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Detection System for Mobile Phone Interface Circuit Board Assembly Based on Computer Vision

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Abstract: *The quality of Mobile Phone Interface Circuit Board Assembly (MPICBA), as one of the main components of mobile, has a direct impact on the entire performance and service life of the final mobile phone, therefore it is highly regarded and widely worried in the process of mobile phone assembly. At the moment, MPICBA is usually assembled on a semi-automatic assembly line, with low assembly quality and low assembly reliability, relying primarily on manual vision for assembly, which has labor intensity and labor inefficiency issues, and thus cannot meet the stability and reliability requirements of mass production. This paper, titled "Detection System for Mobile Phone Interface Circuit Board Assembly Based on Computer Vision," analyzes the above-mentioned content by studying key technologies for MPICBA, such as image acquisition and processing, image extraction algorithm optimization, and edge algorithm recognition, based on the aforementioned problems. This is used to build and create an detection system for MPICBA using computer vision. This paper analyzes and designs a MPICBA detection system, and proposes a computer vision approach to the detection of MPICBA to address the current problem of low manual efficiency in circuit board assembly, and to achieve online detection and assembly of MPICBA, as well as in the design of the automated system for system stability and repeatability.*

Keywords: *Computer Vision; Detection System; Board Assembly; Mobile Phone Interface Circuit*

1. Introduction

With the good and rapid development of China's economy, mobile phone market demand has increased in recent years, and mobile phone manufacturing businesses' production capacity has increased significantly as a result. The rapid growth of the mobile phone manufacturing business has resulted in the growth of the mobile phone parts and assembly sector as well. MPICBA, as a vital component of mobile phone manufacturers, are extremely worried during this process. This assembly has a complicated circuit configuration and a high level of assembly requirements. The quality of the assembly, as one of the main components of a mobile phone, has a direct impact on the entire performance and service life of the final phone, therefore it is highly regarded and extensively concerned in the mobile phone assembly process. Currently, the assembly of MPICBA is usually completed on a semi-automatic assembly line, which has low assembly quality and reliability, and relies primarily on manual vision for assembly, which has a high labor intensity and low efficiency, and thus cannot meet the stability and reliability of mass production requirements. Because there is no unified method to regulate the assembly of this component, manual production detection has a low efficiency and a high error rate, necessitating the development of a new assembly detection system to address the above problems of modular, intelligent, and information-based assembly. This paper analyzes and designs a MPICBA detection system, and proposes a computer vision approach to the detection of MPICBA to achieve online detection and assembly of MPICBA, and the results show that the system is true and reliable in the design of the automated system for system stability and repeatability of the relevant tests.

2. Characteristics of Computer Vision Technology Development and Classification

Computer vision technology refers to systems that use image sensors to recognize, measure, judge, and classify objects and human targets. This study begins with the gathering of specific images of targets using appropriate technologies. With the rapid advancement of industrial automation and computer technology, computer vision emerged and is now widely utilized in the semiconductor and electronics

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industries, primarily for assembly and surface mount technologies, among other things. It's also used in the electronics manufacturing industry. With the advancement of information technology in this field, this technology is also trying to interface with the Internet of Things.

2.1 Advances in Computer Vision Technology

With the high level of development of the information technology process, computer vision technology began to appear on a broad scale in industrial applications. This study begins with the capture of specific images of targets using appropriate equipment. With the rapid advancement of industrial automation and computer technology, computer vision emerged and is now widely utilized in the semiconductor and electronics industries, primarily for assembly and surface mount technologies, among other things. It's also used in the electronics manufacturing industry. At the moment, computer vision technology is mostly used on a wide scale in China in industries such as tobacco, textiles, video outer packing, and agricultural product color selecting.

2.2 Classification of Computer Vision System and Its Characteristics

The two types of computer vision systems are embedded vision systems and PC-based vision systems.

