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論 文 標 題 ： Non-contact detection of steel tube weld area based on photoacoustic effect

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Abstract: An optical ultrasound sensing system based on the photoacoustic principle is developed to monitor and investigate the difference between the weld area and the normal area on the steel tube. The continue wave (CW) laser photoacoustic system is composed of a field programmable gate array controller (FPGA), piezo-electric transducer(PZT), and a continue wave (CW) laser with 1-kHz laser pulse period. Here, the PZT Receiver contains amplifiers and analog-to-digital converter (ADC). The system is adopted as a non-contact detection method to replace the traditional detection methods such as visual inspection (VT), magnetic particle testing (MT) and ultrasonic testing (UT). Due to advantages including miniature size, lightweight, non-destructive detection and distributed sensing capability, the results show that the weld area on the steel tube and the normal area have statistically significant in the frequency range of 1.46-1.5MHz of the PA signals, which is characterized by statistical analysis and deep learning identification.

System architecture

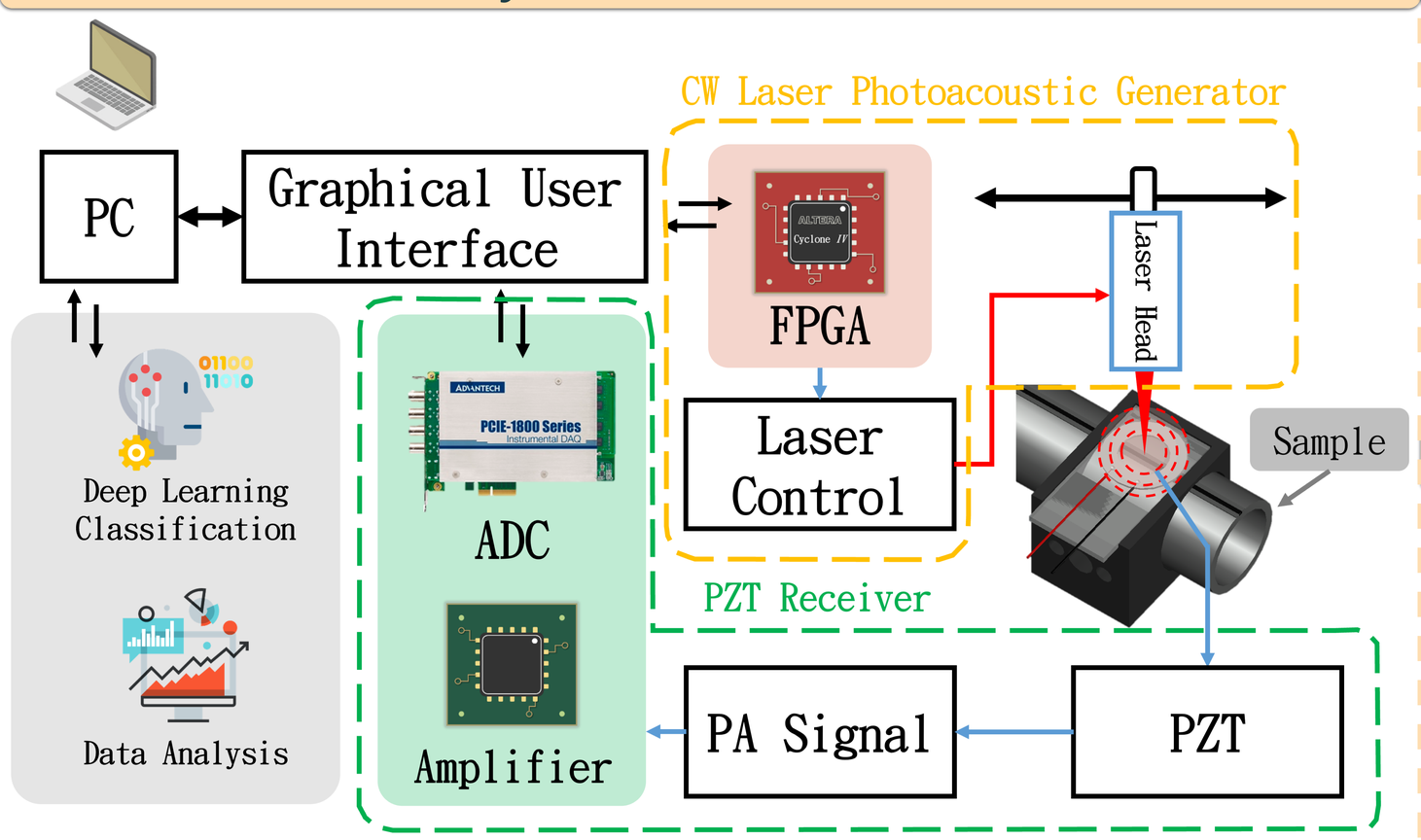

Figure 1. Architecture of the photoacoustic sensing system.

