Chip Recognition Method of LED Chip Tester

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Abstract - In the process of LED production, it is the key to determine the precise location of the LED chip and improve the recognition accuracy of the chip. An image recognition method that based on the method of image threshold segmentation of sub-pixel accuracy is proposed to detect LED chip’s image in this paper. Firstly, make image preprocessing by using this new method, and then extract the ROI(Region of interest) by using K-means clustering algorithm. Finally, the location of the chip is determined by using the NCC (Normalized cross correlation) normalization method. The experimental results show by combination of the sub-pixel accuracy threshold segmentation method and the NCC normalization algorithm in the LED testing instrument, LED chip image can be accurately recognized and pinpoint the location.

Keywords - LED chip; Gray value; NCC; Region extraction; Template matching

I. INSTRUCTION

Light emitting diode (LED) is a electroluminescent semiconductor light emitting device, which belongs to the cold light source. It was used to primarily as a signal light with a relatively narrow application field. With the development of photoelectric technology and material science, LED devices are currently widely used, which has been applied to many industries and can be seen everywhere in our lives as well, such as display, LED panel back lighting, decorative lighting, general lighting etc.

LED chip tester is an important test of LED production line to test each LED chip. LED chip is tiny with size 0.17 mm × 0.17 mm – 1 mm × 1 mm. There should be two complete electrodes on each chip, P and N pole of the diameter about 90 um. it is quite difficult to see it clearly without any tools, showing at Figure 1.

In this paper, the image processing method is used to design the image acquisition system, which will be used to process, recognize and locate the LED chip image, and measure the position of the P and N poles of each LED chip. The collected LED chip image as shown in Figure 2. The location of the chip can be precisely detected by the LED tester, and improve recognition rate and accuracy as well.

II. HARDWARE SYSTEM STRUCTURE OF LED CHIP TESTER

The research of the LED chip tester detection equipment structure is divided into two parts from its function, including the machine vision system and motion control system. As show Fig. 3, LED chip tester is composed of three parts, mechanical devices (test benches, edge finder, workstations, etc.), image recognition system, controlling and measurement system.
III. LED CHIP RECOGNITION METHOD

At present, there are two key problems in the research of the software of vision system for LED chip tester: image acquisition and display; precise pinpoint the target chip. Fig. 4 is algorithm design block diagram based on sub-pixel accuracy threshold segmentation, the entire algorithm contains 3 parts [1]: the image preprocessing, ROI region extraction and NCC normalization algorithm.

![Algorithm design block diagram](image)

**A. Image preprocessing**

In LED chip tester motion control system of mechanical movement, motion data are provided by means of machine vision measurement for motion control [2]. First, Image was collected by the camera and the sub-pixel accuracy threshold segmentation algorithm is used to preprocess it. Sub-pixel precision threshold segmentation processing result is a region, but sub-pixel accuracy outline, and this outline precision threshold segmentation processing result is a region is less than \( g_{\text{sub}} \) [3]. In order to obtain the boundary, the discrete image can be obtained by bi-linear interpolation, as in (1):

\[
g(a, b) = \frac{g(Q_{11})}{(a_2 - a_1)(b_2 - b_1)}(a_2 - a)(b_2 - b) + \frac{g(Q_{21})}{a_2 - a_1}(a_2 - a)(b_2 - b)
\]

\[
+ \frac{g(Q_{12})}{(a_2 - a_1)(b_2 - b_1)}(a_2 - a)(b_2 - b_1) + \frac{g(Q_{22})}{(a_2 - a_1)(b_2 - b_1)}(a_2 - a)(b_2 - b_1)
\]

Selecting a coordinate system to make g ‘s four coordinates as (0, 0) (0, 1) (1, 0) (1, 1), then interpolation equation can simplify as in (2):

\[
g(a, b) = g(0, 0)(1 - a)(1 - b) + g(1, 0)a(1 - b) + g(0, 1)(1 - b)b + g(1, 1)ab
\]

, then the representation is converted to a continuous function as in (3):

\[
g = b(a)g_{(1)}(1 - a)g_{(0)} + (1 - b)a)g_{(10)} + (1 - a)g_{(00)}
\]

Calculated conversed coordinates to four adjacent pixel center in the vertical direction and horizontal direction distance, then according to the distance value to calculate the different gray values for the weights, the results of bi-linear interpolation can be calculated by the equation as given above, which helps to obtain the image of a continuous function. The value of sub-pixel precision threshold segmentation.

The image resolution for recognition and localization of the LED chip is not high enough, in order to improve the sub-pixel edge detection accuracy, in this paper presents a algorithm: it first uses the algorithm based on edge detection to make rough edge location. Then use the ZOM (Zemike operator matrix) matrix operator to make accurate edge detection, and reach the standard of sub-pixel.

