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A Digital Algorithm for Precipitation Self-Recording Paper

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Abstract: The main steps of digital algorithm for precipitation self-recording paper are image rotation correction, coordinate line extraction, tracing curve and extraction. First of all, Canny operator detect the edge of precipitation self-recording paper, and get the angle of image rotation by Radon Transform, and then make a rotation, it can correct the inclined image. Secondly, in accordance with the rule of the lines, it takes advance of projection analysis of image to find the correct location of the axis. Thirdly, the image of precipitation self-recording paper is threshold segmented by Kittler algorithm, and eliminated the interference connected component by morphological filtering. Finally, bianry image is intensified by Gabor filtering algorithm, and we can extract the center line of the precipitation curve according to the maximum vertical position using Skeleton method. And then we get the real data of one minute, ten minutes and one hour from the image of precipitation self-recording paper.

Keywords: Gabor filtering; precipitation self-recording paper; threshold segmentation; projection analysis

1. Introduction

Precipitation self-recording paper is very valuable in meteorological data of the measured. The precipitation curve record objectively the precipitation process of change over time, and reflect the precipitation intensity of various periods, which can not be replaced by the other precipitation data. Precipitation self-recording paper is very important to research the characteristic of rain, particularly storm. Furthermore, it also play a important role in sector of national economy, such as agriculture, urban construction, telecommunications, traffic, water conservancy and so on. Because it recorded on paper, whose information can not be utilized extensively and deep, and because some paper were recorded in a long time ago, and keep in poor environment, some paper are illegible and deteriorate in varying degrees. Therefore, the precipitation self-recording paper need digital processing, which is the only way to change the current state and its information within the meaning is utilized and reflected fully.

In this paper, in order to overcome all kinds of interference factors in digital processing, I adopt Gabor filter algorithm and Skeleton method, which can extract the center line of the curves of precipitation according to the maximum vertical position, and we can get easily the real data from the image of precipitation self-recording paper.

2. Image Rotation Correction

There will inevitably be a certain angle of rotation when the image of precipitation self-recording paper is scanned. Therefore, Canny operator detect the edge of the image, and get the precise angle of image rotation by Radon Transform. Image $f(x,y)$ of the Radon Transform can be expressed as follow:

$$P(t,\theta) = R(t,\theta)\{f(x,y)\} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(t - x\cos\theta - y\sin\theta)dxdy \quad (1)$$

And t is the distance between the origin of coordinates and the projection line, and θ is the angle between the normal vector of projection line and axis x, whose range is $\theta \in [0,\pi)$. Definition of Radon Transform is expressed as Figure 1.

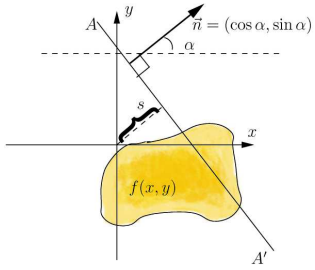
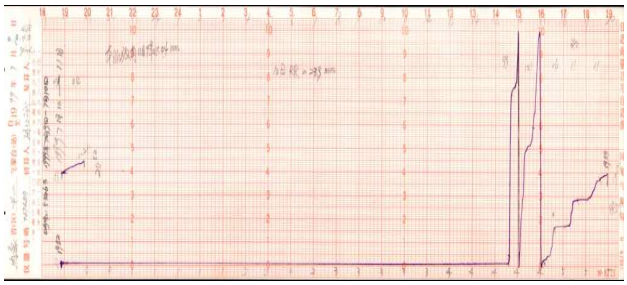


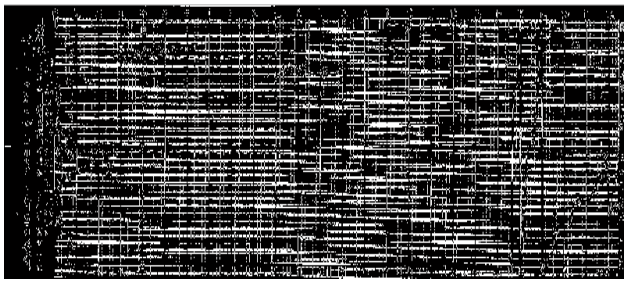
Figure 1. The definition of Radon Transform

