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2017

20th Annual High School Mathematical Contest in Modeling (HiMCM) Summary Sheet

Team Control Number: 8062

Problem Chosen: A

The flying of drone is a popular aerial performance now. The difficulty is that we need to design flight pattern, flight routes, and other flight parameters before performing, that we discussion around those.

Firstly, we get the drone distribution according to the image processing function of MATLAB. For simple patterns (such as Ferris wheel), we find each of the marginal functions and length in the pattern, and assign the drone equally according to the total length of the pattern. For complex images (such as dragon), because can't figure out each of the marginal functions in the pattern, we through the MATLAB transformed into the RGB matrix and then transformed into 0-1 matrix, and then pick the edge pixel of the image, and then according to the distance between the edge pixel points, all the edge pixel points are ordered and the fixed number of drone is distributed according to the sorting results.

And then we choose 300, 400 ...... 1000 drones, and look at the effect of the final impression drawing, found that when the number of drones increased to 500 - 600, the effect of the image is not obvious increase. Therefore, we select the 500 drones which given in the topic for further research. Among them, the flight area of drone is calculated by drone distribution and the distance between adjacent drones can not be greater than 2 meters; the safety factors of drone mainly consider the two factors of drone internal GPS positioning error and external environment factors; drone flight time includes: drone ascent stage, image conversion stage, image rotation phase, descent stage, light duration or intermittent flicker stage.

Finally, we select several images to validate our model, and we conclude that our model is more suitable for images with more smooth edges. The advantage of our model is that we can change any number of drones and any patterns, and then quickly get the position (x_i, y_i, z_i) of the drone, but our model needs to pre-process the image.

Contents

1 Introduction

1.1 Background

Drones not only evince the advanced development of our country, they can also provide us with some significant aerial light shows when numerous colorful drones flying into the air during the quiet night. In 2015, Intel has already devised 100 Shooting Star™ drones and performed wonderful aerial light shows. When drones lit up to the air and merged with the celeste skies and warm sunshine, we were moved by significant visual impacts. After eight months in 2016, they showed this spectacle again by making efficient use of five hundred drones, broking the past records as well as creating new Guinness World Records. Nowadays, aimed to celebrate our city's important festival, we are supposed to design an outdoor aerial show, which includes three different possible performances made by multitudinous drones.

1.2 Problems

For the sake of congratulating a yearly ceremony, we are required to provide the conception of using drones to create three possible light show displays.

In order to ensure the successful procession during three shows:

(a) Ferris

(b) Dragon

(c) Create your own image

We should:

(a) Build models to determine the required number of Drones and every Drone's initial location during the process

(b) Apply mathematical methods to make sure the flight route of every Drone and the setting of drone. Then describe the flight routes according to mathematical language.

Write a two-page memo to the Mayor to report the results of your investigation and make a recommendation as to whether or not to do the aerial light show.

2 Justification of our model

In order to better understand the topic background, just in Wuhan, China on November 4, there is a world conference on flight assembly of unmanned aerial vehicle (drone) cluster light show, I and my team to watch the flight assembly, in the watch, we get the following conclusion: First of all, all of drones lined as a square in the ground. And then, they hovered into the sky in batches according to the command. After arriving in the specified height, their lights were illuminated and they stayed in their own position for a moment in order to present the pattern for spectators. Next, they turned into the icon of Intel on the basis of track, which was set in advance. They moved in different time period, dividing into several regions. Every drone is inclined into disparate degrees so that spectators can see various shapes from diverse angel. When drones reached the visual effect, they descended in order and finished the show.

Based on the requirements and information mentioned in 1.2, when drones are controlled and performed, there are several following challenges that need to be fixed. First, we need to identify the location of each drone. For simple-shape design, drones are arranged in the shape of the design. After graphing design, we calculate the length of each side. And then we use plot, instead of line, to construct outline of the design. The location of each drone is the plot. The increasing complexity of the image leads to the difficulty to plot each drone. We plan to the complex, colored image by forming 0-1 matrix so that edges are simplified into white or black plots. Then, the program will search for the first black plot, and then find the closest black plot with certain distance the second one, and finally get required plots, which are the locations of drones.

Second, when the drones need to be reshaped in the sky, they might crash. Drones are divided into several batches to take off and rise up to different height. Drones in the same height move along the same direction at the same time roughly.

These five pictures represent ’The drone is distributed on the ground’, ‘Drones rise in batches’, ‘The drone light can be switched on the air’’, ‘The drone moves in batches’, ‘Drones rotate to different angles’ respectively.

3 Assumptions

(1)Assuming that the three performances are continuous, there is no drone falling and then ascending in midway.

(2)Assuming that the drone GPS positioning error uses a more advanced double star positioning, positioning error is only 1 meters。

(3)Assuming that there is no cooperative action between drones, that is, the action between each drone does not affect the action of other drones.

(4)Assuming that the distance from the audience to the performance area in the different directions is equal, because the time is limited, and the calculation is simplified.

4 THE MODEL

4.1 Image contour

4.1.1 Mathematical expression for simple graph

Graph of Ferris Wheel is composed of the simple functional graphs such as lines and circles. In this way, we need to determine the expressions of these circles and lines, and their perimeters. The structure of the Ferris Wheel, "The London Eye"[1], can be roughly drafted as mathematical functional figures shown in Fig.1. The cars are referred to as outer circles; the frame is referred to as inner circles and inner lines; and the pedestal is referred to as stanchion lines.

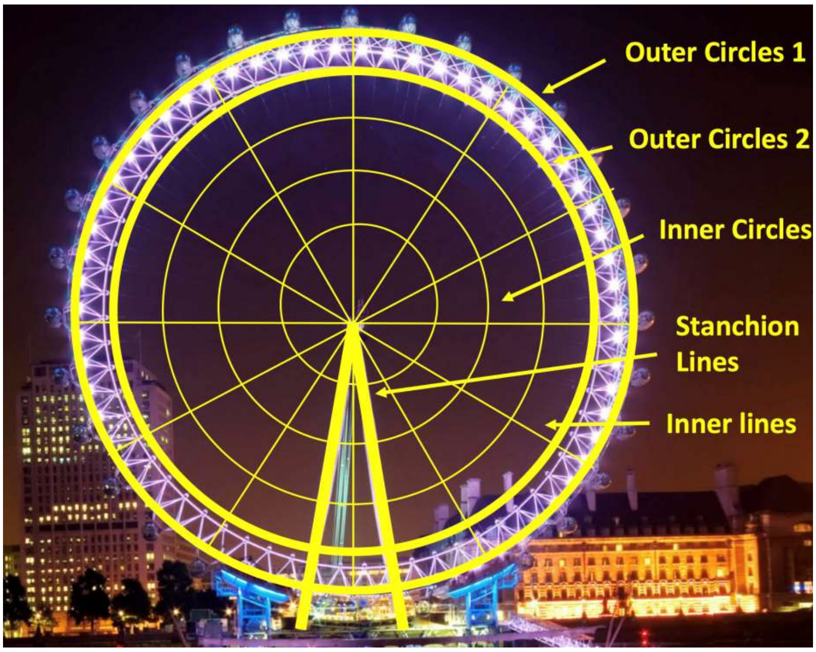


Fig.1 functional expression of The London Eye

Assume that the center of circles is origin. And R_{C1}, R_{C2} are the radii of two outer circles, and C_1, C_2 are represented as the perimeter of the outer circles. The parametric equation of the inner circles is shown following,

$$\begin{cases} x = \sin\left(\frac{2\pi}{t}\cdot m\right)\cdot\frac{i}{n+1}\cdot R_1 \\ y = \cos\left(\frac{2\pi}{t}\cdot m\right)\cdot\frac{i}{n+1}\cdot R_1 \end{cases}$$

$$\begin{cases} m = 1, 2, 3, \dots, t \\ i = 1,2,3, \dots, n \end{cases}$$

where *x* and *y* are the coordinates of every point at the inner circles; t is the number of drones in one inner circle; and n is number of circles inside. By joining the points in one line which passes through the origin, the inner lines could be derived. And the expression of stanchion line could be estimated as a linear function which could by estimating the slope (the slant angle of the pedestal mostly is around 15°) according to the reality. And comparing with the most Ferris Wheels' pictures, it can be measured that the ratio between R_{C1} and R_{C2} is nearly 1.1 (such as for The London Eye, the ratio is 135: 122 = 1.106[2]). By using the MATLAB, the distribution graph of the drone swarm could be realized, shown in Fig.2 following, which the larger points represent the higher brightness.

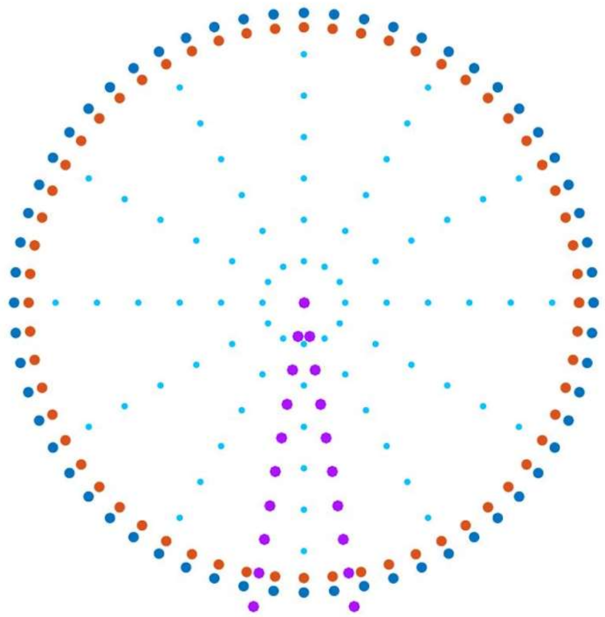


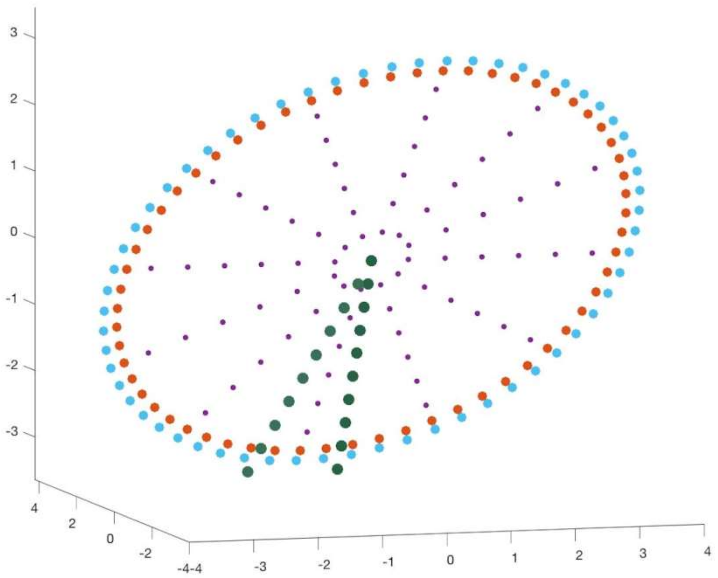
Fig.2 Ferris Wheel Plan

In addition, the amount of drones and their distribution can be obtained by parameterization. Assume that the numbers of drones at each inner circles are N_1, N_2, N_3, … N_i and the radii of each circle are R_1, R_2, R_3, … R_i, respectively. Defining the drones' density:

