哈 尔 滨 工 业 大 学 （深 圳）

Harbin Institute of Technology ,Shenzhen

Interim Assessment of the Thesis

for the Master's Degree

Name	**Wang Jiankun**
Entrance Date	**2017.09.01**
Thesis Title	**Research on Assembly Quality**
Detection Algorithm of Atomizer Based on	
Machine Vision	
Discipline	**Mechanical Engineering**
Supervisor	**Professor Hu Hong**
Report Date	**2019.03.07**

1. Does the thesis progress according to the research objectives and schedule as stated in the primary report? (at least 100 words)

According to the research content of the thesis. I have already constructed the atomizer image dataset, designed the corresponding image processing detection algorithm for different types of assembly failures, carried out research based on deep learning detection algorithm, developed detection software and cloud data management system. I have done some work in advance compared to the schedule as stated in the primary report. But there are still some work that needs further improvement.

In general, the thesis progress does mainly according to the research objectives and schedule as stated in the primary report. And I have finished the research contents on time.

2. The completed work and its related outcomes (at least 1500 words) .

2.1 Building data sets

2.1.1 Data collection

According to the assembly process and actual production experiments, the assembly quality is divided into five categories: normal, missing workpiece, missing cotton core, missing metal sheet and abnormal wire position. We collected image samples on the prototype and collected a total of 382 images. The sample size for each category is shown in Table 2-1.

Table 2-1 Sample size of each assembly failure category

Category	Normal	Missing workpiece	Missing cotton core	missing metal sheet	Abnormal wire
Sample size	234	78	22	30	18

2.1.2 Data enhancement

In order to better adapt to the change of detection environment and provide more data for deep learning algorithm, it is necessary to enhance the data and increase the number of samples.

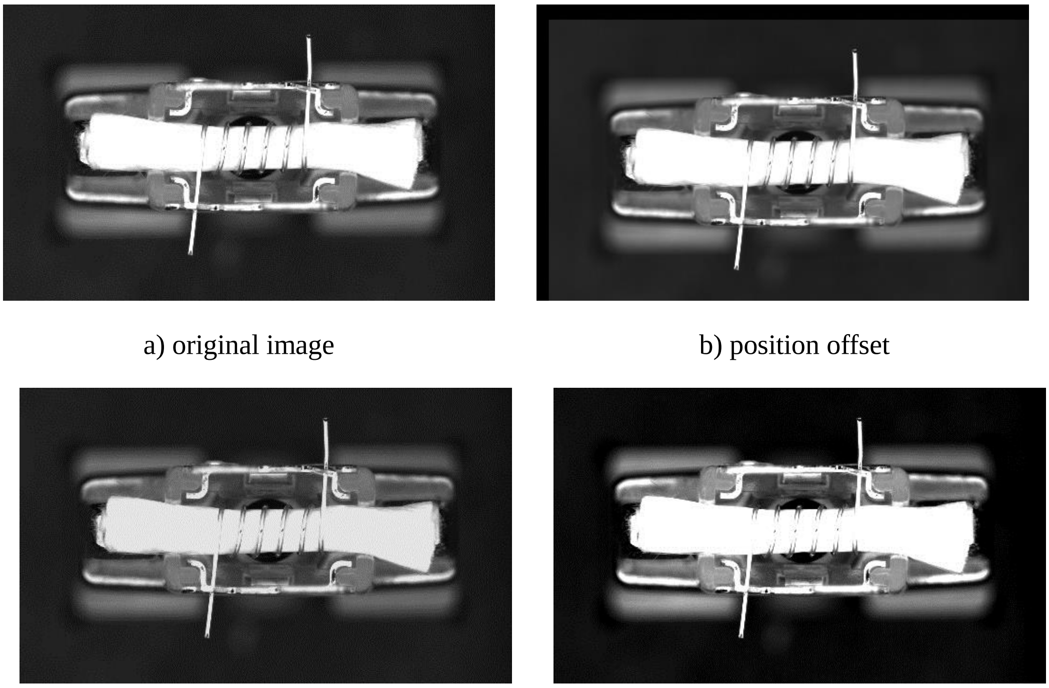
According to the characteristics of the detection project, the following data enhancement methods are proposed in this paper:

(1) Position offset. Because the relative position of fixtures and cameras will produce slight offset because of the installation accuracy, random slight offset of the image can improve the adaptability of the algorithm to the installation location. An example of the location offset is shown in Figure 2-1 b).

(2) Brightness transformation. Different production environments and different light sources will affect the brightness of the image. In order to adapt the algorithm to the change of brightness, it is necessary to enhance the image by appropriate brightness

transformation. An example of brightness transformation is shown in Figure 2-1 c).

