Optical Correlator in Industrial Image Pattern Recognition System

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***Abstract*— The aim of this paper is design a system for recognizing industrial image pattern using optical correlator. The proposed system is used to obtain information about the accuracy of the model and the industrial form of images, in this case – pavements. Cambridge optical correlator is used in designed system as comparator. Several experiments have been done by software called "Fourier Optics Experimenter". Results and conclusion are discussed.**

***Keywords*—Cambridge optical correlator; image recognition; industrial images; pattern recognition**

I. INTRODUCTION

High speed information processing is commonplace in the modern industrial era. Current trend in this area is a high-speed optical information processing, leading to the use of a variety of advanced optical systems such as optical correlators. These correlators guarantee high speed signal processing even when processing large amounts of data in a short period of time. While in the past these systems were almost inaccessible for people, today they are an integral part of everyone who thinks innovative.

The aim of this papers is present basic information about the industrial image pattern recognition system (IIPRS) using Cambridge optical correlator. Cambridge optical correlator is used for the comparison of the pavements with pavements from a reference database. Compared pavements are captured by video camera and pre-processed by software called "Fourier Optics Experimenter".

In Chapter II, the function and hardware scheme of IIPRS is shown and the individual steps and components are described. Chapter III contains experiments and results. Experiments were done with static industrial images - pavements. Conclusions of designed system are summarized in Chapter IV.

II. INDUSTRIAL IMAGE PATTERN RECOGNITION SYSTEM

In the current digital age, it is very important to put emphasis on the simplification of different activities and finding of optimal solutions at minimal effort. Today the emphasis is on high-speed data processing, minimal defects during the manufacturing process and the associated low costs. To minimize losses and maximize results, a continuous innovation, new ideas, thoughts and suggestions are needed. All this is necessary to ensure the rapid and profitable operations. Therefore, even the design of IIPRS described below was created for the purpose of improvement of the system.

A. Hardware scheme of proposed system

The hardware scheme of the proposed system is shown in Fig. 1. It consists of a number of facilities such as transport equipment, camera, computer, correlator and a pneumatic piston. Each of these mechanisms have its purpose and to submit accurate, no less important role than others. In case of failure of any device, the system stops working properly and it is therefore important to choose high-quality devices that meet the requirements sufficiently for the proper functioning of the service.

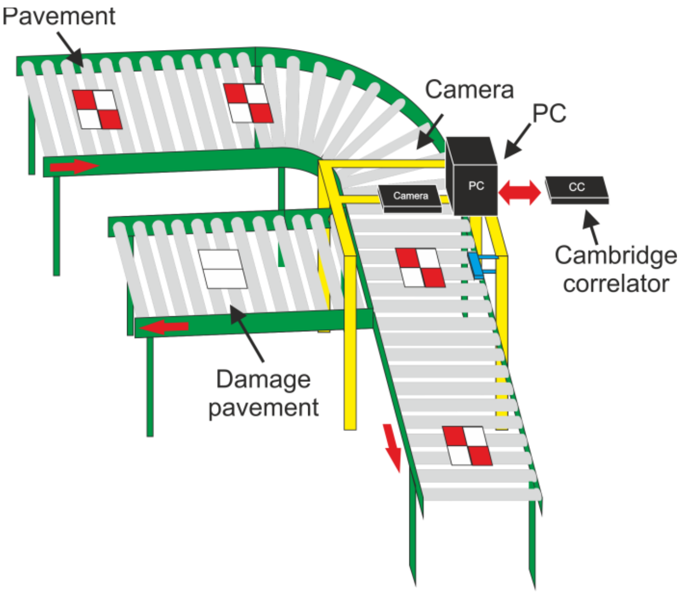


Fig. 1. Input image of Cambridge correlator.

1) Transport device: Roller carriage is used to transport materials and allows transport of material in the production halls or warehouses. The roller conveyor can be made in various designs and with adjustable height and reach. The drive is provided by chain with sprockets. Depending on the size and weight of carried items it can run all or only some of the rollers. The speed of the roller can be changed.

2) Camera: High-speed camera is an effective solution in a proposed system. It has small size, light weight and the ability to connect to Ethernet. The optics of this camera could be compensated and parameters such as exposure time, screen ratio, recording duration and quality could be adjusted. After setting the camera can start scanning the image. It is possible to select where the scanned images will be saved to your computer via Ethernet, without storage in the memory of the camera.

