Classification of the Marking on Integrated Circuit Chips Based on Moments and Projection Profile – A Comparison

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Abstract

In this paper, an Industrial machine vision system incorporating Optical Character Recognition (OCR) is employed to inspect the marking on the Integrated Circuit (IC) Chips. This inspection is carried out while the ICs are coming out from the manufacturing line. A TSSOP-DGG type of IC package from Texas Instrument is used in the investigation. The IC chips are laser printed. This inspection system ensures whether the laser printed marking on IC chips are proper. One of the artificial intelligence components the neural network, is used for inspection. The inspections are carried out to find the print errors such as illegible character, missing characters and up side down printing. The vision inspection of the printed markings on the IC chip are carried out in three phases namely image preprocessing, feature extraction and classification. MATLAB platform and its toolboxes are used for designing the inspection processing technique. Neural network is used as a classifier to detect the defectively marked IC chips coming from the manufacturing line. In neural network, feature extracted from moments and projection profile are used for inspection. Both feature extraction methods are compared in terms of marking inspection time.

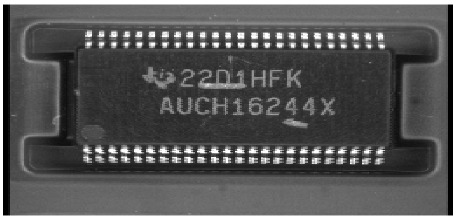
Keywords

Printed marking recognition, moments, projection profile, machine vision, backpropagation.

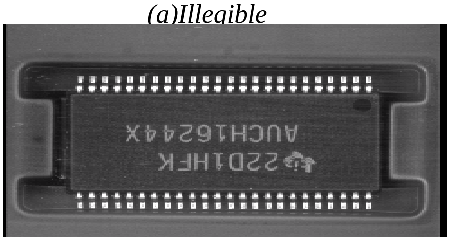
1. Introduction

Since 1950, Optical Character Recognition *(*OCR) has been very active in the application of automatic pattern recognition; now it is used to read the printed characters at high speed [1, 2]. OCR is widely used in recognition of hand written characters and printed characters using Artificial intelligence techniques [1-4]. The OCR is applied for business card recognition [5] where the manual input is optional; however, by scanning, the OCR is able to create an easier database. The document reading and analysis have reached an important position in certain markets. The application of OCR in the postal automation has followed into the banks and industrial inspection processes [6, 7].

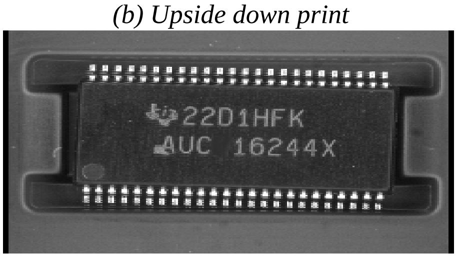
IC chips play a vital role in electronic industries. Mass production of IC chips have brought down the price of the electronic products. Texas Instrument is one of the well-established IC chips manufacturing companies in the world market. In the Texas group, Texas Instrument, Malaysia TI(M), is one of the leading producers of IC chips in. The IC chips undergo many inspections and verifications to ensure a guaranteed quality. Quality control of IC is performed by inspecting the placement of die, inspecting lead dimension, inspecting packaging and inspecting marking of symbols (IC number, year of manufacture and batch code etc). In this research work OCR is employed to check the markings of the IC chips especially, the marking on the *Thin Shrink Small Outline Packages (TSSOP-DGG*) using neural network. Figure 1 illustrates various marking errors that can occur during production where as Figure 2 shows the error free marking.



(a)Illegible



(b) Upside down print



(c) Missing character

Fig. 1: IC chip marking errors

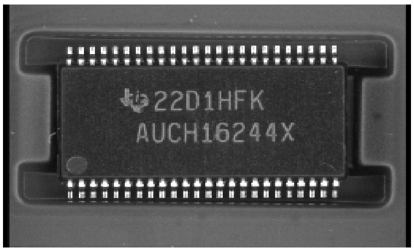


Fig. 2: An error free IC chip

2. Industrial setup

A digital video camera is used to capture the IC marking images of chips coming out of manufacturing line one by one. These images are zoomed about 20 to 30 times in size. Figure 3 shows the dimensions of IC chip. The zooming index depends on the size of the IC chip. Inspection module of the earlier commercially available industrial version checks about 7300 to 7500 IC chips per hour. IC chips undergo on fly inspection as shown in Figure 4 where OCR checks any defects in the markings on the ICs. If there is any defect in the IC chip marking, the marking inspection will check and inform the production inspector the classification of defect; the production inspector then inspects the IC chip manually for taking further decision. A monitor displays the current image of the IC chip.

