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Extraction of Streets from Google earth imagery

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Extraction of Street from Google Earth Imagery

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Abstract

Extraction of streets from Google earth imagery is a hot research topic. The main purpose of this paper is to create a method to extract streets information from satellite image automatically. It is exceedingly difficult to achieve, because every road has different characters and there are a lot of noises (e.g. shadow, building, and vehicle) in the image. By using generic color model and the image analysis techniques, we build up the automatic road extraction system. It extracted road successfully from mid-size city image with a very high extraction rate. Some interesting discoveries and unique creative solution are proposed in this paper.
Key words: Google earth image, road extraction, Matlab, image processing.

Contents

1 Introduction

In this chapter, we are going to introduce the background of map drawing and road extraction. We also describe the technical supports from Morphology, Hough transform, Binarization, Objective extraction. In addition, this chapter provides the limitation of this research, along with the aim of the thesis and research questions.

1.1 Background

In this section, we are going to introduce the evolution of map drawing and the background of road extraction.

1.1.1 The evolution of map

Since the Stone Age, humans had begun to make maps. The oldest map was found in Turkey in 6200 BC [1]. In China, the first map was made on the Xia Dynasty 4,000 years ago. Ancient Greece made lots of contributions in the field of map production. Eratosthenes was the first person who calculated the size of the earth and the length of the meridian circle, and he drew a map of the earth as a sphere. With the start of geographical discovery, more accurate maps were required to meet the needs of many industries. Using triangulation [2] to draw accurate maps became very popular. From the 18th century, many countries have started to draw the accurate maps with details. At the end of 19th century, people began to draw the international accurate map with the unified specification out of the need of economic interests of each country [3].

Figure 1. Hereford Mappa Mundi, about 1300, Hereford Cathedral, England [4].

Before the 20th century, the production of maps mainly relied on human labor. This method is inefficient and low accurate until the remote sensing technology was invented. Remote sensing is a technology to acquire information of an object or phenomenon on different scale by using record device or real-time sensing device. These devices will not contact with the object directly in physical way [5]. In Figure 2, you can see an example of visible spectral remote sensing image with wavelength range from 0.38 to 0.76 microns.

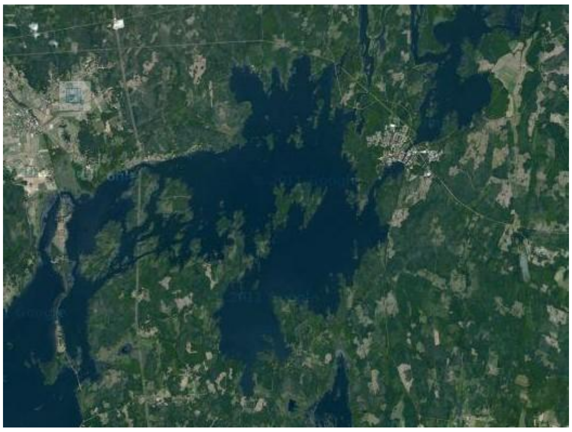


Figure 2. A remote sensing image with visible spectral.

Remote sensing technology not only impels human beings to have a further understanding the earth, but also brings the rapid development of GIS and other sciences. Moreover, it is of great help to drawing maps that people do not need to spend a lot of time and effort for the field exploration, and especially reduces the risk to enter some dangerous areas. By means of this technology, human beings can collect the numerous and accurate information, and focus on how to extract the needed features of interest from the collected information instead of how to collect them. Street information is the most important part in daily life maps (such as tourist map). But some information like mountains, vegetation, and part of the building will be omitted. Thus, extraction of important features, such as streets can be significant. In Figure 3, you may see two examples of the original satellite remote sensing image and street map respectively.

Figure 3.The left one is satellite remote sensing image and the right one is street map.

Source: from Google maps

However, the road system is a huge system. The largest network of roadways is 6,430,366 kilometers (3,995,644 mi) on United State (2005), and the People's Republic of China is listed on the second position with 3,583,715 kilometers (2,226,817 mi) of roadway (2007) [6].

Cities have been changing so fast that the update information cannot keep up with the pace of the cities’ change sometimes, such as new highways, new regional development, and a large number of new buildings. The traditional method for map production cannot meet the requirements of the fast developing cities. Nowadays, some companies provide the latest satellite images. Those images have high quality, and show the latest accurate information of the city changes. This is kind of information is much more accurate and can be achieved in a quick way. So that we can obtain the changes of the earth surface information as soon as possible and modify the map. In this way, there is no problem with the source of the map. The real problem is how to update this kind of information rapidly and accurately? First, people start to record the digital map to speed up the update speed. However, the manual extraction cannot get the information from the images as fast as we want. For example, GPS is the most popular map tools, and its update time is once in a few months. That is the reason why the automatic extraction method is needed for higher update speed. If the map can be updated once a week even once a day, the incoherence between the map and the road will never exist. This automatic extraction method will save a lot of time, human resources, material resources and financial resources efficiently.

At the same time, the road system will be updated annually, which means the roads of the whole world need to be redrawn or modified repeatedly when they are changed. As the result, the workload is enormous. Traditional manual interpretation and identification cannot guarantee the efficiency of information obtained and the precision of identification. Consequently, people commence to try to use computer to assist or even replace human beings to accomplish this task. Satellite remote sensing image contains not only effective information but also interference information. Humans more focus on how to extract streets from images accurately and efficiently. There are usually some interference in maps including shadows, roofs of the building connected with road, and open areas.

However, the technology about streets extraction from digital image is in the initial stage, and more of them are imperfect. Until now, the system, which is able to fully automatic extract different street information, has not created. Most of the existing technologies need human’s assistance to extract road. Due to the variety of roads and plenty of interference, this research becomes one of the most difficult and hottest topics in image processing domain.

1.1.2 Road extraction

Road extraction belongs to the technology of object extraction aiming at extracting effective information from image. There are many mature technologies in objective extraction, for instance, vehicle license plate recognition (which is applied in traffic management), coin identification (which is applied in ATM and vending machines), stamp identification (which is applied in post), word recognition (which is applied in electronic documents) and so on. Street extraction is fundamentally different with other technologies. The information features extracted from plates, coins and stamps are very obvious. For example, the shape of the plates is absolutely standard rectangular with fixed length-width ratio, the license plate only included 26 letters and 10 numbers, and both of them are written in a unified standard. It is very useful of the fixed features of the extracted object, but the uncertain information, e.g. network of road and written words, will greatly increase the difficulty of object extraction. For example, extraction of roads, they have neither unique shape feature as shown in the

Figure 4, nor color feature as shown in the Figure 5. One of the problems is also shown in Figure 5, where most of the roads are made of cement. Also a lot of buildings and plazas are made of same material. They will have the same or similar color in the image.

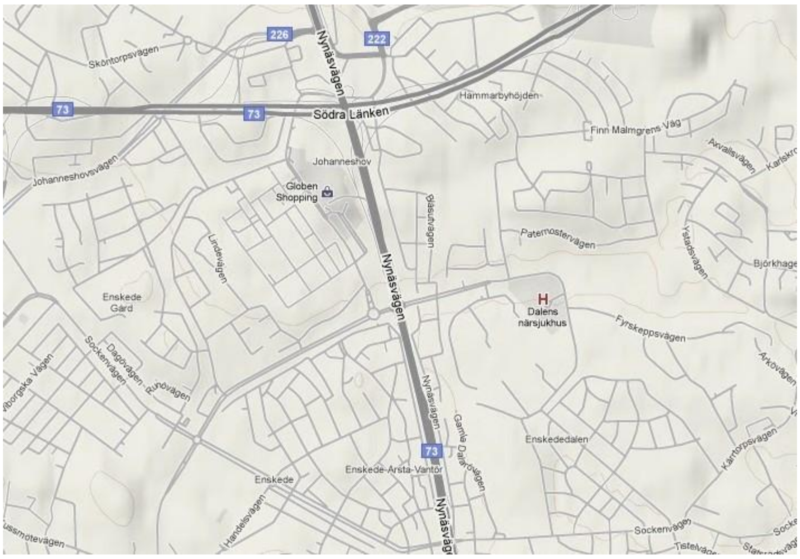


Figure 4. The connections of road are extremely complex

Figure 5. The color of road is similar with other object in the image.

Source: from Google map

Another problem is that the color of roads is interfered by material and shadows. Roads will show completely different color under the shadow or the sunlight, see Figure 6. Consequently, traditional methods of road extraction cannot be used to extract road, such as template matching.

Figure 6. The different colors of roads.

Although roads do not have obvious features of shape or color, they still have some other features, such as the connectivity (roads are always connected) and width (the width of road is regular in a short part). By analysis and testing on these two features, the methods and processes are designed to model and extract roads from the maps.

1.1.3 Technical support

Image processing is an application of signal processing on image domain. Nowadays, most of the images stored as digital signal, which means image processing will be digital image processing on the most cases [7]. The method called template matching was widely applied in vehicle license plate recognition, coin identification, stamp identification, and word recognition, and it is the most traditional and basic one, which is used in image processing. Although the road extraction also in the domain of image processing, it cannot use the traditional method to solve the problem. Opening operation and Hough transform will be used based on the characteristics of road extraction.

Morphology

The definition of Morphology in image processing toolbox [8] is that:

> Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. By choosing the size and shape of the neighborhood, you can construct a morphological operation that is sensitive to

specific shapes in the input image.

The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as a dilation or an erosion.

