University of Victoria
Faculty of Engineering

Work Term Report

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Flood plain water level measurement system

Nanjing Hydraulic Research Institute

River and Harbour Engineering Department

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Work Term I

Software Engineering

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In partial fulfillment of the requirements of the

B.SEng. Degree

Supervisor's Approval: To be completed by Co-op Employer

I approve the release of this report to the University of Victoria for evaluation purposes only.

The report is to be considered : NOT CONFIDENTIAL

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September 5, 2015

Dear Miss. Robin Ley:

The attached Work Term Report entitled “Flood plain water level measurement system” is being submitted as the requirements for work term I.

This report is a summary of my first work term project in Nanjing Hydraulic Research Institute River and Harbour Engineering Department, including the reason of developing this system, system design procedure, hardware and software introduction of the system. I participated in developing a system to measure water level on flood plain, for the purpose of exploring the possibility of flood plain resources utilization. My major task in this project is developing an edge detection program for extracting water surface boundary on flood plain. I was engaged in system design, image acquisition device manufacture and 3G network data transmission as well.

I learned a lot during this coop term, some of them cannot be learned from classes. In this project design, I learned edge detection in image, network transmission, and the most significant thing is how to apply my knowledge into reality.

My supervisor Mao Ning offered much support and advice in this work term. I would like to thank his help. My colleagues who cooperated with me in this project are capable and helpful as well. I am very grateful to work with them.

Sincerely
Jinmin Huang

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Summary

Fertile soil on flood plain is a favorable resource for agriculture, planting industry, etc. Hence, the measurement of water level fluctuation on flood plain is an important issue for us to figure out. Flood plain locates at sides area of riverbed. During high water level period, flood plains are underwater, and reveals during drought period. Flood plain water level measurement system discussed in this essay is our solution for the issue mentioned above. The system takes water surface pictures at a preset intervals and get the data from these pictures. The development of flood plain system is an essential project for Nanjing Hydraulic Research Institute River and Harbour Engineering Department recently.

The whole system includes an image acquisition system and a local server. Image acquisition system is in charge of capturing image, processing image and sending images back to local server. Users remote control the image acquisition system by local server. Local server processes the final image in order to obtain the final data and stores it. The software in image acquisition system receives command from local server, then captures and processes images.

In general, flood plain water level measurement system is a feasible project. However, for the integrity and conciseness of the program, it is a better option to integrate data process code in local server with image process code in image acquisition system together for users' convenience.

Glossary

RS485	A standard defining the electrical characteristics of drivers and receivers for use in balanced digital multipoint systems. [1]
Canny algorithm	An edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images.[2]
Purification AC power supply	A kind of power supply with high stability, output efficiency and anti-interference ability.
CLAHE	The plugin Enhance Local Contrast (CLAHE) implements the method Contrast Limited Adaptive Histogram Equalization for enhancing the local contrast of an image.[3]

1.0 Introduction

Nanjing Hydraulic Research Institute (NHRI), set up in 1935, originally called Central Hydraulic Research Institute, is the oldest of its kind in China. The Institute was designated by the Chinese Government as one of the national non-profit research institutions for public service in 2001.NHRI is a multipurpose national hydraulic research complex, mainly dedicated to basic research, applied research and technological development, and undertaking directional, principal and comprehensive researches for water conservancy, hydroelectric power and waterway transportation projects as well as researches on soft science and macro decision making. At the same time, the Institute acts as the Dam Safety Management Center, the Research Center for Climate Change, the Engineering Quality Inspection Center and the Nanjing Engineering Measurement Examination Center of the Ministry of Water Resources.[4]

The River and Harbor Engineering Department, founded in 1956, is the earliest one in China to conduct model tests on tides, waves, river dynamics and sedimentation, and the first one to perform model tests on irregular waves, flood prevention in unsteady flow areas, sedimentation, pollution and diffusion in tidal rivers. [5]

A flood plain is an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge. It includes the floodway, which consists of the stream channel and adjacent areas that actively carry flood flows downstream, and the flood fringe, which are areas inundated by the flood, but which do not experience a strong current. In other words, a floodplain is an area near a river or a stream which floods when the water level reaches flood stage. [6]

Figure 1.1 – Flood Plain

Flood plain development is a recent project of Nanjing Hydraulic Research Institute River and Harbour Engineering Department. Fertile soil on the flood plain can be used for agriculture and some other industries. However, due to the impact of flood and river water level, possible uses and available area of every flood plain is various according to different seasons and locations. Therefore, it is significant to achieve a precise measurement of water level fluctuation on flood plain to determine the appropriate use purpose and available area of flood plains.