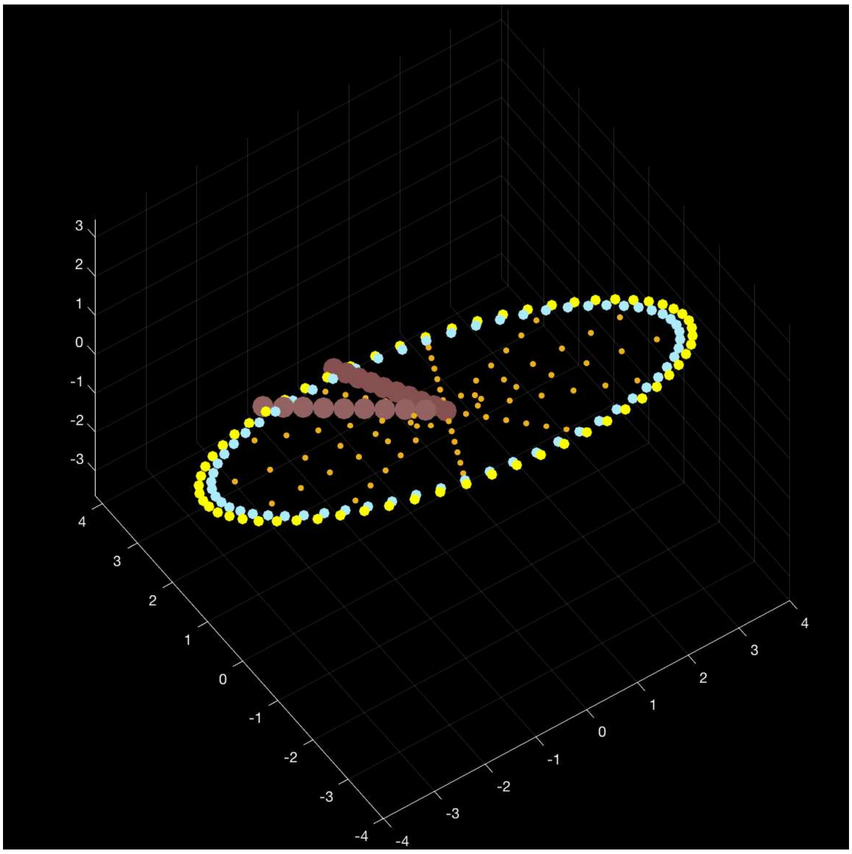
$$\rho = \frac{N_i}{R_i}$$

From the deeper research, errors caused by GPS positioning lead to the minimum safe distance between two normal drones that is around 3 to 5 meters. Thus, every two points in the functional graph should be less than this distance.

When in the real performance, the drone swarms are flied in three dimension. But the movement of each drone is in one dimension. So for every performance pattern, first we could draw the 2-D mathematical image, then slope it in an angle which could enjoy the spectators best (specifically illustrate at 2.1). Assuming the view angle is 30°, the MATLAB simulates the image shown in Fig. 3. a & b.



a. Ferris Wheel in 3-D



b. top view of design sketch

Fig.3 a. & b. show the Ferris-Wheel-shaped function realized in 3-D

The cost and the aesthetics are also the significant consideration of designing. The less drones with more beauty, the better design it is. By changing the number of drones in the outer circles and in the pedestals, we could make trade-off. Several comparison diagrams are shown in Fig.4:

Fig. 4 different numbers of drones in Outer Circles and Pedestals

The second scheme is what we represent: forty drones in each outer circles, twelve drones in each inner circles, nine drones for each pedestal, thirty degrees for the slant angle of two pedestal, and thirty degrees for the angle of inclination in three dimension.

4.1.2 Mathematical expressions of complex graphs

4.1.2.1The preprocessing of the image

As for the complex image, like the image of dragon, we need to preprocess the image first. After finding an image of dragon, we preprocess the image into amonochrome image. In order to diminish distraction image, like fig 3 , We consider two scenarios: (1) only the pattern of edge information, (2) contains the design of the interior elements

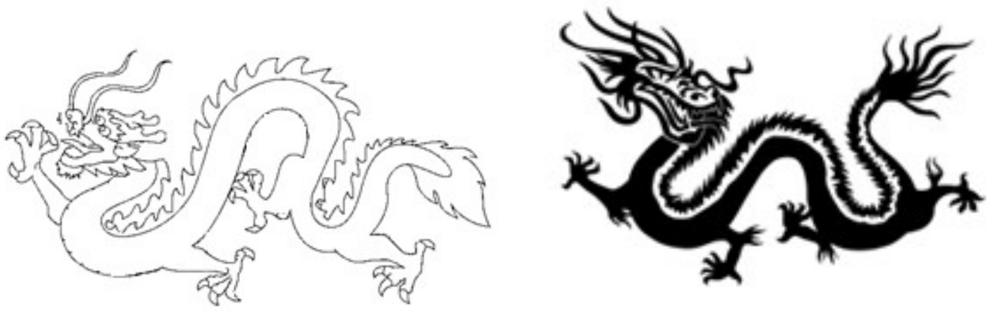


Fig 5

4.1.2.2 Image binaryzation

The arrangement of drones is usually along the edge of the image. If we use gray matrix, the pixel value cannot be identified. Therefore, we use threshold matrix to identify the pixels in the image.

According to knowledge related to computer graphics, we need to handle the image before we divide the pixels that represent the image of dragon and the pixels that represent other things. Normally, through grey processing, we regulate the range of the pixel value from 0 to 255. Then, we set up the threshold value to divide the pixels that represent the image of dragon and the pixels that represent other things

In addition, for a monochrome image, we only need to divide the image into white area and black area.

In order to express the pixels that represent the image of dragon and the pixels that represent other things, we use MATLAB to preprocess the image. First, the image is imported into MATLAB, and MATLAB generate corresponding pixel matrix. According to the knowledge related to computer graphics, the RGB of white area is 255. In order to make the image feature clearer, it's necessary to use image threshold method, showed in the following equations.

$$Q=\begin{cases}0, & q_{ij}\geq 150\\ 1, & q_{ij}<150\end{cases}$$

Attention: We convert the elements greater than 150 to 0, and convert less than 150 to 1, the purpose is to make the original white image turn black (like the night sky), the original edges will become white (like light colors) and can be assigned different colors after the MATLAB imshow function.

In the equations, qij represents the pixel value before image threshold; P_{ij} represents the pixel value after image threshold.

Through image threshold, a series of pixel value matrix are produced, which can be used for image feature extraction.

4.1.2.3 Image edge information extraction

For the picture in Figure 4, we need to extract the edge information. For the picture in Figure 3, we need to delete the redundant edge information. So we all have a process of extracting edge information. There are many ways to extract the edge information, but they are all very complex. Here we think of a relatively simple method of edge information extraction:

For p_{ij}, d_{ij} represent the corresponding gray matrix of the initial image and the corresponding matrix of the edge image respectively. And p_{ij}, d_{ij} are all 0-1 matrices. The principle of extraction is：

$$\begin{pmatrix} p_{11} & & & & p_{1n} \\ & p_{(i-1)(j-1)} & p_{(i-1)j} & p_{(i-1)(j+1)} & \\ & p_{i(j-1)} & p_{ij} & p_{i(j+1)} & \\ & p_{(i+1)(j-1)} & p_{(i+1)j} & p_{(i+1)(j+1)} & \\ p_{m1} & & & & p_{mn} \end{pmatrix} \Rightarrow \begin{pmatrix} d_{11} & & & & d_{1n} \\ & d_{(i-1)(j-1)} & d_{(i-1)j} & d_{(i-1)(j+1)} & \\ & d_{i(j-1)} & d_{ij} & d_{i(j+1)} & \\ & d_{(i+1)(j-1)} & d_{(i+1)j} & d_{(i+1)(j+1)} & \\ d_{m1} & & & & d_{mn} \end{pmatrix}$$

- $If\ p_{ij} = 0, then\ d_{ij} = 0$

If p_{ij} represents the outside region, then d_{ij} is consistent with p_{ij}

- $If\ p_{ij} = 1\ and\ \forall\left(p_{(i+1)j} = 0, p_{i(j-1)} = 0, p_{(i-1)j} = 0, p_{i(j+1)} = 0\right), then\ d_{ij} = 0$

If p_{ij} represents an internal region, then d_{ij} does not agree with p_{ij}

- $If\ p_{ij} = 1\ and\ \exists\left(p_{(i+1)j} = 0, p_{i(j-1)} = 0, p_{(i-1)j} = 0, p_{i(j+1)} = 0\right), then\ d_{ij} = 1$

If p_{ij} represents the edge region, then d_{ij} is in line with p_{ij}

After handling the above principles, we have heard that MATLAB is different

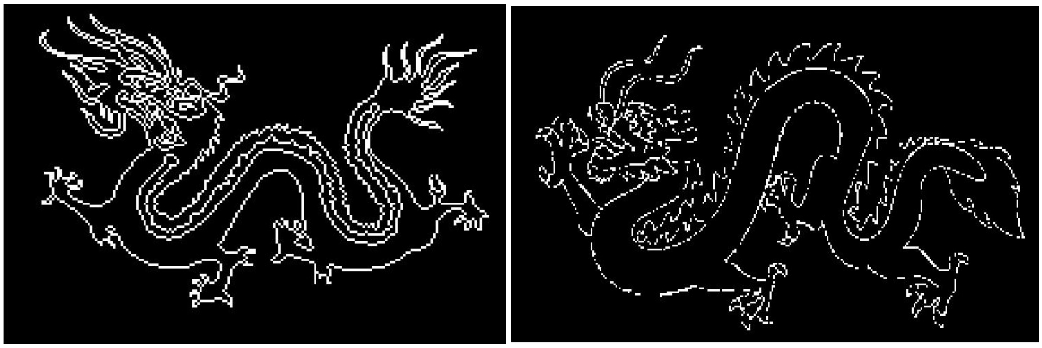


Fig6.

