

Development of Software System for Detecting Defective Symbols on Integrated Circuit Chip with Adjustable Readability Level

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Abstract

In semiconductor fabrication process, symbol or label inspection is one of the main processes that need to be considered seriously. Errors may occur during the printing process of label or name on the integrated circuit chip (IC). If this occurs, the IC chip may have a wrong name. Providing a reliable detection system that is able to detect the errors printed on the IC chip can solve the problem mentioned above.

The symbol detection system that currently being implemented by the semiconductor industry suffers from overkilled and escaped problems. This paper presents the development of a software system, which capable of detecting the defective characters printed on the IC chip using Active Matrox Imaging Library Release 7. The proposed system has an adjustable reading level that can solve the problems mentioned above.

1. Introduction

The character recognition system has many applications. These include license car plate number verification [1], verification of postcodes in handwritten and hand-printed addresses [2], money transfer forms and cheques used by banks

[3], etc. In semiconductor fabrication process, symbol or marking inspection is one of the main processes that needs to be considered seriously.

Symbol or marking inspection algorithms have changed very little since their introduction onto the semiconductor industry in the late 80's. On the contrary, customers' quality requirements have increased many folds. They will no longer tolerate the packing errors such as wrong symbol printed on the IC, unclear characters on IC, etc. At the same time, manufacturers face the problems of overkilled or escaped IC chip. The current inspection system cannot solve the overkilled and escaped problems. Overkilled event occurs when the inspection system rejects the IC, which has a minor error printed on the IC chip. The characters printed on the IC chip can still be read with bare human eyes. However, if this problem is not rectified, the manufacturer will lose its profits. Meanwhile, the escaped event will occur when the inspection system is unable to detect the error printed on the IC chips. This problem will cause the manufacturer to lose its customers because the manufacturer provides wrong or defective IC chips.

The IC chip defective symbols can be classified into four classes. They include illegible symbols, missing symbols, wrong orientation and wrong device symbols. Figure 1 illustrates the

percentage of the occurrences of these defective symbols in the symbol inspection process using the current symbol detection system in the semiconductor industry [4].

The percentage of the illegible symbols printed on the IC chip is 60%, and it is the highest marking fallout. The second highest percentage marking fallout is the wrong orientation, which is about 35%. On the other hand, 3% and 2% are the percentages of marking fallouts caused by the wrong device and the missing symbols, respectively.

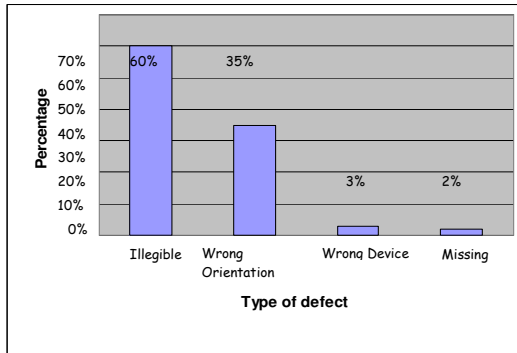


Figure 1: Percentage of marking fallouts for IC chip

The current marking inspection system implemented in the industry needs to be improved since it has several drawbacks such as the system is not user friendly, especially for the operators to operate the system, it has problems of overkilled and escaped of the IC chips, and it is still human dependent. If the problems are not rectified properly, the manufacturer will lose its customers and profits. Based on these problems, an inspection system capable of detecting the defective characters as well as solving the problems mentioned above is proposed.

2. Architecture of the Proposed System

The architecture of the proposed marking inspection system is illustrated in Figure 2. The Graphical User Interface (GUI) enables user to see what happens at each step from the beginning to the end of the system process. The GUI is the interaction between the inference engine and the input or output image ports. The output image port is used to deliver the output recognized results of the IC chip images after going through the image processing procedures of the system. The input image port is used to collect the IC image that is schedule to be

processed by the system.

The inference engine contains an image-loading module, an image processing module, a character recognition module and a readability level module. The inference engine interacts between the GUI, the images database and the on-line interface module. It is designed to control the entire operation of the system.

