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PCB EXPOSURE AND DATA MATRIX BASED JOB VERIFICATION

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Abstract

This article presents a Data Matrix based system for selecting and controlling jobs for the exposure machine. Job selection and proper choice selection and use of phototools are automatically supervised with a help of information transported inside data part of the code. Description, films verification, field id to retrieve information from the database as well is included. Presented method can help to the operator to choose automatically proper settings and transmission of needed parameters for the performed task.

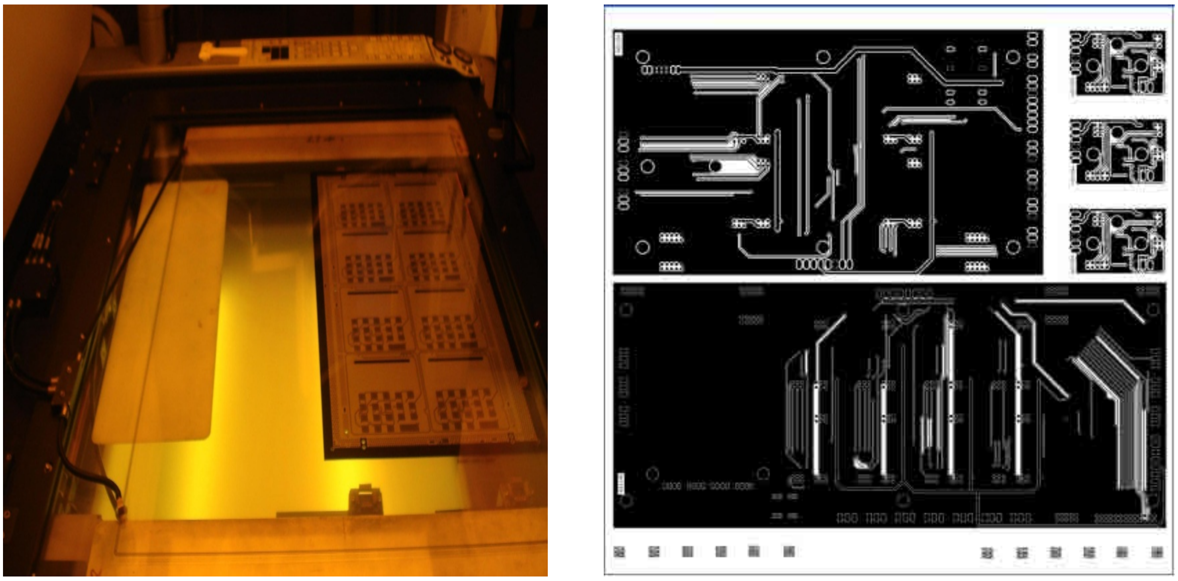
***Keywords**: PCB production, automatic parameters selection, image recognition, Data Matrix*

1. Introduction

Using the "Code Image" is receiving more and more attention in the systems saving and transferring information. Code Image in this case Data Matrix (DM) technique is defining a way for saving array of data (Fig. 1) using a digital image, and next faultlessly and automatically inputting them into a desired process. The authors took up the subject of application of such transfer of parameters in the process of printed circuit manufacturing, or more specifically, during the exposure process, which will transfer the responsibility and fault risk from the machine's operator to the team supervisor, preparing the production and limiting process parameters to the required values.

Fig. 1. Comparison between Bar Code and Data Matrix with its ability to keep information in two dimensional structure

Latest exposure machines are more and more sophisticated. Bare material, photopolymer, film and a light source is still a base but new technology exposure machine can measure, align material, and generate feedback data documenting a production cycle. Moreover, the analyzed system will ensure correctness of machine settings and it will help to verify a film choice, along with a possibility to set its critical parameters related to registration and exposure process (Fig. 2).