(1) Embedded vision system: also known as an intelligent camera, this system works by utilizing a highly integrated computer vision system to perform information processing recognition, image acquisition and recording, communication connection functions, and once completed, can be completed alone sampling, analysis, uploading, and other functions, with modular characteristics, high reliability, each part of the functional modules can be achieved individually replaced, and so on.

(2) PC-based vision system: This system meets detection requirements through high configuration, and its chip circuit board is typically implemented with a single chip microcomputer or microcomputer. Furthermore, due to its PC qualities, it is more scalable and versatile in design, and it may be used to increase the customer's requirements at a later time. However, because this sort of system is often larger and requires more installation space, it is not particularly stable and is not widely employed in the industrial environment.

3. Design of the MIPCBA Detection System and Hardware Selection

3.1 Demand Analysis and Detection Requirements

The demand analysis is separated into two major categories: overall technical requirements, and dection requirements for circuit board connector size.

3.1.1 The detection system's general technological requirements

The overall technical requirements are separated into the categories listed below:

(1) Detection Accuracy: detection accuracy is limited by the detection error rate, which must be 0.01% for category A and 0.5% for category B.

(2) Detection Speed: the detection speed is measured as a whole process from assembly line formation to detection completion and insertion into the information base. Among them is a detection time of no more than 8 seconds calculated from the phone interface into the camera line of sight.

(3) Information Input and Result Storage: the results are displayed as qualified and unqualified to identify; statistical data primarily record the number of qualified and unqualified workpieces; the system should be able to work both online and offline, with a corresponding backup to save the image content; and for different models of mobile phone interface circuit boards, the ability to switch between different identification data and identification procedures.

3.1.2 Detection requirements for circuit board connector size

When doing size detection on a circuit board, the assembly should be appraised based on their size, position, and number, and various forms of assembly flaws should be recorded. There are five general types of flaws, which are as follows:

(1) Missing Assembly: missing assembly on the circuit board caused by a collision of assemblies on the assembly line.

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(2) Absent Assembly Procedure: the PCB board printing process is missing.

(3) Mixed Assembly: incorrect or improper chip positions.

(4) Broken Chip Pins: assembly chip pins are missing.

(5) Improper Chip Press Packaging: the chip is not entirely inserted in the circuit board.

3.2 General Systematic Design Plan

Traditional industrial applications of PC-based vision systems have a number of shortcomings, such as long development cycles, poor system stability, and high maintenance costs; in this design, the mobile phone interface circuit board assembly line has limited installation space, so the PC-based vision system installation space is insufficient. As a result, the embedded system is used to carry out the solution design. Figure 1 depicts the general design plan of Detection System for Mobile Phone Interface Circuit Board Assembly Using Computer Vision

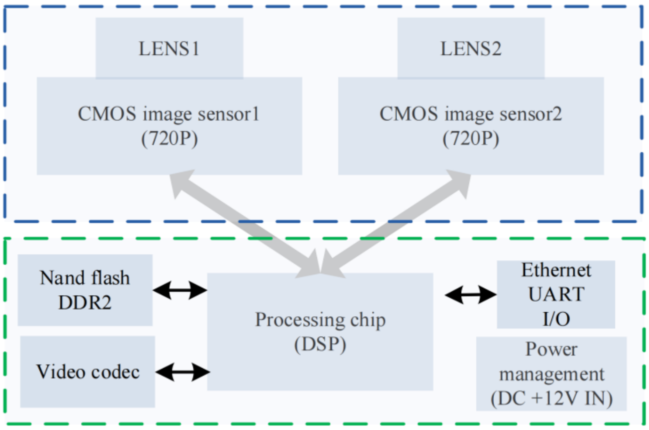

Fig. 1 The General Design Plan of Detection System for Mobile Phone Interface Circuit Board Assembly Using Computer Vision

3.3 Hardware Selection for MIPCBA Detection System

3.3.1 Camera selection

The following are the camera selection criteria:

(1) must be compatible with the image sensor chip.

(2) Determine if the detected object necessitates the line scan digital camera or area-array camera.

