



空间、行为与数据：基于室内定位系统的研究

Space, Behavior and Data: Exploration of Data from Indoor Positioning system

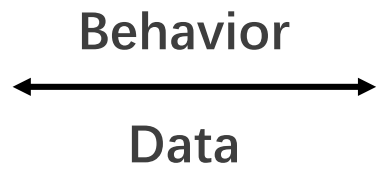
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Architecture
建筑



Human
人



Spatial Network
空间网络



Social Network
社会网络





WI-FI IPS

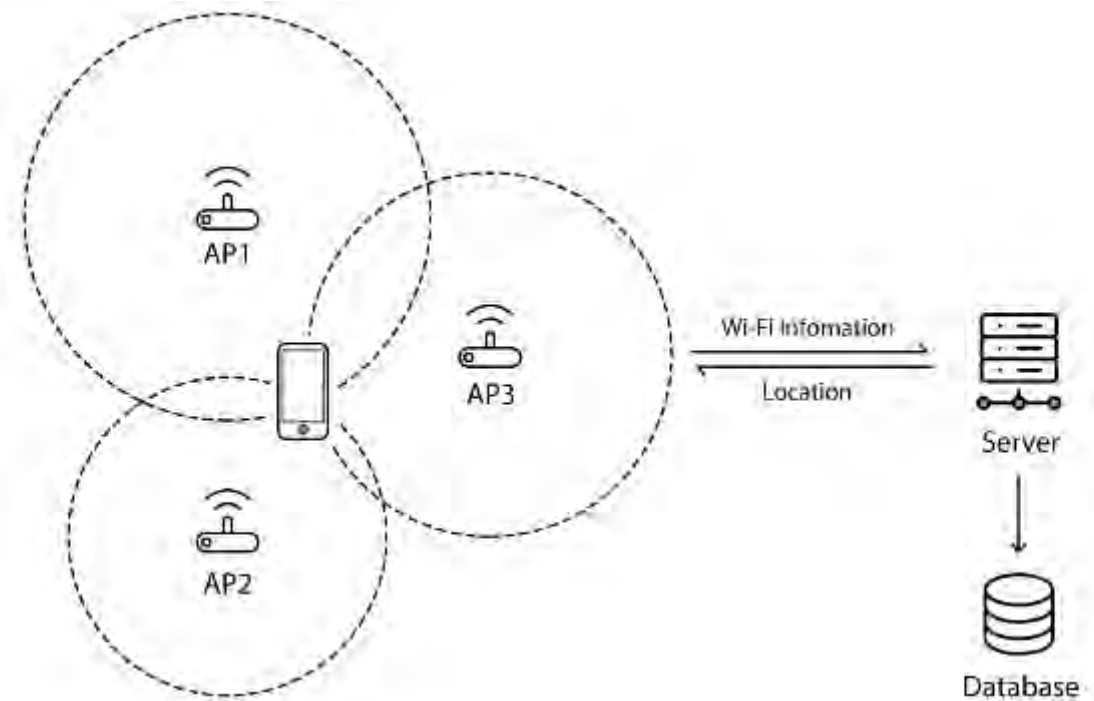
Advantages

GPS tracking technology or antenna signal tracking cannot be used inside buildings.

Radio frequency identification or ultra wideband require the subjects to wear specific devices.

Bluetooth IPS works well, but most people are not accustomed to keep the Bluetooth open.

Wi-Fi monitor is able to record activities of the mobile device unobtrusively. We could collect an amount of long-term, full-coverage information without observer effect.



VANKE SONGHUA LAKE RESORT

Function arrangement

A 250-meters-long commercial pedestrian street, providing ski rental, catering, family hotels.

A family hotel located in the north part of the pedestrian street.

Many restaurants in the middle part, and ski rental area in the south part with the ticket office.

The mountain and ski slopes located further south.



Huang Weixin, Lin Yuming, Wu Mingbo. Spatial-Temporal Behavior Analysis Using Big Data Acquired by Wi-Fi Indoor Positioning System[C]. Proceedings of the 22nd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2017. Suzhou, China. 2017.4.5-2017.4.8

ANALYSIS: SPATIAL DISTRIBUTION

Heat map of devices

Accumulative distribution of data in 60 days. People are mainly distributed along the pedestrian street.

The darker color of areas are important functional spaces such as hotels, restaurants and ski rental shops.

The right part of the figure is beyond the coverage of our data.



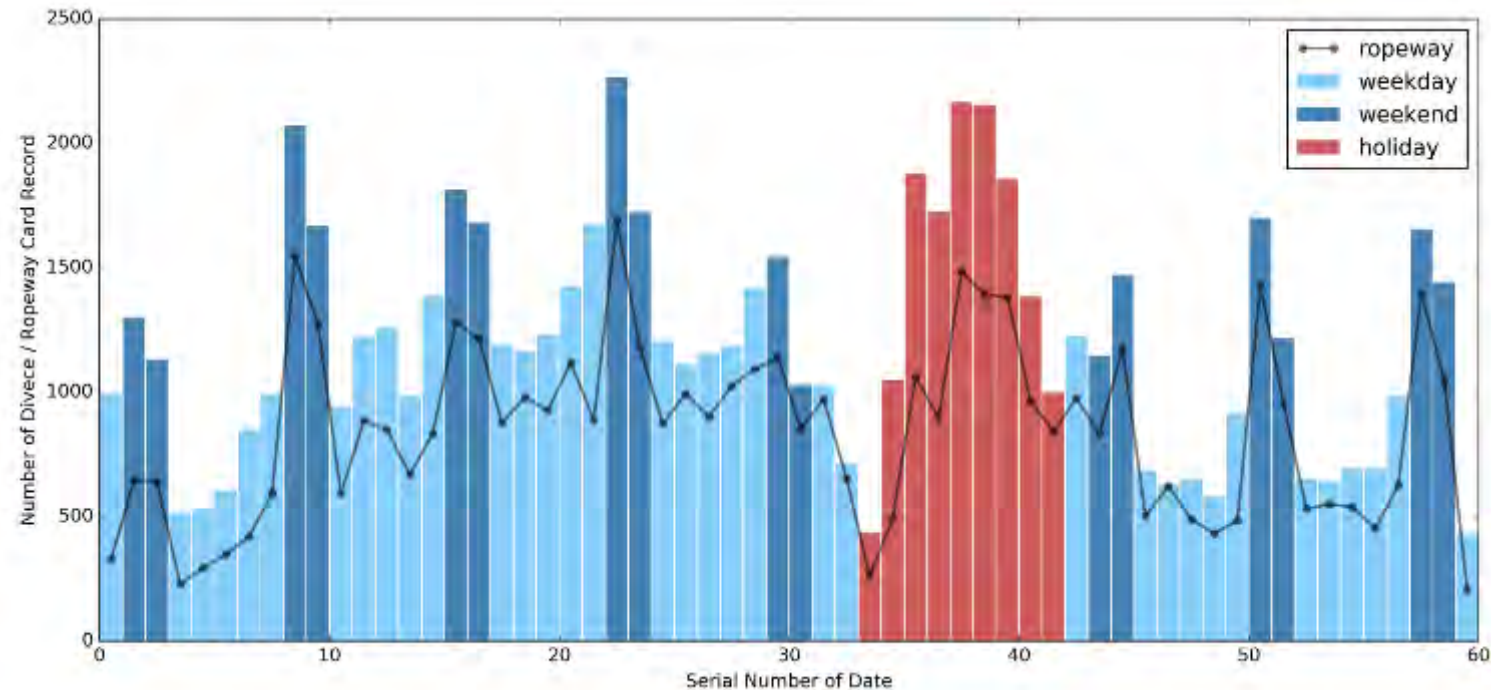
ANALYSIS: TEMPORAL DISTRIBUTION

Daily flow of devices

The flow is about 34% larger in the weekends and 15% larger during the Spring Festival holidays.

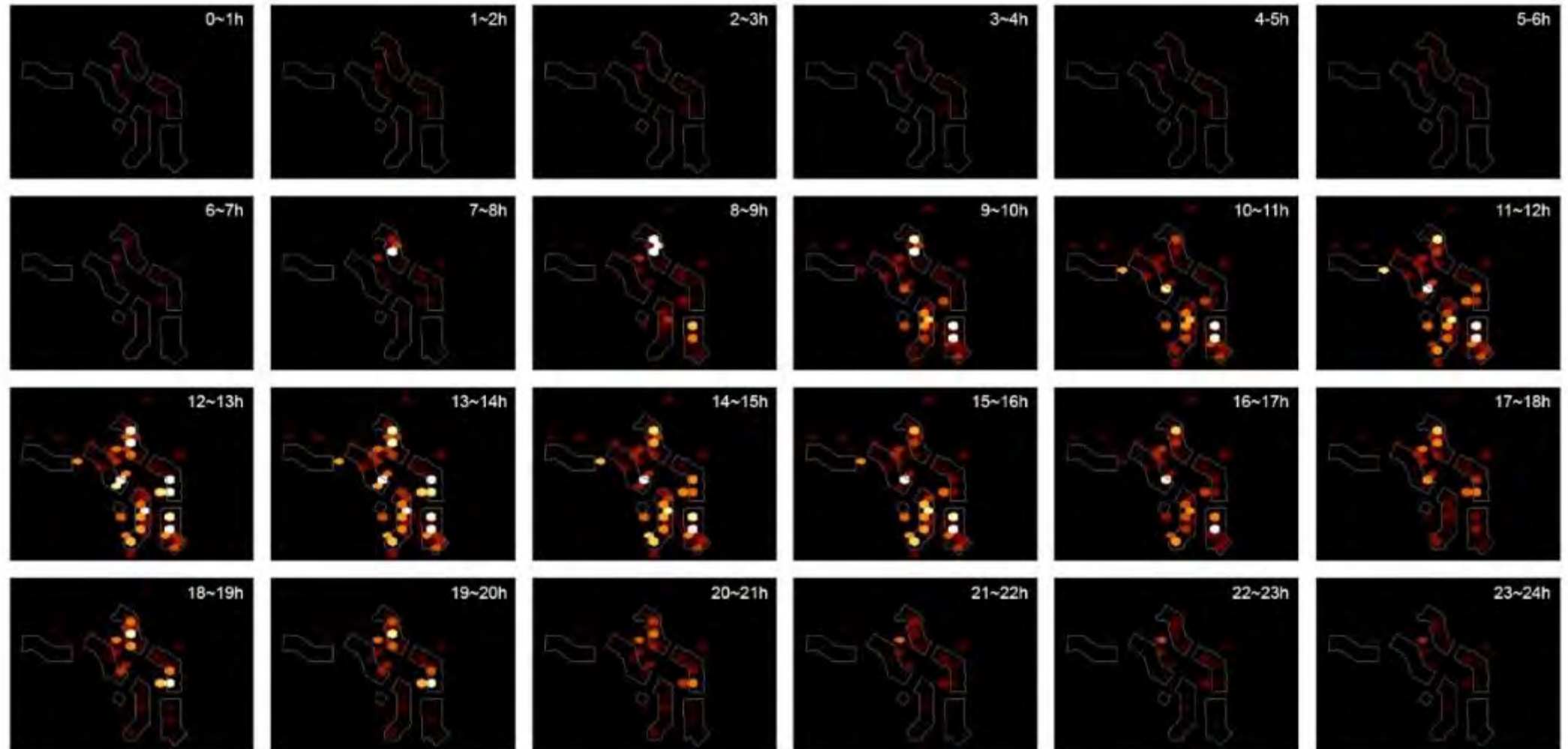
The correlation between the number of ropeway record and the number of devices is 0.9137.

Though do not exactly have one to one correspondence with people, the number of devices is still a reliable reflection of the resort's traffic.



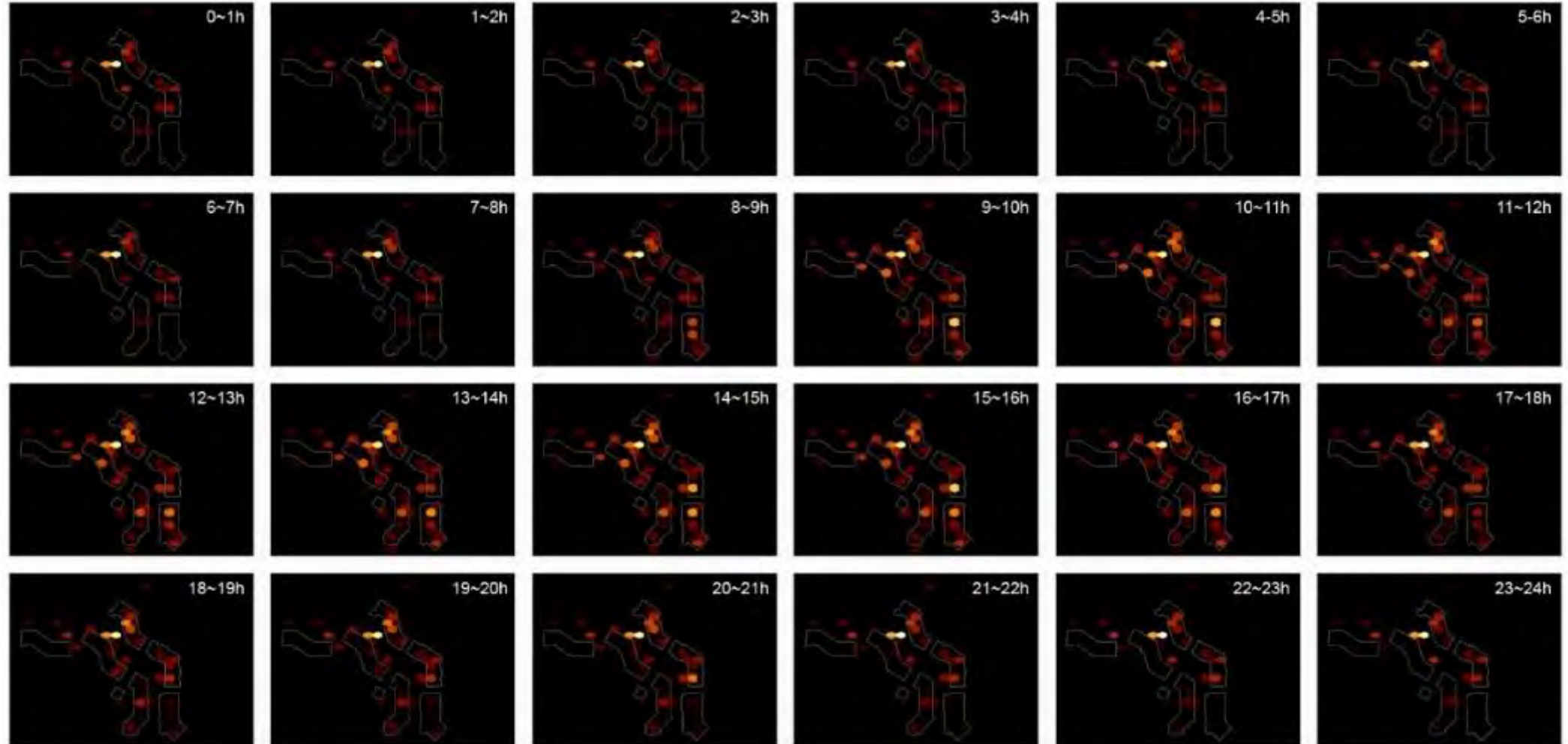
SUB-GROUP ANALYSIS: SPATIAL-TEMPORAL DISTRIBUTION

