Team Control Number

10006

Problem Chosen

A

2019

HiMCM

Summary Sheet

Summary

In recent years, public places are constantly expanding the availability of free electrical outlets and charging services to cater to their visitors' increased demands for energy usage. Our essay will mainly discuss the extent of these costs, how these expenses are defrayed and how to effectively retrench overall expenditure for different types of public places.

Our first task is to record and predict the trends of this type of energy consumption and identify the impact it has the public place itself. Due to the paucity of accessible data, it is difficult for us to accurately trace how this specific type of consumption has changed over the years. Instead we use the trends of total electricity consumption for both China and the world to reflect and predict the trends for this specific type of electricity consumption. After curve-fitting, we conclude that this type of consumption has grown and will continue to grow at an exponential rate for China and the world.

Then we develop Model A to gauge the extent of electricity expenses for public areas. To derive the costs for public places in general, we randomize visitor distribution within the area and calculate the electricity consumption for each outlet in the venue according to its visitor density within a 15-meter radius. To discuss how our model changes for different types of public places, we take the unevenness of visitor distribution into consideration, as for places like shopping malls and schools, visitors are most likely to be distributed in clusters. We assimilate the distribution of visitors around attractions to the electron cloud model and predict the distribution of visitors in the venue, before using the previous method to calculate the total expense. To illustrate how our model works, we apply our model to three types of public areas—the National Exhibition and Convention Center, an airport and a typical café.

We subsequently devise Model B to optimize outlet distribution in order to reduce overall expenditure and boost the business's revenue. We then introduce the value s_{total} to evaluate the distribution of a fixed number of electrical outlets. The value of s_{total} is mainly based on the quantification of customer experience(which may influence additional profits) and electricity costs. After that, we utilize Simulated Annealing to optimize the distribution of outlets and thus derive the optimal scenario for outlet locations.

Finally, we sum up our methods and findings by writing a one-page article for the school newspaper. For dissection of our models' strengths and weaknesses, we conclude that the main advantage of our model is its simplicity, novelty and high generalizability. However, due to idealization and deficiency of accessible data, our results may deviate slightly from reality.

Charge!

Team Number #10006

November 18, 2019

Contents

1 Introduction

In recent years, energy consumption has grown exponentially. In order to cater to their customers' increased demands for electricity, many public places have responded by expanding the availability of electrical outlets, charging stations, and even electric vehicle charging parking spots where visitors may recharge their devices or vehicles for free. As a result, we find ourselves comfortably ensconced in this mobile electronic world in which free charging has become so prevalent. This article will discuss how the resulting costs of the increased demands and energy usage are paid and how to effectively retrench energy expenditure for different types of public places.

1.1 Restatement of the problem

We divide our task into the following three parts:

- Record and predict the trends of this type of energy consumption and identify its impact on public places subject to increasing energy and charging demands from customers.
- Develop a model to gauge the energy expenditure of different types of public places.
- Derive a method to optimize the distribution of outlets and stations for cost reduction.

1.2 Recording and predicting energy consumption trends

As the usage of electronic devices is becoming more ubiquitous over recent years, energy consumption in public places has increased accordingly. Due to lack of relevant data, it is difficult for us to accurately trace how this specific type of consumption has changed over the years. Therefore we focus instead on the trends of electricity consumption to help predict future expenditure.

After obtaining data from the World Bank Organization[1], we use the linear function and the exponential function respectively for curve-fitting to delineate present trends and predict future growth of electricity consumption.

From these two graphs, we find that on the whole, both the world's and China's energy expenditure have been rapidly increasing in recent years, and is most likely to continue its upward climb. Compared to the world's steady increase in electricity consumption, China's expenditure has been skyrocketing in recent years.

We can infer from these charts that with the steady increase of the world's electricity consumption, electricity consumed in public places has also been increasing at a steady pace, while the increase of this type of electricity consumption in China has experienced exponential growth.

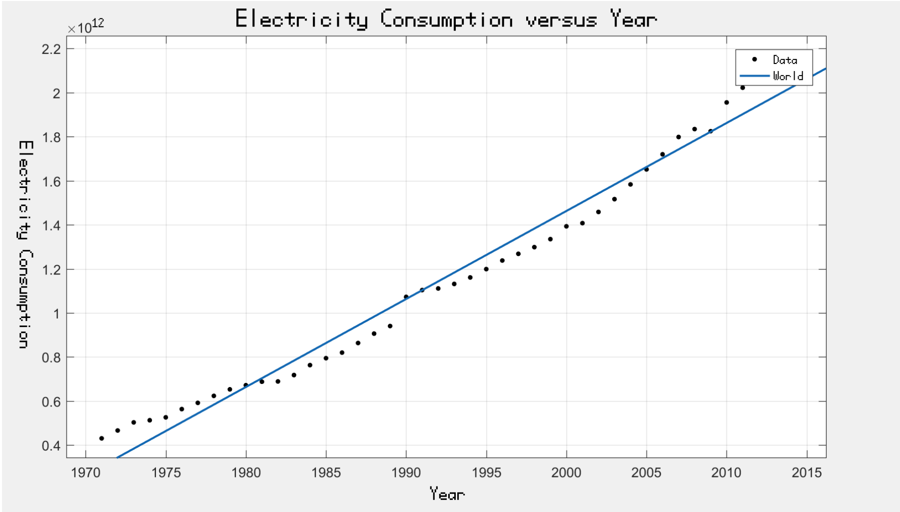

Figure 1: Trend of world electricity consumption

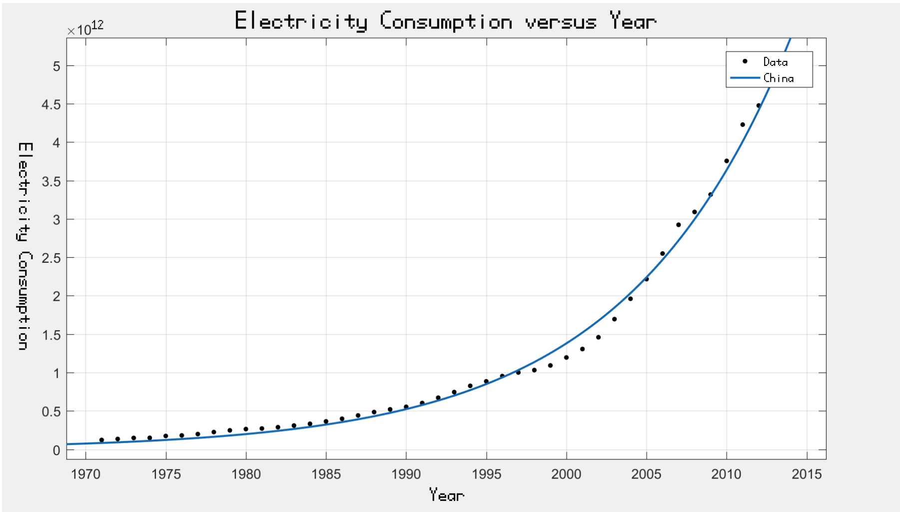

Figure 2: Trend of China's electricity consumption

1.3 Impact on public places

As charging demands from customers have risen greatly in recent years, more and more public places have begun to offer charging services to visitors. Charging services in its nascent form required payment for usage, yet as these services became more prevalent, businesses and companies began to see them in a new light and started offering non-gratuitous charging service, including free electrical outlets and chargers etc. to all visitors indiscriminately to boost overall service qualities and attract more potential customers. Since this has proved to be a good method of acquiring more customers and expanding business, many public places soon followed suit. As a result, most public places worldwide are offering charging for free.

