

Automated Control of Technological Parameters of Ceramic Tiles Using Technical Vision

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Abstract — The results of theoretical study and practical realization of a technical vision system in the production of ceramic tiles are summarized. The possibility of using technical vision during the technological operation to control the absence of defects of ceramic tiles when it moves along the conveyor in the production cycle is shown.

Keywords — technical vision, technological parameters, control of absence of defects

I. INTRODUCTION

In recent years, due to the wide development of digital technologies, automated technological processes have become increasingly important at all stages of production, from the production of raw materials to the production of finished products. Improving the product quality has always been an urgent task of any production.

The role of non-contact methods of product quality control has increased significantly in recent years. A special place in the methods of contactless control is taken by vision systems, which are widely used in various spheres of human activity, including industry [1–4, 6].

A vision system usually consists of an image capture device (camera), a computing device (video processor), and application software. Typical tasks for such systems are the control of geometric dimensions, product counting, 1D and 2D codes reading, color control, surface inspection, etc. There are different approaches to the realization of technical vision systems, such as comparing the image with the master image or building three-dimensional image models according to projections [5, 8, 9].

The scope of technical vision systems for product quality control is expanding every year. Modern cameras for high-speed video are able to measure geometric dimensions with an accuracy of several micrometers and detect defects that are difficult to find visually.

The aim of the work is to increase the efficiency of the Technical Control Department in the production of ceramic tiles. To achieve this goal, a system of geometric dimensions control and detection of defects in products using technical vision has been developed.

The system of technical vision allows you to control the technological parameters of tiles [11–13], automatically determining the products not suitable for realization, thereby increasing the productivity of the Technical Control Department and eliminating the human factor.

II. METHODS AND MATERIALS

The quality parameters of ceramic tiles, which the finished products must meet, the types of defects and the requirements for the production startup are normalized [11, 12]. The defects in appearance are determined in accordance with [11].

The dimensional variation of the finished products is conditioned by the fact that the actual size of the tiles at the furnace exit differs from the nominal one, indicated in the catalogue. It can be determined only by measuring the tiles after they leave the furnace at the final stage of production. The reason for this difference in size is a complex multi-component composition of the tile base mixture. Individual components of the mixture have different coefficients of thermal expansion, which causes the occurrence of inhomogeneities and defects during heating and cooling in the industrial process.

The main object for the research of the control system of technological parameters is floor square tiles format 450x450 mm. The nominal size of the tile is set by the manufacturer, so that the width of the seam is varied from 2 to 5 mm (Fig. 1).

Limit deviations of tile sizes from the nominal ones shall not be more than $\pm 1,5$ mm in length and width. These deviations are regulated by [12].



Fig. 1. Compliance of coordination size with the total amount of nominal tile size and the joint width: K – coordination size, H – nominal size, C – seam width.

The tile appearance is checked visually in daylight or scattered artificial light with illumination from 300 to 400 Lux from a distance of 1 m from the observer's eyes. The difference in colour (colour shade), tracery and the front face relief from the reference samples, as well as the presence of visible cracks and chips are recorded [13].

One of the main problems is the quality control parameters of finished products, which is carried out visually on an automated line and does not guarantee the required quality. As for the visual inspection, there is a human factor, and all control is subjective.

When choosing a camera for automated production, there are a number of criteria: the distance to the object; the size of the object; the speed of movement; the operating environment of the camera; the lighting; the parameters for analysis and their number; the synchronization and integration into the overall system and other parameters. The most important of them are discussed below.

Industrial cameras are divided into matrix and linear. The difference between them is the principle of image capture. The image consists of a certain number of lines. Matrix cameras are equipped with a rectangular sensor containing many rows of pixels that are exposed at the same time. Thus, the recording of image data is carried out in one step, as well as their processing.

Linear cameras are equipped with a single sensor containing only one, two or three rows of pixels. The image data is captured row by row, and the entire image is restored from the individual rows during processing. The question of choosing a matrix or linear camera is related to the scope of the camera and the requirements it must meet [7, 8].

Cameras with KMOII matrices is of great interest. In the KMOII matrix, the processing device is located next to each pixel, thereby increasing the system performance. Also, due to the lack of additional processing devices, we note the low power consumption of KMOII matrices.

If the colour is not a compulsory condition, it is recommended to opt for a monochrome camera. Due to the absence of the need for light filters, these cameras are more sensitive than colour ones and can produce images with a higher degree of detail.

The matrix colour camera IDS UI-3130CP has been chosen for the developed vision system (Fig. 2), since it is necessary to have a large number of pixels for accurate processing of image parameters. It is also important that it is necessary to work with colour drawings on the product surfaces. The camera IDS UI-3130CP with USB 3.0 interface features a KMOII sensor PYTHON 500. The size is 1/3.6" and it is manufactured by ON Semiconductor. The sensor supports

the general exposure mode and allows high-speed shooting of more than 1000 frames per second. Thus, the camera with a KMOII sensor (0.5 Mpix: 800×600, the shooting speed may be as much as 575 frames per second) is applicable in conventional machine vision applications for visualization and analysis of fast processes.