Customer



SUB-GROUP ANALYSIS: SPATIAL-TEMPORAL DISTRIBUTION

Staff



SUB-REGIONS ANALYSIS: TEMPORAL DISTRIBUTION

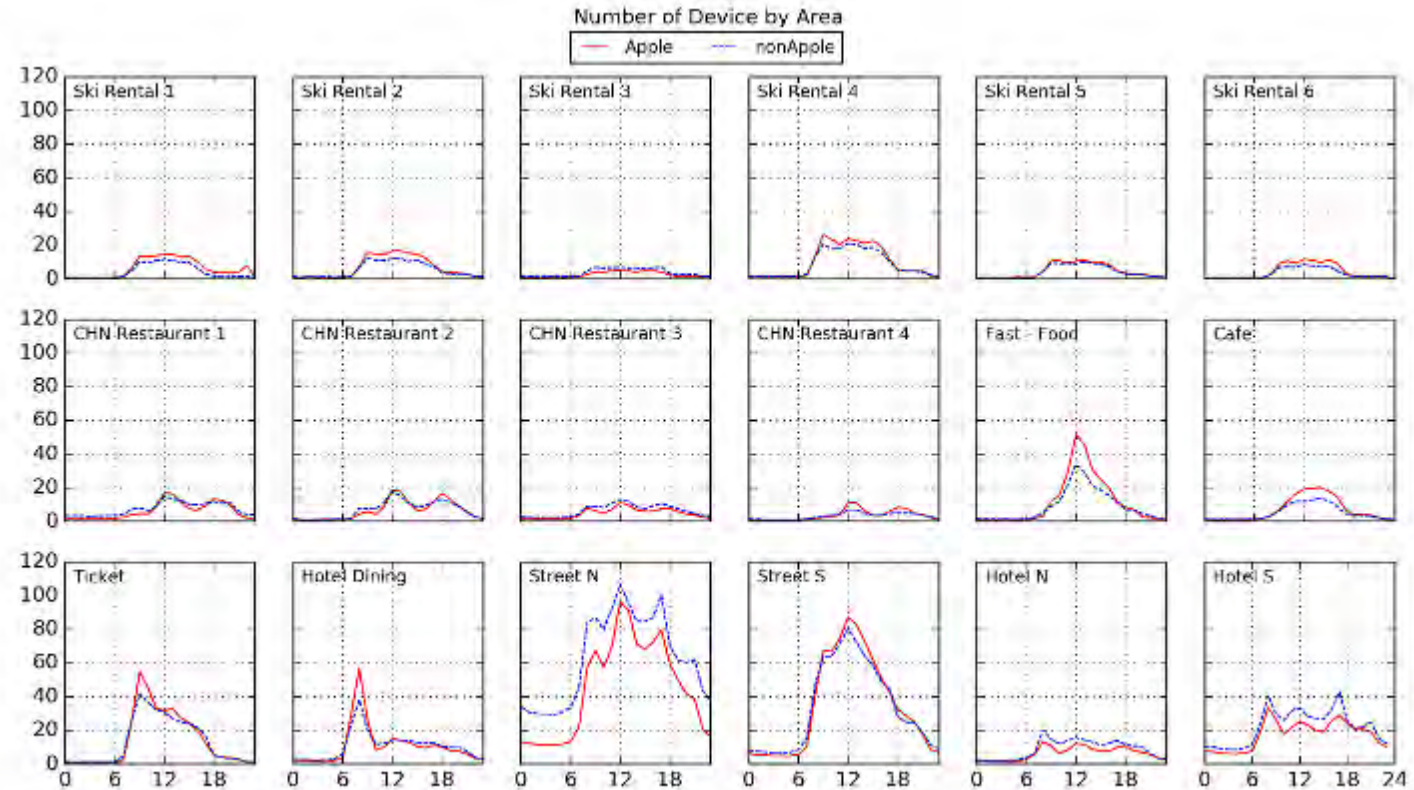
Business type

Ski rental shops have a relatively uniform flow during daytime, with a small peak in early 9-10 am.

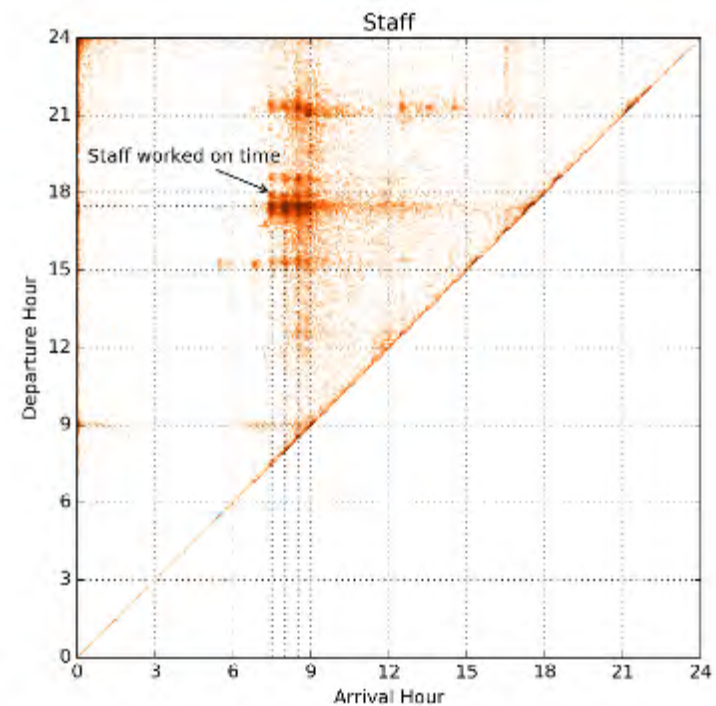
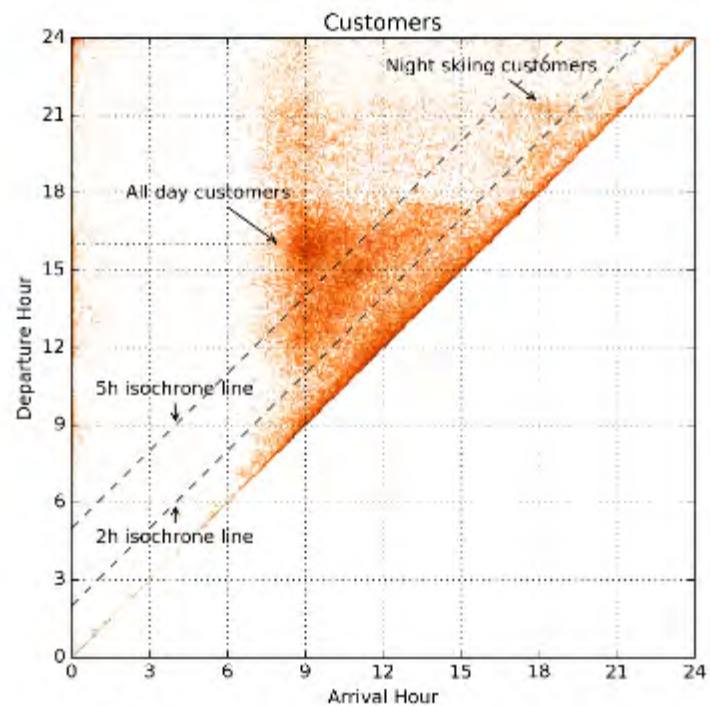
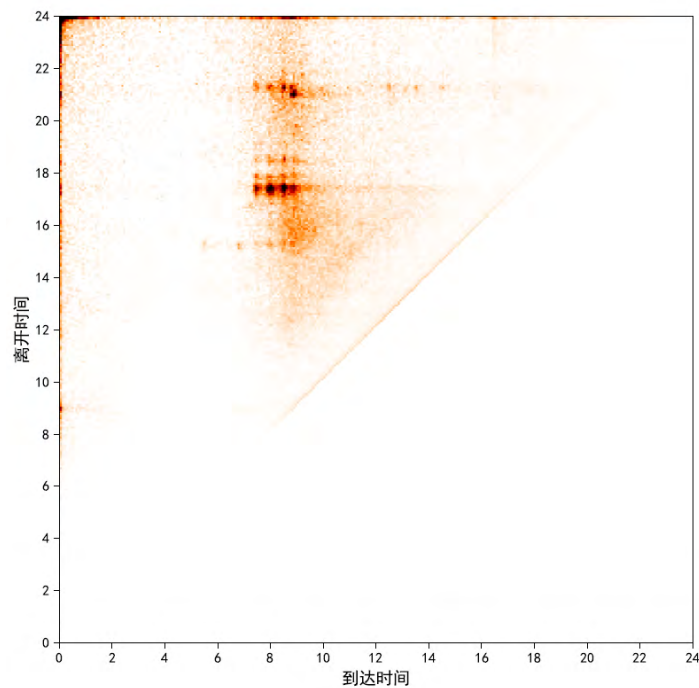
Fast - food restaurants have large traffic concentrated in the lunch time, while Family hotel restaurant has a significant peak in breakfast time.

Peak flow of ticket office emerges at 9-10, and then maintain a certain amount of traffic.

Apple user and non-Apple users can be distinguished, implying to the different consumption habits.