3) Optical correlator: Cambridge correlator is type of Joint Transform Correlator. This device is paired with a software called Fourier Transform Experimenter (FOE) which enables students and researchers to virtually explore a range of themes based on the optical Fourier transform. The optical system of Cambridge correlator is based on the Fourier Transform Engine ©. It is also compact and and very powerful processing system based on the principle of diffraction of the optical Fourier transform. Its new design "W" allows electro-optical components use their full potential (Fig. 4). The Spatial Light Modulator (SLM) is powered by the computer's DVI port using its own board. Images displayed on the SLM are illuminated with constrained low power laser beam and are applied via an optical fibre [1-4].

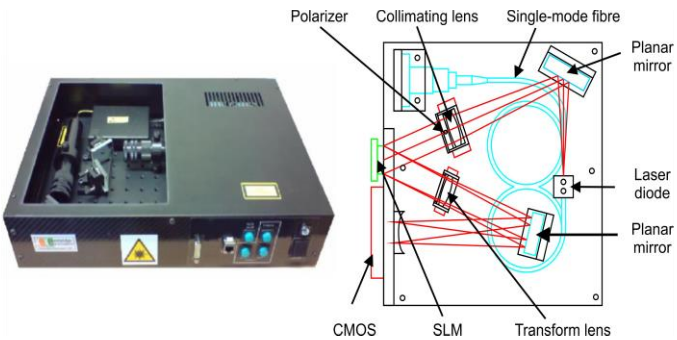


Fig. 2. Cambridge optical correlator.

The main function of Cambridge optical correlator is to compare input images. A created scene is brought to input of Cambridge optical correlator a then process of optical correlation is done. The optical output consists of highly localized intensities, known as correlation spots or peaks and their size reflects measure of similarity of images. The intensity of the spots provides a measure of the similarity of the images being compared. The position of the spots in the output denotes the fact how the images are relatively aligned in the input scene. The most important indicator is the degree of correlation between the reference and an input image [1-4].

4) Pneumatic piston: The pneumatic piston is used where great emphasis is placed on durability and easy handling. It is resistant to corrosion in aggressive environments, the design allows for better cleaning, suitable for dry running and contains a special piston rod seal and wiper guide rod that extends the life of the cylinder.

B. *Block scheme of proposed system*

The Fig. 3 shows function scheme of IIPRS. This system includes a digital video camera system, a transport device, a computer and Cambridge optical correlator.

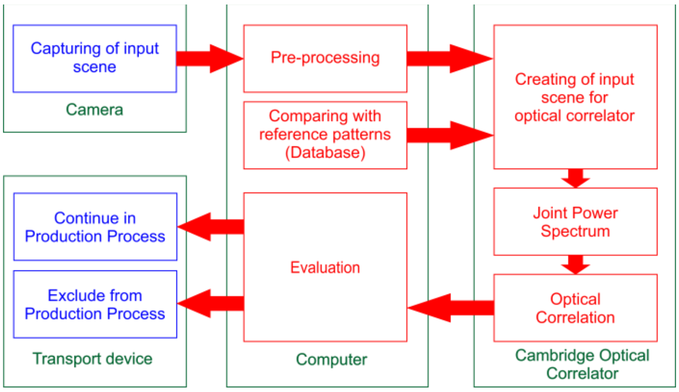


Fig. 3. Function scheme of industrial image recognition system.

The first steps and therefore the starting steps of the proposed system is capturing industrial image. In this case the specific image is pavement. This pavement is a man-made ceramic plate used for lining the walls of different rooms. It may be made of plastic, stone or glass. Pavement is brought under the camera system using the transport device. This device may be made of any material, and operate on different principles. In this case, the track roller is selected which is generally used for the continuous or intermittent movement. The material is transported by the rotation of the roller. The camera system captures an image, which is then sent to the computer for image pre-processing.