Opening is a morphological operator, which can be expressed as a composition of an erosion followed by a dilation, both by the same input structural element. Closing can be expressed as a composition of a dilation followed by an erosion [9].

Hough transform

Hough transform is another basic method of image processing operation, and it extracts the feature information from image. The basic principle of the technique is to transform the curve in the original image space into a point in parameter space by using the duality of points and lines. By this means, the overall feature detection will change to the local feature detection. Such as lines, ellipses, circles, arcs and so on [9].

Binarization

Binarization is a simple method that is widely used in image processing. It is typically treated as simply a threshold operation on gray scale image, set the point with white color if its value is bigger than threshold, otherwise, set it as a black point.

Object extraction

Object extraction from the image is an important research part of the image analysis. Target of the image is usually divided into point targets, linear targets (such as roads, rivers, etc.) and area targets (such as buildings, etc.). Extraction of linear objects has a connecting effect extraction, and extraction of road network plays an important role in linear object extraction.

We will discuss two existing approaches, which extract road automatically:

H. Mayer et al. [10] had use the multiple scales as the implement method, to extent the multi-scale modeling with the context and to use snakes, ribbon snakes can improve the robust when it is used to extract roads, and also recover the gaps caused by the trees and buildings' shadows.

I. Lapter et al. [11] had proposed a new approach to extract road automatically with a model and strategy from aerial imagery and it is major combine the multi-scale detection of roads with the geometry- constrained edge extraction by using snakes.

In this paper, the Google earth image, which is visible spectral remote sensing image, will be used to extract the road. Visible spectral remote sensing is a remote sensing technology, that is, the sensor is only limited to the wavelength of visible light range (0.38-0.76microns). This technique based on received the reflected sunlight, its advantage is that the image will show the real color, but it will be disturbed by the shadow and affected the result of street extraction.

Now, extraction of street is not only a popular topic, but also a very interesting one. In a simply way, extraction of street is a process to isolate the streets from the picture. The pictures will be preprocessed by image processing technique, such as: Gaussian blur [12], noise renovation [13], binarization [14] and etc., then remove the interferences (except street) such as: buildings, plants, square, shadows, vehicles and pedestrians and so on, finally to extract streets depends on their characteristics.

1.2 Research Questions

- Do roads have unique features?
- Are there any methods to extract road based on features?
- Is it possible to extract roads from Google earth image automatically?
- Can computer replace human beings to extract street from Google earth image?

1.3 The Aim of research

The aim of this paper is to design a program and to analyze and process the remote sensing images to extract the streets using multiple methods. We mainly eliminate the interference of building, renovate the broken road caused by shadow, and design an efficient method to adapt different cases of image, thus achieve to extract street automatically. We will specify the list of features needed to extract roads in a robust way. Using those features we will extract the streets and roads from Google map imagery.

1.4 Limitations and Problems

The satellite images using in this study are Google earth image, which do not have uniform specifications. The quality of the image will be different for different regions. An image has high resolution but in a low quality, which will be a factor to affect the extraction effect. Since the diversity of the images and complexity of the road, 100%extraction rate is not realistic, the rate of extraction road only can increased as much as possible depend on the different cases. Besides, it is impossible to match all of cases by one method. According to characteristics, roads can be mainly divided into the following 4 categories:

1). Roads on suburban are low density and less transfer junction, and the vegetation and farmland cover almost all the image and road may pass through some small villages, as shown in picture A of Figure 7.

2). Roads on small or medium town are middle density but a lot of crossing and transfer junction, and there are some low density building on the image, some parts of road are interfered by building’s shadow, as shown in picture B of Figure 7.

3). Roads on large urban are high density, and the image is full of building and most of roads are covered with shadow, as shown in picture C of Figure 7.

4). Roads on factory areas are low density, but there are many open areas and parking lots connected with road, as shown in picture D of Figure 7.

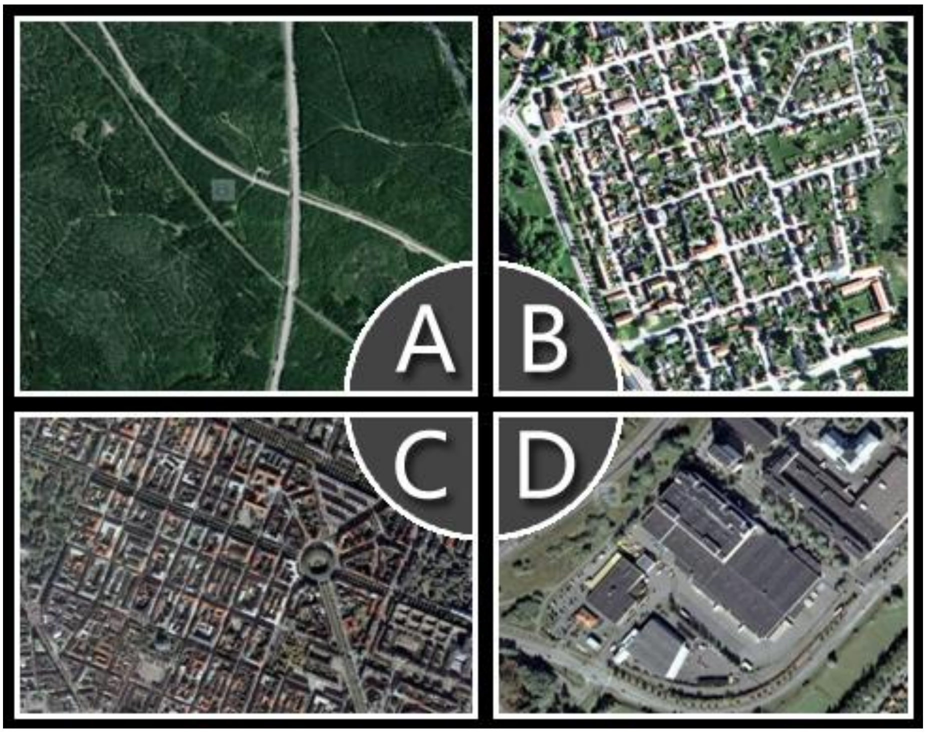


Figure 7. Examples of four different kind roads in image.

Because of the entirely different characteristics of those 4 types of the roads, their extraction processes is different too. In this paper, we mainly focus on how to extract road on suburban and small and medium size town.

Road Extraction is a tough work. It is easier for human beings to judge where the street is than computer. There are two main problems we are facing: one is to eliminate noise and renovate the broken road, and the other one is to identify and extract roads depending on their characteristics. The following will list some examples of problem:

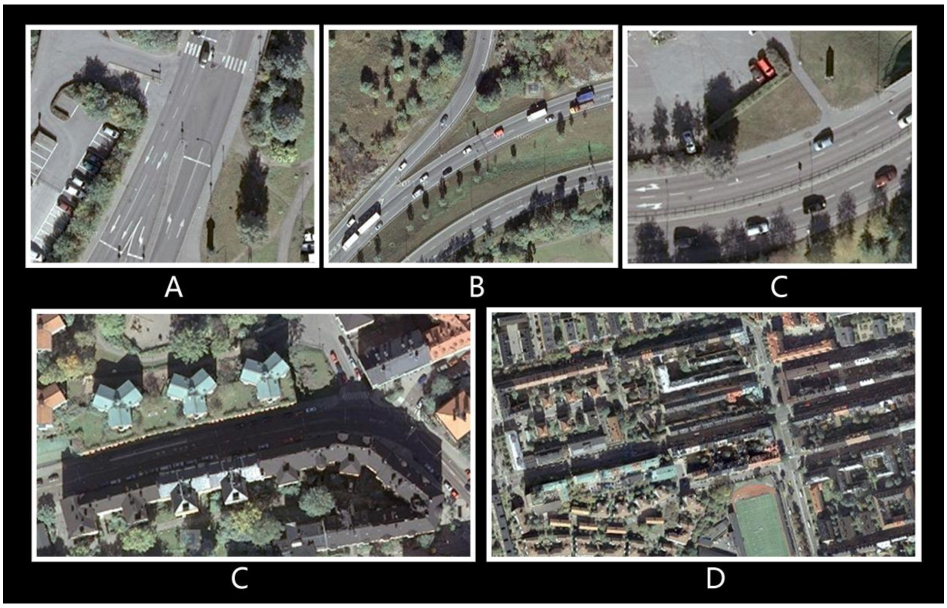


Figure 8. Five cases noise. *Source: from Google map*

a). Noise of road traffic marking, e.g. picture A of Figure 8.

b). Noise of pedestrian or vehicle, e.g. picture B of Figure 8.

c). Noise of roadside vegetation and shadows, e.g. picture C of Figure 8.

d). Noise of building shadow, e.g. picture D of Figure 8.

e). Noise surrounding the road, e.g. Figure 9.

f). Complexity of the road.

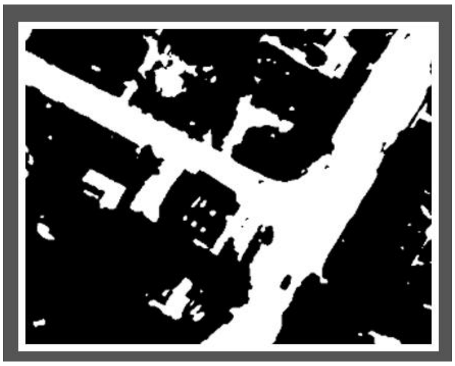


Figure 9. Noise surrounding the road in binary image.

