THEORETICAL AND METHODOLOGICAL PRINCIPLES OF CREATION OF COMPUTER VISION SYSTEMS FOR AUTOMATION OF QUALITY CONTROL TEXTILE MATERIALS

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Abstract: Currently, at textile and light industry enterprises, the detection of defective textile materials is one of the least automated stages of the technological chain. In most cases, heavy manual labor is used, where dozens of people are employed and a huge amount of working time is spent. These costs are not always effective. Improving the quality of products with minimal human labor costs is one of the main tasks in the development of the textile and light industry.

Enterprises in the conditions of market relations are forced to constantly improve their production base, increase the speed of production, and promptly change the assortment. At the same time, raw material prices are steadily rising. In such conditions, the urgency of operational quality control of raw materials and finished products increases dramatically. At the same time, much attention is paid to the development of special hardware and software measuring complexes, where unique software is created for specific technical support - computer vision systems.

Key words: Enterprises, textile materials, important, computer vision system, management activities, products, development.

Currently, the acquisition and high-speed image processing are among the most relevant areas of scientific and applied research. Practical developments in the field of computer vision are actively conducted by laboratories around the world. However, high-tech automated complexes for the disassembly of fabric from due to the high cost, they cannot be purchased by small and medium-sized enterprises. In this regard, research in the field of developing an affordable complex for the search for defects in the production of textile fabrics is of high relevance. The basis of research in this area can be considered the development of mathematical and software for such complexes.

The presented dissertation work is devoted to the development of a set of methods and algorithms that allow real-time evaluation of the quality of textile materials at textile and light industry enterprises, the selection of adequate equipment for the hardware and software complex in solving the tasks.

The aim of the work is to develop theoretical foundations, methods and algorithms of information and measurement systems designed to obtain and process digital images in the tasks of operational quality control of textile materials based on the creation of computer vision systems.

To achieve this goal , the following tasks are solved in the dissertation work:

– development and research of methods and algorithms for obtaining, preparing, analyzing and processing images of textile materials;

– research and analysis of the effectiveness of the use of various technical means of obtaining, transmitting and processing images in computer vision systems for quality control of textile materials;
– development and implementation of a hardware and software complex with the necessary minimum technical characteristics, based on the proposed algorithms, meeting the requirements of existing textile and light industry enterprises, adequate in quality
icene for express analysis of the properties of textile materials and solving other problems.
Theoretical and methodological provisions and the results of the practical implementation of the creation of a computer vision system for automating the quality control of textile materials are submitted for defense.
The main stages of the computer vision system are: obtaining an image, transferring it for processing to a computer, processing images using special algorithms and issuing a control solution. A typical computer vision system consists of one or more photo or video cameras, a data transmission system to a computer and a data processing system (computer).
Most modern quality control systems of textile materials are complex multi-purpose devices that allow you to register almost any defects of textile fabrics. The main manufacturers of automated flaw detection systems for textile materials are the companies ISRA Vision, I2S Linescan, Cognex, Lenzing
Instruments, EasyBraid Co, Elbit Vision Systems, Zellweger Uster, etc. They produce a fairly wide range of systems suitable for most industries.
However, due to their multitasking, these systems require considerable material costs. Therefore, the development of simplified, but effective video recording systems for defects of textile fabrics will help enterprises to obtain a quality control system specifically aimed at solving their tasks, while investing significantly smaller amounts. The works of Korobov N.A., Ivanovsky V.A., Komarov A.B. are devoted to the automation of the detection of defects in textile materials.
Analyzing the supply and demand in the market of quality control of textile materials, it can be noted that there is a need for budget versions of control systems that could perform a smaller number of tasks compared to hardware and software complexes of leading manufacturers, but no less efficiently and at the lowest material costs. This indicates the relevance of this direction.
One of the main roles in such complexes is played by mathematical support. Many methods of assessing the quality of textile materials based on the processing of their images have been developed. Most of them implemented programmatically. The works of Korobov N.A., Sevostyanov P.A., Ivanovsky V.A., Komarov A.B., Gorodnov I.A., Agafonov V.I. are known in this field. Each method has its advantages and disadvantages. Some of them are focused on laboratory research. The wide implementation of others is complicated by the high cost of development and introduction into production. Some algorithms require a lot of CPU time. In this regard, there is a need to create a set of programs that combine all the advantages of well-known algorithms, capable of adapting to any specific task being solved in production conditions.
This work is devoted to the theoretical and practical solution of the issue of automation of quality control of textile materials based on the creation of a computer vision system.

