Cost Effective Optical Mark Reader

Rakesh S[1], Kailash Atal[2], Ashish Arora[3]

[1]Department of Computer Science and Engineering, National Institute of Technology Karnataka, Surathkal, India

[2, 3]Department of Electronics and Electrical Engineering, Indian Institute of Technology Guwahati, Guwahati, India

[1]rakeshsmysore@gmail.com; [2]atalkailash@gmail.com; [3]ashish.arora.iitg@gmail.com

***Abstract*- Optical Mark Recognition (OMR) is an automated process of capturing the information, usually in the form of bubbles or squares and analysing the same using complex computations in order to generate specific required knowledge. We propose a cost effective Optical Mark Reader; also the system is independent of color, brightness and illumination thus making the system flexible and robust for practical applications. The various systems available in the current market for the same purpose are costly, working on dedicated scanners and are dependent on a number of other parameters such as paper and print quality. The proposed system consists of an ordinary printer, scanner and a computer to perform computation and is assisted with a graphical user interface. Users can design forms of their choice and use it for survey or other related activities. The filled forms are scanned and scanned images are given as input to a computer, which does the computation and stores the result in a user understandable spreadsheet. The system is independent of hardware and system platform, thereby making it platform independent. The system was tested for over 5000 test forms with cent percent accuracy, thus proving the efficacy of adaptive comparison method of the proposed system. The system has wide range of applications in the field of exam evaluation, automated attendance and surveys.**

Keywords- Optical Mark Recognition; Adaptive Threshold; Image Processing; GUI

I. INTRODUCTION

Optical Mark Recognition is the technology for electronically extracting data from filled-in fields/bubbles on printed forms [1, 10]. With an increasing need of obtaining and managing information from hand-filled forms by general public, it has become necessary to automate large scale processing of data with high accuracy and speed. The idea of such a system was proposed by R. B. Johnson, a high school science teacher in Michigan, who devised a machine for recording students test answers and to compare them to an answer key. IBM bought rights to his invention and launched the machine in the market by the name-IBM 805 Test Scoring Machine. Currently the advanced version of this inception finds application in areas including examination forms, automated attendance, feedback forms, questionnaires, ballots and community survey forms.

OMR machines with specialized and dedicated Infra-Red OMR scanners have been recently popular mainly because of their high execution speed and appreciable accuracy. Infra-Red OMR scanners work only for specific color and thickness of the form hence cannot be printed on a general purpose printer. Another problem with dedicated machine is their cost and maintenance. Also these scanners expect the form to be in perfect condition; even a slight damaged, crush or fold would be rejected. Although these machines address the problem in hand, their usage is limited due to high cost, strict specifications and inflexibility in format of the form.

The proposed solution to this problem is very simple and cost-effective, which could easily replace the heavy and expensive present day dedicated OMR machines. Unlike scanners and computers, OMR machines are not commonplace hardware resource. The proposed system uses commonly available scanner and computer. The filled-in forms are scanned by a normal scanner, and scanned images are provided as input to an ordinary computer. An image processing application is developed that gives the information of filled and unfilled bubbles in the form. The system is made to run in multiple threads, thus making parallel computation and evaluating thousands of forms in few minutes. The computed results are stored in a spread sheet, thus making it easy to understand and interpret the information. The system offers flexibility to the users, which allows designing and printing of forms on simple ordinary sheets, without the aid of any special pre-processing and color constraints. The OMR forms evaluated by dedicated scanners generally range in the quality of 90-110 gsm, which are much more expensive than the common plain papers (60 – 70 gsm), thus making the system to function on low cost. The substitution of special or expensive dedicated high computational machines by ordinary scanner and computer with no stringent requirements on paper quality makes the proposed system cost effective.

II. RELATED WORK

The OMR scanners began to be used excessively in the early 1950’s, which used a series of sensing brushes in detecting graphite particles on a document that is passed through the machine [1-5]. Image-based OMR studies by Chinnasarn et al. [6] presented PC-type microcomputer and image scanner. The system operation could be distinguished into two modes: learning mode and recognition mode. Data extraction from each area can be performed based on the horizontal and vertical projections. For the purpose of checking answer, the number of black pixels in each answer block is counted, and the difference between those numbers in the input and its corresponding model is used as decision criterion. This was a transition between punch cards and barcodes.