Flood plain water level measurement system is an equipment which can capture image near flood plain and process images. The system will send the final image to local server automatically. Local server gets water level data and stores it. This report illustrates the plan and implementation of the flood plain water level measurement system in detail, including system design, specific functions, hardware and software part.

2.0 System structure

The basic system structure can be demonstrated briefly in a figure below.

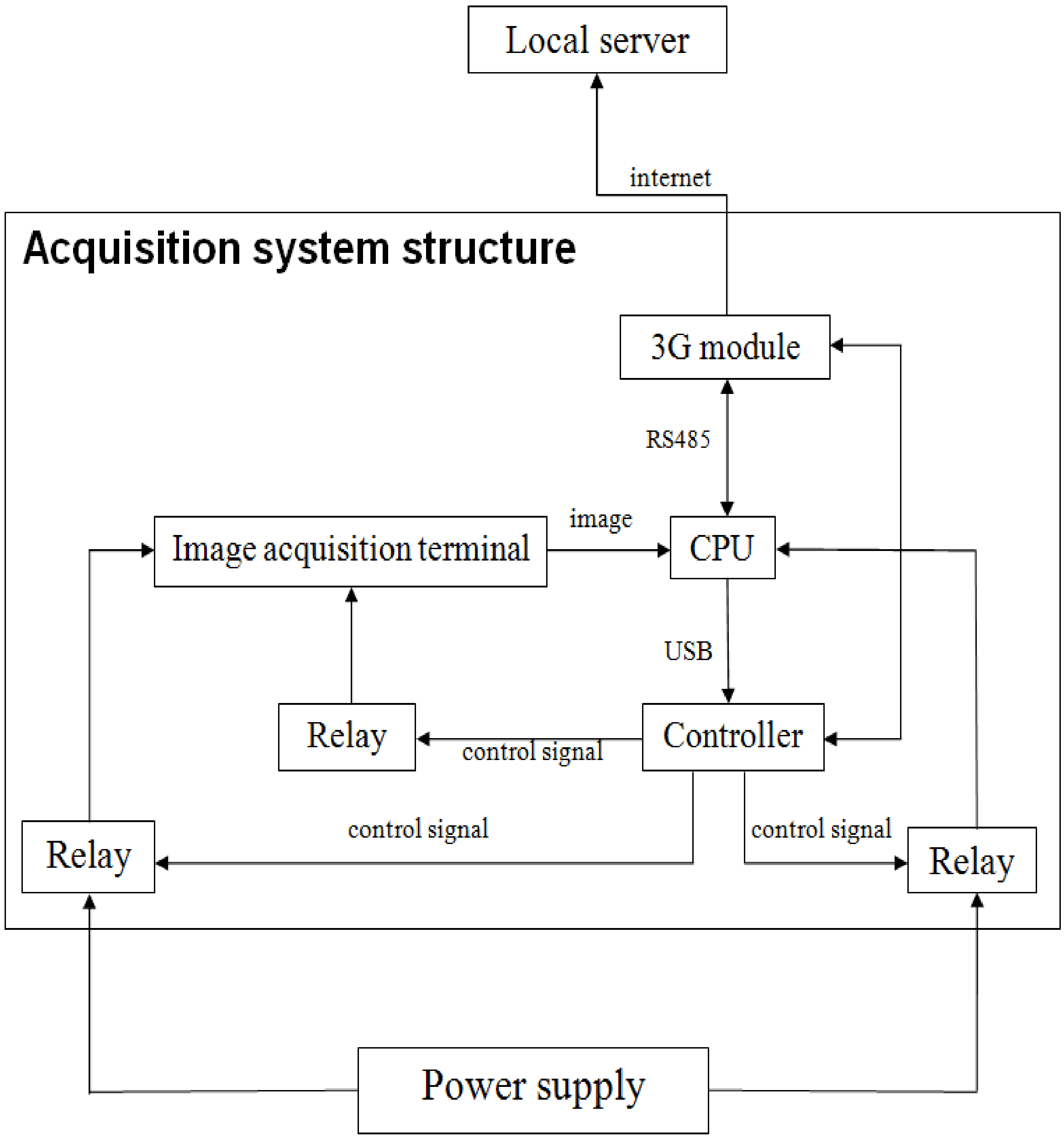

Figure 2.1 – System structure

The entire system consists of several parts as follows.