(3) Contrast transformation. Assembling detection is embedded in the pipeline, and there will inevitably be some vibration, resulting in slightly different contrast in imaging. Contrast transformation enhancement of the image can increase the robustness of the algorithm. An example of contrast transformation is shown in Figure 2-1 d).



a) original image　　b) position offset

c) brightness transformation　　d) contrast conversion

Figure 2-1 Data Enhancement

2.2 Research on detection algorithm based on image processing

2.2.1 Detection target location and ROI settings

In the process of assembly detection, the first step is to locate the detection target. The assembly is fixed inside the fixture. The position of the fixture can be positioned first. Then, according to the relative position of assembly parts and fixtures, ROI is set up to detect assembly defects..

Because the background of the image is black, the image is binarized by formula (2-1), and the fixture and assembly areas are segmented. The results of binarization are shown in Fig. 2-2 b).

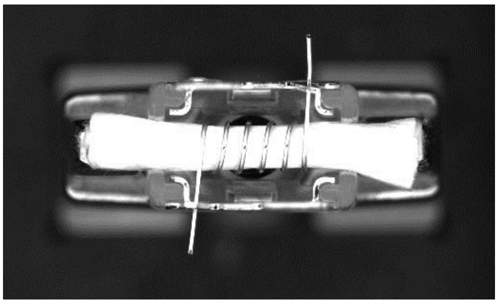
$$\mathrm{g}(x,y)=\begin{cases}255 & f(x,y)>t\\ 0 & f(x,y)\le t\end{cases} \tag{2-1}$$

Where $\mathrm{g}(x,y)$ —— The pixel value at (x, y) after image binarization;

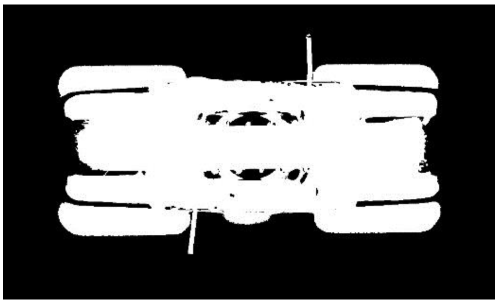
$f(x,y)$ —— The pixel value at the grayscale image (x, y);

t —— Binarization threshold

Since the wire of the assembly will extend beyond the scope of the fixture, it should be handled when positioning the fixture. The protruding wire can be eliminated by opening the image. The open operation is an operation in which the image is first corroded and then dilated to eliminate small objects. Corrosion is the removal of the edge of the white area. Dilation is the expansion of the edge of the white area. The result of the open operation is shown in Figure 2-2 c). The outline of the outer envelope of the fixture can be obtained by contouring the image. The contour search results are shown in Figure 2-2 d).

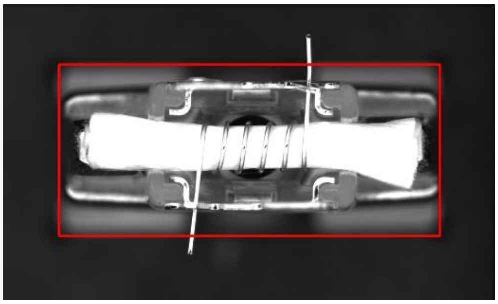


a) picture to be detected



b) for a) binarization

c) for b) open operation



d) for c) find outline

Figure 2-2 Target positioning

In industrial inspection, a region of interest (ROI) set for detection is usually used for detection for different detection items. According to the detection requirements and the analysis of bad samples, a total of eight ROIs are set in this paper, as shown in Figure 2-3. According to the order from left to right and top to bottom, 2, 7 are used for metal sheet missing detection, 4, 5 are used for cotton core missing detection, and 1, 3, 6, and 8 are used for wire abnormality detection.