ARRIVAL-LEAVING



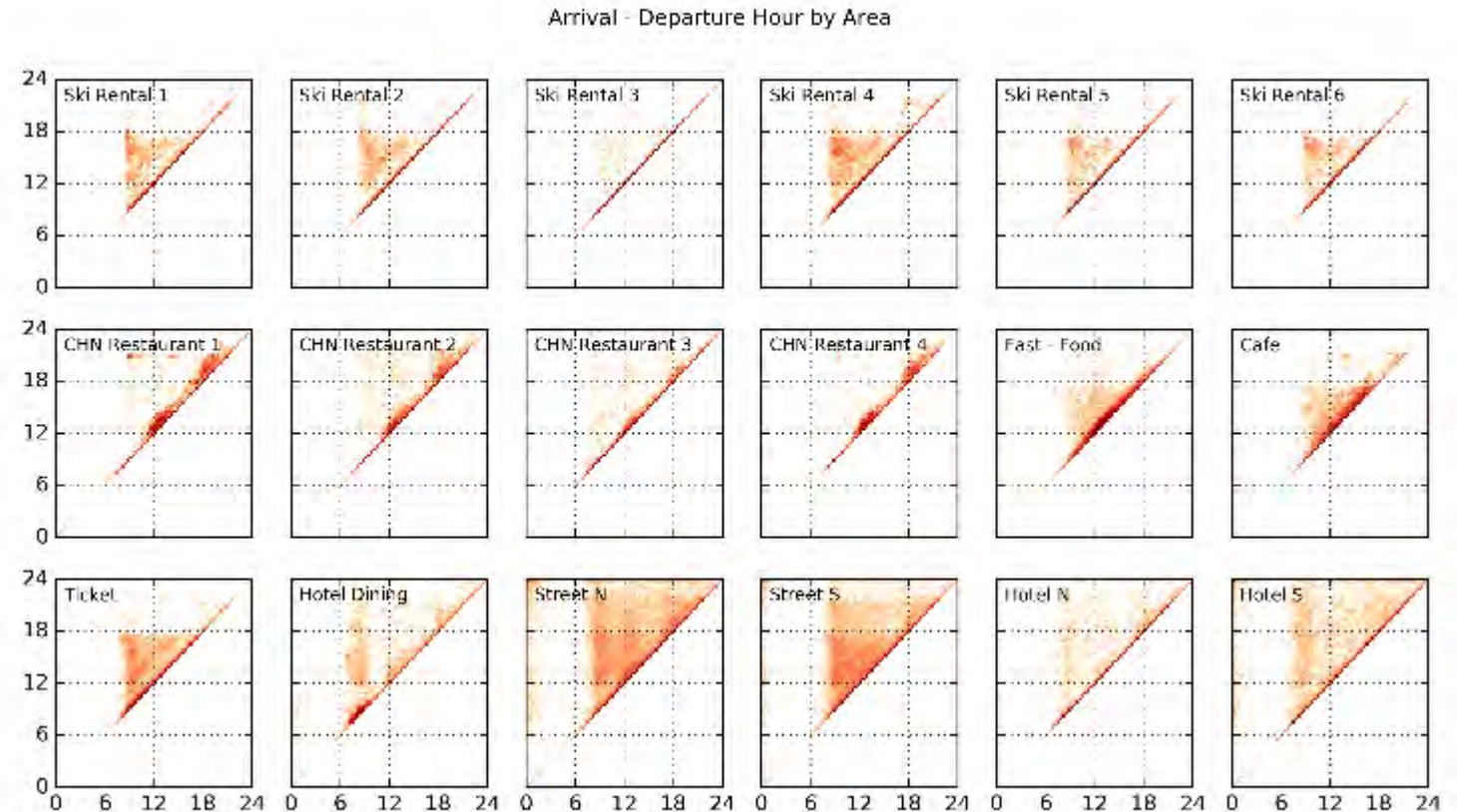
SUB-REGIONS ANALYSIS: ARRIVAL-DEPARTURE

Business type

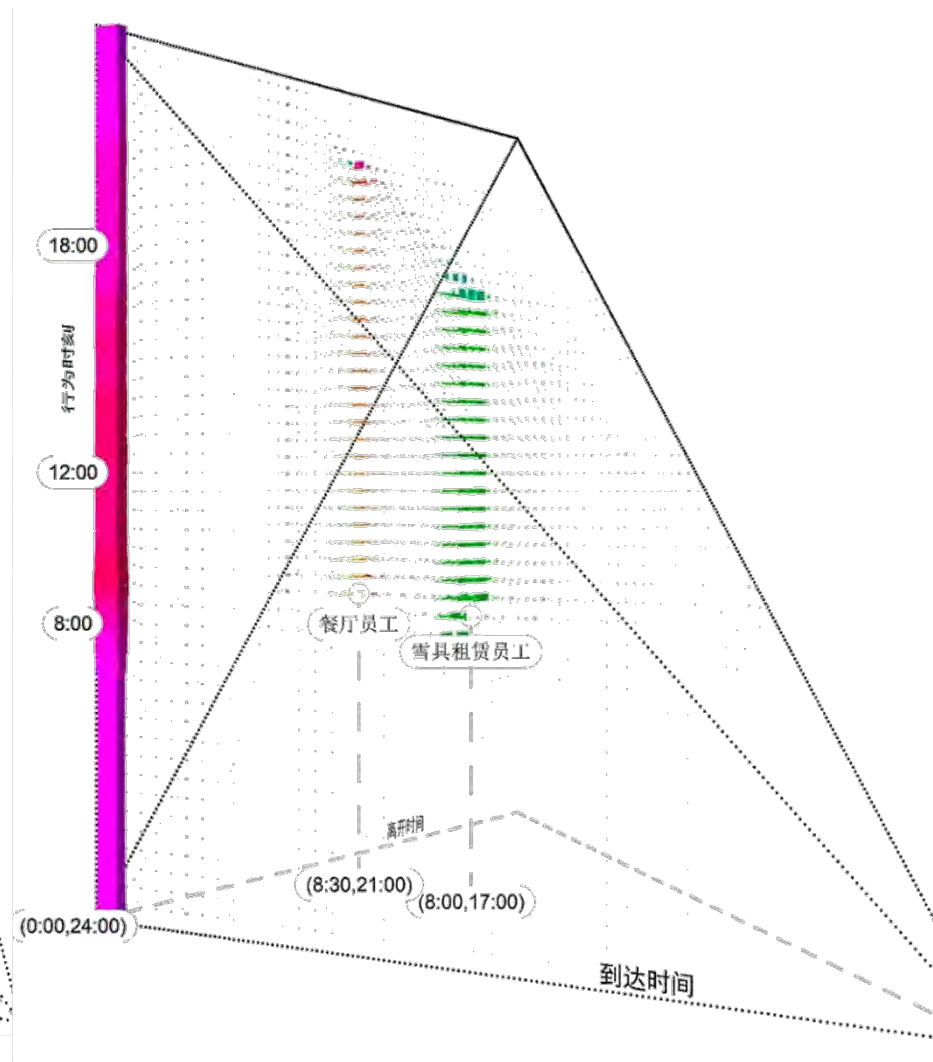
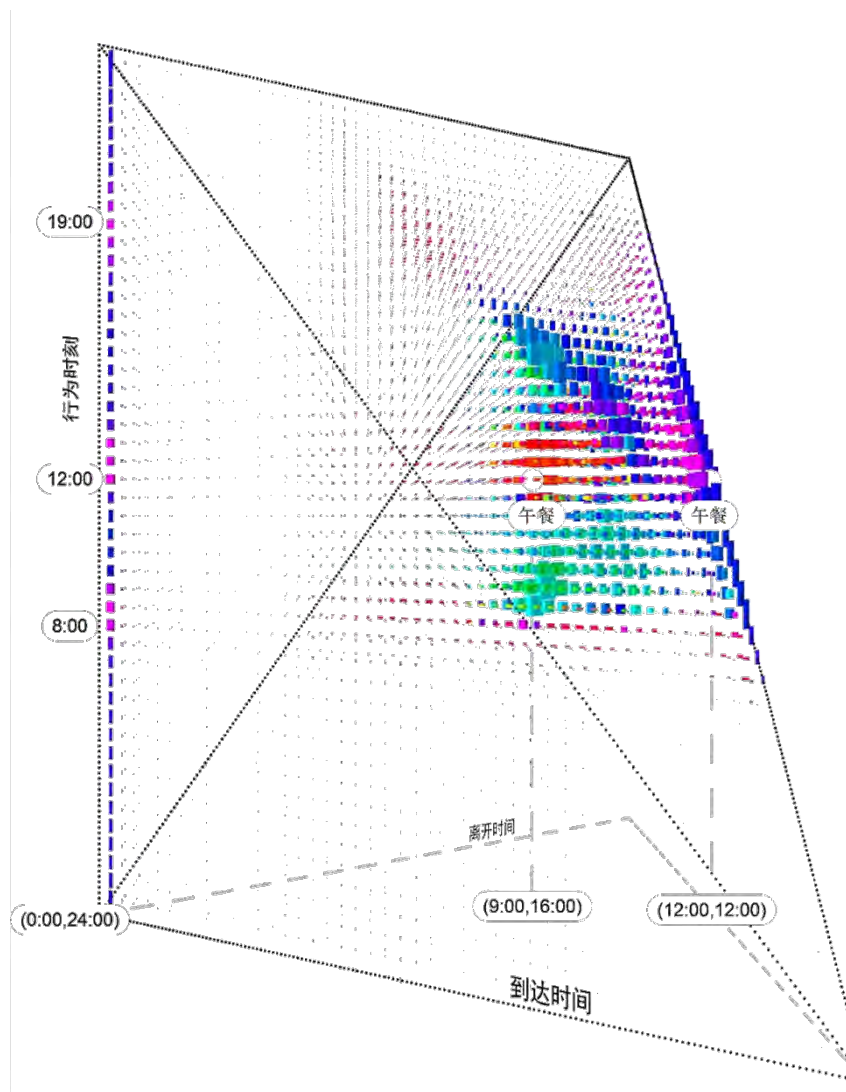
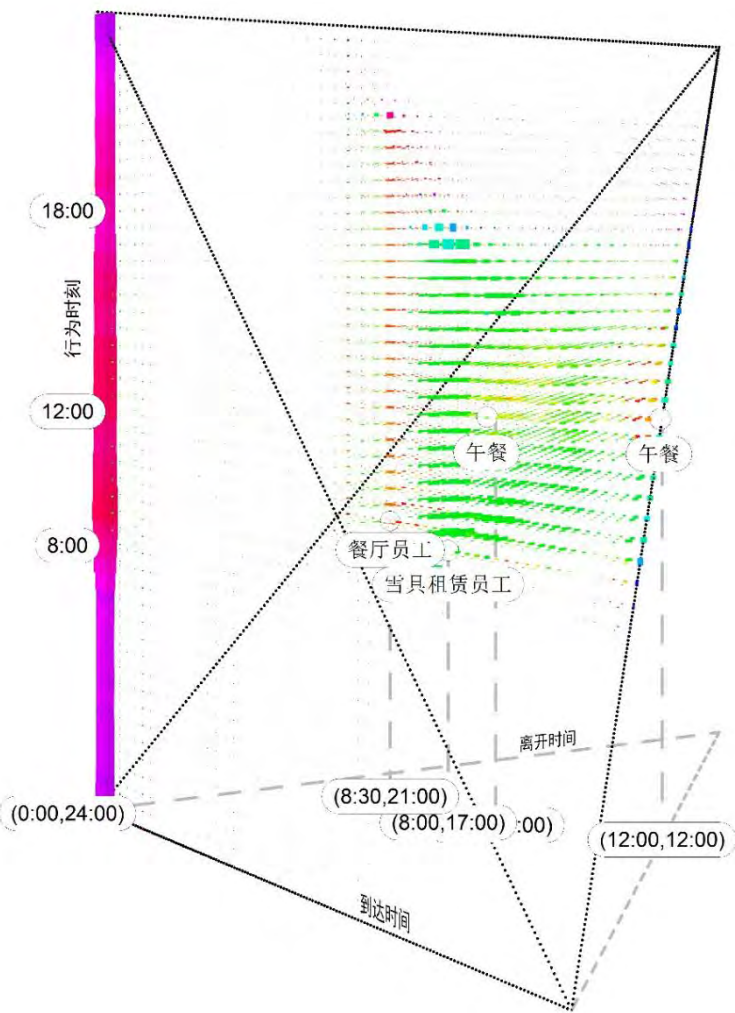
All-day skiers and half-day skiers can also be distinguished in the ski rental shop.

Customers will stay longer in Chinese restaurant during lunch and dinner, while fast - food restaurants may experience a greater peak in lunch, with shorter staying time.

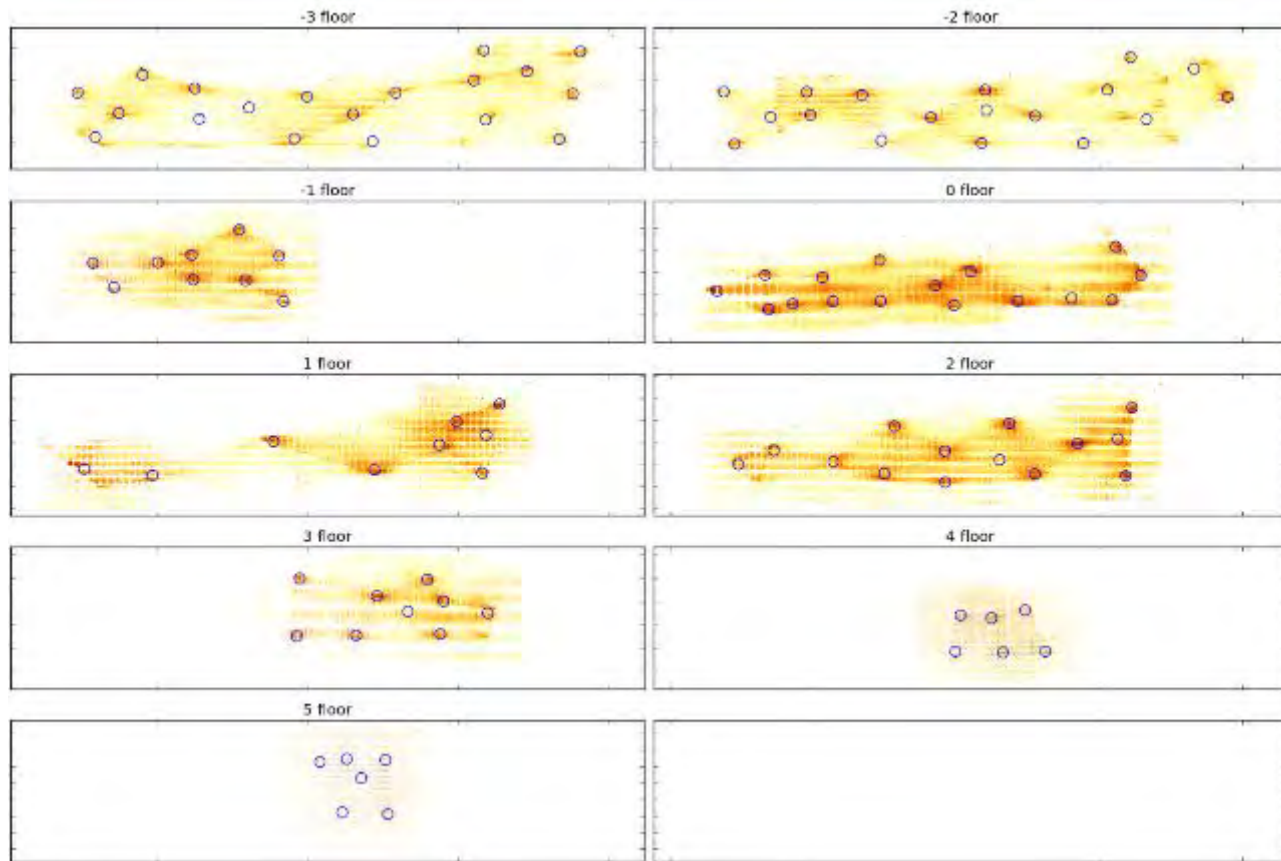
As for the ticket office, the full-day skiers and half-day skiers can be distinguished on the distribution graph.