This phenomenon may have a huge impact on a lot of public places. For one, market competition and rivalry may prompt a business into providing free electricity charging services to customers, yet these additional costs resulting from these non-gratuitous services may add to the financial burdens of a business, thereby inhibiting business expansion and business growth. Therefore it is of great importance to optimize the distribution of electrical outlets and chargers to minimize and retrench electricity fees.

1.4 Our work

Our work may be partitioned into the following steps:

- **Delineating past trends and predicting future growth of this type of energy consumption**
  Based on the assumption that the total electricity consumption mirrors that of this type of energy, we use curve-fitting to outline trends for total consumption and use these trends to predict future growth of this type of consumption.
- **Develop a nascent model for expense calculation**
  For our nascent model for expense calculation, we assume that visitor distribution throughout the whole area is even.
- **Develop an advanced model for expense calculation**
  We make predictions on visitor distribution according to the locations of attractors. After establishing our model, we apply it to three types of venues.
- **Develop a method to retrench overall costs and optimize outlet distribution**
  We devise a method to evaluate outlet distribution and apply Simulated Annealing to optimize outlet distribution.

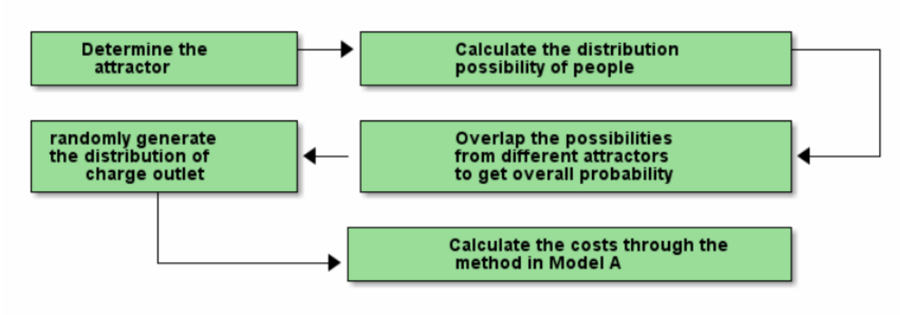

Figure 3: Flow chart for calculating electricity costs

1.5 Assumptions

- **Only electrical outlets or chargers for electronic devices such as mobile phones are available for free.**
  Justification: Free electrical charging of vehicles is extremely rare and considering it would greatly complicate our model.
- **For optimization of electrical outlet distribution, we allocate the highest priority for electrical outlet amenities to crowded places.**
  Justification: The higher the level of visitor density, the more need for electrical outlets there

is. So in order to better satiate customers' needs, we decide to allocate as many electrical outlets as possible to crowded areas.

- **The electricity fee for one hour of recharging for a single device is 0.04 RMB**
  Justification: We roughly estimate that a typical mobile phone charger consumes 100W, and that the electricity fee for 1 kwh is 1 RMB. After calculation, we estimate that the electricity fee for one hour would be 0.04 RMB.

- **We define people who are in need of recharging as those whose devices have less than 30% of power remaining.**
  Justification: We make the assumption in order to enable the calculation of the percentage of people who need phone recharging.

2 Nomenclature

Table 1: The symbol table

symbol	definition
t	The length of time during which the place is open to public
k_i	The percentage of people who need to recharge their electronic devices
n_i	Number of people within a 15m radius of an outlet
N_i	Number of people within a 15m radius who need to recharge their device
d_i	Number of devices plugged into outlet i
P_i	Electricity costs for outlet i per day
A_j	The value representing attractiveness for attraction site(attractor) j, ranging from 1 to 3
S_m	The total attraction area m is subject to
F_{mj}	The attraction site j gives to area m
l_{mj}	The euclidean distance between attractor j and area m
y	The total number of attractors

3 Model A

3.1 Model Overview

In this model, we first develop a method to gauge the energy expenditure of public places in general, and calculate the extent of resulting costs for this type of electricity consumption. After that, we discuss how our calculation varies for different types of public places. Therefore our model can be partitioned into two main steps.

1. Devise a method to calculate the expenditure according to the number of electrical outlets and the distribution and density of visitors.

2. Discuss how our results change for different types of places.

3.2 Calculating costs in general

Although the distribution of people in public places is dynamic, we do not focus on the flow of visitors throughout the corridors. Instead, we only concentrate on the density of visitors throughout the public place when the distribution of people reaches a relative stasis and would no longer experience instable fluctuations.

3.2.1 Calculating the electricity fee for a single outlet

We assume that only visitors within a 15-meter radius of an outlet would be able to utilize it. Therefore the potential users of outlet i would be the number of visitors within that 15-meter radius—n_i. Yet as not all visitors within that area may be in real need of recharging their electronic devices, we introduce the coefficient k_i to represent the percentage of people who may be in need of recharging.

We acquire a rough estimation of k_i by simulating statistics of the remaining power in people's electronic devices with Poisson Distribution. According to our previous assumption that people with less than 30% of phone power left would be in need of phone recharging, k_i would thereby be 0.3.

Therefore the number of people within a 15-meter radius in need of recharging would be $N_i = k_i n_i = 0.3n_i$.

We assume that the maximum number of devices a single outlet would be able to charge simultaneously is 15. If the number of people in need of recharging N_i within the 15-meter radius of an outlet N_i exceeds the maximum limit of the outlet, only 15 devices, according to the maximum limit, would be able to plugged into the outlet. Yet if N_i is less than the maximum limit, the number of devices plugged in would thus depends solely on the need. Therefore the number of devices recharging at outlet i d_i would be:

$$d_i = \begin{cases} N_i & N_i < 15 \\ 15 & N_i \geq 15 \end{cases} \tag{1}$$

According to our previous assumption that a typical charger consumes 100W, we may

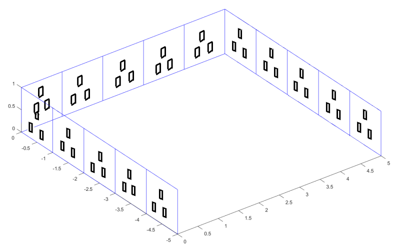

Figure 4: The illustration of an electrical outlet

thus acquire the function for the electricity fee of outlet i— P_i:

$$P_i = \begin{cases} 0.36n_i & n_i < 50 \\ 18 & n_i \geq 50 \end{cases} \tag{2}$$

The total electricity costs would be the sum of all single outlet expenditures.