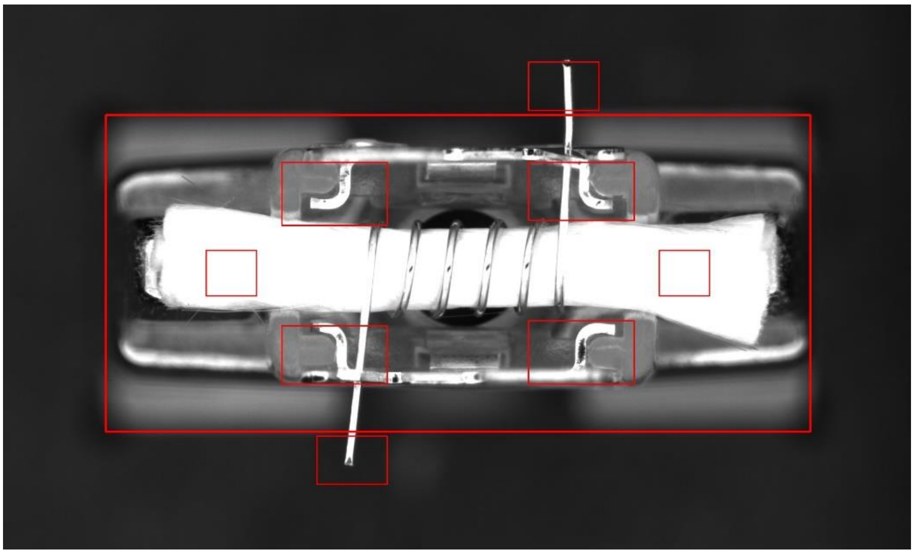
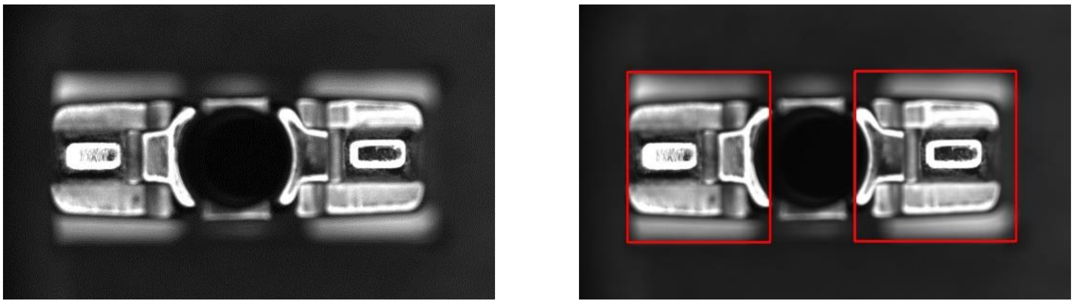


Figure 2-3 ROI settings

2.2.2 Workpiece missing detection

The assembly needs to be clamped several times during the assembly process, and there may be cases where the clamping fails or is lost during the clamping process, so that there is no assembly and only fixture in the detection station.

By setting the threshold of contour area to filter the contour, the contour of small area can be filtered. If there is a missing workpiece, the outline cannot be found in the process of outline search. So we can judge whether the workpiece is missing or not according to the result of contour search when locating the target. Workpiece missing detection is shown in Figure 2-4..



a) missing workpiece　　　　b) find a profile for a)

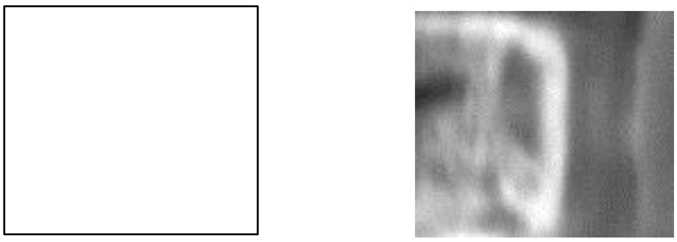
Figure 2-4 Workpiece missing detection

2.2.3 Cotton core missing detection

Since the cotton core is wrapped by a metal wire, in order not to deform the metal coil, the clamping force of the feeding material is small, and it is easy to be lost during handling.

For the cotton core missing detection, this paper uses the pixel statistical method, and the cotton core detection ROI sample is shown in Figure 2-5. The cotton core is bright white when imaging. If there are cotton core, the ROI of cotton core detection should be white pixels. The missing cotton core is judged by counting the proportion of white pixels in ROI. If the proportion is less than the set threshold, it is determined that the cotton core is missing, and vice versa.

The process of counting the number of white pixels is to binarize the picture and set the threshold of the pixel value. For the pixels above the threshold, the value of the pixel is determined to be white, and the value of the pixel is set to 1, otherwise it is set to 0. The white points of the image can be obtained by summing up the whole picture.



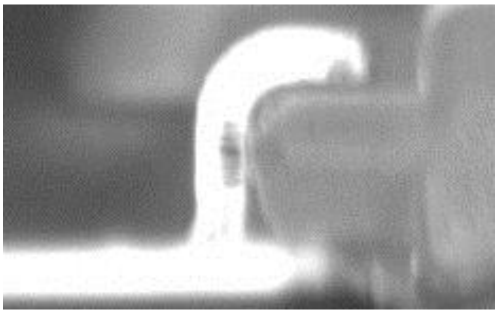
a) cotton core　　　　b) no cotton core

Figure 2-5 Cotton core missing detection

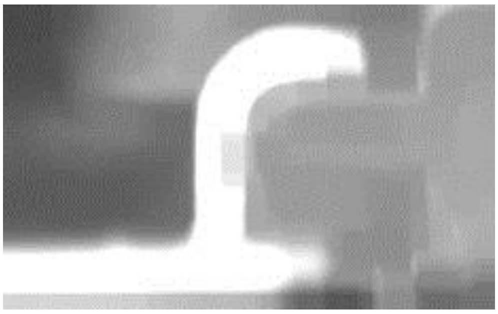
2.2.4 Metal sheet missing detection

For the detection of metal sheets, this paper uses template matching. The metal piece has a claw, and it can be determined that the metal piece is present as long as the claw can be detected. Due to imaging reasons, some dark areas may appear on the metal chip jaws, and the picture needs to be pre-processed.