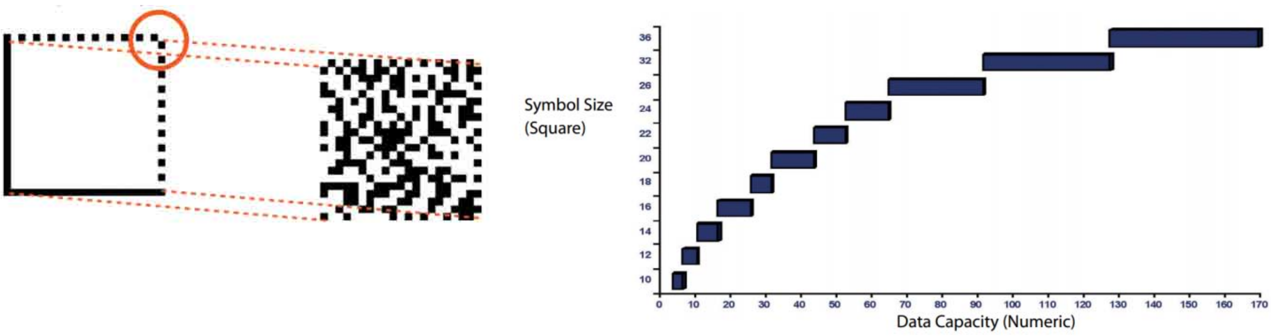
(a) *(b)*

Fig. 2. Exposure Frame with a films and panel loaded (a). Data Matrix placed on the film in predefined location film choice (b), along with a possibility to set its critical parameters related to positioning and exposure

Over the years several image processing algorithms decode and encode data in DM were recreated. These methods provide way to process correctly an input image with a quality do not allowing the encoded information to be read automatically.

Data Matrix is two-dimensional bar code which may have a form of square or rectangular symbol build up of individual cells usually dots or squares. In such form it is a prearranged grid of dark and light cells bordered by a structure of finder pattern (Fig. 3a). The structure of finder pattern is used to detect the orientation and structure of the 2D code symbol. Data encoding process use a series of dark or light cell over a pre-determined size. Size of the cell is called the X-dimension and usually is limited by the parameters of the camera optical channel.

Data Matrix can carry variable amount of data (Fig. 3b). Usually if more data encoded then the size of the resulting DM symbol gets bigger. To keep 1kB of data – it also depends if they numerical or alphanumerical - size of a given Data Matrix approximately will be 96x96.



(a) finder pattern (left) and the data (right) *(b) size and its informational capacity*

Fig. 3. Structure and capacity of Data matrix

The issues related to proper decoding of encoded information arise when defining:

- the size of the image containing information;
- Data Matrix capacity and image resolution (size of a single point);
- uneven light conditions during image acquisition;
- possible mark contamination observed by the camera, as well as on the camera's lens.

The proposed by us method uses the Radon transformation. In the past, there were attempts to use this transformation to analyze and recognize Data Matrix [2, 8]. In this paper authors are describing modified algorithm introducing new improved classifier for a method presented in [8].

2. Data Matrix image analyze characteristics

The registration system, usually has inbuilt set of cameras, used as a part of alignment subsystem of the exposure machine. Every camera has calibrated position and is placed perpendicularly to the observed mark and is an integral part of the whole device (Fig. 4).

Such camera has several tasks and one of them is reading Data Matrix to encode the data contained in the given symbol. Despite it unclear working conditions, which are unfavorable for a correct reading of the data printed on the film may occur frequently.

Therefore a proposed vision system has to be transparent to dynamic lighting changes of the registered scene, regular occurrence of various film defects, and quality of code printed onto the film. Because in most cases – very close to 99% - two films plotted on the internal side are used. Because of their relation to the panel being exposed one of them will provide mirrored images of the DM. Moreover, the size of information portion of the code varies. In most cases DM will be used only for identification, but it can contain information specific for a job including registration and exposure parameters (Fig. 5). Due to this requirement, even knowing the camera's relation to the observed scene it is difficult to define the size of cell carrying information in DM. As a result, system has to automatically calculate the size of the cell using DM finder pattern.

