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Research on Inspection Method for Assembly Integrity of Electronic Components

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Abstract. In order to improve the efficiency of assembly integrity inspection of electronic components and reduce the workload of manual inspection, an automatic inspection method of assembly integrity of electronic components based on vector drawings and digital image matching recognition is proposed. The method first abstracts the circuit symbols in the circuit sheet in vector format into a weighted undirected diagram, and then uses the isomorphic algorithm of the diagram to identify the type and number of symbols in the drawing. Secondly, the Mask R-CNN instance segmentation model is used to identify the type and quantity of electronic components in the circuit board. Finally, the recognition results of vector drawings and digital images are compared to determine whether the assembly is complete. On the experimental data set containing a total of 321 electronic components on 15 circuit boards, 14 pieces of this method were completely matched, and 1 piece of small number of electronic components were identified as errors, but it also can assist inspectors in judging the integrity of the assembly and provides ideas for automated inspections.

Keywords: electronic components, assembly integrity inspection, vector drawing recognition, digital image recognition, isomorphism of graphs, mask R-CNN.

1. Introduction

With the acceleration of the process of informatization construction, the application of electronic equipment has been further extensive, which has become an important symbol of the development of informatization. Circuit boards, as the key to electronic equipment, directly affect the use of electronic equipment. Only by inspecting the circuit board can quality problems be found in time, which is one of the indispensable steps in circuit board assembly. In the production process, after the assembly of electronic components is completed, the inspector will compare the circuit board and circuit drawings with the inserted electronic components through manual inspection to confirm whether the type and quantity of electronic components on the circuit board and the type and quantity of circuit symbols on the circuit drawings are consistent. Incomplete assembly can lead to substandard quality of electronic equipment. At present, most of the assembly integrity inspection of electronic components in China is manual inspection, obviously, manual inspection method is time consuming, laborious, and prone to errors. Transforming manual inspection into automatic verification of the assembly integrity of electronic components with computer programs not only helps to accelerate inspection efficiency and promote the digital transformation of the manufacturing industry [1], but also has important practical application value.

Based on the above thinking, this paper proposes an assembly integrity verification algorithm for electronic components based on image recognition. The main tasks include the following:

(1) Identification of circuit symbol in circuit drawings. DXF files contain a large amount of element information, but cannot be used directly to identify circuit symbols in drawings. This paper is based on AutoCAD(Autodesk Computer Aided Design) secondary development technology to read the DXF file of the circuit drawing, and identifies the type and number of circuit symbols by comparing the primitives with the connected primitives in the block into the diagram structure and the predefined circuit symbol diagram structure template.

(2) Identification of electronic components in images. After the manual assembly of electronic components is completed, the images of the circuit board are collected through the industrial camera. The

marked electronic component training data set is trained to generate the mask R-CNN instance segmentation model to identify the electronic components, including the type and quantity of electronic components.

(3) Matching algorithm of drawings and images. The current assembly of the circuit drawings identified by the circuit symbols and the electronic components identified in the image matching comparison, if the number and type of the two are consistent, the assembly is complete, the electronic components assembly integrity test passed, on the contrary, the assembly is incomplete, you need to manually view the difference in the number of original types according to the identification results of the drawings and images. Compared with manual inspection, this study can greatly improve the inspection efficiency.

2. Identification of Circuit Symbols in Circuit Drawings

2.1. Analyze Drawing Structure

This study uses DXF (Drawing Exchange Format) as the drawing format. DXF is an open CAD (Computer Aided Design) vector data file format that is used widely by users due to its fast read and write speed, it has become the standard for CAD applications. In practical applications, circuit symbols are usually composed of multiple primitives, and multiple element information is saved in a block segment to facilitate the management of circuit symbols.

To obtain the drawing structure, this study uses the DXF secondary development technique to parse the results of segment [1]. If the extract segment is a block segment, all primitives in the segment are extracted for the next step analysis. The specific algorithm is as follows:

- Read the DXF file and get all the segment information according to the DXF file structure;
- Filter the block segment from segment information;
- Extract all element information in block segment;
- Repeat last step until all block segment information is processed and store all extracted element information as blocks.