DOI:10.5963/IJCSAI0302002

Pegasus Imaging Corporation presented a Software Development Kit for OMR recognition from document images. Recent works include software along with specified scanner for specific design of Document or Form for OMR purpose. Tao and Toan [7] presented some difficult problems of optical mark recognition. There are important problems such as the correcting position of form with pattern [8] and correctly detecting geometrical objects. Hussmann S. et al, 2005 proposed a low cost and high speed system using Field Programmable Gate Array (FPGA), but had constraints on the input of the forms [9].

Pegasus Imaging Corporation presented SDK for OMR recognition from document images, which supported template and free recognition mode. An OMR field is defined as a rectangle area containing a specified number of columns and rows of bubbles to be evaluated. The SDK can scan the region horizontally and then vertically to locate the bubbles apart from the spaces between them. Based on the bubble shape specified, the system scans the discrete zones corresponding to the bubble, counting dark pixels to determine which bubble zones qualify as filled in. The Pegasus' technique can support the plain paper printing and design, but in its application in schools, the multiple choice answer recognition success rate cannot achieve the requirements of the examination. The proposed system on the contrary combines the best features of all the above, and presents a low cost and high speed recognition system, which is flexible and custom configured to user requirements, without the aid of complex hardware. Also the experimental results show the high accuracy rate achieved by the proposed system.

Another complex form of OMR is optical character recognition (OCR), which is the technique of converting handwritten or printed text into computer usable form and requires complicated pattern recognition engines. Lais, in 2002 defined that OCR is the translation of optically scanned bitmaps of printed or written text characters into character codes, such as ASCII. This is an efficient way to turn hard-copy materials into data files that can be edited and otherwise manipulated on a computer.

III. PROPOSED SYSTEM

In this section, we propose the novel technique of optical mark recognition system. A custom form is designed using the graphical user interface. The filled forms are scanned using a regular grayscale scanner. Scanned images are processed to automatically retrieve information of filled bubbles. We can divide the proposed system into two independent stages: (a) the interface to design and modify the forms and (b) the recognition part to read the filled bubbles from the scanned form. These have been explained in detail in the following sub-sections.

A. Design of Form

The system provides an easy and simple interface which allows the user to design customized form. Also an existing form can be loaded and modified according to requirements. The interface allows user to select the number of questions in the OMR sheet and their respective position in the form, including candidate's registration number, test code, question booklet number, etc. This information of respective position of bubbles and other details are stored in a file. After the forms have been filled, these are scanned using an ordinary scanner, and the scanned images are fed into the computation system, for further processing. The image of GUI is shown in Fig. 1.

Fig. 1 GUI of the developed system

B. Registration of Forms

When the filled forms are scanned, the position of bubbles corresponding to each question is not identical across all forms. The variance in translation and rotation of position of corresponding bubbles in different forms is attributed to manual error in the alignment of the form during the process of scanning. Thus all scanned images must be registered to a fixed position before further processing, so that the corresponding position of bubbles in all scanned images is same. This is illustrated in Fig. 2. Registration is done by detecting the square boxes located in the corners of the form. The angle α formed by the line segment joining the end points of two consecutive squares in clockwise sense is calculated using simple trigonometry ($\tan^{-1}(ay/ax)$) as shown in a hypothetical sketch, Fig. 3. Similarly β, γ and δ are calculated as mentioned in Fig. 3. The image is rotated by the average of α, β, γ and δ in anti-clockwise sense about the center of the smallest rectangle bounding the four squares in Fig. 1.

DOI:10.5963/IJCSAI0302002

The exact coordinates of these squares are determined, and a suitable transformation matrix is used to translate all the images such that the position of bubbles corresponding to each question in all images is same. An example of image before and after registration is shown in Fig. 4.