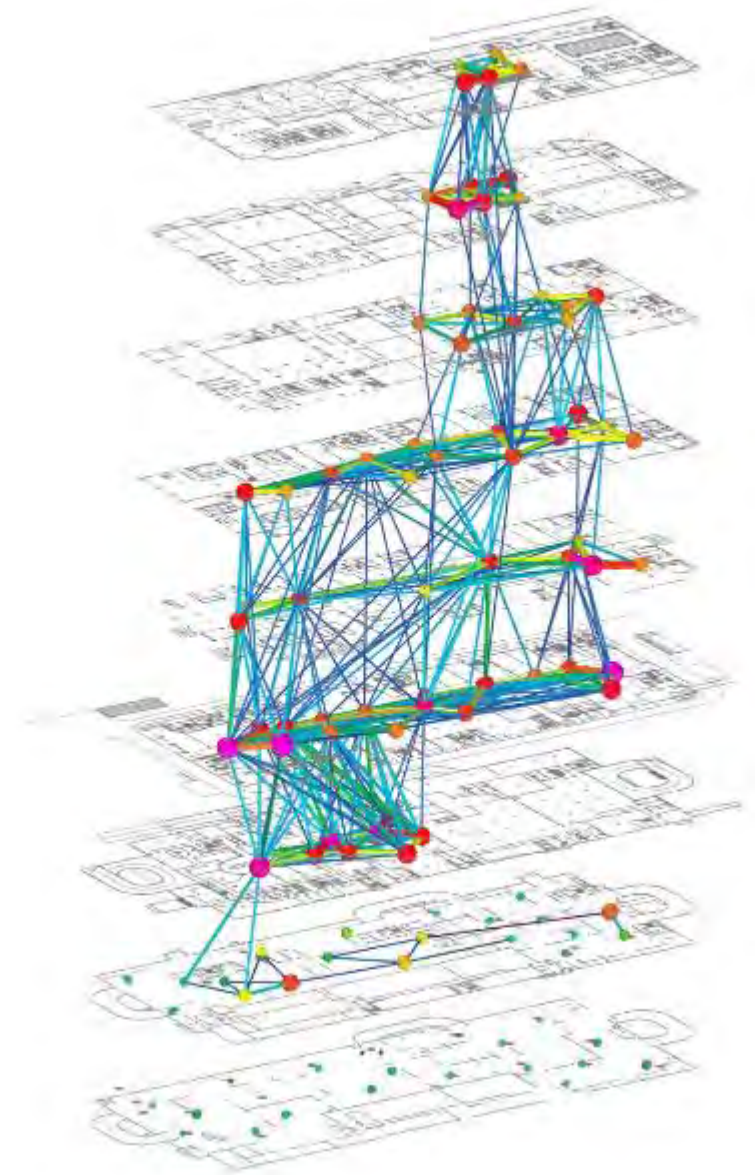
■ 餐饮休闲 ■ 雪具租赁 ■ 室外活动



Shopping Mall in Beijing



IPS data distribution

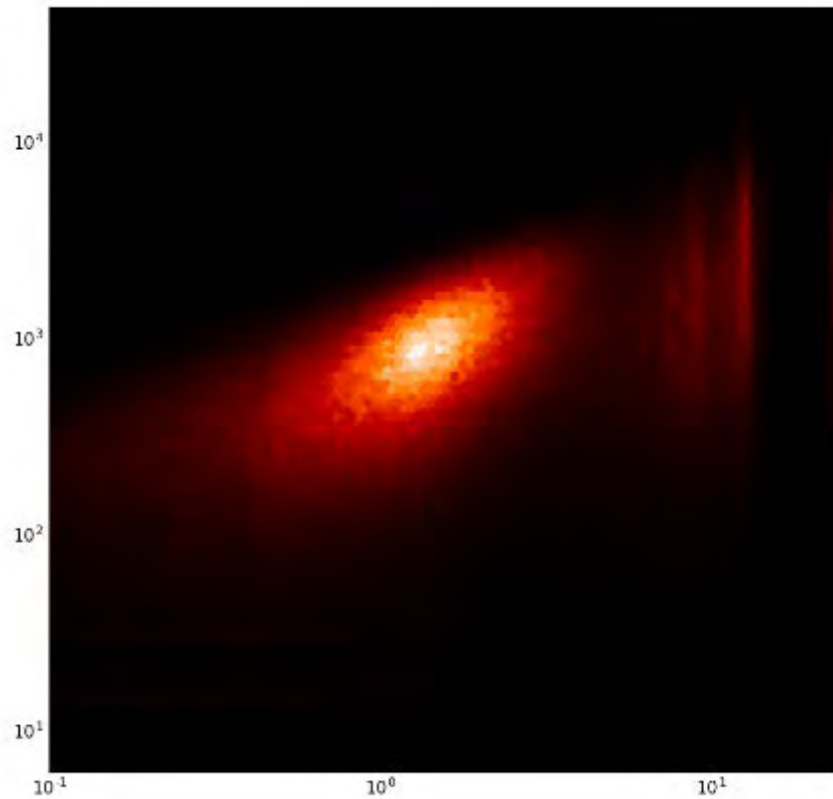


Spatial Circulation

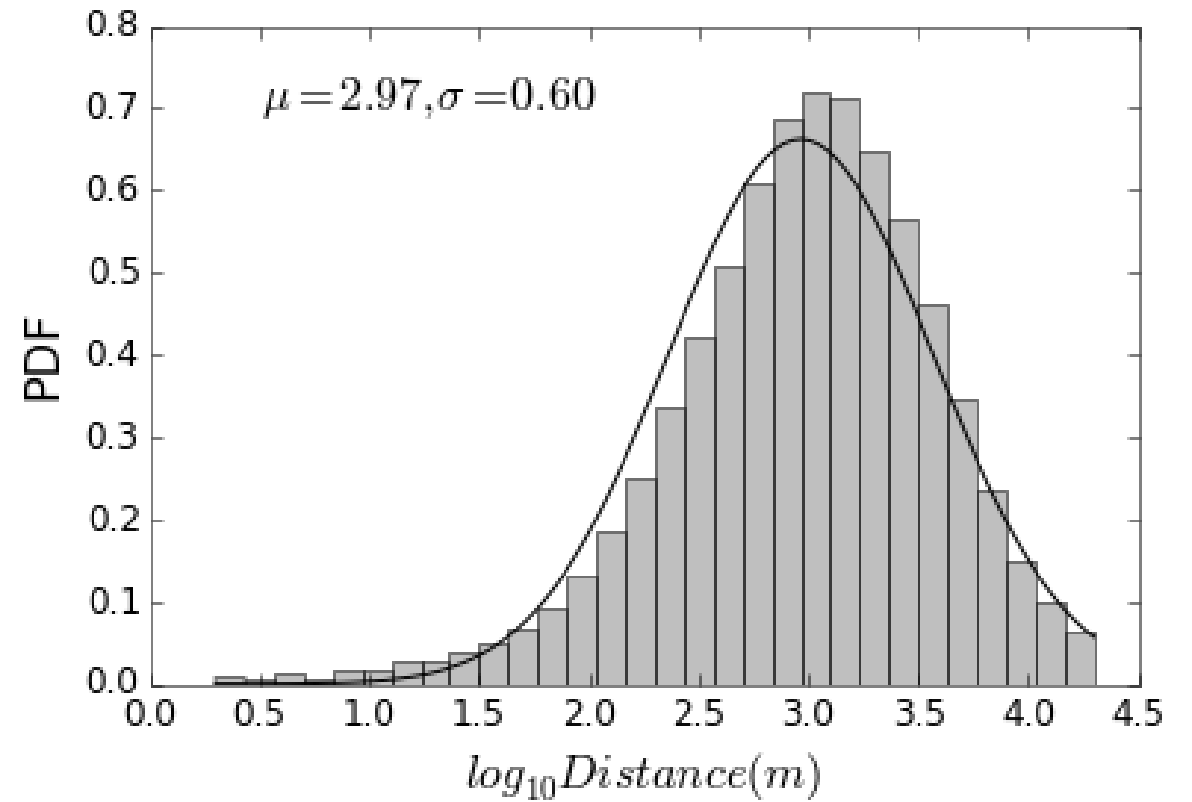
Mobility of Customers

Average stay time: 1.5 hours

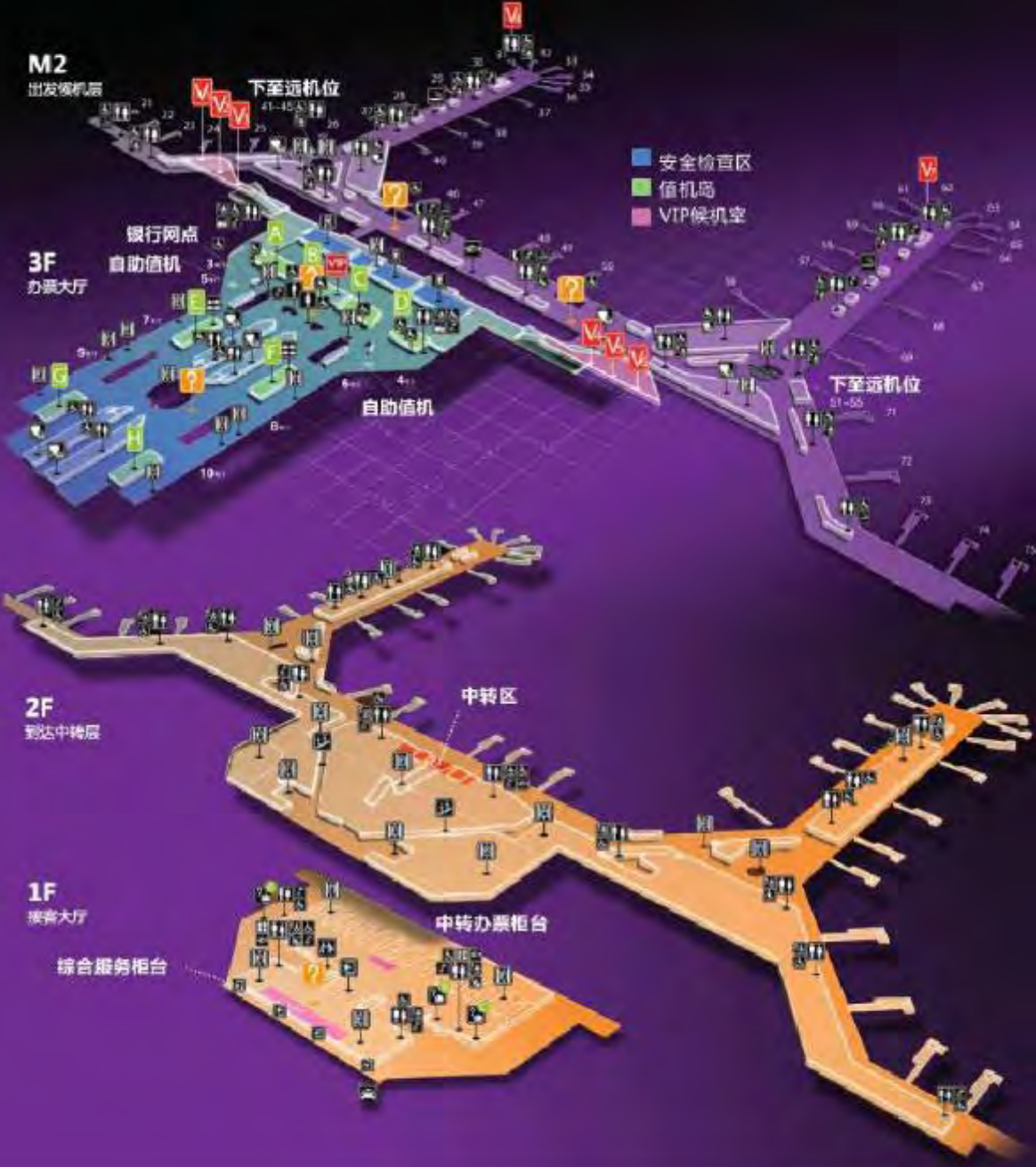
Average speed: 0.2 m/s



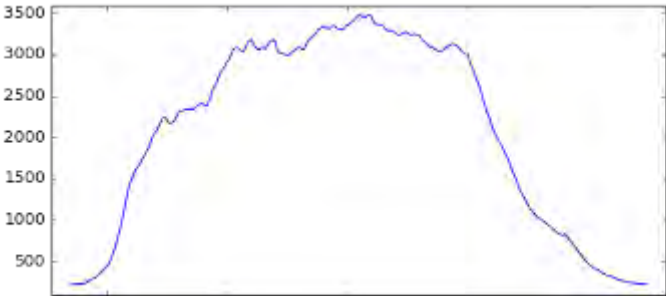
Lognormal Distribution of walking distance



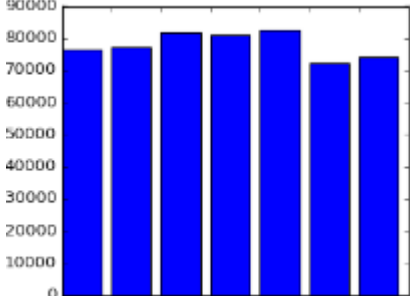
Airport in Shanghai



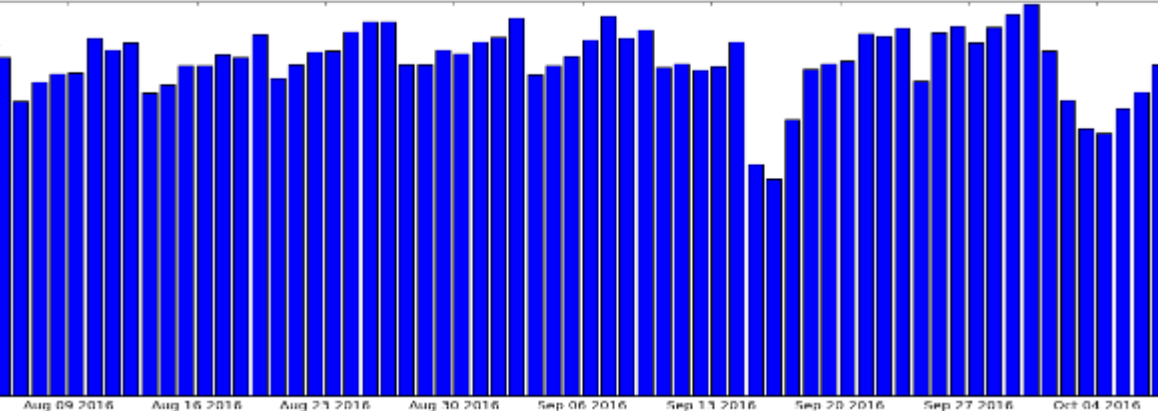
IPS Data Temporal Distribution



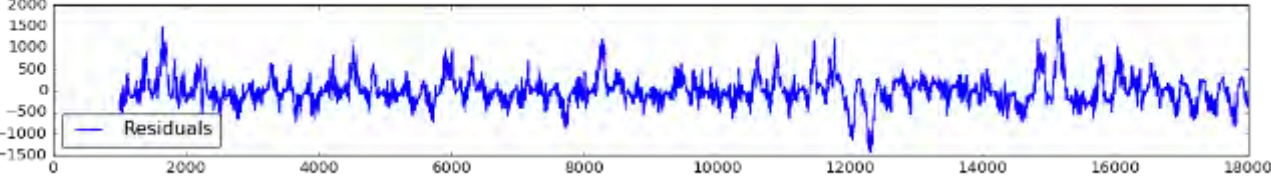
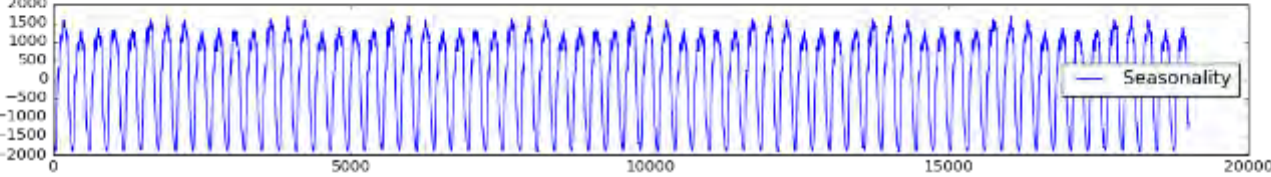
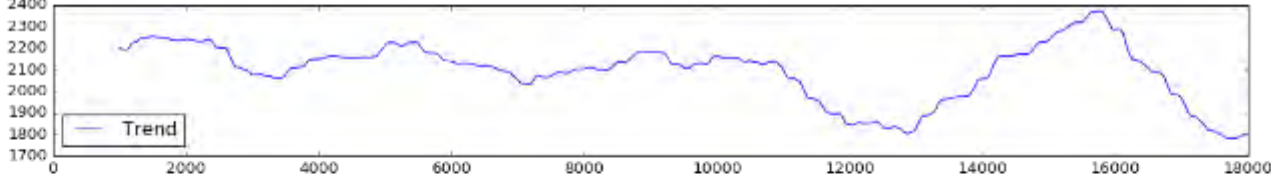
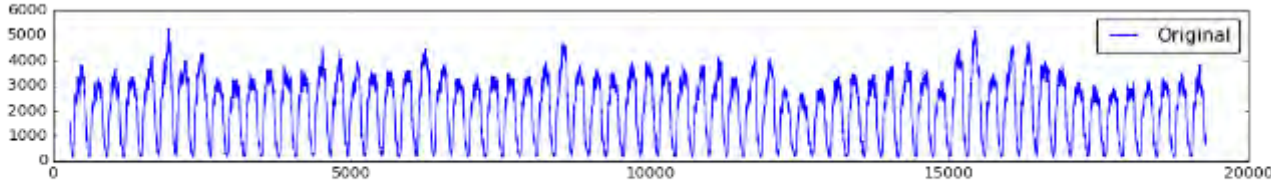
Hourly flow



Weekly flow



Daily Flow

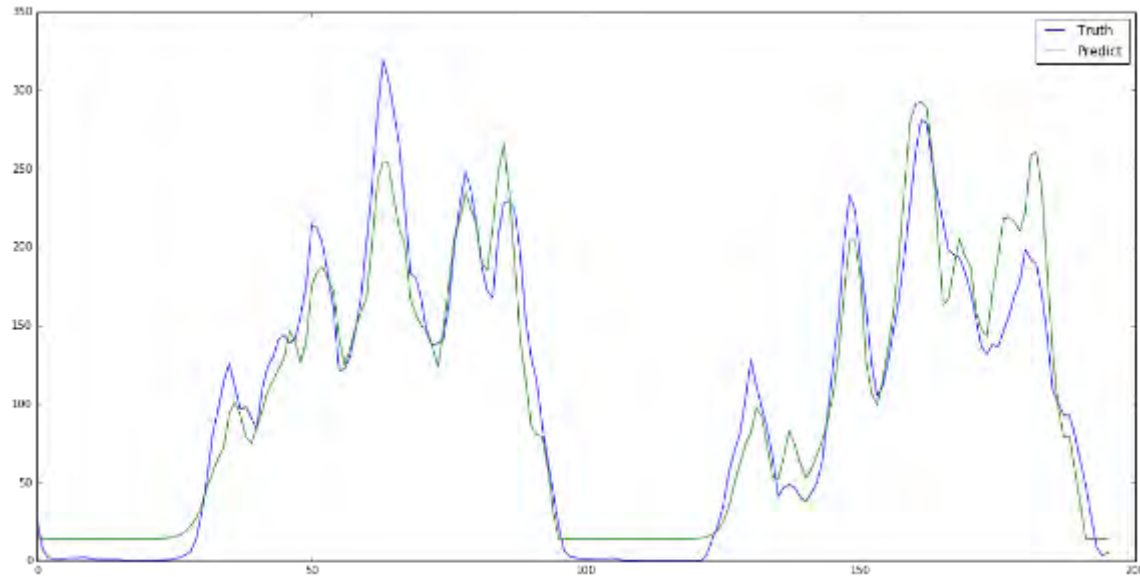


Trend Analysis

Flow Prediction of an Area

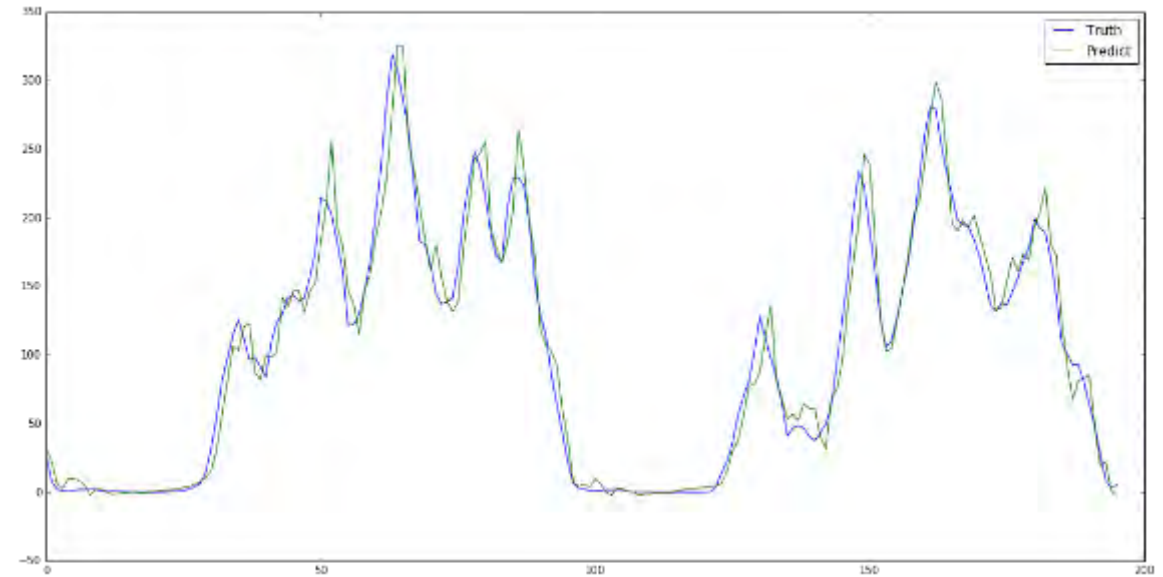
(Several Wi-Fi Antennas and Gates Included)