2.1 Image Transmission

Image acquisition terminal connects with CPU by a USB cable, and transmits images to the CPU.

2.2 Data Processing and transmission

CPU processes images and sends final image to local server through 3G network. Local server calculates a series data of distance and stores, display the data. If the water level rises to the warning stage, the server will alert users.

2.3 Control section of image acquisition terminal

Controller sends two trigger signals to two relays which are connected with the power supply for every preset time interval. Two signals are sequential. One of the signal provides power for camera and the other one provide power for CPU. The last relay which is right below the image acquisition terminal in the figure is for capturing picture.

The time interval is adjustable according to different experimental circumstances, operating conditions and other specific requirements. When the system is in low sampling frequency, controller can control the power supply by sending signal to relays in order to conserve energy. The entire system will be switched to sleep mode during a long time interval.

2.4 Control section of the entire acquisition system

The entire acquisition system's functions list below:

1. Adjust sampling time interval of acquisition system.
2. Control when the data will be transmitted from acquisition system to local server and make sure the local server do not need to be online permanently.

The exact method is as follow:

Local server sends commands about changing sampling parameters to acquisition system through 3G network. After receiving a command from local server, the processor element sends serial port instruction to controller, thereby adjusting output signal of controller in order to control parameters of entire acquisition system.

Local server sends the obtained data to local host and transfers data instruction to the measurement system through internet. After receiving the command, system transmits undelivered data to local server through 3G network. Two following advantages can be realized by this mode of data transmission:

1. Real time monitoring data acquisition

   The above data transmission type is able to ensure that local server will be online whenever data is ready to be sent. In addition, local server transfers data instruction to acquisition system according to a regular time interval, synchronizing with sampling time interval. Therefore, the entire system realizes real time monitoring of the measurement.

2. Offline data acquisition

   When the local server is offline, pictures are stored in the acquisition system temporarily. Local server can require image transfer any time from acquisition system anytime. Then, undelivered images will be sent to local server. In this way, acquisition system is always waiting for command of local server and local server do not need to be online all the time.

3.0 Power supply and the power of device

3.1 Choice of power supply

Stabilized voltage purification AC power supply is the ideal and final option of our system since it is able to provide steady current output without influenced by external interference. Moreover, the allowable input voltage range of stabilized voltage purification AC power supply is larger than common power source. However, direct current requires only 2/3 ~1/3 wire of alternating current when offering same power output. In order to save expenditure and reduce wire cost , an AC adapter is utilized to transfer AC to DC for powering the device.

3.2 Protective action of power supply

Nature conditions such as lightning strike, wind and rain or surge on the river are possible risks for our power supply. For preventing the instability of power supply due to lightning, we combine lightning rods and power supply lightning arrester together. In detail, guide lightning arrester and lightning rod guide lightning to underground and release the power in order to contribute an safety area. The guide lightning wire is thick enough to guide lightning to underground and ground resistance is strong enough to release the energy of lightning.

Ordinary method of preventing lightning is to leave an outer case of device to earth potential and penetrate the wire through an iron tube and bury the tube underground finally. We fasten the power supply at about 2m off the ground and equip a nonconductive outer case for the device in order to avoid the influence of rainy day and waves.

3.3 Power consumption

(1) Operating power consumption

The total operating power consumption is 61.56W, including 5W for controller, 25W for operating power consumption of CPU, 7.56W for image acquisition terminal and 24W for two 3G wireless module.

(2) Sleeping power consumption

The total sleeping power consumption is 26W, including 2W for sleeping power consumption of CPU, 24W for two 3G wireless module.

4.0 Software part

4.1 Flow chart of software

The general structure of software is shown as below. The illustration in detail follows:

1. Control section

The program in operation center sends command to controller through 3G network. Controller controls image acquisition terminal to obtain data according to command received from operation center. Meanwhile, controller controls the power on-off of image acquisition terminal and CPU.

2. Acquisition section

According to the time sequence sent from the controller, image acquisition terminal started to collect and store images into CPU.