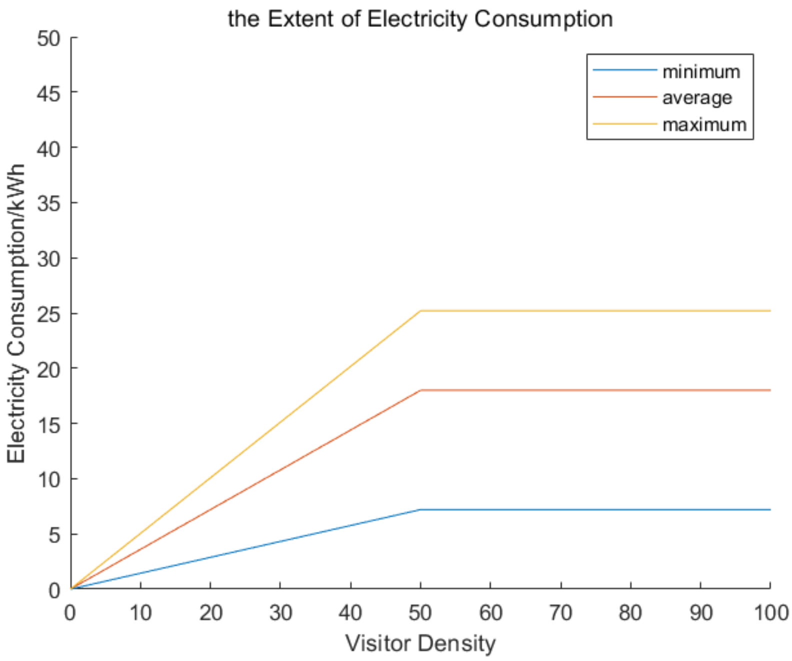

Figure 5: The electrical expenditure of an outlet for electricity consumptions of 40W, 100W and 140W respectively

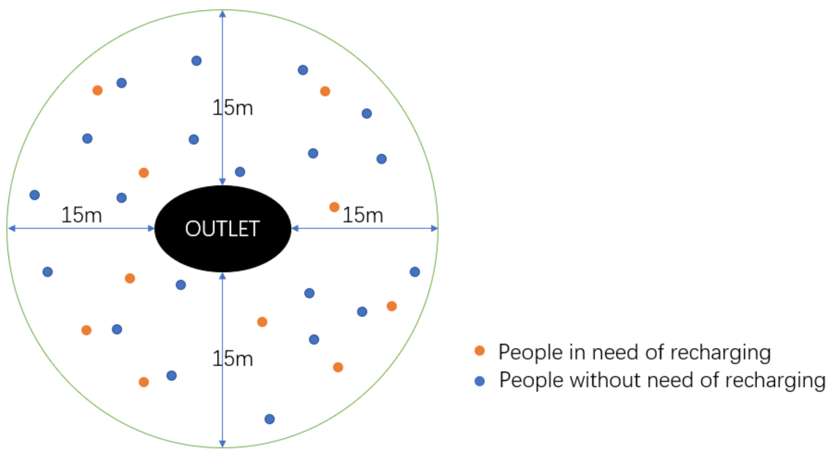

Figure 6: Demonstration of visitor distribution

3.2.2 Determining the extent of costs

In order to determine the extent of electricity fees for public places, we create a simulation for a $397 \times 397m^2$ public area. After randomizing its visitor density by randomly assigning each square meter with a value ranging from 0 to 1 (which stands for the number of people per square meter), we randomly allocate a total number of 63 outlets to different locations in the area, as is shown in figure 7.

Therefore the total electricity cost per day(t =12 hrs) for the simulation is 1134 RMB.

The simulated area measures around $1.5 \times 10^5 m^2$, which is roughly 1.2 times the size of Shanghai Library. As a result, we conclude that for sizable public areas, if it

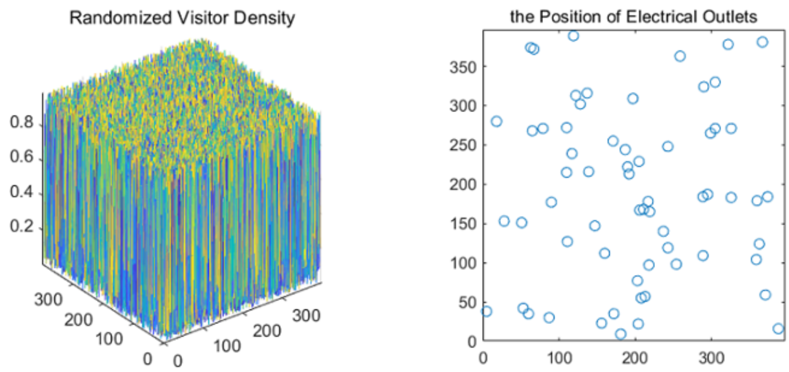

Figure 7: Randomized visitor density and outlet distribution

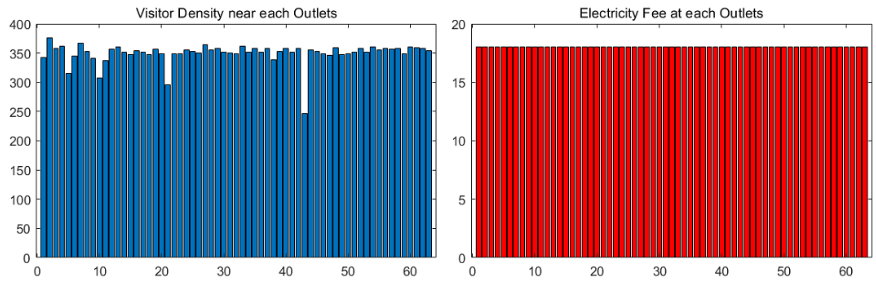

Figure 8: Visitor density near outlets and the position of electrical outlets in the simulation

were to provide ubiquitous and easy access to electricity for most visitors, the resulting costs would be exorbitant. Therefore reducing electricity costs in electricity could greatly retrench overall expenditure and boost a business's revenue.

3.2.3 How electricity costs are paid

For public places which fall into the category of social amenities and non-profit organizations such as schools, this type of electricity fee is defrayed by financial subsidy from the government, while for private organizations and businesses including cafés and shopping malls, it is mainly paid from the business's profits.

For private businesses, their choice of offering free charging services for electronic devices is mainly due to tough market competition. As businesses which offer free access to electrical outlets are more likely to attract more potential customers, electricity expenditure can be easily defrayed with additional revenue resulting from higher popularity.

3.3 Electricity expenditure for different places

For many public places such as cafés and restaurants, the distribution of its visitors is relatively random, therefore we may obtain the total electricity expenditure by randomizing visitor distribution in the public area. However for venues such as museums, shopping malls and schools, the visitor density of different locations may vary dramatically as areas with resting rooms and exhibitions naturally attract more people. In these occasions, we need to develop a method to estimate the distribution of visitors inside the venue for further calculation.

3.3.1 Calculating visitor distribution

As visitors naturally cluster around resting rooms, exhibition centers and such, we make an analogy between visitors' gathering around attraction sites(nicknamed attractors) and the model of electron clouds. Thus for a single square area, the attraction it is subject to mainly depends on the distance between the area in question and all the different attractors.