According to the principle of extraction, we can achieve extracting Fig5. by using MATLAB, and the extracting figure compared to the previous figure that are not be extracted show at figure.

We used MATLAB to find out that there are 2328/2374 pixels in the image above. Since the number of Drones is limited, it cannot reach 2328/2374 so I need to choose N pixels from an average of 2328/2374 pixels. N is the number of dones.

4.1.2.3 Rank the edge pixels

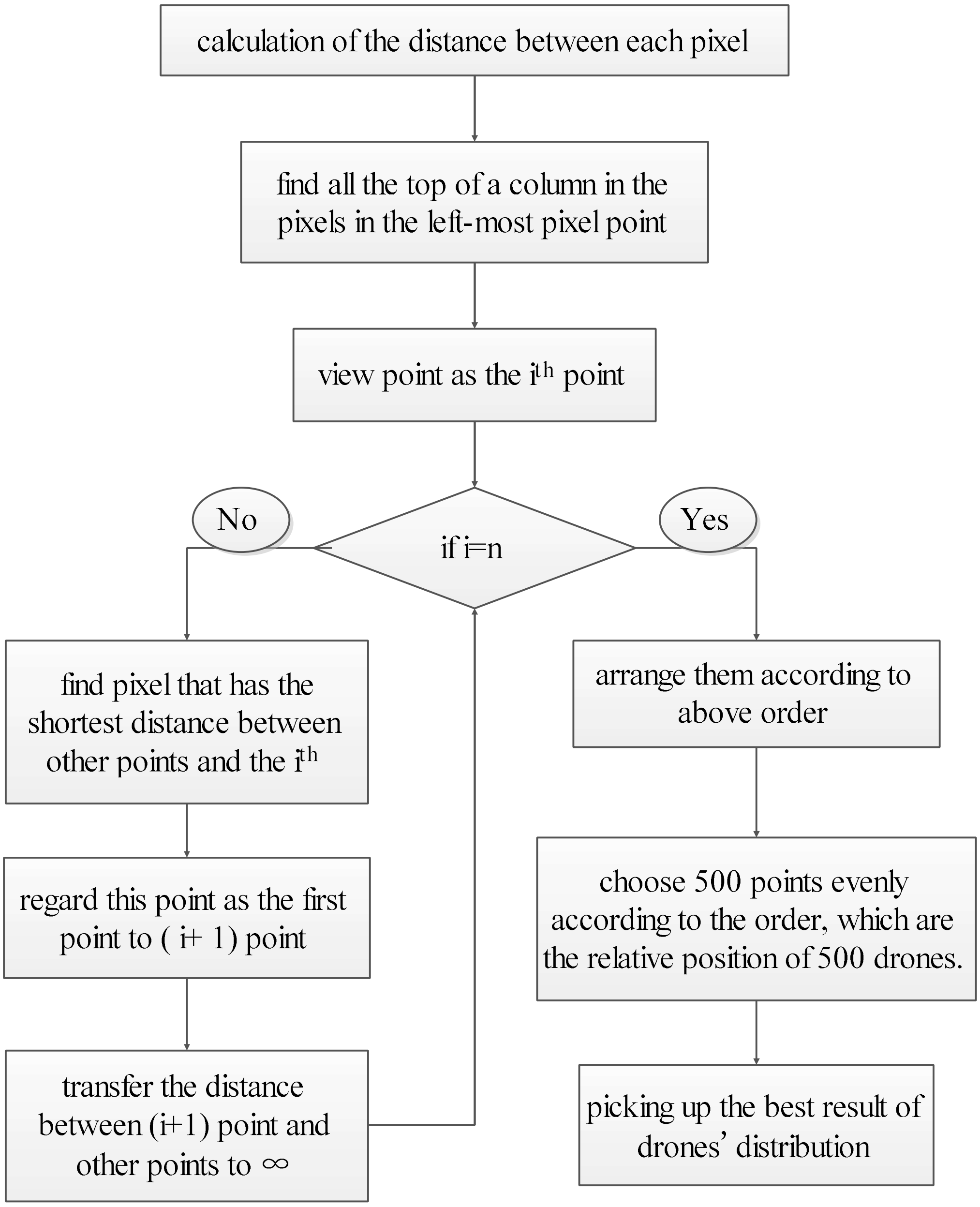
In this part, we choose a method called average selection. Average selection does not mean choosing at random or choosing at the standard of horizontal and vertical, and it means choosing on the basis of the edge length of pixels, but the edge of pixels is too difficult to calculate. Therefore, we need to rank the pixels.

Choose the initial point (the left-most point at top)

We can use matrix B and check from one line. If it exits 1, that point is the initial point, and if it does not exist, we can check continually.

We can calculate the distance from other points to initial point, and find the point that has the nearest distance, so this one is the second point. We can find other points through circulation by imitating the preceding procedure, and this circulation has eight hundred and ninety times.

This process can be depicted by the following flow chart. We can locate the position of drones by average choosing five hundred points from 2328 or 2374 points. The 2D expression to show the coordinate of drones is (x_i, y_i).



4.2 Three Displays

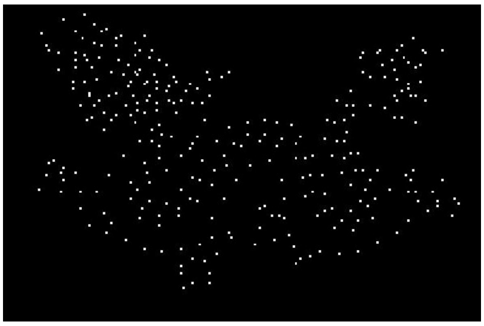
We have to design three different images, the first image is Ferris wheel (can be expressed by function); the second is the dragon (the edge of the image is not smooth);

the third we choose the panda with Chinese characteristics (smooth edge of the image)

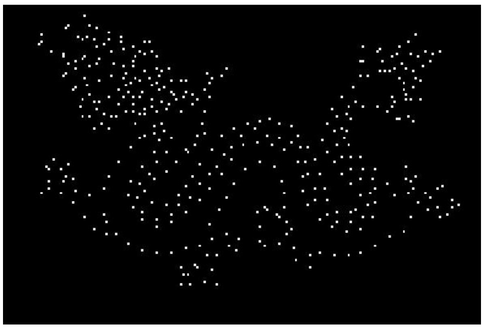
Fig7. The panda image

4.2.1Determination of the number of drones

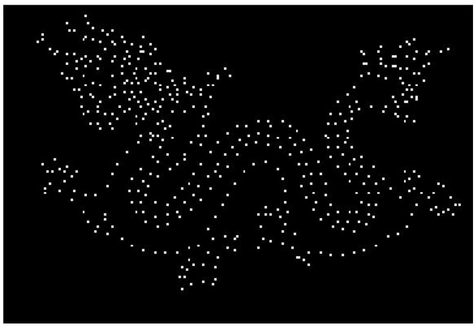
We know that the patterns of dragons are the most complex in many patterns of drones, complex patterns require the highest number of drones, So our team's dragon pattern determines the best number of drones : So we chose different numbers of drones to draw the drawing. The principle of drawing was based on 4.1, and the result was shown as follows:



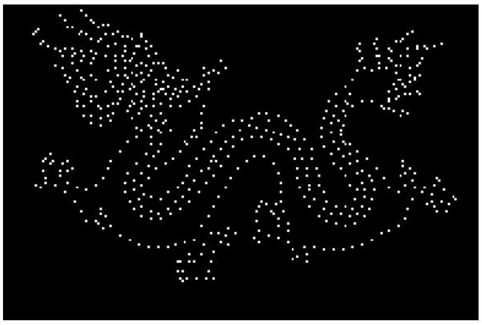
300 drones renderings



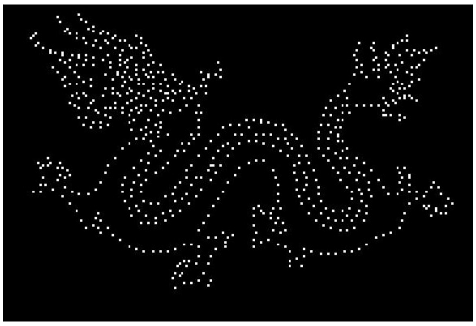
400 drones renderings



500 drones renderings



600 drones renderings




700 drones renderings 800 drones renderings


900 drones renderings 1000 drones renderings

Fig8 Different Numbers of drones renderings

As can be seen from the above diagram, it is not hard to find that the effect of the drone is not obvious when the number of unmanned aerial vehicles exceeds 600. Therefore, we directly select 500-600 drones to complete our performance needs. And it doesn't waste resources.

