SPACE COMFORT ANALYSIS OF UNIVERSITY CANTEEN BASED ON BIG DATA

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ABSTRACT: Comfort measurement of human in public space has been a major concern for quality of urban life and facility management. Measurement of comfort in general may be difficult and is usually conducted via subjective survey and interviews. As a subjective indicator, comfort is determined by physical conditions of environment and human beings' perception. The former may include weather and temperature, noise and personal space. Existing studies have been mainly investigating thermal comfort measurement and models. Personal space comfort which is related with congestion levels in indoor space has been rarely studied. It can be measured as population density in given space. Canteens are typical public spaces for students and faculty members to have food and communicate general information. Congestion in canteens can produce negative eating experience and further increase mental stress of patrons. This work conducts data processing and analysis for people density calculation in university canteens in order to measure dynamic space comfort. Campus card transaction data and wireless log data were acquired after anonymized processing and used to extract entering and leaving time of canteen patrons. Based on reconstructed three dimension space of canteens, we derived human density and seat ratio of the crowds. The two indicators are inversely correlated with space comfort. For the research area, it is found out that space comfort gradually decreases when seat ratio is greater than 0.6, and human density exceeds 0.4. Normally space comfort reaches the lowest value during peak hours. The results can be used to monitor changes of crowd flow, provide support to managers to improve canteen facilities, offer suggestions to university calendar to adjust daily lecturing schedules.

1. INTRODUCTION

Comfort is taken as basic needs of human in Maslow's Hierarchy of Needs and interpreted as a part of physiological accommodation (Ural, 2018). Human comfort in public spaces is important especially when a large number of people use them as regular visiting destinations. It is directly related with people's quality of life in urban environment. Canteens on university campus are typical public indoor spaces where faculty members and students have to visit regularly every day. Comfort eating experience not only helps people enjoy food but also gives people a refresh break.

In general, comfort of public spaces is a subjective indicator which is determined by physical conditions of environment and human beings' perception. The former may include weather and temperature, noise, personal space and others. Existing studies have been mainly investigating thermal comfort measurement and models (Enescu, 2017). Researchers have evaluated thermal comfort in relation to outdoor activity in different public places, such as plazas, squares, streets, and parks. By improving the physical and climatic aspects of urban places, it is possible to revitalize parts of the city and improve the quality of life provided by buildings (Thorsson, 2007). A fine adjustment of warming/cooling systems and lighting to meet human comfort requirements can improve user experience, productivity and energy efficiency (Ruppa et al., 2015). Public spaces can be roughly grouped into two categories. One is that the spaces accommodate specific number of users, for example class rooms and theatres. Capacity in this kind of spaces is normally fixed at design stages according to space functions. And comfort measurement can be a combination of thermal, acoustic, and visual indicators (Buratti et al., 2018). The second type of public spaces, whether indoor or outdoor, is designed for an uncertain number of visitors with an upper limit, for example museums, restaurants and public transportation transits. Comfort measurement of this type of spaces needs consider not only above indicators, but also crowd congestion or population density. However current research mainly investigates comfort in way of subjective survey and interviews, for example in a dining context (Heung and Gu, 2012), and a combination of questionnaire survey and modeling of physical parameters measurement, for example on a public transportation buses (Shek and Chan, 2008).

Canteens on university campus are typical public spaces for students and faculty members to have food and communicate general information. Congestion in canteens can produce negative eating experience and further increase mental stress of visitors. Spatial temporal patterns of human flow in a university canteen are critical to university management to take measures to improve patrons' dining experience, which is an important part of livability of a university campus.

Researchers have conducted comfort modeling in similar spaces and incorporated indicators including facility aesthetics, ambience, lighting, service product, layout, and service staff (Ryu and Jang, 2008). Human variables, including crowding level, have been examined in shopping business to evaluate positive and negative customers' experience (Jung et al., 2017). Methods in existing works are implemented in quantitative ways, which are based on surveys of a sub group of participants, with traditional or online questionnaires. So most researches are reported in a term of perceived crowding (Li et al., 2009).

Based on 3D canteen models, campus card transaction data and wireless log data after anonymized processing, the paper designed and implemented a methodology to evaluate comfort of canteens on university campus by calculating dynamic indicators of human density and seat ratio.