2 Extraction of streets from Google earth imagery

In this section, we will present the method about how to extract road based on the characteristics, along with the result of road detection.

2.1 Characteristics of road and overall idea

Road system is a very complex system. It has neither fixed shape, nor uniform color. The only significant features are: connectivity feature and width feature. Therefore, we focus on these two features in two situation of road through this study: situation one is to extract roads on suburban (Figure 10, left), and situation two is to extract roads on small and medium size town (Figure 10, right).

Figure 10. Two cases road, left one is on suburban, right one is on small or medium size town.

As it is seen in the Figure 11, roads are marked with red color. Two features of road (connectivity and fixed width) are reflected obviously.

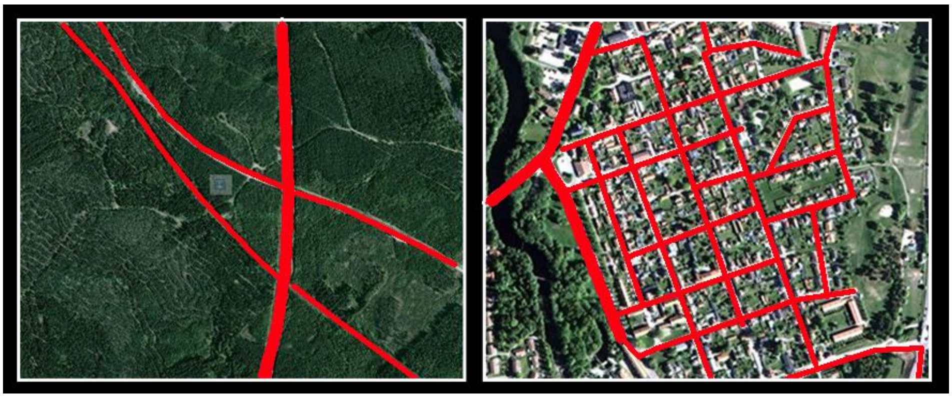


Figure 11. Two conditions of road are marked with red color.

Some roads do not meet the connectivity feature and width feature as a result of noise, and those noises should be eliminated in the image. Roads may be broken by shadow or other interference after noise renovation, so we have to repair them as much as possible.

We sort the possible interference into 3 types as below:

I. Roof. It can be mainly divided into two kinds: roof of small building, and roof of large building. As shown in the left picture of Figure 12, the small area-building roof is easy to distinguish from the road because of the different color. However, due to the reflection of sunlight, roofs will have the same spectral property with road and they will become noise in the binary image (Figure 12, right). Most of the large building roofs are made of cement, same material with road, so they have same spectral property and this will cause the big size noise in binary image, as shown in Figure 13.

Figure 12. Small building roof, left one is original image and right one is binary image.

Figure 13. Large building roof, left one is original image and right one is binary image.

II. Open area connected with the road, such as small parking lot, basketball courts and etc. Because they have the same spectral property with road, it is hard to tell the different of them by color in the binary image. Fortunately, the size of the open place is larger than road, as show in the figure 14. The size characteristic will be used to distinguish them.

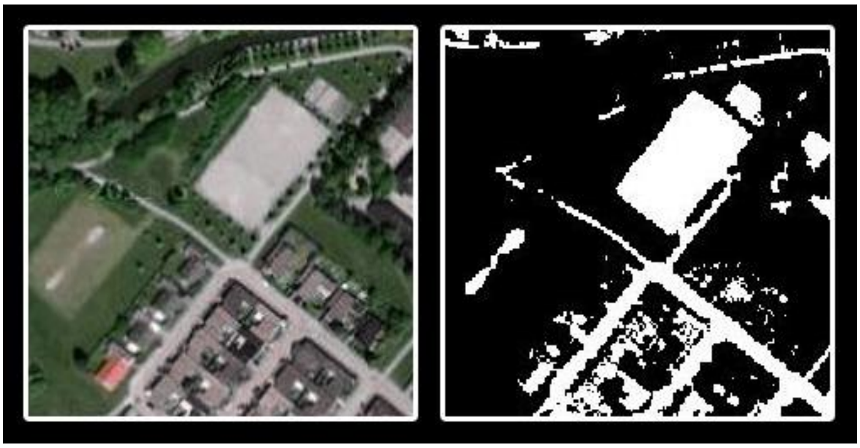


Figure 14. Open area connected with road, left is original image, right is binary image.

III. Direct interference on roads, such as shadows and vehicles. This kind of noise interfere the road surface directly, it affects two significant features of road (width features and connectivity features). Especially the shadow of tree and building beside the roads will seriously affect the width feature of the road and even sometimes damage the connectivity feature of the road in earth image. (Figure 15).

Figure 15. Direct interference.

Through research, we found that the noise, which occurred on the case of mid-size town, will occur on the suburban too. As long as we eliminate the noise in the first case, the problem of second case will be solved as well. Therefore, we will major focus on extraction of street on small and mid-size towns.

The following model (Figure 16) shows the process of extracting road automatically step by step.

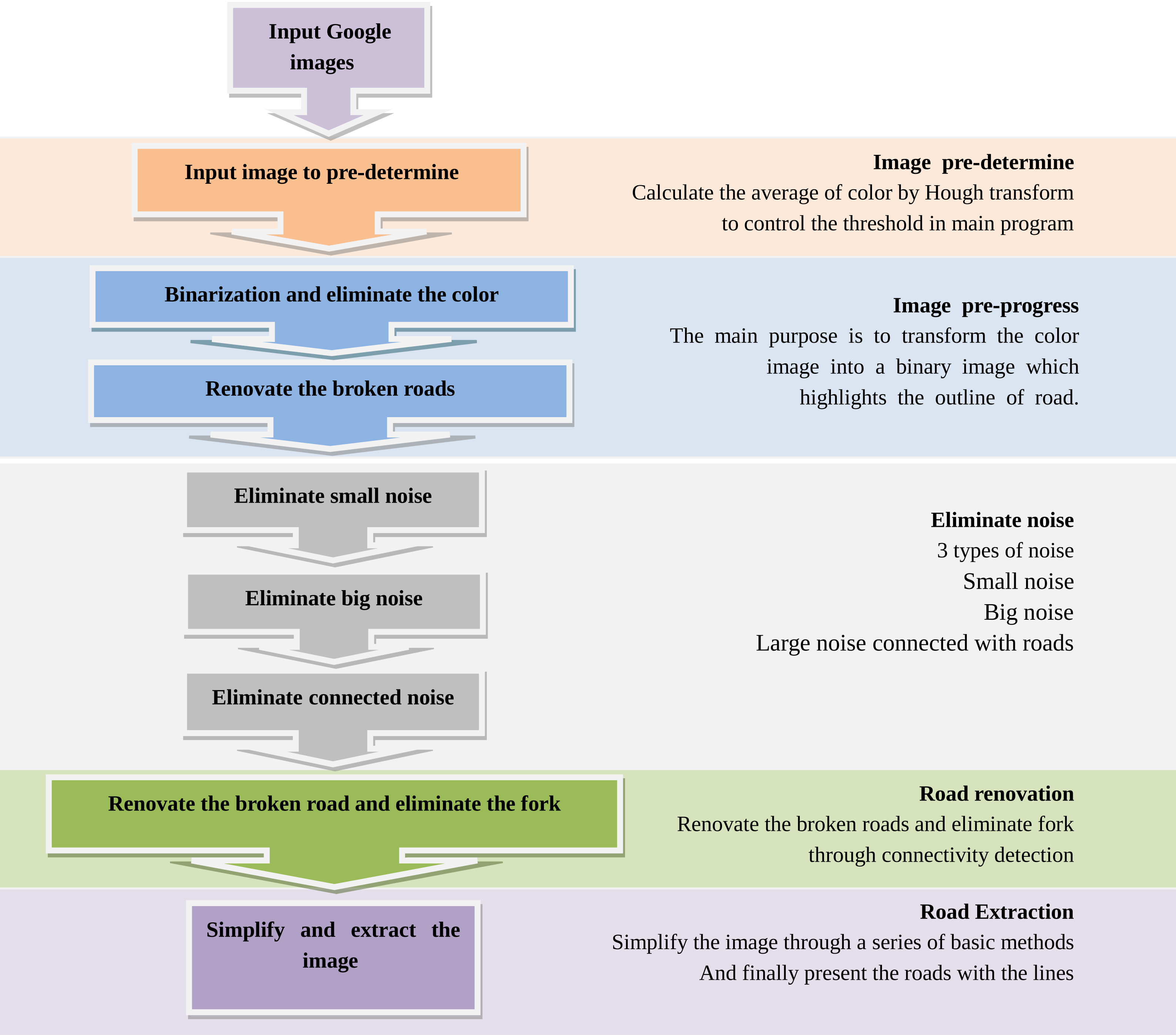


Figure 16. Road extraction model

2.2 Analyze the steps of application

In this section, we will present the idea, method and result of our designed program. There are 5 main steps of the solution about this program:

Step1: automatic identification.

Step2: image preprocessing;

Step3: noise elimination;

Step4: road renovation;

Step5: road extraction;

2.2.1 Automatic identification

In Google earth image, the color of each photo may be different because of many factors, such as sunlight intensity, dust and so on. It is necessary to adapt different image by adjusting parameter, which means, it has to be pre-judged color of road in program. After that there is a need to transmit the most suitable parameter to the main program. For the purpose to achieve pre-judgment of roads' color, the situation of road must be understood roughly. The main purpose of this step is to calculate the average value of road color, and then transmit this average number as a threshold value to the main process to adjust the parameter. Because the image is original one without processing, it is hard to figure out the average value of roads' value. Therefore, we randomly select some samples of roads from the image, and calculate the average value of their color.