Fig. 2. USB Camera UI-3130CP

One of the important advantages of this camera is the use of DIS technology. This technology provides software image processing that compensates for camera jitter. Image stabilization is performed programmatically in the camera processor. An intelligent algorithm provides a comparison of sequential frames. In this case, it is determined in which direction and how much the whole scene has shifted relative to the frame boundaries. After that, a program transfer of the "shifted" frame in the opposite direction is made. The frame offset is compensated, and the monitor displays a photo in which the scene is not shaking.

The use of the given camera with this DIS technology makes it possible to achieve the minimum error associated with mechanical vibrations occurring during the operation of the automated conveyor.

One of the important aspects of the control system of technological parameters is its location in the chain of technological processes of the production of ceramic tiles. The control system must be located at the final stage of the technological process of the production of ceramic tiles after such technological operations as drying, coating, patterning and firing were performed. On this basis, it is advisable to install the system before the area of packaging and rejection of non-conforming products in order to control the technological parameters of the finished ceramic tiles.

The control accuracy during video shooting is ensured by the rigid fastening of the camera over the conveyor, its protection against vibration, pollution and the choice of the correct lighting system. Under operating conditions, it is not allowed to shift the camera from the initial position of fixing, as when changing its position there is an error in measuring the technological parameters of the ceramic tiles, and the camera must be calibrated again.

The point of fixing the camera was chosen according to the technological process condition; the ease of the placement of lighting fixtures; the possibility of stationary and rigid fixing of the USB camera; easy installation of fastening devices [1].

On the basis of the above conditions, the option of fastening the bracket that holds the USB camera in the support located next to the conveyor has been chosen. Its aim is to

place an automated line of lighting devices, cable channels and other servicing devices above the conveyor.

Based on the analysis of works [2, 3, 5], it was found that the best option for working with the technical vision system when choosing the type of lamps is a LED lamp. In order to get rid of glare and shadows on the tile surface under study, it is advisable to use volumetric two-way lighting. There is a camera fixed above the conveyor in the centre of the exposition, above which linear LED lamps are fixed at a distance of 800 mm from each other and 400 mm from the camera.

The realization of the software module begins with the capture of individual images of the video stream. Then the resulting image must undergo pre-processing, such as noise elimination; brightness, contrast and colour levelling; separation and removal of glare and shadows [2, 3]. Image preprocessing can be simple, but can involve a complex technology. The digital image generated by the video or camera is entered into the computer and digitally processed to determine the geometric parameters of the object. One of the important tasks is the automatic selection of moving objects, which is a necessary preliminary step in solving the tasks. There are two main classes of methods for selecting moving objects:

- 1) by means of analysing their boundaries (contours);
- 2) by means of analysing the entire area of the object on the frames.

The main idea of the methods of the first class is to find differences in the optical flow vectors with the subsequent construction of the contours of moving objects. Methods of the second class, on the contrary, are based on the grouping of similar vectors from the optical flow together in regions, which are fed to the output of the algorithm as moving objects. Most classical methods do not analyse the video sequence frames themselves but the optic flow (the field of visible displacements of image pixels), built on these frames [5–10].

The next step is to single out the object features that depend on the tasks. For example, the developed programme will support several surface control functions, such as:

- search for special points on the object to compare the image of the object obtained from the camera with the master image;
- detection of surface defects;
- control of geometrical parameters.

To solve the tasks a personal computer based on Windows OS is used. The development of the control program was carried out in the Visual Studio programming environment, in the C++ programming language. To support all graphics functions the OpenCV library is used. The library contains the realizations of some steps of the investigated methods, such as the construction of an optical flow, the calculation of the gradient and contour search. It also contains a simple and easy interface to work with cameras and displaying the result [6, 10].

OpenCV is an open-source library of computer vision, image processing and general-purpose numerical algorithms. The library is written in C and C++ and runs on computers based on Linux, Windows, Mac OS X. The OpenCV Library was developed to improve computational efficiency and with a focus on real-time applications. OpenCV is written using the optimized C language and can use multi-core processors. One of the main goals of OpenCV is to provide an easy-to-use interface that will allow people to build quickly complex applications using computer vision. The library interfaces for Python, Ruby, Matlab and other programming environments are also being actively developed.

OpenCV is structured around five main components, four of which are shown below. The CV component contains basic image processing algorithms and high-level computer vision algorithms; ML contains machine learning library, which includes statistical classification and clustering tools. The HighGUI module provides functions that allow you to interact with the operating system, file system and computer hardware such as cameras. HighGUI allows you to open windows, display images, read and write graphics files and videos, simply handle the mouse and the keyboard [10].

