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Intelligent Recognition of Laser Welding Deviation Based on Improved Neural Networks

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Abstract: Laser welding technology has become one of the most commonly used high-precision welding methods in the field of modern industrial manufacturing, but there are deviations in the laser welding process, such as uneven weld seams and positional shifts, etc., which will directly affect the quality and performance of the welded joints. Therefore, accurately identifying and timely correcting these laser welding deviations is crucial to ensure welding quality and improve productivity. The aim of this study is to realize the intelligent identification of laser welding deviations based on an improved neural network approach.

Keywords: Neural Network; Laser Welding Deviation; Intelligent Recognition

Introduction

Laser welding technology has become an important welding process in the field of modern industrial manufacturing due to its high precision, high efficiency and non-destructive features. However, deviation problems due to material expansion, deformation or other factors often occur in the laser welding process, leading to quality degradation of the welded joints. Therefore, timely and accurate identification and control of laser welding deviation is of great significance to ensure welding quality and improve production efficiency.

1. Current laser welding deviation recognition methods

The current laser welding deviation recognition methods are mainly two kinds: based on image processing and based on sensor data analysis.

The first is an image processing-based method that collects image data during the welding process, uses image processing technology to extract features and performs deviation recognition. This method can accurately capture the shape and position of the weld seam and other information, but it requires high image quality. The second method is based on the analysis of sensor data, but through the acquisition of the welding process sensor data (such as temperature, pressure, current, etc.), the use of mathematical models and signal processing technology to analyze these data, and then determine whether there is a deviation. This method does not need to rely on image quality, but has certain requirements on the accuracy of the sensor and the frequency of data acquisition.

Comprehensively comparing the two methods, the laser welding deviation recognition method with improved neural network algorithm has the advantages of strong training capacity and good adaptability, which is one of the hot directions of current research.

2. Improved neural network algorithm for laser welding deviation recognition

2.1 Data collection and preprocessing steps

2.1.1 Laser welding process data collection

Laser welding process data collection is crucial for improving the laser welding deviation recognition algorithm of neural network. By collecting the relevant data in the laser welding process, it can help us gain insight into the changes and deviations in the welding process and provide support for subsequent analysis and identification. During the laser welding process, real-time monitoring can be carried out by equipment such as high-speed cameras or laser scanners to acquire weld images, which can provide information on the spatial distribution and shape characteristics of the welding process, and are crucial for the detection of weld quality and the identification of deviations. In order to ensure the quality of the data, it is necessary to select the appropriate image acquisition frequency and resolution, and perform the necessary denoising and enhancement processes.

Sensor signals are also an important part of laser welding process data. Temperature sensors, pressure sensors, current sensors, etc. can be real-time acquisition of physical quantity information in the welding process, such as temperature, stress and current, etc. These sensor data can reflect the state and characteristics of the welding process, and play an important role in analyzing and identifying deviations. At the same time, it is necessary to collect and record welding parameters, such as laser power, welding speed, welding angle, etc. These parameters provide a key reference for evaluating welding quality and analyzing deviations.

2.1.2 Data preprocessing

Data preprocessing plays a key role in improving the laser welding deviation recognition algorithm of neural network, denoising and image enhancement are common data preprocessing techniques.

Images captured from data may be affected by lighting conditions, camera equipment and other factors, containing noise or poor quality. Denoising can reduce the noise level in the image by applying filters, Fourier transforms, etc., to improve the image quality and recognition of welding features.

Image enhancement techniques such as histogram equalization, contrast enhancement and sharpening can improve image quality, highlight weld features and details, and provide better input data. Image alignment and normalization can also be performed. Image alignment corrects image distortions and provides better consistency in the acquired image. The normalization operation converts the image to a uniform scale and color space, which facilitates neural network parsing and feature extraction.

2.2 Neural network model design

2.2.1 Network structure selection

When designing the neural network model for laser welding deviation recognition, we can consider using Convolutional Neural Network (CNN). CNN is a neural network model especially suitable for image processing, which can automatically learn and extract the features in the image.

A multi-layer convolutional neural network structure can be designed for the characteristics of laser welding images. Feature extraction and dimensionality reduction of the image is achieved by stacking convolutional and pooling layers. The convolutional layer captures the local features of the image, while the pooling layer reduces the amount of computation and the number of parameters while retaining the key feature information; then a fully connected layer is added to associate the output of the convolutional layer with the labels for final classification or regression. To avoid overfitting problems, regularization techniques such as Dropout and L2 regularization can be introduced. The size and number of layers of the specific network structure need to be adjusted according to the size, complexity and resource constraints of the dataset. Experimental methods such as cross-validation can determine the optimal network structure parameters.

2.2.2 Feature Engineering and Feature Selection

Feature engineering and feature selection are important steps in machine learning for preprocessing and optimizing input data.