This paper uses a closed operation for preprocessing. The closed operation is an operation in which the image is first dilated and then corroded to eliminate small holes. The results of the closed operation on the metal sheet detection ROI are shown in Figure 2-6 b).

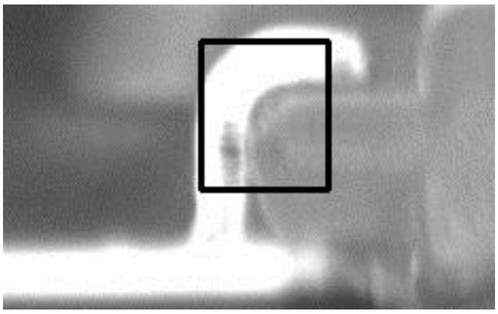


a) picture to be detected



b) on a) closed operation

c) for b) binarization



d) template matching results

e) template picture 1

f) template picture 2

Figure 2-6 Metal sheet inspection

Before performing template matching, the image is binarized so that the area other than the metal piece becomes black, as shown in Figure 2-6 c), which can make the template matching not interfere with the background, and improve the accuracy and stability of the template matching. The template image we use is also binarized. The template images in two different places are shown in Figure 2-6 e), f).

There are many template matching methods, and this paper chooses the normalized square difference method. The normalized squared difference formula is shown in equation (2-2). This method is simple and fast. The principle of the normalized square difference method is to first calculate the squared difference of the pixel values of the template image and the image to be detected, and then normalize the result, so that the range of the value range is transformed into [0, 1], and the smaller the value the more matching. The template matching results are shown in Figure 2-6 d).

$$R(x,y) = \frac{\sum_{x',y'}\left(T(x',y') - I(x+x',y+y')\right)^2}{\sqrt{\sum_{x',y'} T(x',y')^2}\sqrt{\sum_{x',y'} I(x+x',y+y')^2}} \quad (2\text{-}2)$$

Where $T(x',y')$ —— The pixel value of the template graph at (x',y');

$I(x+x',y+y')$ —— The pixel value to be matched at $(x+x',y+y')$;

2.2.5 Wire anomaly detection

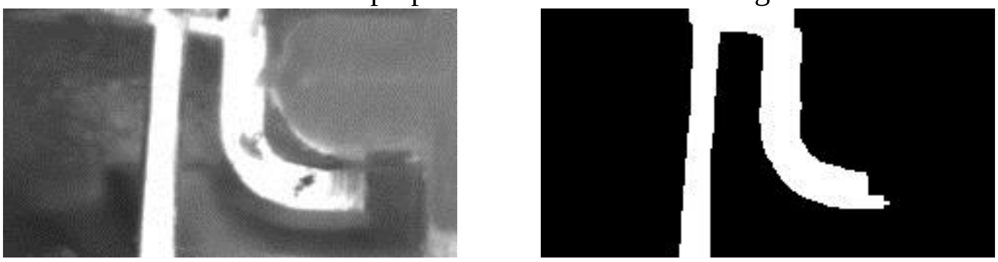
There are two cases of abnormal wire, one is that the wire is too short, and the other is the positional deviation caused by the wire being not pressed. For the first case, the pixel statistical method is used to judge, similar to the method of cotton core detection, and will not be described here. The ROI sample of the wire is too short to be shown in Figure 2-7.

a) wire b) no wire

Figure 2-7 Cotton core missing detection

For the second case, this paper determines by measuring the distance between the wire and the vertical side of the metal chip jaw. When the distance deviates from the normal range, it is determined to be abnormal. Analysis of the picture shows that there will be a large number of bright white areas between the wire and the claw of the metal sheet, and most of the other areas are gray. The distance can be measured by finding two bright white areas.

Firstly, the image to be detected is preprocessed, including closed operation and binarization. Closed operation eliminates black holes and binary operation divides bright white areas. The results of preprocession are shown in Figure 2-8.