2. DATA AND METHODS

Four canteens on the Capital Normal University (CNU) campus are used as research areas in this work (see Figure 1). In order to determine the number of patrons at different time, campus card transaction data and wireless log data were used, which are generated by campus information infrastructures in real time. Both datasets can be pinpointed at preset positions according to positions of card readers and wireless internet accessing points.

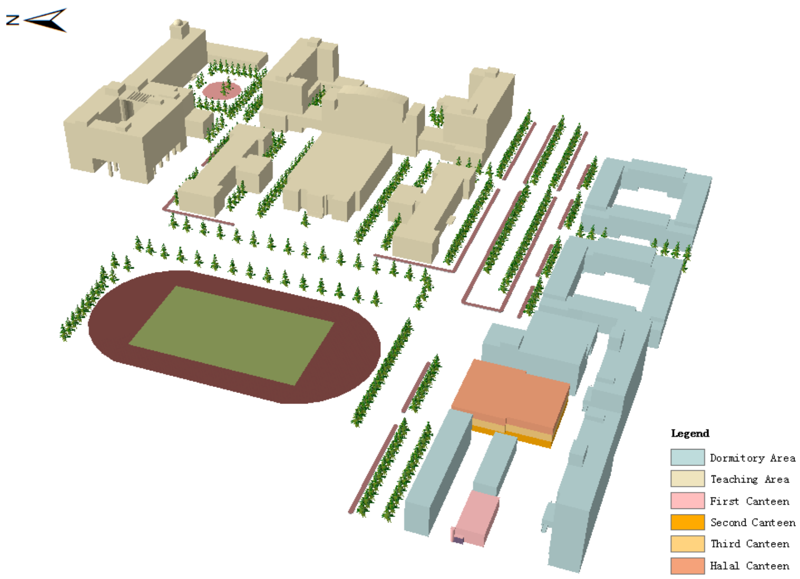

Figure 1. Schematic map of CNU

2.1 Campus Card Transaction Data

Campus card used by faculty members and students can effectively integrate all resources and behaviors on campus. The wide range of usage makes campus cards a rich source of data to reveal users' behavior patterns (Ebadi et al., 2017). Campus Card Transaction(CCT) data can record the time and user activities, including anonymous ID, location, department, etc. Therefore, their behaviors can be indirectly analyzed with that data. Anonymized CCT data covering April of 2017 from Digital Campus Center was acquired in CSV files to further understand the dining habits of employees and students.

All records are grouped into different datasets according to transaction locations, which are the card readers' positions. There are actually some exceptions that people prefer take meal back to dormitory. These situations are hard to distinguish after data anonymous processing, which is regarded as having meals in the canteen.

2.2 Wireless Log Data

Wireless Internet access points (APs) are becoming widespread in many environments in urban areas. In general, mobile devices can be configured to scan the surrounding environment for APs and continue to transmit signals. Universities have pioneered the development of infrastructures to provide connectivity (Zola et al., 2010) and users usually move around while connected. The research area is fully covered by wireless networks. So human mobility patterns can be mapped by identifying which building the AP belongs to. The canteens host 15 active APs sharing the same network name, which makes users roam seamlessly from one access point to another. This paper acquired anonymized wireless connection log data of 2 months. Each record of the log files presents AP name, the anonymous ID, the MAC address of the AP, received signal strength indicator (rssi), the time stamp at which the AP received the signal.

CCT data and wireless log data were both anonymized from two independent systems. It is not possible to identify the same user in the two datasets. Due to latency and positioning problems, wireless log data cannot be used to pinpoint the exact time of arrival of canteen patrons. On the other side, CCT data can be used to determine the time and position of a user starting his/her first transaction during breakfast/lunch/dinner. To determine how long patrons stay in a canteen, both datasets can be used complementarily. We assume that people will leave immediately after their meal, and people would spend one minute passing by adjacent canteens in the same building. The data used to infer human footprints need to be processed into datasets with some necessary fields, such as AP name, log-in time and log-out time. Three goals need to be achieved during data processing. Firstly, a majority of users could connect to different APs over the period, while some users are only captured by a single AP. In order to minimize spatial inaccuracy, these data need to be removed from the dataset. Then, we retain the observation with the highest value of rssi to identify the closest AP during meal time. Secondly, we set time threshold to eliminate two kinds of noises, which are signal jumps between two access points of adjacent floors and passing by canteens without having meals. It can eliminate noises of the user's records in identifying his/her true location, which is beneficial to extract the accurate dining locations. Thirdly, it is essential to cope with the time stamps at which the right AP received and disconnected the signal to obtain dining end time. Therefore, we can calculate meal duration in a way that can be feasible and objective without any subjective surveys and tests.

