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Seam Tracking of Intelligent Arc Welding Robot

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Abstract: Intelligent welding robots obtain a good quality of the welding results. Research on automatic and intelligent control of Arc welding is an important means for ensuring weld quality, raising productivity, and improving labor conditions. Despite its widespread use in the various manufacturing industries, the full automation of the robotic welding has not yet been achieved partly because mathematical models for the process parameters for a given welding tasks are not fully understood and quantified. The first problem that should be solved for the automation of welding processes is weld-seam tracking. In this research, an attempt has been made to recognize path of weld groove by vision.

Key words: Arc welding robot, Seam tracking, Vision, Image processing.

1 Introduction

Robotic Gas Metal Arc Welding (GMAW) is a manufacturing process that is used to produce high quality joints and has a capability to be utilized in automation systems to enhance productivity. Sometimes welding process called metal active gas (MAG) or metal inert gas (MIG) welding, is a welding process that yields coalescence of metals by heating with a welding Arc between the continuous filler metal electrode and the work piece. The continuous wire electrode is drawn from a reel by an automatic wire feeder and then fed through the contact tip inside the welding torch. The filler wire of welding is melted mainly by heat generated from the welding Arc. The heat is concentrated by the welding Arc from end of melting electrode to molten weld pool and by the molten metal that is being transferred to the weld pool. The molten weld pool and the electrode wire are protected from contaminants in the atmosphere by the externally supplied shielding gas such as Ar, Co_2, or mixtures Ar with O_2, He, or Co_2 in various combinations.

2 Intelligent Arc welding robot equipments

Intelligent Arc welding robot system is constructed with welding robot, robot controller, robot programming pendant, low pass filter, A/D converter, personal computer, ProfiBus module, ProfiBus cable, CCD camera, welding power source, welding wire feeder, welding torch, supplying shielding gas, gas regulator, gas cylinder, work piece, power switch, terminal to welding torch (+), terminal to work piece (-), metal consent to welding wire feeder, consent to gas heater, welding cable, control cable, gas hose, lead wire of gas heater, secondary cable to work piece, primary cable, nozzle cleaner, cooling water system [1].

3 Categories of seam tracking systems

The key problem in promoting intelligent control of welding robots is the automatic seam tracking. There are two categories of seam tracking systems:

1. A non-vision type of automatic seam tracking: the sensor for this category is based on the principle of sound, magnetism, capacitance, etc. An Arc sensor is one of the most promising sensors for seam tracking [2].
2. A vision type of automatic seam tracking: the most popular vision sensor is a scanning laser or other structured light. A camera takes an image and the groove centerline is obtained from the image by data processing [2-3].

4 Problems in Arc welding

1. The welding process introduces distortion.
2. Process parameters will be obtained according to the environment and the work piece.
3. If there is Arc blow or cast in the welding wire, the Arc will not coincident with centerline of the torch.

All of these constraints can be overcome only by using an image processing system.

5 Recognition path using an image

The recognition of a weld groove or detection of a groove edge is the basic problem for weld path detection because there are some problems in an actual welding environment, for instance: the noise is received by camera from different sources. Comparing various interferences sources such as rust, stain, scrapes and oxide films using an image, the groove edge is smooth and continuous while the other interference sources are curved edges with discontinuities. Also, in a local small window, the groove edge can be considered as a straight line. For a conventional V-groove, the image pattern is shown in Fig.1.

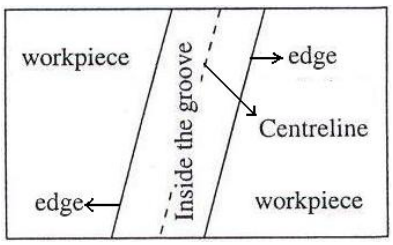

Fig. 1 – Recognition pattern of a weld groove in an image

Images are important sources of information for analysis. In order for computers to process images, the images must be numerically represented. This process is known as image digitization [3]. Once images are represented digitally, computers can reliably automate the extraction of useful information through the use of digital image processing. Digital image processing performs various types of image enhancements, distortion corrections, and measurements. In this research, the recognition of a weld groove is presented. The image processing consisted of the following steps:

1. Grab an image. In order to save time, an image of 100*100 pixels, which includes the groove edge, is taken for processing from whole 512*512 image, which is shown in Fig.2.

