Intelligent Methods in Engineering Sciences 2(2): 048-051, 2023

IMIENS

INTELLIGENT METHODS
IN ENGINEERING SCIENCES

https://www.imiens.org

International Open Access

June, 2023

e-ISSN 2979-9236

Research Article

https://doi.org/10.58190/imiens.2023.12

Welding Robot Design with Machine Learning Based Intelligent Vision System

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ARTICLE INFO

Article history:
Received 12 January 2023
Accepted 7 April 2023

Keywords:
Artificial intelligence
Deep learning
Machine learning
Robotic welding
Welding robot design

ABSTRACT

The use of welding technologies in the manufacturing sector plays a very important role and increases its popularity thanks to developing technologies. Welding technologies are used in almost every field where production takes place, and the speed and efficiency of welding technologies have increased in these sectors in recent years. The fact that artificial intelligence techniques are at the forefront and the efficient use of these techniques together with sensors has led to development in welding technology. Thus, welding robots emerged with the support of robots with artificial intelligence techniques, and adaptive systems that can adapt to different types of workpieces working autonomously in the manufacturing sector are shaping the sector. Despite these developments, non-autonomous systems are still used today by teaching the welding points to the robots by the operators. Along with the concept robotic system to be designed and implemented within the scope of this study, it is planned to determine the welding trajectory autonomously with artificial intelligence techniques, and to perform the welding process by following the welding trajectory by the robot.

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1. INTRODUCTION

Determining the welding trajectory autonomously and following the specified welding path are very important in reducing operator-related errors and increasing the welding quality. Studies such as monitoring and realizing the weld trajectory autonomously with welding robots, improving the weld images together with them, determining the quality of the welding externally by methods such as machine learning and deep learning take place on a very large scale in the literature [1,2]. However, when welding is desired using an autonomous system, it is inevitable to use sensors. Many types of sensors are used to determine the welding trajectory. Some of them can be counted as acoustic sensor, ultrasonic sensor, electromagnetic sensor, vision sensors [2–8]. However, the most preferred sensors in the studies examined are vision sensors.

Studies using vision sensors are divided into two. The systems in which the images are taken by the camera by reflecting the laser sensor on the materials to be welded are called active vision sensing, while the systems in which only cameras are used are called passive vision sensing systems. Du et al. [9] have established an active vision system by placing the camera and laser sensors with the plates designed on the torch in the system they developed for gas metal arc welding. In this system, a deep learning network was established for image segmentation and it was requested to quickly extract the features. Not only the trajectory was determined by the extraction of the desired region and edge detection algorithms, but also a Convolutional Neural Network (CNN)-based mesh structure was proposed to recognize different insertions such as butt weld and groove weld. In another system [10] in which the laser sensor is used, a study was carried out to find the laser strip despite the noises that appear in the image while performing the welding process. While Faster-RCNN is used to extract the part of the structure where the laser strip is located, different algorithms are used to find the midpoints of the continuing and non-continuing laser strips. Zhang et al. [11] proposed a four-step system for obtaining the trajectory for welding flat and S-shaped work-pieces. The parts were scanned with the laser sensor, and the obtained features were corrected by filtering.

The number of beams emitted by the laser sensor also varies in some studies. Multi-line laser beams can also be used depending on the application conditions. In the study, in which a three-line laser sensor was used, the ECO-tracker algorithm was used to determine the feature points [12]. Li et al. [13] focused on the localization of the laser strip in high noise environments such as arc splashes. Line

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fitting and curve fitting algorithms were used for feature extraction. Shen et al. [14] successfully tried to perform seam tracking using a robot manipulator in gas tungsten arc welding. In experimental applications, they have succeeded in welding with very low error rates. Ma et al. [15] performed the control of the welding trajectory with PID (Proporitonal-Integral-Dervative) and Fuzzy-PID in the study where optimal trajectory tracking was desired. Zou et al. [16] performed seam tracking using three line lasers and cameras in the system they created. They proposed the Generative Adversial Networks structure for noise reduction. After the noise was reduced, the heat map method followed successfully.

In this study, which is planned to be done, it is primarily planned to complete the system design and implementation. After the system is realized, the supply of workpieces in different shapes such as S-shape, Zigzag-shape will be carried out, and images of these workpieces will be taken with the high resolution camera to be placed on the system. The welding trajectory will be determined on these images by using image processing techniques and some autoencoder architectures (e.g. U-net, Att-U-net, etc.).

2. Material and Method

The welding trajectory of the system must be determined and followed, both for welding workpieces placed flat and for welding workpieces with curved surfaces. For this reason, the extraction of the welding trajectory will be performed with image processing techniques. After the application of image processing techniques, if the resulting images contain noise, adding noise removal work with machine learning-based algorithms will contribute to more efficient operation of the system. The system, which will have the capacity to move in 2D or 3D, will ensure efficient welding of parts with different profile structures. It is planned that the workpieces, whose quality is determined as a result of the tests after the welding process is completed, can be predicted with artificial intelligence.

Within the scope of this study, a concept welding robot was tried to be designed and made. For this, in the system similar to CNC (Computer Numerical Control) milling design or called cartesian robot, besides products such as aluminum profiles, stepper motors, spindles, bearings, slides, belts and motor holders, torch holders, pen holders, belt tension adjuster system equipment created by 3D printer were designed. The system has been assembled and the system has been made operational as a prototype.