2.2. Circuit Symbol Abstraction

All primitives in the block extracted in the previous step are used as nodes in the topology graph, and the primitive type is used as the attribute of the node; If there is a connection relationship between primitives, edges are established for the two nodes of the topology graph. In this way, a circuit symbol can be abstracted into a topology graph, which is an undirected graph [2]. Taking capacitance as an example, there are 7 primitives in total, which are the nodes of the topology. The types are lines, and there is a connection relationship between (1,2), (3,4), (3,5), (4,6), (5,6), (6,7) to establish edges between nodes. After the above operations, according to the characteristics of electronic component symbols in the drawing, other circuit symbols can also be abstracted into topology graph, as shown in Fig. 1. In the process of converting into topology graph, some complex topology graph will appear, mainly because circuit symbols contain more primitives. For example, in the arrow on the left of the variable resistor, there are three parallel lines with different lengths and the same midpoint, there are four small circles at the top right of the triode. These primitives are connected to other primitives. Take the topology graph in Fig. 1 as a template, and follow the same operation to establish the topology graph of each circuit symbol from the drawing for further identification.

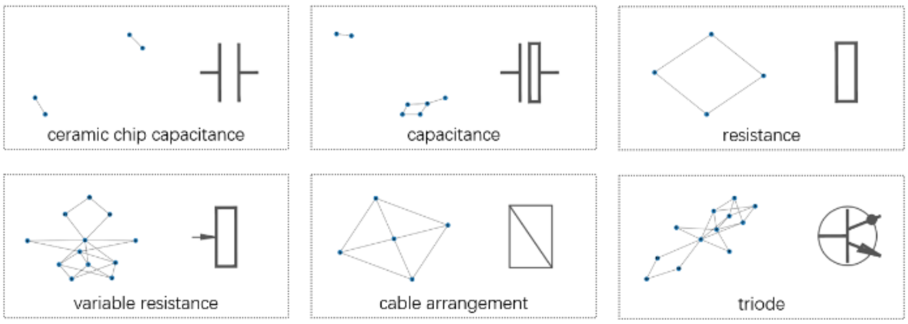

Fig. 1: Circuit symbols and corresponding topology.

2.3. Circuit Symbol Recognition

Different circuit symbols correspond to the number of nodes, node properties and edges of the topology graph are different, in order to identify different types of circuit symbols, you can convert the comparison of circuit symbols and templates in the drawing into a comparison of whether the topology graph is isomorphic [3]. The definition of isomorphism is as follows:

Let two graphs $G = (V, E)$ and $G' = (V', E')$, if there is a double-shot function $g : V \to V'$, so that for any $e(u_i, v_j) \in E$ if and only if $e' = (g(v_i), g(v_j)) \in E'$, and the multiples of e and e' is the same, then called G and G' is isomorphism, noted $G \cong G'$. If the two graphs are isomorphism, it means that the number of nodes in the two graphs is the same, the number of nodes with the same degree is the same, and the number of edges is the same.

Circuit symbol recognition the specific process is as follows:

- Construct Topology graph template for all circuit symbol types;
- The element information extracted in the "Analysis Sheet Structure" is processed as follows: the topology graph is established according to the number of primitives and the position relationship, where the number of primitives is the number of nodes in the map, the element type is the attribute of the node, and if there is a connection relationship between the primitives, Establish edges between nodes;
- Compare the topology graph established in the previous step with the circuit symbol template topology diagram through the isomorphism algorithm, if the two diagrams are isomorphism, then compare whether the attribute types of each node are consistent, if consistent that indicated the circuit symbols is successfully identified, record the type and number of circuit symbols. If the attribute types are inconsistent, need to continue comparing with other templates. If no isomorphism and node attribute type are found after comparison with all the templates, the current circuit symbol is skipped;
- Repeat last step until all established topology diagrams are processed.

3. Identification of Electronic Components in Images

3.1. Prepare Training Data Set

The core of machine learning is to analyze data by imitating people's learning ability, and then make decisions or predictions on the problems to be solved. The goal is to get good results on the new data set after learning, not just limited to the training data set. The so-called training data is a data set with relatively stable and accurate feature description after preprocessing, usually after manual annotation. Training data generally needs as large data samples as possible, and the data is diversified, and the quality of data samples should be high. Before the segmentation and recognition of circuit board, we need to collect the images of various electronic components as the training data set of machine learning. In this study, six types of electronic components were collected. Some images of electronic components came from the network, and some images of electronic components were the images of test circuit boards collected by the author in simulated production environment. Then, each electronic component in the circuit board was extracted into a single image, including 300 pictures of each type of electronic components, a total of 1800 training data sets, an example of a dataset sample is shown in Fig. 2.