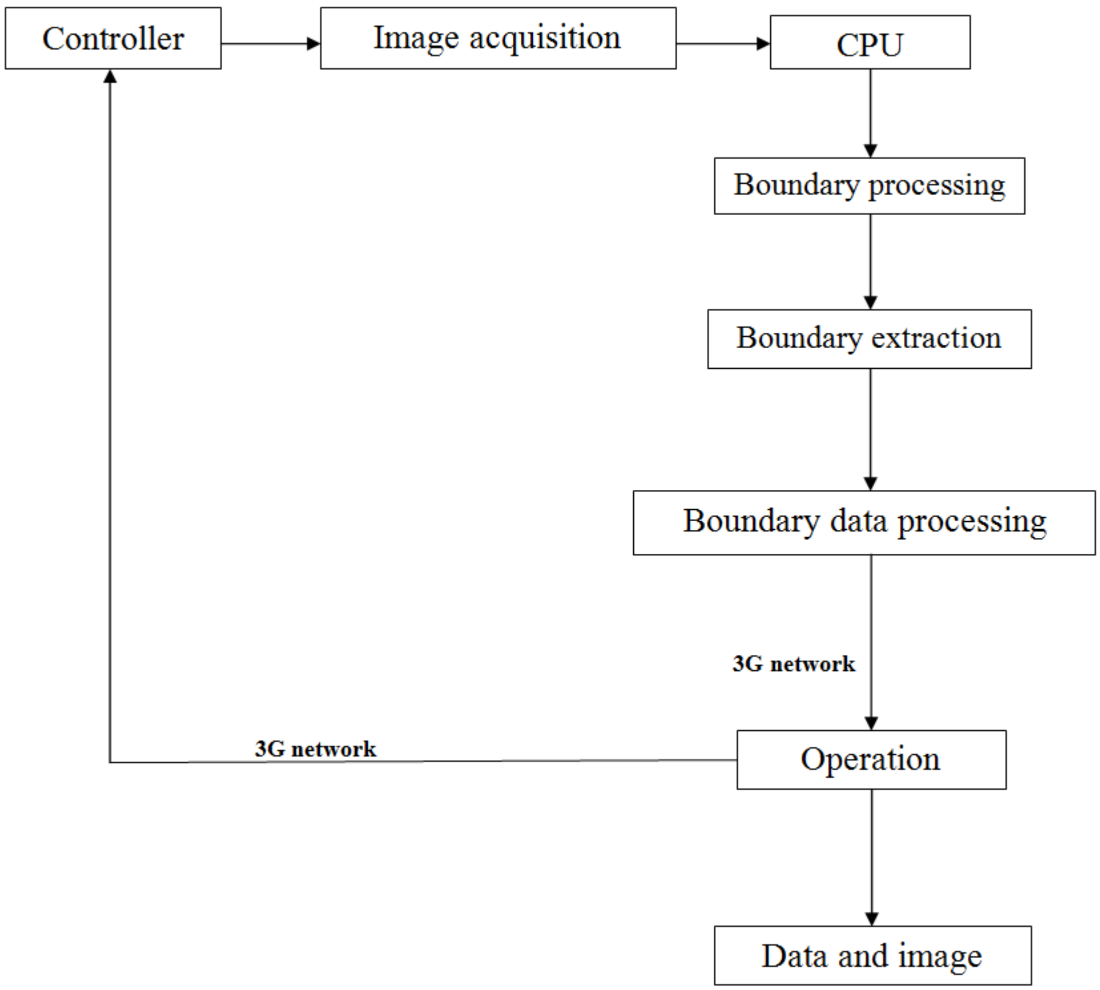

Figure 4.1 – Software flow chart

3. Process section

After boundary processing and boundary extraction, CPU transmits treated boundary data to the server in operation center through 3G network.

4. Display section

Operation center displays data and images by the display function of program.

4.2 Implementation of picture processing

The following part is a demonstration about how get the final image step by step. This is my major contribution in this project.

Figure 4.2 – Initial image

The first step is to wipe off vignettes in the image. The solution is to create a dark circle in the image. The outside of the circle becomes white gradually, and finally overlay with the initial image.

