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FEATURES OF THE IMPLEMENTATION OF COMPUTER VISION IN THE PROBLEMS OF AUTOMATED PRODUCT QUALITY CONTROL

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Abstract. *The article analyzes the fields of application of machine vision. Special attention is focused on the application of Machine Vision in intelligent technological systems for product quality control. An important aspect is a quick and effective analysis of product quality directly at the stage of the technological process with high accuracy in determining product defects. The appropriateness and perspective of using the mathematical apparatus of artificial neural networks for the development of an intelligent technological system for monitoring the geometric state of products have been demonstrated. The purpose of this study is focused on the identification and classification of reed tuber quality parameters. For this purpose, new methods of identification and classification of quality control of various types of defects using computer vision and machine learning algorithms were proposed.*

Keywords: machine vision, intelligent technological system, quality control, neural networks

CECHY IMPLEMENTACJI WIZJI KOMPUTEROWEJ W PROBLEMACH AUTOMATYCZNEJ KONTROLI JAKOŚCI PRODUKTÓW

Streszczenie. *W artykule dokonano analizy obszarów zastosowań widzenia maszynowego. Szczególną uwagę zwrócono na zastosowanie widzenia maszynowego w inteligentnych systemach technologicznych kontroli jakości wyrobów. Ważnym aspektem jest szybka i skuteczna analiza jakości produktu bezpośrednio na etapie procesu technologicznego z dużą dokładnością w określaniu wad produktu. Pokazano celowość i perspektywę wykorzystania aparatu matematycznego sztucznych sieci neuronowych do budowy inteligentnego systemu technologicznego do monitorowania stanu geometrycznego wyrobów. Celem badań jest identyfikacja i klasyfikacja parametrów jakościowych rurek trzcinowych. W tym celu zaproponowano nowe metody identyfikacji i klasyfikacji kontroli jakości różnego rodzaju defektów z wykorzystaniem wizji komputerowej i algorytmów uczenia maszynowego.*

Słowa kluczowe: wizja maszynowa, inteligentne systemy technologiczne, kontrola jakości, sieci neuronowe

Introduction

Modern technological equipment of various functional purposes must fully meet the requirements of digital production and have the ability to quickly integrate into the structure of intelligent smart enterprises, which turn into intelligent cyber-physical technological systems. Machine Vision (MV) is a necessary component of such intelligent cyber-physical technological systems and a promising method of automation, which allows you to maintain operations of capture, movement of various objects, in particular parts [2], maintain quality control [13, 14], contribute to the improvement of technology. security [5], etc. In addition, machine vision is increasingly used in modular machine tools.

Machine vision is one of the fastest-growing fields in the field of intelligent technologies. According to forecasts in the USA, the total machine vision market in the industry will reach 12.29 billion US dollars by 2023 [4].

The given data indicate a high need for large companies to implement maximum automation of technological processes, in particular operations of product quality control [6]. The growing demand for machine vision systems is due to the fourth industrial revolution, Industry 4.0, and the development of such technologies as artificial intelligence and the Internet of Things.

The rapid growth of demand for Machine Vision technologies is closely related to the development of information technologies. Machine Vision technology is distinguished by the recognition of images of objects with the help of images, followed by their presentation in the form of two-dimensional projections, which in turn are processed with the help of mathematical transformations into text information.

Whenever it comes to mass production, issues of ensuring quality, efficiency, and minimizing time costs arise. To solve these issues, the industry is increasingly resorting to modern means of automation, namely the continuous operation of automated production lines with intermediate quality control. Recently, thanks to the effective combination of information technology and modern digital cameras, image processing have become more accessible. The quality and capabilities of image processing software have become higher, and more reliable while providing better initial product quality control [3]. Therefore, the application of Machine Vision technologies in intelligent technological systems for product quality control is appropriate and relevant.

Currently, machine vision is widely used in medicine, the automotive industry, robotics, the military, biotechnology, and industrial production. This is due to the fact that these industries have clearly formulated tasks that can be successfully solved using Machine Vision technology [12].

The use of classical methods of product quality control is associated with additional costs of human labour and largely depends on the nervous and physiological state of workers-controllers. An important aspect is also the fastest and most effective analysis of the quality of products at the stage of the technological process with high accuracy in determining the defects of the manufactured products. Therefore, the application of modern computer-based technologies is becoming more and more relevant in intelligent technological systems to control the quality of products and the state of technological processes and production facilities (machine tools, tools, technological equipment, etc.).