The ActiveMIL ActiveX control module is used to link the Matrox Imaging Library with the inference engine and the rest of the system. The proposed system is developed using Microsoft Visual Basic Version 6.

The Matrox Imaging Library (MIL) is a high-level programming library with an extensive set of optimized functions for image processing and optical character recognition (OCR), etc.

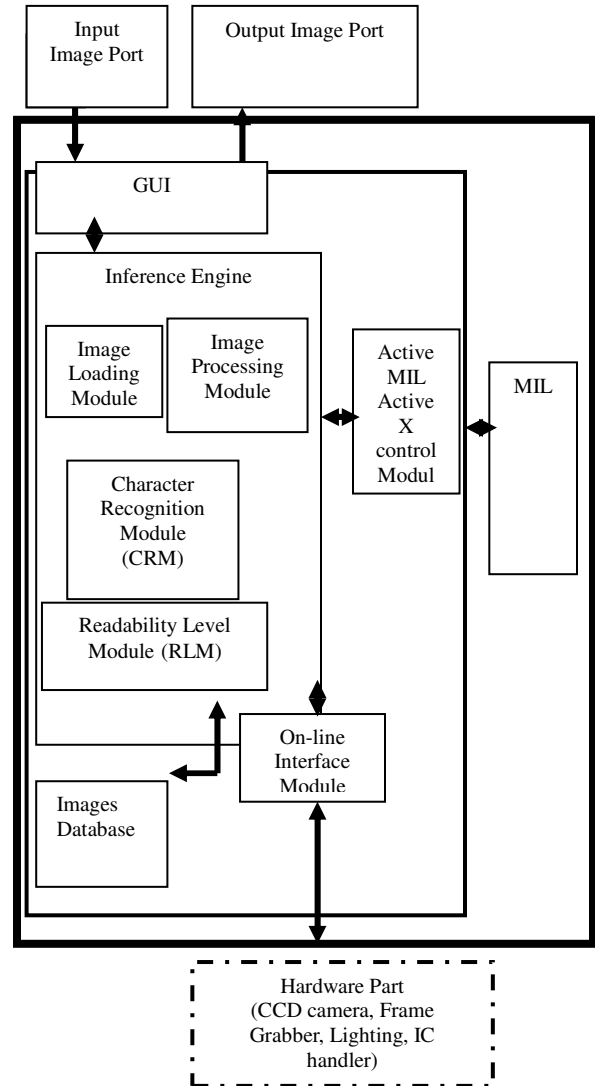


Figure 2 : Architecture of the Proposed Marking Inspection System

The device image database keeps and manages the data of the IC chip images. The on-line interface module is used to link the proposed software system to the hardware system. The hardware system such as a CCD camera, a frame grabber, a lighting module and an IC handler is used during the on-line operation.

3. Methodology

Figure 3 shows the flowchart of the proposed system.