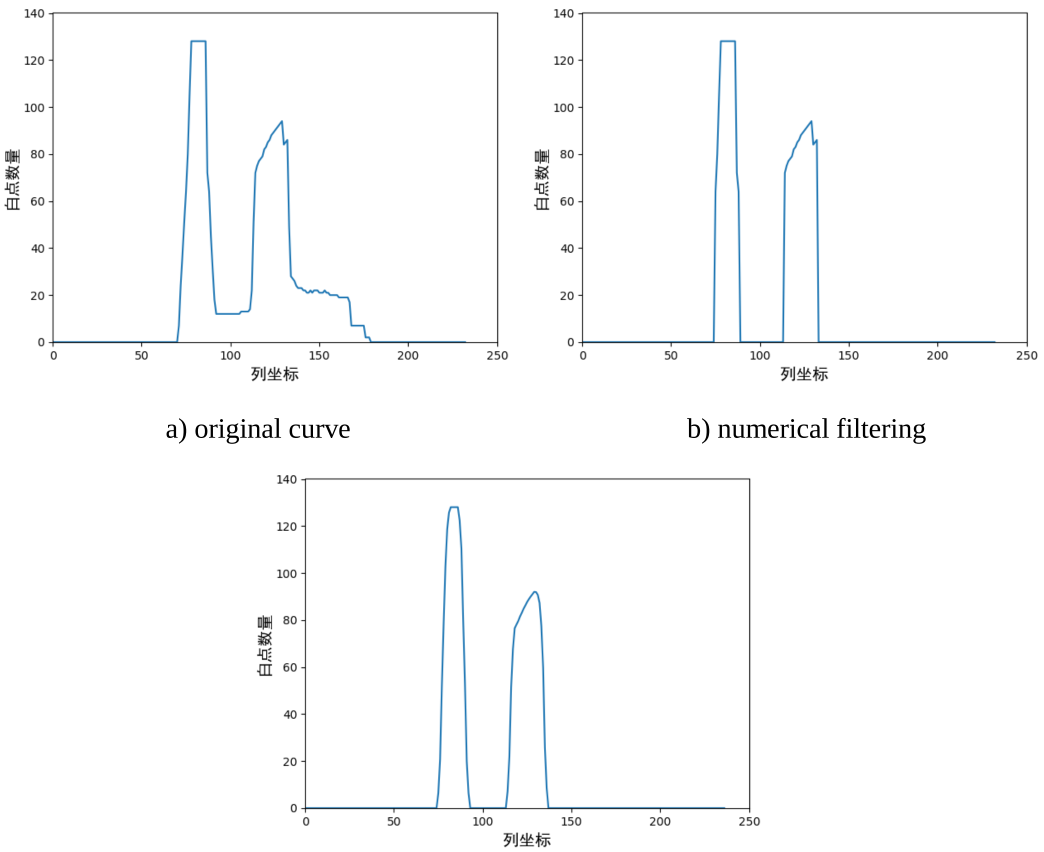


a) Image to be tested b) Pretreatment results

Figure 2-8 Wire distance measurement preprocession

For the preprocessed image, the number of white dots in each column is counted and the curve is drawn. There will be a lot of white spots at the vertical edge of wire and metal card claw, and there will be two maxima. Because there are other white areas and noise points in the image, the curve is not smooth enough to find the correct maximum.

In order to find the maximum accurately, this paper preprocesses the statistical sequence. The first step is to filter the values of the logarithmic series, so that the values less than a certain value become zero, and get the region between the vertical edges of the wire and the metal card claw. The second step is the smoothing of the sequence, after finding two maxima, the distance between them can be measured. The pretreatment process of statistical sequence is curvilinearized as shown in Figure 2-9.



c) numerical smoothing

Figure 2-9 Curve Processing

2.2.6 Experimental analysis of image processing detection algorithm performance

Two important indicators for evaluating the performance of detection algorithms in industrial inspection are the detection rate and the false detection rate.

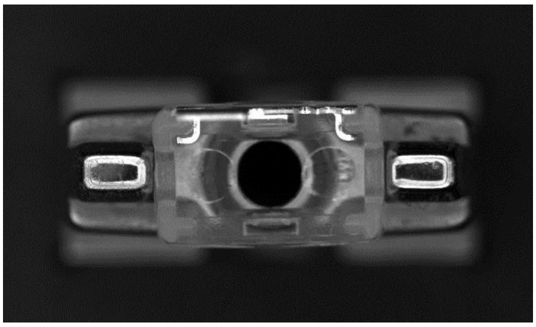
This paper uses the detection algorithm based on traditional image processing to test the performance of the collected image data sets. The number of samples tested is shown in Table 2-1, and the detection rate and false detection rate of various bad categories are shown in Table 2-2.

Table 2-2 Traditional image processing algorithm detection performance table

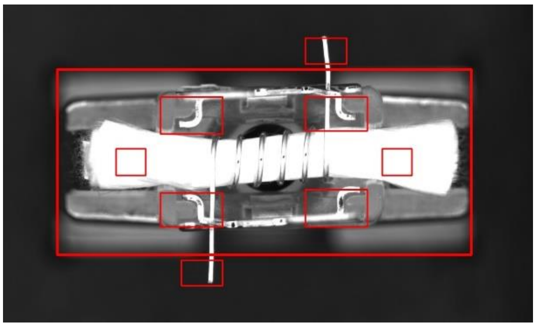
Category	Right detection rate	False detection rate
Normal	96.16%	-
Missing artifact	100%	0%
Missing cotton core	72.72%	0%
Missing metal piece	100%	0.85%
Abnormal wire	100%	2.99%

Traditional image processing algorithms have a large number of parameters to be set, and different parameters will get different results. Because of the strict requirement of detection rate in industrial detection, the principle of determining parameters in this paper is to reduce the false detection rate as much as possible under the condition of ensuring high detection rate.