Fig. 2: Sample of training data set.

3.2. Expand Training Data Set through Data Augmentation

With the deepening of neural network, the parameters to be learned increased in the meantime, which will more easily lead to over fitting. When the data set is small, too many parameters will fit all the characteristics of the data set rather than the commonness between the data. In order to prevent over fitting, the data augmentation [4] method is used to expand the training data set. In this study, because the camera position is fixed when taking images of the actual circuit board, when taking larger circuit boards, the shape of electronic components on the circuit board will change and shift according to the shooting center point. In addition, the insertion direction of electronic components is not fixed, and the size of some electronic components is not uniform. In order to solve the above problems, the data augmentation method of affine transformation, rotation, flipping and scaling is used. Based on the original 1800 images, the training data set is expanded to 3600 images by using the data augmentation method. The reasons for using data augmentation methods are shown in Fig. 3, Fig. 4, Fig. 5.

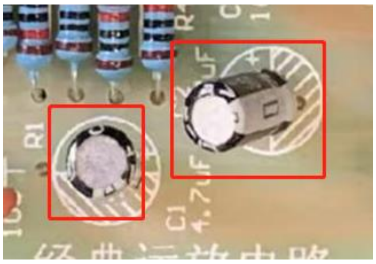

Fig. 3: Capacitance offset image.

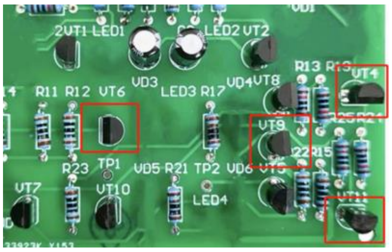

Fig. 4: Triode with different insertion directions.

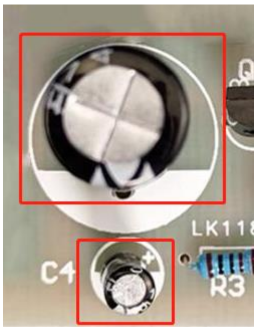

Fig. 5: Capacitors of different sizes.

3.3. Mark Training Dataset

Since the semantic segmentation needs to rely on the image with pixel level mask, the training data set needs to be marked manually. This study uses lableme software produced by the computer science and Artificial Intelligence Laboratory of MIT. The software is an open source annotation software tool, which is mainly used to label image data, mark regions of interest and so on. In order to make the effect of deep learning better, this study uses user-defined polygons to manually edit the region of interest according to the outline of electronic components, the sample of the marked training data set is shown in Fig. 6. After data cleaning, the training data set is converted into JSON (JavaScript Object Notation) format. The JSON file contains the manually marked contour coordinates of electronic components, the type of electronic components, the content of base64 format image and other information.

Fig. 6: Sample of marked training data set.

3.4. Identification of Electronic Components Based on Mask R-CNN

In order to identify the type and quantity of electronic components from the circuit board, this study uses mask R-CNN [5] model for identification. Mask R-CNN model is an instance segmentation model obtained by adding mask semantic segmentation branch to fast R-CNN [6] model. The model can identify different instances from the image using the method of target detection, and then mark them pixel by pixel through the semantic segmentation method, which can accurately classify and identify the electronic components in the circuit board. The model is shown in Fig. 7:

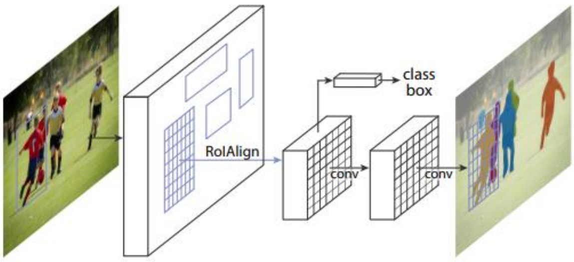

Fig. 7: Mask R-CNN framework.

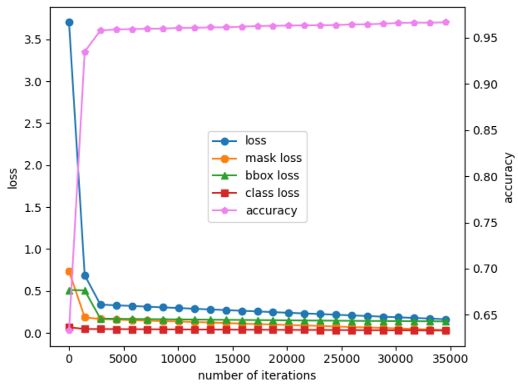

Fig. 8: Parameters of model training.