(3) Determine whether a color camera is required based on the color resolution specifications.

(4) Determine the camera frequency based on the dynamic detection speed requirements.

(5) Determine the camera resolution based on the detection accuracy needs of the system.

Based on the above design requirements, the camera lens of the charge-coupled device was selected for image acquisition. In summary, the colour camera IS Micro-1400C from Cognex was selected for the circuit board work piece place detection, and the black and white camera IS Micro-1403 was selected for the assembly position work piece place detection.

3.3.2 Industrial lens selection

The following are the selection criteria for industrial lenses.

(1) Working Wavelength, Vari-focal Lens and Fixed-focal Lens: Selection according to working distance.

(2) Depth of Focus and Lens Type: based on camera position and wide angle.

(3) Determination of Image Surface Size and Field of View: determined by the range to be captured.

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(4) Resolution: The camera's resolution is $\frac{1}{2d}$, and the resolution unit is $\mathrm{lp/mm}$ (line pair/mm). The black and white stripe spacing should ideally be $\sigma = 1.22\lambda \cdot F$, where the centre wavelength is λ, F is the derivative of the relative aperture. As a result, the lens's resolution can be computed using the following formula:

$$N_L = \frac{1}{1.22\lambda \cdot F} \tag{1}$$

The maximum resolution of a machine vision system is determined by the resolution of the image sensor picture elements. The resolution of a picture element is defined as half the number of pixel units per millimetre, i.e.

$$N_F = \frac{1}{2P} \tag{2}$$

The pixel unit’s size is denoted by the letter P.

In summary, the detecting work piece place employs a Computar industrial lens, model M2514-MP2, which has a fixed focal lens and an aperture that may be manually adjusted.

3.3.3 Selection of light source and lighting method

There are three types of light source lighting:

(1) Halogen Lamp: high light brightness, but generates a lot of heat and has a slow response.

(2) Fluorescent Lamp: homogeneous light, low brightness, slow response, suited for irradiating wide areas.

(3) LED: stable light, long life, no strobe effect, but poor homogeneity.

The design uses LED light source as the image acquisition external trigger light source photo light. The circuit board detecting work piece place selected an OPT company OPT-RI9000 white ring light source and used direct lighting, whereas the assembly position detecting work piece place selected an OPT company OPT-RI9030 red ring light source and used low-angle illumination.

3.3.4 Selection of the I/O modules

Because the I/O module requires CC-link functionality for field communication, the Cognex CIO-MICRO-CCI/O module was employed.

4. Image Pre-processing of Mobile Phone Interface Circuit Board Assembly

4.1 Overview of Digital Image Pre-processing Strategy

Digital image processing is the process of converting an image signal into a digital signal. A two-dimensional function $f(x, y)$ represents an image, with the x and y representing the spatial coordinates, and a grey-scale image $f(x, y)$ being the grey-scale value at the point (x, y).

4.2 Pre-processing Strategy based on Image Enhancement

Image enhancement is accomplished by changing the original image to conduct a Fourier transform, a technique based on the frequency domain modification of pixel points that is handled by image enhancement in the equation below:

$$g(x, y) = T[f(x, y)] \tag{3}$$

where $f(x, y)$ is the gray value of the input picture at (x, y); $g(x, y)$ marks the point after (x, y)’s spatial domain enhancement algorithm processing of the gray value of the output image; and T is the pair of f in the spatial domain enhancement algorithm. Figure 2 depicts a schematic representation of the aforesaid strategy method:

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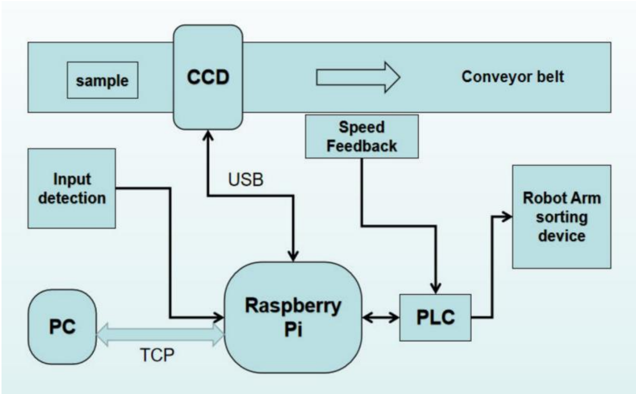

Fig. 2 A Flow Chart Depicting an Image Enhancement-based Pre-processing Strategy.

