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APPLICATION OF MACHINE LEARNING ALGORITHMS IN IMPROVEMENT OF THE TEXTILE PRODUCTION EFFICIENCY

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Abstract. The light industry of Russia is a large national economic complex, which occupies an important place in the formation of the gross national product and has a significant impact on the economy. This research examines the possibilities of using a hardware-software complex based on machine learning algorithms to automate the process of detecting defects in fabrics at a textile enterprise. Throughout the study, the authors define the main reasons for the urgent need to automate the process of unpacking fabrics, draw up the system of requirements for the hardware-software complex using machine learning algorithms to detect and classify defects in fabrics, justify the effectiveness of the implementation of the developed hardware-software complex. As a result, it was proved that the implementation of this complex will contribute to improving the overall efficiency of textile production by automating the process of fabric quality control.

Keywords: textile industry, defects of textile products, quality control, software and hardware complex, convolutional neural networks, efficiency of implementation

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ИСПОЛЬЗОВАНИЕ АЛГОРИТМОВ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ПРОИЗВОДСТВА ТЕКСТИЛЬНЫХ ИЗДЕЛИЙ

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Аннотация. Легкая промышленность России – это крупный народнохозяйственный комплекс, который занимает важное место в формировании валового национального продукта и оказывает значительное влияние на экономику страны. В данном исследовании рассматриваются возможности применения программно-аппаратного комплекса на базе алгоритмов машинного обучения для автоматизации процесса обнаружения дефектов тканей на текстильном предприятии. В ходе работы были выявлены основные причины острой необходимости в автоматизации процесса разбраковки тканей, разработана система требований к программно-аппаратному комплексу с использованием алгоритмов машинного обучения для обнаружения и классификации дефектов на тканях, а также доказана эффективность внедрения разработанного программно-аппаратного комплекса. Было установлено, что внедрение данного комплекса будет способствовать повышению эффективности производства текстильных изделий посредством автоматизации процесса контроля качества тканей.

Ключевые слова: текстильная промышленность, дефекты текстильных изделий, контроль качества, программно-аппаратный комплекс, сверточные нейронные сети, эффективность внедрения

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Introduction

Sustainable development of the light industry is crucial for the social aspect of citizens' lives. Light industry enterprises shape the basis for the existence of many small towns, determining their main activities and creating jobs for local residents. Currently, the textile industry ranks second in the domestic market of the country, following the food industry. An important feature of the modern development of the textile industry is that the production of fabrics is not limited to the needs of ordinary consumers. Now the textile industry also plays an important role by supplying inputs to many industries such as the aircraft industry, agriculture, the automobile industry, etc.

However, in the last few years, a much slower dynamics are observed in the development of the domestic textile industry. The reason lies in a number of problems, for instance, the current dominance of foreign textile companies and equipment in the Russian market.

At present, an important task is to strengthen the position of local textile mills and thus ensure the intensive development of the Russian textile industry. One of the main solutions to this issue is the digital transformation of the textile industry. It is a well-known fact that industrial production plays a significant role in the growth of any country's economy. It is digital transformation that can help Russian firms to regain their competitiveness, ensure further retention of their positions in the textile market, and even enable individual factories to become leaders in their textile products.

The process of digital transformation may include the creation of smart factories, automation of a significant part of production processes, widespread use of information technology, and the introduction of enterprise platforms based on machine learning technologies.

Materials and Methods

The data for this study primarily rests on the materials from OOO "Textile" enterprise, scientific papers and Internet resources on the topic. The methods used throughout the research include: business process modeling, comparative analysis, literature review and analysis, multi-criteria decision analysis, classification, performance evaluation.

Results and Discussion

The organizational structure of OOO "Textile" can be characterized as linear-functional. This form of management organization is based on the principle of separation of cost centres and responsibility centres.

In the current organization of the quality control process, a number of shortcomings can be identified:

1. Due to the presence of the human factor in the process of fabric inspection, there may be unjustified overestimation or underestimation of the quality of rejected material. Both will result in additional production costs.

2. Many defects may go unnoticed, resulting in customer complaints. This will not only lead to a loss of money spent on production and delivery but may also have a negative impact on the reputation of the textile company as a whole.

3. The process of disassembling fabric by a person can take quite a large amount of time due to its laboriousness, which leads to a direct increase in the costs of this process, as well as a later detection of defects.