After Radon Transform, we can get the rotation angle of the image from the maximum of transformation matrix. The processes of image rotation correction are ex-

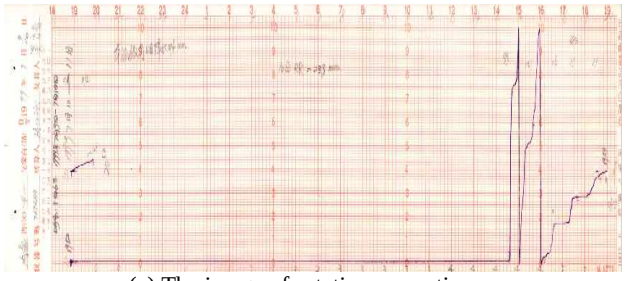
pressed as Figure 2. The rotation correction algorithm can satisfy the needs of practical applications.



(a) The image of precipitation self-recording paper



(b) The image of Canny edge detection



(c) The image of rotation correction

Figure 2. Image Rotation Correction

3. Coordinate Line Extraction

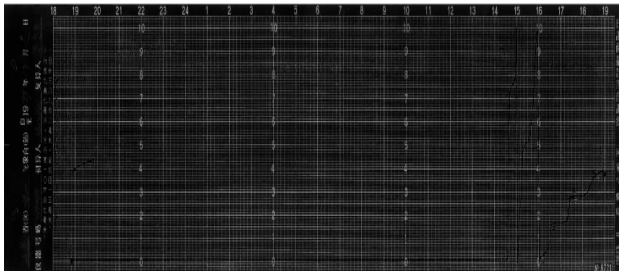
From the image of precipitation self-recording paper, we can find that coordinate line is yellow, and curve is navy blue. Therefore, in order to determine the exact location of coordinate line and the curve, we must extract the yellow and black component from the image, and RBG image will be converted to CMYK image. Formula are expressed as (2),(3).

$$Y = 255 - B \tag{2}$$

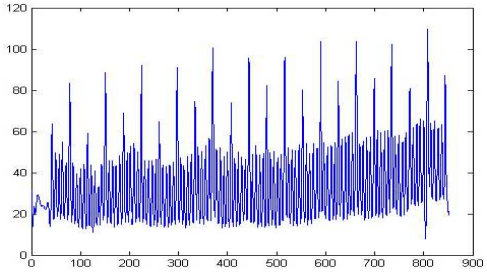
$$K = \min(\min(255 - R, 255 - G), 255 - B) \tag{3}$$

The black component is just curve image, and the yellow component is coordinate line and curve image. So we can get the image of coordinate line by the yellow component subtracting the black component. There is expressed as Figure 3.

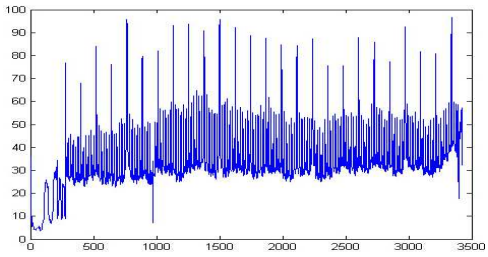
In accordance with the rule of the lines, it takes advance of projection analysis of image to find the correct location of the axis.



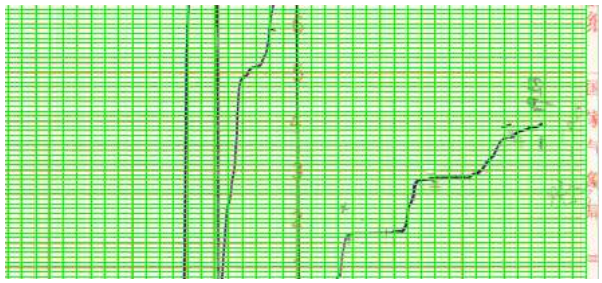
(a) The image of the yellow component subtracting the black component