4.2.1 Equalization of histograms

The probability of occurrence of a grey level r_k in an image can be approximated by the following equation:

$$P_r(r_k) = \frac{n_k}{n} \quad k = 0,1,2,\cdots,L-1 \tag{4}$$

In the above equation, the grey level r_k is the function $P_r(r_k)$ of the normalised histogram of the image. Where n is the total number of pixels, n_k is the number of pixels in the image with a grey level, and L represents the range of grey levels in the image. The histogram equalisation formula for an image is given by:

$$s_k = T(r_k) = \sum_{j=0}^{k} P_r(r_j) = \sum_{j=0}^{k} \frac{n_k}{n} \quad k = 0,1,2\cdots, \quad L-1 \tag{5}$$

Therefore, the output image s_k is converted from the above equation to the pixel values in the input image with a grey level of r_k.

4.2.2 Grey level transformation

The grey level transformation is mainly achieved by a linear transformation, the result of which is shown in Figure 3.

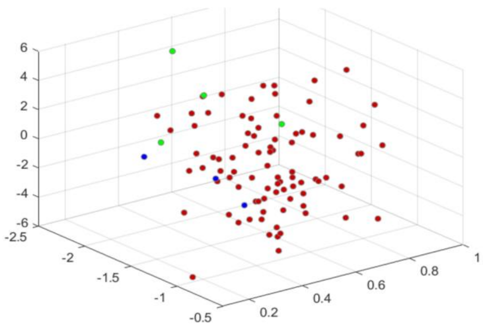

Fig. 3 Schematic d\Diagram of the Grey Level Transformation Results

4.2.3 Overview of the result analysis method

This design performs original image analysis by means of a grey level stretching transformation method to facilitate subsequent processing.

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4.3 Image Sample filtering

Image filtering is derived from band-specific filtering in the communications industry and is widely used in image acquisition. Image edge noise can affect the high frequency part of the sampling and cause confusion in the image, whose original and unfiltered images are shown in Figures 4 and 5 respectively.

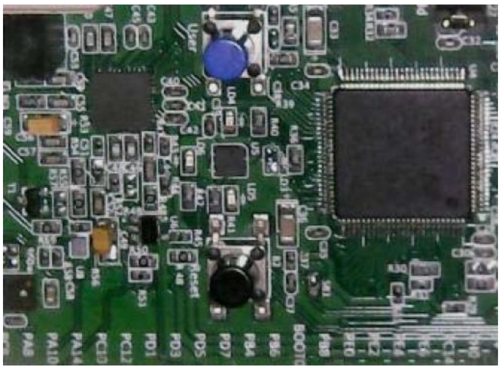

Fig. 4 Original Image of Circuit Board

Fig. 5 Sampling Diagram of a Circuit Board subject to Interference

4.3.1 Mean filtering

Mean filtering is a linear filtering algorithm in which the sampling neighbourhood averaging method determines a filter mask and replaces the original grey level value with its neighbourhood pixel average. This is shown in the following equation:

$$g(x,y)=\frac{1}{m}\sum_{i=1}^{m}f(x,y) \tag{6}$$

where, m is the total number of pixels in the mask.

The filtering results are shown in Figure 6 below.