4.2.2 The imaging effect of the third image

We use 500 drones to show the drone pattern of the third image, which is the panda, as shown below:

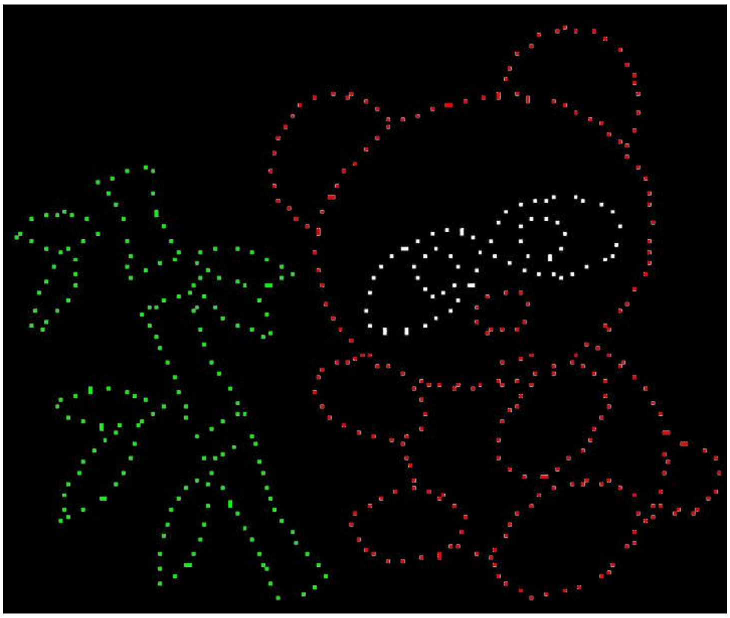


Fig9 Panda final image

We painted the colors of the bamboo green, and the color of the panda was painted red to make it look better.

4.3 Flight range

The number of Drones is n, which changes as the image changes.

$$x_{max} - x_{min} = \text{horizontal distance}$$

$$y_{max} - y_{min} = \text{vertical distance}$$

We can calculate the maximum performance area due to certain plotting scale and horizontal and vertical distance.

Calculate the distance of complex graph

The distance between the i^{th} pixel and $(i-1)^{th}$ pixel is di. We calculate every distance between two neighboring pixels, guaranteeing the smallest distance among all as safe distance-2m.

Calculating the number of pixels (x,y),

$$x/\min(di) = \text{the length of performing region/safety distance}$$

$$y/\min(di) = \text{the width of performing region/safety distance}$$

Calculate the distance of simple graph

Ferris wheel's radius is 1 and it has 60 points. The distance of every two points is 1/60.

$$1:2\pi = \text{performance areas/ safe distance}$$

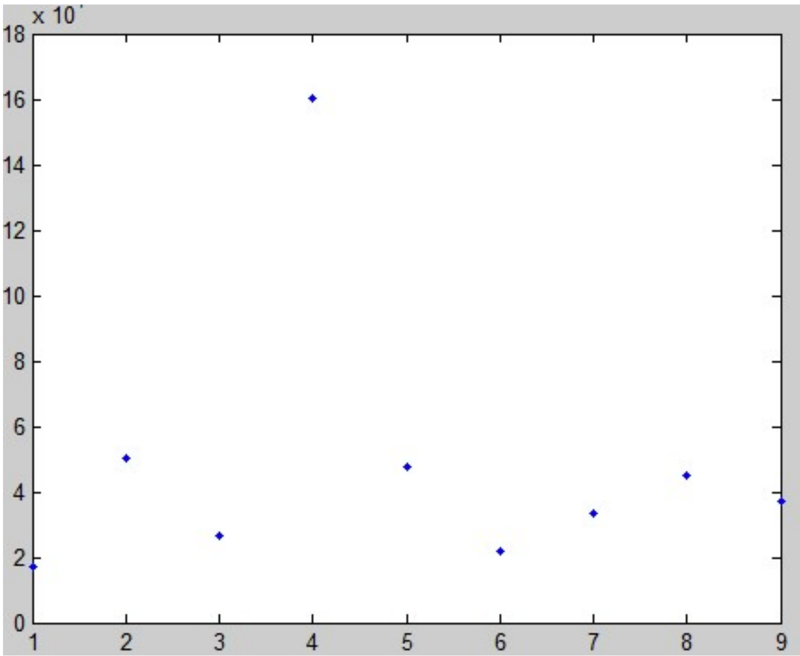


Fig10

We can see that the fourth image has the biggest area of demand, because the fourth image is more than complex and it has some protruding regions that are so concentrated. Based on this conclusion, we know that we need to avoid designing this kind of image in the future creation.

Different areas for graphs：

17300 50100 26800 160200 47585.33333 21789 33400 45066 37211.23779

Security factors

The error of GPS will lead the Drones to crash and cause malfunction of the Drone system so that it threatens the security of audiences.

4. 4 View angle

4.4.1 Plan to 3D graph

The drone show performs in the sky, so that people need to raise their heads to watch the show. In order to maximize the performance effect, we incline the Drone array to certain degrees. According to knowledge related to human mechanics, the suitable angle is around 30 degrees, which is the incline angle value of the Drone array as θ. The distance between audiences and performance region is L in meters. The height of the Drone array is depicted as (L, θ). With certain length of L, we can determine the height of each Drone from the equation:

$$h = L * \tan(90 - \theta).$$

The coordinate of every Drone in the 3-dimension is (x, y, z).

$$\begin{cases} x_0 = x \cdot \sin\theta \\ y_0 = y \\ z_0 = x \cdot \cos\theta + h \end{cases}$$

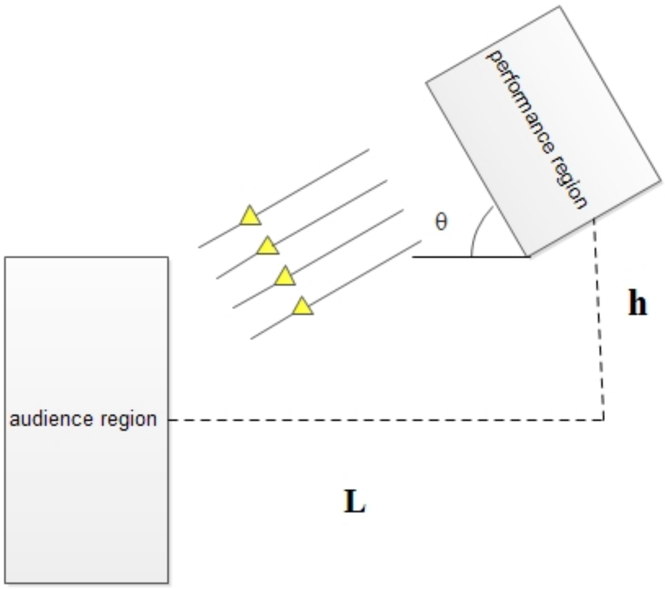


Fig 11

The figure shows the perspective of the audiences to the Drone arrays.

4.5 Performance time

In order to determine the total time of the performance time, we can divide the time into several portions, T_1 for the time that Drones flying from the ground to the sky; T_2 for the rotation time in the sky; T_3 for the different graphs changing time; and T_4 for the landing time. Assume that there are x batches of Drones flying from the ground to the sky, and the flight distance of the i^{th} Drone is L_i, and L_{ij} shows the partial distance during the T_j period such as L_{i1} is the departure time, the L_{i2} is the changing time, and (x_{i1}, y_{i1}) and (x_{i2}, y_{i2}) illustrates the Drone's initial position on the ground and the position in the sky. More specifically, the departure time can be subdivided into the time that Drones fly vertically to the sky and the shaped time. Define L_{i1}^0 and L_{i1}^1 as each flight distance during the first process. The equation can be deduced following,

$$L_{i1}^{0} = h_i$$

$$L_{i1}^{1} = \sqrt{(x_{i1} + x_{i2})^2 + (y_{i1} + y_{i2})^2}$$

$$L_{i1} = L_{i1}^{0} + L_{i1}^{1}$$

$$t_i^{total} = \frac{L_{i1}}{v_0}$$

$$t_{i1}^{total} = t_{i1}^{0} + t_{i1}^{1}$$

where v_0 is the constant velocity of the Drone flying vertically to the sky. Therefore, T_1 can be derived:

$$T_1 = \frac{(\, h_i + \sqrt{(x_{i1} + x_{i2})^2 + (y_{i1} + y_{i2})^2}\ )}{v_0}$$

About the rotation time, we just need to consider the rotation time of the outermost points because require the longest time for rotation. Assume that the center of the rotation is the origin, then the equation:

$$T_2 = \frac{\max\,(\sqrt{{x_i}^2 + {y_i}^2})}{v_{max}}$$

where v_{max}, which is the largest velocity, is the outermost points' velocity, determined by the Drones' Product parameters and manipulators. And the angular velocity ω of whole system can be determined by:

$$\omega = \frac{2\pi}{T_2}$$

Moreover, the changing time actually has been expressed in the T_1

$$T_3 = t_{i1}^{total} - t_{i1}^{0} = t_{i1}^{1}$$

For the landing time, it is equal to the take-off period,

$$T_4 = T_1$$

By parameterizing every time period and assuming that the number of the performing pattern is *n*, the total time of whole aerial light shows can be expressed as following：

$$\mathrm{T} = T_1 + n \cdot T_2 + (n-1) \cdot T_3 + T_4$$

$$T = T1 + T2 + T3$$

$$t1 = \frac{2 \times (h_i + \sqrt{\left(x_{i1} + x_{i2}\right)^2 + \left(y_{i1} + y_{i2}\right)^2})}{v_0} +$$

$$t2 \frac{n \times \max\left(\sqrt{{x_i}^2 + {y_i}^2}\right)}{v_{\max}} +$$

$$t3 \frac{(n-1) \times \sqrt{\left(x_{i1} + x_{i2}\right)^2 + \left(y_{i1} + y_{i2}\right)^2}}{v_0}$$

Because the speed of the UAV can not be determined, so we can not find the specific time, can only be based on some video and World Fly-in Expo summarized results, 3 patterns of performance can last about 10 minutes, if it lasts for 30 minutes, you need to prepare 10 patterns.

5 Model examination

In order to check the accuracy and range of the model, we choose more graphs to calculate this model.