Prediction based on flight information



MAE: 27.866909
MAPE: 23.4%

Prediction together with real time Wi-Fi data

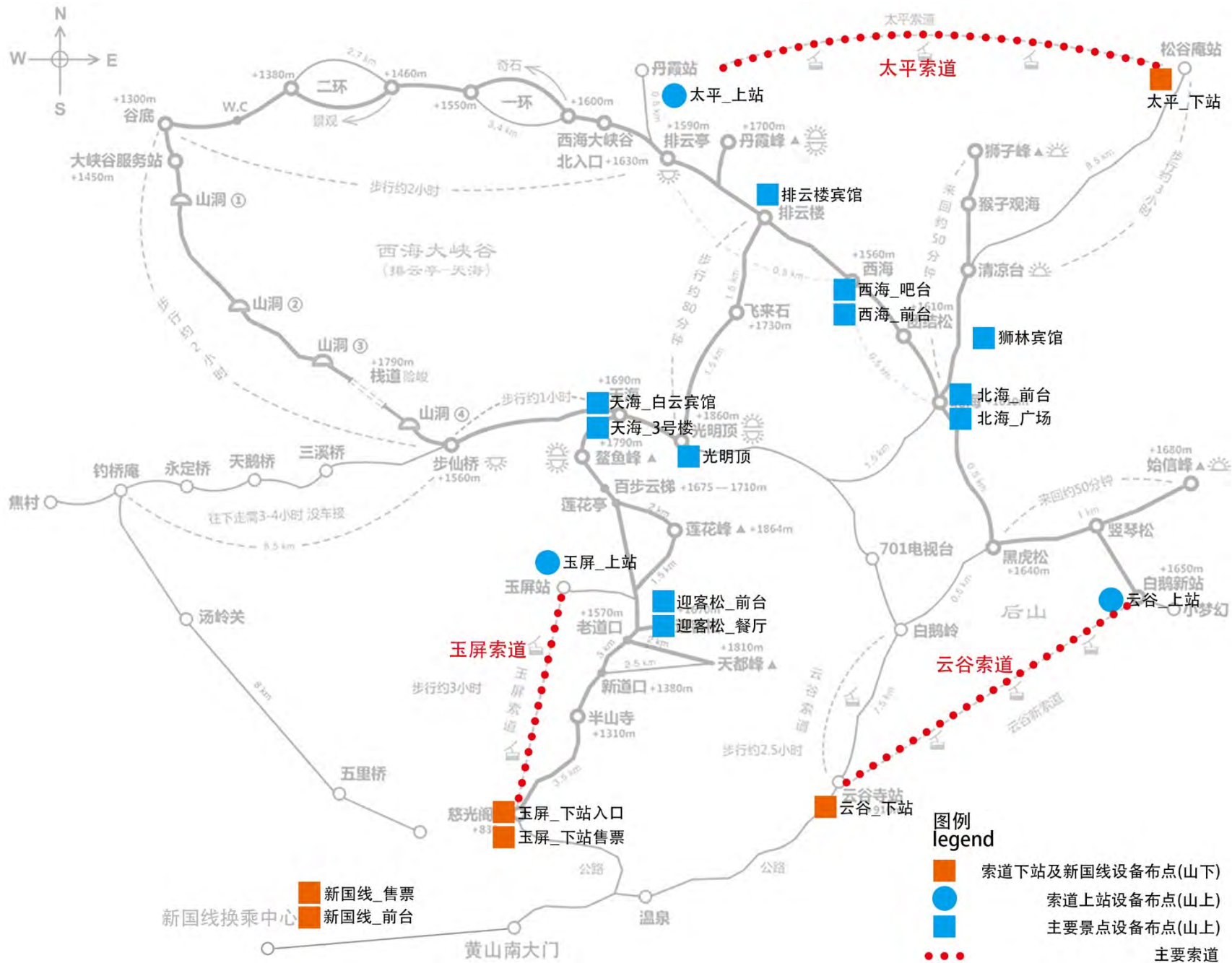


MAE: 11.394500
MAPE: 9.58%

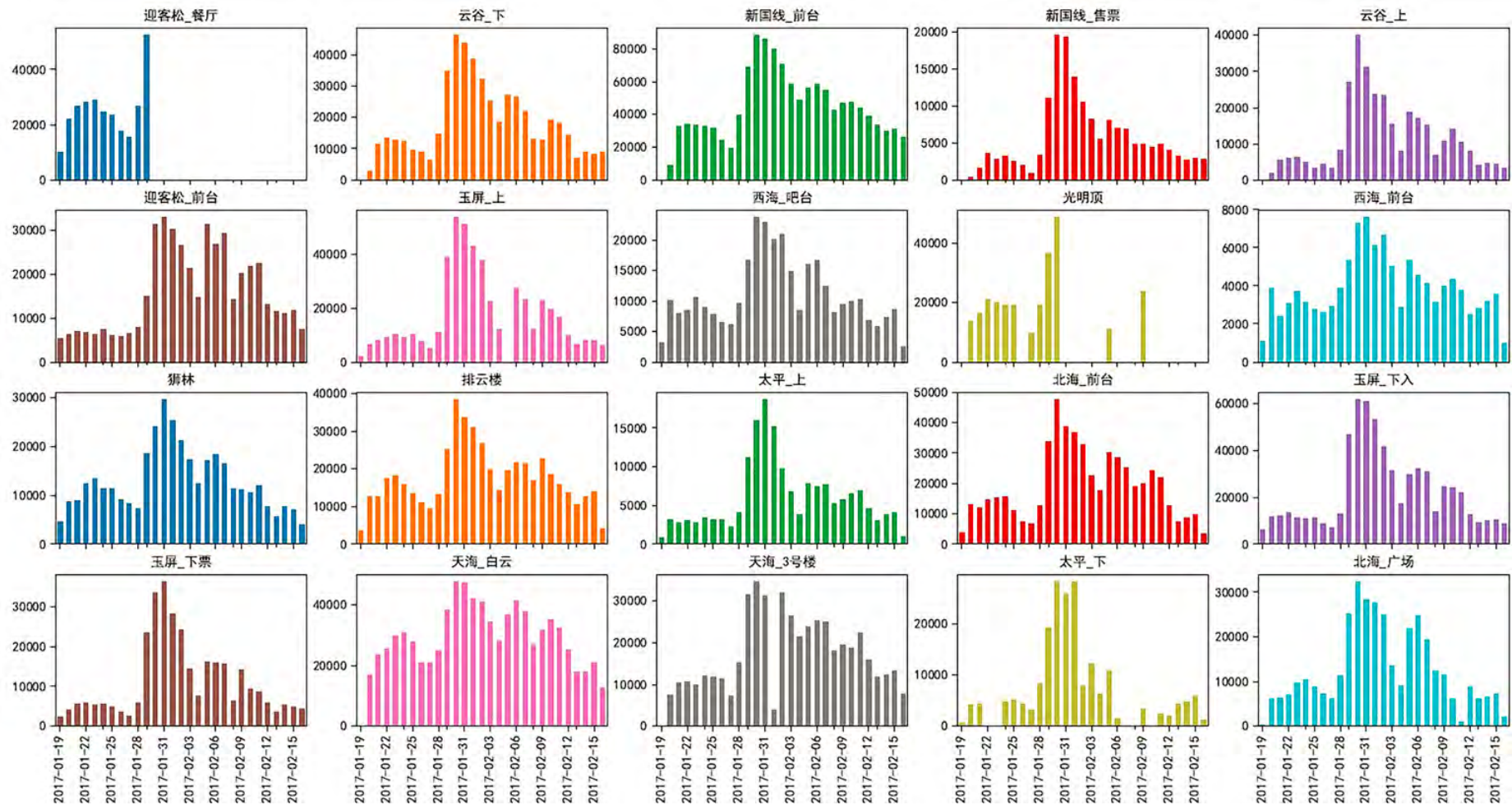
黄山 Huangshan



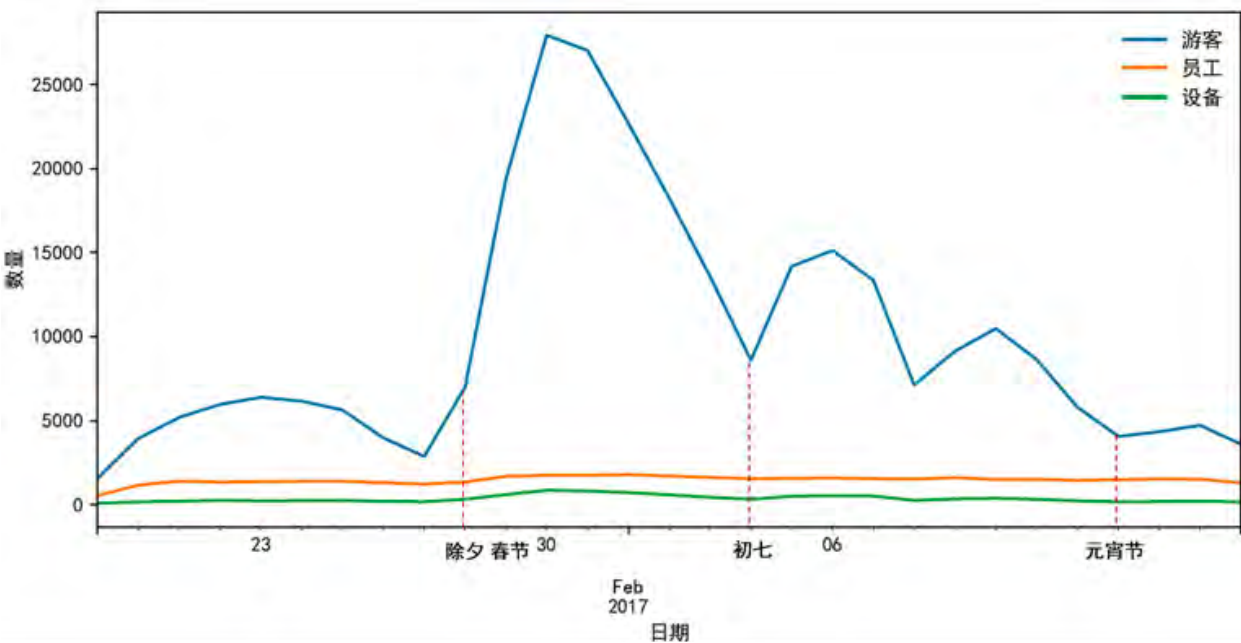
黄蔚欣, 张宇, 吴明柏, 党安荣. 基于WiFi定位的智慧景区游客行为研究——以黄山风景名胜区为例[J]. 中国园林. Vol.34, No.267, pp25-31, 2018.03