Feature engineering involves transforming, combining, and creating new features from raw data to improve the model's representation of the data and learning, which can include operations such as data cleaning, normalization, and coding, as well as extracting more representational features from the raw features. Feature selection is the process of filtering the most relevant and important subset of features from all features to reduce redundancy and noise and to improve the generalization ability of the model, which reduces model complexity, speeds up training while preventing overfitting and improving the model's explanatory power.

The precision, accuracy, and stability of the model can be improved by proper feature engineering and feature selection. However, choosing the appropriate feature engineering method and feature selection strategy needs to be determined based on the specific problem, dataset, and algorithmic model to obtain the best results.

2.3 Neural Network Training and Tuning

2.3.1 Division of training, validation and test sets

In the process of neural network training and tuning, dividing the training set, validation set and test set is a very important step. The training set is the dataset used to train the model and optimize the model parameters by input samples and labels. The validation set is used to tune the hyper-parameters of the model (e.g., learning rate, regularization parameters, etc.) to select the best model and prevent overfitting. The test set, on the other hand, is used to evaluate the generalization ability of the model on unseen data.

Typically, we divide the dataset proportionally into training set, validation set and test set. A common division is 70% of the data as the training set, 10-15% as the validation set, and the remaining 15-20% as the test set. The division needs to ensure that the distribution of the dataset is similar and try to avoid duplication of data. If the dataset is small, consider using cross-validation to more fully utilize the data. Dividing the training set, validation set and test set in a reasonable way can help to evaluate the generalization ability and performance of the model. Meanwhile, the evaluation results from the validation set can guide the hyper-parameter tuning of the model. Finally, after completing the model training and tuning, the test set is used to test the performance of the model and evaluate its performance in real applications.

2.3.2 Loss function selection and optimizer settings

In the training and tuning of neural networks, choosing the appropriate loss function and optimizer is crucial. The loss function measures the difference between the model's predicted results and the true labels. Different loss functions can be selected for different tasks, such as cross entropy for classification tasks, mean square deviation for regression tasks, etc., to better guide the training process. Optimizers update the model parameters according to the gradient of the loss function, commonly including Stochastic Gradient Descent (SGD), Adam, Adagrad, and so on. Choosing the right optimizer can accelerate convergence and improve training efficiency. When setting up the optimizer, hyperparameters such as learning rate, momentum and regularization need to be considered. Learning rate controls the parameter update step, momentum accelerates convergence, and regularization helps prevent overfitting. By trying different loss function and optimizer settings and adjusting the hyperparameters, the best combination can be found to optimize the neural network model and improve performance and training results.

2.3.3 Hyperparameter tuning

Hyperparameter tuning is a very important step in the training and tuning process of neural networks. Hyper-parameters are parameters that need to be set in advance before model training, such as learning rate, batch size, regularization parameters, etc. Reasonable selection and tuning of hyper-parameters can improve the performance and generalization ability of the model.

Hyper-parameter tuning methods include grid search, stochastic search, Bayesian optimization and so on. Grid search searches for the optimal hyperparameters by traversing a given combination of parameters, but with a large computational overhead; random search evaluates a set of parameters by randomly selecting them, which is more efficient but does not traverse all possibilities; and Bayesian optimization utilizes a probabilistic model to model the relationship between the hyperparameters and the performance of the model in order to efficiently search for the optimal parameters. When performing hyperparameter tuning, it is necessary to select and adjust according to the characteristics of the specific problem and dataset, and it is usually recommended to start searching from a larger range, and then gradually reduce the range to obtain more accurate parameters. Reasonable tuning of hyperparameters can significantly improve the performance and generalization ability of the neural network model, and by combining different search methods and experimental validation, the best combination of hyperparameters can be found to provide effective guidance for model training and optimization.

3. Trends in laser welding technology

Laser welding technology in the future development will continue to usher in some important trends, the development of laser sources will focus on the power increase and higher efficiency, in order to meet the demand for higher welding speed and more complex processes. Laser welding technology will gradually expand into the fields of multi-material welding, thin plate welding and 3D printing to meet the needs of different industries. Welding process automation and intelligence will become the trend, such as machine learning and artificial intelligence technology to achieve real-time monitoring, control and optimization of the laser welding process. At the same time, the research of environmentally friendly laser welding technology will also be paid attention to, in order to reduce the pollution of the environment and energy consumption. The development of laser welding technology will pursue higher power and efficiency, broaden the field of application, realize automation and intelligence, and focus on the improvement of environmental performance.

4. Conclusion

Intelligent deviation recognition of laser welding technology is the key to ensure welding quality and improve production efficiency, and it is hoped that the method based on the improvement of neural network can provide an effective solution for solving the problem of laser welding deviation, and promote the application and development of laser welding technology in modern manufacturing.

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