Fig 12

Put above graph into Matlab, and stipulate to use 500 drones. We can finally get the following image:

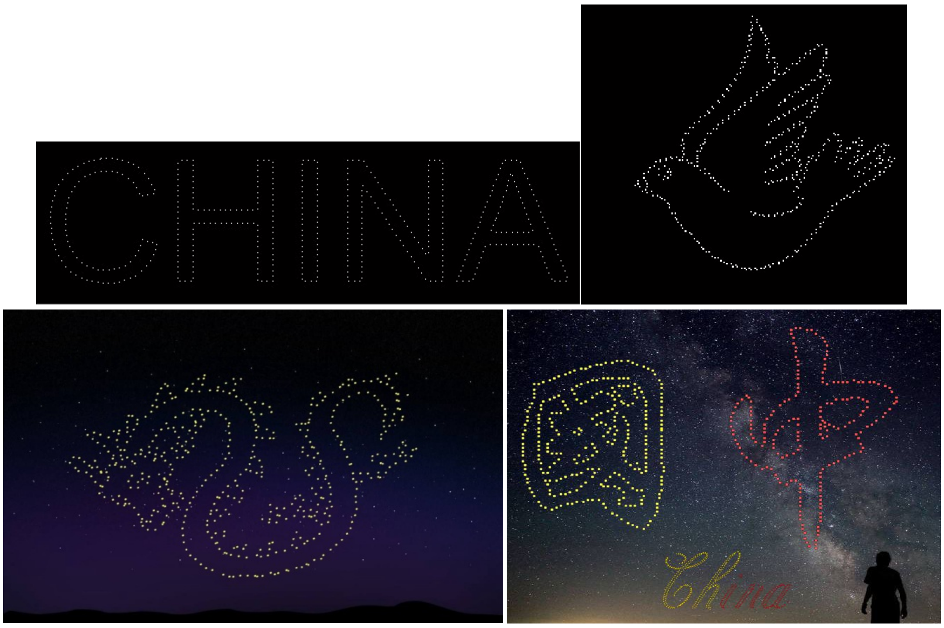


Fig 13

According to above figures, we can conclude:

When we deal with some pictures which have smooth edge, such as fronts and pandas, our model can work well. However, when we address the rough graph like dragon, it does not have great effect. Consequently, we need to avoid choosing pictures with rough edge. If we need to deal with such kind of pictures, those edges need to be polished.

6 Error check

According to the previous, we can know that drones can make some errors because of the GPS positioning error. Therefore, we can know the error range is 1 meter or 1 to 3 meters from previous section. We choose the accurate GPS and GALILEO binary positioning to check error for drones, which means the error range is 1meter.

We choose the image of 3th image (Padan), and the corresponding distribution is matrix t1, t2, and t3. We randomly decrease or increase ΔL of elements in the matrix t1, t2, and t3. ΔL conforms to the randomly arrangement: and we will get the new matrix as well as turn it into the following image:

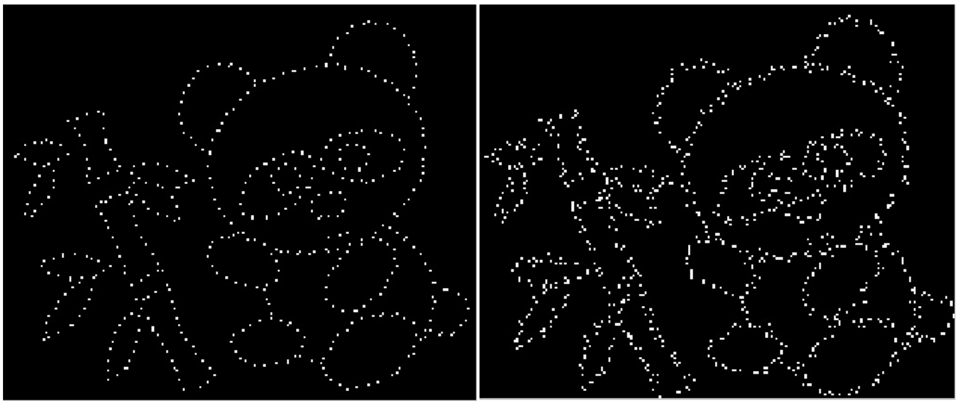
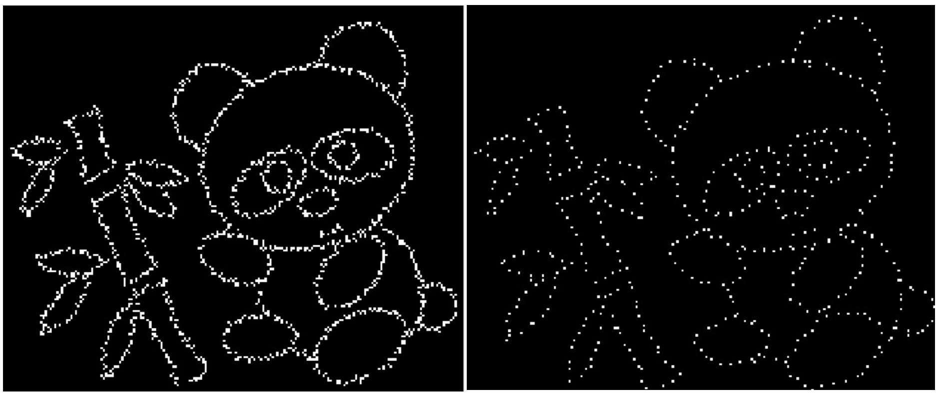


Fig 14

According to the comparison images above, we can find that even though there are errors. For fig 14, the images can be recognized. However, for fig 14, it's relatively harder to recognize the image. There are the main reasons: in fig 14, the curve distribution of the edge of the image is disperse; the curve distribution of edge of the image is concentrated for fig 14. In order to decrease the impact caused by the system error, we need to disperse the concentrated curve. Our conjectural solution plans are 1. Improve the technology of GPS and reduce the errors. 2. Increase the number of the drones and expand the image. 3. Expand the images directly, including expansion of the center of the image as original point proportionally due to the size of the drones.

Furthermore, solution plan 1 is limited by the technology, and solution plan 2 and solution plan 3 are shown below:



Solution plan2. Solution plan 3

Fig 15

According to the images shown above, solution plan 3 is better than solution plan 2. Therefore, we can employ any of them. The advantages and disadvantages are that solution plan 2 needs more drones and requires more cost; solution plan 3 is too diverse to make the figure clear enough without sufficient light.

7 Model evaluation

Advantages

This model could get the arrangement of the drones with any given number as soon as people draw the image that they want.

- This model could determine the location and arrangement of the drones with any given number, and according to the distribution image, we can get the most suitable number of the drones directly.
- This model avoids calculating the length of the edges of complex images directly, instead calculating the number of pixels and their locations.

Disadvantages

- When we deal with the keen and slender figure such as the tendrils of the dragon and the back of the dragon, it easily causes the congestion of drones. Our models cannot give the better resolution, and the only way to solve this is disposing the previous figure artificially.
- Our models have the high standard of figure's edge. If the image is too wide, the possibility of two edges will come. Our models do with this problem by using Image processing software to reduce the size of pixels at present.

All in all, the advantages of this model are the accuracy, convenience, and the diversity of the results. However, the requirement for the images is high-standard.

References

[1] http://uav.huanqiu.com/hyg/2017-10/11328630.html

[2] https://www.duitang.com/blog/?id=477001999

[3] https://wenku.baidu.com/view/f855190003d8ce2f006623db.html

[4] http://www.wfewh.com/

A letter

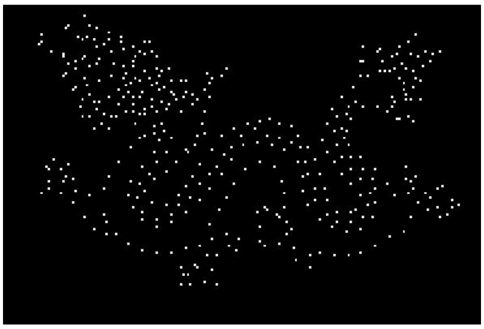
Dear mayor：

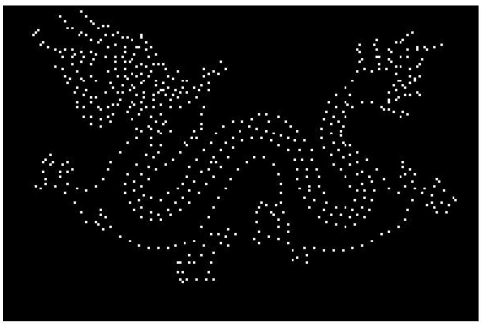
How are you, it's an honor to be able to design a "Drone Clusters as Sky Light Displays " for our city. Our team four people after 36 hours of research, and our team made a preliminary preparation for the lighting performance of the drone cluster. We went to Wuhan, China to watch the drones show of the world flight conference. Finally, we come to the following conclusions: drone performance is very beautiful, in the performance process, the drone can rotate around the center, so that the audience in different directions can see the best effect of the image, So in our city's drone cluster lighting show, the choice of the site can be for all directions, for more people to watch, such as parks and other areas.

Our model runs very well, and can be applied to different patterns, different numbers of drones, as long as you give different patterns you want, and the budget of the funds, we can achieve what you want, In this paper, we selected three images: Ferris wheel, dragon and Chinese characters to show. If you want more image display, you can run the code in the appendix, and you can get.

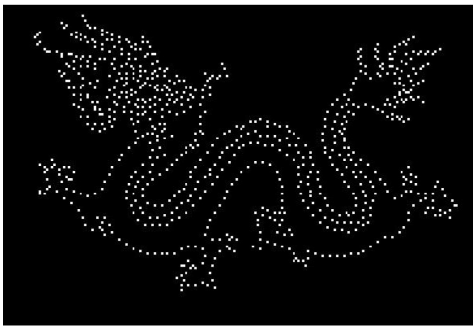
Here are three renderings of the pattern, the background after PS handle, it is easier to see the night sky effect:

Here are the effects of different numbers of drones（(page limited, only show the 400/600/800/1000 drones effect, respected mayor, you can overall consider the drone performance and drone performance price two aspects, the higher the price, the more the number of drones, but the better the display effect）:





600 无人机效果图




800 无人机效果图 1000 无人机效果图

Other matters needing attention in drones performance:

(1) If 500 drones are selected to perform, the performance area of the drone is about 300 meters long and 200 meters wide, while the drone performance area should be isolated to prevent the audience march into the arena.

(2) The lighting and pattern effects of the drone can be changed, but try to make the edges smoother.

(3) The drones performance of the three patterns is shorter and we expect to be within 10 minutes. According to the drone performance in other areas, they prepared a lot of patterns, about 10 - 20, lasting for 30 minutes or even longer.

(4) During the drone performance, too many streetlights should be avoided in the acting area so as not to affect the performance.

