DEVELOPMENT OF LASER VISION SENSOR WITH MULTI-LINE FOR HIGH SPEED LAP JOINT WELDING

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ABSTRACT

Generally, the laser vision sensor makes it possible design a highly reliable and precise range sensor at a low cost. When the laser vision sensor is applied to lap joint welding, however, there are many limitations. Therefore, a specially-designed hardware system has to be used. However, if the multi-lines are used instead of a single line, multi-range data can be generated from one image. Even under a set condition of 30fps, the generated 2D range data increases depending on the number of lines used. In this study, a laser vision sensor with a multi-line pattern is developed with conventional CCD camera to carry out high speed seam tracking in lap joint welding.

Keyword

Laser vision sensor, image processing, high speed welding, lap joint, range data

1. Introduction

A laser vision sensor uses a monowavelength light to project a pattern onto the object. Then, the pattern is obtained from the object using a vision sensor. The image obtained through this method is analyzed to determine the range data. Since the laser vision sensor is one of the non-contact sensors, it can be used in various applications.[10]

The laser vision sensor, which uses a laser pattern as a light source to obtain the range data, generally uses a line pattern. Smati et al.[1], Clocksin et al.[2] and Agapakis[3] suggested the use of a typical laser vision sensor recognize the welding point from the range data of the base metal. Later, Suga and Ishii [4] applied the laser vision sensor to automatic welding inspection and welding process control, while Kugai et al.[5] applied the sensor to control welding machine.

However, it is impossible to satisfy the ever growing demand for faster and more accurate seam tracking with the previous vision sensor. Even if the image processing time could be reduced by developing the software, the CCD posed a limitation in terms of hardware. It was impossible to obtain capturing speed of over 30fps without using a special CCD. Therefore, many researches were performed to overcome the problems. Rotating laser pointer system was used to scan the area in Oxford Sensor Technology Ltd. However, this sensor is hard to apply to measure various joint types because the laser circle size has a limitation. Owing to using scan type laser, the sensor must have complex mechanical parts.

However, when using multi-lines in the laser pattern, it is possible to obtain multiple range data from a single image, and a prism can be used to obtain a pattern with a conventional device. Therefore, even when using a CCD of 30fps, the number of 2D range data obtained increases proportionally to the number of lines. By using this method, it is possible to obtain sampling results of over 30fps while using a typical CCD.

In this study, a laser vision sensor using a multi-line pattern consisting of five parallel lines is developed. Through this method, it is possible to obtain multiple 2D range data with a single measurement, with which a 3D shape is obtained. In order to classify each of the multiple lines within a single image, the pattern matching method was implemented on the intensity of the image obtained from image processing. After the lines were classified, they were processed and the required 3D data were extracted. The entire system was modeled and a simulation system was formulated to optimize each algorithm and evaluated its performance. The sensor was then applied to the actual weld seam tracking process.

2. Principle of Multi-lines Laser Vision Sensor (MLVS)

The laser vision sensor basically obtains range data through optical trigonometry. Because the optical trigonometry is used, the laser plane must form a consistent angle with the base plane of the CCD, which is used as the index point. In the case of MLVS, the distance between the starting point and sensing position differs in each laser plane when the CCD is positioned perpendicular to the surface and the angle of the laser is adjusted. Here, a disparity can be observed in the intensity of the laser lines, causing uneven thickness in the laser line produced by each laser plane. The uneven thickness of the laser lines causes the precision of the sensor to decrease and makes it more difficult to process the image. Therefore, MLVS must have the perpendicular laser plane and the tilted CCD. Even when the laser plane is perpendicular to the measuring object surface, each laser line has a different angle and different distance from the CCD, excluding the center laser line. Therefore, each laser plane must be classified and calibrated when carrying out the actual measurement process.