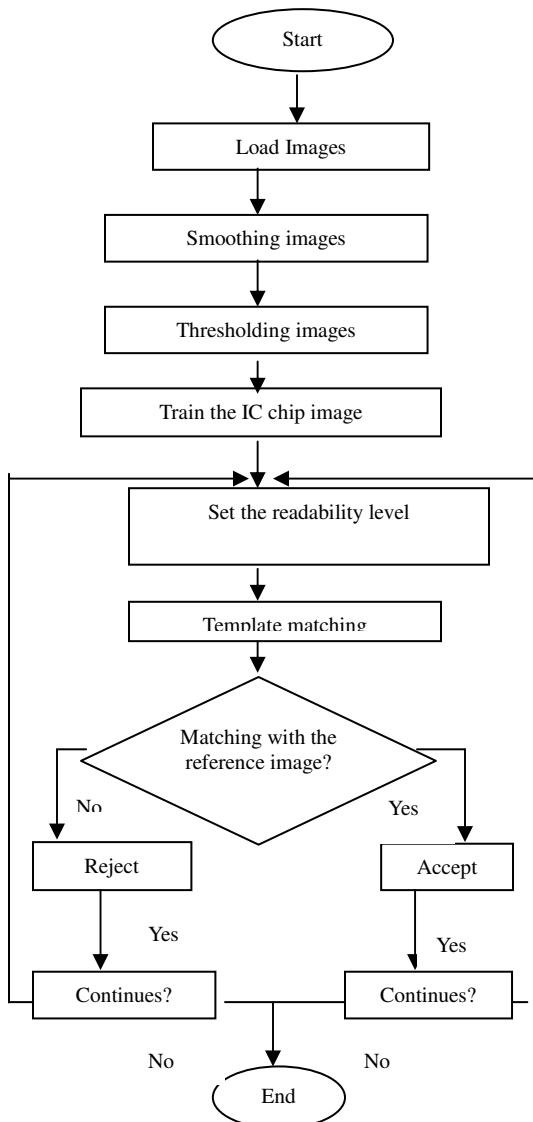


Figure 3: Flowchart of the proposed system

Firstly, the IC chip image is loaded from the bitmap file for analyzing. The user can select the IC chip image to be analyzed. Since the input IC chip image has noise, therefore the smoothing

process of the image is needed to reduce the noise. After the smoothing process is done, the thresholding operation process is performed (clipping) to separate the region of interest of a specific character to be analyzed and to binarize the grayscale level of the image. Then, the output result of the thresholding operation process is trained by the OCR controller and the image is stored as a reference image.

The perfect IC chip image must be trained first. The data of the trained image is referred as the reference image to be compared with the defective image of the IC chip symbol. The system introduces a new readability level algorithm. If the value of the readability of the slider is set to 100%, it means that the system would not accept any defective character. If the value of the slider is reduced to, let say 90%, it means that the system would accept about 10% defect presents in the character. The proposed system uses the template matching method to recognize the characters of the IC chip image. The template matching operation method is activated by pressing the 'read string' button. The template matching method is adopted in the proposed system for matching the input image sample with the reference image. The comparison between the reference image and the input image sample would produce the output results whether the character of the IC chip image would be accepted or rejected.

Generally, the proposed system could be operated either by using manual or automatic mode. The manual mode is used to check the individual function of components of the system. For example, to check the 'Load' button effect. In this mode, the system would wait the input from the user to move from one operation to another operation. The automatic operation is used to run the detection process automatically without any assistance from the user. This mode can be activated by pressing the 'Automatic Process' button. The selected module included in the inference engine will be discussed in the following section.

3.1 Readability Level Method

The readability level module is designed to reduce the overkilled and escaped problems in semiconductor industry. The readability level module is created on the form window by the slider control. By scrolling out the slider control, the user can set the readability level value of each character on the image. The readability level is linked to the read string button operation. The operation process of the readability level is

illustrated in Figure 4.

For example, if the readability level is set to 100%. After the read string operation is activated, the graylevel value of the input image is compared to the of the reference image. If the graylevel value is not equal to the reference image, then the image would be rejected. Otherwise, it would be accepted. In another example, if the slider value is set to 70%, the value of the graylevel input image is compared to the graylevel value of the reference image. If the graylevel value is between 70% to 100%, then the image would be accepted, otherwise the image would be rejected. The readability level test is also carried out to check the effectiveness of the proposed software system.

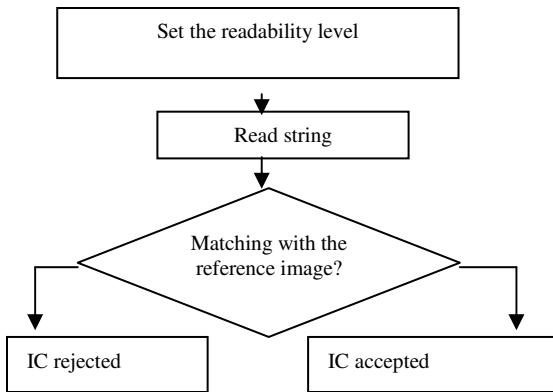


Figure 4: Flowchart of readability level module

4. Results and Dissussion

The tests of the proposed system include functionality testing of each component of the software such as load image, smoothing, thresholding, read string, readability level adjustment slider, text display and statistical display. The major tests, i.e., readability level test, accuracy test, overkilled and escaped test of the software were also conducted. The image tested in this project consists of 340 IC chip image samples. They represent four different types of defective symbols. The four types are illegible symbols, wrong orientation symbols, wrong device symbols and missing symbols. The sample images were provided by the Texas Instrument Malaysia. Only selected results are presented in this paper.

