UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF AN OPTICAL CHARACTER RECOGNITION FUNCTION SYSTEM FOR INTEGRATED CIRCUIT LABEL CLASSIFICATION USING NEURAL NETWORK

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By

VASAN MARIAPPAN

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia in partial fulfilment of the Requirements for the Master of Science.

December 2007

DEDICATION

This piece of work is dedicated to :

The Light and Sound of God,

My Loving Father: late Mr. Mariappan Subramaniam,
My Loving Mother: Mrs. Anjalai M.,
My Wife: Raja Devi Raja Gopal V.,
My Son; Vengkdes Raaja Vasan,
My Daughter; Jaivaisnavi Devi Vasan,
My Sweet Sisters: Subathiradevi Muru, Prema Narayana Chetty & Elamathiy Thana.
My In-Laws: Dato Raja Gopal & Family.
My Loving Amma: Margherita Pospischil.
All my friends,
And to the Humanity.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirement for the degree of Master of Science.

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December 2007

Chairman: Associate Professor Megat Mohamad Hamdan Megat Ahmad, Ph D.

Faculty : Engineering

Presently, many Integrated Circuit (IC) manufacturers are applying machine vision solution to ensure the legibility of characters printed on the top surface of IC Package. In template matching technique there are about 10% of ICs rejected due to very little defects in quality of marking even though the characters are correct. The objective of this project is to develop an IC inspection system that has optical character recognition function system by using neural network. Feed forward back propagation neural network method is used in this task. The system developed is able to read 36 characters (A to Z and 0 to 9) printed on ICs. The recognition time in template matching is 650µs. In neural network technique, by feeding-in Raw Data, Feature, and Hybrid (combination of Raw Data and Feature), they clock 18.22µs, 15.64µs and 19.32µs respectively. The recognition accuracy is 96.26% for the former and 98.25%, 98.83% and 99.61% for the latter. This is a solution to minimise rejects of ICs in manufacturing process. The reduction of processing time in manufacturing process contributes to the increase of productivity. Moreover, application of this technique gives a solution to avoid mismatch of parts (ICs) in manufacturing lots.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN FUNGSI SISTEM PENGECAMAN AKSARA OPTIK BAGI MENGKLASIFIKASI CETAKAN DIATAS LITAR BERSEPADU DENGAN MENGGUNAKAN RANGKAIAN NEURAL

Oleh

VASAN MARIAPPAN

Disember 2007

Pengerusi: Profesor Madya Megat Mohamad Hamdan Megat Ahmad, Ph D.

Fakulti : Kejuruteraan

Pada masa ini, kebanyakan pengeluar litar bersepadu (IC) menggunakan penglihatan mesin bagi memastikan aksara yang dicetak pada permukaan IC adalah betul. Melalui teknik padanan cetakan asal, terdapat lebih kurang 10% IC yang tidak diterima oleh kerana ianya tak cukup padan dengan cetakan asal walaupun aksaranya adalah betul. Objektif projek thesis ini adalah untuk menghasilkan satu sistem pemantauan visual yang mempunyai fungsi sistem pengecaman aksara optik dengan menggunakan kaedah rangkaian neural. Di dalam rangkaian neural kaedah "Feed Forward Back Propagation" di gunakan dalam menghasilkan sistem pengecaman ini. Sistem ini berupaya membaca 36 aksara (iaitu dari A ke Z dan dari 0 hingga 9) yang tercetak pada permukaan IC. Tempoh pengecaman aksara melalui teknik padanan cetakan asal adalah 650µs. Melalui kaedah rangkaian neural, dengan suapan sebagai Data Asli, Cirian dan Hybrid (kombinasi Data Asli dan Cirian), masa yang diambil untuk pengecaman adalah 18.22µs, 15.64µs dan 19.32µs. Kejituan pengecaman adalah 96.26% bagi padanan cetakan asal dan bagi rangkaian neural adalah 98.25%, 98.83% and 99.61%. Ini merupakan salah satu cara untuk mengurangkan penolakan/tidak terima di dalam proses pembuatan IC. Pengurangkan masa pemproses merupakan faktor untuk menambahkan produktiviti. Malahan, aplikasi teknik ini adalah satu kaedah untuk mengelakkan kesalahan aturan IC di dalam lot pembuatan.

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Through God's Grace and His Blessings, this piece of work was completed. From the bottom of my heart, I am thanking the Light and Sound of God, the force within me that did this work and still keeping on moving forth. This is just another beginning, another step in my own individual path.