This system is mainly composed of continue wave (CW) laser and PZT receiver. First, the continue wave (CW) laser switch is controlled by the field programmable gate array controller (FPGA), then the continue wave (CW) laser periodically irradiates the sample to generate a PA signals. The signal is sampled and stored through an analog-digital converter (ADC) to analyze the responded PA signals.

Steel tube entity diagram

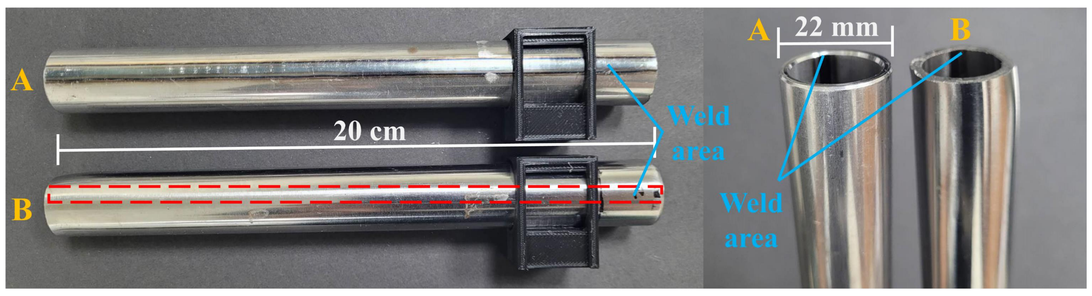

Figure 2. Steel tube entity diagram.

Convolutional neural network (CNN)

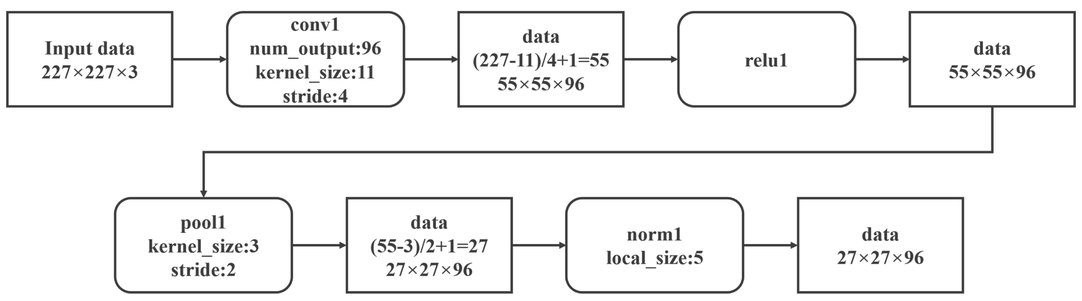

Figure 3. Flow chart of training on the first convolution layer of AlexNet.

Deep learning classify effectively on monitor spot in real time through a pre-trained classification model, so a convolutional neural network (CNN) is used for further FFT image analysis. The training flow chart of the first convolutional layer of AlexNet is shown in Figure 3.