The model extracts the features of the input image through the backbone network of convolutional neural network [7], and obtains a series of feature maps through FPN (feature pyramid networks) [8], a series of anchor boxes are generated by RPN (region proposal network) [9] to filter the feature map and obtain the candidate region. Finally, the final recognition result is obtained by inputting it into the modules of classification, bounding box regression and semantic segmentation. The loss function of mask R-CNN is defined as the sum of classification, regression and segmentation losses, the definition is as follows:

$L = L_{cls} + L_{reg} + L_{mask}$, where L_{cls} and L_{reg} are classification and bounding box regression losses, L_{mask} is the segmentation loss of the mask segmentation module. During training, the parameters of convolution kernel and model weight are adjusted through continuous gradient descent and back propagation, and finally the target recognition and segmentation are realized. Considering the training time and accuracy, ResNet101 [10] is used as the backbone network. The training parameters are shown in Fig. 8, and the model training results are shown in Fig. 9.

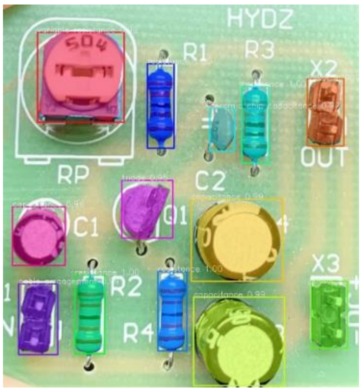

Fig. 9: Identification results of test data set.

3.5. Assembly Integrity Inspection

After obtaining the identification results in the drawings and images, the results of the assembly integrity inspection of electronic components are obtained according to the differences in the calculation of the type and quantity of the two results.

In order to ensure the correctness of the assembly integrity inspection of electronic components, 15 circuit board images and corresponding circuit drawings are used as experimental data, and the experimental data sample is shown in Fig. 10.

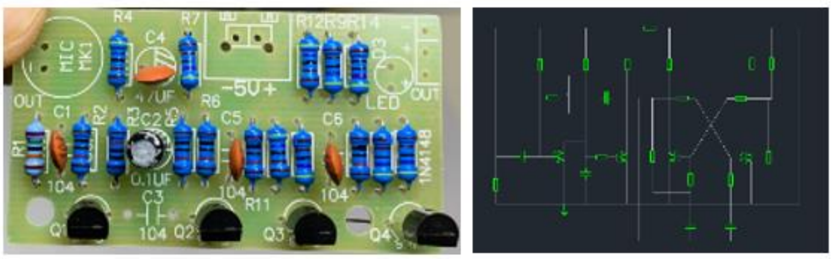

Fig. 10: Sample of experimental data.

The experimental results show that there are 321 electronic components in total, of which 14 drawings are completely correct and 1 drawing has a little error in recognition. On the aspect of electronic component identification, occurs 1 identification error, with a recognition rate of 99.6%. On the aspect of circuit symbols identification, the recognition rate is 100%. 14 completely correct drawings show that the electronic components are assembled completely. Although one drawing is wrong due to identification, it can still assist the inspector to identify which kind of components are wrong and reduce the workload of the inspector. In addition, in order to test the comparison results, several electronic components in the circuit board are removed and compared with the corresponding circuit symbols to obtain the missing electronic components. In case of incomplete assembly, the type of electronic components not installed can be judged according to the number of wire holes and the position relationship, and marked in the image of the circuit board to facilitate the inspection by the inspectors.

4. Conclusion

This study proposes an assembly integrity inspection method for electronic components. First of all, by reading the circuit drawing information, the primitives in the drawing block segment are converted into the form of the topology diagram and the circuit symbol topology diagram template through the isomorphic algorithm to identify the circuit symbol. Secondly, the training dataset of electronic components is trained, and Mask R-CNN instance segmentation model is generated to identify the type and number of electronic components. Finally, the difference between the circuit symbol and the type and quantity of electronic components is calculated electronic components assembly integrity inspection results, which can assist inspectors in judging assembly integrity. This research combines the fields of work and research directions, based on actual needs, has practical significance, and promotes the gradual digital transformation of electronic components in industrial production through new technologies.

However, the recognition rate of electronic components identified by this method is not ideal, because the image is affected by noise, and insufficient data set. Therefore, the future research direction is to optimize the identification of electronic components.

5. References

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