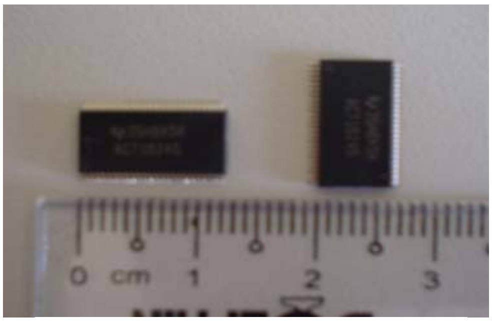


Fig. 3: Dimension of IC chips

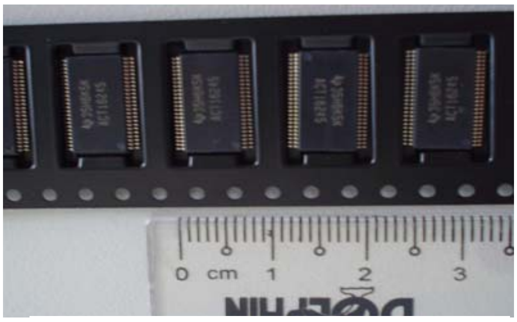


Fig. 4: IC chips in the conveyor

3. Marking Inspection Process

After final packaging, the IC chips are lined up in a conveyor for marking inspection. The marking on the IC chips are captured as a movie clip by a Charged Couple Device (CCD) non-standard camera. Images of the IC chips are extracted from the Moving Picture Expert Group (MPEG) format. The extracted images undergo certain image processing techniques namely preprocessing [1, 6, 7], feature extraction [7,8] and classification using AI technique [9-12] These processing stages are shown in Figure 5.

3.1 Preprocessing

The inspection begins with the extraction of single image from the moving picture. The extracted color image is converted into a 256 gray scale image. Then, the gray scale image is binarized with a threshold value. The binarization converts the image pixels into '0' (black) and '1' (white). The threshold value differentiates the foreground and background of the given image. Region of Interest (ROI) as specified by the production inspector is extracted for feature extraction. If the ROI is not specified, a search for the ROI from the extracted full image has to be made but it is time consuming.

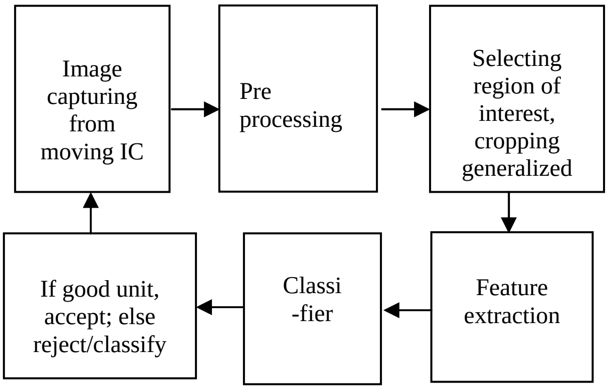


Fig. 5: Image processing sequence

3.2 Feature Extraction

Feature extraction is carried out to the processed and cropped image. Two different feature extraction methods are used. They are moments and profile projection. Feature extraction processing time for moments and projection profile is 0.2610 -0.2710 sec and 0.1900 -0.2100 sec respectively. This has been found by experimental results.

3.2.1. Moments

Moments have been used in recognizing the printed and hand written characters and are also widely used in pattern recognition. There are different types of moments used for recognition of characters; here Central moments of binary image for each column of the image orders are obtained. The image orders can be 2 or 3. In the order 1, moments values are zero. On the other hand, orders more than 3 produces smaller and smaller moments values that cannot be generally used for feature extraction.