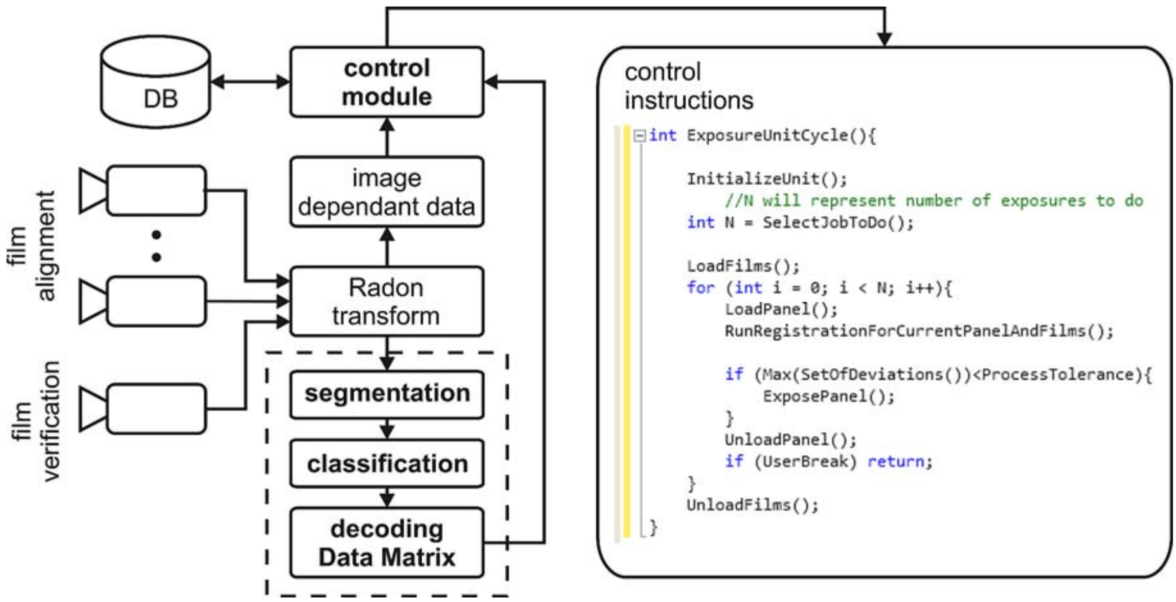


Fig. 4. Simplified exposure unit registration system diagram: set of movable industrial cameras, PC based control controller, database to exchange and carry system data

In the considered arrangement (Fig. 5) image $I[x,y]$ will have blocks $B[x_0,y_0]$ of a constant, undefined but detectable size. Moreover, every such block adheres to the next one. While adjacent blocks possess a noticeable different and at the same time they represent significant insensitivity function value, the boundaries between them can be determined easily. However, for DM it is not a rule. Very often adjacent blocks have same insensitivity function value. While analyzing an input image, that is filtering a given image with an edge filter, regularity can be observed, where every set of blocks (of the same or similar insensitivity function value) is demarcated from other sets with straight, mutually perpendicular sections. Thanks to such assumption existing algorithm of searching of straight lines in the picture can be used.