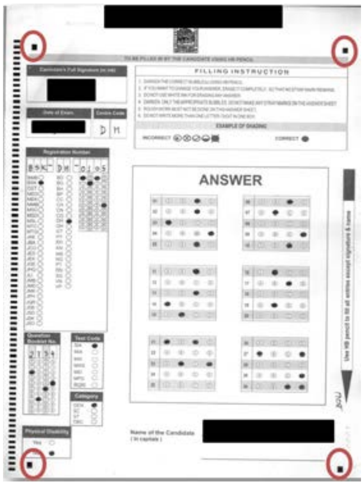


Fig. 2 Original image of scanned form with square boxes in each corner

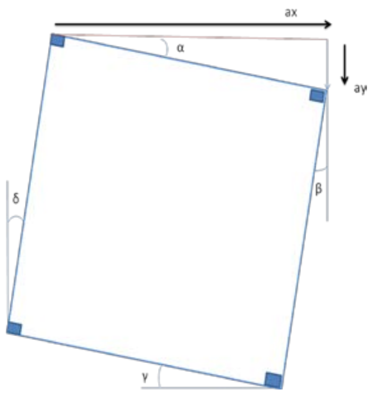


Fig. 3 Illustration of evaluation of angle for correcting rotational variation in a hypothetical scanned image using the coordinates of location of squares in each corner of the OMR form

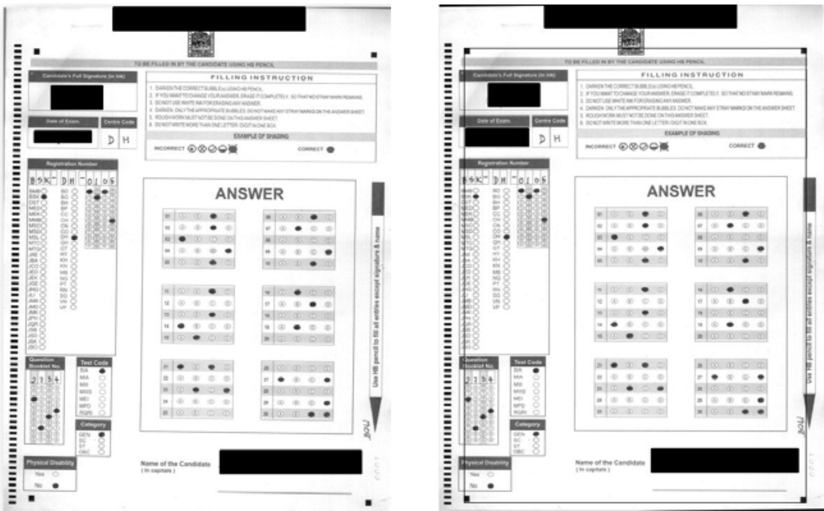


Fig. 4 Original Image (left) and Registered image (right)

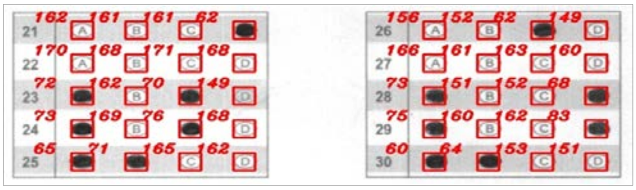
C. *Form Evaluation*

After registration of the answer sheets, we detect the rectangular contours of main answer box and sub-answer boxes in the OMR sheet as shown in Fig. 5 (a). Relative to these contours, the position of all the bubbles in the form is fixed. The grayscale value of a bubble is defined as the average of grayscale value of all the pixels in the smallest rectangular region that completely bounds the bubble. Experimental results show that the mean grayscale value of pixels corresponding to filled-in bubbles is

DOI:10.5963/IJCSAI0302002

relatively much lower than the unfilled ones, which is clearly depicted in Fig. 5(b). The average grayscale value of the smallest rectangular region that bounds the bubble completely is much lower for a filled bubble compared to that of an unfilled bubble.

