Edge Detection of Tank Level IR Imaging Based on the Auto-adaptive Double-threshold Canny Operator

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Abstract

One new approach for detection tank level is investigated based on the auto-adaptive double-threshold Canny operator, considering IR imaging of tank level and aiming at the problem of the detection of tank level. Edge operator of tank level based on the auto-adaptive double-threshold Canny operator can set double-threshold automatically, according to different tank level IR imaging gray gradient histogram's feature, instead of traditional Canny operator in which double-threshold should be set artificially, to avoid the loss of edge information especially liquid level's information because of improper artificial selection. In the process of picking up liquid level's information, it can analyze the number of horizontal stripes, and get their idiographic position according to the number, making edge operator more practical in application of tank level detection .The simulation result indicate that edge detection of tank level based on the auto-adaptive double-threshold Canny operator apply in detection of tank level very well.

1. Introduction

In petroleum, chemical, industry and mining enterprises, there are many oil depots. The measurement of oil tanks is significant for process control, inventory management and settlement. Accurate detection of tank Level, which prevents excessive oil spilling storage tank is also an important means to ensure environment of oil storage tanks secure. When tank Level lower than the pump's oil exportation, the tanks take out air and can not pump oil[1]. As a result, in some depots, even some vicious incidents like oil spillage are caused. It is not only wasteful, but polluting air and water seriously. Monitoring of the depot for the automated management of the oil tanks, in control of the liquid level, temperature, pressure and other parameters, can greatly enhance the efficiency of the oil depot' storage, effectiveness of management about it and enhance guarantee of security. Therefore, the tank level monitoring has broad application. With the development of tank level measurement, measuring methods and measuring instruments also increase. At present, there are some practical techniques and methods of tank level measurement, such as direct reading, buoyancy, hydrostatic, capacitance, ultrasonic, microwave, magnetostrictive instrument etc.

2. The way to acquire IR imaging of oil tanks

The programme needs to monitor a number of tanks all-day. In the system each tank can be monitored by a separate thermal imaging device, and then images are sent to a PC for processing. However, many thermal imaging devices will undoubtedly increase the cost of the system, not suitable for expansion. To improve it, we can install thermal imaging equipment in rotational flat, which is installed at a suitable region, able to achieve horizontal direction rotation and the vertical direction rotation, and with features to maintain a fixed position to take photographs. In the design, it is considerable that two-step motors control the horizontal and vertical direction movement of rotational flat. If we choose the right step angle Motors, supplemented by micro-controller, the system can achieve the design requirements well and achieve more complex movements, such as horizontal and vertical direction movement at the same time. IR temperature measurement technology is quick without delay, to avoid the complex sensor installation[2]. Large area can be measured, for a number of oil tanks in tank farm collecting data simultaneity. It's not necessary to alter any of the existing oil tanks, and its integrated security cost is lower.

The temperature of tanks containing the oil distribute regularly. The temperature has many differences between oil and the mixture of air above the oil, that there is

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temperature gradient from the air to the oil. Using IR thermal imaging device to make the photo of the tank, the imaging image Have a clear dividing line. Analyzing according to the temperature distribution of the image and considering the physical size of the oil tank, we can get the oil tanks' liquid level.

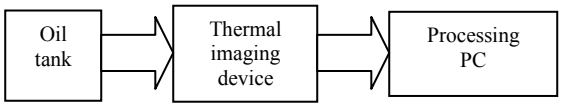

Figure 1 Graph of principle.

3. Edge detection based on the auto-adaptive double-threshold Canny operator

Among the many edge detection operator, Canny algorithm has better maturity, and edge information achieved is the most comprehensive in some detection algorithm.

3.1. Traditional Canny edge detection operator

In 1986, Canny starting from the three criteria which edge detection operator should meet, derived the optimal edge detection-Canny operator, which is the most complete theory of so many edge detection algorithm relatively[3]. The three criteria of Canny operator performance evaluation are:

(1) Criteria of a good signal to noise ratio: the probability that fake edge points are sentenced to be the edge point is low, and the probability that the edge points are sentenced to be fake edge points is low.

