By using Axial Map in Depthmap, the outer space of the residential area is translated into axis chart, which is calculated for another step to receive the integration map representing the integration level of space by running run graph analysis. The integration level

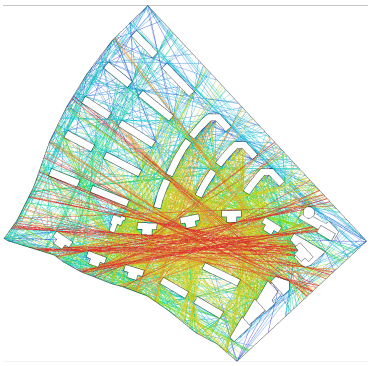


Fig.4: Public space axis

Fig.5: Generalization of Axis Chart and Analyzing Point Position

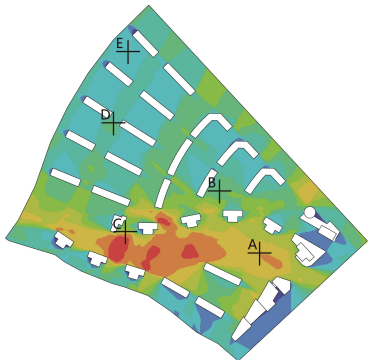


Fig.6: The Integration Distribution Chart of Public Space

demonstrates the degree of dispersion: the higher the integration is, the reachability becomes higher, and *vice versa*. According to the chart, each particular axis has its own property value of integration; the color of the axis reflects the level of integration - red for higher, blue for lower.(Fig.4)

Nest task was to produce the general axis chart through the order of reduction to fewest line map to superimpose the current public space with the residential area. (Fig.5). According to the public space and transition flow lines, the spatial frame of the plan is mostly alike in the simulation result. We produced an evaluation of public space use related to sun environment by selecting the axis with different integration as well as the different type crossing points of public space as the analysis point. It also involved a comparison of the simulation and data of spatial integration and sun radiation strength of the analysis points.

To produce the integration value of points, we need to analyze the axis chart with visibility graph

in order to have a visual integration chart. We calculated every single value of the segregated cellular in public space (Fig.6) and the statistics of points is as follows. (Tabe1)

Table 4: Spatial Topology Data of Analysis Point

Point number	Ref number	Connectivity	Integration[HH]
A	4784158	1311	12.8221
B	4849712	762	9.83257
C	2228261	1123	12.4928
D	1966147	688	11.1159
E	2359395	340	6.99387

4.2.2. The simulation of public space sunshine environment.

The next step is to simulate the sunshine radiation situation of residential public area, and select 3 periods in each day for the research based on the usage situation during winter in cold area, including 8 to 10 in the morning, 12 to 14 and 14 to 16 in the afternoon. The algorithm used is the simulating calculation of daily average radiation amount for a particular period of time, will

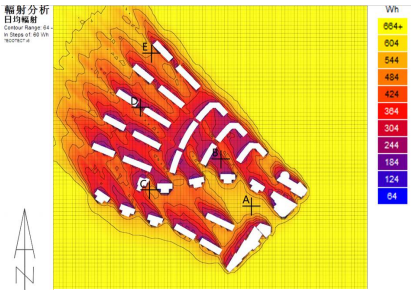


Fig.7: The 8:00-10:00 solar radiation isogram
Source: author

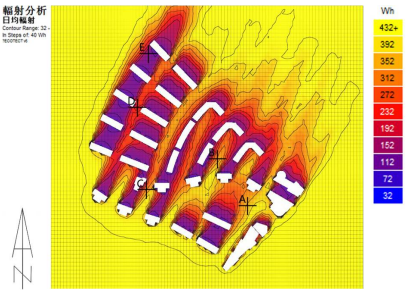


Fig.8: The 12:00-14:00 solar radiation isogram
Source: author

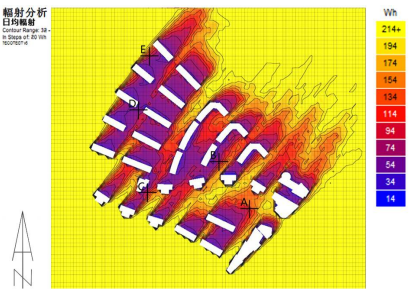


Fig.9: The 14:00-16:00 solar radiation isogram
Source: author

eventually produce the isograms for different times. (Fig.7， Fig.8， Fig.9)

By using the data analysis function, we calculate the average sun radiation quantity hour by

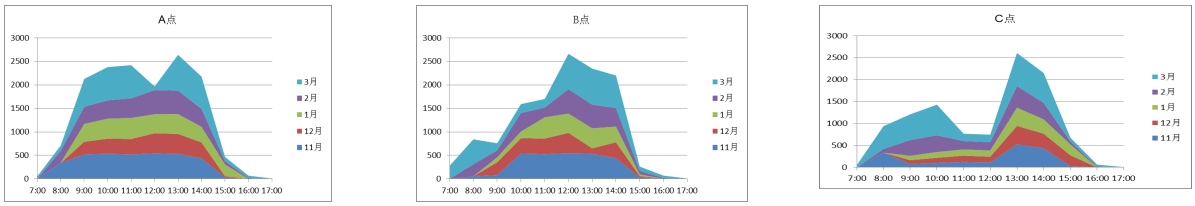
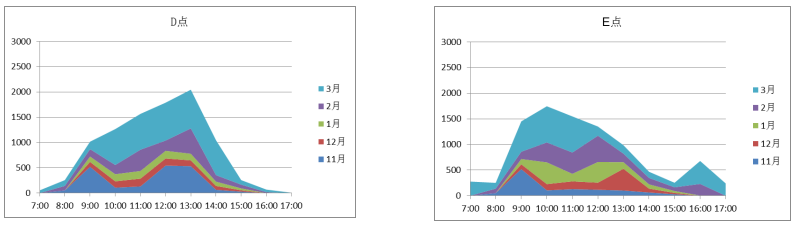


Fig.10: The accumulating area chart of sun radiation at each analyzing points (w/m^2)
Source: author



different hours in each month during winter (Fig.10) and eventually produce the accumulating area chart of daily average sun radiation.

