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

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INTRODUCTION

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.

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;
- 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).

Defect detection and classification are two topics that need to be treated as unique problems related to the field of artificial vision. Digital image processing problems mainly derive from specific conditions in which researchers aim to mimic or substitute human vision and decision methodologies with artificial techniques. The general purpose of mimicking human vision is to identify and classify a subject: these two goals are always strictly bonded together. Literature on artificial visual processing is usually categorized into visual processing algorithms, which consist in the recreations of the human vision, and classifiers, which are a remodeling of the human decision techniques. In this paper, we address both categories, but, instead of summarizing all the visual processing methodologies, we focus on the specific solutions that are strongly related to visual processing methods and, specifically, on visual inspection techniques for metallic, ceramic or textile surfaces in industrial applications.

Quality control is a crucial aspect in the industrial production line. Several approaches are currently used to assess the quality of a product or the outcome of a process. Non-destructive testings (NDTs) aim at monitoring a component to detect a defect without extracting samples from it, or permanently damaging it. Mostly used in the aeronautic field, NDTs are classified as: visual-based method, dye penetrant inspection, radiography, ultrasonic testing, eddy current approach, and thermography.

CHAPTER 1. FABRIC INSPECTION

1.1. Visual (Traditional) fabric inspection

Product inspection is an important aspect in modern manufacturing industries such as in case of electronics, automotive and medical industries. This process is a preventive one that could be broadly defined as the process of determining if a product deviates from a given set of specifications [3]. Mainly, fabric defect detection has two distinct possibilities [13]. The first one is the product or end (offline) inspection in which the manufactured fabric has to be inspected through fabric inspection machines [4]. The second possibility is the process inspection (online) in which the weaving process (or its parameters) can be constantly monitored for the occurrence of defects. Our survey focuses on both methods to explain the procedure, the advantages, and the drawbacks as well of each one.

Fabric like many intermediate products is available in a web form (continuous rolls) where a typical fabric web is 1.5-2 meter wide. In addition, defects to be detected by inspection are numerous and present complex appearance [4]. Consequently, industrial web inspection [5] has extremely high requirements and is most challenging as compared to other inspection problems. As it is a textured web, the concept of fabric inspection consists of grading the materials based on their overall texture characteristics such as material isotropy, homogeneity and coarseness or the severity of its defects.

Traditionally, this procedure must performed by well-trained (expert) human inspectors [6]. The existing methods of fabric inspection vary from mill to mill. In few mills, trained labors pull the fabric over a table by hand. As shown in figure (2.2), most mills have power driven inspection machines where the manufactured fabric rolls are removed from the weaving machines and unrolled on an inspection table (under adequate light) at a relatively higher speed of 8-20 meters per minute [13].

When the inspector notices a defect on the moving fabric, he stops the machine, records the defect and its location, and starts the motor again. For each inspected fabric roll, the number of defects per meter length is calculated and the fabric is classified. The early detection of repetitive defects and extraordinary defect rate is left to the operators or so called (roving inspectors) [11]. During the control, if the operator notices an extraordinary defect rate or repeating defects, these roving inspectors warns the production department so that appropriate measures can be taken to decrease the defect rate. Bowling et al. [2] proposed the use of two inspectors on the same machine when inspecting the fabric as another procedure to decrease this rate.

1.2. Drawbacks of visual fabric inspection

Typically, the inspection process relies strictly on the human eye and is done after the fabric formation process. According to the poet Alexander Pope “to err is human; to forgive divine”. This may be the slogan in the morale sphere, but modern manufacturing is unforgiving of error. A key fact: that even with the best-designed man-machine interface, the probability of human error cannot in practice be reduced to zero [3]. In addition, the visual inspection has worked well for many years in part because the amount of data has been small and manageable [4]. Lastly, with the modern weaving machines, the production speeds and consequently productivity are faster than ever. The experiments show that the error rate begins to rise rapidly as information output approaches about 8 bits/s. Therefore, the traditional visual inspection method has no ability to cope with today requirements. Although humans can do the job better than machines [4] in many cases, the visual inspection suffers from many drawbacks. It is found that, each surveyed article [1-149] contains only some of them. Because these drawbacks represent the main arguments for the advent of another robust inspection method, they can be gathered, summarize and discriminated as follows:

- Human experts are difficult to find or maintain in an industry.
- Human requires training and their skills take time to develop.
- In some cases visual inspection tends to be tedious or difficult, even for the best trained experts.
- Human is slower than the machines which means that inspection is a time consuming task.
- Human inspectors fatigue over time (get tired quickly). Therefore, visual fabric inspection is extremely tiring task, and, after a while, the sight cannot be focused (the maximum period of concentration is 20-30 min). However, the operator inevitably misses small defects and sometimes even large ones with the number of meters of the inspected fabric.
- Human inspectors have to deal with an extensive variety of defects (there are almost 50 different kinds of flaws) either due to mechanical malfunction of the loom, or due to low-quality fibers and spreads.
- Human inspectors make mistakes because inspection is unreliable when the fabric of 1.6-2 meters width is unfolded at a speed of 20 m/min. It is difficult for humans to keep up with these hard conditions. Because their efficiency is based on experience and even in a well-run operation, the reproducibility of a visual inspection will rarely be over 50% while the maximum detection efficiency is about 70%-80%.
- The inspector can hardly determine the level of faults that is acceptable, while comparing such a level between several inspectors is almost impossible.
- It is a subjective method that difficult to reproduce result.
- The grading process is slow and varies from mill to mill.