(2) Criteria of a good signal to noise ratio: the probability that fake edge points are sentenced to be the edge point is low, and the probability that the edge points are sentenced to be fake edge points is low.

(3) Criteria of single edge response: one edge has only one single response, and the probability that single edge has a number of responses is lower. And the response of fake edge should be inhibited greatest.

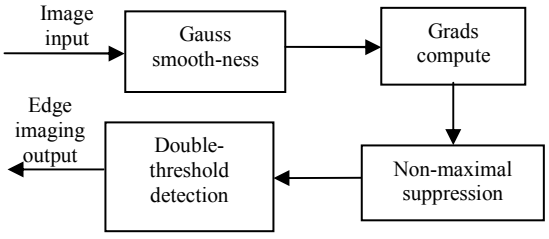

Figure 2 Edge detection with Canny operator.

The Gauss function of the image:

$$G(x,y,\sigma)=\frac{1}{2\pi\sigma^2}\exp(-\frac{x^2+y^2}{2\sigma^2}) \quad (1)$$

is smoothed, and the image's noise is restrained. In the formula, σ is the smooth parameter, commonly between 1.0 and 2.0; After finishing grads compute, grads scope and direction of smoothed data array is computed; Non-maximal suppression is used to refine the matrix of grads scope, looking for possible edge points in the image; double-threshold detection search the edge points in the image through recursion of double-threshold, to realize pick up edge points. The grads vector
is divided into row filter and column filter of one

$$\nabla G=\begin{bmatrix}\partial G/\partial x\\ \partial G/\partial y\end{bmatrix} \quad (2)$$

dimension.

$$\begin{cases}\dfrac{\partial G}{\partial x}=kx\exp(-\dfrac{x^2}{2\sigma^2})\exp(-\dfrac{y^2}{2\sigma^2})\\ kx\exp(-\dfrac{x^2}{2\sigma^2})\exp(-\dfrac{y^2}{2\sigma^2})=h_1(x)h_2(y)\end{cases} \quad (3)$$

$$\begin{cases}\dfrac{\partial G}{\partial y}=ky\exp(-\dfrac{y^2}{2\sigma^2})\exp(-\dfrac{x^2}{2\sigma^2})\\ ky\exp(-\dfrac{y^2}{2\sigma^2})\exp(-\dfrac{x^2}{2\sigma^2})=h_1(y)h_2(x)\end{cases} \quad (4)$$

$$\begin{cases}\dfrac{\partial G}{\partial x}=h_1(x)h_2(y)\\ \dfrac{\partial G}{\partial y}=h_1(y)h_2(x)\end{cases} \quad (5)$$

where the k is a constant.

In application, canny operator is better than Robert operator, Sobel operator, Laplace operator, orthogonal and non-orthogonal wavelet, general fuzzy operator etc. But canny operator has some disadvantages, for example, traditional canny operator use fixed double-threshold to pick up edge point in image, in lack of auto-adaptive characteristic, depending on manpower, low in automatization[4].

3.2. Adaptive double-threshold edge operator

(1) Sub-image is background completely: if sub-image correspond the non-edge region of the original image completely, not including any margin, the number of the edge in the entire sub-images should be set 0, which can inhibit the local Noise coming from the dynamic threshold.

(2) Sub-image both has the edge and the background: most sub-images are in the state which include a large number of background, and a small amount of the edge[5].

