

# Study on robot motion control for intelligent welding processes based on the laser tracking sensor

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**Abstract.** A robot motion control method is presented for intelligent welding processes of complex spatial free-form curve seams based on the laser tracking sensor. First, calculate the tip position of the welding torch according to the velocity of the torch and the seam trajectory detected by the sensor. Then, search the optimal pose of the torch under constraints using genetic algorithms. As a result, the intersection point of the weld seam and the laser plane of the sensor is within the detectable range of the sensor. Meanwhile, the angle between the axis of the welding torch and the tangent of the weld seam meets the requirements. The feasibility of the control method is proved by simulation.

## 1. Introduction

Robot welding processes using the teaching mode is widely used in aerospace, automobile, ships and other areas. However, there exist a lot of factors, such as manufacturing error, location error and heat distortion, making the torch track deviate from the weld seam trajectory [1]. Kinds of seam tracking sensors are used to solve the problem. For examples, ultrasonic sensors, contact sensors, arc sensors and optical sensors. Among them, optical sensor [2-3] is becoming more and more popular as it has the advantages of non-contact, high precision and stability.

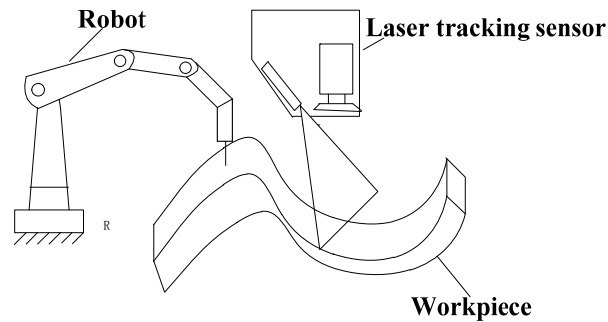
Li [4] presented a new tracking method for straight seams based on the laser sensor. The least square method is used to improve the welding accuracy. Based on that, Zou [5] obtained the three-dimensional data in real time by optimizing the image processing algorithms. As a result, the welding accuracy is improved furthermore. Ma [6] proposed a seam tracking method for sheet workpieces by measuring the offset between the welding torch and the weld seam periodically.

However, the above work above is mainly aimed at simple planar weld seams while it is much more complex for spatial curve seams. In this paper, a robot motion control method of seam tracking is presented for intelligent welding process of complex spatial curve seam based on the laser tracking sensor. Genetic algorithms [7] is used to find the best posture of the welding torch so that the welding process is under constraints.

## 2. Structure of intelligent robot welding system

The structure of intelligent robot welding system is shown in Figure 1. The robot holding the welding torch moves according to the seam trajectory detected by the laser tracing sensor.



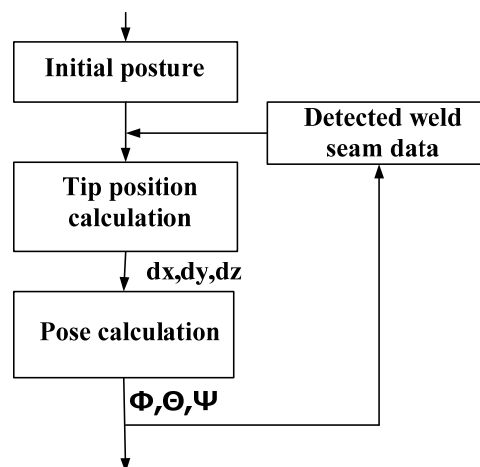


**Figure 1.** Structure of the intelligent robot welding system

The laser tracking sensor is composed of industrial CCD camera, line structured laser emitter, anti-splash baffle and optical filter. The sensor calculates the intersecting point of the laser plane and the seam using triangulation principle.

### 3. Robot motion control strategy

The key to the robot motion control is to know the posture of the welding torch at each control period time. The posture can be divided into two parts: tip position and pose. Herein we calculate the tip position of the torch firstly and then search the optimal pose under constraints. The laser tracking sensor provides the weld seam trajectory data as feed-back signals automatically. The flow diagram of the calculation of the welding torch posture is shown in Figure 2.