Before processing an image, it is necessary to evaluate its quality, to develop indicators by which you can evaluate the image as a whole. In our case, brightness and contrast can be considered as the main indicators.

Before developing criteria and methods for evaluating image quality, you need to choose a color model. The RGB model is the easiest to understand and most convenient for mathematical description. It is used in almost all technical devices for obtaining raster images and software products for processing these images. If necessary, it can be easily converted to other color models.

The brightness of the image Y can be expressed as the average brightness of all pixels. In accordance with the recommendations of the Federal Communications Commission (FCC) standard, the brightness of the image is calculated by the formula:

$$Y = \frac{1}{N}\sum_{p=1}^{N}(0{,}299 * R_p + 0{,}587 * G_p + 0{,}114 * B_p),$$

where Rp, Gp, Bp are the values of the RGB model components, N is the number of pixels of the image.

The coefficients correspond to the brightness of the YCrCb color model. The Sc and Si components contain information about color and saturation. These two color models are connected by the following matrix transformation:

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} 0,299 & 0,587 & 0,114 \\ & & 0,08131 \\ -0,168874 & -\ 0,33126 & 0\ ,5 \end{bmatrix} \text{x} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

The brightness variance of image pixels can be considered as a criterion for assessing brightness contrast:

$$\sigma^2 = \frac{1}{N}\sum_{p=1}^{N}(Y_p$$

It is possible to judge the type of marriage only after determining the contours of the defective area, its size and shape.

In the field of image processing, there are many algorithms for selecting contour boundaries. The very operation of selecting the boundaries of the contours is to enhance the sharp differences in the brightness of neighboring pixels. This is achieved by differentiating the two-dimensional image field in different directions of the definition area. At the same time, a peak is formed in the vicinity of the difference in the brightness function, which can be easily registered. The derivative of the function is defined here as the difference between the values of neighboring pixels:

$$\frac{dy}{dx} = y(x+1) - y(x)$$

One of the best algorithms for determining the contours of an image is considered to be the Canny operator. It is used in this work. There are five main stages in the algorithm:

– To reduce computational costs, the image is converted to grayscale at the beginning.

– To remove noise and unnecessary details in the image, a smoothing operation is performed. A filter based on the first derivative of the Gaussian with parameter = 1.4 is used.
– Search for gradients. The borders are marked where the gradient of the image acquires the maximum value.

For express control of the unevenness of the linear density of non-woven fabric, you can use images of the canvas obtained on the lumen. Obviously, the higher the linear density of the canvas, the worse the canvas transmits light, and, accordingly, the image turns darker.

It is proposed to use the moving average method, which is a smoothing method in order to exclude the influence of a random component.

In this case, a simple smoothing (not weighted) is used, which consists in the usual replacement of the values of the terms of the series by the arithmetic mean:

$$X_{cp}(k)=\frac{1}{n}\sum_{k=1}^{n} x(k),$$

where n is the number of pixels in the image.

The average color value of a particular image is calculated. In the RGB model, the white color recording form looks like (255,255,255). The entry (0,0,0) corresponds to black. The obtained average value can be taken as an analogue of the linear density of the nonwoven fabric sample under study, since it is inversely proportional to the illumination of the sample.

The assessment of the quality of textile materials is based on the analysis of the results of laboratory tests. This task is often solved by selection. In accordance with the specific situation, not only classical distributions can be chosen as an approximation model, but also models that are obtained as a result of summing certain combinations of standard distributions. These models have recently become increasingly popular.