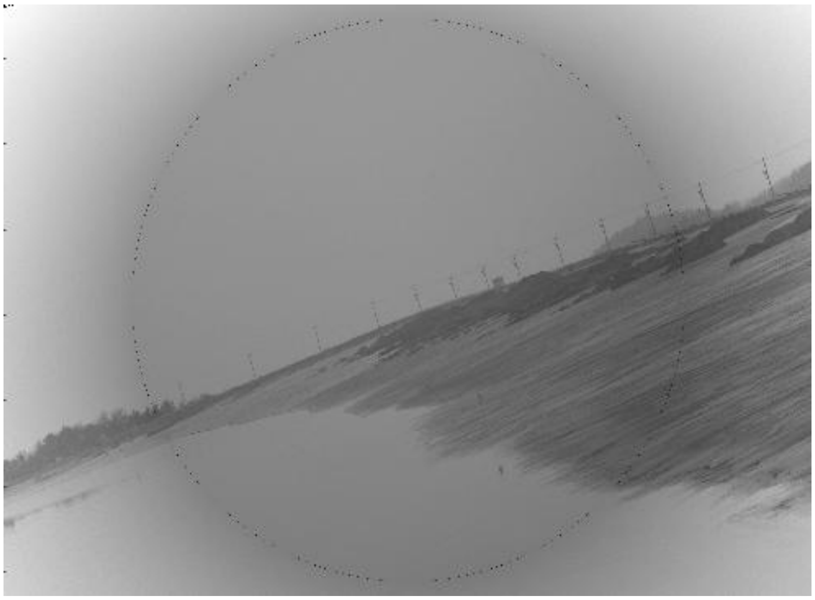

Figure 4.3 – Vignette filter

The source code we used to complete this task is as follows.

```
def vignette_filter(img, pixels_falloff = 0, types=0):
    height, width = img.shape
    radius = max(width, height) / 2.0 * 0.95
    radius = min(width, height) / 2.0 * 0.95
    row_ctr = height / 2;
    col_ctr = width / 2
    max_img_rad = math.sqrt(row_ctr * row_ctr + col_ctr * col_ctr)
    res = img.copy()

    if types:
        trow = pixels_falloff
        lcol = pixels_falloff
        brow = img.shape[0] - pixels_falloff * 2
        rcol = img.shape[1] - pixels_falloff * 2
    for i in range(height):
        for j in range(width):
            dh = abs(i - row_ctr)
            dw = abs(j - col_ctr)
            if not types:
                dis = math.sqrt(dh * dh + dw * dw)
                if dis > radius:
                    if dis > radius + pixels_falloff:
                        res[i, j] = img[i, j] * (dis) / radius
                    else:
                        sigma = (dis - radius) / pixels_falloff
                        res[i, j] = img[i, j] * (1 - sigma * sigma)
                else:
                    pass
            else:
                dis1 = min(abs(i - trow), abs(i - brow))
```

```
                dis2 = min(abs(j - lcol), abs(j-rcol))
                if i<= brow and i >= trow and j >= lcol and j <= rcol:
                    pass
                else:
                    sigma = (dis1 + dis2) * (dis1 + dis2) / (dis1 * dis1 + dis2 * dis2)
                    res[i, j] = img[i, j] * sigma
    return res
```

After that, we blurred to vignette filtered image.