(a)



(b)

(c)

Fig. 5 (a) Main answer and sub-answer boxes in the OMR form. (b) Grayscale value of filled and unfilled bubbles. (c) Grayscale of the bubbles in sorted order

The minimum (V_{min}) and maximum (V_{max}) average grayscale value of all the bubbles in a scanned image is computed. If the bubble having average grayscale value V_i is closer to V_{min} and much lower than V_{max}, the bubble is filled, i.e.,

$$V_i < V_{min} + (V_{max} - V_{min}) * p \quad (1)$$

Similarly a bubble is unfilled if V_i satisfies the following condition:

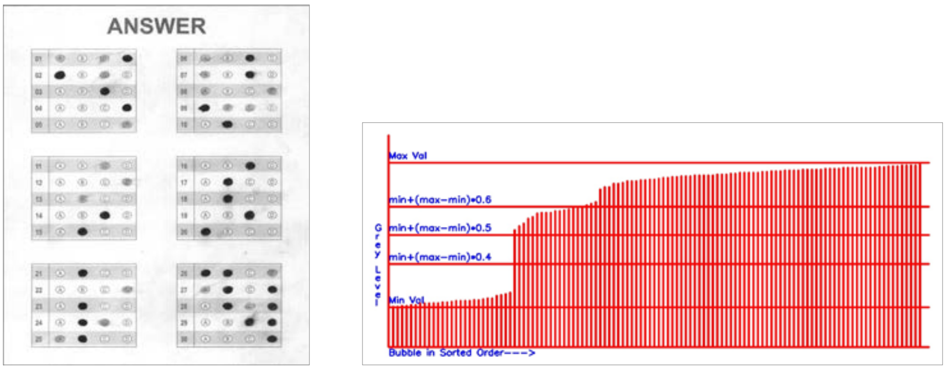
$$V_i > V_{min} + (V_{max} - V_{min}) * q \quad (2)$$

where p and q are user defined adaptive threshold factor and $0 < p < q < 1$. The threshold parameters p=0.4 and q=0.6 were used in this sample space, which was determined statistically after analysis of the grayscale values of more than ten thousand filled and unfilled bubbles. However, it is also necessary to take care of the boundary conditions, when all bubbles of the form are filled or left blank. In this case, a threshold parameter, 't' based on the difference between V_{min} and V_{max} is used. The average of V_{min} and V_{max} , 't' is compared against absolute minimum and maximum grayscale value of the form (0 and 255 for 8 bit grayscale image) to conclude whether all the bubbles are filled or unfilled.

There may be ambiguity in some cases, when a filled bubble is not erased properly. An example of this is depicted in Fig. 6(a). The plot of grayscale value of bubbles in sorted order in Fig. 5(c) & 6(b) clearly shows that the erased bubbles have grayscale values between the threshold parameters p=0.4 and q=0.6. An intermediate value of V_i other than the two cases mentioned in Equations (1) & (2) is an indication of ambiguity and in this case, rather than storing 'a' or 'b' or 'c' or 'd' as filled ones, we print "undetected" in the corresponding cell in the spreadsheet. This is done so that, the OMR sheet can further be manually verified in order for system to be fair evaluation and not involving default decision, which may affect an individual's future. In examination, this way of classifying an ambiguously erased bubble with error in due regard to the filled-in choice may bring him/her to some credit, which may be of critical importance for the carrier of that candidate. Also, the probability of such an ambiguous case is very low, and the proposed system may require little manual assistance in such cases.

The recognized bubbles are stored in the spreadsheet, and are compared against the correct answer keys provided by the administrator. The evaluated results are also stored in the same spreadsheet and made available to the administrator for further grading.

DOI:10.5963/IJCSAI0302002

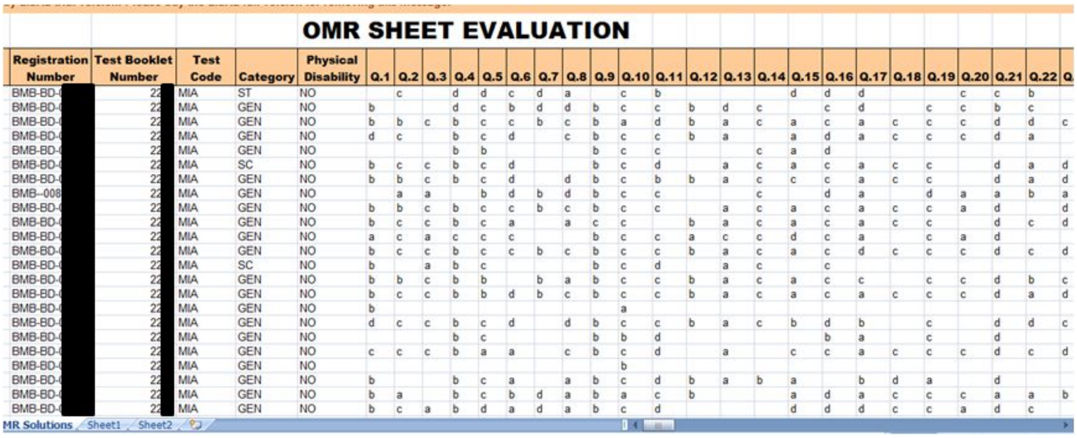


(a) (b)