4.2.3 Simulation Result Comprehensive Analysis

Utilize the received data of analysis points; calculate the daily average radiation intense in 3 period of time. Combine Depthmap and get the spatial integration level of analysis point, demonstrate the environmental features of each analysis point in winter.

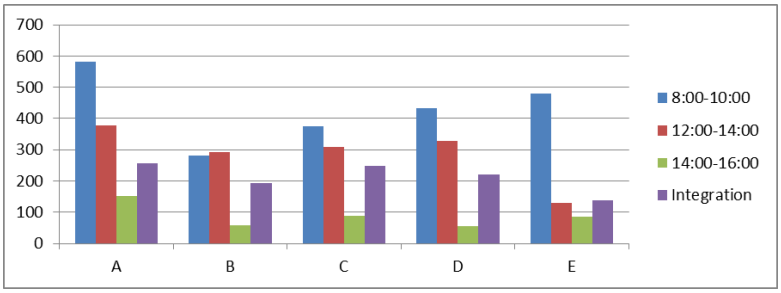


Fig.11: The daily average radiation intense and spatial integration of each analyzing point in winter.
Source: author

1) **Point A:** High Integration, radiation in each period is strong and is capable of being the main public space in a residential area.
2) **Point B:** Low Integration, radiation in each period is weak and is incapable of placing any large public space. Green space or car parking could be considered.
3) **Point C:** High Integration, radiation during evening is high, and is capable of being a children's activity based on the small distance from school.
4) **Point D:** high Integration, the radiation after midday is high. it is capable of arranging a small public space for people to walk & talk, etc.
5) **Point E:** Low Integration. The radiation during the entire afternoon is relatively low, but high in the morning. Here it is capable of producing a weak public space, including morning exercise or rest in group.

4.3 Design optimization

Provide a public space optimizing a strategy combining the daily average radiation chart in winter, spatial integration distribution chart and radiation situation in each period.(Fig.12)

Point A: Point A core public space can be extended to the west for using the sunshine environment.
Point D: There should be benches and other facilities that could be put on both sides of the transition space at Point D.

Point E: The north side small squares represented by point E should be related to the buildings in the North and capable for arranging sports facilities.
Point B: Crossing Space represented by Point B is good for a landscape area or parking lots.

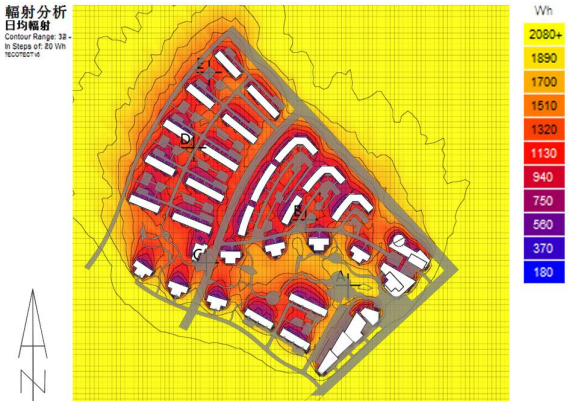


Fig.12**:** Average solar radiation throughout the day in winter
Source: author

5 Findings

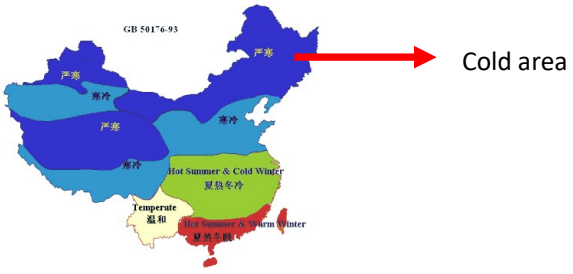
By analyzing and researching the sunshine environment features in winter about public space in cold areas of small towns, this paper shows the necessity and problems of cold area suitability planning, and introduce a digital simulation strategy into the design and research of public space sunshine environments. It also shows that simulation and analysis of the physical environment and spatial structure based on the two softwares: Ecotect Analysis and Depthmap could be used. It is the first time they are combined, and this paper has proposed the most optimized sunshine accessibility design of random spatial position based on the connection of different data.

Digital Simulation technology upgrades the scientific property and efficiency of sustained design, and can also abstractly simulate the real-time human activity other than physical environments. This provides a reality possibility for the computer aid design during the conceptual stage, and breaks the limitation of application of digital simulation on planning. Thereby, it provides more possibilities for planning, and lifts the scientific-ness of planning and design.

The methods provided in paper has potential for development including real-time interaction between two programs by building a digital model, and can be used in one unified platform. The combination of environmental simulating data and spatial topological value calculating result is translated into different spatial types of expressions, and is represented in partition to aid our design, and thus eliminates the process of artificial comparison data. Making sustained design more scientific, easy, widely accepted and popular, is the fundamental object of digital simulation technology and needs our continuing research and exploration.

Notes

1. "Sunshine Environment" is a technical term when the study is about changes in the physical environment caused by the sun radiation, it is more professional than "natural light", for example: "*Sunshine environment and spectrum analysis for concentrator PV systems in Japan", Solar Energy Materials and Solar Cells [J].*
2. "Cold Area" is widely used in the north of China, and it is recognized by most experts.



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