So, from our team's observation on the "drone show", Not only has it impacted our vision, but also more of our progress in science and technology, In the future, we hope to encourage some students to apply their knowledge to practical life. Cultivate practical ability to push our other technologies to a higher level. We also learn a lot during this practice, and we hope that we should do air light show.

Appendix

```
clear
clc
A=imread('d4.png');
A(find(A<150))=1;
A(find(A>=150))=0;
A=double(A);
A=A(:,:,1);

%imshow(A)
[x,y]=size(A);
B=zeros(x,y);
for i=2:x-1;
    for j=2:y-1;
        if A(i+1,j)==0 | A(i-1,j)==0 | A(i,j+1)==0 | A(i,j-1)==0
            B(i,j)=1;
        end
        if A(i,j)==0;
            B(i,j)=0;
        end
    end
end
%imshow(B)
n=sum(sum(B));
zero=find(B(1,:)==1);
zero=zero';
[sizex sizey]=size(zero);
zero_indexs=[ones(sizex,1) zero];
for i=2:x
zero=find(B(i,:)==1);
zero=zero';
[sizex sizey]=size(zero);
zero_indexs=[zero_indexs;i*ones(sizex,1) zero];
end

distance=zeros(n,n);
for i=1:n
    for j=1:n
        x0=zero_indexs(i,1)-zero_indexs(j,1);
        y0=zero_indexs(i,2)-zero_indexs(j,2);
        distance(i,j)=x0^2+y0^2;
    end
end
distance=distance+eye(n,n)*max(max(distance));
```

```
zero_xin=ones(n,2);
zero_xin(1,:)=zero_indexs(1,:);
ymin=1;
for i=2:n
        Dis=distance(ymin,:);

        [xmin yminmin]=find(Dis==min(min(Dis)));
        distance(ymin,:)=max(max(distance));
        distance(:,ymin)=max(max(distance));
        ymin=yminmin(1,1);
        zero_xin(i,:)=zero_indexs(ymin,:);
end

shumu=500;
bianhao=linspace(1,n,shumu);
bianhao=round(bianhao);
zero_xinxin=zero_xin(bianhao,:);
tu=zero_xinxin;
%plot(tu(:,1),tu(:,2),'.')
C=zeros(x,y);
for i=1:shumu
        qwe=tu(i,1);
        ewq=tu(i,2);
        C(qwe,ewq)=1;
end
imshow(C)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
x66=zeros(shumu,10);
y66=zeros(shumu,10);
double(tu1);
double(tu2):
for i=1:shumu
      x66(i,:)=linspace(tu1(i,1),tu2(i,1),10);
      y66(i,:)=linspace(tu1(i,2),tu2(i,2),10);
end

for i=1:10
plot(x66(:,i),y(:,i),'.')
pause(0.5)
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% 2-D Ferris Wheel
alpha=0:pi/30:2*pi;
  R=2;
  x=R*cos(alpha);
  y=R*sin(alpha);
  plot(x,y,'.','MarkerSize',20)
  axis equal
hold on
```

```
alpha=0:pi/30:2*pi;
R=1.9;
x=R*cos(alpha);
y=R*sin(alpha);
plot(x,y,'.','MarkerSize',20)
axis equal
m=1:12;
x0=[];
y0=[];
for i=1:6
x=sin(2*pi/12*m)*i*2/7;
y=cos(2*pi/12*m)*i*2/7;
x0=[x0 x];
y0=[y0 y];
end
plot(x0,y0,'.','color',[0 191 255]/255,'MarkerSize',12)
XY=[x0;y0]';
hold on
x = linspace (-0.35,0,10) ;
y = 6*x ;
plot (x,y,'.','color',[2/3 0 1],'MarkerSize',25) ;
hold on
x = linspace (0,0.35,10) ;
y= -6*x ;
plot (x,y,'.','color',[2/3 0 1],'MarkerSize',25) ;
hold on
x=0;y=0;plot(x,y,'MarkerSize',50)


% 3-D Ferris Wheel

alpha=0:pi/30:2*pi;
R=2;
x=R*cos(alpha);
y=R*sin(alpha);
x0=2*x;
y0=-y*2;
z0=-0.5*y0*3.^0.5;
plot3(x0,y0,z0,'.','MarkerSize',25)
axis equal
hold on

alpha=0:pi/30:2*pi;
R=1.9;
x=R*cos(alpha);
y=R*sin(alpha);
x0=2*x;
y0=-y*2;
z0=-0.5*y0*3.^0.5;
plot3(x0,y0,z0,'.','MarkerSize',25)
```

```
axis equal
hold on


m=1:12;
x0=[];
y0=[];
for i=1:6
x=sin(2*pi/12*m)*i*2/7;
y=cos(2*pi/12*m)*i*2/7;
x0=[x0 x];
y0=[y0 y];
end

y0=-y0*2;
z0=-0.5*y0*3.^0.5;
plot3(2*x0,y0,z0,'.','MarkerSize',12)
hold on

x = linspace (-0.35,0,10) ;
y = 6*x;
y0=-y*2;
x0=2*x;
z0=-0.5*y0*3.^0.5;
  plot3(x0,y0,z0,'.','MarkerSize',30)

hold on

x = linspace (0,0.35,10) ;
y= -6*x ;
y0=-y*2;
x0=2*x;
z0=-0.5*y0*3.^0.5;
plot3(x0,y0,z0,'.','MarkerSize',30);

hold on
```

Appendix 2

2D 2/5000

No.	dragon-0		dragon-1		dragon-2		CHINA		PANDA		DOVE	
	173	225	167	300	134	200	162	538	167	200	93	200
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	34	18	67	34	16	18	83	20	65	2	49	6
2	43	21	82	38	15	20	77	20	64	3	51	7
3	39	21	63	38	13	20	72	20	89	4	45	8
4	31	22	88	42	67	20	93	22	66	4	49	8
5	45	26	67	44	77	22	88	22	60	4	52	8
6	35	26	84	44	79	22	67	22	85	4	43	10
7	49	29	87	48	70	23	99	23	80	4	46	10
8	38	30	65	50	19	24	61	23	90	5	48	11
9	53	31	74	52	75	24	104	26	77	5	53	11
10	67	33	60	52	70	25	56	26	68	5	44	12
11	63	33	80	54	21	26	109	27	59	5	50	12
12	58	33	84	54	65	26	51	27	88	5	46	13
13	42	33	65	56	20	28	115	31	73	6	55	13
14	44	33	90	58	78	29	45	31	111	6	51	13
15	45	35	63	62	69	29	120	35	59	6	47	15
16	59	35	70	62	29	30	40	36	85	6	56	15
17	41	36	88	64	70	31	74	40	109	7	51	15
18	70	38	60	70	74	31	79	40	69	7	48	16
19	49	38	95	70	21	32	84	40	142	7	43	17
20	50	38	80	72	25	32	90	40	135	7	57	17
21	21	38	72	72	31	32	126	40	139	7	52	17
22	25	40	63	74	68	32	68	42	58	7	46	18
23	75	40	61	76	8	32	95	42	114	7	58	18
24	55	42	86	76	11	34	63	43	132	7	43	19
25	51	42	102	78	31	35	101	43	141	7	48	19
26	20	42	64	80	82	35	34	43	68	7	50	19
27	57	42	68	80	72	35	58	44	82	7	54	19
28	72	43	68	82	21	36	106	46	59	8	44	20
29	28	44	74	82	36	36	131	47	108	8	60	20
30	78	44	91	84	78	36	52	48	71	8	51	20
31	47	46	113	86	11	36	111	50	75	8	51	21
32	22	46	65	88	24	37	30	50	78	8	45	22
33	73	47	93	88	27	37	47	52	129	9	61	22
34	32	47	70	90	70	37	134	54	115	9	47	23
35	37	48	73	90	36	38	117	55	126	9	42	24
36	79	48	56	94	23	40	27	56	139	9	45	24
37	50	49	52	94	39	40	42	58	66	9	62	24
38	77	49	115	94	43	40	122	62	60	9	44	25
39	42	49	95	94	15	41	137	62	106	10	47	25
40	74	51	83	94	30	41	24	65	107	10	40	26
41	47	51	79	96	46	41	37	66	123	10	64	26
42	41	51	87	96	87	41	125	69	50	10	49	26
43	26	51	122	96	5	42	139	69	64	10	42	28
44	51	51	110	98	14	42	22	71	116	11	65	28
45	82	51	75	100	22	42	35	73	136	11	23	29
46	29	53	127	100	26	42	140	75	117	11	67	29
47	93	53	52	102	34	42	127	77	136	11	14	30
48	87	53	105	102	80	42	21	78	120	11	21	30