Fig. 6 (a) Scanned form with ambiguously erased bubble. (b) Plot of average gray value of bubbles in sorted order for the form in (a)

IV. EXPERIMENTAL RESULTS

The proposed system has been tested on more than 5000 scanned images for an Entrance Examination of an esteemed institute in Kolkata. We consider a dataset of an examination conducted at the institute, which consists of student name, register number, subject, question booklet number and the answer keys. The software was installed in three different laptops and a desktop, and was tested independently. The evaluation results of the proposed system were verified by automated comparison against that of standard OMR scanner and were found to be cent percent accurate. None of the bubbles was wrongly detected. However for 39 out of 5000 forms, some of the bubbles were ambiguously erased as shown in Fig. 6 (a) and the output of the system for such bubbles was ‘undetected’ instead of classifying them as filled or unfilled, which is not desirable in real life examination. Even if such unresolved ambiguity is considered a part of system efficiency, then the system is accurate up to 99.20 percent. The average speed of processing forms excluding scanning time is over 400 forms in less than a minute, with each form consisting of more than 250 bubbles. A sample format of the resultant spreadsheet produced by the evaluation is shown in Fig. 7.



OMR SHEET EVALUATION

Registration Number	Test Booklet Number	Test Code	Category	Physical Disability	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10	Q.11	Q.12	Q.13	Q.14	Q.15	Q.16	Q.17	Q.18	Q.19	Q.20	Q.21	Q.22	Q.
BMB-BD-[redacted]	22[redacted]	MIA	ST	NO		c		d	d	c	d	a		c	b				d	d	d			c	c	b	
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b			d	c	b	d	d	b	c	c	b	d	c		c	d		c	c	b	c	
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	b	c	b	c	c	b	c	b	a	d	b	a	c	a	c	a	c	c	c	d	d	c
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	d	c		b	c	d		c	b	c	c	b	a		a	d	a	c	c	c	d	a	
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO				b	b				b	c	c			c	a	d							
BMB-BD-[redacted]	22[redacted]	MIA	SC	NO	b	c	c	b	c	d			b	c	d		a	c	a	c	a	c	c		d	a	d
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	b	c	b	c	d		d	b	c	b	b	a	c	c	c	a	c	c		d	a	d
BMB--008[redacted]	22[redacted]	MIA	GEN	NO		a	a		b	d	b	d	b	c	c			c		d	a		d	a	a	b	a
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	b	c	b	c	c	b	c	b	c	c		a	c	a	c	a	c	c	a	d		d
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	c	c	b	c	a		a	c	c		b	a	c	a	c	a	c	c		d	c	d
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	a	c	a	c	c	c			b	c	c	a	c	c	d	c	a		c	a	d		
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	c	c	b	c	c	b	c	b	c	c	b	a	c	a	c	d	c	c	c	d	c	d
BMB-BD-[redacted]	22[redacted]	MIA	SC	NO	b		a	b	c				b	c	d		a	c		c							
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	b	c	b	b		b	a	b	c	c	b	a	c	a	c	c		c	c	d	b	c
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	c	c	b	b	d	b	c	b	c	c	b	a	c	a	c	a	c	c	c	d	a	d
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b									a													
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	d	c	c	b	c	d		d	b	c	c	b	a	c	b	d	b		c		d	d	c
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO				b	c				b	b	d					b	a		c		d		
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	c	c	c	b	a	a		c	b	c	d		a		c	c	a	c	c	c	d	c	d
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO										b													
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b			b	c	a		a	b	c	d	b	a	b	a		b	d	a		d		
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	a		b	c	b	d	a	b	a	c	b			a	d	a	c	c	c	a	a	b
BMB-BD-[redacted]	22[redacted]	MIA	GEN	NO	b	c	a	b	d	a	d	a	b	c	d				d	d	d	c	c	a	d	c	

MR Solutions Sheet1 Sheet2

Fig. 7 Excel-Spreadsheet generated using the proposed OMR system showing filled-in bubbles

Note that empty cell in spreadsheet implies that no bubble was filled for the corresponding question.