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The most important of all, I would like to express my deepest appreciation and thanks to my parents, wife, son, daughter, sisters and my in-laws for their love, encouragement and patience. I see this world through my father's eyes. He has given the best education that he can afford. It is because of his initiative and effort for what I am right now. He lives in me.

I certify that an Examination Committee met on___________to conduct the final examination of VASAN MARIAPPAN on his Master of Science thesis entitled “DEVELOPMENT OF AN OPTICAL CHARACTER RECOGNITION FUNCTION SYSTEM FOR IC CLASSIFICATION” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 12 June 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

VASAN MARIAPPAN

Date: 19 August 2008

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
BP	Back Propagation
DTCNN	Discrete Time Delay Cellular Neural Networks
DIP	Digital Image Processing
GUI	Graphic User Interface
IC	Integrated Circuit
LPR	License Plate Recognition
OCR	Optical Character Recognition
PCNN	Pulse Coupled Neural Network
PNN	Probabilistic Neural Network
ROI	Region of Interest
TDNN	Time Delay Neural Network

CHAPTER 1

INTRODUCTION

1.1 Visual Inspection in IC Manufacturing

Inspection is the process of determining whether a product deviates from a given set of specifications (Newman and Jain, 1995). Usually, computer vision techniques are employed in the inspection operation to automate the manufacturing process and improve the quality control.

In the manufacturing of integrated circuits (ICs), the ever-decreasing physical dimensions of IC devices as well as the high volume of production of these devices make it increasingly difficult for humans to identify the defects. As a result, computer vision has become very essential to automate the IC manufacturing process (Nello, 1993; Pau, 1990). In almost every stage of the IC manufacturing process, computer vision is applied to check and evaluate the quality of the manufactured IC devices.

In the IC manufacturing process, there are a number of standard inspection procedures including MIL-STD-883-D (Military Standard-Test Methods and Procedures for Microelectronics, 1990) which is the visual inspection criteria for military products specified by Department of Defence of USA, and other specifications given by ESA, NATO or national equivalents (Pau, 1990). The standard inspection procedures specify the criteria for a wide range of defect types and can be adopted according to specific manufacturing requirements.

A typical inspection procedure after wafer fabrication is shown in Figure 1.1 (Owen et al, 1989; Huang, 1983). For more details about inspection and fabrication process in IC manufacturing can be referred to Pau (1990), MIL-STD-883-D (1990) and Elliot (1989).

The main objective of the first optical inspection is to ensure the quality of the produced wafer in which most manufacturing steps are performed. It is for this reason that most of the inspection of IC chips occurs at the wafer level. In the wafer fabrication process, silicon wafers are patterned using masks that contain the circuit geometry. During the process, various inspection operations including pattern inspection, particulate contamination inspection and detection of other causes of electrical faults may be performed after the photomask/reticle inspection (Dom and Brecher, 1995). Furthermore, the wafer labels that are printed on wafers using laser etch techniques, are identified and recognised using computer vision based techniques to simplify lot tracking, wafer probing alignment and process control (Pau, 1990).

The second optical inspection, also called die high power inspection, occurs after the wafers are sawed (or diced) into individual dies or chips. Defects on the dies to be detected at this stage include missing probe marks, cracks, chipped edges, metalisation or passivation defects, contaminants, etc (Huang, 1983).

The third optical inspection (Negin, 1985) which is often called 'pre-cap' inspection, is performed after wire bonding and just before the encapsulation of the IC chips. Bonded wires are inspected to locate defects such as broken wires, missing wires, insufficient wire clearance, incorrect wire path, lifted wires, tight wires, and sagging wires. In addition to the bonded wires, the inspection task also includes some of the die defects inspected in the second inspection.