A typical example of distributions is a mixture of normal distributions called the "Tukey model". At the same time, it is assumed that observations are taken from the general population, given by the density function of the form:

$$f(x) = (1-\varepsilon) * \varphi(x; m, \sigma_1^2) + \varepsilon * \varphi(x; m, \sigma_2^2),$$

For asymmetric blockages, the Shurygin blockage model can be used. An additional parameter "a" is introduced into the model of the blockage mixture, reflecting the shift of the blockage relative to the main distribution,

having a density function $\psi(x; \theta, \sigma)$. Then the mixture model has the form:

$$f(x) = (1-\varepsilon) * \psi(x; \theta, \sigma) + \varepsilon * h(x-\theta-a),$$

The main characteristic affecting the reaction time of the computer vision system is the total execution time of each of the tasks being solved:

$$T = Tc + Tl + Ta + Tr,$$

where T is the reaction time of the complex as a whole;

Tc – time of receiving and processing data on the camera;

Tl is the time taken to transfer data from the camera to the computer;
Ta – time of image analysis on a computer;
Tr is the reaction time of the machine to the obtained calculation results.
These values depend on a large number of parameters: frame resolution, color depth, number of frames per second, type of interface, image processing algorithm used.
After selecting the hardware configuration and data processing algorithms, it is necessary to analyze the performance of the project, to assess how it meets the time constraints for solving the tasks.
One of the most relevant areas of development of computer-aided design systems for the decoration of fabrics is the creation and maintenance of electronic collections of images applied to fabrics. Replenishment of such collections with new samples can also be carried out using the hardware and software complex offered in operation, since the images are captured by a WEB camera.
Along with this, the opposite task can also be solved – to find similar drawings in the database based on the available image. Software-implemented algorithms have been developed that recognize linear and checkered elements in textile patterns using a color neighborhood graph.
The search method is based on comparing the visual primitives of the sample with similar visual primitives of point images. The entire set of colors of the image is broken up by disjoint and completely covering subsets of it. For this split, a histogram is formed that reflects the proportion of each subset of colors in the color gamut of the image. When searching for images with color scales similar to the color gamut of a given sample, the distance between histograms is calculated, which is the criterion of this similarity.
However, it is obvious that there are images that have the same histogram vectors, but differ from each other in color perception, because perception depends on the colors of neighboring image points. An example of such drawings: a canvas with stripes of four colors and a canvas with dots of the same four colors. The implementation of the proposed modified method requires for each image, in addition to constructing a histogram vector, an additional calculation of the color neighborhood matrix.
Therefore, the proposed work is aimed at developing theoretical foundations, structures and research methods that make it possible to create automated systems for controlling the tension of the base, increasing the stability of the created tension and reducing the tension and discontinuity. All this, in turn, makes it possible to increase the efficiency of warping and dressing machines and looms, as well as the quality of the harsh fabrics produced.
Thus, the relevance of the topic is determined by the need for a unified integrated approach to the creation of a thread tension system for the basis of weaving machines, taking into account the impact on the quality indicators of the fabric produced and the performance of the equipment. An integrated approach provides for the development and experimental verification of the SAR tension framework and the creation of measuring instruments for the main indicators of the quality of regulation characteristic of the textile industry.
In the conditions of operating enterprises, an analysis of the effectiveness of using various methods of obtaining and processing digital images of textile materials obtained using computer vision systems to solve problems of quality control has been carried out.
Software has been created that implements the proposed algorithms and methods. The presented developments implement a modular concept that allows replacing the used

software modules depending on the operating conditions of the hardware and software complex.

The proposed methods are used in the development and implementation of a hardware and software complex based on computer vision systems for operational quality control of textile materials in the production process at textile and light industry enterprises and solving other enterprise tasks where digital images of objects can be used. The cost of the complex makes its acquisition affordable for small and medium-sized enterprises.

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