As prior knowledge tells us, the proportion of non-edge region is far greater than the proportion of marginal region, so，pixel collection corresponding single peak in gradient histogram is certain non-edge pixel collection. Gradient value which have the largest number of pixels in the gradient histogram is named as the gradient extremum of pixels $H_{\max}$, calculated the variance which come from the grads of all the pixels relative to gradient extremum of

pixels $H_{\max}$, is named as the variance of pixels extremum grads $\sigma_{\max}$.

$$\sigma_{\max} = \sqrt{\sum_{i=0}^{m} (H_i - H_{\max})^2 / N} \quad (6)$$

where the m is the pixels extremum grads and $m \neq 0$, N is the pixels' sum. When gradient histogram only has single peak, gradient value of pixel concentrate on the hereabout of $H_{\max}$, and $\sigma_{\max}$ is very small.

When the gradient histogram has not only the single peak of non-edge gradient pixels, but also the distributing of the gradient of edge pixels, the gradient of the edge pixels is far from $H_{\max}$, so $\sigma_{\max}$ is large, and it can be set the fixed threshold for estimate (for example, can set the fixed threshold value1) [6]. When the fixed threshold is more than $\sigma_{\max}$, and all sub-images are the background of non-edge image, setting the value of the gradient 0, so it do not need to track these edge, saving computing time and reducing the complexity of the calculation, if $\sigma_{\max}$ greater than the fixed threshold, while that both contain non-edge image and the edge, it need for further processing.

The description of traditional Canny algorithm indicates that the high threshold τ_h must select gradient histogram out of the non-edge region, otherwise it will bring a lot of noise of the fake edge. In this paper, it can set a high threshold of the threshold τ_h adaptive, $H_{\max}$ reflects the centre of non-edge distributing in the regional gradient histogram, while $\sigma_{\max}$ is the discrete level of gradient's distributing relating to $H_{\max}$ in gradient histogram, that is, discrete level of relative to non-edge region, so the region of non-edge can be compute using $H_{\max}$ and $\sigma_{\max}$ [3]. If the High threshold τ_h is more than the value of $H_{\max}$ and $\sigma_{\max}$, it can be considered that τ_h is out of the non-edge region, this could prevent fake edge in a contour map, the formula for calculating τ_h :

$$\tau_h = H_{\max} + \sigma_{\max} \quad (7)$$

Adaptive dynamic threshold is relative to conventional fixed threshold value, the optimal in principle overall situation, according to the gradient histogram characteristics different of sub-images, to determine the different thresholds of various sub-images[7]. To the overall thresholds for the foundation, using and adjusting the gradient distribution of sub-images, which it can get is the dynamic adaptive threshold. In any image, it establish τ_H and τ_L as the high-threshold and the low-threshold of the whole image overall in this method, while τ_h and τ_l is the local high-threshold and the low-threshold of sub-image in this method, then the final high-threshold and the final low-threshold of split imaging are:

$$\tau_{High} = (1-\beta)\tau_H + \beta\tau_h \quad (8)$$

$$\tau_{Low} = (1-\beta)\tau_L + \beta\tau_l \quad (9)$$

where the β is the rate of threshold adjustment, $\beta \in (0,1)$. If $\beta = 0$, it need not adjust, and indicated that it implement image segmentation according to the characteristics of the overall gradient histogram; If $\beta = 1$, it implement image segmentation according to the characteristics of local images' gradient histogram, so the dynamic threshold algorithm is took into account the overall best and lossless of local details. The value of β can be determined according to in the practical application, the size of sub-images can be properly selected. The calculation of the high threshold parameters α_h can be came from τ_{High}, α_h representative the scale of the gradient pixel value, which is less than τ_{High}.

With the Canny operator noise estimation method, assuming that the response of the edge signal is relatively little and the value is relatively large, but the response of lots of noise has the relatively small value, then the threshold can get through the statistics accumulated histogram of the filtered image. However, a threshold is not enough. As a half noise signal response is greater than the threshold value, resulting in a stripe, which means the edge is off. If lower this threshold, there will be always wrong "marginal". To solve this problem, a double-threshold method is brought. It can get a high-threshold T_1 with statistics cumulative histogram, and then take a low-threshold $T_2 = 0.4T_1$ [8]. If the response is greater than high-threshold T_1, then it must be the edge, if below the low-threshold, then it certainly is not the edge, if the response is between the low-threshold and the high-threshold, then it depends on its eight neighborhood pixels whether there are edge' s pixels more than high-threshold.