**Figure 2.** The flow diagram of the calculation of the welding torch posture

#### 3.1 The tip position of the welding torch

Assuming that the current position of the welding torch tip is  $P_0(x_0, y_0, z_0)$ , its position at the next moment is  $P_1(x_1, y_1, z_1)$ , the welding velocity is  $v$  and the control period time is  $t$ .  $P_1$  can be found from the seam trajectory detected by the laser tracking sensor. The distance  $s$  between  $P_0$  and  $P_1$  is:

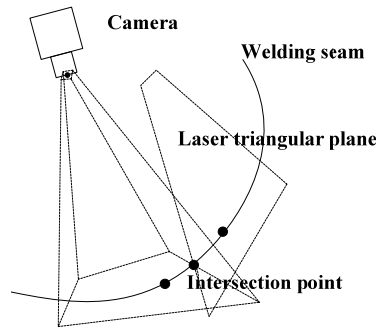
$$s = vt \quad (1)$$

Then the translation vector  $\mathbf{d}(d_x, d_y, d_z)$  of the torch tip is:

$$\begin{cases} d_x = x_1 - x_0 \\ d_y = y_1 - y_0 \\ d_z = z_1 - z_0 \end{cases} \quad (2)$$

### 3.2 The pose of the welding torch

There exist two constraints affecting the welding process. One is the detectable range constraint of the sensor, the other is the welding angle constraint. The relationship between the laser tracking sensor and the weld seam is shown in Figure 3. Optimization is carried out to find the best pose of the welding torch under the constraints.



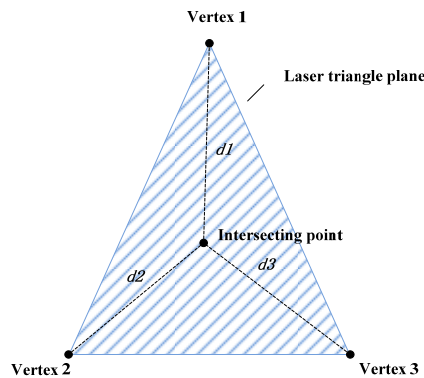
**Figure 3.** The relationship between the laser tracking sensor and the weld seam.

**3.2.1 The detectable range constraint.** In order to detect the intersecting point of the weld seam and the laser plane correctly, the point should be located in the detectable range of the sensor. The best position is the center of the laser triangle plane shown in Figure 4. Assuming that the current detected point is  $P_1$ , the previous point is  $P_0$  and the next point is  $P_2$ . The three points are considered to be collinear. That is:

$$|P_0P_1| = |P_1P_2| \quad (3)$$

The total distance  $d$  of the point to the three vertices of the triangle plane is:

$$d = \sqrt{d_1^2 + d_2^2 + d_3^2} \quad (4)$$



**Figure 4.** Illustration of the detectable range of the sensor.

**3.2.2 The welding angle constraint.** Assuming that the angle between the axis vector  $\mathbf{a}$  of the welding torch and the tangent vector  $\boldsymbol{\tau}$  at the welding point of the seam is  $\beta$ . It can be calculated as:

$$\beta = \arccos\left(\frac{\mathbf{a} \cdot \boldsymbol{\tau}}{|\mathbf{a}| |\boldsymbol{\tau}|}\right) \quad (5)$$

Usually, the angle  $\beta$  has a range constraint during the welding processes.

**3.2.3 Genetic algorithms.** Based on the two constraints above, we can find the optimal pose of the welding torch with genetic algorithms. The variable  $\mathbf{x}$  is:

$$x = (\phi, \theta, \psi) \quad (6)$$

Where  $\phi$ ,  $\theta$  and  $\psi$  are the RPY angles representing the pose of the welding torch.