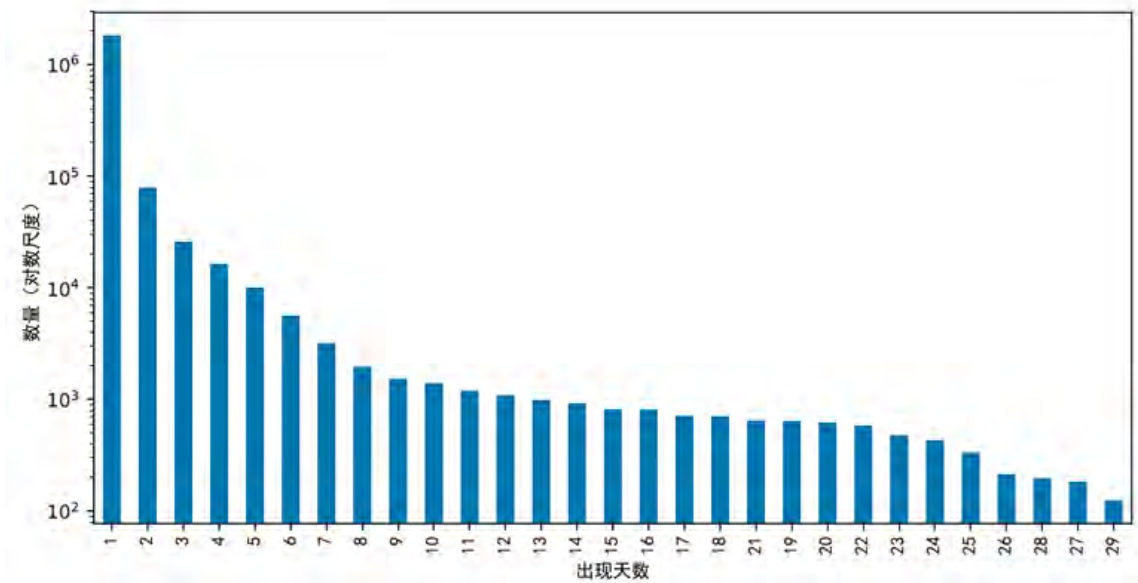
Wi-Fi Antenna



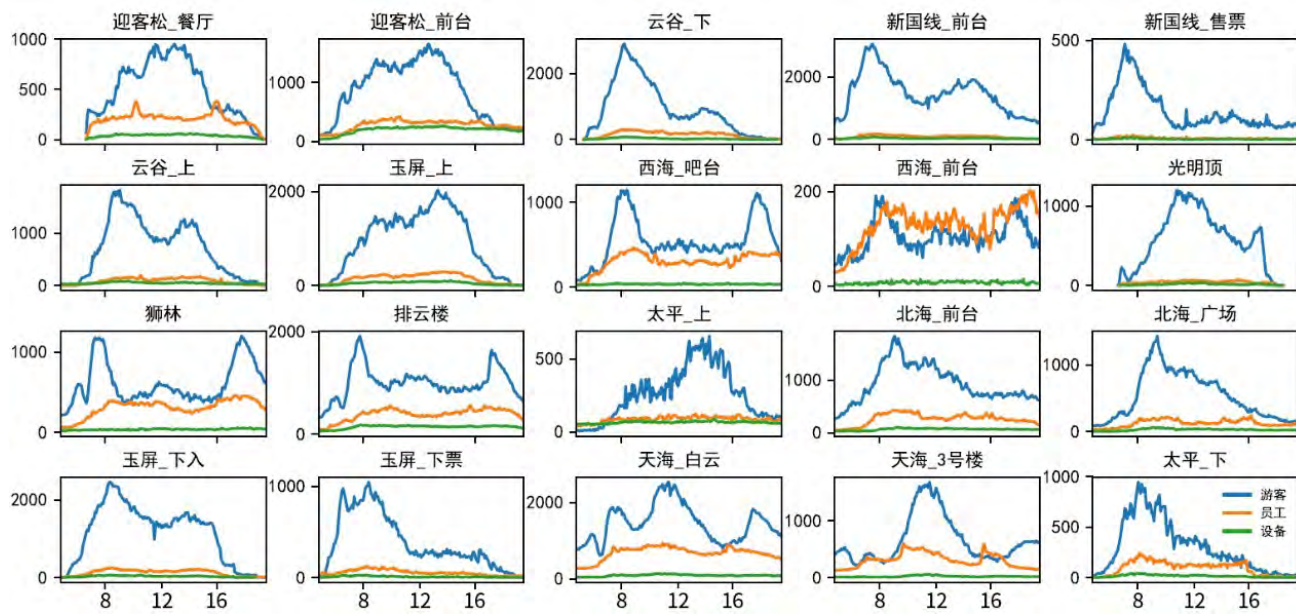
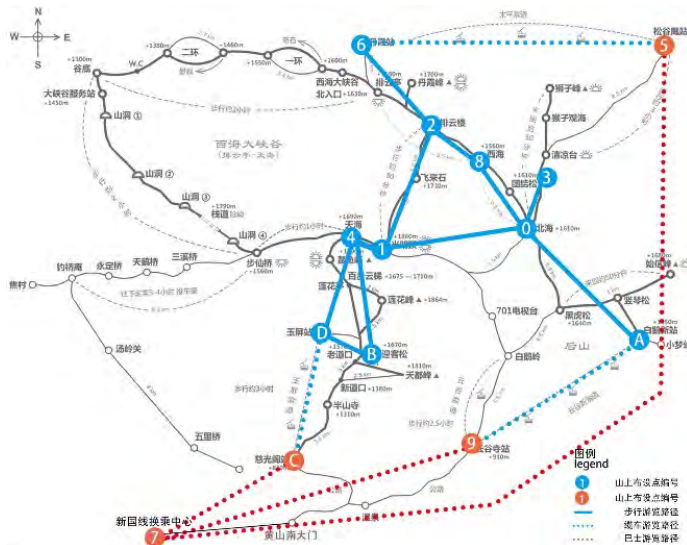
各设备逐日接收数据量变化曲线



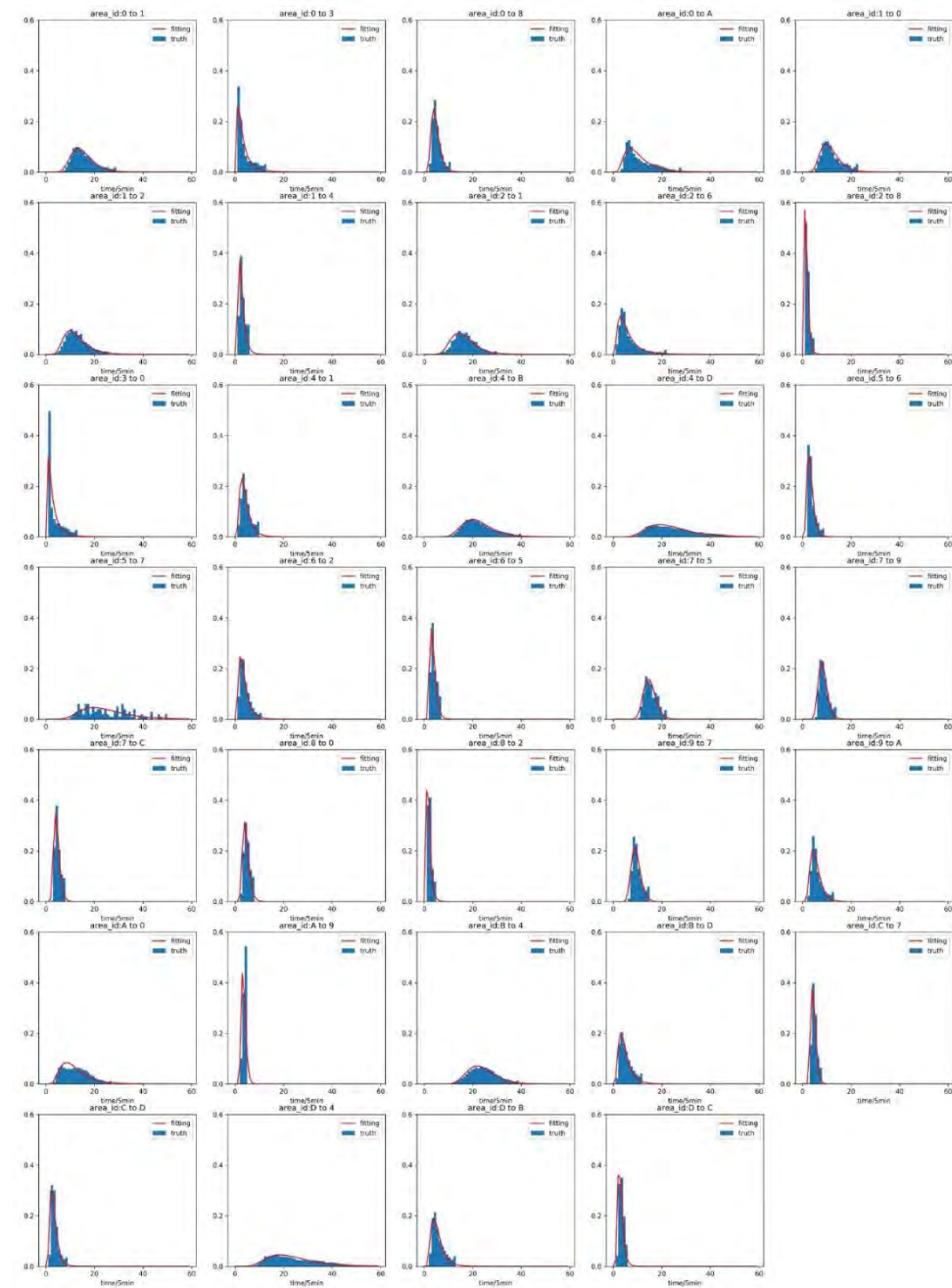
游客/员工/WiFi定位设备逐日流量变化



游客在黄山智慧景区游览的天数分布

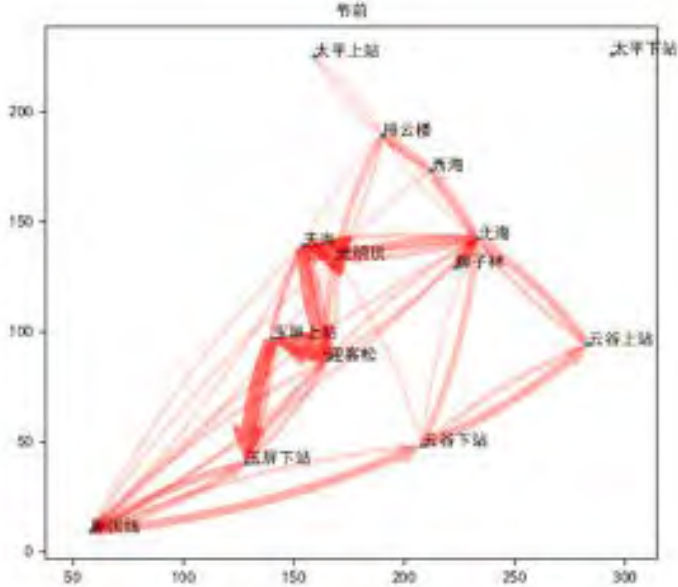


Hourly Flow on Nodes

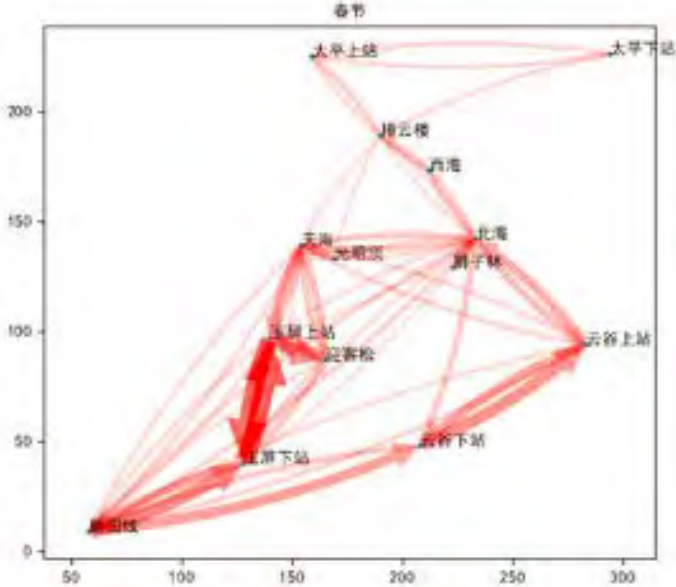


Time Span of Edges

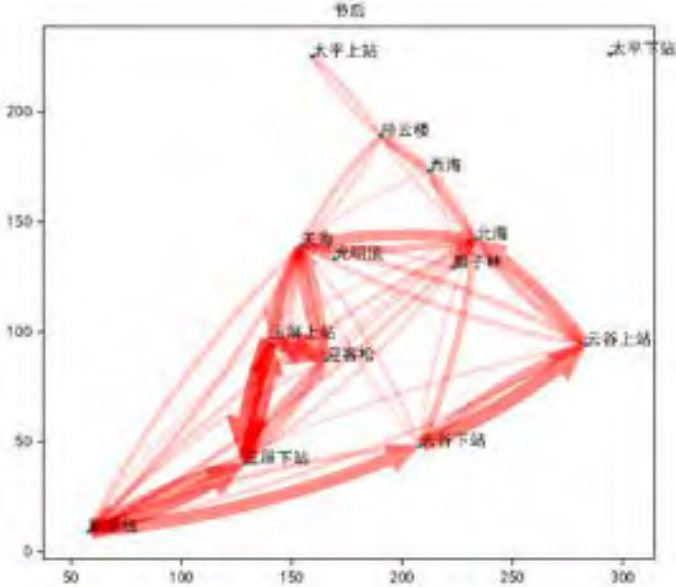
Circulation Network



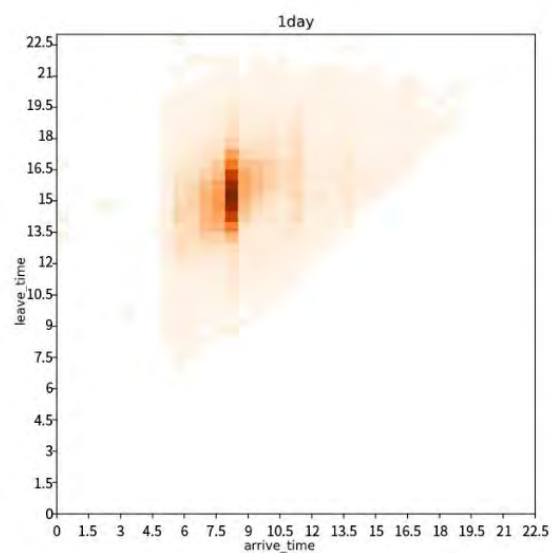
节前



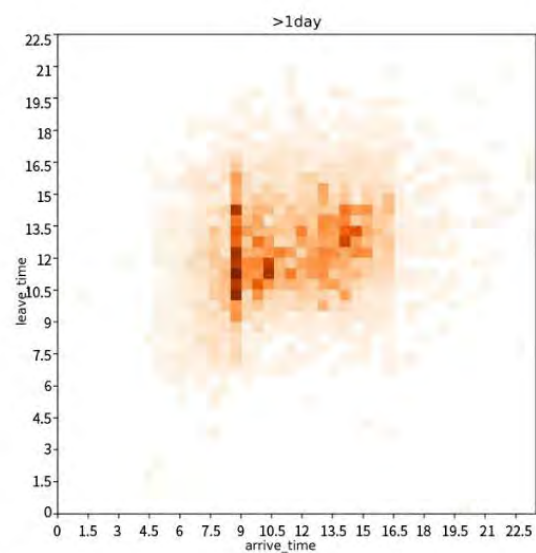
春节



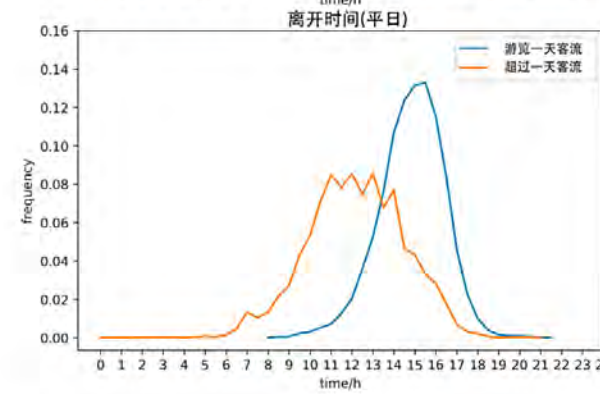
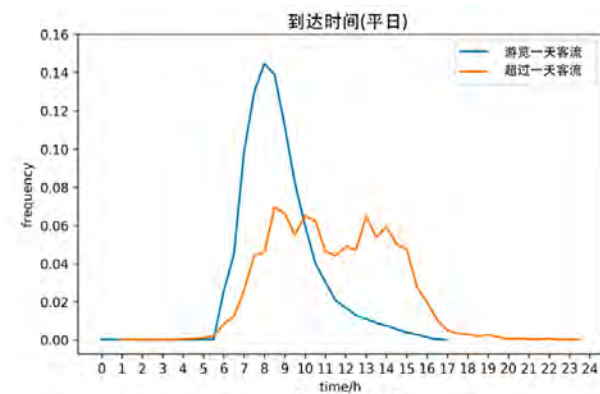
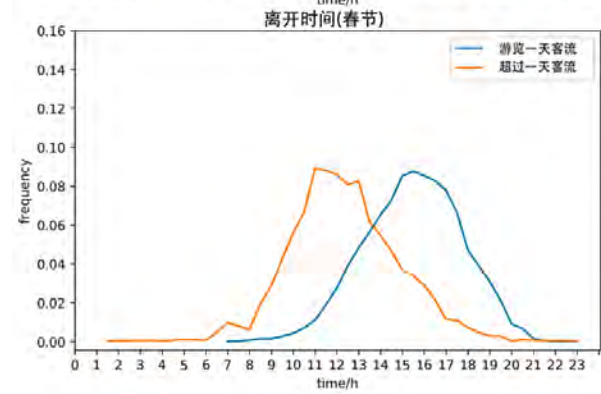
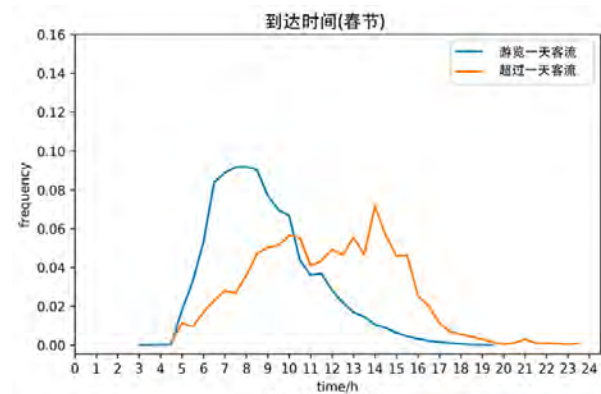
节后