Let f(x,y) be an image. Then, the 2D continuous function of the moment of order (p+q), M_{pq}, is defined as [6].

$$M_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x,y)dxdy \qquad (1)$$

The central moment , μ_{pq} , of f(x,y) is defined as is [6].

$$\mu_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)dxdy \qquad (2)$$

where $\bar{x} = \frac{M_{10}}{M_{00}}$ and $\bar{y} = \frac{M_{01}}{M_{00}}$.

If f(x,y) is a digital image then equation (2) becomes

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y) \qquad (3)$$

where p and q are nonnegative integer values.

The moment values are considered for extracting the feature. This method takes the central moments value of each column of the binary image. D_i, i =1,..,k is the central moment value of each column from 0 to k of the marking. D_i can be computed using Equation (3). In this work k is taken as 25.

3.2.2. Projection Profile

The row-sum (P_h) and column-sum (P_v) features of each character are displayed as projection profiles. Horizontal projection (row sum) and vertical projection (column sum), are extracted for the each character image. Let S (n, m) be a binary image of n rows and m columns. Then,

Vertical Profile: Sum of white pixels of each column perpendicular to the x-axis; this is represented by the vector P_v of size n as defined by [8]:

$$P_v[j] = \sum_{i=1}^{m} S[i, j]. \qquad j = 1,2,3,\ldots,n \qquad (4)$$

Horizontal Profile: Sum of white pixels of each row perpendicular to the y-axis; this is represented by the vector P_h of size m

$$P_h[i] = \sum_{j=1}^{n} S[i, j]. \qquad I = 1,2,3,\ldots,m \qquad (5)$$

Profile projection of an acceptable image character "A" and that of an illegible character "A" are shown in Figure 6 and Figure 7 respectively to differentiate the acceptable and illegible characters

4. Marking Inspection Using Neural Network

Recently there has been a high level of interest in applying artificial neural network architecture for solving many problems [9-12]. The application of neural network gives easier solution to complex problems such as character recognition. Here, neural network is employed to classify the character by the extracted features (moments and projection profile). A feed forward neural network is proposed to identify the various types of illegible marking of symbols is shown in Figure 8 and Figure 9. The moments value for two different orders such order 2 and order 3 and projection profile data (extracted features) are considered for training. The extracted features are taken as input to the network model.

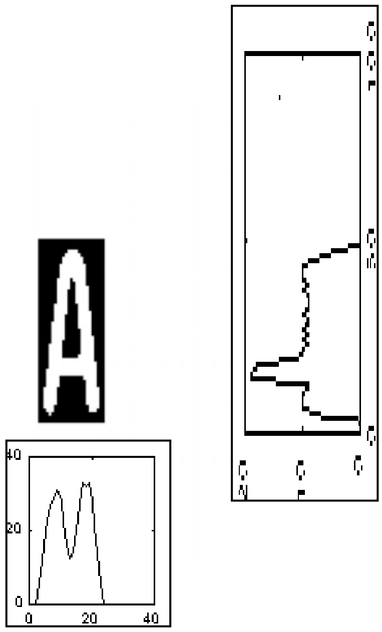


Fig. 6: Projection profile for acceptable IC image "A"

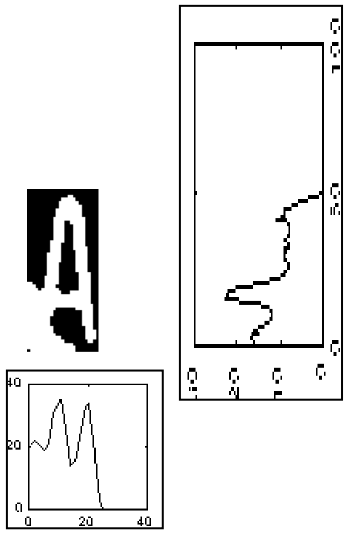


Fig. 7: Projection profile for illegible image "A"

The Training is carried out for 10 times in each case of input data, moments and projection profile. Table 1 and Table 2 indicate the maximum and minimum epoch and duration of convergence in seconds among the all 10 training schedules. Various sizes of images are used for training; they are 28(14*14), 38 (25*13), 75 (50*25) and 94 (63*31). These input sizes are used in neural network training. Input size 75 is found to offer faster training time. The image size (50*25) and the input size of 75 to neaural network are retained for the rest of the work [13].