We assign each attraction the value A_j to represent its attractiveness to visitors. The higher its attractiveness, the higher A_j will become. We divide all attractions into three categories according to their attractiveness, and assign them with values of 1, 2 and 3.

We grid the public area in question into tiny squares, and calculate the total attraction that each square is subject to by adding each separate attraction caused by a single site together resulting in a total sum representing how much total attraction each square area is subject to—S.

As we have assimilated the distribution of people around attraction sites(attractors) to that of electrons, the attraction that site j gives to square m can be calculated using the following formula:

$$F_{mj} = \frac{A_j}{{l_{mj}}^2} \tag{3}$$

, in which l_{mj} represents the euclidean distance between attractor j and area m.

The total attraction area m is subject to S_m would therefore be:

$$S_m = \sum_{j=1}^{y} F_{mj} \tag{4}$$

, in which y represents the total number of attractors.

The possibility that a person would be located in area m—p_m can be calculated with the formula below:

$$p_m = \frac{S_m}{\sum_{m=1}^{397\times 397} S_m} \tag{5}$$

Thus the distribution of visitors around the attractors would be similar to that of figure 9.

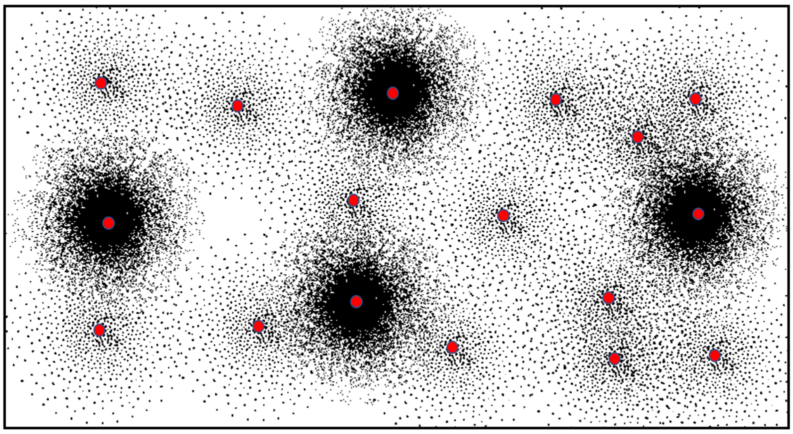

Figure 9: A simulation of visitor distribution, with center points(red) representing attractors

3.3.2 Model application

In order to elaborate on how exactly our model can be implemented, we select three typical venues which are Shanghai National Exhibition and Convention Center, Shanghai Pudong International Airport and a random café respectively as examples for further explication.

The two-dimensional layout of the National Exhibition and Convention Center is depicted in figure 10. We first divide the whole area into 397×397 square areas. Then we allocate each attractor on the layout with an attractiveness value ranging from 1 to 3 as shown in table 2. After such assignment, it would be possible to calculate the total attraction each area is subject to, and with the total attraction for area m—S_m, we derive the possibilities of visitor distributionp_m for each area in the 397×397 grid.

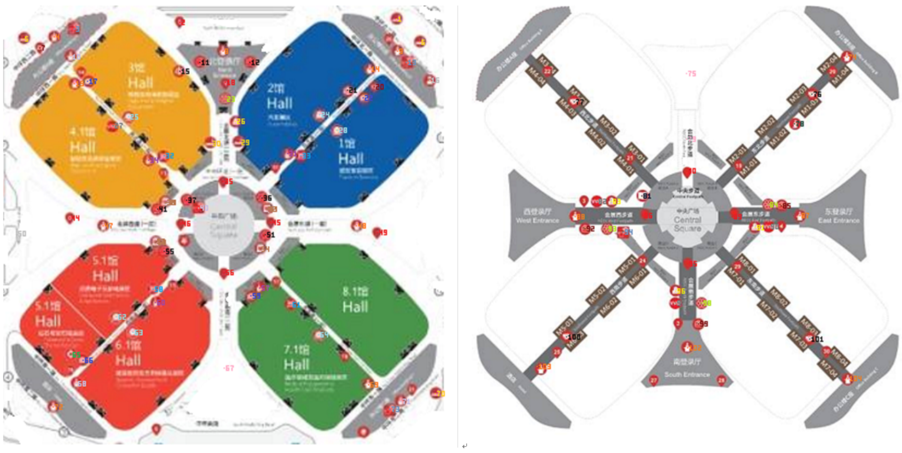

Figure 10: The floorplan of the National Exhibition and Convention Center

A ratio between the possibilities of visitor distribution for each area is roughly the equivalent of a ratio of the number of actual visitors in each area. Thus the distribution of people throughout the whole public place may be calculated and simulated as can be

Table 2: The attraction value for different attractors

Name of the attractor	Attraction value
Exchange point	2
VVip Lounge	3
Cloakroom	1
Information Counter	1
Security Check point	1
Business Center	2
Medical Station	2
Joint Office	2
Media Lounge	3
Rest Area	3
Police Station	1
Bank	2
Souvenir Store	1
Media Center	3
Smoking Area	3
Metro Station	1
Comprehensive Service Center	3
Reservation Office for 2nd	2
Railway Automatic Ticketing Machine	1
IPR Protection and Commercial Dispute Resolution Service Center	1
Trade Talk Area	2
China Themed Book	1
Prayer Room	1

seen in figure 12.

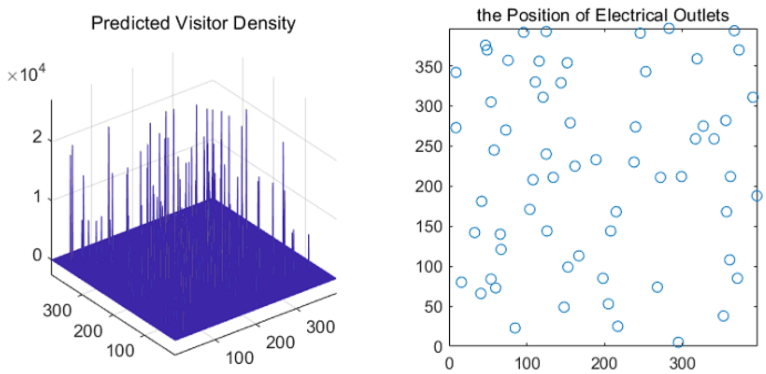

Figure 11: The distribution of visitors at the National Exhibition and Convention Center and the randomized distribution of outlets

After acquiring the distribution of both visitors and outlets through calculation and randomization, we may proceed to calculate the electricity consumption and expenditure for each outlet according to the method used in section 3.2.1 ,and by adding these costs up together, obtain the total electricity cost for the whole center, the results of which are shown in figure 11.