2.3 Research Methods

Human density denoted by D means that the average number of people who have meals in a canteen during a unit of time period. Meanwhile, seat ratio represented by S shows the real-time use of canteen seats. From this point of view, it is critical to sequentially acquire dining start time and end time with CCT data and wireless log data. We can accurately count how many people are having meal at a certain moment. These show that how the two datasets are used to determine population at given locations, offering a more efficient and comprehensive alternative to common approaches. The calculation formulas of S and D at the moment T are as follows:

（1）

（2）

Where t is the average meal duration, P_i is the number of people in the canteen at time i, and, N_{seat} and $N_{area}$are the number of seats and area of the canteen. Considering a phenomenon of waiting in line during meal peak, we subtract two minutes to acquire the final meal duration.

3. RESULTS and ANALYSIS

A choice of which canteen a patron prefers to go depends not only on personal dinning habits, but also on dining environment. Usually, the number of people could exceed the capacity of the physical space of the canteen during peak hours. This potentially deteriorates the quality of patrons' dining experience. We can find that lunch time is mostly between 10 and 30 minutes in

Figure 2. However, there are some differences between four canteens. To be more accurate, we calculate average meal durations (Table 1) to derive the amount of people having meal in canteens during a day.

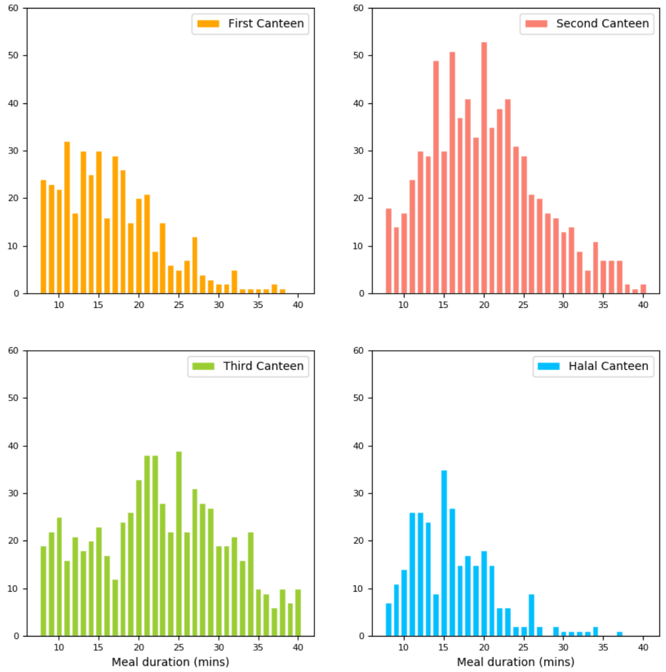

Figure 2. Meal Duration at Lunch

Table 1. Average Meal Duration

	First Canteen	Second Canteen	Third Canteen	Halal Canteen
breakfast	8min	9min	0min	9min
lunch	17min	19min	23min	15min
dinner	18min	21min	23min	17min

As shown in the time series line charts of dining flows (Figure 3), the peaks appear at about 11:20am during lunch time. However, the population in Halal Canteen is much lower than the other three ones. In addition, there are dining valleys which happen in a short time in First Canteen, Second Canteen and Third Canteen.