However, here we have a problem must be solved, that is how to select the sample of road from the image? First, a small value of threshold is set to transform the original image into a binary image as shown in the left picture of Figure 17, so that most of roads are maintained in the binary image. Some invalid information is remained, but only a few road samples are needed in the image to calculate the average. Afterwards, Hough transform is used to find the straight line in the image. In order to ensure these lines are roads, a strict value of threshold is set. That means that the length of line must have 150 pixels or more and the fracture cannot be found. Through using Hough transform to find out 3 straight lines, which satisfy the condition, see the 3 red lines in left picture of Figure 17. We record the coordinates of each pixel in these 3 lines in the binary image, and then find out the corresponding points based on the coordinates in the original image, so that we can calculate the average value of those points, which are in different color. After testing, it is easy to find out 3 straight lines on the 99% matching objects, finally, we compute the mean of their pixel color value as the mean of roads, see the Figure 17. By using the average value of roads, the ratio can be discovered to control the threshold in the main program to achieve the best extraction effect.

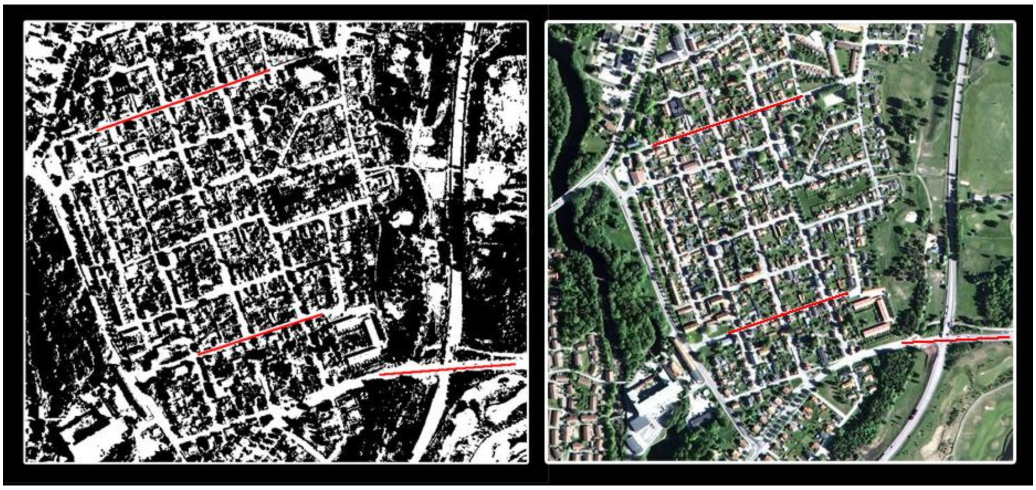


Figure 17. Find out 3 straight lines from image

2.2.2 Image preprocessing

Generally, it is too complicated to detect target from a color image, in order to identify the outline of target easier, an approach named binarization was usually used as a solution in image processing. In most cases, the color of road is lighter than other object in the image. We can distinguish the road by the following step: firstly, transform the color image into a gray scale one, then set a threshold to distinguish the road from the gray scale image, but the result is unfavorable, as shown in Figure 18.

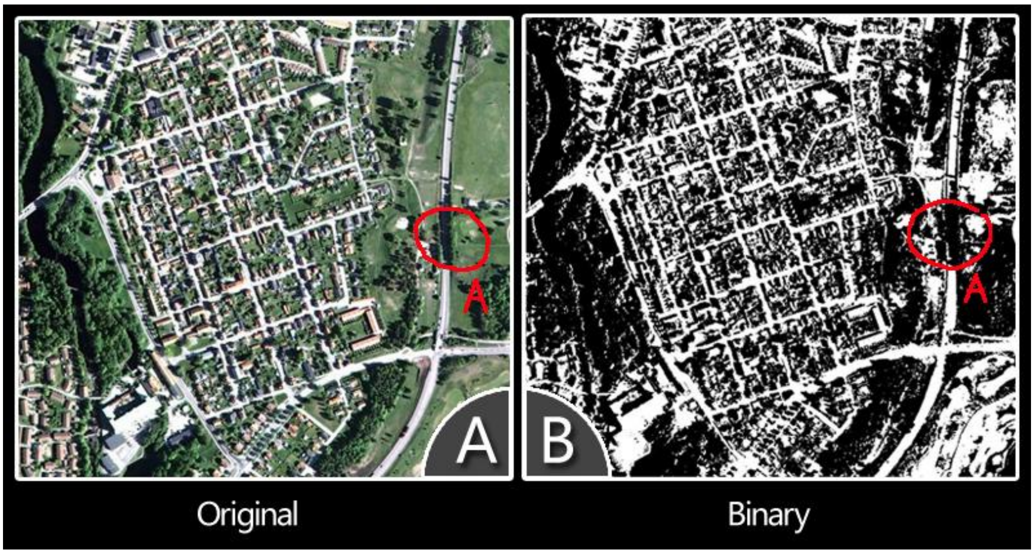


Figure 18. The image after binarization, and the red cycle show an undesired situation.

As we can see in Figure 18, the result of the binary image is unsatisfactory, amount of noise points can be found in the binary image, and many building's roof are also transformed as the same color with road. What's more, the roads are broken by shadows, such as the marker (A) in this Figure 18 where you can see the road is completely broken.

It is very critical of the image pre-processing step. The quality of this step's effect determines the final result, so that we have to reserve the useful information as much as possible. In addition, it is better not to remove all the useless information in this step, because the process is irreversible. If too many information are removed in this step, it is extremely difficult to repair them in the later step.

Due to the nature of the binarizaiton method (only can be judged based on the shade of pixel), it is impossible to gain the outline of the road only using binarizaiton method in this step. Moreover, we need to address two issues:

- Eliminate the noise, which caused by the building's roof.
- Renovate the broken roads caused by the last step.

The building's roofs are a serious noise in the binary image, but in the color image most of them have different color if you compare to roads (the color of roads are gray), as shown in Figure 19.

Figure 19. The color of roofs.

In a color image, there are 3 channels: red, green and blue, the range of each channel is 0 ~ 255. When the values of them are close to each other, the color will become gray, such as RGB (21,20,22), RGB (132,130,135). A threshold is set to compare the difference of these three channels' value, if the difference is small, the pixel is marked as gray in the gray scale image but white in the binary image, otherwise, the pixel is marked as color in the gray scale image but black in the binary image. After this operation, the changed image is obtained, as shown in top left image of Figure 20. By removing the color roof using an "AND" operation to the last resulting image with the binary image, we get a result shown in Figure 20.