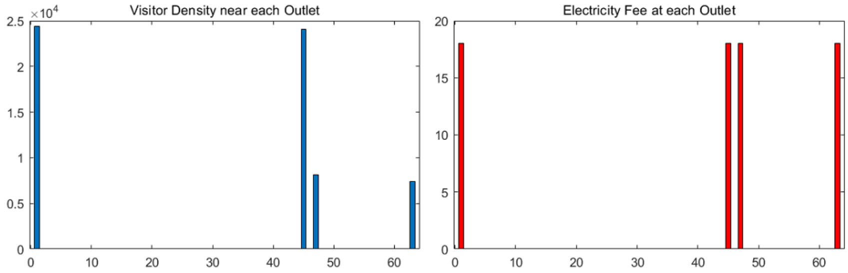

Figure 12: The visitor density near each outlet (within a 15-meter radius) and electricity fees for each outlet

As a result, we calculate that such type of electricity cost for the center is 72 RMB per day.

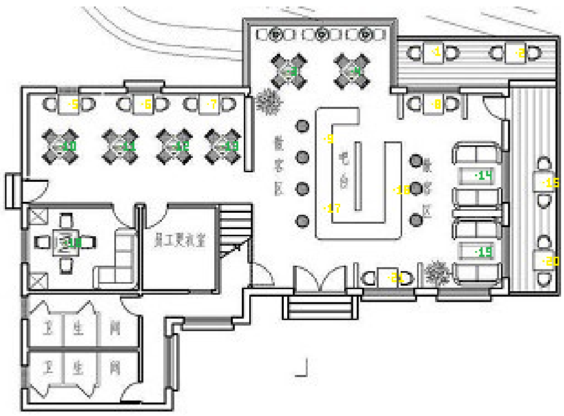

Figure 13: Layout of the café in question

We use similar methods to calculate the electricity costs for Shanghai Pudong International Airport and the café, as is shown in figure 17, 18, 15 and 16. The predicted costs for Shanghai Pudong International Airport is 36 RMB per day, while the expense for the café is calculated to be 360 RMB per day.

4 Model B

4.1 Model Overview

In order to reduce costs for public places providing free electricity recharging services, we develop a new model based on the previous one and utilize the Simulated Annealing Method(SAM) to optimize distribution for a fixed number of electrical outlets.

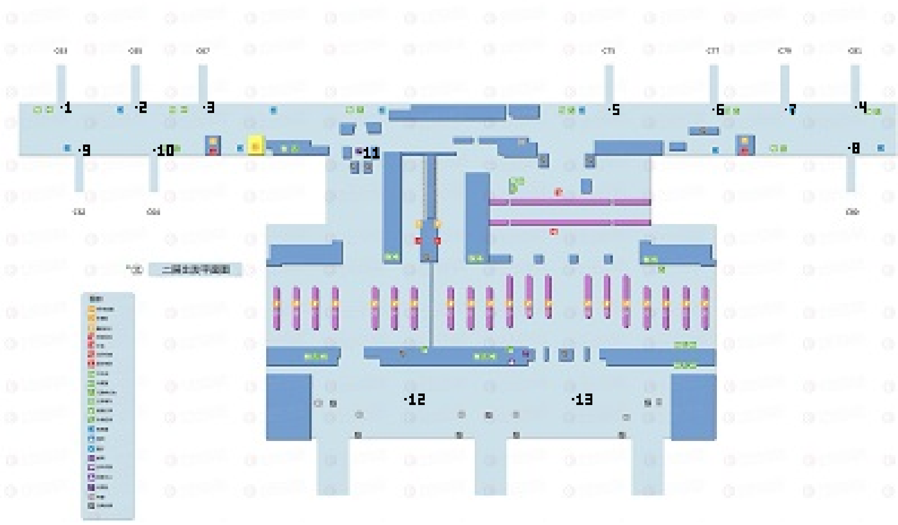

Figure 14: Layout of Shanghai Pudong International Airport

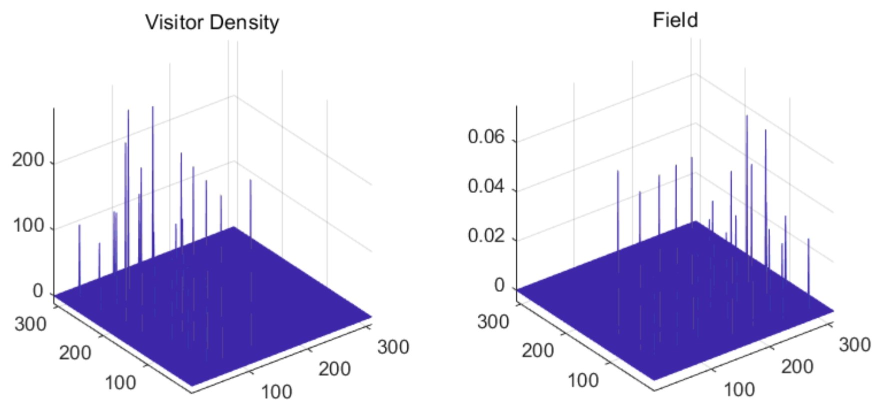

Figure 15: Distribution of visitor density for the café

4.2 Model assumptions

- **The number of outlets inside a public venue is predetermined.**
  Justification: This assumption can greatly simplify our calculations as our main focus would thus be on the distribution of electrical outlets.
- **Only the profits of businesses are taken into account for optimization.**

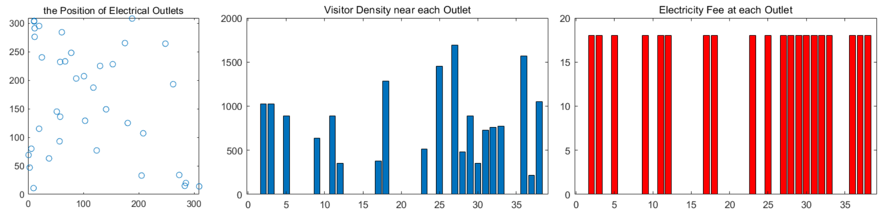

Figure 16: Resulting expenses for the café

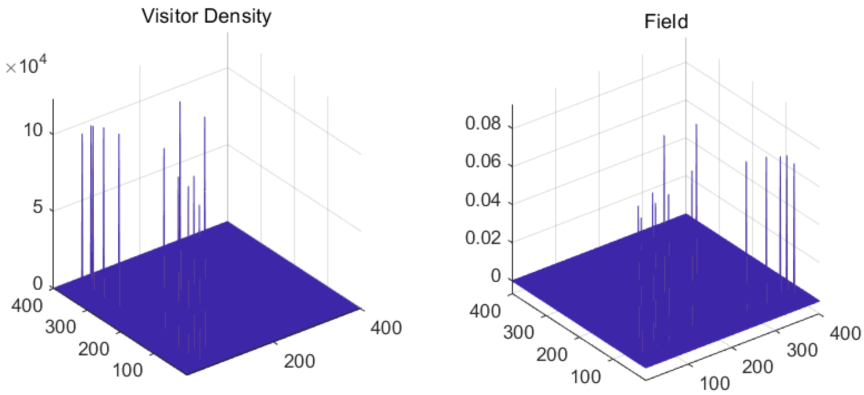

Figure 17: Distribution of visitor density for Shanghai Pudong International Airport

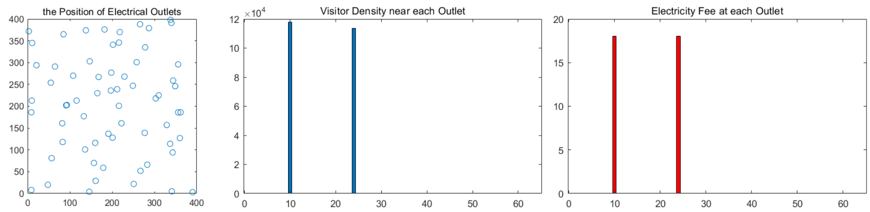

Figure 18: Resulting expenses for Shanghai Pudong International Airport

Jusification: The ultimate goal of most businesses is to gain more profit and reduce overall costs.