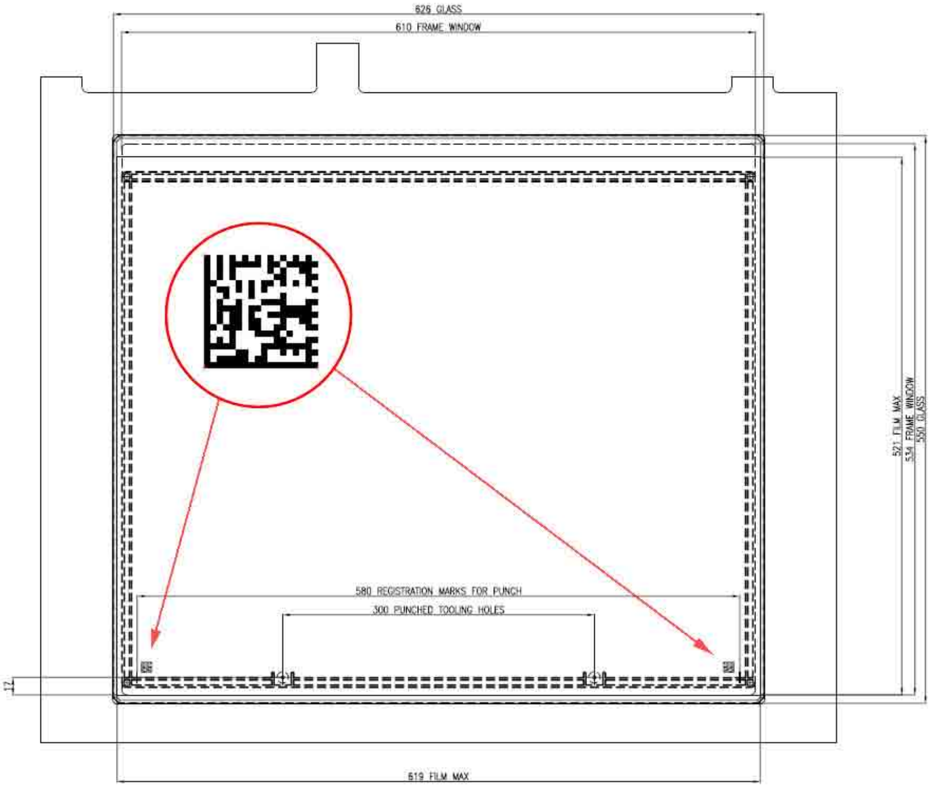


Fig. 5. Film definition presenting predefined DM location in relation to the frame limits [8]

The Radon Transform (1) is defined as [1, 6]:

$$R_\theta(\rho) = \int_{-\infty}^{+\infty} f\left(x'\cos\theta - y'\sin\theta, x'\sin\theta + y'\cos\theta\right) dy', \qquad (1)$$

where

$\delta > 0$ and $\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$.

The Radon operator maps the spatial domain $f(x,y)$ to the projection domain (ρ,θ), in which θ is the angle and ρ the smallest distance to the origin of the coordinate system.

Detection of straight lines in the picture is performed through finding in the domain maxima transforms, which clearly indicate the angle of the straight line and its distance from the center of the image [3, 4, 5].

It means that performing a Radon transform for an edge image and finding a maximum value for this function we can define the angle of our image. However, any occurrence of contamination on the lens or film (scratches etc.), can induce serious errors.

In the process of angle analysis of the image we look for a pair of values $R_{\theta_1}(\rho)$ and $R_{\theta_2}(\rho)$ where the image angle is expressed as $\theta_I = \max\left(R_{\theta_1}(\rho), R_{\theta_2}(\rho)\right)$ under assumption $\theta_1 = \theta_2 + 90^o$.
Such approach allows finding the demarcation lines of the individual cells, even with a high noise. However, for specific cases, it is likely to not find a line of demarcation. This can occur when two columns, or two rows, next to each other are similar to each other. It means that the $\sum\left|R_{\theta_1}(\rho_n) - R_{\theta_1}(\rho_{n\pm1})\right| = k$ where $k \ll N$ (N - number of cells) Fig. 6 or when the edge of cells is not blurred (edge operators can't detect).

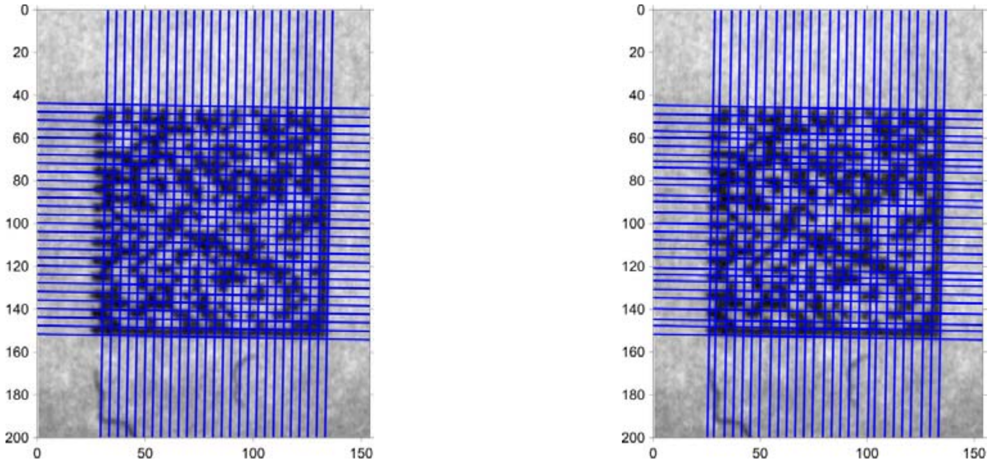

(a) (b)

Fig. 6. Some segmentation process results (a) without tolerance (b) using analyze of local Radon transform maximum

In order to eliminate uncertainty of the presented method we suggest certain modifications in our implementation. They are possible only under such conditions:

- the camera is perpendicular to the observed surface (only insignificant deviations are allowed);
- the dimensions of a single cell in Data Matrix are known.