1. Materials and methods

At present, the development of methods and algorithms for image processing and machine vision has been allocated enough domestic and foreign publications in various fields of mechanical engineering. For example, in [7], the authors consider in detail the methods of solving computer vision tasks, and cite their advantages and disadvantages. The prerogative of using Gaussian transformations to simplify algorithm calculations, based on the interpretation of objects, is noted. The authors consider alternative applications of machine vision in solving tasks in systems with limited resources, namely unmanned aerial vehicles, mobile devices, robotics and satellite systems.

Wide possibilities of application of neural networks, due to their flexibility, and the ability to adapt in almost any field, in particular in machine vision, are shown in [11]. The possibilities of computer vision to learn for programmed goals are considered. The advantage mentioned in this work is that the created systems are flexible and can adapt to such tasks, taking into account the variability of conditions and variable factors.

Kazemian et al. developed a computer vision system for real-time adaptive manufacturing extrusion output quality control [1]. The neural network in this work is used to create feedback control systems that ensure the speed of extrusion and, if necessary, control the feed. In this system, the cameras are located perpendicular to the object of control, and the system perceives the layer of material as a straight line and interprets it as a dynamic width through mathematical transformations, which is used to analyze the extrusion process [1].

Researchers Moru and Borro in their work [8] used high-precision equipment for the development of computer vision systems aimed at sub-pixel quality inspection of gears. Cameras with a telecentric lens, with a calibration error of only 0.06 pixels at the time, made it possible to ensure a measurement accuracy of up to ±0.02 mm. To carry out control, they developed three simultaneously working algorithms for checking the internal and external diameter and the number of teeth.

In [10], the authors of Sahoo S. K., Sharma M. M., Choudhury B. B. propose a system for dynamic control of glass bottles. The first image was viewed by a high-resolution intelligent camera. Then, some techniques were depicted to reduce noise and improve the quality of the images produced. Segmentation techniques were used to separate the background from the original image and render the image in vector form for outlier detection. An artificial neural network trained using the error backpropagation algorithm was used to analyze the obtained graphics for the extraction of defective features. The authors of this work compared different classification algorithms using three feature extraction methods with and without sensor implementation in the machine view verification system.

The analysis of the latest research and publications showed virtually unlimited use of Machine Vision technologies. An important element of Machine Vision technologies in intelligent technological systems should be the possibility of prompt and as accurate recognition of specified types of defects with their subsequent separation and utilization, which significantly increases the productivity of product quality control processes.

Machine Vision is a three-level system consisting of a video information collection system, analysis, description and recognition system, and artificial intelligence.

In the video information collection system, information about the image, with the help of optical-electronic converters and video sensors, is provided as part of electrical signals. Information obtained in this way is processed hierarchically. First, the image is processed by video processors. Here, the key parameter is the contour of the image, which is specified by the coordinates of many of its points. The optical system projects the image on the sensitive elements, while the previously larger size of the working area is covered by the sensor.

The system of analysis, description and recognition includes a high-performance computing node and complex software and algorithmic support for processing the received image.

Artificial intelligence, as a rule, includes a specialized computing unit and a software neural network.

The main components of the machine vision system are:

- lighting elements;
- optics;
- optical data capture sensor (machine vision camera);
- optical data processing system and computer node;
- data transmission system and means of communication.

The components of the machine vision system provide automation of industrial processes in intelligent technological systems as follows (Fig. 1). The working area, where the parts are placed, is illuminated by lamps. A video camera is located above the working area, information about which is sent to the main unit of the Machine Vision system via cable or wireless communication. From the main block of information (in a processed form) the controlled automation system device is presented. The automation system in the form of work or actuators for processing sorting or quality control of parts, their orderly placement in containers with a clear correspondence of information coming from the software of the Machine Vision system.

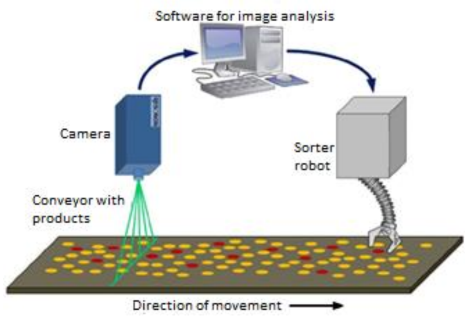

Fig. 1. Scheme of operation of the machine vision system

The intensive implementation and development of Industry 4.0 put robotics, artificial intelligence, machine vision, big data cloud computing and machine learning at the forefront. This created large-scale opportunities for improving the quality of products, reducing pollution, automating processes, increasing the stability of production cycles, and reducing operational costs for the involvement of the human factor in the operations of the manufacturing process. Industry 4.0 makes it possible to create intelligent cyber-physical technological systems, so-called "smart factories", which are based on the use of various sensors to control automated processes. One of the main effective technologies contributing to this is Machine Vision, which is an integral component of automated production. This technology is most widely used for automated product quality control. Machine Vision technology allows you to exclude such human factors as fatigue, unimportance, limited ability to quickly process a large amount of information, and others. The preferred machine type is continuous 24/7 control of set parameters, with the ability to process information at a speed of 20,000 k/s, while human capabilities are limited to 24 k/s.