The term image pre-processing represents adjusting the captured image so it is easier to get the necessary information from it. First, an image is transformed to grayscale image that carries brightness information only. The grayscale images are converted to binary images by a thresholding process. Thresholding is the simplest method of image segmentation. White pixels represent the pixels of the image which value is within the threshold range. Black pixels represent out of the threshold range values. After this, we used morphological operation – dilatation. Dilation allows objects to expand, thus potentially filling in small holes and connecting disjoint objects. The Roberts edge detector is applied to the images and we get files of closed curves that indicate the boundaries of objects and planes. Last step is select and bound the region of interest (ROI). The region of interest represents region where pavement should be located. Then ROI is extracted from this pre-processed image [5-9].

Thus, pre-processed image with the reference image from database creates an input image of the Cambridge optical correlator. Cambridge Optical Correlator is coupled with simulation software FOE, to learning and easy understanding Fourier Optics, especially optical correlation. FOE allows make process of optical correlation based on Cambridge Optical Correlator between two or more images.

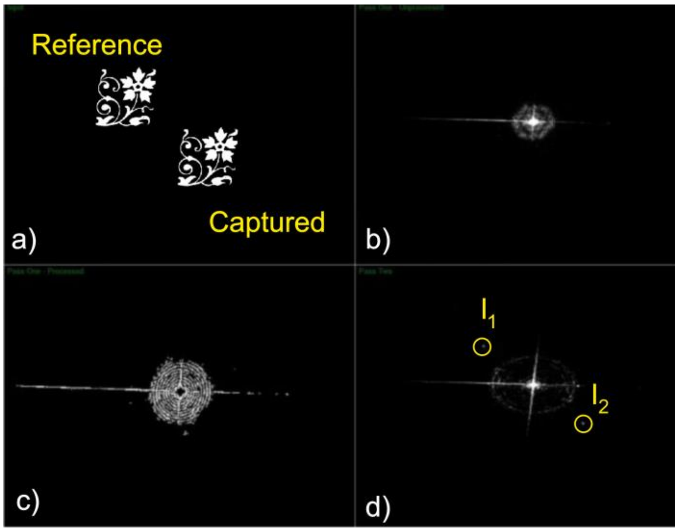


Fig. 4. Process of optical correltion between two same image.

Fig. 4 shows process of optical correlation between captured and reference pavement. The input scene (Fig. 4(a)) is created by images mentioned above and then are transformed and the Fourier transform produces a Joint Power Spectrum (JPS) (Fig. 4(b)). Next, JPS is binary or threshold processed (Fig. 4(c)). Cross-correlation is occurring and thus the output of Cambridge correlator is displayed on the correlation plane and contains correlation peaks as is shown in Fig. 4(d).

Correlation peaks values are recorded in a text file that is generated by program FOE. This value of correlation peaks is within range from 0 to 255, where value "255" refers to total match and value "0" refers to mismatch. The equation (1) means percentage match between images situated in the input scene, where I_1 and I_2 are intensities of the correlation peaks:

$$I(\%) = \frac{I_1 + I_2}{510} * 100. \quad (1)$$

Values of intensities of correlation peaks of experiments shown in Fig. 4 are I_1 = 208 and I_2 = 238. So according to equation (1) match of input images is 87 %. The resulting values are sent to a computer which then decides whether the correlation peaks reach a certain percentage intensity value - threshold. The threshold value of each type of pavement stored in database is calculated by multiple experimental comparing the same two types of pavements by Cambridge optical correlator [1], [2], [10] and [11].

Followed by the disposal of industrial scanned image from the manufacturing process or vice versa, the computer decides to continue the scanned image in the industrial production process. Wrong pavements are moved to a side track roller by a pneumatic piston. If pavements meet the all required criteria, they will continue in production process on a track roller, which was brought under camera. Setting the tolerance range of values of correlation peaks, the correct setting of SLM and specific values for edge detection are individual for each pavement.

III. Experiments and Results

Every day people buy different things with different requirements. Each product has a certain criterion that has to be met and if it does not comply, it cannot get from the factory to the store. Based on this assumption IIPRS controls two criteria that should be given product meets, in this case pavement, is a pattern and shape.

Fig. 5 shows the reference pavements stored in database which were compared with captured images. In our case, reference pavements with various deformations represent captured images. For each type of reference pavements was created four deformations. The recognition process is carried out by the Cambridge Optical Correlator which function is to compare input and reference images situated in the input scene. In our case, the captured image represents the input image and it is compared with the reference pavements.