It is known that the losses of a textile company due to the presence of defects on its sold products can be quite significant. In small and medium-sized enterprises, the detection process can be carried out manually by the quality department staff. For such enterprises, it may not be economically feasible to use information technology to automate this process. For large enterprises, however, it is recommended to replace manual labour with machine labour.

For this purpose, the use of machine vision-based systems together with the corresponding software and equipment has been gaining popularity recently. Such a system can significantly facilitate the process of defect detection and make the results of fabric quality testing more reliable and accurate.

Before designing the necessary machine learning-based software and hardware complex for optimizing the process of tissue defect detection, it is necessary to identify a number of requirements for the implemented solution.

The requirements for the implemented solution will be divided into three groups: business requirements, user requirements, and functional requirements.

During the requirements definition phase, it was possible to establish the following business requirements:

1. Increasing the efficiency of the textile quality control process by minimizing the role of the human factor.

2. Reduction of the company's costs due to the reduction of expenses for the quality control

process.

3. Improved reputation of the company due to the reduced number of defects in the textile materials supplied to customers and, consequently, the reduced number of customer complaints.

User requirements include:

1. Move from visual inspection of fabrics by quality department personnel to an automated system for rapid defect detection.
2. Perform automated rejection in real time.
3. Collect complete statistics on the quality of products.
4. Prevent defective products from reaching the consumer or the next stages of production.
5. Ensure impartial quality assessment and grading of fabrics.
6. Control the process through a program.
7. Reduce the impact of human error by reducing manual labour.
8. Increase the accuracy of defect detection.
9. Increase the speed of the quality control process.
10. Increase the quality of finished products.

The functional requirements should include:

1. Obtaining images from typical or specialized linear and matrix video cameras.
2. Pre-processing of the received images: elimination of geometric distortions, normalization, and protection from interference.
3. Scanning of the product surface and detection of the smallest defects.
4. Segmentation and filtering of defects according to their size, geometric properties, location, and statistical characteristics.
5. Reflection of the fact of defect occurrence and information about it in the program.
6. Providing viewing of defect history, providing information about its characteristics, defect class, size, location, and visualization of defects in the form of photos.
7. Saving reports, images (both with and without detected defects), and detailed visualization of processing results.

To create a database of defects of textile products, fabrics received from OOO "Textile" were used. The process of database formation is as follows. First, all supplied fabrics are placed on the stand for photographing the existing defects. Then all received information about defects with photos is entered into the database.

An important point before starting the development is to design the architecture of the created solution, maximally corresponding to all the requirements of the customer. The created complex should provide an opportunity to read all incoming information, process it, store it, and output it in a user-friendly form (Abdukhalilova, Ilyashenko, Alchinova, 2023; Terekhina, 2020).

For reading information in the architecture of the complex, there are cameras that record all the defects of tissues and transmit images further to the computer. The cameras transmit the information to the calculator through a switchboard. In the role of the calculator is a computer, which must be equipped with a network card for reliable reception of data from the cameras, as well as a video card that supports the calculations of the neural network (Ilyin, 2015).

Further, all incoming data are stored and processed in the software part of the complex, which consists of a number of modules that will be discussed in more detail in the next section (Saidi, 2020).

The task of detecting defective areas on tissues is reduced to the search for anomalies that should differ from the normal pattern of tissues (Sheromova, 2016). To detect anomalies, methods based on prediction are used: statistical methods, classical machine learning methods, and methods using deep neural networks.

The software part of the architecture shall include the following parts:

1. The kernel of the software part serves for preparation for work and launching of all program modules and also provides interaction between them. Development of the kernel and all modules is performed in C++ language and using Boost libraries (Popova, 2019).
2. The configurator is responsible for saving parameters of operating modes of all available program modules.
3. Camera management module includes the camera operation module and the state manager. The camera module helps to exchange data with cameras.
4. The image-saving module. All images can be saved in different formats.
5. The image processing module is responsible for image preprocessing as well as subsequent defect search in streaming mode.
6. Report generation module.
7. File storage. SSD drives are capable of providing faster data access.

The hardware part of the complex also includes two parts: an image capture module and a processing module. In general, the architecture of the hardware part consists of the following elements:

1. Image capture camera and lens.
2. A board with LEDs, lenses for LEDs, and a power supply.
3. Computer and power supply.
4. Ventilation system.
5. Construction elements.