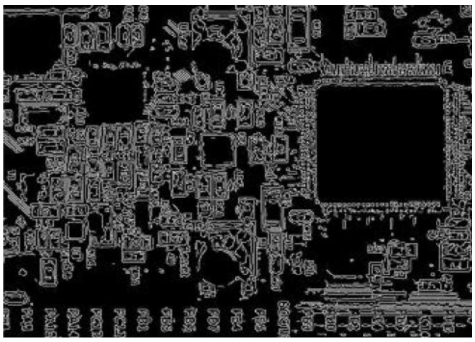

Fig. 6 Sampling Diagram of Circuit Board after Mean Filtering

4.3.2 Median filtering

The median filter is developed by sorting the filter window from largest to smallest and by outputting the median value as the central pixel point grey level. The diagram is shown in Figure 7 below.

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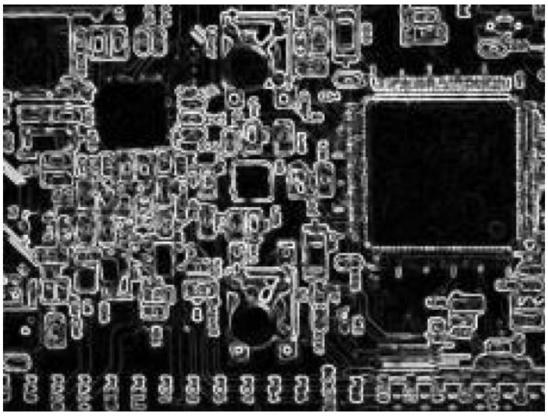

Fig. 7 Sampling Diagram of the Circuit Board after Median Filtering

4.3.3 Gaussian filtering

Gaussian filtering is linear smoothing filtering, by pixel point itself and within the shower pixel value weighted average, through the template of the scan results of the weighted average grey level instead of the original pixel point value, its schematic diagram is shown in Figure 8.

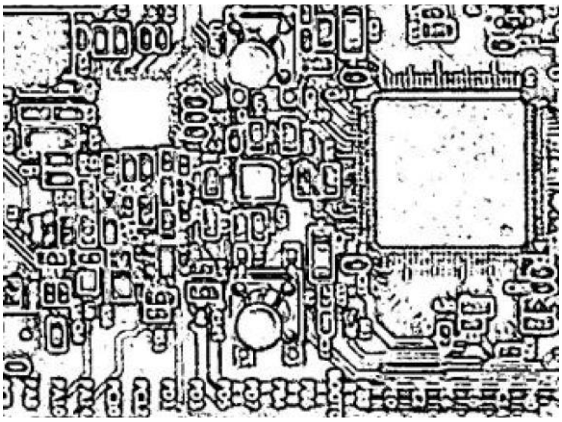

Fig. 8 Sampling Diagram of Circuit Board after Gaussian Filtering

5. Mobile Phone Interface Circuit Board Assembly Detection Algorithm Research

5.1 Edge Detection

As one of the most significant features of an image, edges are generally sampled using first-order or second-order differential, as shown schematically in Figure 9.

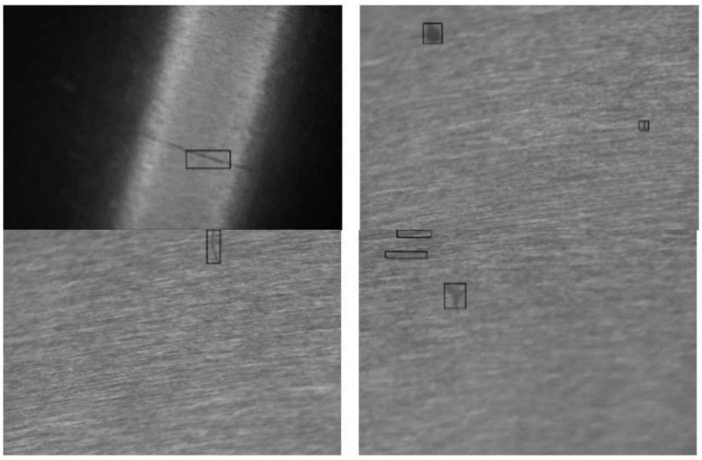

Fig. 9 Schematic Diagram of Edge Detection

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5.1.1 First-order differential edge detection