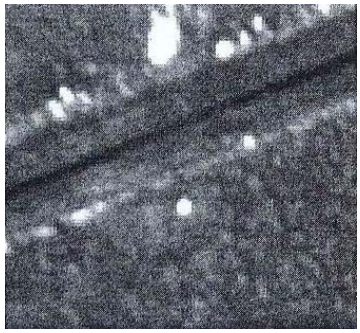

Fig. 2 – Actual image of weld groove

2. Smooth the image to remove noise produced during the grab. Various interferences are eliminated first by smoothing, which is shown in Fig.3.

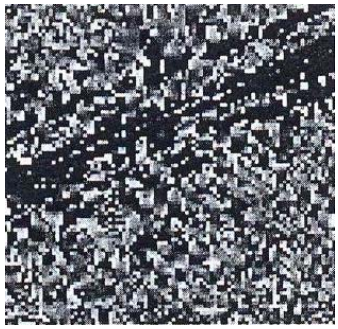

Fig. 3 – Smooth image of weld groove

3. Generate histogram. A histogram is the intensity distribution of pixel values in an image and is generated by counting the number of times each pixel intensity occurs.

This information is useful to select a threshold level when binarizing an image, which is shown in Fig.4.

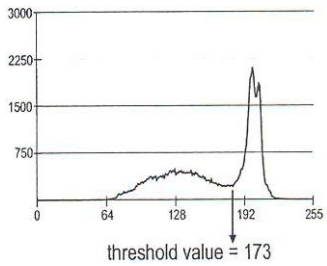

Fig. 4 – Histogram of weld groove image

4. Determining threshold value from histogram. Threshold value is set to the minimum value between the two most statistically important peaks in the histogram; these peaks represent the object and the background. If the histogram contains only two peaks, the threshold value will be set to the minimum value between these peaks. If the histogram contains more than two peaks, then the threshold value will typically be set between the two principle peaks. The pixels, which have the gradient $G < TH_1$ were omitted, which is shown in Fig.4.

5. Binarize the image so that the particles and the background have different values, represent particles in white and background in block. This will allow you, later, to label each particle with a unique number, which is shown in Fig.5.

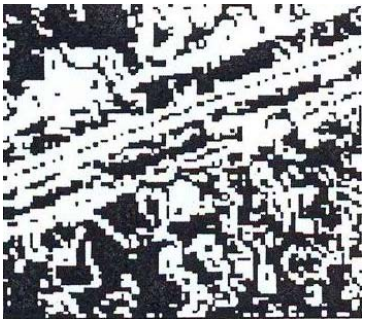

Fig. 5 – Image after sieving by threshold filtering

6. Perform an operating operation to remove small particles from the image, which is shown in Fig.6.

Fig. 6 – Image after removing small particles

7. Label each particle with a unique consecutive number starting with the label 1.

8. Calculate and read the extreme value of image. This value also corresponds to the largest label. Since the image particle is also labeled with a number that corresponds to the number of particles in the image.

9. Determination of groove-edge location. The laplacian operations place emphasis on the maximum values, or peaks, within the image. This is why, once this operation has been performed, the edge representation of image generally looks very similar to actual image, which is shown in Fig.7.

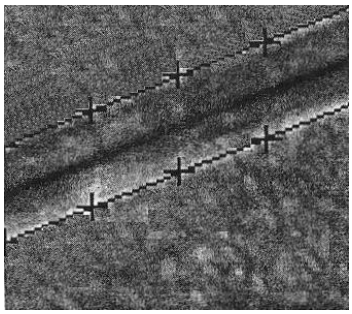

Fig. 7 – Determination of groove-edge location

The algorithm described above recognizes the weld-groove image taken under mild environmental conditions. A CCD camera was located 400 mm above the groove, which was a V-groove, butt joint, lap joint, corner joint, edge joint or T joint, which is shown in Fig.8. If the error in recognizing the edge point was within 2 pixels of the real edge, it was considered to be a correct recognition. If the location error from the real edge was 3-4 pixels, the result was considered unreliable.