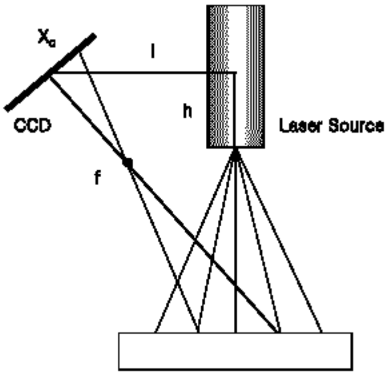

Fig. 1 Conceptual structure of MLVS

3. Image processing and 3D modeling

In order to obtain the desired range data from the image, the laser vision sensor must obtain the range data through pre-image processing, laser line recognition and feature point extraction. The range data obtained through this method is used to recognize the object. This process may be altered by where the laser vision sensor is applied.

For example, image processing and object recognition are dependent on the application such as weld seam tracking or bead shape inspection. In this study, image processing and 3D modeling was designed for the weld seam tracking in lap joint.[6][7]

3.1 Pre-image processing

As welding process produces undesirable spatter and arc unstability, captured images are not clear. The prism which produces the multiple laser plane does not only produce desired planes, but creates an unlimited number of planes in consistent intervals. Therefore, multiple laser lines can always be observed in the image, along with the effects of double reflection. An advanced median filter is used to reduce or eliminate such noise. The special mask is used to increase the laser intensity while to reduce the noise. The filtering algorithms are expressed as in equations (1), (2). (3).

$$I_{new}(X,Y)=\frac{\sum_{j=Y-m}^{Y+m}\sum_{i=X-n}^{X+n} I_{raw}(i,j)}{(2n+1)(2m+1)} \quad (X=n,\cdots,(640-n),\ Y=m,\cdots,(480-m)) \tag{1}$$

$$I'_{new}(X,Y)=\begin{cases} I_{new}(i,j) : if \prod_{j=Y-a}^{Y+a}\prod_{i=X-a}^{X+a} I_{new}(i,j)>0 \\ 0 \qquad : otherwise \end{cases} \quad (X=n,\cdots,(640-n),\ Y=m,\cdots,(480-m)) \tag{2}$$

$$I''_{new}(X,Y)=\begin{cases} \dfrac{\sum_{j=Y-a}^{Y+a}\sum_{i=X-a}^{X+a} I'_{new}(i,j)}{(2a+1)^2} : if \sum_{j=Y-a}^{Y+a}\sum_{i=X-a}^{X+a} I'_{new}(i,j)>0 \\ 0 \qquad : otherwise \end{cases} \quad (X=n,\cdots,(640-n),\ Y=m,\cdots,(480-m)) \tag{3}$$

where, $I_{new}(X,Y)$ is the new image produced after image processing and $I_{raw}(X,Y)$ is the image before processing. (2n+1) is the number of pixels in the mask to the direction of the x axis, while (2m+1) is the number of pixels in the mask to the direction of the y axis.

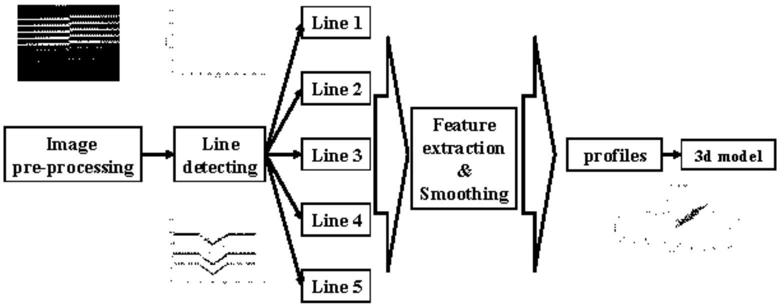

Fig. 2 Flow char of image processing

3.2 Classification of lines

From the obtained image, five laser lines are extracted and classified. To do this, the advanced threshold method is used to increase the contrast of the light intensity.

Equation (4) is used to carry out the advanced threshold process on each Y value.

$$II_{new}(X,Y)=\begin{cases}0 & if\ II_{raw}(i,Y)<th-value,\ (i=0,\cdots,640)\\ II_{raw}(i,Y)\ otherwise & \end{cases} \tag{4}$$

where,

$$th-value=\max\left[\frac{\sum_{k=i-n}^{i+n} II(k,Y)}{n}\times 0.7\right],\ (k=n,\cdots,(640-n)) \tag{5}$$

where, $II_{new}(X,Y)$ is the new image generated after image processing, and $II_{raw}(X,Y)$ is the image before processing. Also, n is the number of pixels in the mask to the direction of the y axis. In order to classify each laser line from the processed through the above method, the laser lines are divided by perpendicular lines, forming regions. The pattern generated by the intensity of the laser lines in each region is observed.