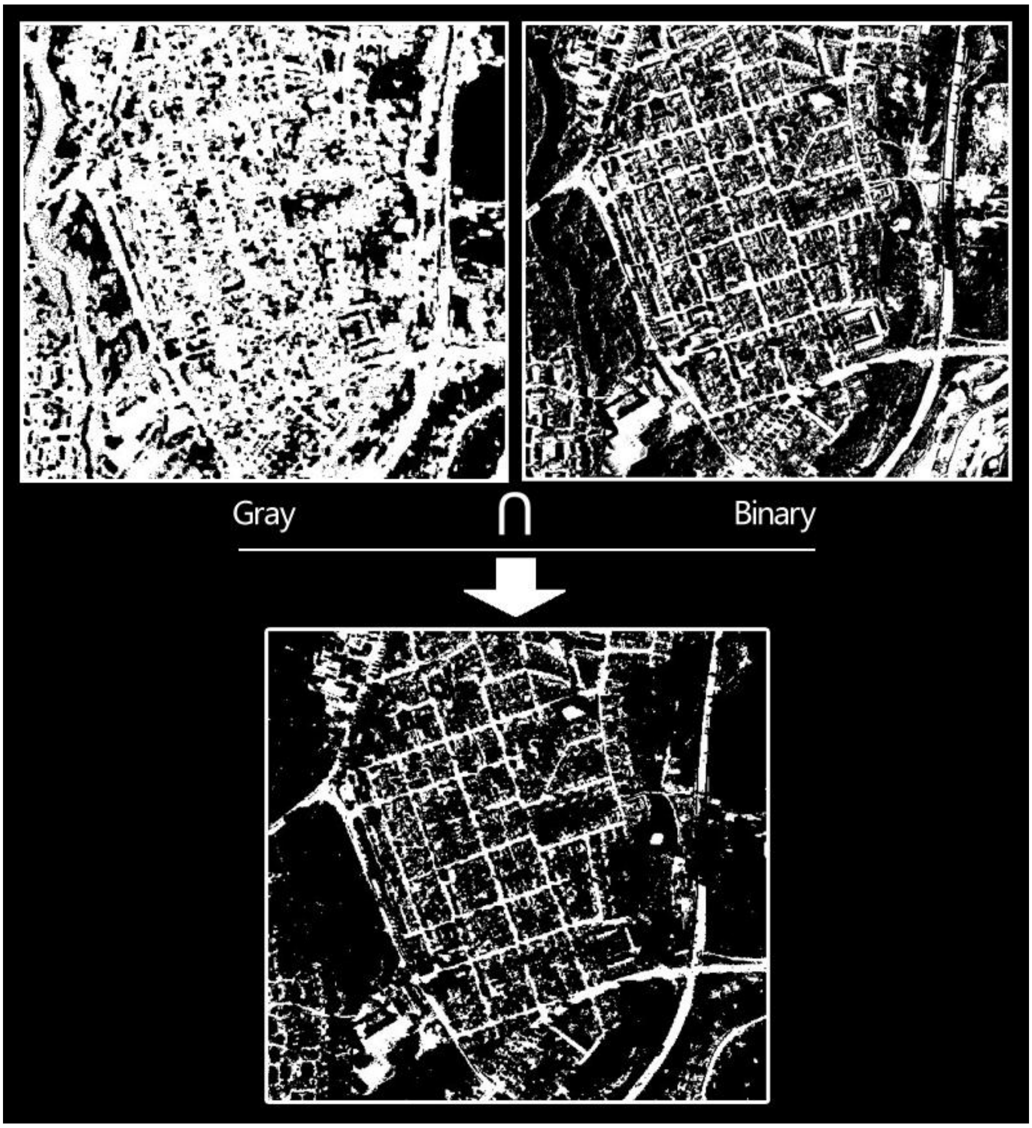


Figure 20. Remove the roof interference

The next question of us is how to renovate roads broken by shadow? This is a key problem in the road extraction. Many methods are designed to renovate some connected parts, which are broken by shadow in the binary image. However, all of those methods are all fail because the size of the shadow is too big. What is worse, some roads are broken by shadow so serious that it is very tough for people to identify whether it is a road or not, to say nothing of road renovation by computers. Top right picture in Figure 19 is a good example. This problem is solved by a smart yet simple approach. The idea is that the shadow on the road is not black or dark gray as we can see in the color image by naked eyes, actually they are blue. In other words, the blue channel of shadow in RGB image is slightly higher than the other two channels around 20 to 40 degree, as shown in Figure 21. It is difficult to distinguish by the naked eye, but the computer can easily do it.

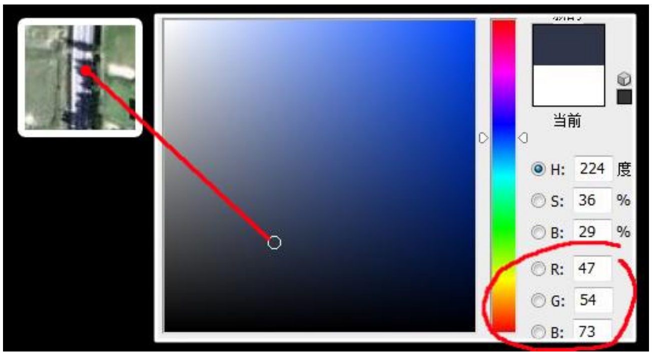


Figure 21. The color of shadow in RGB channel

According to the research, most of the images have this phenomenon when there is sufficient sunlight, but in the weak sunlight or poor air quality condition, this phenomenon will became less obvious. Consequently, a "shadow index " is set as a threshold to judge whether the pixel satisfies this index or not, and the pixel will be transformed into white color in the shadow image if it satisfies the index, otherwise it will be black, see the left top of Figure 22. By incorporating the shadow image with the last resulting image, we obtain the image of the road contour, which will be used to renovate road, as shown in Figure 22. Although the resulting image is still messy, the contour information of the roads is almost retained. After this step, the connectivity of street is insured.

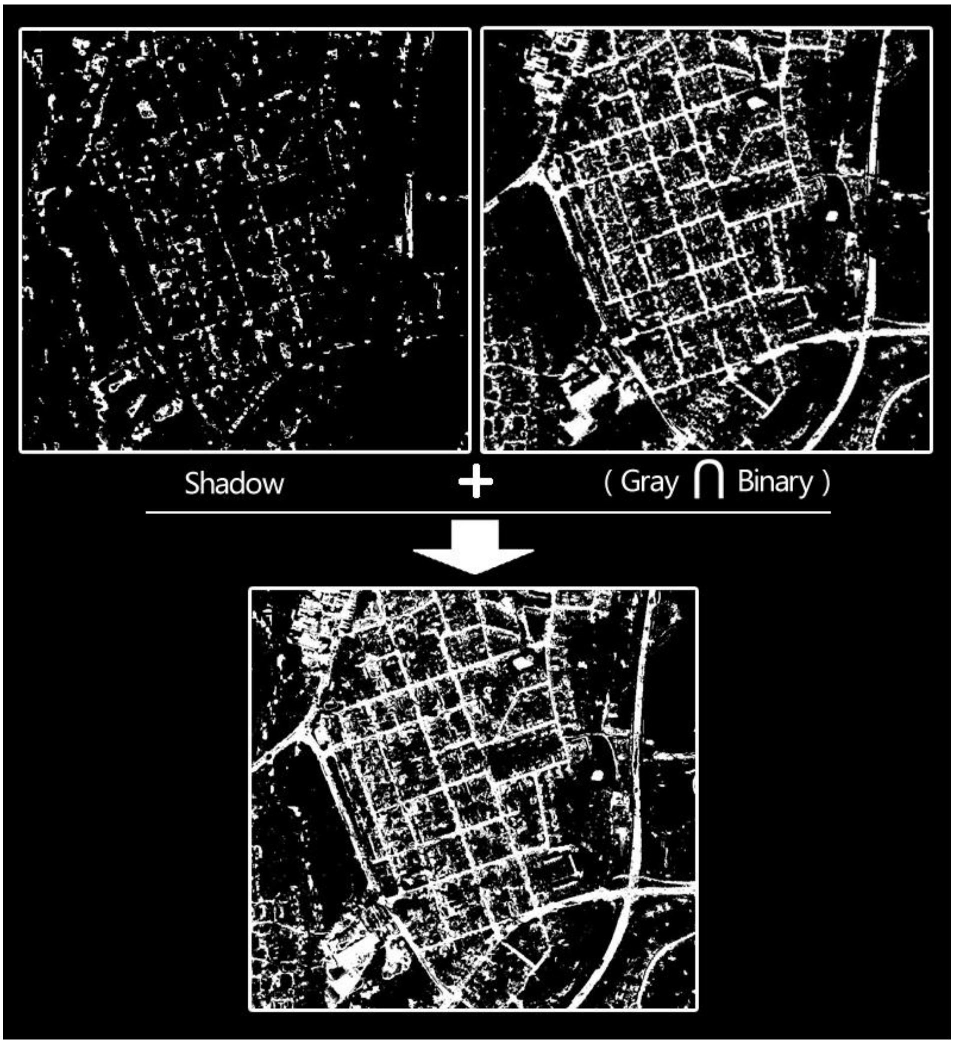


Figure 22. The contour of the road.

2.2.3 Noise elimination

In the first place, the noise in the image after preprocessing is divided into three categories:

Table 1. Three different kinds of noise.

1.Small noise (Not connected with the road and the area is less than 50 pixels)	Caused by the highlight parts, e.g. the reflection of leaves, or reflection of some facilities. (As marked by red circle)	
2. Big noise (Not connected with the road and the area is more than 50 pixels)	Caused by the reflection of small and medium buildings' roof. (As marked by red circle)	
3. Large noise (connected with the road)	Mostly caused by some small parking lot, open area beside the road or some roofs of building closed to the roads. (As marked by red circle)	

With regard to eliminating the first noise (small noise), first of all, we compute the pixels of the connected area by numbering them, for example, a pixel will be numbered 12 if its size is 12. Then we delete the noise which size is less than 50 directly, as show in Figure 23.

Figure 23. Elimination of small noise

About the second noise (the big noise), there may be some broken roads in the image, as shown in Figure 24. Some broken roads will be identified as noise and the removed if we eliminate the noise depend on their size. Therefore, how to distinguish the broken roads from noise becomes a problem that should be concerned.

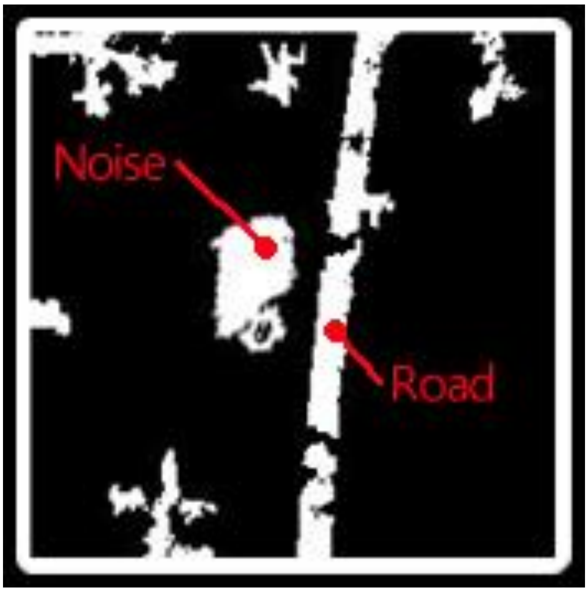


Figure 24. The big noise and broken road

It is observed that the shape of roads like long strip but the roof is similar with rectangle commonly. As a rule, for the same size, the bigger ratio of length and width will have a longer perimeter. An approach is designed to compare the perimeter and the size of connected region (P / S, perimeter signed as P and size signed as S). Since each size of connected regions is different, they will be zoomed out separately. By tests, 8000 pixels of the connected region are more suitable to remain the shape as well as to save the computing time. Afterward a different threshold value will be set to eliminate the noise with different shape. A simulation with different shape of noise that occurs in maps showed in Figure 25. Picture A is the original testing image with different shape noise, such as circle, rectangle, line object and so on.