First-order differential detection is performed by measuring the Euclidean length of the gradient phase volume and then applying the template with the Robers operator for edge response detection, the algorithm of which is shown in Figure 10.

```
#refference image
cannyr = cv2.Canny(reff,100,200)
#test image
cannyt = cv2.Canny(test,100,200)
#subtraction test
```

Fig. 10 First-order Differential Edge Detection Algorithm Code

5.1.2 Second-order differential edge detection

Second-order differential edge detection is performed by means of a second-order differential operator, which reduces the noise sensitivity by the double edge effect of the Laplace operator, making the edges more curved. The algorithmic strategy is shown in Figure 11.

```
ddepth = cv2.CV_64F #output image depth
ksize = 3 #3x3 common sobel masking matrix
#refference image
sobelrx = cv2.Sobel(reff,ddepth,1,0,ksize)
#hor grad
sobelry = cv2.Sobel(reff,ddepth,0,1,ksize)
#vert grad
sobelr = (sobelrx*sobelrx +
sobelry*sobelry)**0.5
cv2.imwrite('sobelreff.jpg',sobelr)
#test image
sobeltx = cv2.Sobel(test,ddepth,1,0,-1) #hor
grad
```

Fig. 11 Second-order Differential Edge Detection Algorithm Code

5.2 Template Matching Strategy

5.2.1 Template matching strategy based on Grey Level Value

This strategy mode is implemented by calculating the similarity between the template and the image to be searched, and its matching strategy is shown in Figure 12.

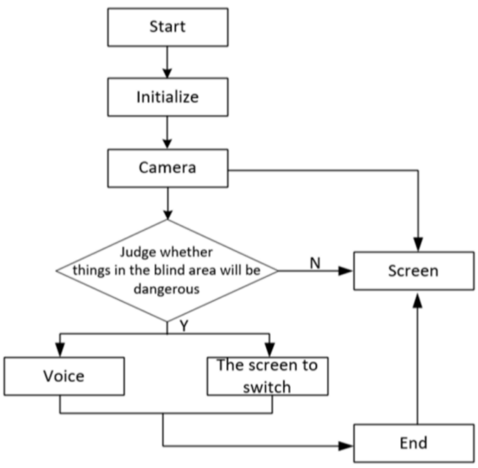

Fig. 12 Flowchart of a Template Matching Strategy based on Grey Level Value

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This strategy is generally used for geometry matching.

5.2.2 Template matching strategy based on circuit board geometric features

This strategy matches significant geometric features of an image by level scaling, which is shown schematically in Figure 13.

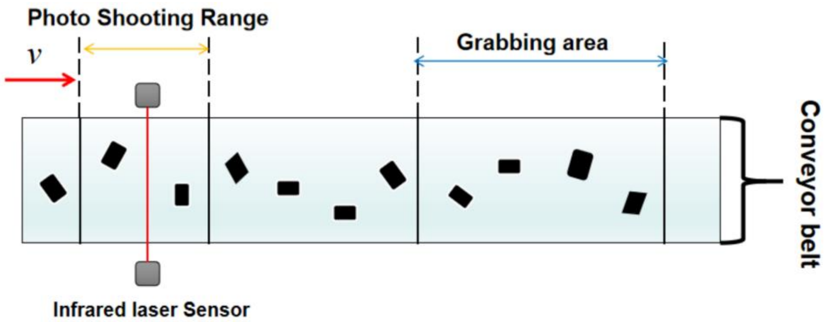

Fig. 13 Schematic Diagram of Template Matching based on Circuit Board Geometry Features

5.3 Colour Detection

Common colour models are RGB (red, green, blue), HSI (hue, saturation, luminance), HSV, CHL, LAB, CMY, etc. The colour characteristics are generally displayed by model overlay colour gamut discrimination, the flow of which is shown in Figure 14 below.