(b) Horizontal projection curve



(c) Vertical projection curve



(d)Horizontal and vertical coordinate line

Figure 3. Coordinate line extraction

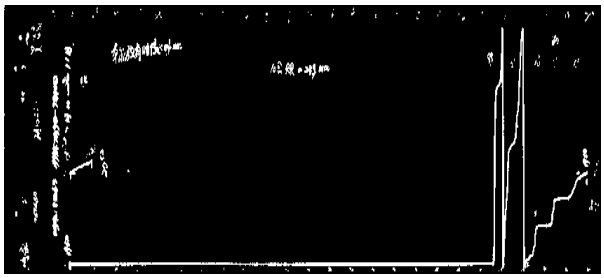
4. Tracing curve and extraction

In order to extract precipitation data from the image, we need detect the center line of the precipitation curve. But the precipitation curve is easily effect by some interference factors, such as ink contamination, curve fracture, pencil scratch, coordinate lines and so on. In this paper, in order to eliminate these interference fac-

tors, we use the Kittler binarization algorithm which we can deal with the gray image of precipitation self-recording paper, thus an optimized segmentation result is obtained. The Kittler formula is expressed as follow:

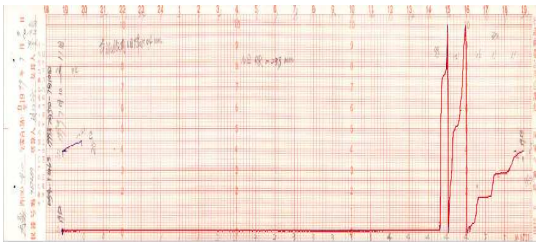
$$T = \frac{\sum_x \sum_y e(x,y) f(x,y)}{\sum_x \sum_y e(x,y)} \tag{4}$$

In this formula: $f(x,y)$ is the original gray image, $e(x,y) = \max\{\,|e_x|, |e_y|\,\}$ is maximum gradient, and $e_x = f(x-1,y) - f(x+1,y)$ is horizontal gradient, $e_y = f(x,y-1) - f(x,y+1)$ is vertical gradient. T is global threshold which is got from Kittler algorithm.



(a) Threshold image

(b) The binary image after Gabor filtered



(c) The result of tracing curve and extraction

Figure 4. Tracing curve and extraction

There are some interference factors at extracting precipitation curve, for example curve fracture and pencil scratch, therefore, in this paper, we adopt Gabor filter to deal with them. Since the band-pass characteristics of Gabor filter, if a frequency range consistent with Gabor filter passband, the output of Gabor filter will be very large, on the contrary, the output will be restrained. The filter could eliminate small fracture, when the output is maximum value. Because the intensity of pencil scratch is less than curve, it can also weaken the impact of the pencil scratch. Gabor filter general form is expressed as follow:

$$h(x,y;\phi,f) = \exp\left\{-\frac{1}{2}\left[\frac{x_\phi^2}{\delta_x^2} + \frac{y_\phi^2}{\delta_y^2}\right]\right\}\cos(2\pi f x_\phi) \tag{5}$$

$$x_\phi = x\cos\phi + y\sin\phi \tag{6}$$

$$y_\phi = -x\sin\phi + y\cos\phi \tag{7}$$

ϕ is the direction of Gabor filter; f is the frequency of sine wave; δ_x and δ_y are envelope constant along the x and y axis. It's evident that the frequency characteristics f and direction of filter is determined absolutely by the frequency of a certain part, the larger the value of δ_x and δ_y become, the stronger the ability of noise reduction will be, on the contrary, the weaker the ability of noise reduction will be. According to experiment, there is a better experimental result, when $\phi = 45^\circ$ and $\delta_x = \delta_y = 4.0$. The result as follow:

5. Conclusion

In this paper, we deal with a lot of precipitation self-recording paper by means of image rotation correction, coordinate line extraction, tracing curve and extraction, finally, we get optimal algorithm after many experiments. We effectively solve some problems which does not solve previously, such as curve fracture, pencil scratch. We can get a good result when the quality of precipitation self-recording paper is better. However, for some paper with a large block ink contamination, there are some large errors, and we can solve these problems by means of manual intervention.

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