As it was determined, the methods of higher computer vision for their operation involve the use of sensors, cameras and computing power, often cloud-based, which in due time makes production lines more optimized, saves the area of production premises, provides increases industrial safety due to the exclusion of many components. Also, this technology is effective in reducing labor costs. thanks to this, it also ensures the overall level of product quality, more precisely screening out low-quality or defective products.

The technology works on the basis of algorithms with programmed defects, which are detected by a computer program during the analysis of the received images from the production line. The obtained two-dimensional values are analyzed by software based on the mathematical apparatus of Gaussian transformations. Unnecessary noise and structural elements of production lines are filtered out. The final result of digital processing is obtained and compared with the programmed database of existing defects to identify the state of the controlled object. If deviations are found, the product is sent to one of two streams, reprocessing or recycling into waste.

As an example of the importance of using Machine Vision technologies, we will cite a study by the World Security Fund. According to their data, almost 75% of single aircraft approaches and landings occur at airports where precision approach instruments are unavailable or absent, in poor visibility conditions. In this regard, one of the important directions of improvement of on-board avionics is the development of hardware and software complexes of enhanced vision (Enhanced Vision Systems, EVS). As sources of information in such systems, television video sensors, infrared (IR) sensors of various sections, millimeters radars (MR), laser locators (LL), databases of terrain relief along flight routes, databases of airports and runway objects can be used. (RWP), navigation parameters and a number of others.

Analysis of systems and capabilities of computer vision methodology. The described advantages of using Machine Vision will be considered in more detail in the example of solving typical tasks [8]:

1. Recognition is a classic task that arises in image processing and detection of some characteristics of an object. This task is easily solved, but machine vision is still not able to withstand human qualities, in a situation with objects that go beyond the programmed limits.
2. Identification – an indication of a special instance of the object. For example, identification of a person, fingerprints or license plate. In intelligent technological systems – reading of QR codes, which mark or technological documentation.
3. Detection – the obtained results are checked if a certain condition is present. For example, in medicine, the presence of possible damaged cells or tissues in images is under a microscope. Sometimes it is used to compare areas on the analyzed images, to detect minor deviations.
4. Evaluation – determination of the position or orientation of a certain object relative to the camera. An example of the application of this technique can be assisting the work hand in removing objects from the conveyor belt on the product assembly line.
5. Locomotion is a multitasking survey motion in which an image sequence is processed to find a velocity estimate for each point in the image or 3D scene. Examples of such tasks are observation, that is, following the movement of an object.
6. Image restoration – the error of image restoration is noise removal (sensor noise, blurriness of a moving object, etc.). The simplest approach to solving this problem is different types of filters, such as low- or medium-pass filters. More complex methods require the detection of how certain areas of the image should look, and based on this, create their changes.

Machine Vision is not limited to basic methods for solving problems. It is multifaceted. Each of the tasks can be considered differently by the so-called genetic algorithms, but all the main approaches are:

- contour analysis is a curve (a set of curves) that is the end point of the object in the image, therefore, with the help of this method, not a complete image of the object is analyzed, but only the obtained contour, which provides the speed algorithm, due to the initial limitation;
- pattern search – the most advanced method in computer vision, designed to detect certain, programmed, features of an object on the generated image;
- search outside templates – occurs in the recognition of deviations from the standard, namely, the finding of defects, chips, cracks, pigmentation, and deviations from the given geometric parameters;
- data fusion – designed to obtain effective results by processing different types of signals received from cameras and sensors.

Complex performance of tasks requires multi-chamber systems that will be used in arrays. Cameras are used to track the movement of individuals indoors or in places with limited visibility (warehouses in seaports, factory areas, etc.). They are also used for traffic management in intelligent transport systems. The main areas of use of this technology are: production automation; video surveillance from a UAV; 3D movies; interactive AR/VR games; recognition of persons, movement, identification, etc.

Today, when solving tasks in intelligent cyber-physical technological systems, one cannot do without the use of specialized software. The main ones are listed below [1].

OpenCV (Open-Source Computer Vision Library) is a library of computer vision algorithms, image processing and general-purpose numerical algorithms. Implemented in C/C++, also developed for Python, Java, Ruby, Matlab, Lua and other languages.

PCL (Point Cloud Library) is a large-scale open-source project for processing 2D/3D images and cloud points. The PCL platform contains many algorithms, including filtering, feature estimation, surface reconstruction, registration, model selection, and segmentation.