OpenCV features that allow you to interact with the operating system, file system and hardware, such as the camera, are collected in the HighGUI library. HighGUI allows you to open windows to display images, read and write image files (images and videos), process simple mouse, pointer and keyboard events. This library also allows you to create useful elements such as a slider. HighGUI has sufficient functionality for the development of various applications. The advantage of this library is cross-platform.

The HighGUI library consists of three parts:

- hardware;
- file system;
- GUI.

The hardware is primarily concerned with the camera. In most operating systems, the camera control code is complex and cumbersome. HighGUI provides simple mechanisms for connecting and then capturing images from the camera.

Everything about the file system is primarily about loading and saving the image. An important feature of the library is the presence of methods that equally process the video stream from the file and from the camera. The same idea lies in the methods of image processing. The functions simply rely on file extensions and automatically process all image encoding and decoding operations. The third part of HighGUI is GUI. The library provides several simple functions that allow you to open a window and display images in it. There is also a possibility to process the events received from the input devices – the mouse and the keyboard.

OpenCV provides a fast and easy – to-use interface for performing morphological transformations of images. Such basic morphological transformations as expansion and blur can be applied in the situations of noise removal, the selection of individual elements and the connection of dissimilar image

elements. Morphological transformations can also be used to find intensity bumps or holes and the image gradient.

Since its alpha release in January 1999, the OpenCV library has been used in many applications, products and research. Applications such as images matching in satellite systems and web maps, image alignment, noise reduction in medical images, object analysis, intrusion detection systems, automatic control, security systems, production of control systems, camera calibration, wide military applications, pilotless flying, ground and underwater vehicles.

OpenCV Features:

- human-machine interaction;
- identification of objects;
- segmentation and recognition;
- face recognition;
- gesture recognition;
- motion tracking;
- movement structure;
- stereo cameras calibrating;
- 3D tracking.

Today, there are various methods of detecting objects in a digital image: Viola – Jones boosted cascade of simple features, generalized Hough transform, Kapoor–Wynn method and others. However, object detection methods with high reliability and stability require significant time and machine resources for training at new facilities.

Methods of object detection on a digital image, according to the method of labelling the image area as the area of interest, can be divided into two large groups: generalizing methods and distinguishing ones.

Generalizing methods give an abstract idea of the structure of the object on the basis of positive training images. When analyzing a new image, generalizing methods estimate how accurately this image corresponds to the constructed model. In addition to analyzing the available images, generalizing methods can use the obtained model to construct new images of the object. When teaching generalized methods negative training images are not required.

In this paper we used one of the most popular generalizing methods – generalized Hough transform. The essence of the method is that in the process of teaching some characteristic points are marked out on the image of the object. Every point has a radius vector that connects it to the geometric centre of the object. When a feature point is detected on the image under study, the corresponding radius vector indicates the expected position of the centre of the object. An extra vote is added to the pixel located in this position. The pixel with the most votes after scanning the whole image will correspond to the most probable position of the object centre. Thus, it is possible to find the correspondence between the training or master image and the image of the object obtained from the video sequence. Some characteristic areas are marked out on

the investigated image and are brought in correspondence with the elements of the object or the display background (Fig. 3). Then, using exhaustive search, we find the most plausible correspondence [2, 3].

There are also distinguishing methods, which are more complex and specific, so they are used much less often. The distinguishing methods use a special classifier function to detect an object on a digital image. In the teaching process, they highlight the differences between positive and negative learning images. Based on these differences, they select the parameters of the classifier function. The resulting function is used to divide the new input images into images that contain and do not contain the area of interest. The most popular discriminative methods are Viola – Jones object detection, LeCun and Papageorgiou methods.

Thus, the distinguishing methods focus on the differences between positive and negative images of a particular training sample, while the generalizing methods try to recreate the structure of the object itself by its images. Therefore, when teaching generalizing methods, negative images are not required, and the required number of positive images is significantly less than that when teaching the distinguishing methods. It can be concluded that to select an object from the video stream quickly and easily, generalizing methods should be used.

The work of the created software module for monitoring the technological parameters of ceramic tiles begins with the fact that the program is loaded with a master image of the product, which is currently running on an automated production line. Then the program receives a video stream from the camera, where it captures images of ceramic tiles and performs the necessary processing, such as elimination of noise, glare, shadows and binarization.

At the stage of process parameters control the program controls two groups of parameters. First, the geometric parameters of the product are controlled taking into account the necessary tolerances or gauges of ceramic tiles. In case of non-compliance of the product with this group of parameters, the program gives a signal of non-compliance without checking the following quality criteria.