4.1 Readability Level and Overkilled Tests

The detail discussion of readability level technique is presented in Section 3.1. Readability level is the ability of each character printed on IC chip images to be recognized by human eyes. The proposed system provides the readability level technique to reduce the overkilled and escaped problems. Its algorithm is developed using the OCR controller. Figure 5 shows the readability level that is set to 100% for testing the defect character ‘2’ printed on the IC chip image. Although the human eyes can recognize the first character as ‘2’, the system detects it as defective character. Therefore, the system rejects the IC. This would cause the overkilled problem to occur as shown on the screen window in Figure 5.

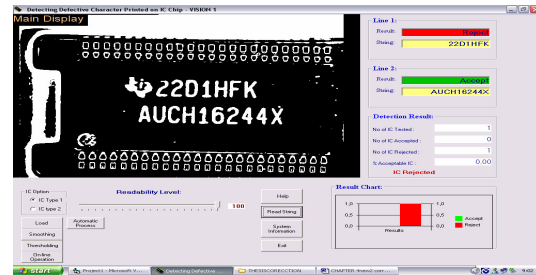


Figure 5: The readability level is at 100% that causes the overkilled IC chip

The advantage of this system is that its readability level can be adjusted to solve the overkilled problem. This is demonstrated in the following example. When the system processes the same image with 95% readability level, the result indicates that the system accept the IC characters printed on it as readable as indicated in the display of the system in Figure 6. This would solve the overkilled problem.

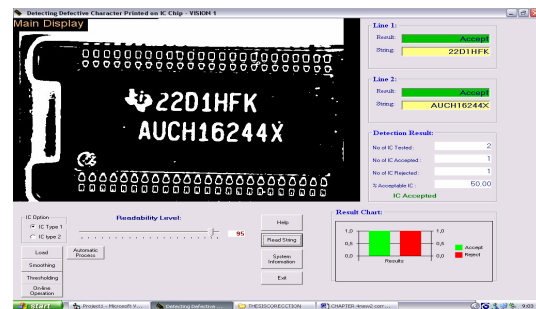


Figure 6: The readability level is set at 95% to eliminate the overkilled IC chip

4.2 Accuracy Test

The accuracy test is a test that is used to tune the system. The system was tested with a good IC chip image sample. The detection of the good IC chip image was carried out before the test of the defective symbol. During the accuracy test, the gray level of the image was computed. The gray level of each character printed on IC chip image is based on the average value, which is computed by the OCR controller.

Twenty tests were conducted to detect the good and defective IC chip image samples. The detection operation of the IC chip image is based on the AND logical operation. This operation is classified into two categories. The first category is a local detection and the second category is a global detection. The local detection detects the individual character, while the global detection monitors the results of all local detection.

According to the AND gate operation for characters of IC chip image, if all the characters printed on IC chip are perfect or acceptable, the output of the detection result is 'accepted'. On the other hand, if one of the characters printed on IC chip is false or rejected, then the output of the detection result is 'rejected'. Figure 7 shows the accuracy test for good IC characters and Figure 8 demonstrates that the proposed system can detect the missing character on the first line of the characters printed on the IC chip.

