Weld Seam Tracking System Based on Vision Sensing
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Abstract. The seam tracking system is designed for welds with very small gaps. This system is based on vision sensing technology. This system uses LED lamp as auxiliary light source, CCD camera as image acquisition unit and industrial computer as system control core. This system can extract the weld location information through a variety of image processing algorithms. After calculating the position deviation between the weld seam and torch, the system can control the actuator to look for the center of the weld. So the goal of weld seam tracking can be achieved.

Introduction

In the automatic welding process, in order to reduce the welding position deviation caused by mechanical manufacturing and installation, fixture precision, Type of weld groove, workpiece machining accuracy, workpiece surface condition and workpiece thermal deformation[1], the seam tracking technology becomes a very important research topic. At present, the domestic and foreign scholars mainly study the seam tracking system based on laser vision. But this kind of system is only applicable to track the weld seam with groove. It is difficult to detect and identify the weld seam without groove[2].

The aim of this paper is to realize the tracking of the butt weld and make up the shortcomings of the weld seam tracking system based on laser visual sensor. The weld seam tracking system in this paper consists of four parts: vision sensing unit, information processing unit, actuator unit, and expansion I/O unit. In the welding process, the visual sensor unit accurately detect and obtain the location information of the weld seam, and then pass it to the information processing unit. After the information extraction is completed, information processing unit will send signal to actuator unit to complete the welding.

The Working Principle of the System

The working principle of seam tracking system is shown as Figure 1. Before the tracking starts, Place the workpiece on the clamping platform and compress it. Then Lift cylinder will drive welding torch down. After the welding starts, the walking motor drives the corrective mechanism (including CCD camera and welding torch) to move along the weld direction. At the same time, CCD camera captures
the weld image and passes it to the computer via the GigE data interface. As the camera in front of the torch, the acquired image is pre-welding image. In order to achieve "real-time seam tracking", it is necessary to call a delay program to deal with the image. Through a series of complex image processing algorithms, the computer will send the acquired weld position information to the stepper motor driver via RS485 communication mode. And then, the stepper motor driver will drive the tracking motor to control welding torch for real-time correction.

**Image Processing**

Scratches, oil and oxide films on the surface of the workpiece and the arc, splash, dust and so on generated during the welding process will interfere with the original images collected, it is difficult to extract the weld characteristic values directly. In order to obtain the weld position information accurately, a variety of image processing algorithms are used to filter noise. The image processing is shown in Figure 2.

![Image Processing Diagram](image)

The image processing algorithms in this paper is based on openCV. It requires that the image must be a single channel image before binarization. But the format of the image acquired by CCD camera is RGBA, and its channel number is 4. So the original image must be converted to a single channel image before binarization. The image processing result is shown in Figure 3(b).

Binarization is the most usual method to isolate the object from the images with complex background and noise. And the results of binarization is depend on the threshold\(^{[3]}\). Usually the pixel value below the threshold is set to 0, otherwise set to 255. In order to make the image more clear, this paper uses the iterative method to binarize the image. The algorithm is as follows:

1. Traverse the pixels, find the minimum gray value and the maximum gray value of the image, and record them as \(F_{\text{min}}\) and \(F_{\text{max}}\). So the initial threshold value \(T_1\) is:

\[
T_1 = \frac{F_{\text{min}} + F_{\text{max}}}{2}
\]  

(1)

2. According to \(T_1\), the image is divided into two parts: the targets and the backgrounds. Then calculate the average value \(F_1\) and \(F_2\) of these two parts:

\[
F_1 = \frac{\sum_{(i, j) \leq T_1} F(i, j) \times N(i, j)}{\sum_{F(i, j) < T_1} N(i, j)}
\]

(2)

\[
F_2 = \frac{\sum_{(i, j) > T_1} F(i, j) \times N(i, j)}{\sum_{F(i, j) > T_1} N(i, j)}
\]

(3)

Where \(F(i, j)\) represents the gray value, \(i\) and \(j\) represent the space coordinate(position). \(N(i, j)\) represent the weight coefficient of \((i, j)\).