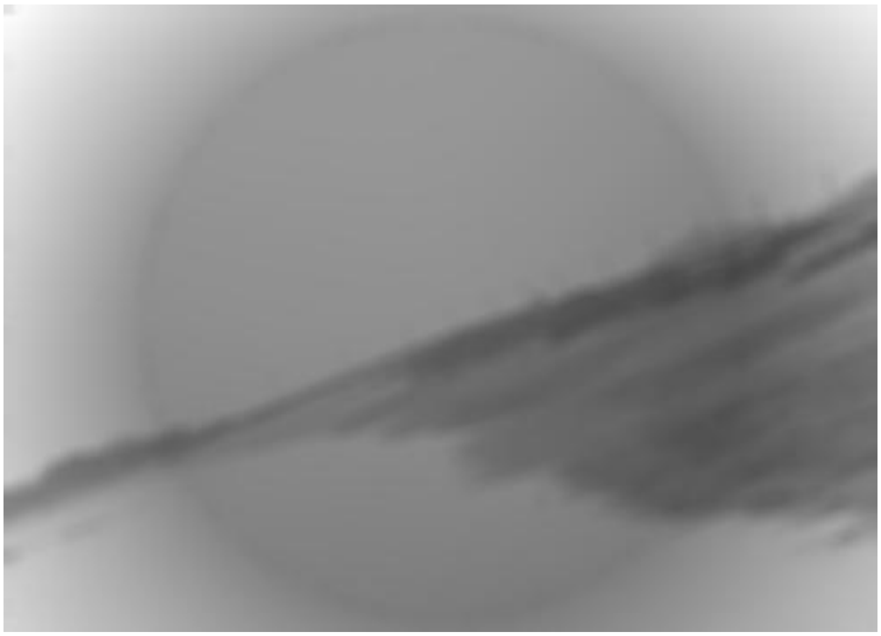

Figure 4.4 – Vignette filtered blur

We blurred the initial image as well.

Figure 4.5 – Original image blur

After that, Figure 4.3 and Figure 4.4 are combined together.