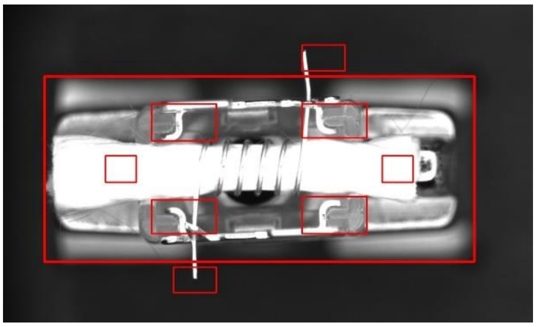
Cause of missing inspection of cotton core: The missing samples were detected as missing parts. Because individual pictures without cotton core are dark, outline search fails. Reasons for metal slice misdetection: ROI is not accurate (the area of metal claw is incomplete). Because the image size of fixtures at different workstations is different, the position of the assembly in the fixture will rotate, resulting in some deviations in the relative position of the assembly in the fixture. The reason of wire misdetection is that on the one hand, ROI is inaccurate, on the other hand, ROI may include some interferences, resulting in inaccurate ranging. Examples of missing samples are shown in Figure 2-10.



a) missile inspection sample



b) metal chip misdetection sample



c) wire misdetection sample

Figure 2-10 Sample of missed detection and false detection

2.3 Research on Detection Algorithms Based on Convolutional Neural Network

2.3.1 Model Selection

According to the characteristics of industrial detection, this topic chooses the MobileNet convolution neural network model. MobileNet is a model based on deep separable convolution. Compared with other models, its computation is much less than other models when the accuracy is not different.

2.3.2 Model Training

The parameters of convolution neural network model need to be determined by data training. The two main parts of model training are loss function and optimization algorithm.

(1) Loss function. The loss function is used to measure the difference between the predicted value and the real value. The smaller the loss function value is, the better the result of model learning is. Loss function has a great influence on the learning effect of the model. Choosing the appropriate loss function can get better results. Cross-entropy

loss function is usually used in image recognition. See formula (2-3). It can be seen from the formula that the closer the predicted value is to the real value, the smaller the loss function value will be, on the contrary.

$$L(\hat{y}, y) = -y \log \hat{y} + (1 - y) \log(1 - \hat{y}) \quad (2\text{-}3)$$

Where y —— Real value;

$\hat{y}$ —— Predicted value;

(2) Optimal algorithm. The optimization algorithm is an algorithm that updates network parameters according to the value of loss function and certain rules. The updating formula of network parameters is shown in formula (2-4). The selection of optimization algorithm determines the training time and convergence effect of the model. The commonly used optimization algorithms are gradient descent, momentum gradient descent, RMSprop, Adam and so on. This paper chooses Adam optimizer, which combines momentum gradient descent and RMSprop. It is a widely used and proven optimizer.

$$\omega = \omega - \alpha \frac{\partial L}{\partial \omega} \quad (2\text{-}4)$$

Where ω —— Parameters;

α —— Learning rate;

L —— Loss function;

Learning rate is also an important parameter, which can be divided into fixed and dynamic ways. The advantage of dynamic learning rate is that a larger learning rate can be set in the early stage of the training model to accelerate the training speed, and the learning rate will continue to decay in the later stage to converge steadily to a better solution. There are many kinds of dynamic learning rates. In this paper, step-down is used, that is, the learning rate is reduced once every certain number of iterations.

(3) Model training. The training of the model is an iterative process, which can be completed by setting the threshold of loss function or the maximum number of iterations.

2.3.3 Performance analysis of convolutional neural network detection algorithm

The prediction results of deep learning algorithms are usually classified into four categories: real case (TP), false positive case (FP), true negative case (TN), false negative case (FN). The real case is that the positive case is predicted to be the positive case. The false positive case is that the negative case is predicted to be the positive case. The true negative case is that the negative case is predicted to be the negative case. The false negative case is that the positive case is predicted to be the negative case. The commonly used evaluation indicators are Accuracy, Precision, Recall and F1 coefficients. The formulas are as follows: Formula (2-5), Formula (2-6), Formula (2-7) and Formula (2-8), respectively.