ROS (Robot Operating System) is a software development platform for robots. It is a set of tools, libraries and applications that simplify the development of complex and efficient programs for managing many types of work [9].

MATLAB is a high-level language and interactive environment for programming, numerical calculations and visualization of results. With MATLAB you can analyze data, develop algorithms, and create models and programs.

CUDA (Compute Unified Device Architecture) is a hardware and software architecture for parallel computing that allows you to significantly increase computing performance through the use of Nvidia graphics processors.

SimpleCV is a system for creating applied computer vision. Provides access to a large number of computer vision tools similar to OpenCV, Rygame, etc. Does not require deep loading into the theme. It is suitable for rapid prototyping.

2. Experiment and results

Reed tubers, from a few places of their cultivation and with differences, were chosen as the research object of the sample, and several reference products were also chosen. The main learning criteria were selected, such as pigmentation, color, geometric dimensions, inner film, cracks, chips and defects during cutting (Fig. 2). The samples are not raw data, which are digitized for each type of deviation using a digital camera to generate training and test training sets.

According to the peculiarity of the products, namely the various natural factors of shape, pigmentation and colour. The technological process involves the application of a continuous control method. It includes the distribution of products according to eleven quality characteristics, which include various defects: cracks, damage by pests, pigmentation, length deviations, diameter distribution and deviations from the shape. We proposed using optical cameras that work by analogy with the human eye to determine these characteristics. The use of ultrasonic or infrared sensors does not provide a complete picture due to the local concentration of the investigated area. The use of mechanical contact methods is limited by the variety of product shapes.

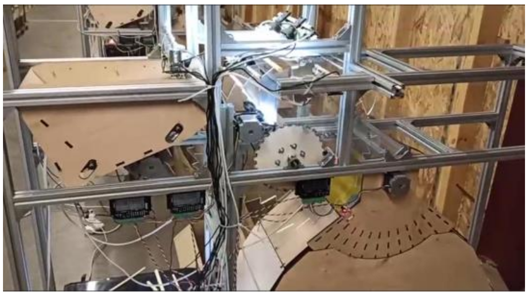

Fig. 2. Collection of data from samples of reed tubes and their quality control

11 classifiers were created, both for training and for test sets, each of them was assigned a single defect, but machine vision recognizes combinations as well (Fig. 3). After entering the data, they are analyzed for the presence of the main deviation criteria, each product carries its fate in the initial process, after analyzing the data, the study offers three options for the final classification: finishing, waste and finished product.

Image preprocessing is very necessary to optimize the model and reduce the computation time. The resulting images are not guaranteed to contain all information related to the task. For example, the background content may contain a large part of the image, which will lead to unnecessary calculations in the next stage of identification. Thus, filtering techniques can improve the quality of captured images and remove unnecessary content. The final step is to compress the image to reduce data redundancy in the image so that it can be quickly uploaded to the cloud and stored without taking up a lot of space.

Noise removal is the main procedure for signal amplification, for this preliminary control the area is highlighted in white, for better detail and additional illumination of the control area is added (Fig. 4)

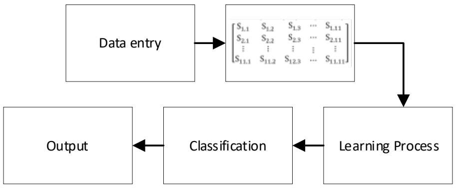

Fig. 3. Setting up machine learning

Fig. 4. Defective reed tube, in the control area

The database used by the image identification algorithm contains collected product image samples labelled according to classifiers, separated in an indicative way on the training and evaluation images. In the training phase, training images are performed for continuous parameter correction with a supervised learning approach to minimize prediction errors. However, model evaluation is essential to find a good network structure and an appropriate learning strategy, thus obtaining a practical model for identification and retention. Finally, the built classification model analyzes the processed image in real-time and provides feedback to the next controller ("defective product", "refinish defect" or "defect-free product").

3. Conclusions

The rapid spread of machine vision technology covers almost the entire field of industrial production. The implementation of Machine Vision technology in intelligent technical systems of the smart-enterprise type gives high results where this technology is implemented. This, in turn, contributes to the implementation of the ideas of the fourth industrial revolution Industry 4.0 and reduces the participation of people in the same type of routine tasks in production.

In the perspective of further research, there is the development of a computer vision system that provides monitoring of the actual geometric state of the product (workpiece) and its comparison with the (learned) using mathematical neural network devices. By applying machine vision technology in comparison to other methods, observing and optimal methods, we obtained a high level of repeatability and robustness at a significantly lower cost. The high advantage is that every manufactured product is inspected for all kinds of defects and compensation from the human eye, the deployed system can work continuously without loss of productivity.

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