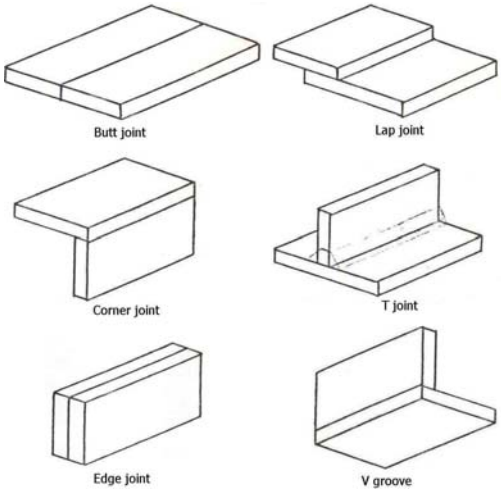

Fig. 8 – Types of weld-joint

6 Arc welding robot structure

In this research, the Arc-welding robot has 6 degree of freedom that is used in automotive industry. The robot model is Hyundai HR006 [4-8]. The robot consisted of two parts: arms and a wrist. The main component of robot system is a system controller, which includes a microcomputer and some interface units for the peripherals. The operator console is equipped with a CRT and a keyboard. Via this unit the operator can edit the programs and can monitor the operation status of the robot. A teaching pendant is the other robot communication devices attached to the system controller. It is possible for these tuned parameters to be reflected in the programmed welding parameters automatically. The repeatability of this robot is ± 0.1 mm and the weight that could be grasped was 6 kg, which is shown in Fig.9 [4].

Fig. 9 – Arc welding robot structure

7 Robot programming

Welding Intelligent Language provides the user with a simple programming system with various sophisticated welding functions. It contains many macroinstructions and an editing function that combines the teaching programs and the numerical control of the traversing function and produces the work piece programs, which is shown in Fig.10 [8].

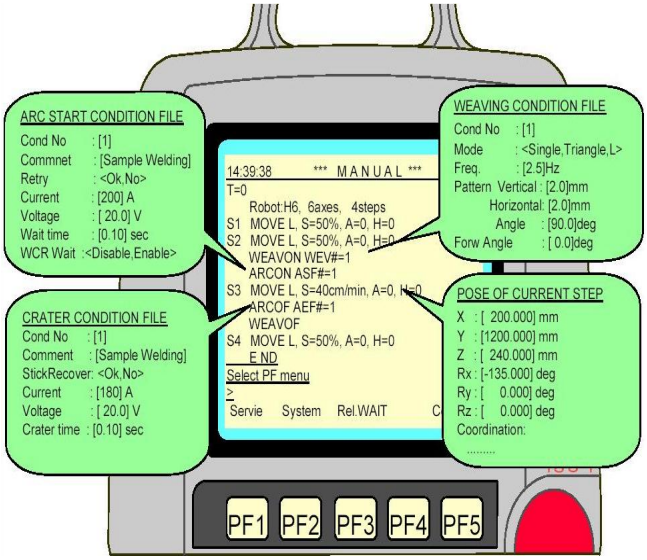

Fig. 10 – Robot programming pendant

There are fundamental instructions that are used for setting the welding parameters [8]:

1. 'S' is used for setting the travel speed of the torch.
2. 'C' welding current output value (0 ~ 500).
3. 'V' welding voltage output value (0 ~ 40).
4. 'MOVE' Move<interpolation>, S=<speed>, A=<accuracy>, H <tool number>.

4.1. Interpolation:

P: Point to point or no interpolation.
L: Straight or linear interpolation.
C: Arc or circle interpolation.
Which is shown in Fig.11.

Fig. 11 – Types of interpolation

4.2.Speed: The moving speed of the tool end (Unit: mm/sec, cm/min, cm/sec, %)

4.3.Accuracy: 0 is most accurate and accuracy 3 has the largest difference (0 ~ 3), which is shown in Fig.12.

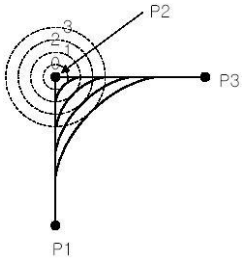

Fig. 12 – Path of P2 according to accuracy

4.4. Tool number: (0 ~ 3).

5.'WEAVON' starts the weaving motion, which is shown in Fig.13.

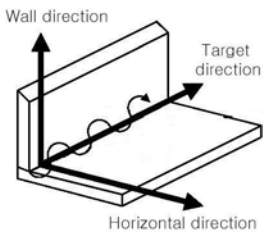

Fig. 13 – Weaving Coordinate system

6.'ARCON <File>' starts welding as set by the conditions of condition file, which is shown in Fig.14.