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \quad (2\text{-}5)$$

$$\text{Precision} = \frac{TP}{TP + FP} \quad (2\text{-}6)$$

$$\text{Recall} = \frac{TP}{TP + FN} \quad (2\text{-}7)$$

$$\text{F1} = \frac{2 \times Precision \times Recall}{Precision + Recall} \quad (2\text{-}8)$$

The data set is detected by the convolutional neural network detection algorithm. The detection performance of the algorithm is shown in Table 2-3.

Table 2-3 Convolutional Neural Network Algorithm Detection Performance Table

Category	Precision	Recall / Right detection rate	F1	False detection rate
Normal	98.63%	99.31%	98.97%	-
Missing artifact	100%	100%	100%	0%
Missing cotton core	100%	100%	100%	0%
Missing metal piece	94.44%	97.14%	97.14%	0.69%
Abnormal wire	100%	83.33%	90.91%	0%

It can be seen that compared with the traditional image processing detection algorithm, the classification accuracy and false detection rate of the convolutional neural network algorithm are improved, but the detection rate is slightly reduced. The main reason is that convolutional neural network algorithms treat each category equally. Subsequent optimization of the detection rate will be made.

2.4 Detection software and cloud data management system design

2.4.1 Detection software design

The detection software needs to implement a combination of detection algorithms, detection information management, and graphical interfaces. According to the functions implemented by the software, the detection software can be divided into four parts: image processing detection algorithm, convolutional neural network detection algorithm, graphical user interface, database.

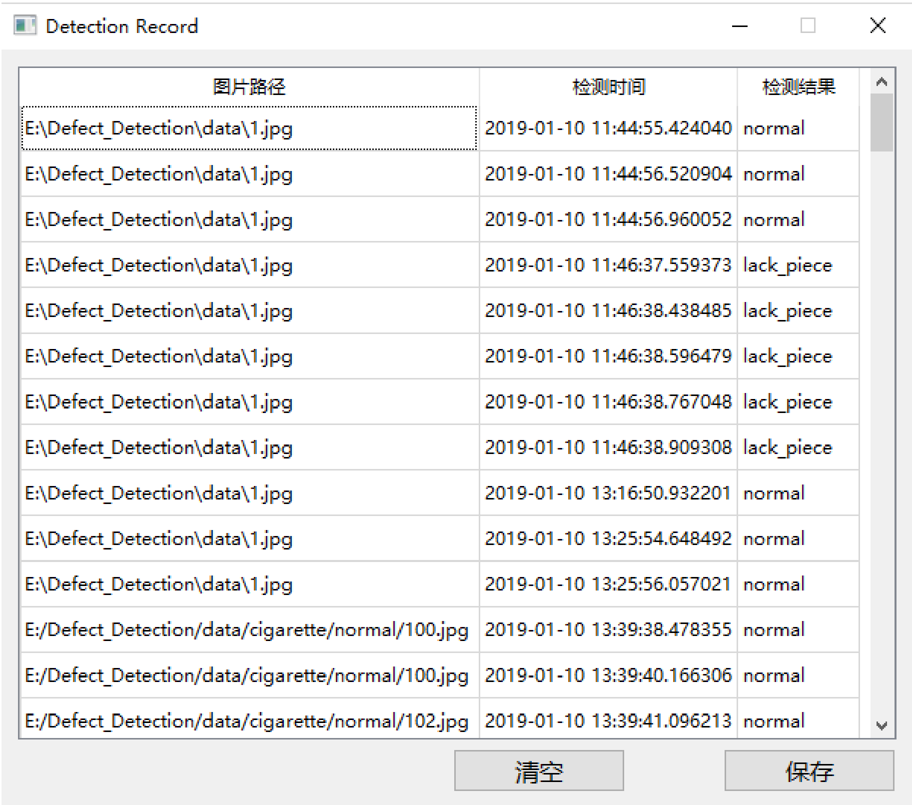
(1) Image processing detection algorithm. This paper uses OpenCV image processing library to design image processing detection algorithm. Due to various types of assembly defects, the detection sequence of this subject is: workpiece missing detection, cotton core missing detection, metal sheet missing detection, wire anomaly detection.

(2) Convolutional neural network detection algorithm. This paper uses the TensorFlow deep learning framework to design a convolutional neural network algorithm. TensorFlow is an open source framework developed by Google Inc. and is currently the most popular development framework for deep learning. When using the convolutional neural network algorithm for detection, the network weight file initialization model needs to be loaded first. In order to make the operation of the software more convenient, it is selected to perform related initialization when the software is started.

(3) Database. This paper uses the MySQL database management system to store and manage detection information. The MySQL database management system is a relational database management system (RDBMS) that uses a structured query language SQL for database management. Simple, compact and free, it is ideal for the needs of this thesis. At the end of each test, the detection software generates a test record to be saved

in the database, including the detected image path, test result and detection time.