The second module of the architectural part is the module of processing and storage of the received images. It is responsible for processing the images received from the cameras, performing procedures to detect and classify the defects found, and storing all the necessary information about the defects and samples. The key element of this module is an industrial computer. At this stage, it is recommended to use a GPU graphics processor, as it has a higher processing power than the CPU. The Nvidia 1060-1080 series is taken as the main graphics gas pedal. These graphics cards have high performance and efficiency when working with graphics applications and calculations that utilize CUDA technology. In addition, Nvidia 1060-1080 series graphics cards have a large enough memory capacity, which allows you to work with large amounts of data. USB 3.0 controllers are built into the motherboard for interaction with the external environment.

Conclusion

The authors evaluated the compliance of the developed complex with the relevant requirements. The evaluation results are presented in Table 1.

Table 1. Analysis of the solution compliance with the requirements (designed by the author)

№	Requirements	Features		Result
		Planned	Obtained	Compliant
1	Business requirements	Improving the efficiency of the quality control process of textile materials	By minimizing the role of the human factor, the process was optimized, and efficiency increased	Compliant
		Reduction of operating costs	Reduction of costs for quality assurance process by 60%	Compliant
		Enhancing the reputation of the company	Reduced number of complaints and fewer defects resulted in a stronger company reputation	Compliant

№	Requirements	Features		Result
		Planned	**Obtained**	**Compliant**
2	User requirements	Transition from visual inspection by the operator to an automated system of operational defect detection	The platform has been implemented, with testing showing that the system detects 5.63 times more defects than humans do	Compliant
		Automatic rejection in real time	The system successfully detects and classifies defects for a moving fabric web	Compliant
		Collection of complete statistics on the quality of output products	All characteristics of the found defects are stored in a separate module of the program part of the complex	Compliant
		Preventing defective products from reaching the consumer or subsequent stages of production	The number of undetected defects is minimized	Partly compliant
		Ensuring impartial quality assessment and grading of fabrics	Fabric grades are determined automatically by the program based on fabric parameters and defects	Compliant
		Reduce the impact of the human factor by reducing the amount of manual labor	Automation of defect detection has virtually eliminated human intervention in the process	Compliant
		Increase defect detection accuracy	Testing has shown high accuracy of defect detection	Compliant
		Increase the speed of the quality control process	The system's defect detection rate is far superior to that of the quality department staff	Compliant
		Improve the quality of finished products	Product quality improved due to reduction of undetected defects	Compliant
3	Functional requirements	Acquisition of images from standard or specialized linear and matrix video cameras	Images are produced with high sharpness, brightness and contrast	Compliant
		Image preprocessing: geometric distortion removal, normalization and noise protection	The preprocessing of the acquired images is successful	Compliant
		Scanning the surface of the product and detecting the smallest defects	Defect detection is correct	Compliant
		Segmentation and filtering of defects according to their size, geometric properties, location and statistical characteristics	Classification of defects is provided in accordance with the specified classes	Compliant
		Reflection in the program for the operator of a defect and information about it	Defects are signaled, defect data is recorded and available for review by quality personnel	Compliant
		Providing viewing of defect history, providing information about its characteristics, defect class, size, location, visualization of defects in the form of photos	All information about the defects, including pictures of them, is provided by the	Compliant
		Saving reports, images (both with and without detected defects), detailed visualization of processing results	All defect reports are generated and saved	Compliant

№	Requirements	Features		Result
		Planned	**Obtained**	**Compliant**
4	Technical requirements	Accuracy of localization of defect boundaries – 1mm	95% of detected defects have precise boundary localization	Compliant
		Recall – at least 80%	Recall accuracy 99.7%	Compliant
		False positive rate – at least 0.1%	False alarms detected 0.02%	Compliant
		Maximum material handling speed - 1 m/s	The maximum material handling speed during testing was 66 m/min	Compliant
		Number of detectable defects – not less than 10 types of defects	Seventeen types of defects occurring at various stages of textile production were detected	Compliant
		The system response time is no more than 1 s.	The system response time was less than 0.9 s	Compliant
		Resolution – at least 1 megapixel	Resolution greater than 5 megapixels	Compliant

Based on the developed table, it can be concluded that the hardware-software complex meets the stated requirements. Eight defects of four different types were not detected due to the fact that the defect database lacks a sufficient number of examples. It can be remedied in the future by supplementing the defect database with images of defects of the corresponding types.

The application of machine vision-based systems in the textile industry is an effective solution for improving the quality and productivity of production. Such solutions allow detecting defects and problem areas quickly and accurately, classify defects, and establish the grade of fabric. The development of software and hardware complexes based on machine vision requires high qualifications of specialists, but when implemented properly, it can significantly improve the enterprise efficiency.

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