4. The processing of tank level IR imaging

The image processing's basis is Tank imaging characteristics. Tank's temperature is related to imported oil's temperature, storage time, the temperature of outside tank, etc. Oil component is not the only one, the mixture may be contain some materials, such as water, sand etc., are the specific impact on the oil tank temperature distribution and image collection[2].

4.1. Characteristics of tank IR imaging

The vertical temperature distribution of crude oil in oil tank has nothing to do with central temperature, oil

temperature, and other parameters and stable or unstable tank. Where the l0m around has the highest temperature in tank, that is in the central of oil tier in tank. High temperature in the oil tank is in central location on the upside, but at a lower level (10m) this law is not in evidence. The vertical distribution's major factors of temperature effect in the oil tank is from the internal heat conduction and on the surface[9].

Observation and treatment of color for the human eye is a physical and psychological phenomena, the mechanism has not been fully clarified, thus the many conclusions of the color are built on the basis of the experiment. Experimental data show that the wavelength of visible light district in the 400 nm~700nm, when the spectral sampling restricted to three human visual system sensitive to the red, green, blue band, it sampling the three spectral bands of light energy, can be get a color image.

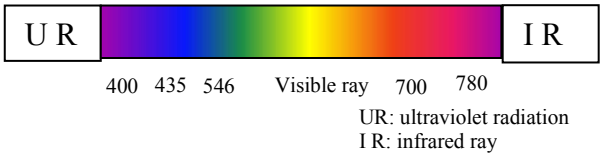

Figure 3 Spectral bands distribution.

CIE provided to 700 nm (red), 546.1 nm (green), 435.8 nm (blue) for the three primary colors, also known as the physical three primary colors. All the colors of nature can be a mixture of proportion of these three different colors. RGB on behalf of the three kinds of colors[2]: R representative of red, G on behalf of green, B representative of the blue. In the RGB color image, for each pixel by representatives of three main color of strength, every single element called a passage. RGB color models that use RGB for each pixel in the image of the RGB component within the scope of strength of 0~255. For example: pure red R value is 255, G value is 0, B is 0; gray R, G, B's value is equal (exception of 0 or 255); R, G, B's value of white is 255; R, G, B's value of black is 0.

The scene collected image for the JPEG format, in the image information, we are most concerned about in the image on the edge information. We focus on analysis the RGB gray value of the edge in the regional image, finding that gray value has a jump in the vicinity of the level of liquid, near the level line of liquid is descending, we judge the level of step-edge.

According to the analysis of images collected at the scene, the image has the following features:

(1) Tank top and the side of tank have an obvious dividing line with the air;

(2) Dividing line between the reservoir and the air in the image is a clear horizon;

(3) Appendage on the oil tank surface, such as bracket, and bracket and pipeline imaging a certain angle, the pipeline in the vertical direction mostly, adjunct imaging smaller, in different directions.

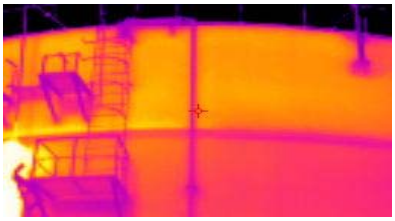

Figure 4 The scene for collection of the tank top.

Shown in the figure 4, there are many brackets in the left of the image, and other appendage, but the whole image only has two clear horizons.

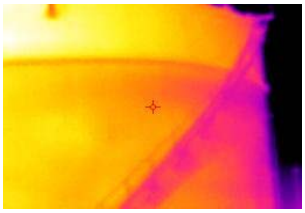

Figure 5 The scene for collection of the middle tank.