1 day



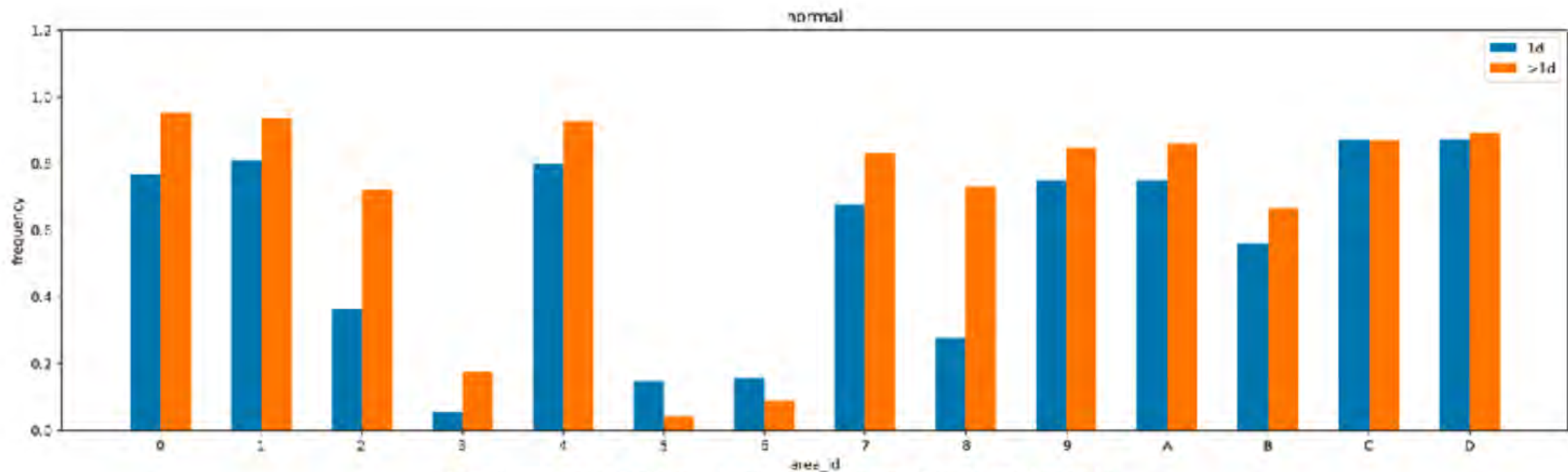
>1 day



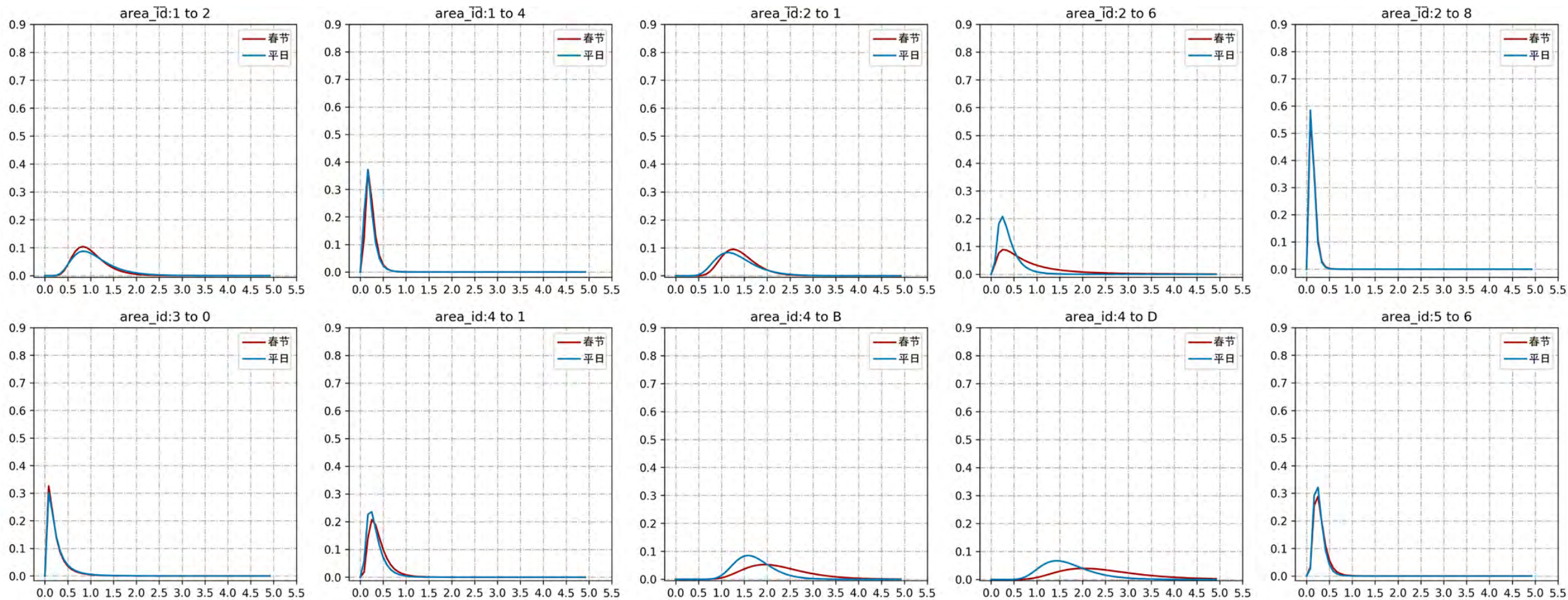
Arrival

Leaving

- 游玩一天和超过一天游客游览区域编号2（排云楼）、编号8（西海）存在显著差异；
- 超过一天游客大部分会绕道排云楼、西海游览光明顶。

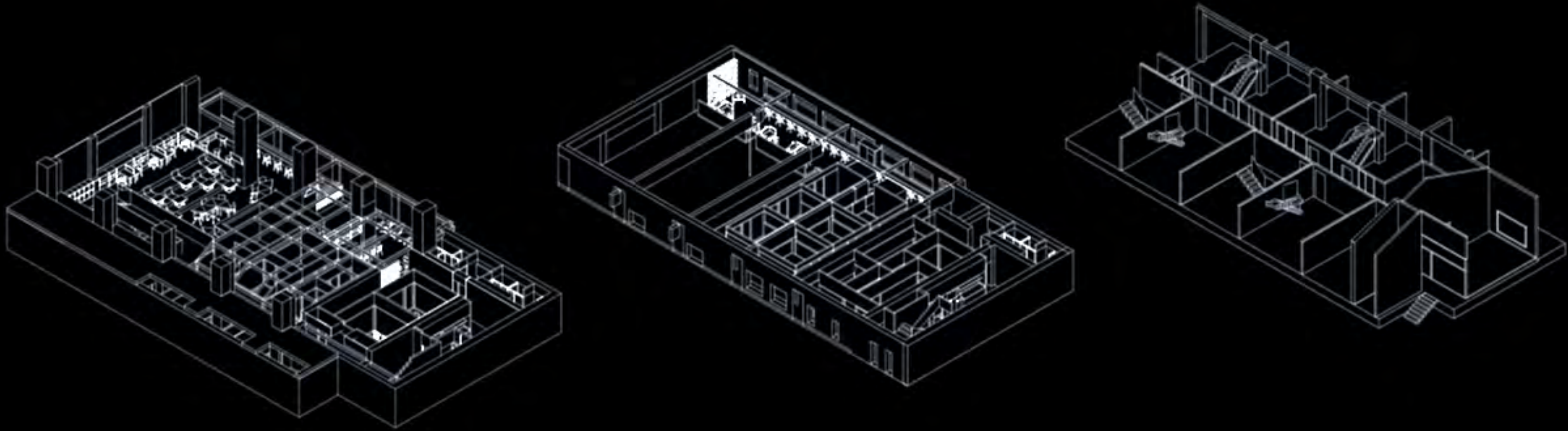


不同游玩天数人群中经过某地点的轨迹数量占轨迹总数的比

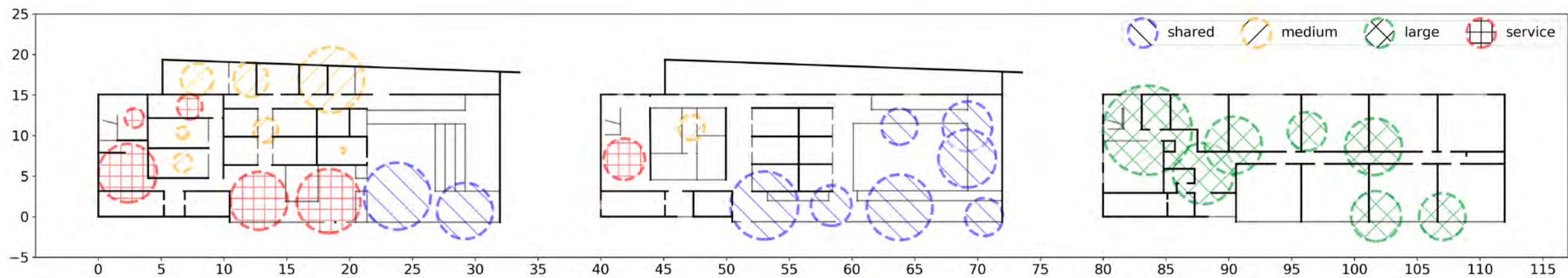


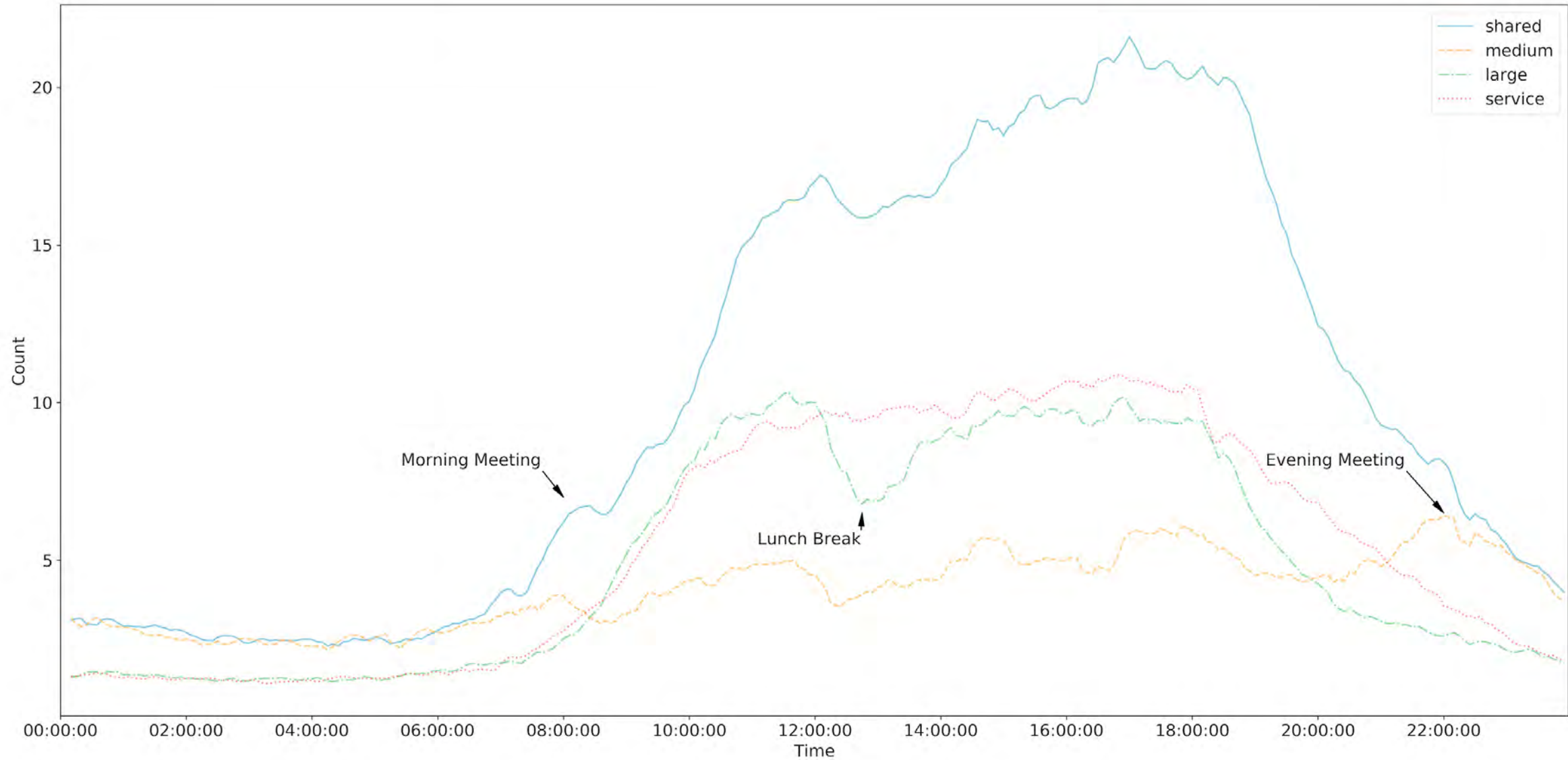
Comparison of Travel Time of Spring Festival and Normal Days

燕京里联合办公空间 Yanjing Lan Co-Working Space



Lin, Yuming and Huang, Weixin , Social Behavior Analysis in Innovation Incubator Based on Wi-Fi Data - A Case Study on Yan Jing Lane Community, Learning, Adapting and Prototyping - Proceedings of the 23rd CAADRIA Conference - Volume 2, Tsinghua University, Beijing, China, 17-19 May 2018, pp. 197-206