49	98	53	82	102	8	43	33	79	53	12	25	30
50	66	55	55	104	45	43	129	83	106	12	43	30
51	48	55	59	104	91	43	141	83	49	12	12	31
52	94	55	101	104	24	44	20	86	56	12	16	31
53	62	56	67	104	38	44	19	87	132	12	18	31
54	26	56	72	104	50	44	32	87	118	12	45	31
55	97	56	87	104	10	46	129	90	116	13	68	31
56	102	56	43	106	15	46	142	90	60	13	20	32
57	70	57	47	106	33	46	19	94	129	13	27	32
58	34	57	77	106	39	46	32	94	47	13	47	32
59	38	57	132	106	80	47	142	97	66	13	70	32
60	41	57	50	108	95	47	129	98	73	13	11	33
61	28	59	38	108	22	48	19	102	107	13	31	33
62	24	59	89	108	27	48	32	102	70	14	72	33
63	45	59	47	110	43	48	128	105	76	14	22	33
64	42	59	59	110	45	48	142	105	125	14	12	34
65	52	59	64	110	50	48	20	109	121	14	29	34
66	98	60	71	110	93	48	33	109	108	14	33	34
67	60	61	61	112	16	49	127	112	116	15	48	34
68	64	61	50	114	34	49	141	112	86	15	14	35
69	37	61	87	114	41	49	21	116	115	15	30	35
70	48	61	100	114	52	49	35	116	46	15	74	35
71	104	61	77	114	23	49	139	118	74	15	23	35
72	91	62	63	116	11	50	125	120	109	15	49	36
73	33	65	68	116	19	51	23	124	84	16	75	36
74	49	65	37	116	90	51	39	124	89	16	24	36
75	51	65	74	118	88	51	121	126	53	16	15	37
76	94	65	32	120	46	51	137	126	47	16	31	37
77	32	66	83	120	13	53	25	130	113	16	35	37
78	70	66	138	120	76	53	43	130	92	16	38	37
79	91	66	54	122	96	53	115	133	58	16	51	37
80	24	68	64	122	50	54	135	133	84	16	77	37
81	28	68	60	122	39	54	48	135	59	16	54	37
82	63	68	83	122	11	55	28	137	95	17	37	38
83	102	68	71	124	16	55	110	137	72	17	40	38
84	20	69	33	124	46	55	54	139	151	17	62	38
85	66	69	97	124	52	55	105	140	155	17	56	38
86	45	69	58	126	30	55	130	141	159	17	52	38
87	102	69	75	126	24	55	56	143	82	17	25	38
88	29	70	49	128	93	55	99	143	62	17	16	39
89	51	70	30	128	71	55	34	145	146	17	32	39
90	16	72	45	130	35	56	125	148	111	17	42	39
91	45	72	72	130	38	56	55	149	99	18	45	39
92	98	72	50	132	17	56	101	149	143	18	49	39
93	81	73	68	132	22	56	39	151	66	18	78	39
94	86	73	57	134	48	57	120	153	139	18	64	39
95	19	74	95	134	67	57	45	155	103	18	57	39
96	26	74	142	134	43	59	102	156	71	18	53	39
97	86	74	55	136	14	60	54	157	157	18	37	40
98	76	74	29	136	26	60	114	157	81	19	47	40
99	63	75	87	136	29	60	50	159	107	19	48	40
100	91	75	39	138	98	60	109	160	69	19	59	40
101	23	77	43	138	16	61	104	161	136	19	56	40

155	9	98	37	172	17	74	83	233	121	27	5	52
156	118	98	77	172	71	74	70	238	82	27	7	52
157	36	98	20	174	54	74	83	239	126	27	26	52
158	153	98	83	174	57	74	70	246	151	27	84	53
159	128	99	69	174	29	74	83	247	92	27	67	53
160	123	99	122	174	64	75	70	253	129	27	85	53
161	89	99	61	176	44	75	83	254	154	27	4	54
162	48	99	17	178	55	75	70	260	71	28	27	54
163	40	99	78	180	29	77	83	261	78	28	2	55
164	37	99	53	180	25	77	70	268	86	28	6	55
165	54	99	100	180	19	77	83	269	133	28	29	55
166	115	100	115	180	33	77	70	274	155	28	84	56
167	43	100	144	180	41	77	83	276	47	28	10	56
168	6	101	68	182	83	77	70	282	78	28	7	56
169	111	101	104	182	89	77	83	282	91	28	5	56
170	132	101	117	182	104	77	70	289	136	28	85	56
171	130	101	59	184	72	78	83	291	159	28	15	57
172	44	101	72	184	93	78	69	296	42	28	12	57
173	58	101	144	184	66	78	63	296	51	28	16	57
174	156	101	81	186	50	78	58	296	139	28	17	58
175	16	103	37	186	55	78	53	296	38	29	30	58
176	113	103	63	188	45	78	47	296	55	29	84	59
177	86	103	79	188	25	79	42	296	163	29	19	59
178	30	103	51	188	34	79	37	296	73	29	31	59
179	107	104	40	188	36	79	31	296	76	29	20	60
180	136	104	108	188	43	79	26	296	142	29	33	60
181	122	104	120	188	60	79	21	296	35	30	84	61
182	53	104	143	188	40	80	139	296	57	30	22	61
183	157	104	84	190	57	80	133	296	32	30	25	62
184	4	105	97	190	49	80	128	296	75	30	34	62
185	139	105	68	192	104	81	122	296	145	30	84	62
186	52	105	113	192	52	81	117	296	60	31	83	63
187	9	107	142	194	28	83	112	296	148	31	59	63
188	140	107	38	196	35	83	106	296	29	31	26	65
189	126	107	104	196	84	83	101	296	162	31	36	65
190	40	107	64	198	92	83	96	296	62	32	58	65
191	57	107	54	200	63	83	90	296	151	32	82	66
192	14	108	99	200	88	83	85	296	27	33	28	66
193	102	108	118	200	28	84	140	301	69	33	29	67
194	105	108	29	202	38	84	21	304	107	33	37	67
195	83	108	109	202	69	84	140	308	160	33	57	67
196	112	109	141	202	51	84	21	311	63	33	81	68
197	29	109	88	204	32	85	23	316	74	33	31	68
198	54	109	34	204	45	85	28	316	64	33	39	68
199	124	111	112	204	56	85	33	316	103	33	55	68
200	137	111	79	206	40	85	39	316	154	33	80	70
201	43	111	24	208	34	86	44	316	58	33	32	70
202	48	111	92	210	81	86	49	316	78	33	40	70
203	15	112	62	210	67	87	55	316	101	33	79	71
204	99	112	97	210	87	87	60	316	111	33	34	71
205	143	112	140	210	104	87	65	316	83	34	42	71
206	81	112	78	212	41	87	71	316	157	34	54	71
207	106	113	68	212	38	87	76	316	54	34	52	72

261	21	137	143	282	70	107	93	375	91	42	54	126
262	149	137	48	284	89	107	98	375	68	42	51	127
263	152	137	137	284	110	107	104	375	127	42	62	127
264	86	138	151	284	115	107	109	375	106	43	48	128
265	58	138	146	284	58	108	114	375	131	43	51	129
266	43	138	36	284	67	108	120	375	133	43	55	129
267	123	139	99	286	106	108	125	375	73	43	52	129
268	144	139	157	286	30	108	130	375	32	43	63	129
269	53	139	141	286	31	108	136	375	66	43	65	129
270	48	139	148	288	72	109	21	416	76	43	48	131
271	23	140	96	290	84	110	136	416	104	43	66	131
272	46	140	102	292	63	111	131	416	109	43	68	132
273	51	140	137	292	97	111	125	416	117	43	49	133
274	86	140	97	294	27	111	120	416	152	43	45	133
275	166	140	156	294	54	113	115	416	113	44	70	133
276	83	142	91	294	68	113	109	416	89	44	48	134
277	152	142	149	296	80	113	104	416	70	44	46	134
278	127	143	87	296	102	113	98	416	79	44	43	134
279	25	144	90	296	30	114	93	416	134	44	41	135
280	20	144	38	296	60	115	88	416	105	44	50	135
281	126	144	42	298	75	116	82	416	30	45	72	135
282	80	146	100	298	98	116	77	416	64	45	39	137
283	117	146	130	298	103	116	72	416	81	45	73	137
284	88	146	144	298	51	117	66	416	87	45	37	138
285	19	147	29	298	63	117	61	416	68	45	51	138
286	130	147	81	300	97	117	56	416	105	45	75	138
287	122	147	95	300	57	119	50	416	151	45	48	139
288	28	148	140	302	70	121	45	416	136	45	36	140
289	76	148	76	302	51	122	40	416	152	45	46	140
290	115	148	131	304	59	122	34	416	135	46	50	140
291	92	148	73	304	55	123	29	416	80	46	76	140
292	152	150	89	304	67	126	140	417	29	46	35	141
293	72	151	86	306	58	127	21	422	63	46	44	141
294	126	151	25	306	49	128	140	425	29	46	78	141
295	80	151	39	308	54	128	21	430	149	46	52	141
296	89	151	118	308	102	128	140	432	85	46	42	142
297	25	152	103	308	88	128	51	434	70	46	33	143
298	32	152	129	308	93	129	56	434	138	47	40	143
299	119	152	68	308	98	131	62	434	106	47	79	143
300	126	152	64	310	88	132	67	434	78	47	53	143
301	84	152	88	310	66	132	72	434	105	47	39	144
302	153	152	134	312	85	132	78	434	149	47	54	144
303	18	153	93	312	49	133	83	434	82	47	32	145
304	35	155	31	312	59	133	88	434	73	47	80	145
305	66	155	60	314	55	133	94	434	145	48	30	146
306	68	155	115	316	51	134	99	434	63	48	38	146
307	130	155	132	316	99	134	104	434	64	48	81	146
308	149	155	91	316	88	134	110	434	28	48	56	146
309	22	156	87	316	56	138	115	434	141	48	29	148
310	122	156	84	316	86	138	121	434	78	48	27	148
311	39	157	36	318	69	138	126	434	106	49	36	148
312	40	157	120	318	60	139	131	434	78	49	82	148
313	62	157	110	318	89	139	137	434	65	49	57	148