The networks with each of the above mentioned data are trained using a backpropagation training algorithm. The learning parameters for moments and projection profile are chosen as given in Table 1 and Table 2 respectively: The cumulative errors versus epoch characteristics of the training for moments (order2 and order 3) are shown in Figure 11, Figure 12 and for projection profile are shown in Figure 13. The time and epoch details for both moments and projection profile are given in Table1 and Table 2.

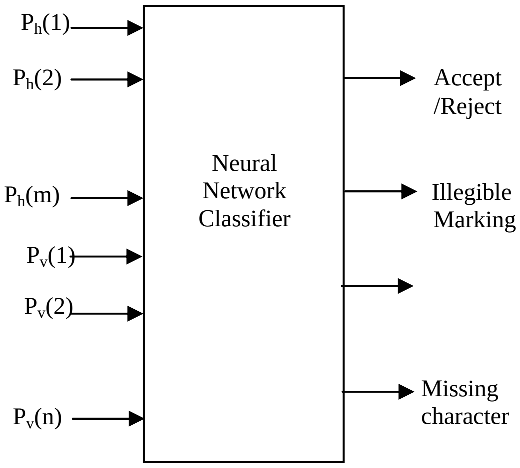


Fig. 8: Neural network model for projection profile

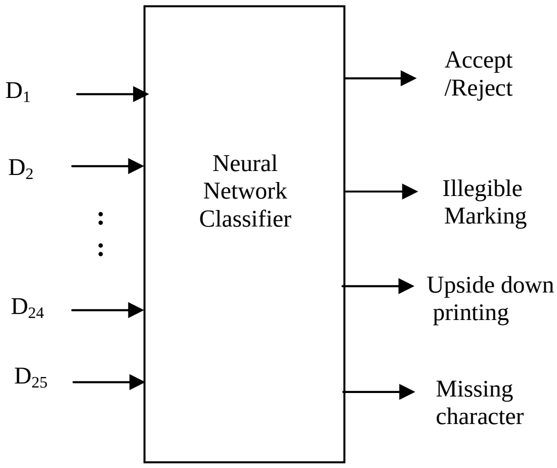


Fig. 9: Neural network model for moments

Conclusion

AI techniques such as neural network are applied to marking inspection of IC chips. The preprocessing and two feature extraction methods have been suggested for this inspection. A feed forward neural network has been developed for training and testing the samples of marking. Two different feature extraction (moments and projection profile) methods have been involved in this training. Trainings are carried out for moments order 2, moments order 3 and projection profile using backpropagation algorithm. Comparing moments order 2 and order 3, order 3 is faster for training. Among these training, projection profile is found to be faster in training. The projection profile method of marking classification can be used for real time application such as marking inspection when the IC chips are coming out of manufacturing line.