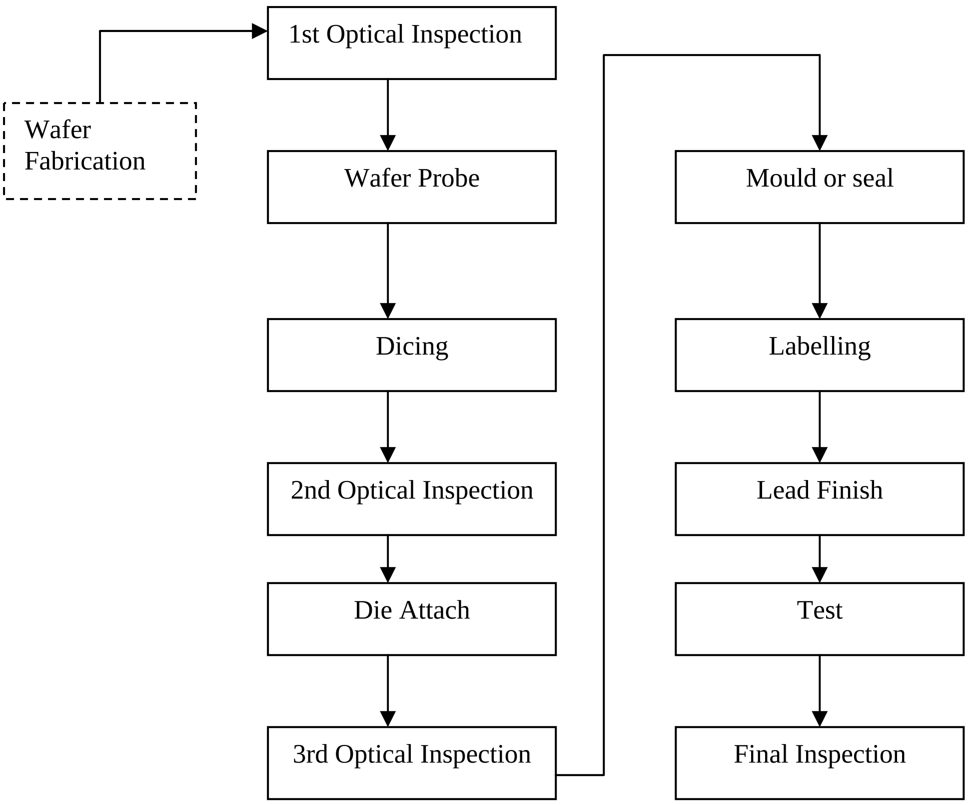

Figure 1.1: Typical procedures of IC manufacturing and inspection after wafer fabrication

The final inspection or visual/mechanical (VM) inspection (Christian, 1987), is the last visual inspection of the IC product before it goes to the customer or into the Printed Circuit Board (PCB). The objective of the final inspection is to detect the defects of IC packages caused in the earlier stages including die attachment, soldering, molding and labelling stages, as well as mechanical damages due to handling. The technical progress in the IC chip manufacturing and packaging (Marts, 1996) makes it the current trend to install smaller electronic parts and higher density in IC products As a result of this trend, more delicate inspection skills are needed to perform the inspection task and there is still a high rate of human involvement and reliance on human eye in the final visual inspection (Okabe et al, 1993). As IC devices get smaller, there is a need for updating the inspection capabilities for automatic inspection to match the packaging trend.

There are several types of IC package defects that should be inspected to ensure the production quality of the packages. The items to be inspected can be categorised as follows

1. lead defects including lead coplanarity defects, bent leads, uneven leads, lead mark cheeks, scratches on leads, and foreign objects on the leads.
2. marking defects including off-centre marks, broken characters, blurred marks and overlapped marks.
3. mould defects on the surface of IC packages including voids, holes, peelings, blisters and foreign objects, cracks, etc. This also includes the legibility inspection of the label.

1.2 Problem Statement

With the increasing customers' demand for higher quality, 100% inspection of integrated circuits (IC) packages marking or symbolization is a norm in the semiconductor IC assembly industry. Marking inspection is important as the marking uniquely identifies the component for the manufacturer and the user. Clear and legible marking ensures that components are not mistakenly used in down stream of electronics assembly and external appearance of good quality marking also reflects the manufacturer's image and the quality of the IC itself.

Studies have shown that the application of vision systems gives rapid investment payback (Berger et al., 1985). They are significantly more efficient and more adept at performing current high speed manufacturing than human inspection and thus contributes to better process control. Additional advantages includes the fact that vision systems are able to outperform humans in terms of reducing erroneous judgement that are associated with fatigue and boredom. These benefits, which are seldom evaluated, contribute to:

i. Reduction of whole-lot rework if internal quality control sampling finds error levels above acceptable limits.
ii. Avoid shipment of some unacceptable parts to customer.
iii. Reduction of whole-lot return if customer incoming inspection finds unacceptable rates of defects.
iv. Avoid mismatch of components in substrate.