The fitness function in the genetic algorithm is defined as follows:

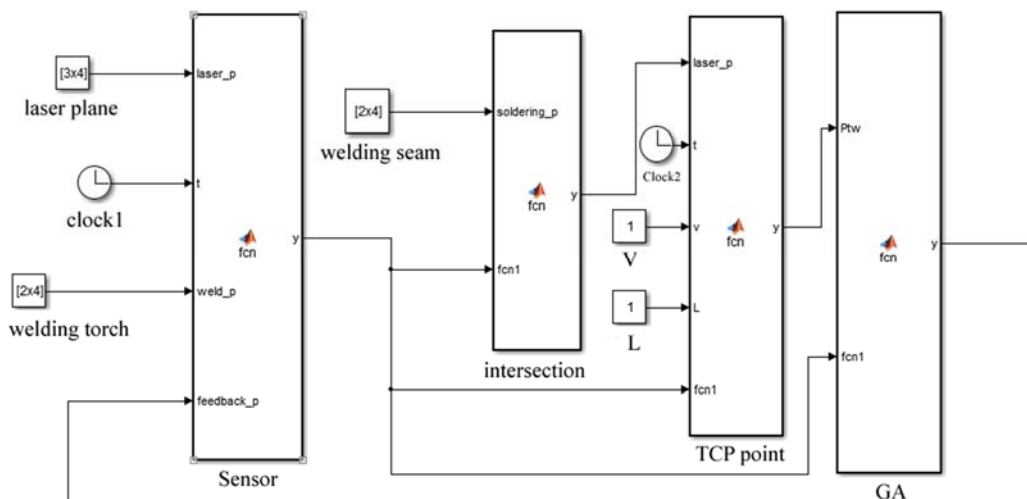
$$f(x) = \begin{cases} k_1 d + k_2 \sqrt{(\beta_1 - \beta)^2 + (\beta_2 - \beta)^2}, & \beta_1 \leq \beta \leq \beta_2 \\ +\infty, & \beta < \beta_1 \parallel \beta > \beta_2 \end{cases} \quad (7)$$

Where  $k_1, k_2$  are weight coefficients,  $[\beta_1, \beta_2]$  are the range of  $\beta$ .

Once the tip position and the pose of the welding torch are determined, the robot can be controlled step by step through inverse kinematics. This is not discussed in this paper.

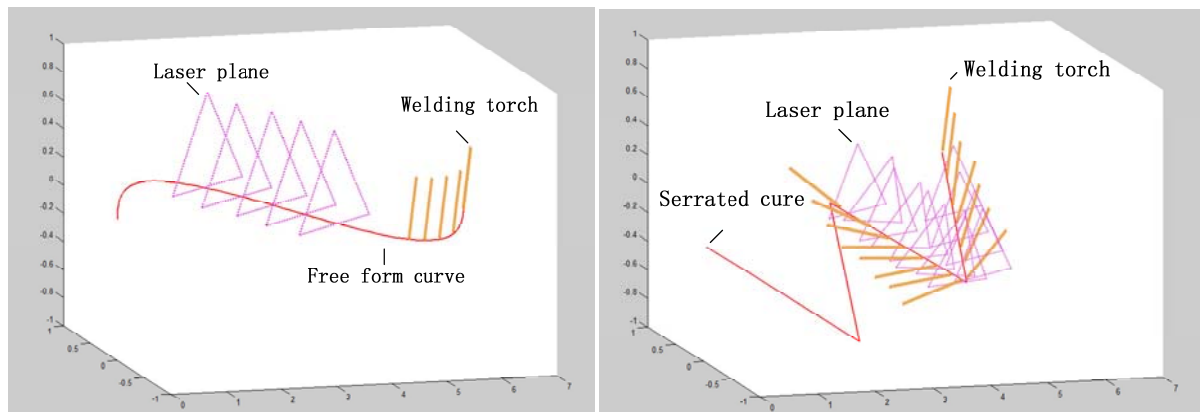
## 4. Simulation

The control strategy of the robot is simulated with Simulink. The structure diagram of the model is shown in Figure 5.



**Figure 5.** The structure diagram of the simulation model.

Two kinds of weld seams are simulated. One is a spatial free curve and the other is a serrated curve. The simulation results are shown in Figure 6.



**Figure 6.** Simulation result.

From the simulation result, we can find that the torch moves along the weld seam trajectory continuously and accurately. The result proves the feasibility of the control method.

## 5. Conclusion

A robot motion control method is presented for intelligent welding processes of complex spatial curve seams based on the laser tracking sensor. The feasibility of this method is proved by simulation. The further work will focus on improving the robustness and efficiency of the algorithms.

## Acknowledgments

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