The first assumption permits upholding the condition that Radon transform maximum values which indicate cell demarcation lines are distributed for angles that fulfill a condition: $\theta_1 = \theta_2 + 90^o$.
In practice there exists high probability that demarcation lines designated using edge detecting filters (Sobel, Roberts, Canny) will be not parallel to each other, which means the conditions cannot be fulfilled. That is why during the implementation of algorithm insignificant deviations of designated edges being unparallel on the $\pm1^o$ level were taken into consideration (Fig. 7).

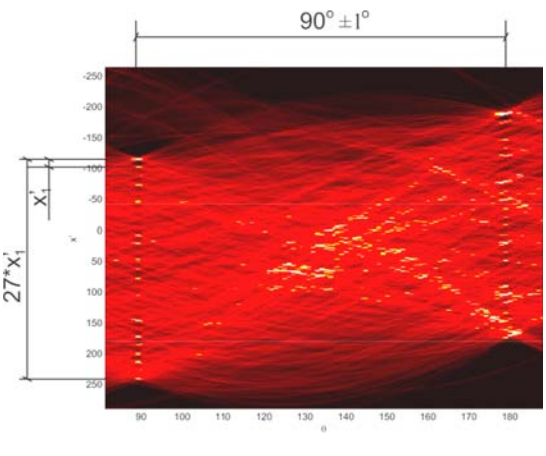


Fig. 7. Radon Transform of Data Matrix Using 110 Projections

Second assumption allows us to limit the amount of calculated lines separating cells. Let N be a number of cells in a row or a column in Data Matrix, then $\rho_a = \{x', x' + nx'_1\}$ and $\rho_b = \{x', x' + nx'_1\}$ where $n = \{1, 2, \ldots, N+1\}$. However even here difficulties concerning quality of image acquired from the camera can be encountered. Due to used camera resolution and electronic noise introduced during video signal transmission, the dimensions of individual cells, both horizontal and vertical, can vary. It is a crucial aspect during classification process for very small cells, 5x5 pixels and smaller. That is why introductory assessment of θ_I, on the basis of aforementioned conditions, and then a search in the nearest vicinity i.e. $\theta_1 \pm 1^o$ and $x'_1 \pm 1px$ for ρ_a and $\theta_2 = \theta_2 \pm 90 \pm 1^o$ and $x'_1 \pm 1px$ for ρ_b is advised, a result of which is a division of the image (Fig. 8b).

On the base of such a demarcation line set, a set of image points belonging to a given cell (classification process) can be specified.

Despite the specific assumptions in the segmentation process (Fig. 8), we are not able to fully eliminate image pixels whose brightness value of the function clearly represents the value of a cell. Therefore, the DM shall be determined by the classifier (2):

$$M_{DM} = \begin{cases} 0 & \text{for} \quad median(B[x,y]) > \tau \\ 1 & \text{for} \quad \text{other} \end{cases}, \tag{2}$$

where $B[x,y]$ is a block of image appointed by the demarcation lines, τ is a threshold defined as $\tau = \min\left(R_{\theta_1}(\rho_a), R_{\theta_2}(\rho_b)\right)$.