Figure 2-11 Detection software main interface



图片路径	检测时间	检测结果
E:\Defect_Detection\data\1.jpg	2019-01-10 11:44:55.424040	normal
E:\Defect_Detection\data\1.jpg	2019-01-10 11:44:56.520904	normal
E:\Defect_Detection\data\1.jpg	2019-01-10 11:44:56.960052	normal
E:\Defect_Detection\data\1.jpg	2019-01-10 11:46:37.559373	lack_piece
E:\Defect_Detection\data\1.jpg	2019-01-10 11:46:38.438485	lack_piece
E:\Defect_Detection\data\1.jpg	2019-01-10 11:46:38.596479	lack_piece
E:\Defect_Detection\data\1.jpg	2019-01-10 11:46:38.767048	lack_piece
E:\Defect_Detection\data\1.jpg	2019-01-10 11:46:38.909308	lack_piece
E:\Defect_Detection\data\1.jpg	2019-01-10 13:16:50.932201	normal
E:\Defect_Detection\data\1.jpg	2019-01-10 13:25:54.648492	normal
E:\Defect_Detection\data\1.jpg	2019-01-10 13:25:56.057021	normal
E:/Defect_Detection/data/cigarette/normal/100.jpg	2019-01-10 13:39:38.478355	normal
E:/Defect_Detection/data/cigarette/normal/100.jpg	2019-01-10 13:39:40.166306	normal
E:/Defect_Detection/data/cigarette/normal/102.jpg	2019-01-10 13:39:41.096213	normal

Figure 2-12 Detection record interface

(4) Graphical user interface. This paper uses the QT software interface design

framework to develop a graphical user interface. The main functions include detection algorithm selection, detection object selection, detection result display, software operation information prompt, detection record query and export. The main interface of the detection software is shown in Figure 2-11. The detection record query and export interface is shown in Figure 2-12.

2.4.2 Cloud Data Management System Design

With the advent of the industrial intelligence era, detection data and data mining in industrial production are becoming more and more important, and it is necessary to design a corresponding cloud data management system.

This paper uses the Django framework to develop cloud systems. Django is an open source web application framework written in Python. Django is a framework based on the MVC structure. But in Django, the part of the controller that accepts user input is handled by the framework itself, so Django is more concerned with models, templates, and views, called MTV patterns.

Figure 2-13 detection record query

Figure 2-14 bad image query

(1) Model. That is the data access layer. Handle all transactions related to the data,

including how to access it, how to verify validity, and the relationship between the data. The connection between the model and the database uses Object Relational Mapping (ORM), which defines the data model in the form of a Python class. It can manipulate the database using object-oriented ideas and also supports raw SQL statements.

(2) Template. That is, the presentation layer. Handling performance-related operations, how to display them in pages or other types of documents, templates are inheritable.

(3) View. That is the business logic layer. Access the model and retrieve the relevant logic for the corresponding template. A view is a bridge between a model and a template.

The cloud data management system designed in this paper consists of two modules. One is the detection record query module, and the other is the bad picture query module. The detection record query module can query the detection record according to the time period and can view the corresponding picture. Figure 2-13 shows the interface of the test record query module. The bad picture query module can query the corresponding bad pictures according to the time period and the bad type, which is convenient for observation and summary. Figure 2-14 shows the interface of the detection record query module.

3. The work to be completed and its schedule .

The work that needs to be completed in the future is to improve and optimize the convolutional neural network algorithm, improve the detection software and the cloud data management system.

The specific schedule is as follows:

Time	Schedule
2019.03—2019.05	Improve the convolutional neural network algorithm, try to modify the loss function, use the Siamese network, and optimize the training strategy.
2019.06—2019.07	Improve the database and cloud management system for detecting data.
2019.08—2019.09	Optimize the corresponding detection algorithm and debug related detection software.
2019.10—2019.12	Organize research results, write master's thesis, and prepare a defense.

4. The existing or expected difficulties and problems.

The existing problem is that the convolutional neural network algorithm has improved the overall accuracy of the classification, and the robustness of the algorithm is better, but the missed detection rate cannot meet the requirements of industrial detection.

The expected difficulty is that there is no relevant research based on the Siamese network in industrial detection, which makes the research more difficult.

5. The considerations on the possibility of completing the thesis on-time (at least 100 words).

Up to now, the atomizer image dataset has been constructed, the corresponding image processing detection algorithm for different types of assembly failures has also been designed, the deep learning detection algorithm have been researched, the detection software and cloud data management system has been basically formed. In the following time, image processing detection algorithm and detection software were modified and optimized and deep learning detection algorithm will be design.

In general, most of the work of the thesis has been completed, and there are still some challenges. With the guide of teacher and the help of my colleagues and classmates, I believe that I can finish the graduated thesis on time.