- Usually, there is an absence of feedback to support processes for corrective measures.
- The low quality control speed when compared to the production speed offers a
- major bottleneck in the high-speed production lines.
- It is extremely difficult to achieve100% fabric inspection with this traditional method.
- Labour-intensive and more floor space required *i.e.,* there is an expense of manual inspection, which is essentially a non-value added activity.
- Traditional visual fabric inspection is cost-intensive. Even, through the incidence of serious weaving faults can be reduced by the use of modern weaving technology, fault detection in many plants still continues to create considerable extra cost (which increases with the labour cost).
- Moreover, the problem of the visual inspection does not correspond only to the
- undetected defects but also, it changes the mechanical properties of the fabric under inspection.

For instance, the fabric dimensions (longitudinally and width-wise) usually changed due to the applied tension on fabric roll during the inspection process. Both are not good for the customers because they pay for false materials.

Moreover, the shrinkage takes place after the spreading of the fabric in cutting departments increases the probability of producing second quality garment either due to poor assembling (sewing) quality or incorrect size.

Because of these vast drawbacks and in order to increase accuracy, attempts are being made to replace manual visual inspection by automated one that employs a camera and imaging routines to insure the best possibility of objective and consistent evaluation for fabric quality

1.3. Automated fabric inspection

Automatic inspection systems are designed to increase the accuracy, consistency and speed of defect detection in fabric manufacturing process to reduce labor costs, improve product quality and increase manufacturing efficiency [1-148]. At ITMA' 97 in Hannover [36], the first automatic fabric inspection machine based exclusively on a laser scan system was presented to world specialists. In the last two decades, there have been several key developments in automated visual inspection technique for fabric defects where new approaches such as an ultrasonic imaging system [7] and laser-optical systems [8, 9] have been proposed. But the main common alternative to human visual defect detection is the use of a computer vision system to detect differences between images acquired by a camera [4]. In this process, the fabric is inspected with the resolution that is achieved by an inspection person at a distance of one metre from the fabric [10].

Unser et al. described Texture as the term used to characterize the surface of a given object or phenomenon. From the optical point of view, a fabric has the property of a texture. Therefore, fabric detection can be considered as a texture segmentation and identification problem. This means that texture analysis plays an important role in automatic visual inspection of surfaces [3, 14].

Handle et al. defined defects as either non-textured or different textured patches that locally disrupt the homogeneity of a texture image (An image is said to have a uniform texture when it gives an almost homogeneous visual impression). Since fabric faults normally have textural features which are different from original fabric features, automated defect detection in textured materials is simply performed by identifying the regions that differ from a uniform background [4, 9]. Industrial web materials like fabrics take many forms but there is a remarkable similarity in visual inspection automation requirements [6, 13]. The operation of an automated visual inspection system can be broken down into a sequence of processing stages: image acquisition, feature extraction, comparison, and decision. It is important to note that the success of an automatic inspection system relies on the approach used.

1.4. Online automated fabric inspection

It is called also real-time fabric inspection where production and production control work together or in real time. The need for this vision system stems from the fact that fabric inspection with present methods (offline) is an inadequate task: thousands of off quality fabric meters will be produced before the problem is recognized. Thereby, the main object of this vision system is to detect the defects at an early manufacturing stage in order to prevent foreseeable fabric defects in mass production or at least to insure a corrective action during the process. If the inspection system is agreed to be online, we have to explain why it should be automated. Beside the high cost, low accuracy and very slow performance of human visual inspection, the slow fabric manufacturing speed (0.3-0.5 meters per minute) [13] is insufficient to keep a human inspector occupied and human inspection is therefore uneconomical. Also, the relatively hostile working environment near the weaving machines is not suitable for human inspection.

Behera et al. [6] have described the real-time defect detection system as an intelligent optical head assembled on a loom to acquire and analyze a huge number of images while the fabric is being produced. Frank and Ding [50] defined the process of online detection as input and output signals. The output of the fault detection system may be simply an alarm signal that takes two values, high for defect and low for defect-free or, more sophisticatedly, knowledge of faults such as location, spectrum or amplitude. Some researchers [4, 26, 51] determined the essential requirements for an online automated inspection system to be reliable as follows:

- The system must operate in real-time with good results,
- It must reduce escape rates,
- It must reduce false alarms,
- It must be robust and flexible. Thus, it should adapt itself automatically and achieve consistently high performance despite irregularities in illumination,

marking or background conditions and, accommodate uncertainties in angles, positions, etc.,

- It must be fast and cost efficient,
- The system must be simple to operate and maintain.