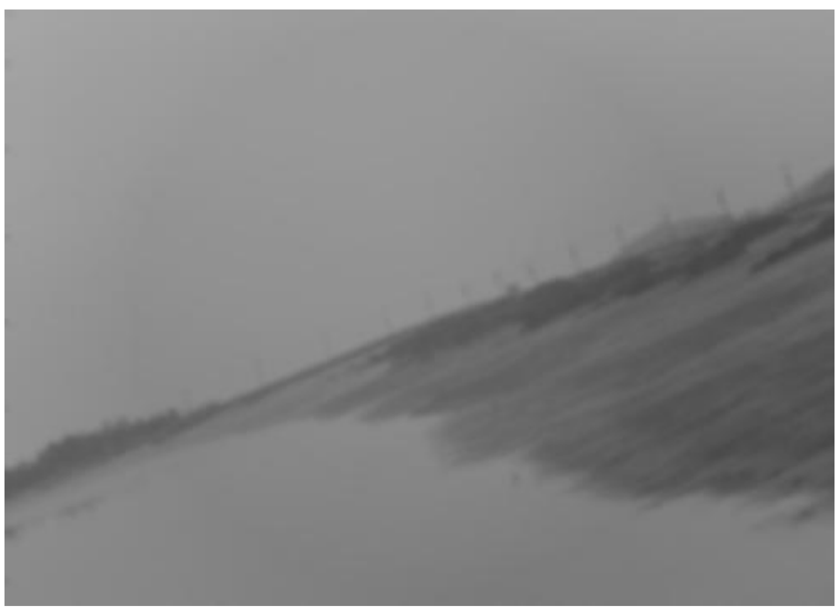

Figure 4.6 – Integration previous two images

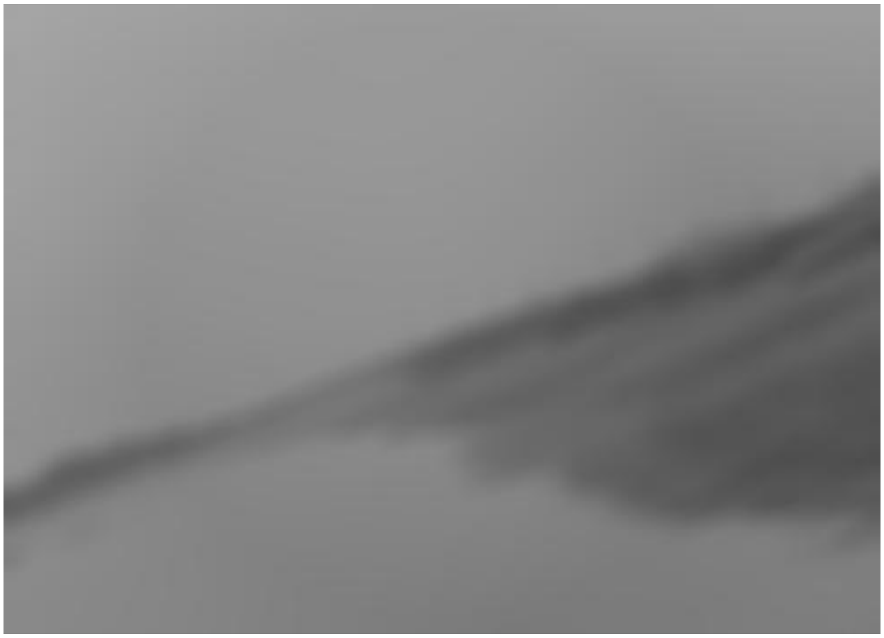

Figure 4.7 – Blurred version of the previous image

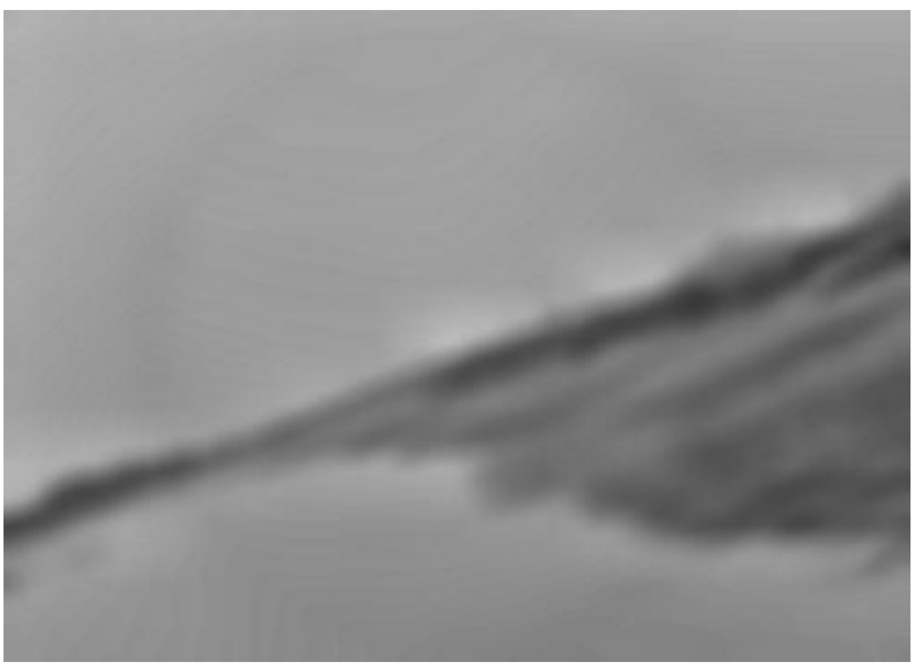

Figure 4.8 – Previous image with CLAHE applied

Figure 4.9 – Edge detection based on the previous image

Figure 4.10 – Overlay the edges on the original image

There are skyline and water level line in the image right now. Since the skyline is a straight line, we can find it by using straightline-finding method which applies linear equation **y=kx+d** to calculate k and d.

```
def find_skyline(x1, y1, x2, y2, img):
    k = 1.0 * (y2 - y1) / (x2 - x1)
    d = 1.0 * (y1*x2 - y2*x1) / (x2-x1)
    return (k, d)
```

After finding the skyline, we set the sky as background color.

```
    minLineLength = 100
    maxLineGap = 10
    lines = cv2.HoughLinesP(edges,10,np.pi/180,100,minLineLength,maxLineGap)
    a1, b1, a2, b2 = (0, 0, 0, 0)
    dis = 0
```

Many short straight line in the image will be found as well. So we take the longest one as the skyline.

```
    for x1,y1,x2,y2 in lines[0]:
        if (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2) > dis:
             a1, b1, a2, b2 = (x1,y1,x2,y2)
    (k, d)= find_skyline(a1,b1,a2,b2, img)
```

The water boundary will be highlighted in the original image according to canny line. The result is stored in "original".

```
    original = cv2.imread("1.png")
    for row in range(original.shape[0]):
       for bt in range( original.shape[1]):
              if dst[row, bt] == 0:
                     pass
              else:
                     original[row, bt] = BLUE
```

The initial radiation point will be calculated according to k and d.

```
    srcy1 = img.shape[1]
    srcx1 = k * srcy1 + d
    srcx2 = img.shape[0]
    srcy2 = 0
    srcx3 = img.shape[0]
    srcy3 = img.shape[1]
    pts1 = np.float32([[int(srcy1) , int(srcx1)],[srcy2,srcx2],[srcy3,srcx3]])
    pts2 = np.float32([[img.shape[1] * 0.9, 0],[0, img.shape[0] /
7],[img.shape[1]*0.75, img.shape[0]]])
```