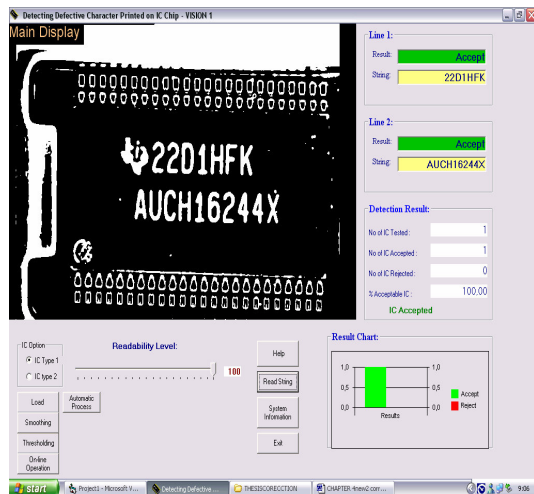


Figure 7: Test result for good characters IC chip

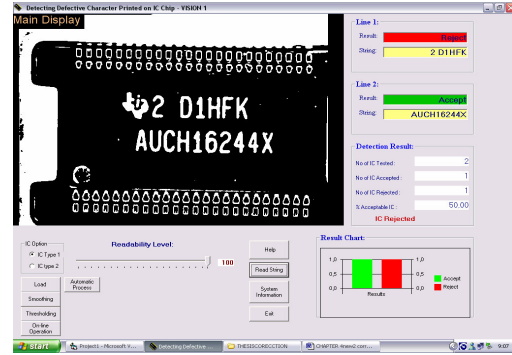


Figure 8: Test result of missing character IC chip

4.3 Escaped Test

From the previous test, the proposed system is capable of testing any defective IC chip image. The perfect or good IC chip image is accepted when the setting of the readability level value is 100. Therefore, the detection results of any type of defective IC chip are rejected because the gray level of the input IC chip image is not equal to the gray level of the reference image. Hence, the proposed system can solve the escaped problem.

4.4 Data of the Experimental Results

Table 1: Experimental results of the accuracy and readability tests for the IC1 chip images

Type of IC chip images testing	No of test	No of accepted	No of rejected	Ability testing (%)
Good IC chip images	20	20	0	100
Illegible symbol IC chip images	20	0	20	100
Missing symbol IC chip images	20	0	20	100
Wrong orientation IC chip images	20	0	20	100
Wrong device IC chip images	20	0	20	100
Readable IC chip images	68	68	0	100
Total	168	88	80	100

From the test results as shown in previous Figures 5 to 8, the recognition of the IC chip images were successfully carried out. The tests

were conducted on six different types of IC chip images such as the good IC chip images, illegible symbol IC chip images, missing symbol IC chip images, wrong orientation symbol IC chip images, wrong device IC chip images and the editable IC chip images. The proposed system used 340 samples of IC chip images for testing the detection operation process. The experimental results of IC chip image tests are tabulated in Tables 1 and 2. Tables 1 and 2 show the ability testing in every type of the IC chip images. The results indicate that the system performs according to its functions. The data from Tables 1 and 2 show that the good, defective and readable symbols were detected by the proposed system correctly. The percentage of the detection results of the IC chip image is 100%. This represents that the system was successfully designed and implemented. Based on the high percentage of the detection results, the proposed system can detect any type of defective IC chip images.

Table 2: Experimental result of the accuracy and readability test for the IC2 chip images

Type of images testing	No of test	No of accepted	No of rejected	Ability testing (%)
Good IC chip images	20	20	0	100
Illegible symbol IC chip images	20	0	20	100
Missing symbol IC chip images	20	0	20	100
Wrong orientation IC chip images	20	0	20	100
Wrong device IC chip images	20	0	20	100
Readable IC chip images	72	72	0	100
Total	172	92	80	100

5. Conclusions

The design and implementation of the software system for detecting defective symbols on IC chip with adjustable readability level was presented and discussed. It is capable of eliminating the overkilled and escaped problems

occur in the semiconductor industry. All the objectives set up for this project have been achieved successfully. The features of the system such as the GUI, inference engine, various buttons and displays, etc were successfully designed, implemented and tested. The system can be operated either by manual or automatic modes. The detection accuracy of this system is 100%. As a conclusion, the proposed system is successfully developed and tested to solve the semiconductor industry problems.

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