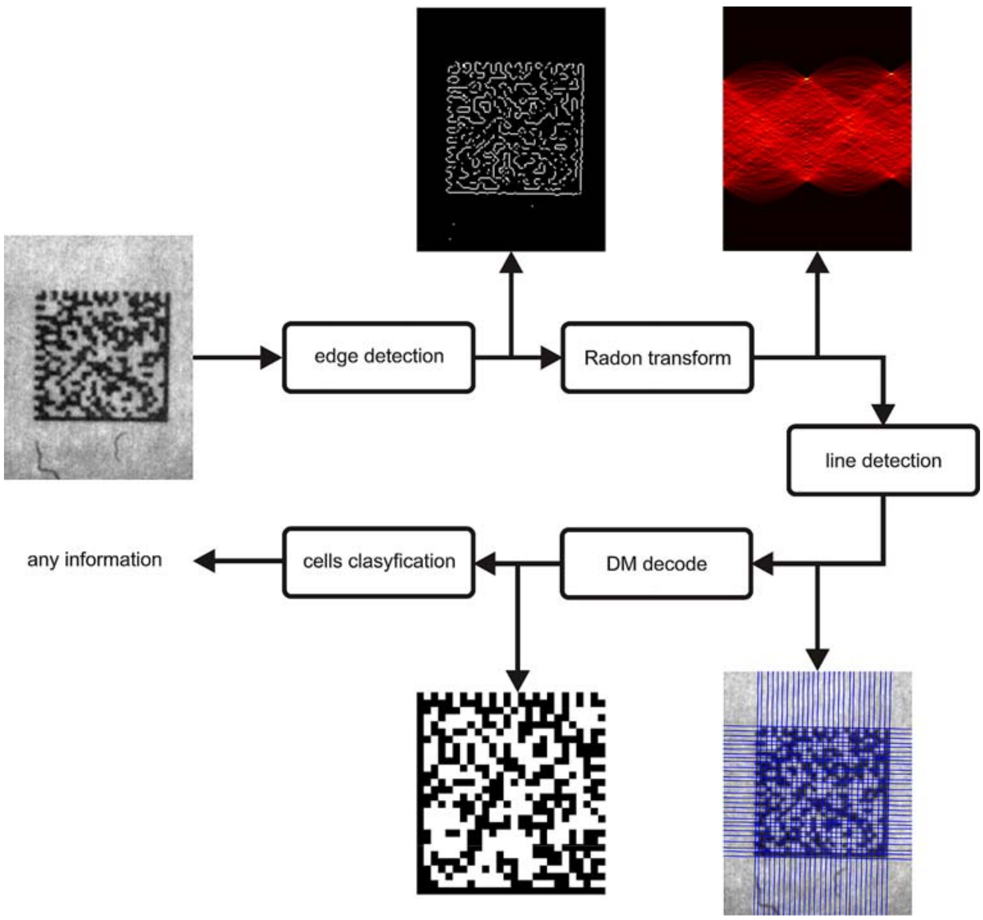
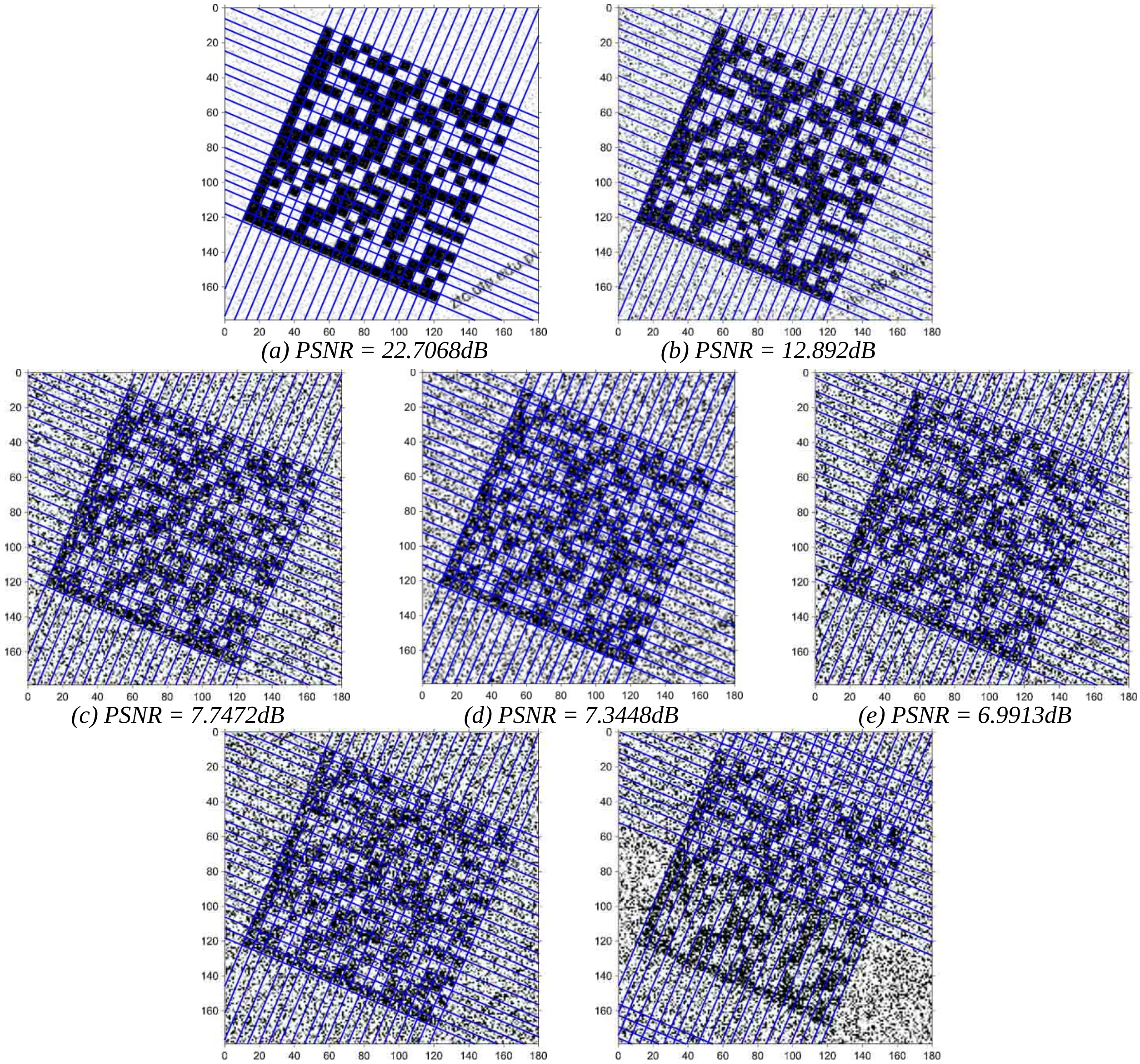