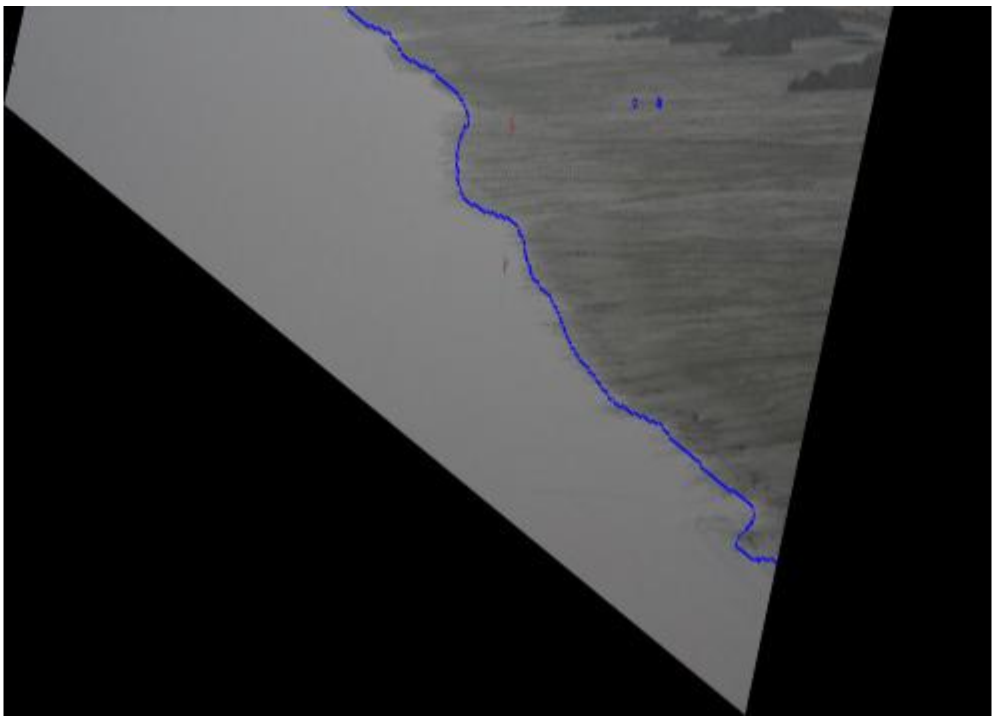

Figure 4.11 **– Final result after corrections**

The blue curve is the water boundary of a flood plain.

4.3 3G transmission module and post processing

The entire software system running on a regular microATX factor PC. We connect local server and system with 3G internet and transmit data through TCP/IP by writing a socket program. Image acquisition and process part of the system link with a 3G module by a RS485 so as to data transmission. After receiving processed image, local server can calculate the distance between water boundary and river bank and achieve the physical coordinate of water boundary in order to figure out the accurate water level. The final water level data are stored as txt format automatically in local server, waiting for further analysis. Since I did not participate in those designs mentioned in section 4.3, this report just describes these parts briefly.

5.0 Conclusion

In sum, the entire flood plain water level measurement system consists of a image acquisition system and a local server. It realize functions including remote system control, image acquisition , process and measurement data remote transmission.

Flood plain water level measurement system acquires data and images on-site and sends data and image back to designated local server. Specifically, at a preset time interval, image acquisition system captures images, calculating and processing image as well. Finally, image acquisition system sends processed image back to local server. Local server makes calculation according to images in order to obtain final data and stores it.

Furthermore, local server is able to send command to image acquisition system remotely, thereby controlling sampling frequency and data transmission. Server sends command to image acquisition system through 3G network so that image acquisition system take actions depending on command, such as changing sampling frequency, changing time interval or starting transmitting acquired data, etc.

6.0 Recommendation

The specification of this system indicates that it is using regular personal computer as the central control unit. However, a regular PC would easily reach a power consumption level of 45 W or higher. As the image processing process for this particular application is not excessively CPU intensive. It's possible to use a SoC (e.g. Raspberry Pi) as the central control unit. In this way, it could reduce the power consumption down to 1.5 W and save at least 96.7% energy.

In addition, the post processing of data is operated in local server. This step can be integrated in image acquisition system as well. All steps can be done in image acquisition system so that it will enhance efficiency and conserve resources. In this case, the final data could be sent to any computer according to users' requirement instead of setting up a local server.

References

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