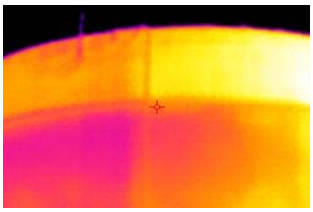

Figure 6 The scene for collection of the whole tank.

Shown in figure 5 and Figure 6, between the tank top and air, oil and air, and the sand at the bottom have clear dividing lines.

4.2. The IR feature extraction of tank level

The idea of extraction the overall tank level:

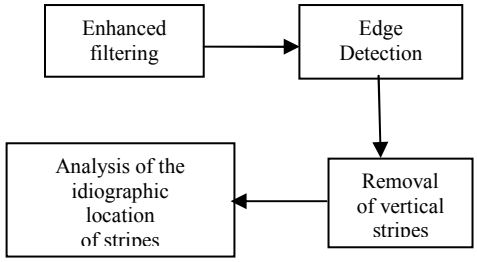

Figure 7 Level information extraction.

After IR imaging pre-filtered, Canny algorithm is used for detecting tank level information. After detecting the edge of the image is the binary image, the image value 1 is the bright spot, 0 is scotoma. We can see the edge information of the oil tank from the image clearly. According to numerical characteristics, we do the statistics a numerical point 1 according to row, finding that only lots of 1 presence in the regional is the information of real tank level edge. And according to statistics on the number of distribution of 1, we analyze the horizontal stripes in the image. From the horizontal stripes distribution of our image, we remove vertical stripes of image for the follow-up to enhance the level accuracy of information extraction, reducing the vertical stripes on the impact of the level data.

The defect of IR imaging is mainly low-resolving power, the image contrast is not high, much noise and

non-uniformity, and so on. Therefore, real-time IR imaging processing algorithms are mainly concentrated in image enhancement, de-noising and non-uniformity correction, and so on. The discussion of filtering noise and enhancement is as follow.

Select the scene image Figure 4 to 6 to processing, which have a representative.

Figure 8 The ultimate effect of the 4th image .

As shown in Figure 8, the left of the original image has many brackets, and other appendage such as vertical pipe, the right of the image's vertical edge information has been better filtered from edge detection, many brackets filtered at a certain extent, you can also actual see the horizontal stripes, so there are some horizontal direction edge information, it is because interference by surface of the tank appendage, such are not care, we discard it.

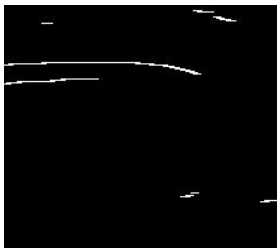

Figure 9 The ultimate effect of the 5th image.

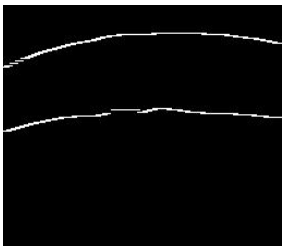

Figure 10 The ultimate effect of the 6th image.

In figure 9, the original image has the oblique staircases, and the oblique information is wiping off after detection. In the image 10, tank surface is bright and clean, no surface appendage. The horizontal stripes get clear after the detection. Level information is based on ideological edge detection, oil extraction and oil line contours. The design use the adaptive double-threshold Canny operator to edge detection, it is better able to extract edge information from the IR imaging.

5. Conclusions

The adaptive double-threshold edge detection operator based on Canny criteria can set the threshold level according to different image histogram feature automatically, to avoid the artificial choice threshold inappropriate the edge information loss, in particular, the information of tank level loss. In the process of extract tank level IR imaging information, the number of horizontal stripes automatically is analysed, based on the number of landscape orientation stripes, getting the specific location of each horizontal stripes. The simulation results indicate that edge detection of tank level based on the auto-adaptive double-threshold canny operator apply in detection of tank Level very well.

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