1) Definition of ZOM orthogonal matrix

Set \( f(x, y) \) for image, then n order m times ZOM orthogonal matrix of \( f(x, y) \) as in (4):

\[
Z_{nm} = \sum_{x, y} f(x, y)\overline{V_{nm}(\rho, \theta)} \quad x^2 + y^2 \leq 1,
\]

The integral and function \( V_{nm}(\rho, \theta) = R_{n,m}(\rho)e^{in\theta} \), \( \overline{V_{nm}(\rho, \theta)} \) is \( V_{nm}(\rho, \theta) \) of the conjugate, as in (5).

\[
R_{n,m}(\rho) = \sum_{i=0}^{\infty} \left( \frac{-1}{n + |m|} \right) \left( \frac{n - |m|}{2} \right)_{i}
\]

2) Test method

According to the following equations, the position of the sub-pixel [4] edge can be pinpointed as in (6) (7) (8) (9).

\[
\begin{align*}
x_i &= x + N \times 1 \times \cos \theta \\
y_i &= y + N \times 1 \times \sin \theta
\end{align*}
\]

\[
\theta = \arctan \left( \frac{\text{Im}[Z_{11}]}{\text{Re}[Z_{11}]} \right)
\]

\[
F_{i1} = \text{Re}(Z_{11})\cos \theta + \text{Im}(Z_{11})\sin \theta
\]

\[
Z_{11}, Z_{20},
\]

By the above equations, the position of the edge points can be obtained, the position of each point along the direction of \( \theta \) to search extreme value point and get the edge position [5]. Then put these points with the least squares fitting link into the border. So that in this way, any edge location can be reached as in (10):

\[
\text{MIN} = \frac{1}{N} \sum_{i=1}^{N} \left[ y_i - g(x_i) \right]^2
\]

B. ROI region extraction

In the sub-pixel accuracy matching algorithm the contour image after median filtering has been extracted. The next application of K clustering algorithm is extracted from the
chip in which K value clustering algorithm is applied [6]. K-
means clustering algorithm is given a number of K, using
the principle of nearest distance will be assigned to N
objects of a class K. Clustering results is expressed by the K
cluster centers. Given clustering objective function is based
on gray value of objective function in the region. Adding
Each data point and the cluster’s the center of gravity of the
distance which makes greatest similarity between objects,
minimum similar between classes . The gray value of the
selected area is used as the object of the K value clustering
algorithm to distribute the K cluster centers. The region of
the maximum gray value and the minimum gray value is the
K clustering center of the clustering objective function of the
boundary function [7], as in (11) (12):

\[
\begin{align*}
    g_{\min} &= \min_{(r,c) \in k} g_{r,c} \\
    g_{\max} &= \max_{(r,c) \in k} g_{r,c}
\end{align*}
\]

(11) (12)

The average value of gray value in the region is another
gray value feature, as in (13):

\[
g = \frac{1}{a} \sum_{(r,c) \in k} g_{r,c}
\]

(13)

\(a\) is a regional area, and the average value of gray level
is a measure of the similarity between objects within a class.
Reference region in gray value of the average values were
measured to determine the changes of similarity between
objects in two different reference areas calculated average
gray value between the measurement of N objects of similar
changes, and thus to determine the calculation of every time
the distance reduced in the direction of objective function.
Average gray value is a statistical feature. The other is a
gray histogram difference

\[
s^2 = \frac{1}{a-1} \sum_{(r,c) \in k} (g_{r,c} - \bar{g})^2
\]

and standard deviation

\[
s = \sqrt{s^2}.
\]

In a reference area measured average value and standard
development can be used to establish a linear gray-scale
transformation. The transformation can be changed in
compensation within class similarity. Standard deviation can
be used to adjust the segmentation threshold. Region matrix
is extended based on gray value features. \(p \geq 0, q \geq 0, (p, q)\)
order matrix is defined as gray value. As in (14):

\[
m_{p,q} = \sum_{(r,c) \in k} g_{r,c} r^p c^q
\]

(14)

Similar to the regional matrix, the matrix \(a = m_{0,0}\) can
be regarded as the area of the gray value of the area. It is the
gray value function \(g_{r,c}\) in the region of the "volume".
Similarly, the matrix is similar to the region, and the
normalized matrix is defined as in (15):

\[
n_{p,q} = \frac{1}{a} m_{p,q} r^p c^q
\]

(15)

Matrix \(n_{1,0}, n_{0,1}\) is defined as the regional the center
of gravity of the gray value [8]. According to this center of
gravity, the center gray value matrix is defined as in (16):

\[
\mu_{p,q} = \frac{1}{a} \sum_{(r,c) \in k} (r - n_{1,0}) (c - n_{0,1})
\]

(16)

C. Image matching algorithm based on region gray value

Based on regional gray scale image matching is to make
image segmentation which should divided into many image
blocks or change the size of the scale of the image and
determine the corresponding area. This concept is achieved
by template matching [9]. The position and orientation of the
target object can be assumed as a translation description.
The template has an image \(t(r,c)\) as well as the
character region of interest \(T\) specified. In order to
carry out the template matching, the template moves along
all the points in the image and the similarity of each location
is calculated. Therefore, similarity measures is a function,
the parameters in the function include the gray value \(t(r,c)\)
of the point in the template and the gray value
\(f(r + u,c + v)\) of the region of interest. When the template
region of interest is moved to the current position of the
image, a scalar value is calculated as the similarity measure.
Using this method, each point in the transformation space is
a similar measure and this result can be seen as an image. As
in (17):

\[
s(r,c) = s(t(u,v), f(r + u,c + v); (u,v) \in T)
\]

(17)

In order to make this abstract equation concrete, several
useful similarity measures based on gray value is discussed
as well.