Fig. 8. DM information image recognition algorithm diagram. On the left main system elements, on the right effects visualization of subsequent process steps

3. **Experimental results**

Series of trials for real images registered by the exposure machine were conducted; however, the preliminary research was conducted for synthetic images. The group contained images whose single Data Matrix cell dimensions were 5x5 pixels. For this group trials were conducted (Fig. 10). In order to define the method's sensitivity for every synthetic image a Gaussian white noise with different mean and variance values is added. In this way both the image's PSNR level and the size of a single mark for which the algorithm recognizes the code was estimated.

In Tab.1 PSNR values were included along with recognition of image code sequence percentile. Additionally, series of trials for real images registered by the exposure machine were conducted. This way an impressive outcome of 98% of correctly recognized marks on the images was obtained.



(a) PSNR = 22.7068dB *(b) PSNR = 12.892dB*

(c) PSNR = 7.7472dB *(d) PSNR = 7.3448dB* *(e) PSNR = 6.9913dB*

(f) PSNR = 6.8222dB *(g) PSNR = 6.5802dB*

Fig. 10: Sample results of PNSR impact on image recognition capacity

Tab. 1. Results for code cell based on 5x5 pixels

PSNR	22.7068	12.892	7.7472	7.3448	6.9913	6.8222	6.5802
Recognition	100%	100%	100%	94%	83%	67%	26%

4. Conclusions

This article presents a approach to Data Matrix code analysis using new optimized new improved classifier. In the case of exposure unit proper DM detection is considered as start point of the unit setup procedure. Decoded data is verified over the information saved in the database and is leading to the quick and reliable process of setting up the exposure machine parameters. The proposed method of getting inputs from DM is based on Radon Transform. Beside image analyze, research process was extended by fallowing decoding step and extracting stored encoded information. Acquired results are promising. Proposed algorithm can detect and decode barcode fast and correctly. It allows eliminating mistakes resulting from image processing methods' imperfections. Of course, the presented method was tested with DM symbols with a low modulation grade and blurred symbol images. DM with damaged borders, uneven illumination, omni-directional symbol recognition can be processed as well. In any case it is necessary to remember stability of the process can be illumination dependent especially in the production conditions of a yellow room. Because of the specific setup of the camera and artwork including DM, issues like perspective and significant geometric distortions was assumed to not be a case for this system. The results showing algorithm limitations will be presented in next articles.

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