Figure 1. Some hardware equipments for system

In Figure 1, the appearance of some hardware elements required for the system is given. Afterwards, all necessary equipment was completed and the assembly process was carried out. Figure 2 shows the completion of the assembly part and some work with the pen holder.

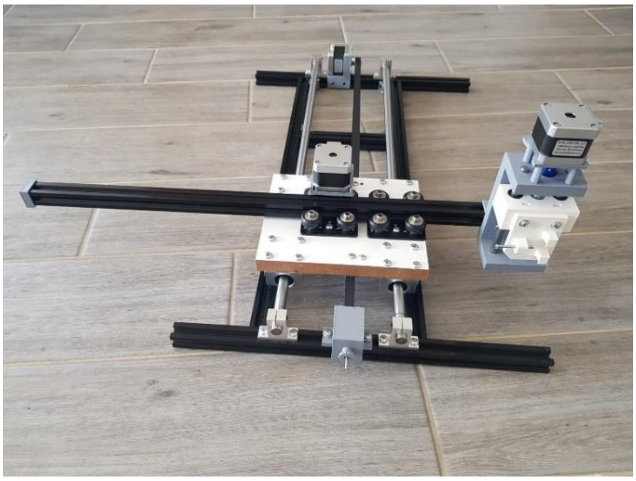

Figure 2. The view of the system after installation

Before starting the welding process, a pencil holder has been designed so that the necessary experiments can be carried out, and studies are being carried out to draw the trajectory or desired trajectory that emerges as a result of image processing. In order to hold the torch, the design has been made and the production has been carried out, but when the necessary work is completed, the pen holder will be removed and the torch holder will be mounted on the system. The designed torch holder is presented in Figure 3.

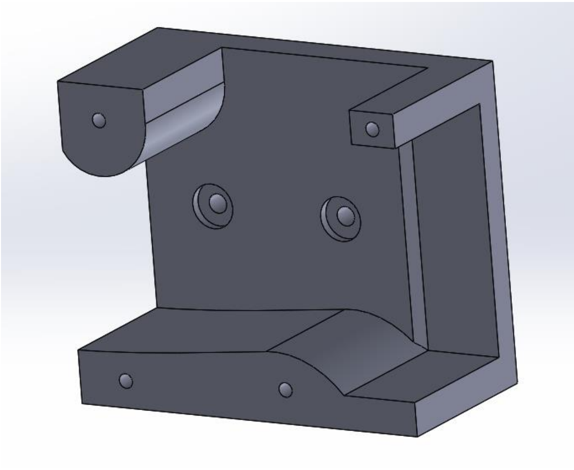

Figure 3. Designed torch holder CAM model

The system will be ready with the installation of the existing high resolution camera to the system. By adding the camera to the system, image processing techniques and machine learning algorithms will be used to detect the weld trajectory. It is planned to follow the trajectory by detecting the trajectory with the least possible error and sending the obtained coordinate to the given controller.

3. Results and Discussions

Studies carried out to determine and perform the welding trajectory autonomously and to minimize the operator effect have attracted the attention of researchers for a long time. At the same time, when the literature studies are examined, it is striking that studies have been carried out in recent years, which are similar to each other, but with minor changes. In other words, different approaches have been made for this purpose and studies continue today to find the best solution.

When the studies on tracking the welding trajectory are examined in detail, active vision systems have been proposed especially in recent years. These studies are carried out by reflecting the laser beam on the workpiece and following the points where the light is refracted. Although perfect results are not obtained in the results obtained, it is understood that sufficient results have been obtained. Similarly, satisfactory results can be achieved in passive vision systems. However, when the distance between two workpieces is narrow or workpieces with complex shapes, it may be difficult to determine the welding path.

In our study, a system that can be welded with a more affordable budget was designed and realized. With this system, it is aimed to determine and monitor the welding trajectory with artificial intelligence techniques. In addition, after the welding processes are completed, studies are carried out for studies such as determining the welding quality with deep learning algorithms.

4. Conclusions

In the studies on the determination of the points to be welded on the images, it is aimed to minimize the difference by comparing the application performed with the optimum value that should be using different algorithms. Within the scope of this study, artificial intelligence algorithms will be used for the same purpose, and if there is noise on the images, it will be emphasized that these noises are eliminated by using machine learning algorithms. At the same time, determining the welding quality after the welding process is finished will add originality to the work.

In this project work, some stages of the designs, productions and test parts on the monitoring of the welding trajectory have been completed, and the work of some stages is continuing. The original values that will emerge after the completion of the study can be listed as follows;

- Cartesian concept welding robot design and realization,
- Determining the welding path with image processing techniques and using machine learning algorithms if the images need to be improved,
- Traceability of the determined welding path with minimum error,
- Determination of welding quality with artificial intelligence techniques.
- Before starting the welding process, it is predicted that the trajectory to be obtained from the images from the system will give more robust results with machine learning algorithms compared to classical methods, and the results will be compared and presented.

Author's Note

Abstract version of this paper was presented at International Conference on Engineering Technologies (ICENTE'22), 17-19 November 2022, Konya, Turkey.

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