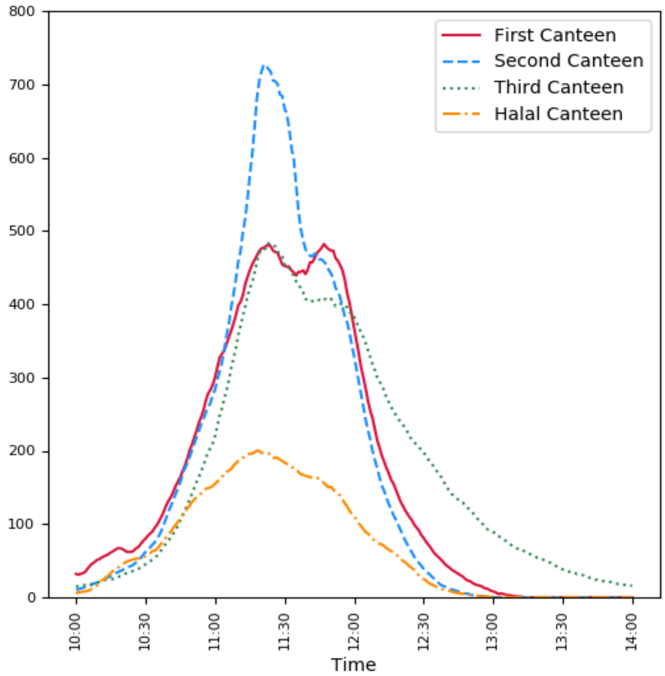

Figure 3 Time Series of Dining Flows at Lunch

Spatial comfort in this paper could be used to evaluate the congestion of canteens. When the number of people in the cafeteria reaches a certain level, the individual will feel uncomfortable which will affect dining experience and even the absorption of nutrients (Stroebele, 2004). In the Figure 4, we see that human density and seat ratio seem to have similar trend. When the canteens are in use, the curves of two indicators climb quickly. This situation reflects that spatial comfort of canteens would be weakened. Moreover, human density of Second Canteen fluctuates more obviously. The value of seat ratio exceeds 1.0 from 11:15am to 11:35am, which means that people are difficult to find comfortable seats to have meal.

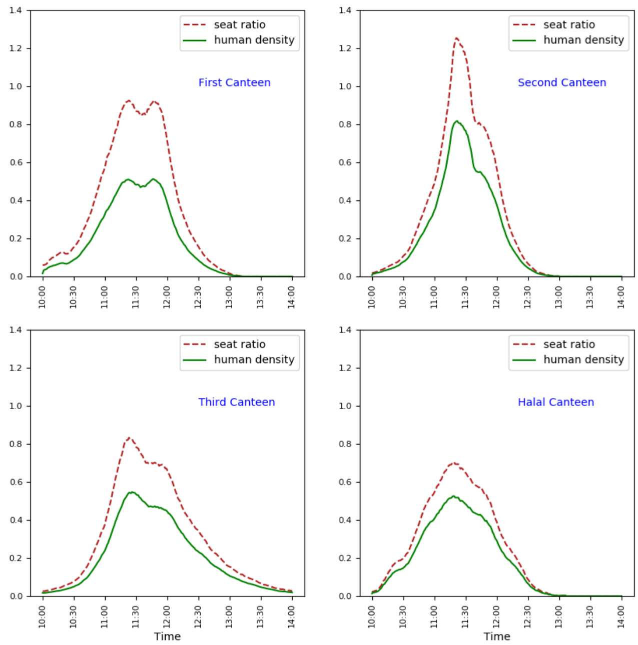

Figure 4 Time Series of Spatial Comfort

According to early analysis of dining behaviors and spatial comfort, we can quantitatively evaluate dining environment in an objective way. When $0.3<S<0.6$ and $0.2<D<0.4$, the dining environment is more comfortable. People can make full use of spatial for communication, and there is no idle waste in the canteen space resources. When $0.6\leqslant S\leqslant 0.8$ and $D\geqslant 0.4$, the dining space is crowded, and the spatial comfort is weakened. People need to spend time searching space to have meal and communicate with others. Once $S>0.8$, dining peak could make people feel more crowded. A suitable seat is not available to everyone, which directly influences their sense of spatial scale and even reduces the dining efficiency finally.

4. CONCLUSIONS

With the rapid development of colleges and universities, the function of the canteen is more diversified. Canteens have gradually been developed into comprehensive architectures that combine food, business, entertainment and other activities. In this paper, we present an integrated methodology that can employs CCT data and wireless log data to extract human behaviors of employees and students on a university campus, and measure spatial comfort of the canteen by human density and seat ratio. It can provide some useful information for them to have meal in a more comfortable manner. Additionally, efficient use of canteen space is conducive to improving the overall image and learning atmosphere of the campus, which can gradually improve the livability of campus space.

The big geospatial data generated by the campus IT systems can provide further insights beyond survey data, support multiple-day observations, reveal more robust mobility patterns, and cover wider geographic areas. In this context, it is extremely meaningful to mine and analyze big data in education to provide support to facility management and upgrading for a better livable space. The method presented here can be further modified and extended to summarize spatial-temporal behaviors in other environment, such as teaching building, library, playground, etc. The small-scale behavior evidence could enable planners to reasonably arrange the relationship of resources and users, which is expected to improve the level of harmony between campus space and human.

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