3. Use the following formula to find the new threshold:

\[
T_2 = \frac{T_1 + T_2}{2}
\]

(4)

As shown in Figure 3(c) there are still a lot of noises in the non-welded boundary of the image after binarization. These are caused by complex welding environment and insufficient lighting conditions. It is necessary to use adding window processing to eliminate this part of the noise. The image processing result is shown in Figure 3(d).

The effect of Hough transformation is to extract the geometric figure with some same characteristics from the image with many noises. In this paper, the weld center line is detected by Hough transformation. The formula is as follows:
\[ x \cos(\theta) + y \sin(\theta) = r \]  \hspace{1cm} (5)

Where \( \theta \) is the angle between \( r \) and the x-axis, and \( r \) is the vertical distance from the coordinate origin to the straight line. The coordinate \( P(x, y) \) of each pixel in the image is known. A point on the image x-y plane corresponds to a curve on the parameter r-\( \theta \) plane. M points on the image plane are M curves on the r-\( \theta \) plane, and these curves produce a large number of intersections. Suppose there are \( n \) curves intersect at each intersection. Find the maximum value of \( n_{\text{max}} \). The intersection produced by these \( n_{\text{max}} \) curves corresponds to the weld center line on the image plane. The processing result is shown in Figure 3(e).

The basic principle of the least squares method is to find an appropriate function by minimizing the error so that the function can fit a set of points as accurately as possible. That is, as long as the value of \( \delta \) is minimized, a fitting curve which is very close to the weld center line is acquired.

\[ \delta = \sum_{i=1}^{n} [\varphi(x_i) - y_i]^2 \]  \hspace{1cm} (6)

Where \( \varphi(x_i) \) represents the values of fitting curve, \( y_i \) represents the Measured value, \( \delta \) represents sum of square. processing result is shown in Figure 3(f).

![Processing Results](image.png)

Figure 3. Results of image processing.

**Control of the Actuator**

Actuator unit mainly consists of walking motor and tracking motor. The walking motor controls the welding torch to move in the direction parallel to the weld. The tracking motor controls the torch to move in the direction perpendicular to the weld. The tracking processes of the walking motor and the tracking motor are shown in Figure 4.
Weld Tracking Experiment

In the experiment, MIG welding was used to weld carbon steel and aluminum plate. The thickness of carbon steel is 3mm. Welding process parameters are shown in Table 1.

Table 1. Welding process parameters.

<table>
<thead>
<tr>
<th>Base metal</th>
<th>carbon steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint form</td>
<td>Butt joint</td>
</tr>
<tr>
<td>Groove form</td>
<td>No groove</td>
</tr>
<tr>
<td>Weld gap(mm)</td>
<td>1.5</td>
</tr>
<tr>
<td>Wire diameter(mm)</td>
<td>1.2</td>
</tr>
<tr>
<td>Welding current(A)</td>
<td>150</td>
</tr>
<tr>
<td>Welding voltage(V)</td>
<td>20</td>
</tr>
<tr>
<td>flow of protect gas (L/min)</td>
<td>15(Ar)</td>
</tr>
</tbody>
</table>

The results of weld tracking experiment are shown as Figure 5. The experimental results show that the proposed weld tracking system has the ability to produce a uniform weld, and the weld quality is easy to accept, as shown in Figure 5(a). The tracking error of all experiments was kept within 0.3mm, as shown in Figure 5(b).
Conclusion

In terms of the system structure, the seam tracking system consists of two sets of seam tracking devices. Two torches can start welding at the seam time. Thus the production efficiency can be improved.

Aiming at the situation that the weld without groove, a set of effective image processing algorithm is proposed, which makes up the defect of laser tracking in this aspect. The experimental results show that the tracking error of this system is less than 0.3mm, which meets the actual production needs.

References