It was observed that the intensity of the laser line in each region formed a pattern in the shape of a mountain peak with regular intervals. This process is applied to the entire area to classify each of the five laser lines. MLVS makes it possible to obtain five range data from a single image. The range data is used to design a 3D model. The method employed in 3D modeling differs according to the object. When performing weld seam tracking on a lap joint, the 3D model can be expressed through two planes and one curve.

4. Weld seam tracking simulation

Before designing the actual system, a simulation system was established to verify the feasibility of applying MLVS to real high-speed welding. In order to simulate the weld seam tracking system, a model of the real process is needed. To design the model, the weld seam tracking system was divided into a specific part and conceptual part.[8][9]

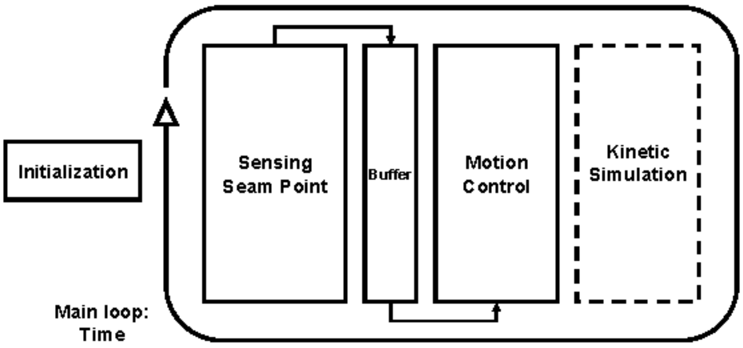

Fig. 3 Simulation flow diagram

The specific part includes the base metal, laser vision sensor and robot model which comprise the seam tracking system. The conceptual processes include the seam extracting process which is a model of the laser vision sensor extracting the tracking point from the base metal model, the seam tracking algorithm which determines how the weld seam is to be tracked using the data obtained from the laser vision sensor, and a model of the process in which the robot is controlled by receiving orders from the tracking algorithm model.

The results of seam tracking carried out by a high-speed weld seam tracking system which welds seams as shown in Fig. 2 are shown in Table 1.

Table 1 Weld seam tracking error according to the number of laser lines

Welding speed	10mm/sec(0.6MPM)		25mm/sec(1.5MPM)		40mm/sec(2.4MPM)	
Error	Mean	Max.	Mean	Max.	Mean	Max.
Single line	0.068mm	0.082mm	0.284mm	impossible	0.509mm	impossible
Multi-line(5lines)	<0.01mm	0.01mm	<0.01mm	0.01mm	<0.01mm	0.011mm

Through the simulation, it was verified that, it is possible to track the weld seam using the multiple laser lines even in high-speed welding, where seam tracking was not possible using the previous laser vision sensor with a typical CCD.

5. Experiment

An experimental MLVS system was formulated to carry out weld seam tracking at 10MPM in GMAW thin plate welding. The results of the experiment showed that the seam was successfully tracked even in the areas where the weld seam was distorted due to defects in the manufacturing process of the thin plate, as well as areas where tack welding had been carried out. Welding was also successfully carried out by tracking the seam even when the thin plate was severely distorted.

Fig. 4 Welding result of deactivated tracking system

Fig. 5 Welding result of activated tracking system

6. Conclusion

In this study, a vision sensor with multiple laser lines was developed to overcome the limitations of conventional laser vision sensors. Through simulation, it was verified that MLVS was more suitable in processes which required higher levels of speed and precision. Also, an image processing algorithm and 3D measuring method was developed for application to the MLVS. The MLVS was tested in real weld tracking procedures, and it was proven that the MLVS resulted in lower error and hence applied to a precise high speed welding system.

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