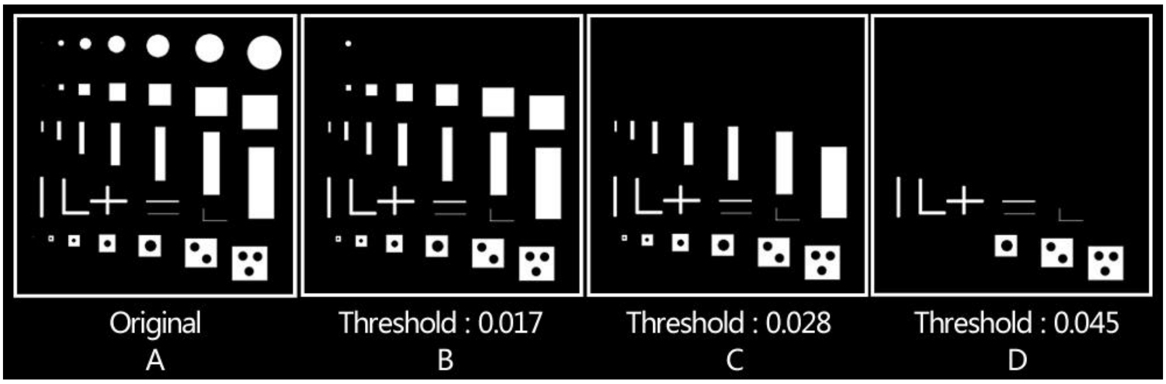


Figure 25. Eliminate different shape of object

By our analysis, a conclusion can be summed up based on elimination sequence: the ratio value (P /S) of the circles is the smallest, see Picture B of Figure 25, the square shape take the second position (Picture C of Figure 25), then the rectangle and finally the linear object (Picture D of Figure 25). In this way, it is easy to eliminate non-linear noise such as building roofs, and it is quite completely maintain the broken roads in the binary images, as shown in Figure 26.

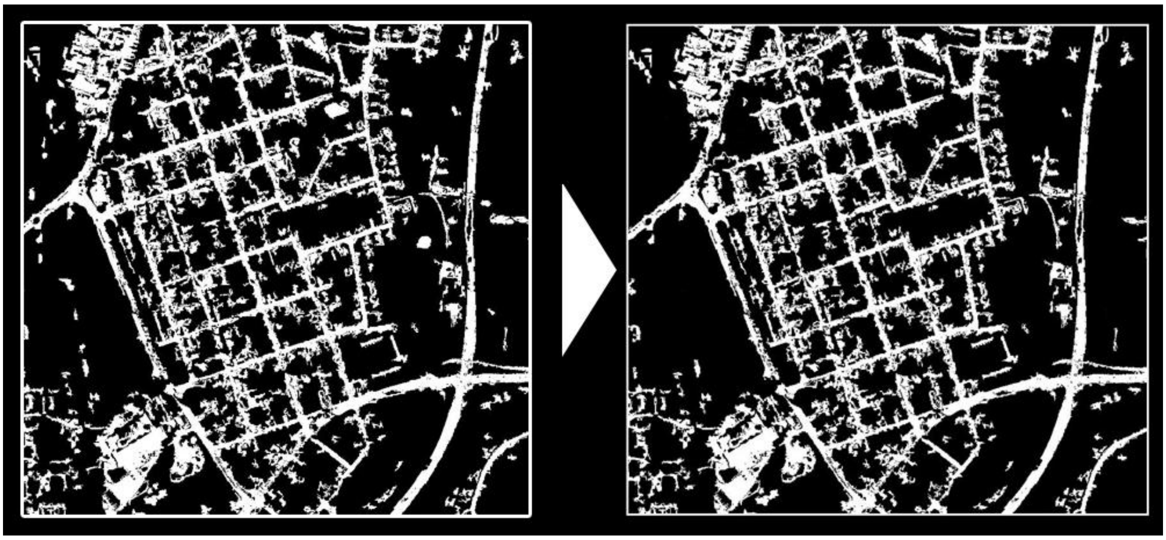


Figure 26. The result after eliminating the noise of roofs but maintaining the broken roads

For the third noise (the large noise connected with road), this kind of noise has one of the roads' features: connectivity as it is connected with the road, thereby it can be only eliminated depend on the other feature: the width of road. An approach is designed to judge whether the area is satisfied the width feature or not. Its basic principle is to count the distance from each pixel to the edge, and use certain algorithms to determine the pixel is inside or outside the road, as shown in Figure 27. We use a method to judge whether the pixel is meet the width of road or not. There is a simulation of width judgment that occurs in maps.

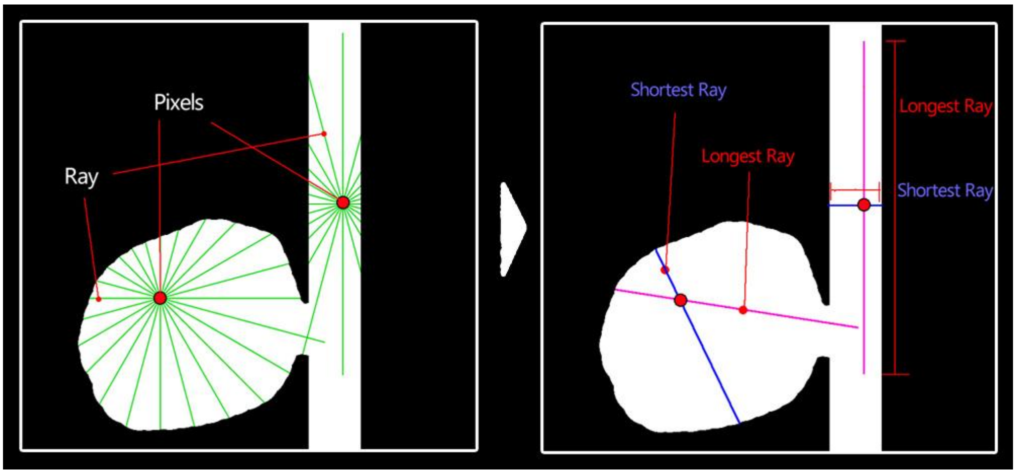


Figure 27. Width judgment of roads

Algorithm radiates rays, which is 70 pixels long on 40 directions (we design to divide 360-degree into different directions (10, 36, 40 and 80), the results show that 40 directions is sufficient to meet the needs. For ray length, 40 pixels, 50 pixels, 60 pixels, 70 pixels, 80 pixels and 90 pixels are tested, 70 pixels' ray length works best. The rays are ended on the edge and the total number of the pixels in the direction and the opposite direction is calculated. Subsequently, the ratio of the longest ray and the shortest one is calculated too. When the pixels in the road, the shortest line should be the width of road and the longest line should be the direction along the road. So, the value of ratio between the shortest line and the longest one is regarded as a criterion to judge whether the pixel is in the road or not. The value should be small when the pixel is in the road. Otherwise, it is outside the road. It is clearly showed the principle of the algorithm in Figure 27. The testing result of the method is shown in Figure 28. This is a simulation of situations that occur in maps. The left image is the original testing image, which has the different size of circles and squares noise connected with road. The aim of this operation is to test whether the open area connected with road can be eliminated.

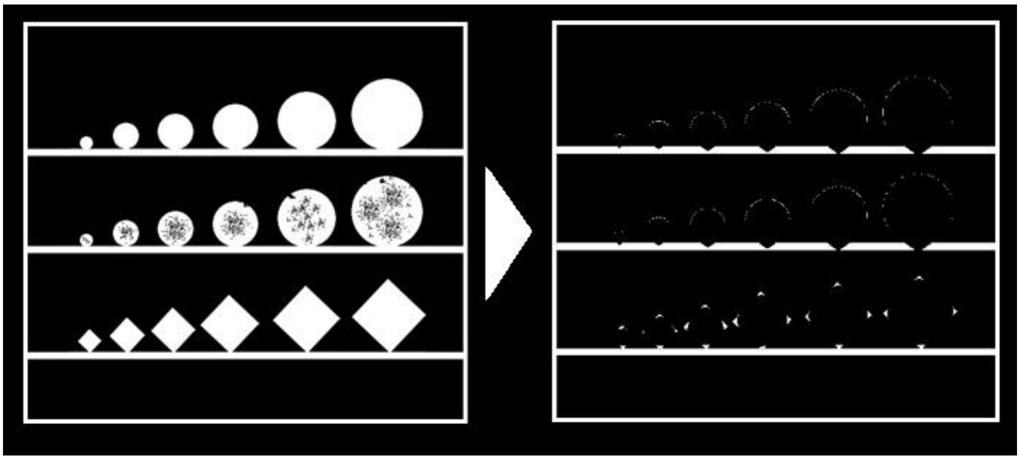


Figure 28. Testing result of eliminating the large noise connected to the roads

As it can be seen in the Figure 28, the testing result is satisfactory, because the lager noise connected with roads is eliminated by this method. There is still remaining some small noise or even some small break on the road, but it is easy to eliminate the noise or renovate broken area. Figure 29 shows the result of big size noise elimination by this method.