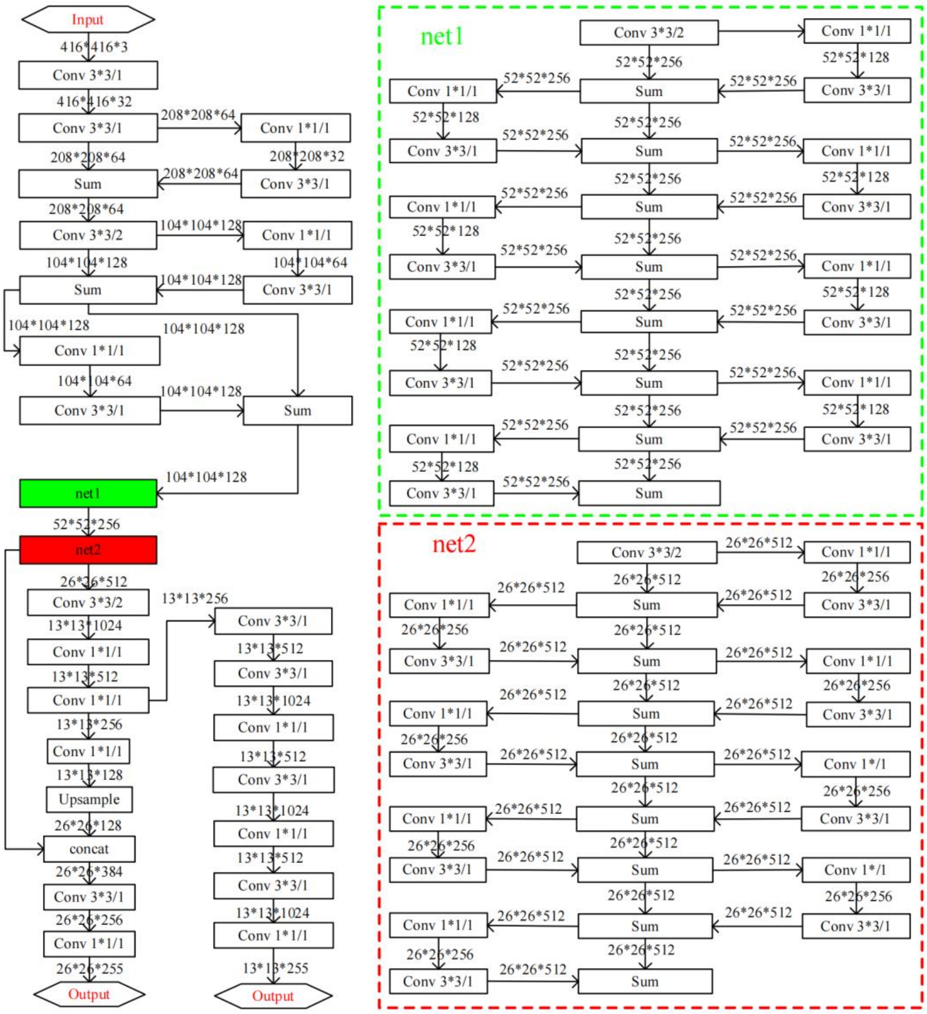

Fig. 14 Flowchart of Template Matching based on Circuit board Colour Features

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6. Conclusion

This paper proposed and implemented a detection system for mobile phone interface circuit board assembly based on computer vision. A systematic analysis of the above has been carried out by studying the key technologies for MPICBA, such as image acquisition and processing, image extraction algorithm optimization, edge algorithm recognition, and other aspects, on which a detection system for MPICBA has been designed and developed. The purpose of this study is to analyze and build a MPICBA detection system. To address the existing problem of low manual efficiency in circuit board assembly, a computer vision technique to detecting and assembling mobile phone interface circuit board assemblies is offered. In addition, necessary tests on system stability and repeatability are performed during the automated system's design, and the results prove that the system is real and reliable.

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