4.3 Optimization of outlet distribution

4.3.1 How to evaluate outlet distribution

In order to maximize the total revenue, we have to consider two factors— the magnitude of electricity expenditure and how much additional business electrical outlets could bring. The costs of electricity consumption can be easily calculated using the formulas of Model A. In order to quantify customer satisfaction, we assume that the increased popularity of a public venue mainly depends on the ratio between the number of customers who have access to electrical outlets and the total number of customers inside the venue.

Based on these two parameters, we introduce the value s_{total} to evaluate the distribution of electrical outlets.

$$S_{total} = k_1 \times \frac{N_a}{N_{total}} + k_2 \times \sum_{x=1}^{n} P_i \tag{6}$$

, in which N_a represents the number of people who have access to electrical outlets inside the venue, and N_{total} stands for the total number of people inside the venue. P_i represents the electricity costs for outlet i per day. k_1 and k_2 are both coefficients which may vary according to the type of venue in question.

Hence our goal would be to maximize the value of S_{total} in order to optimize the distribution of electrical outlets.

4.3.2 Maximizing S_{total} via Simulated Annealing

Simulated annealing (SA)[2] is a probabilistic technique for approximating the global optimum of a given function. Specifically, it is a metaheuristic to approximate global optimization in a large search space for optimization. For problems where finding an approximate global optimum is more important than finding a precise local optimum in a fixed amount of time, simulated annealing may be preferable to alternatives such as gradient descent.

In our model, we harness this method to optimize the distribution of outlets by maximizing the value of S_{total}.

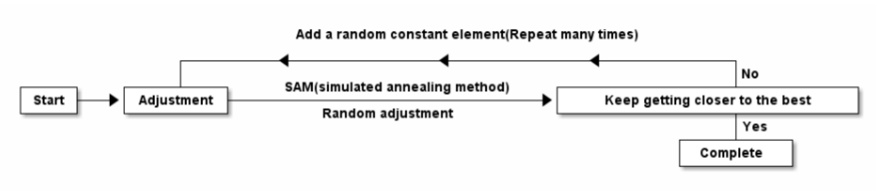

Figure 19: Demonstration of Simulated Annealing

4.3.3 Model application and results

To better illustrate how our model works, we apply it to the layout of the National Exhibition and Convention Center. According to the predicted visitor density we derived in Model A, we use Simulated Annealing to acquire the final optimized position of electrical outlets, as depicted in figure 20. The coefficients k_1 and k_2 for calculation of s_{total} that we use is 1 and 50 respectively. The electricity expenditure for each outlet may thus be calculated, and the total electricity cost in the optimized scenario is 126 RMB per day.

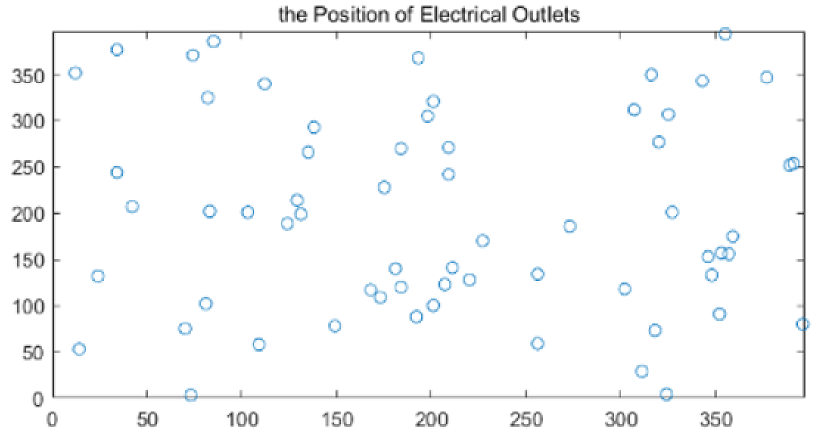

Figure 20: Optimized outlet distribution

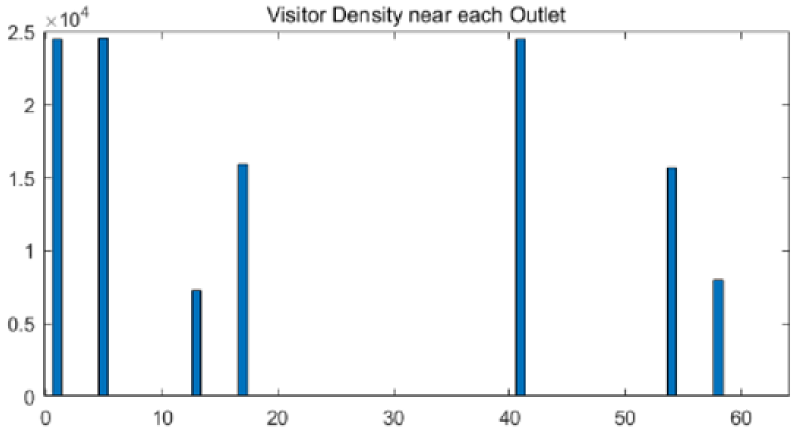

Figure 21: Visitor density near each outlet

5 Conclusion

5.1 Findings and recommendations for the school newspaper

After our study of the placement of free mobile phone charging piles in public places, we come up with the following results:

With the development of global science and technology, the total consumption of electricity has been steadily increasing throughout recent years. After curve-fitting, we predict that both electricity consumption for the world and for China will continue to grow at a rapid pace. As the changes in this specific type of electricity consumption mirrors that of overall technological development(which is reflected in total electricity consumption), we conclude that this type of energy consumption will increase in a linear fashion for the world, yet at an exponential rate for developing countries such as China. Then we move on to devise a model to measure the extent of electricity expenditure in public places. In our nascent model for cost calculation, we assume that the distribution

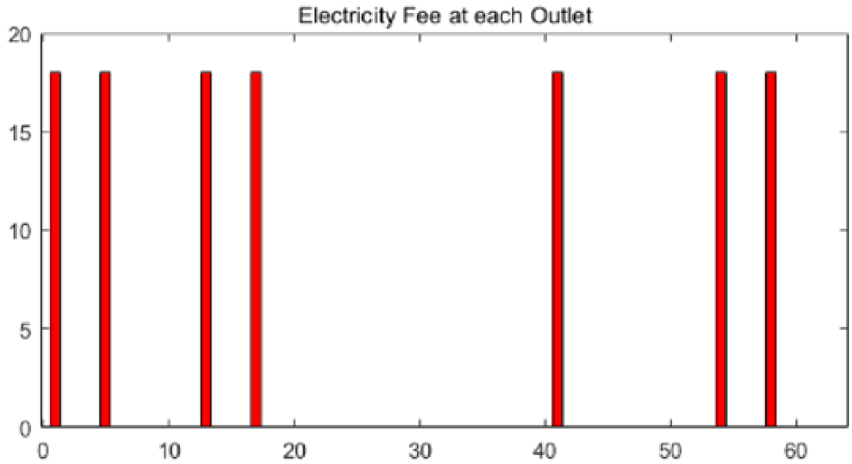

Figure 22: Electricity expenditure for each outlet.

of visitors in the public venue is purely random. To calculate the overall costs, we come up with a formula to calculate the usage of electricity for each electrical outlet distributed in the public area, and present the sum of all costs for each outlet as the total expense for a venue.