Although the efficiency of such vision systems far surpasses the manual visual inspection, there are some problems still faced by the current application of vision algorithms. One is the user friendliness of the systems. Most applications still require human intervention to adjust parameters which are critical to the system such as identifying the symbols to inspect, adjusting the threshold value for image binarization and inspection acceptance threshold. Whenever a new IC package is introduced, the user of the vision inspection system will have to custom teach the system based on the new device and a new set of parameters. With the shortage of skilled personnel these jobs may have to be performed by machine operators themselves. Due to the heavy reliance on the inconsistency and subjective nature of human judgement, inspection criteria thus may differ from one package to another, or one operator to another. Another prevalent problem faced is the robustness of present vision algorithms. The systems may be unreliable, that is classifying markings as bad although they are good and vice versa.

Most of the systems in the IC manufacturing industry is using template matching technique for inspection process. A best image is used as a reference or bench mark. The image of each ICs is matched with the best image. With some level of acceptance, the IC is accepted or else rejected. The ejected parts are good product, only the quality of the marking is poor. Moreover, in this technique, it is difficult to differentiate between number one (1) and letter ‘I’, or number zero (0) and letter ‘O’. There is no actual reading of the characters. Even though the ICs can perform good, errors or rejection occurs in this template matching technique if quality of marking is poor, poor image acquisition technique, uneven illumination and unaligned text orientation (skew). Looking as all these constrains, Optical Character Recognition (OCR) with Neural Network is the best solution for this problem.

1.3 Objective of the Thesis

The objectives of this project are as the followings:

i) to develop an optical character recognition function system for IC recognition with the application of Neural Network.

ii) to achieve a recognition time for all 36 alphanumerics of not more than 0.05 seconds.

iii) to achieve recognition accuracy with a minimum of 95% recognition rate for all good production quality image.

The system developed is dedicated to read the text and digits (labels) printed on the surface of IC package. This type of inspection focuses on the final inspection (Fig. 1.1) of an IC making industry. The system involves with setting up inspection parameters automatically (or learning) by simply running a few components through the system. The system is developed for minimal teaching of parameters that are critical to the inspection system.

1.4 Thesis Layout

This thesis is divided into six chapters. The first chapter gives an introduction and background about the visual inspection in IC package industry. It is followed by problem statement, the objectives and the layout of the thesis. The literature review in chapter 2 looks into the digital image processing techniques that are used in this system and also some other similar studies done in this field. In Chapter 3, the methodology and an Optical Character Recognition (OCR) system design have been discussed. Image capturing device and illumination is discussed here. In chapter 4, an implementation in GUI is discussed. Chapter 5, discussed the experimental results indepth. Finally, chapter 6 concludes with some suggestions for further development in this area.

CHAPTER 2

LITERATURE REVIEW

2.1 Digital Image Processing

Image Processing is transformation of an initial image into a second image with more desirable properties, such as increased sharpness, less noise, and reduced geometric distortion (Christian, 1987). Interest in digital image processing methods stems from two principal areas: improvement of pictorial information for human interpretation, and processig of scene data for autonomous machine perception (Gonzalez and Woods, 1993). Image processing techniques is a series of process to extract characteristic and interpret of a digital image taken from the real world. Generally, these techniques may be divided into several sub-processes (Hussain, 1991).

i) Sensing :- the process to acquire image from real world. A machine vision system is needed for this purpose.

ii) Pre-processing :- focus on image enhancement and noise suppression.

iii) Segmentation :- the method of partitioning an image into useful set of objects and background.

iv) Description :- to label the objects which are also known as blobs and to store their features such as sizes and positions.

v) Recognition :- to identify the labelled objects.

vi) Interpretation :- to interpret the entire recognized objects into the real world context.

2.2 Machine Vision System

A machine vision system is comprised of all the elements necessary to obtain a digital representation of a visual image, to modify data, and to present the digital image data to the external world (Galbiati, 1990). The system may appear complex in an industrial environment due to all the associated manufacturing process equipment used in the application. A model of machine vision is discussed in this chapter for the possible application for this project.

A vision inspection system's aspects are indicated in Figure 2.1. All functions or parts are highly interrelated, and an understanding of each part is important in achieving the objective of the application or task. The vision system observes the object (ICs), determines if it is within specifications, and generates command signals according to the determined results. The image acquisition includes the lights, camera and frame grabber. The process equipment includes both hardware and software in the vision processing unit, and the output equipment is the electronics interfacing the system to various parts of the manufacturing world; examples are the process controller, CIM, and/or alarm. The electrical instruction signals control the unit, taking objects (ICs) off the assembly line and placing them in accept or reject containers, according to the level of acceptance (quality). Data is transmitted to the computer-integrated-manufacturing system for statistical analysis and inventory control, which sounds an alarm if something is wrong. In the following sub-chapters, a few important factors in the vision system are explained.