V. CONCLUSION

We have proposed a simple and cost-effective software tool to evaluate OMR forms with high accuracy and execution speed. This system can easily replace current day heavy machinery which consists of expensive dedicated scanners that achieve the same objective with multiple dependencies and strict constraints. The proposed system uses normal printer and scanner with no added cost, and allows the forms to be printed on normal paper, without any constraints on quality or color. User is provided with an easy interface, which helps him to design his own forms or modify existing ones, and evaluate and store the filled forms in an Excel spreadsheet. The system is designed to cater the need of vast population, also it is easy to install and use. Experimental results clearly depict the robustness and correctness of the proposed system, proven to be invariant of color, brightness and affine transformations. Another dimension to the utility of the software is that the program is made to execute in parallel using multiple threads and implements pipelined architecture, thus improving performance and processing capability. The proposed system finds its application in fields such as institute examinations, voting, lottery, community surveys, etc. As a part of future work, we also plan to make use of CUDA architecture, using the computational capability of NVIDIA GeForce or Tesla processors to further enhance processing. The idea can also be extended to implement

DOI:10.5963/IJCSAI0302002

the system through a website and make this utility available over the internet, where authenticated users can login, design forms and get the filled forms evaluated.

ACKNOWLEDGEMENT

The satisfaction that accompanies the successful completion of any task would be incomplete without the mention of people whose ceaseless cooperation has made it fruitful. We take immense pleasure in thanking our esteemed guide Prof. Bhabatosh Chanda, ECSU, Indian Statistical Institute, Kolkata for his insightful advice, constant guidance, valuable suggestions and encouragement throughout the project. Without his continued support and interest, this project would not have been the same as presented here. We are also grateful to the people at ECSU, ISI Kolkata for their support to use resources and cooperation in carrying out the project work.

REFERENCES

[1] A. M. Smith, “Optical mark reading - making it easy for users”, In Proceedings of the 9th annual ACM SIGUCCS conference on User services, United States, 1981, pp: 257-263.

[2] K. Toida, “An Overview of the OMR technology: based on the experiences in Japan”, Workshop on Application of new information technology to population: Paper based data collection and capture, Thailand, 1999.

[3] Sabyasachi Das, “Optical Mark Recognition Technology for Rural Health Data Collection”, November 2010.

[4] Hui Deng, Feng Wang, Bo Liang, “A low-cost OMR solution for educational applications”, Parallel and Distributed Processing with Applications 2008, ISPA 2008.

[5] E. Greenfield, “OMR Scanners: Reflective Technology Makes the Difference”, Technological Horizons In Education, Vol. 18, pp: 1991.

[6] K. CHINNASARN, “An image-processing oriented optical mark reader”, Applications of digital image processing XXII, Denver CO, 1999.

[7] Ngo Quoc Tao and Do Nang Toan “Some Charactistical aspects of Markreader Software Package for Automatic Mark Data Entry”, Circuits and Systems, 2002. APCCAS '02, pages 437 - 442 vol.2, 2002.

[8] N.Q.Tao, D.N.Toan, “Some Methods Improving Efficiencies Of The Mark Recognizing For Designing Automatic Form Entry System-Markread,” Journal of Computer Science and Cybernetics, Vol.15, No. 4, Hanoi, 1999.

[9] Stephen Hussmann and Peter Weiping Deng, “A High Speed Optical Mark Reader Hardware Implementation at Low Cost using Programmable Logic”, Science Direct, Real-Time Imaging, 11(1), 2005.

[10] Palmer, Roger C., The Basics of Automatic Identification [Electronic version]. Canadian Datasystems, 21 (9), p. 30-33, Sept 1989.

DOI:10.5963/IJCSAI0302002