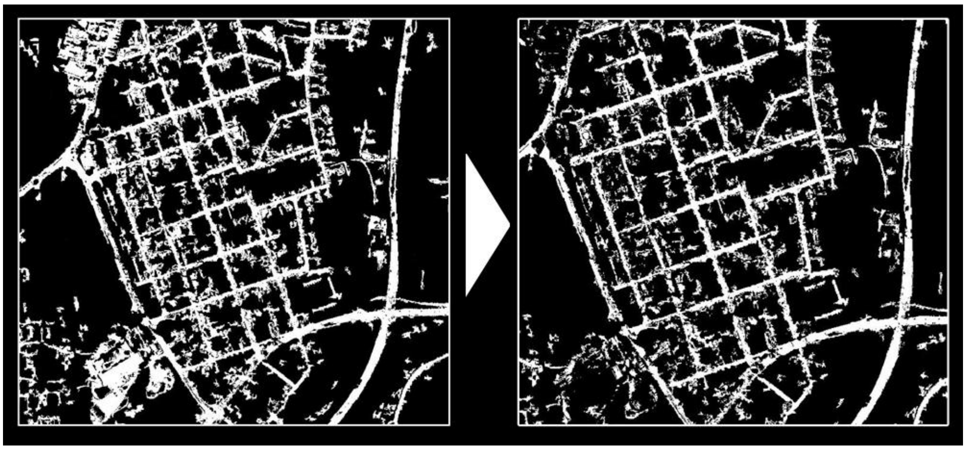


Figure 29. The resulting image is after eliminating the noise by using aforementioned method.

2.2.4 Road renovation

The aim of this section is to renovate broken roads and further eliminate redundant parts of the image. It is the key part of the program.

In this step, an approach is designed to detect the connectivity of road. By this method, the disconnected regions will be eliminated while the connected part will be renovated. The basic principle is to detect the existence of connected pixels around the road. Algorithm emits rays to the target pixel on 40 directions, each ray is 70 pixels long, and then find out the ray which has the large number of white pixels. Once the number of the white pixels is greater than 40, roads are considered to be broken and this pixel will be filled with white point. If the number of white pixels is less than 30, the pixel is considered as it is not in the road and set it with black color. Figure 30 is the simulation of the algorithm. The left picture is the original image, there are two simulated pixels, one is inside the noise, and the other is in the broken part of road. Those two pixels will find the longest ray covered by white color. As it can be seen in Figure 30, the longest white ray of left pixel is shorter than the right one. By this means, we can judge which pixel is in the road. Thus, the left pixel will be eliminated because it is not in the road, and the right pixel will be renovated because it is in the road.

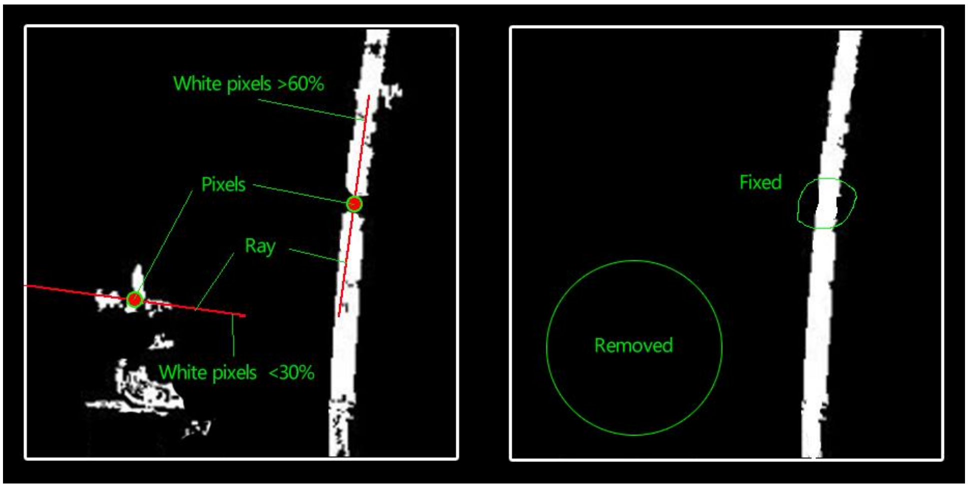


Figure 30. Eliminate the noise and renovate the broken road

The algorithm was tested, and the result is shown below (Figure 31). The left image is the original test image, which is used to renovate the broken part of line in different direction, and minimize the impact of road outline.

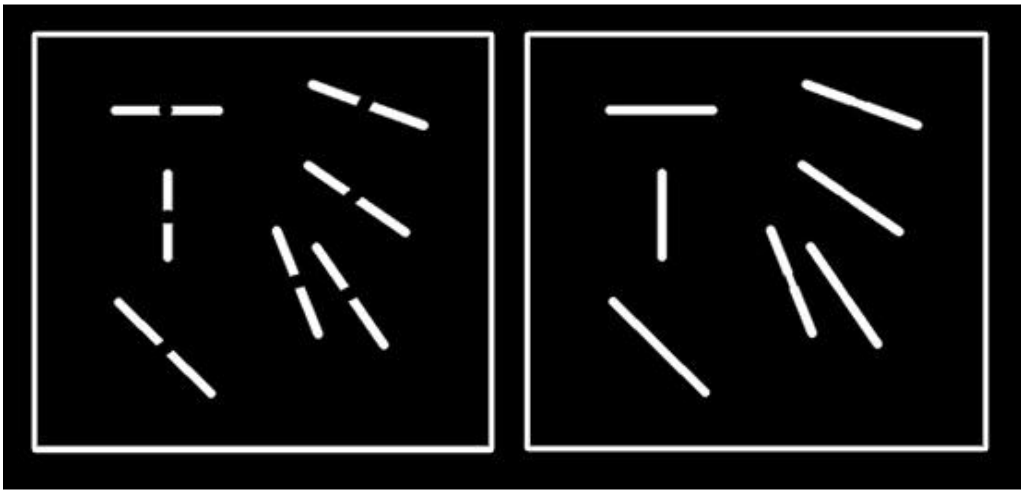


Figure 31. The resulting image of testing the algorithm.

From the tested result can be seen, the broken points are entirely renovated by using the above-mentioned method. The resulting image of renovation broken road through this method is shown in the Figure 32. As a result, roads become clear and most noise around the edges are renovated and the connectivity of road is reserved completely.

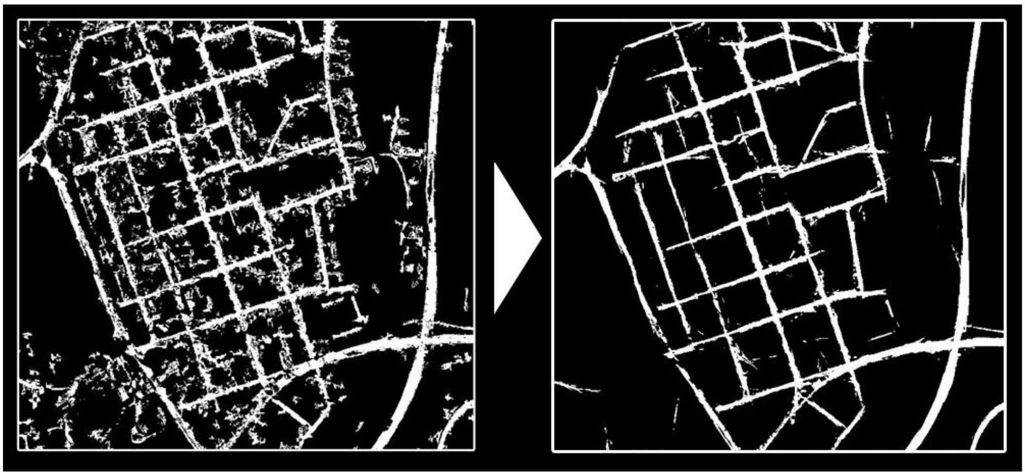
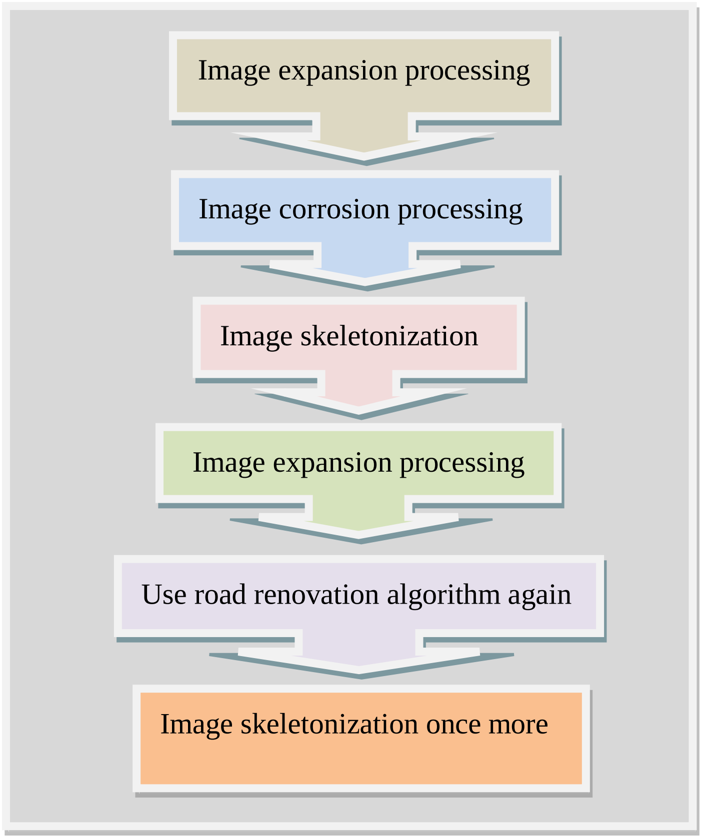


Figure 32. A resulting image of road renovation.