Experimental Results

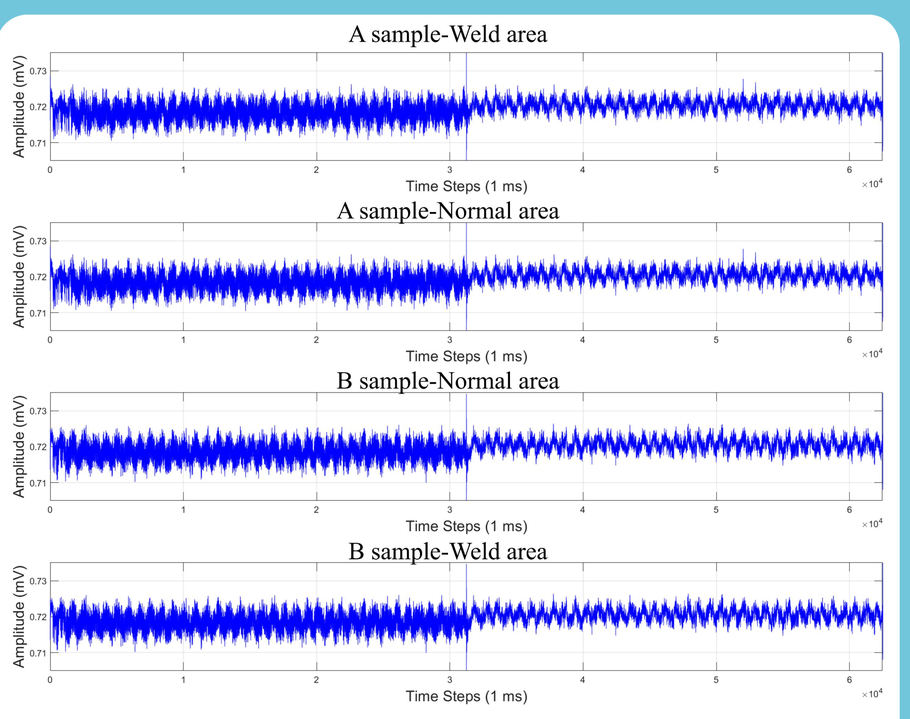

Figure 4. PA signals in the time domain.

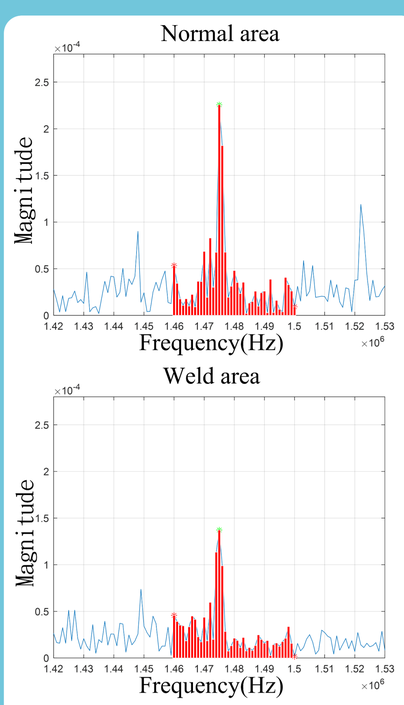

Figure 5. Features of PA signals in the frequency domain.

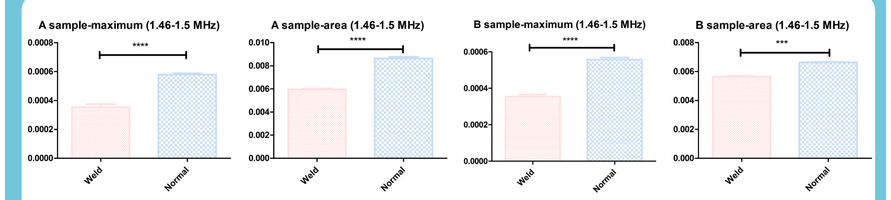

Figure 6. Mean standard and deviation comparison.

Table 1. Average value and standard deviation of the maximum value of PA signal.

Sample	A Sample Weld area ($*10^{-4}$)	A Sample Normal area ($*10^{-4}$)	B Sample Weld area ($*10^{-4}$)	B Sample Normal area ($*10^{-4}$)
Mean value /Standard deviation(V)	3.53±2.40	5.79±0.80	3.54±1.30	5.58±1.20

Table 2. The mean and standard deviation of the area of PA signal.

Sample	A Sample Weld area ($*10^{-4}$)	A Sample Normal area ($*10^{-4}$)	B Sample Weld area ($*10^{-4}$)	B Sample Normal area ($*10^{-4}$)
Mean value /Standard deviation(V)	5.95±0.82	8.64±1.50	5.65±0.50	6.63±0.36

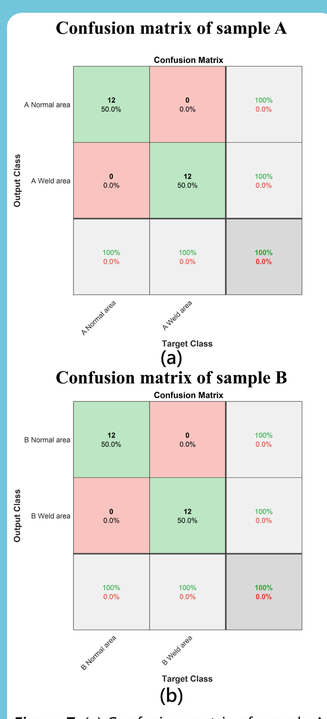

Figure 7. (a) Confusion matrix of sample A. (b) Confusion matrix of sample B.