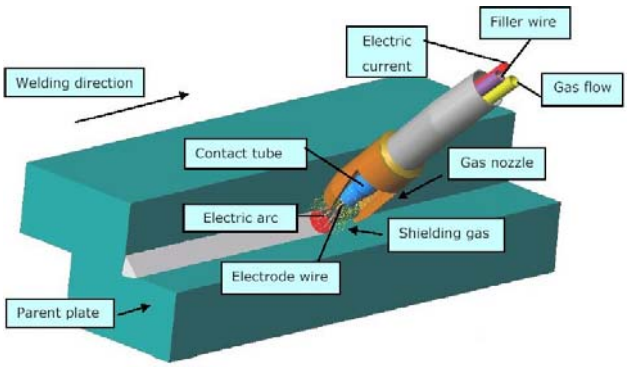

Fig. 14 – Arc welding process

7.'ASF' the number of the welding start condition file. In this file, we set the welding current value and the welding voltage value, etc.

8.'Retry' retry when the Arc generation fails.

9.'Wait time' the wait time prior to the motion start after Arc on (0 ~ 10).

10.'ARCOF <File>' welding ends as set by the conditions of condition file.

11.'AEF' the number of the welding end condition file.

12.'Crater time' the delay time of the robot body before the Arc off (0 ~ 10).

13.'WEAVOF' stops the weaving motion.

There are other fundamental instructions which control the I/Os prepared for the user devices.

8 Control system

The centerline information of weld-groove is obtained from binary image. These calculations are executed for every half cycle of the weaving motion (Frequency = 2.5 HZ). Then these values are sent to the robot controller by profibus bus cable from computer (profibus module CP5613) [9]. The positional compensation is given to the position of the welding torch and the angles are determined by the inverse kinematics transform as stated before. The Cartesian co-ordinates of all points and the angles of the joints are calculated by robot controller and commands are sent by the controller to drive servomotors in robot.

9 Improving accuracy

Weld-path error can be reduced or eliminated using the following measures:

1. The accuracy of CCD camera depends on density of pixels on the optically sensitive surface. If a CCD allowing 1024*1024 pixels were to be used instead of 512*512 pixels, the accuracy would be improved greatly.
2. The accuracy of the chosen robot can be improved.
3. The accuracy increases as area of the viewing field and distance of camera from the work piece are reduced.
4. The camera is calibrated accuracy.

10 Image-recognition program

The program consisted of two parts, namely, calibration of the camera, and recognition of the weld groove and control of the welding process.

The function of calibration is to determine the co-ordinates of robot and its relation with parameters of camera.

11 Calibration of camera

1. Clamp object in the gripper of robot.
2. Connect the robot, vision system and camera to their power sources.
3. Set the camera in an appropriate location (it is better to attach the camera to the fifth arm of robot for welding), adjust the aperture, zoom in or out from the object and set the focus length.
4. Touch 'vision program name' on the keyboard to start the calibration program.
5. Move the object using the control box to a location where it is visible to camera. Push key 'enter' so that image can be seen. The moving scope should be in the required working space. The co-ordinates are stored in the robot for calibration.
6. Touch the number on the keyboard for the desired number of observations. Number of observations is used to evaluate the accuracy of calibration.
7. Execute the program according to step 5. Pushes enter so that computer takes the images.
8. Repeat step 7 until the desired number of observations is completed.
9. Touch the number on the keyboard for the desired number of observations, which are used for calibration.

12 Conclusion

This paper has presented an algorithm that is useful for vision based Arc welding robot having 6 axes of freedom for seam tracking. Welding path image is taken every half cycle of weaving motion (Frequency = 2.5 HZ) by camera and computer calculates welding path information after image processing. Then these values are sent to the robot controller by profibus cable and robot corrects path motion by this values. Many variables are encountered during robotic Arc welding that present problems and can result in the production of an unsatisfactory weld or welds. The majority of the problems do not result from the operation of the robot, their occurrence usually results from welding process variables such as distortion, product variation, poor fixture and clamping, and, if performed manually, human-induced variables. As a result, the utilization of robots to perform the weld does not necessarily result in the production of a quality joint. What is needed is an adaptively controlled robot, the operation of which can be controlled and modified through vision inputs from the weld, to respond to changing welding conditions. This capability is called robotic Arc seam tracking systems. Robotic welding has the following advantages compared to manual welding:

1. Ability to weld in all positions.
2. Good weld appearance and quality.
3. Possibility for using real-time control when an automatic seam-tracking system is incorporated.
4. Possibility for working in extreme conditions (for example: at high-temperatures) and bad working environments (for examples: the deep sea, outer space, and radioactive areas).

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