2.2.5 Road Extraction

In this step, lines are used to represent roads in the image. It is complicated to extract road from earth image although the roads have been renovated. There are some steps to simplify the roads and transform them into lines. The purpose of this step is to smooth the edges of roads and remove some small forks. Some methods will be re-used to achieve a better effect. The model below shows the specific steps:



The result becomes clear after noise elimination, then we use line to instead of road. See Figure 33.

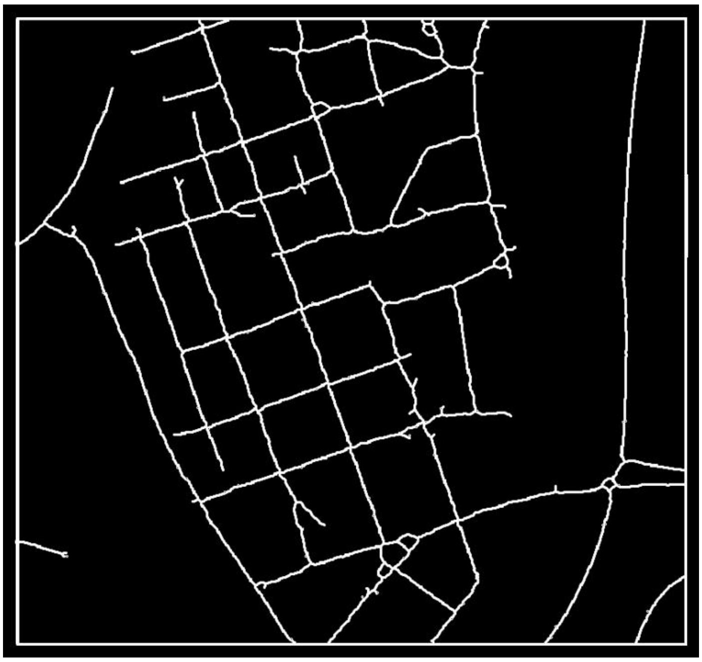


Figure 33. The final resulting image.

3 Results

In this section, we will present the result from our application. Several examples are tested to accomplish automatic process, and the resulting images comparing with the original one are shown below respectively (Figure 34-35).

Figure 34. Three examples resulting images

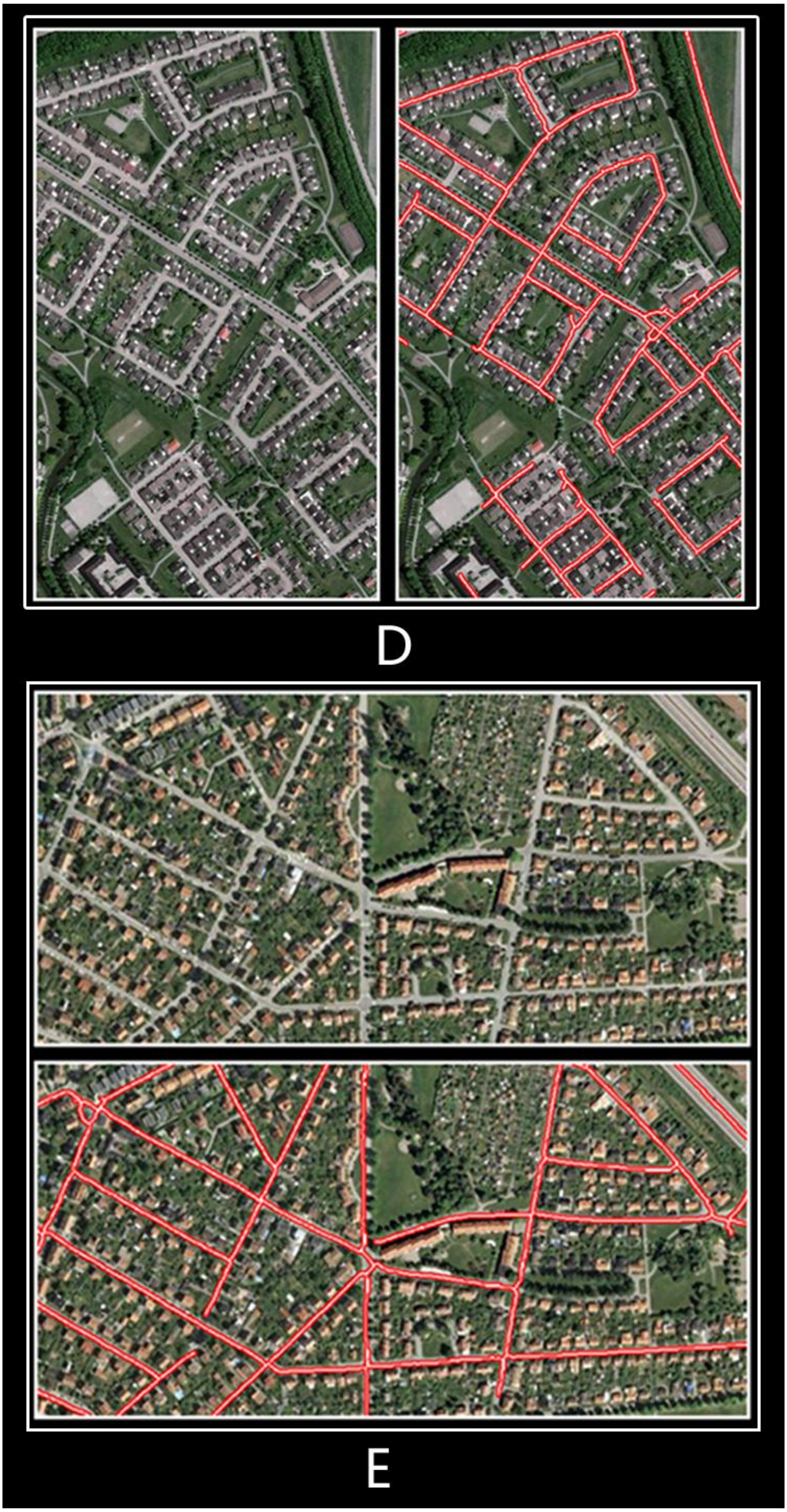


Figure 35. Two examples of result

There are 5 cases, and each of them will be analyzed one by one.

Case	**Analysis**
Case A	It is a model of the residential area that has sufficient light. The matching percentage is 97%, almost not interfered by noise, e.g. shadows or some open area.
Case B	It is an example of the situation when in low sunlight. Moreover, there are many narrow roads, which may cause misjudgment. The matching percentage is 93%.
Case C	It is one model of the residential area that has sufficient light, but some small open areas are caused by noise. 96% is the matching extraction percentage. Figure 36 shows that street still can be identified even the noise is very serious, which are difficult to identify even for human beings, can be very accurate identified by our program
Case D	It is one model of some low sunlight photo and with some open area, the extract matching 94%, the open areas cause the main noise, and some roads are broken.
Case E	It is an example of the residential area with bad air-quality, which leads to the low quality of image. The matching percentage is 99%. Almost not interfered by noise, e.g. shadows or some open area.

From the figure, we can see that the desired goal is achieved very well, depend on statistics data which we test, the extraction rate is greater than 90% in this type of road.

Figure 36. Resulting image compared with original image

4 Discussions

Our program is finished successfully. In the whole application process, the images we extracted are cited from the Google earth image. We tested 30 Google earth images with our program, the results certified that this program is suitable to extract streets or roads from earth images of mid-size city. Although a lot of factors can affect the quality of images, such as poor air, low light intensive and colorcast, our program can still get the good result with these low quality images. We used the shadow color to distinguish the shadow from other objects. This shadow color method is original created and unique, which cannot be found in others' paper.

We designed three algorithms: the first one is to identify noise based on shape; the second one is to eliminate the open area noise connected with road; the third one is to renovate the broken roads. Two prior ones can be successful used to in different cases, and the last one is considered to be the most successful algorithm in our program while it can still be improved. About the last algorithm, the ray used to detect is straight. That is the reason why the efficiency will be high when the road is straight, otherwise it will be low. If the detect ray can change with the direction of road, we will get a more satisfactory and accurate result.

Can computer totally replace the human beings to extract the road? Unfortunately, so far the answer has to be a no. Road extraction problem is far beyond the scope of image processing, and AI (artificial intelligence) technology is deadly needed, as a lot of analysis and judgment is required. It is hard for program to go beyond human beings in this aspect, so it can only assist people to extract the road currently. The automatically road extraction will be possible when AI technology has the huge breakthrough in the future.

5 Conclusions and Future Works

In the end, the goal of our thesis is completely achieved. But nothing is perfect. This program also has problems. For example: under the limitation of the algorithm, the rate of curved road extraction will be declined, and there will be some broken points in the corner of roads. The shadow color will not always be blue deviation. This characteristic will show up when the image with low sunlight intensive or poor air quality. A good result will be outputted so long as the shadow color is blue deviation, but if the color is not, our program can also work.

There is another issue worthy of further study. In the image pre-judgment step, many parameters can be adjusted to improve the result. Currently, only the mean value of roads' color is regarded as reference to adjust the threshold in binarizaiton. Most of other parameters are constants in our program. By representing them to variables, we can get better result. Unfortunately, the image pre-judgment step cannot adjust those fixed values now. We should pay more attention to these parameters, e.g. the color of vegetation, the width of road, air quality, and so on. In addition, the efficiency of the algorithm also needs to be improved. It takes 40 seconds to operate a 1000 * 1000 picture now.

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