The simplest similarity measure is the sum of the
absolute value of the difference between the template and
the image (SAD and SSD). As in (18) (19):

\[
sad(r,c) = \frac{1}{n} \sum_{(u,v) \in k} |t(u,v) - f(r + u,c + v)|
\]

(18)

\[
ssd(r,c) = \frac{1}{n} \sum_{(u,v) \in k} (t(u,v) - f(r + u,c + v))^2
\]

(19)

In these two equations, the n is the number of regions of
interest in the template, namely \(n = |T|\).

D. Normalization processing by NCC

It is a great impact on machine vision because of the
intensity of the light on the related work. The stability of
light is not easy to be controlled, so the results of SAD, SSD
similarity measure must be normalized, only by this way can
make the similarity measure ignorance the change of any
linear illumination.

Next context, the normalized cross correlation coefficient
NCC is used, which is able to achieve such
requirements of a similarity measure. As in (20):

\[
ncc(r,c) = \frac{1}{n} \sum_{(u,v) \in k} \frac{t(u,v) - \bar{m}}{\sqrt{\bar{s}^2}} \cdot \frac{f(r + u,c + v) - \bar{m}}{\sqrt{\bar{s}^2}}
\]

(20)
In the formula, the average gray value of the K value clustering selected by \( m_f(r,c) = \frac{1}{n_{(u,v)}} \sum_{(u,v)} f(r+u,c+v) \) (21)

\( s_f^2(r,c) = \frac{1}{n_{(u,v)}} \sum_{(u,v)} (f(r+u,c+v)-m_f(r,c))^2 \) (22)

The normalized cross correlation coefficient has a very intuitive explanation. What needs to be noted is \(-1 \leq \text{ncc}(r,c) \leq 1\). If the \( \text{ncc}(r,c) = \pm 1 \), image is a linear proportional version of clustering, as in (23):

\[ \text{ncc}(r,c) = \pm 1 \Leftrightarrow f(r+u,c+v) = at(u,v) + b \] (23)

If the \( \text{ncc}(r,c) = 1 \), then \( a > 0 \), that is to say, clustering and image have the same polarity; if the \( \text{ncc}(r,c) = -1 \), then \( a < 0 \), that is to say, clustering and image have reverse polarity, as a result, the linear illumination change don't change the result. Only in the \( \text{ncc}(r,c) = \pm 1 \), clustering and image can complete the match. So the greater the absolute value of the normalized cross-correlation coefficient, the more close to zero between the cluster and the part of the image that is being detected.

Because the average gray value \( m_f \) and the standard variance of the cluster \( s_f^2 \) are unchanged after each shift of the cluster, the two values need to be calculated only once. Secondly, the only optimization with SAD similarity needs to be performed, so as to adjust the threshold value \( t_s \).

IV. SOFTWARE DESIGN

A. Select and set the template

When the image acquisition is completed, the image of a series of LED chips can be clearly seen in the interface [10]. At this point, to choose the qualified chips, using the mouse to select the box, so a standard template is obtained. In fact, the template selection is to set a sense of region of interest, and template learning is a sense of region of interest extraction process that based on regional gray value feature extraction algorithm, in order to get two electrodes on the LED chip gray value and its distribution, fig.5 is the flow chart of template setup.

B. Software implementation process in LED chip tester

The extraction of template image details aims to access to the image matching the template. For the detection equipment, the most important problem is how to achieve high accuracy and high speed. Before editing the recognition of the template, template scale and ration range needs to be determined, because these two parameters directly affect the size of the recognition of the speed and the integrity of the information. In this system, the scale range is, 0.9f ~ 1.1f, as ration is \( \pm 10^\circ \). These two parameters also can be adjusted according to the actual situation, fig.6 is the flow chart of recognition.

![Flow chart of template setup](image)

![Flow chart of recognition](image)
C. Results

The recognition results can be obtained through processing by the system, as shown in Fig. 7.

![Recognition results after normalized processing](image1)

The photograph of LED chip tester under the microscope was shown in Fig. 8.

![Photograph of LED chip test under the microscope](image2)

V. CONCLUSIONS

In this paper, making research and analysis on the LED production of the testing equipment of the machine vision system, using a template matching algorithm to the recognize LED chip’s image, detection and recognition accuracy of 98.5%, can meet the detection equipment for visual recognition accuracy and speed requirements. In particular, effective algorithms are the key to achieve the basic requirements of production in the recognition of the chip search. In the design of the sub-pixel precision threshold segmentation of the LED chip’s image recognition method. The experimental results show that the chip recognition and localization of the realization of the method can effectively and reach 98.5% recognition accuracy. If higher accuracy is needed, more time is required.

LED chip tester software system also need to further improve the accuracy of the vision system, speed and motion control system, chip size, more rapid, more accurate recognition and positioning of the meet the basic requirements of industrial production. If used in industrial production, it will have an important impact on the production and development of LED tester production.

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