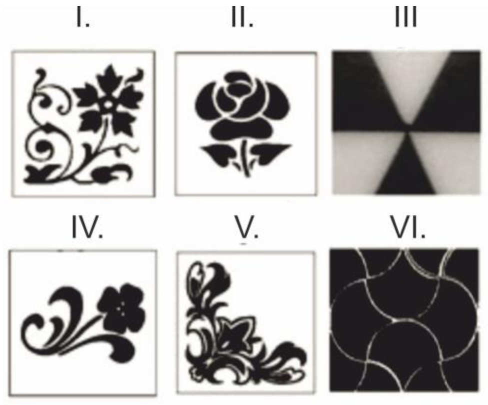


Fig. 5. Patterns of pavement.

Hundred measurements for each type of pavements were made in each experiment. Complete overviews of the experiments are shown in TABLE I. – TABLE VI. The tables contain original and distorted pavements, average intensity and results intensity (%), which was obtained by Cambridge optical correlator and threshold. Thus, if a percentage intensity of the pattern is above this level, it can be said that the pattern is not damaged and it will not be excluded from the manufacturing process.

TABLE I. Results of Experiment I.

Reference Pavement					
Captured Pavement					
Average Intensity	223	34	162,5	86,5	184
Result Intensity	87 %	13 %	64 %	34 %	72 %
Threshold	79 %				

TABLE II. RESULTS OF EXPERIMENT II.

Reference Pavement					
Captured pavement					
Average Intensity	214	96,6	191,3	56,1	45,9
Result Intensity	84 %	38 %	75 %	22 %	18 %
Threshold	82 %				

TABLE III. RESULTS OF EXPERIMENT III.

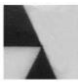
Reference Pavement					
Captured Pavement					
Average Intensity	206,6	56,1	81,6	1	140,3
Result Intensity	81 %	22 %	32 %	0 %	55 %
Threshold	79 %				

TABLE IV. RESULTS OF EXPERIMENT IV.

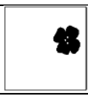
Reference Pavement					
Captured Pavement					
Average Intensity	219,3	145,4	74	117,3	66,3
Result Intensity	86 %	57 %	29 %	46 %	26 %
Threshold	81 %				

TABLE V. RESULTS OF EXPERIMENT V.

Reference Pavement					
Captured Pavement					
Average Intensity	219,3	91,8	114,8	0	153
Result Intensity	86 %	36 %	45 %	0 %	60 %
Threshold	78 %				

TABLE VI. RESULTS OF EXPERIMENT VI.

Reference Pavement					
Captured Pavement					
Average Intensity	214,2	91,8	86,7	66,3	107,1
Result Intensity	84 %	36 %	34 %	26 %	42 %
Threshold	78 %				

Based on the obtained results it can be seen that the pavements, which did not include a complete pattern, were partially damaged, broken off, or otherwise deformed had a lower percentage of intensity and thus allow them to be distinguished from the pavements. The pavements in which the pattern was not damaged, and therefore, meet all requirements of the predefined templates in advance. Each pavement had individual threshold of intensity. If a pattern was only partially damaged, the percentage of intensity was close to the threshold and this value decreased depending on the extent of damage.

IV. CONCLUSION

Industrial image pattern recognition system is a complex system for controlling quality of production process – quality of pavements. The individual steps necessary for a complete comparison of controlled pavement with a reference pavement have been described above. Experimental verification of the proposed system consisted of a comparison of six types of pavements with different pattern. 500 measurements were made for each type of pavement. Each pattern contained one original and four deformations. 3000 measurements were carried out in total.

Thresholds were determined on the basis of the measurements (minimum percentage of intensity) for specific patterns of pavements. From the tables of the results it is possible to see which pavements meet the required threshold intensity. Experimental measurements are shown the proper functioning of the system with the result that the pavement which has not been damaged (achieved a minimum percentage of intensity) continues in the production process and pavement, which has been damaged in any way (short of the minimum percentage of brightness), is taken out of production.

Optical image processing by using Cambridge optical correlator has some potential in this area and Cambridge optical correlator will be implemented in the field of biometrics and many others areas, where you need to pay attention to the speed and accuracy of image processing.

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