STUDY ON RESIDENTIAL BEHAVIOUR BASED ON ULTRA-WIDEBAND (UWB) IPS 基于UWB的居住行为精细化研究

居住地区：北京

家庭结构：老年退休夫妇

住宅户型：两室两厅

住宅面积：77m²

调研时间：三周左右

研究过程：

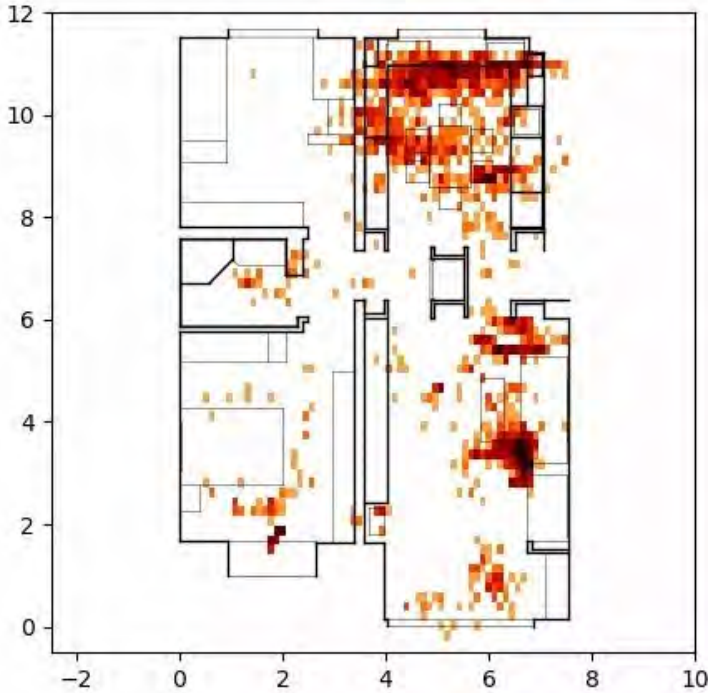
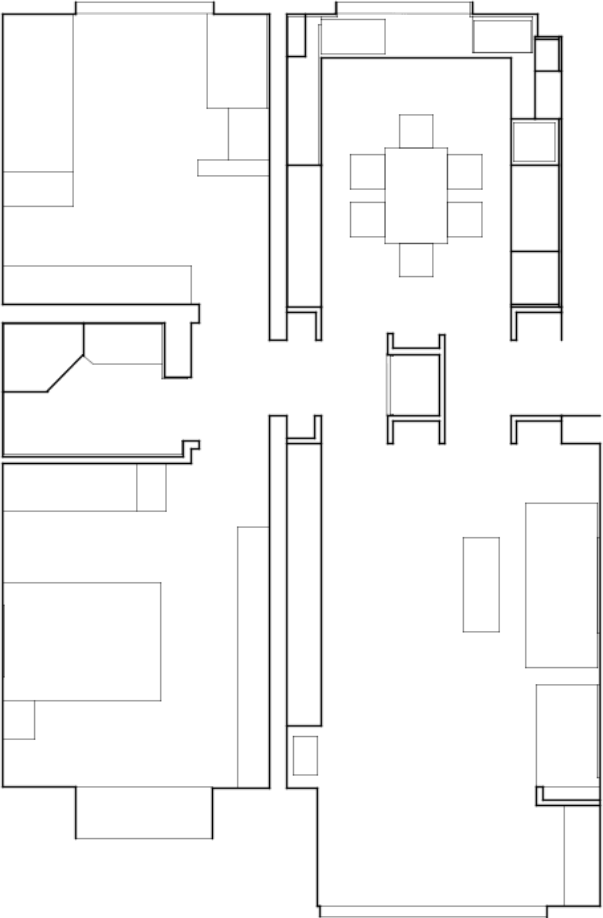
室内安装调试、持续的数据监控、系统优化、问卷调查等

分析过程：

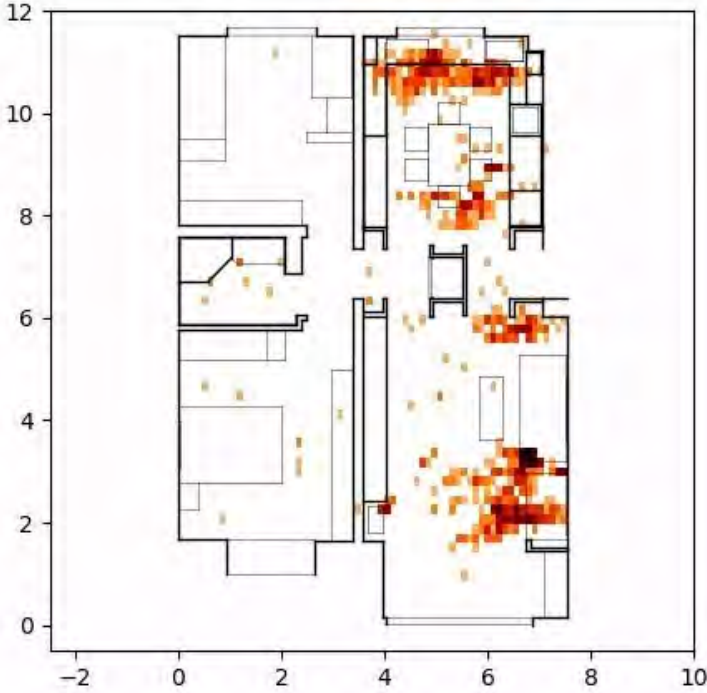
数据收集、数据过滤与清洗、数据填充、数据降噪等



UWB in Apartment of an Old Couple



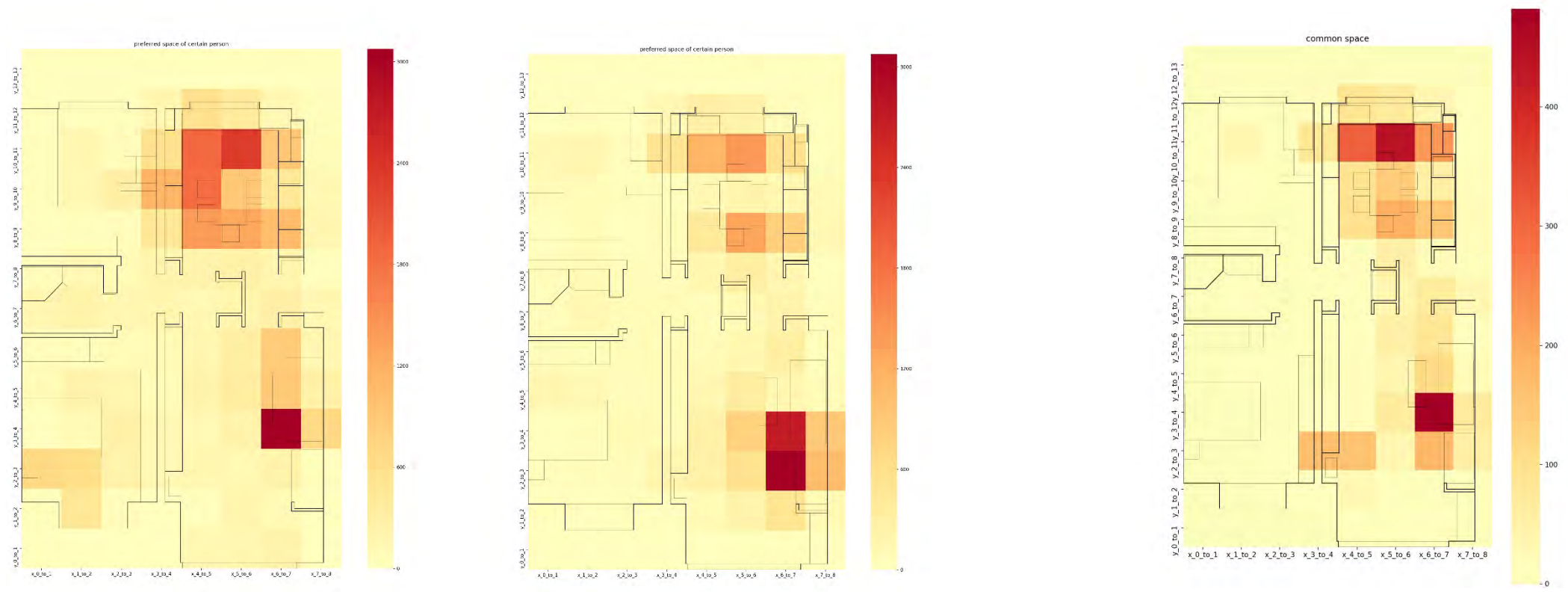
Host



Hostess

日常活动空间分布

- 热度图显示了在调研时段，两位老人停留时间最长的空间区域分别是**客厅沙发**和**客厅电脑前**，其次分别是**厨房**和**餐厅区域**。结合问卷调查推测，男主人日常主要在客厅沙发活动或在餐厅看电视，而女主人主要是在客厅使用电脑、在厨房做饭。
- 两位老人共处时间最长的空间是**客厅沙发区域**，其次是**厨房区域**。



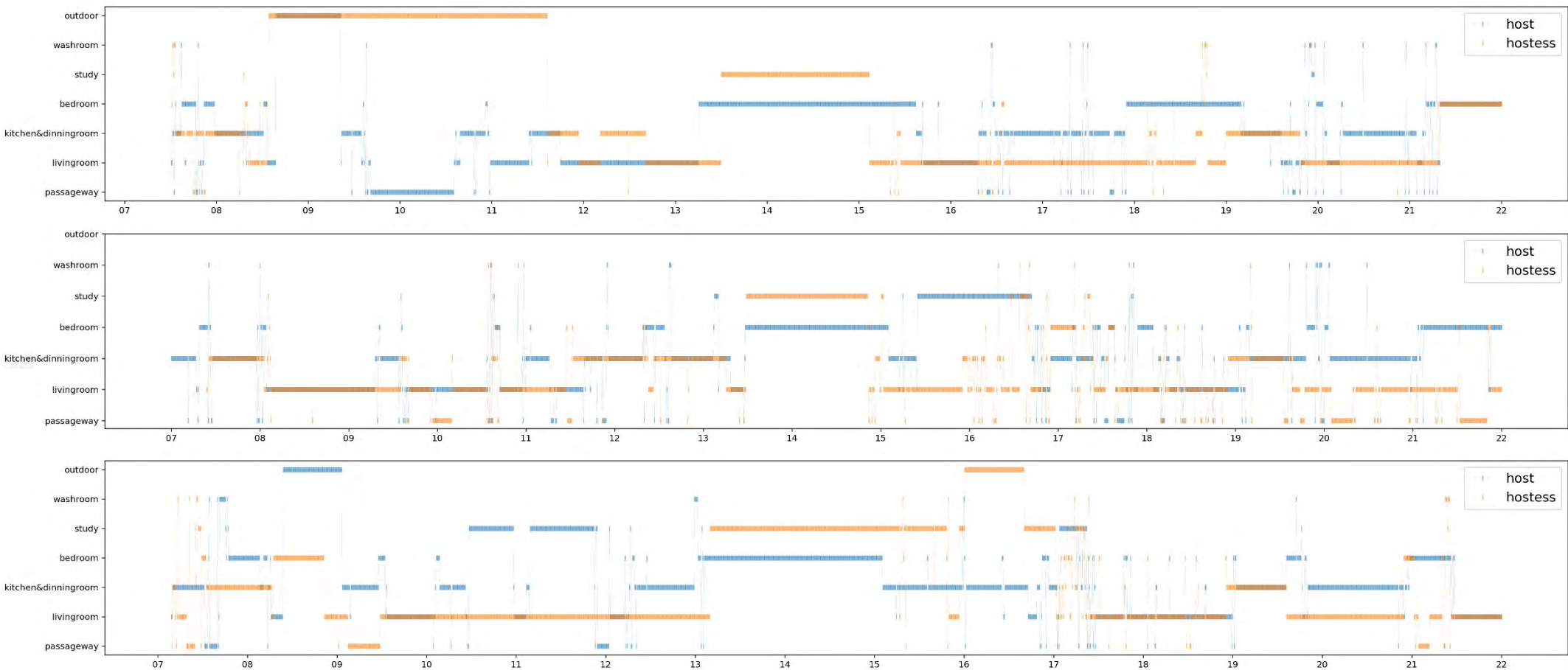
Host

Hostess

Shared space

行为时序分析

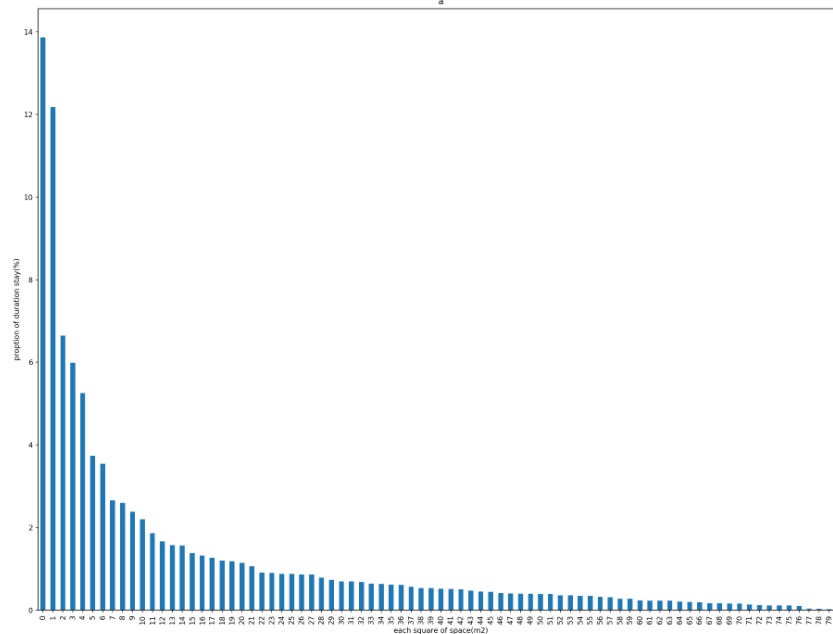
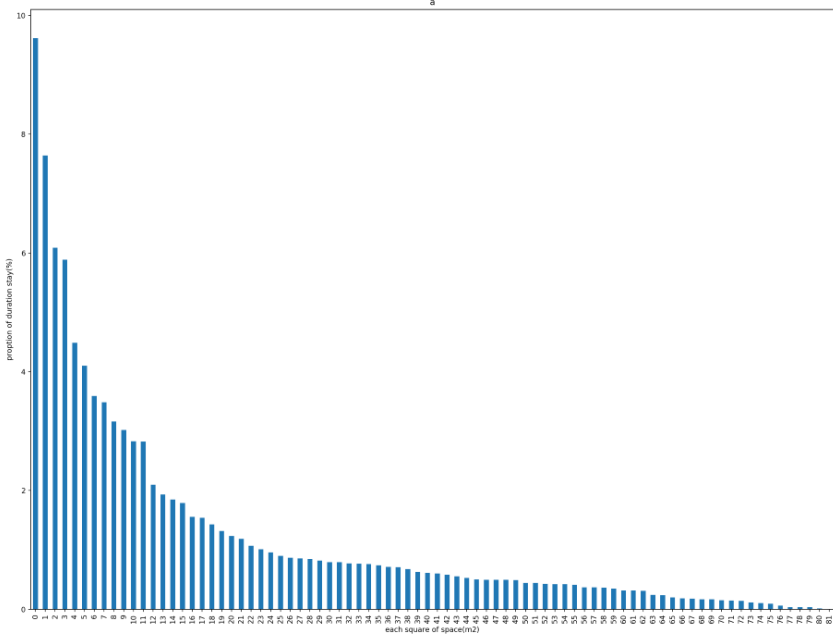
- 引入时间序列，将人、功能与时间结合起来，挖掘人每天在各个功能房间停留情况的变化。
- 通过比较几天的不同行为时序图，可以获得一些新的信息，如两位老人每天的生活规律性较强，一般上午会有一段外出，在中午午休时，两位老人会分别在卧室和书房休息等。



两位老人七日行为时序图

时空维度综合统计分析

- 可以看出在白天，除去睡眠时间和外出时间，有大于75%的空间（约55m²），人们的停留率小于1%（停留时间不足10分钟），而停留率超过5%（停留时间超过半小时）的空间大约占总面积的5%左右（约4m²），整个数据分布接近幂律分布。



两位老人的每平米空间的停留时间百分比分布



DISCUSSION

It can de-picture the whole spatial-temporal trace of individuals, and different patterns of behavior in the space

It has potential of revealing the spatial function network and the social network of people.

Possible Application:

Post Occupancy Evaluation 使用后评估, 反馈到规划设计;

Facility & Public Space Management 商业物业的运营管理; 景区管理, 拥堵疏导;

Community Construction 社区营建, 空间营造;

Apartment Product Placement 住宅产品定位

Design Research: At The Cutting Edge

“设计研究：前沿进展”国际学术研讨会

October 27-28th, 2018

Host: School of Architecture, Tsinghua University



John Gero



Mary Lou Maher



Athanassios Economou



Dan Zhang



Shonghai Zhang



Qing Jingyan



Tao Yang



Weixin Huang



Xiaolin Hu



清华大学建筑学院黄蔚欣研究室