CHAPTER 2. COMPUTER VISION SYSTEMS FOR AUTOMATION OF QUALITY CONTROL TEXTILE MATERIALS

2.1. Most modern quality control systems of textile materials

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:

$$T = T_c + T_l + T_a + T_r,$$

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.

2.2. Advantages of online automated inspection system

Honestly, and before discussing the advantages of an online automated inspection system, one should mention the drawbacks. Behera [10] has mentioned the correlation between both of production and inspection speeds. Moreover, the production speed determines the inspection system so that it is not always possible to take full advantage of maximum throughput speed of the inspection system. Due to their computational costs, very few available practical systems represent another drawback [5].

To refute these arguments, we should admit that the low speed of an online automated inspection system will not disrupt its continuous development since the need for effective quality measurement is more important than ever and there is a need for a comprehensive, consistent way to establish the quality of fabrics. Financially, Nickolay et al. [6] have shown that the investment in automated fabric inspection system is economically attractive when reduction in personnel cost and associated benefits are considered. Also, Zhang et al. explained that recent advances in imaging technology have resulted in inexpensive, high quality image acquisition, and advances in computer technology allow image processing and pattern recognition to be performed quickly and inexpensively. In addition, the use of online automated systems reduces the total cost through the reduction in inspection labor costs, rework labor and scrap material.

Therefore, an efficient online automated product inspection is a key factor for the increase of competitiveness of the textile and clothing industry [8]. Let us mention now extra advantages of online automated visual inspection [10]:

- the results of such a system are reliable, reproducible and free from the subjective deficiencies of the manual fabric inspection,
- The system can increase the efficiency of production lines and improve quality of product as well,
- A good system means lower labor cost (the labor of the machine also operates
- the inspection system),

- shorter production time,
- Minimum floor space.

For the two past decades, interesting surveys relevant to automated fabric inspection have been published. It is admitted that all surveys interpreted the task of detecting defects as a texture analysis problem [1-149]. Obviously, based on the used approaches (algorithms) till the date of publishing, each survey subtracted its classification. Despite the fact that this work is to be considered as a wealth, one should not only confine himself to, but also, use the numerous last available research works to describe an improved classification. With reference to several survey papers [4, 9, 13], we will categorize the texture analysis problem into six approaches according to the used algorithm; structural approaches, statistical approaches, spectral approaches, model-based approaches, combination of computational methods, and finally, comparative studies. In fact, statistical approaches are very popular. The following part of the literature presents in brief as possible an idea about these approaches while Table (2.2) summarizes our modified classification.

CONCLUSION

This monograph provides a review of defect detection methodologies described in more than 220 scientific contributions. A significant amount of works is based on statistical observations and uses statistical or filter-based methods. The Gabor filter is one of the most commonly used methods. However, most of the studies present specific limitations, being heavily dependent on the pattern, material and texture. Solving the segmentation and windowing problems of overlapping objects is still a ponderous topic approached by several researchers. Images having color features can multiply the complexity of these problems.

Neural networks are a powerful technique often employed in artificial image processing since they can nearly solve every classification problem. However, the main drawback is the required large amount of training samples. In artificial image processing, this issue can be easily solved with labeled datasets, or applying stochastic solutions (i.e., mini-batches). However, in other fields such as robotics, or other systems that learn from real-world operations, it is still a challenging problem. Improving the training efficiency and convergence capability of neural networks is an ongoing research area. It is also notable that large neural networks used for deep learning require significant computational resources, which lead to an unavoidable parallelization of the challenges.

Supervised learning methods are well-functioning and straightforward to use. Due to their capabilities, supervised methods are the most preferred for classification in industry but in many cases they are time consuming to train and require large datasets.

Unsupervised learning is used for density estimation, dimensionality reduction and clustering problems. However, in many cases, unsupervised methods have shown lower efficiencies than supervised learning methods. Natural supervision is an emerging topic in the field, due to its similarities to biological learning behaviors. From another perspective, artificial neural networks are inspired by biological neural networks, but do not necessarily replicate them. Back propagation is the essence to train many artificial neural networks, although no such mechanism exactly exists in biological networks. This means that biological neural networks gave a good inspiration to develop artificial neural networks that can be used as classifiers; however, sufficiently modeling them for technological use is still an unsolved topic.

In artificial image processing, different textural databases are available for testing, although several studies do not provide satisfactory results due to the lack of testing samples and frequent inconsistency of such databases. Moreover, there is still a huge demand for developing general defect detection methods able to deal with any kind of defect on every kind of material, and also able to establish a general and reliable defect description system. Due to the lack of solutions, there is a huge demand in industry to increase the defect identification efficiency with multi-sensory systems applications. To this aim, deep learning is the emerging field that could solve the generalization requirement and hyper-complexity of problems without drastically increasing computational costs.

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