314	145	157	57	320	49	140	46	436	151	49	59	149
315	152	157	27	320	100	140	22	437	88	49	26	150
316	44	159	95	322	73	140	27	441	84	49	35	150
317	50	159	117	324	95	140	52	441	74	49	83	150
318	54	159	88	326	92	141	33	447	105	49	24	151
319	59	159	100	326	83	141	57	447	69	49	33	151
320	19	160	34	328	78	141	38	452	27	50	22	152
321	49	160	101	328	87	143	63	452	81	50	84	152
322	68	161	22	328	51	144	43	456	91	50	20	153
323	148	161	109	330	63	144	68	456	152	51	33	153
324	121	163	113	330	56	144	49	461	90	51	19	154
325	129	163	51	334	102	145	73	461	66	51	31	154
326	40	164	97	336	59	146	54	465	154	51	17	156
327	61	164	33	340	96	146	79	467	150	51	84	156
328	127	165	110	340	53	147	84	471	70	51	15	157
329	152	165	21	340	106	147	60	472	26	51	12	157
330	50	166	89	342	67	149	89	475	27	51	30	157
331	64	168	112	346	106	149	65	476	104	51	10	158
332	69	168	82	346	76	150	70	480	157	51	7	158
333	119	168	28	346	62	150	95	480	125	51	5	158
334	133	168	50	348	57	151	76	486	120	51	84	158
335	43	169	33	350	72	151	100	486	61	51	66	158
336	124	169	77	352	107	151	105	490	105	52	85	158
337	129	169	109	356	81	152	81	491	115	52	2	159
338	166	169	23	356	67	152	86	495	99	52	28	159
339	152	169	33	360	104	153	111	495	90	52	5	159
340	116	172	114	360	109	153	92	500	22	52	67	160
341	166	172	51	360	61	154	116	500	159	52	4	161
342	47	173	21	364	71	154	97	504	146	52	27	161
343	51	173	120	366	75	154	121	504	80	52	84	161
344	120	173	54	368	86	156	102	510	58	52	85	161
345	131	173	77	370	79	156	127	510	19	52	6	162
346	150	173	29	370	83	157	132	514	143	52	25	162
347	135	173	125	372	66	158	108	515	128	52	8	163
348	135	174	35	374	71	159	113	519	112	52	9	163
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350	137	177	23	374	104	159	112	523	15	53	14	163
351	148	178	66	376	75	162	106	523	26	53	16	163
352	135	178	61	376	80	162	101	523	104	53	44	163
353	140	178	98	382	55	162	95	523	140	53	24	163
354	129	179	129	382	60	163	90	523	111	53	56	163
355	133	181	111	384	50	163	85	523	90	53	67	163
356	117	182	38	386	88	163	79	523	161	54	11	164
357	163	182	104	386	56	163	74	523	108	54	37	164
358	101	182	105	388	84	164	69	523	98	54	84	164
359	143	183	28	388	64	164	63	523	80	54	52	164
360	106	183	90	390	46	164	58	523	56	54	57	164
361	121	183	101	392	105	164	53	523	62	54	16	165
362	121	185	115	392	93	165	47	523	66	54	43	165
363	84	185	90	394	50	166	42	523	130	54	48	165
364	136	185	107	394	87	168	37	523	88	54	17	166
365	100	185	131	394	68	168	31	523	74	54	18	166
366	126	186	42	396	41	168	26	523	27	54	21	166

367	116	186	83	396	91	168	21	525	28	54	41	166
368	89	186	99	396	60	168	140	526	83	54	36	166
369	161	186	94	396	55	168	21	531	70	54	23	166
370	70	187	31	396	46	169	140	533	13	55	83	166
371	140	187	91	398	94	170	21	538	163	55	51	166
372	133	187	112	398	63	170	140	541	138	55	56	166
373	65	189	27	398	105	170	24	542	105	55	67	166
374	138	189	44	402	71	171	29	542	97	55	30	168
375	74	190	74	404	58	171	34	542	60	55	34	168
376	84	190	117	404	49	171	40	542	102	55	40	168
377	92	190	35	404	38	172	45	542	55	55	47	168
378	110	190	92	406	53	172	50	542	10	55	35	168
379	127	190	107	406	56	172	56	542	135	55	82	168
380	158	191	48	408	91	172	61	542	75	55	50	168
381	101	191	85	408	87	174	66	542	130	56	56	168
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383	75	192	67	410	67	174	77	542	130	56	20	169
384	112	192	54	412	43	174	83	542	60	56	46	169
385	129	192	132	412	48	175	88	542	55	56	29	170
386	117	194	43	412	60	175	93	542	70	57	33	170
387	90	194	108	414	45	175	99	542	71	57	39	170
388	84	194	116	414	35	176	104	542	28	57	81	170
389	67	194	35	414	65	176	109	542	100	57	49	170
390	96	194	80	416	95	176	115	542	133	57	55	170
391	121	194	38	416	104	176	120	542	102	57	19	171
392	125	194	71	418	87	177	125	542	54	57	44	171
393	112	195	101	418	79	177	131	542	75	57	80	171
394	106	195	106	418	71	177	136	542	9	57	66	171
395	101	195	109	418	41	177	140	561	128	57	18	172
396	95	195	67	420	44	178	135	564	61	57	28	172
397	71	195	59	424	91	178	130	566	68	58	32	172
398	155	195	111	424	83	180	125	569	76	58	38	172
399	65	198	135	424	30	180	140	569	8	58	48	172
400	152	199	51	424	20	180	119	572	29	58	54	172
401	61	202	89	426	68	180	114	574	161	58	59	172
402	55	203	100	426	64	180	109	577	64	58	27	174
403	148	203	46	426	25	181	140	577	125	58	43	174
404	60	204	65	428	21	181	103	580	132	59	79	174
405	144	205	94	428	75	181	98	582	99	59	47	174
406	52	207	87	430	103	181	138	582	75	59	44	174
407	57	208	106	430	25	182	93	585	9	59	56	174
408	140	208	78	434	92	182	133	585	31	59	64	174
409	135	209	100	434	29	183	127	588	97	59	16	175
410	131	211	53	434	72	183	87	589	54	59	32	175
411	49	212	95	438	88	183	122	590	160	60	37	175
412	82	212	79	442	84	183	82	592	100	60	41	175
413	76	212	83	446	79	183	77	593	123	60	49	175
414	84	212	136	446	43	184	117	593	132	60	53	175
415	86	213	72	450	89	186	111	596	55	60	58	175
416	71	213	121	450	68	186	72	596	94	60	26	176
417	55	213	76	454	75	187	106	599	131	60	38	176
418	123	213	67	456	84	187	67	599	73	60	77	176
419	127	213	116	456	101	187	62	601	33	61	51	176

420	75	213	144	456	30	188	104	605	120	61	55	176
421	115	215	140	456	20	188	56	605	9	61	62	176
422	109	215	121	458	79	188	90	607	102	61	15	177
423	103	215	151	458	23	189	51	608	117	61	24	177
424	97	215	74	460	18	189	46	609	95	61	31	177
425	91	215	70	460	25	189	85	609	34	62	36	177
426	120	215	155	460	45	190	80	612	157	62	40	177
427	54	216	110	464	73	190	104	613	114	62	53	177
428	67	216	139	464	26	192	40	613	132	62	34	178
429	105	216	146	466	31	192	92	613	56	62	51	178
430	110	216	71	468	43	192	78	613	11	62	13	179
431	117	220	91	468	97	193	35	616	89	62	30	179
432	64	220	98	468	77	194	73	616	104	62	33	179
433	123	221	103	468	26	195	29	619	108	62	74	179
434	53	222	123	468	22	195	67	619	71	62	48	179
435	119	225	146	468	39	195	104	620	37	63	49	179
436	62	225	151	468	22	196	92	620	131	63	23	180
437	124	225	136	470	26	196	24	621	111	63	28	180
438	52	228	68	472	41	196	62	621	97	63	72	180
439	50	230	139	472	46	196	57	623	90	63	12	181
440	60	232	125	474	47	198	21	625	156	63	21	181
441	109	233	150	474	43	198	104	627	154	63	31	181
442	112	233	70	478	96	198	92	627	58	63	71	181
443	121	233	83	478	18	199	51	627	70	63	47	181
444	125	233	127	478	27	199	46	628	67	63	12	182
445	124	234	67	480	31	199	41	629	39	64	20	182
446	52	235	130	482	81	199	35	632	14	64	27	182
447	48	235	150	482	33	200	21	633	85	64	69	182
448	107	235	147	482	38	200	104	635	133	64	45	182
449	49	238	139	482	41	201	92	635	100	64	11	183
450	115	238	158	484	49	201	36	635	62	64	18	183
451	116	238	69	486	74	201	42	638	99	64	26	183
452	60	239	146	488	70	201	21	640	18	64	21	183
453	122	239	154	490	16	202	47	640	40	64	44	183
454	46	241	81	492	22	202	104	642	43	64	14	184
455	111	241	132	492	27	202	92	642	83	64	15	184
456	52	243	68	494	36	202	52	643	149	64	24	184
457	119	243	70	494	41	202	23	646	36	65	68	184
458	62	246	153	496	47	202	58	646	21	65	22	185
459	94	246	147	498	93	202	29	648	23	65	65	185
460	95	247	88	500	17	204	63	648	79	65	42	185
461	112	247	130	500	34	204	104	650	145	65	64	187
462	89	248	70	502	78	204	92	650	135	65	41	187
463	120	248	83	504	73	204	34	651	103	65	63	188
464	66	250	97	506	36	205	68	651	148	65	46	188
465	53	250	125	506	39	205	74	654	31	66	43	188
466	70	251	141	506	88	205	39	655	26	66	49	188
467	86	251	133	508	15	206	104	656	46	66	48	189
468	91	251	69	510	23	206	92	656	140	66	43	189
469	75	252	129	510	29	206	79	656	49	66	62	190
470	81	252	73	512	49	206	45	658	75	66	46	190
471	109	252	85	516	70	206	84	659	142	66	61	193
472	115	252	125	516	77	206	50	660	106	66	49	193

473	77	254	102	518	20	207	90	662	53	67	45	193
474	88	255	129	518	34	207	104	663	56	67	59	194
475	55	255	75	522	39	207	55	663	66	67	43	194
476	120	255	103	524	40	207	61	667	69	67	50	195
477	113	255	68	526	84	207	106	670	72	67	47	195
478	106	256	100	526	29	208	66	670	61	67	54	195
479	116	256	88	530	72	208	111	673	138	67	58	196
480	54	258	69	534	79	210	72	673	110	67	45	196
481	85	259	82	536	32	211	116	675	141	67	42	196
482	109	259	109	538	26	211	77	675	134	68	53	196
483	61	260	87	540	21	212	122	678	113	68	48	197
484	118	260	72	540	20	213	82	678	138	68	57	198
485	81	261	106	542	25	213	127	681	129	68	52	198
486	88	261	111	546	81	213	88	682	124	68	56	199
487	63	263	72	552	86	214	132	683	118	68	46	199
488	114	263	77	554	79	216	93	685	118	69	51	200
489	78	264	113	560	85	217	138	687	126	69	55	201
490	84	264	73	562	75	218	98	687	140	69	51	201
491	89	264	77	568	88	218	104	690	139	70	53	202
492	73	265	82	568	20	219	140	691	121	70	50	202
493	67	265	91	570	76	220	109	693	121	70	45	202
494	55	265	115	570	87	220	114	695	140	71	47	203
495	114	265	86	572	19	223	140	698	139	72	44	203
496	57	269	99	576	86	223	120	699	123	72	52	204
497	71	269	105	576	81	224	125	702	136	73	49	204
498	75	271	92	578	88	225	130	705	125	73	49	205
499	57	272	110	578	84	226	140	706	134	73	45	205
500	76	273	115	582	84	229	136	707	129	74	48	206