The program provides the statistical inference of the total number of products tested and the number of products that do not meet the technological parameters. The system controls two groups of parameters: geometric parameters and drawing accuracy parameters. Depending on the ratio of the rejection rate of each group of parameters and the total number of non-conforming products we can conclude that there are violations in the technological process of the production of ceramic tiles.

III. RESULTS

In the course of research, the data of the number of products and the ratio of flawed items for each of the controlled parameters and the total number of the items have been obtained. To accumulate the statistical data, we have studied the results of measurements of the system of technical vision for a shift. The total number of product units checked by the control system of technological parameters for one shift has been 1264 tiles, the number of units that the control

system recognized as non-conforming, has been 104 items or 8 % of the total number per shift.

Engineering and technological personnel can use empirical tables with the allowable percentage of defects per shift and the ratio of defects belonging to different groups to identify the technological operation in which problems arise and take measures to eliminate or reduce the percentage of defects in the production of ceramic tiles.

IV. CONCLUSION

To date, the practice of using vision systems by domestic and foreign enterprises indicates the suitability of implementing such systems to solve a wide range of problems. The distinctive features of vision systems are contactlessness and measurement capability in dynamics.

The work is urgent now, as its introduction excludes a normal inspector from the decision-making process concerning the value of the measured physical quantity, which objectively improves the accuracy figures, reliability and geometrical measurements.

The developed software and hardware system based on the vision system makes it possible to automate the process of geometric parameters control and the defects of ceramic tiles when moving along the conveyor, eliminating the human factor and thereby ensuring the quality of products with increased productivity.

The use of automated control of technological parameters of ceramic tiles allows engineering and technological personnel to make timely adjustments to the process, reducing technological losses.

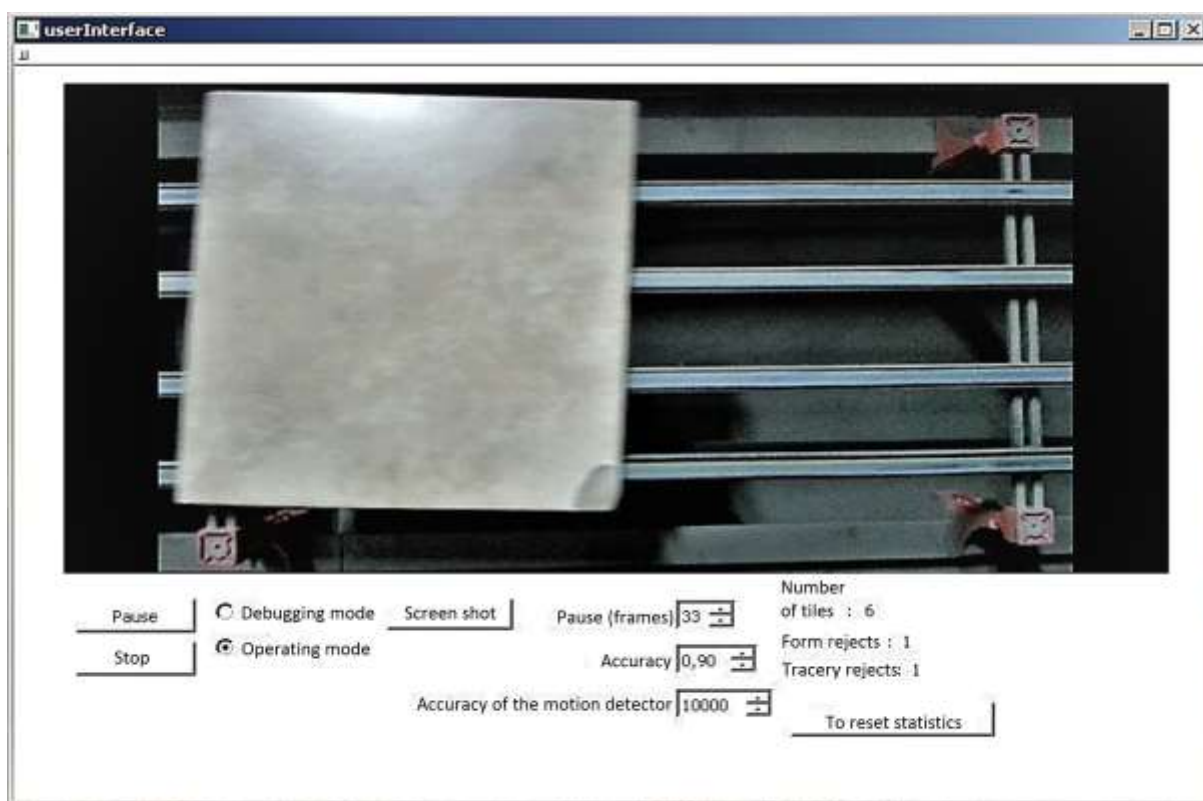


Fig. 3. Program interface

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