For a more advanced model which can be adapted to different types of venues, we take the distribution of visitor density into consideration, as some public places such as schools, hospitals and museums have an uneven visitor distribution. To predict the distribution of visitor density, we assimilate the visitors gathering around attractions to the electron cloud model and thus devise a method for prediction of visitor density around electrical outlets. Then we use our previous method to calculate electricity costs for each outlet and therefore derive the total expenditure of a public venue. To find out how results may vary for different types of venues, we apply our model to three public places of different types—which are Shanghai National Convention and Exhibition Center , Shanghai Pudong International Airport and a typical café respectively.

In order to boost the businesss revenue, we set up a model to evaluate the distribution of electrical outlets based on two factors—customer experience (which may result in higher popularity and profits) and overall electricity expenditure. Then we utilize Simulated Annealing to optimize outlet distribution for a fixed number of outlets by maximizing the score of this evaluation. We apply our cost-reduction model to Shanghai National Convention and Exhibition Center and derive the electricity expenditure in the optimal scenario.

5.2 Strengths and weaknesses

5.2.1 Strengths

Novelty: We are avant-couriers in likening our visitor distribution model to that of electron distribution.

Low calculation complexity: After making an analogy between distribution of people to that of electrons, we have greatly simplified our calculation of visitor density for different areas.

High Generalizability: Our model is highly adaptive and can be utilized for variegated types of public places.

5.2.2 Weaknesses

Idealization: Harnessing the electron model of distribution renders our model very idealized, as we assume that people only cluster around attraction sites.

No verification of raw data: The deficiency of accessible statistics disables us to guarantee the accuracy of our raw data, and thus our results may deviate slightly from the reality.

References

[1] The World Bank organization:
https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC

[2] Wikipedia:
https://en.wikipedia.org/wiki/Simulated_annealing

Appendices

Here are programs used in our models.

Appendix A Source codes of the public place simulation

Input Matlab source:

```
n=input('');
tic
a=zeros(n);
%for i=1:n
%    a(i,:)=i*n-n+1:i*n;
%end
a=rand(n)*9;
b=zeros(n);
for i=1:n
    for j=1:n
        for k=1:n
            for l=1:n
                if i~=k&&j~=l
                    b(i,j)=b(i,j)+a(i,j)*0.01/((i-k)^2+(j-l)^2);
                end
            end
        end
    end
end
c=randi([1 n],2,floor(n^2/2500));
d=zeros([1 floor(n^2/2500)]);
for i=1:n
    for j=1:n
        for k=1:floor(n^2/2500)
            if (c(1,k)-i)^2+(c(2,k)-j)^2<=25
                d(k)=d(k)+a(i,j);
            end
        end
    end
end
s1=subplot(2,2,1);
mesh(s1,a)%bar3
title('Randomized Visitor Density')
cameratoolbar
% s2=subplot(2,2,2);
% mesh(s2,b)
% title('Gravity Field')
% cameratoolbar
s3=subplot(2,2,2);%4,5);
plot(c(1,:),c(2,:),'o')
title('the Position of Electrical Outlets')
axis([0 n 0 n])
s4=subplot(2,2,3);%8,[11 12 13]);
bar(1:floor(n^2/2500),d)
title('Visitor Density near each Outlet')
s5=subplot(2,2,4);%8,[14 15 16]);
syms f(x)
f(x)=piecewise(0<=x&x<50,0.36*x,x>=50,18);
bar(1:floor(n^2/2500),f(d),'r')
```

```
title('Electricity Fee at each Outlet')
toc
```

Appendix B Source Codes of electricity expenditure calculation for a single outlet

Input Matlab source:

```
syms x
hold on
fplot(piecewise(0<=x&x<50,0.144*x,x>=50,7.2));
fplot(piecewise(0<=x&x<50,0.504*x,x>=50,25.2));
axis([0 100 0 50])
title('the Extent of Electricity Consumption')
xlabel('Visitor Density')
ylabel('Electricity Consumption/kWh')
legend(['minimum';'maximum'])
hold off
```

Appendix C Source codes of floor plan processing

Input Python source:

```
# -*- coding: utf-8 -*-
"""
Created on Thu Jun 20 17:04:25 2019

@author: zsc_c
"""

# -*- coding: utf-8 -*-
"""
Created on Tue Apr 16 17:52:11 2019

@author: zsc_c
"""

import numpy as np
import matplotlib.pyplot as plt
def Addstring2(s,out,a,b,times=1,color=np.array([0,0,0])):
    a=a-times
    b=b-times
    standard=plt.imread('C:/Users/zsc_c/Desktop/.png')
    output=plt.imread(out)
    size=standard.shape
    standard=standard.reshape(size[0]*size[1],size[2])
    standard=standard.T
    standard=standard[0:3]
    standard=standard.T
    standard=standard.reshape(size[0],size[1],3)
    size=output.shape
    output=output.reshape(size[0]*size[1],size[2])
    output=output.T
    output=output[0:3]
```

```
    output=output.T
    output=output.reshape(size[0],size[1],3)
    first=b
    for i in range(len(s)):
        if s[i]!='\n':
            for j in range(11):
                for k in range(6):
                    for l in range(1,times+1):
                        for m in range(1,times+1):
                            if standard[j][ord(s[i])*7+k][0]==0:
                                output[a+j*times+l,b+k*times+m,:]=color
            b+=4*times
        else:
            b=first
            a+=12*times
    ans=plt.imshow(output)
    ans.write_png(out)
```