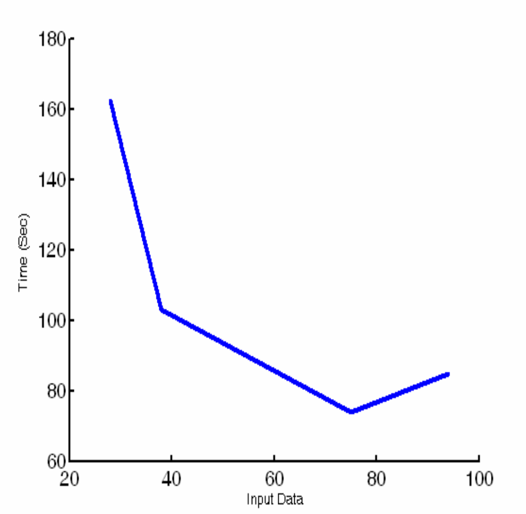


Fig. 10: Input data and time for convergence

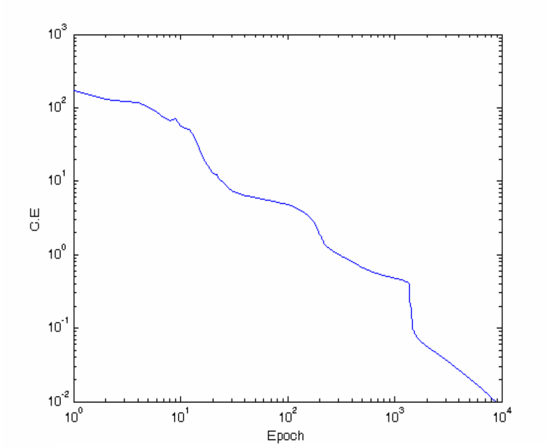


Fig. 11: Cumulative error versus epoch plot for moments second order

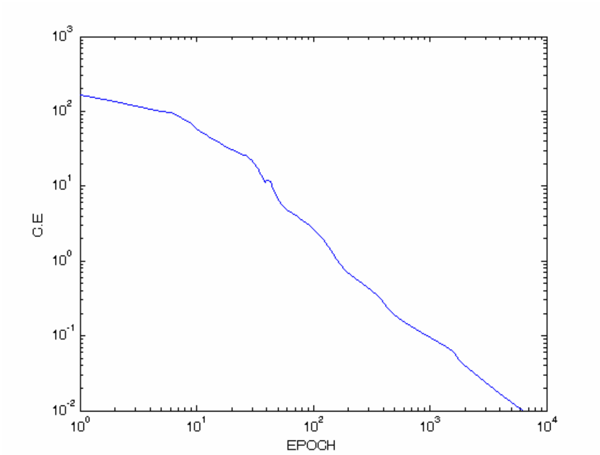


Fig. 12: Cumulative error versus epoch plot for moments third order

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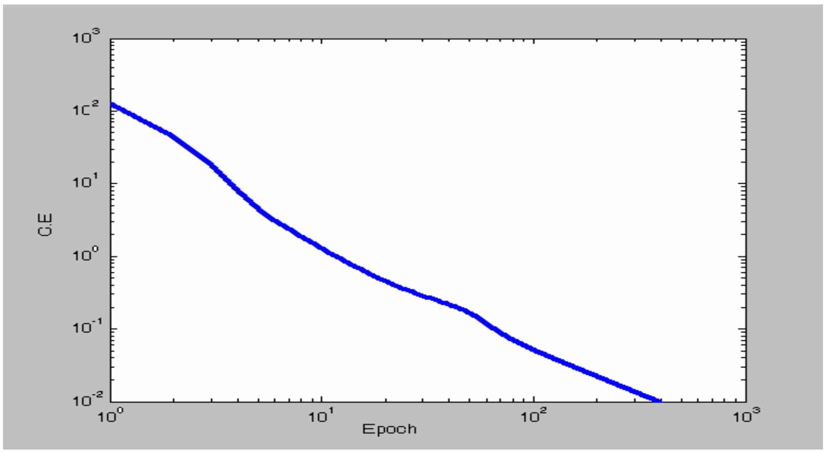

Fig. 13: Cumulative error versus epoch plot for 75 projection profile with input size

Table 1. Data Trained for Two Different Moments order for Neural Network

BackPropagation Algorithm — $q_h = q_0 = 1.0$ — Testing tolerance: 0.05
Output neurons: 6 — Hidden neurons: 20 — Learning rate: 0.2
Activation function: $(1/(1+e^{-x}))$ — Momentum factor: 0.87 — No. of samples: 664
Training tolerance: 0.01 — No. of trained samples: 400 — Training done: 10 times

S.No	Order	Training Epoch	No. of Epoch			Time(Sec)			Misclassification
			Min	Max	Ave	Min	Max	Ave	
1	2	16000	8414	16567	9254	316	624	401	0
2	3	14000	6325	10038	8326	246	403	330	0

Table 2. Trained for Projection Profile Data

BackPropagation Algorithm — No. of training of input size: 12 times
Output neurons: 4 — Hidden neurons: 20 — Learning rate: 0.25
Activation function: $(1/(1+e^{-x}))$ — Momentum factor: 0.87 — Training tolerance: 0.01
No. of trained samples: 400 — Testing tolerance: 0.1 — No. of samples tested : 664

S.No	Input Size	Training Epoch	No. of Epoch			Time(Sec)			Misclassification
			Min	Max	Ave	Min	Max	Ave	
1	75	2000	1012	724	896.6	86	62	73.8	0

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