Input Python source:

```
# -*- coding: utf-8 -*-
"""
Created on Fri Nov  8 16:42:02 2019

@author: zsc_c
"""

from Addstring2 import *
import matplotlib.pyplot as plt
count=1
standard=plt.imread('C:/Users/zsc_c/Desktop/.png')
standard=standard.reshape([23,4])
standard=standard.T
standard=standard[0:3]
standard=standard.T
standard=standard*255
output=plt.imread('C:/Users/zsc_c/Desktop/1 - .png')
outgraph=plt.imshow(output)
outgraph.write_png('C:/Users/zsc_c/Desktop/1.png')
size=output.shape
output=output.reshape(size[0]*size[1],size[2])
output=output.T
output=output[0:3]
output=output.T
output=output.reshape(size[0],size[1],3)
output=output*255
ans=np.zeros([2001,4])
for i in range(size[0]):
    for j in range(size[1]):
        for k in range(23):
            if(output[i][j][0]==standard[k][0] and output[i][j][1]==standard[k][1] and output[i
                Addstring2(str(count),'C:/Users/zsc_c/Desktop/1.png',i-2,j+2,color=[standard[k]
                ans[count][0]=i
                ans[count][1]=j
                ans[count][2]=k
                count=count+1
output=plt.imread('C:/Users/zsc_c/Desktop/ - .png')
outgraph=plt.imshow(output)
outgraph.write_png('C:/Users/zsc_c/Desktop/.png')
size=output.shape
output=output.reshape(size[0]*size[1],size[2])
```

```
output=output.T
output=output[0:3]
output=output.T
output=output.reshape(size[0],size[1],3)
output=output*255
for i in range(size[0]):
    for j in range(size[1]):
        for k in range(23):
            if(output[i][j][0]==standard[k][0] and output[i][j][1]==standard[k][1] and output[i
                Addstring2(str(count),'C:/Users/zsc_c/Desktop/.png',i-2,j+2,color=[standard[k][
                ans[count][0]=i
                ans[count][1]=j
                ans[count][2]=k
                count=count+1
"""output=plt.imread('C:/Users/zsc_c/Desktop/2 - .png')
outgraph=plt.imshow(output)
outgraph.write_png('C:/Users/zsc_c/Desktop/2.png')
size=output.shape
output=output.reshape(size[0]*size[1],size[2])
output=output.T
output=output[0:3]
output=output.T
output=output.reshape(size[0],size[1],3)
output=output*255
for i in range(size[0]):
    for j in range(size[1]):
        for k in range(23):
            if(output[i][j][0]==standard[k][0] and output[i][j][1]==standard[k][1] and output[i
                Addstring2(str(count),'C:/Users/zsc_c/Desktop/2.png',i-2,j+2,color=[standard[k]
                ans[count][0]=i
                ans[count][1]=j
                ans[count][2]=k
                count=count+1"""
np.savetxt(r'C:\Users\zsc_c\Desktop\1.csv',ans,delimiter=',')
```

Appendix D Source Codes of predicting visitor distribution

Input Matlab source:

```
load a
n=397;
tic
aa=zeros(n);
%for i=1:n
%    a(i,:)=i*n-n+1:i*n;
%end
for i=1:length(a)
    aa(a(i,1)+1,a(i,2)+1)=a(i,3);
end
b=zeros(n);
for i=1:n
    for j=1:n
        for k=1:n
            for l=1:n
                if i~=k&&j~=l
                    b(i,j)=b(i,j)+aa(i,j)/((i-k)^2+(j-l)^2);
                end
            end
```

```
        end
    end
end
%MTKL Algorithm
Sum=sum(sum(b));
b=b/Sum;
bb=[0 reshape(b,[1 n^2])];
for i=2:n^2+1
    bb(i)=bb(i-1)+bb(i);
end
a=zeros(n);
for i=1:n^2*9
    k=rand;
    for m=1:n
        flag=false;
        for j=1:n
            if bb((m-1)*n+j)<=k&&k<=bb((m-1)*n+j+1)
                a(m,j)=a(m,j)+1;
                flag=true;
                break
            end
        end
        if flag
            break
        end
    end
end
c=randi([1 n],2,floor(n^2/2500));
d=zeros([1 floor(n^2/2500)]);
for i=1:n
    for j=1:n
        for k=1:floor(n^2/2500)
            if (c(1,k)-i)^2+(c(2,k)-j)^2<=25
                d(k)=d(k)+a(i,j);
            end
        end
    end
end
s1=subplot(2,2,1);
mesh(s1,a)%bar3
title('Randomized Visitor Density')
cameratoolbar
% s2=subplot(2,2,2);
% mesh(s2,b)
% title('Gravity Field')
% cameratoolbar
s3=subplot(2,2,2);%4,5);
plot(c(1,:),c(2,:),'o')
title('the Position of Electrical Outlets')
axis([0 n 0 n])
s4=subplot(2,2,3);%8,[11 12 13]);
bar(1:floor(n^2/2500),d)
title('Visitor Density near each Outlet')
s5=subplot(2,2,4);%8,[14 15 16]);
syms f(x)
f(x)=piecewise(0<=x&x<50,0.36*x,x>=50,18);
bar(1:floor(n^2/2500),f(d),'r')
title('Electricity Fee at each Outlet')
toc
```

Appendix E Source Codes of optimization for Model B

Input Matlab source:

```
load mm
tic
%cc=randi([1 n],2,floor(n^2/2500));%zeros([2,floor(n^2/2500)]);
% for m=1:floor(n^2/2500)
%     aaa=zeros([1 n^2]);
%     maxx=1;
%     for i=1:n
%         for j=1:n
%             ccc=cc;
%             ccc(:,m)=[i;j];
%             jiyihua=false(n);
%             d=zeros([1 m]);
%             for k=1:m
%                 for ii=ccc(1,k)-5:ccc(1,k)+5
%                     for jj=ccc(2,k)-5:ccc(2,k)+5
%                         try
%                             if (ccc(1,k)-ii)^2+(ccc(2,k)-jj)^2<=25
%                                 d(k)=d(k)+a(ii,jj);
%                                 jiyihua(ii,jj)=true;
%                             end
%                         end
%                     end
%                 end
%             end
%             aaa((i-1)*n+j)=sum(b(jiyihua))/Sum-2019*sum(f(d));%Sensitivity Analysis
%             if(aaa(maxx)<aaa((i-1)*n+j))
%                 maxx=(i-1)*n+j;
%             end
%         end
%     end
%     cc(m)=[floor(maxx/n);maxx-floor(maxx/n)];
%     toc
% end
jiyihua=false(n);
d=zeros([1 length(cc)]);
for i=1:n
    for j=1:n
        for k=1:floor(n^2/2500)
            if (ccc(1,k)-i)^2+(ccc(2,k)-j)^2<=25
                d(k)=d(k)+a(i,j);
                jiyihua(i,j)=true;
            end
        end
    end
end
maximum=sum(b(jiyihua))/Sum-100*sum(f(d));
toc
for m=floor(n^2/2500):-1:1
    p=randperm(floor(n^2/2500),m);
    ccc=cc;
    for i=p
        ccc(1,i)=randi([1 n]);
        ccc(2,i)=randi([1 n]);
    end
    jiyihua=false(n);
    d=zeros([1 length(ccc)]);
```

```
    for i=1:n
        for j=1:n
            for k=1:floor(n^2/2500)
                if (ccc(1,k)-i)^2+(ccc(2,k)-j)^2<=25
                    d(k)=d(k)+a(i,j);
                    jiyihua(i,j)=true;
                end
            end
        end
    end
    result=sum(b(jiyihua))/Sum-100*sum(f(d));
    if result>maximum
        disp(ccc)
        disp(cc)
        cc=ccc;
        maximum=result;
        disp('ţ')
    end
end
save mm
toc
function ff=f(x)
    ff=x*0.36.*(0<=x&x<=50)+18*(x>50);
end
```