

A review in the use of artificial intelligence in textile industry

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Abstract. This paper presents an analysis of the state of the art of artificial intelligence applications in the textile industry. A review of the existing literature was performed. This article presents three methods of analyzing textile yarn. Some techniques, used in textile fabric inspection, are presented throughout this paper, as well as the use of artificial intelligence on improving the performance of productive systems using neural networks and artificial vision. The preliminary results demonstrate that the techniques covered are an asset in obtaining defects in textile fabrics at the industrial level. Taking into account the various methods of inspection and analysis of textile yarn, all present pros and cons in applicability in the textile area. In terms of advantages, all allow a better analysis of the textile yarn and defect detection with high quality, but with applicability in more complex systems. As a disadvantage, they present the fact that they do not have an already standardized algorithm that can be used, which makes its use more complex. Some possible future applications are also described.

Keywords: artificial intelligence (AI), Textile Industry; Industry 4.0, Yarn evaluation, Machine learning, Image processing.

1 Introduction

The textile sector is one of the most important for the quality of life of the entire world population. Clothing is part of one of the basic needs of the human being.

Among the strategies used to stay competitive in the market, one of the most essential for the textile industry is innovation. New practices, use of computer intelligence and development of sustainable materials are increasingly present in the universe of fashion, sport, uniforms and objects. The technological evolution of fabrics brings important functionalities and can be a differentiating factor in this type of industry.

The manufacture of fabrics and clothing has gone through an update process that goes from choosing the raw material to the production methods. Low environmental impact solutions have been the subject of ongoing research and investment in new production machines, energy and methods.

One of the applications that has been widely used at an industrial level is the use of vision systems, which allows the analysis and recognition of patterns in fabrics in the textile industry. One of the companies that uses this technology is COGNEX. For this, it uses a platform called Cognex ViDi that analyzes patterns in textile fabrics, such as finishes. The main objective is to integrate this technology in an industrial textile system in order to obtain predefined images of fabric samples, to carry out two analyzes. The first analysis will be more preliminary to detect more visible defects and, at a later stage, a more detailed analysis of defects that are not visible to the naked eye (figure 1). [1]

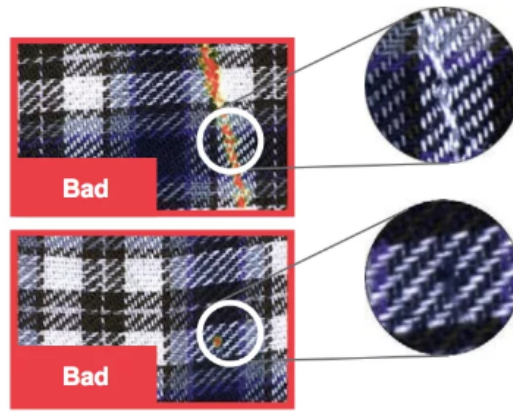


Fig. 1. Yarn dye plaid image capture system [1]

This renewal meets new market needs in order to add value to the product while re-thinking costs. Some biological processes applied in the dyeing phase, for example, can reduce, on average, 30% in water and electricity consumption. [2]

The outline of this paper is as follows. In Section 2, Artificial intelligence (AI) in textile industry is presented. In Section 3, it is described a yarn analysis solution using AI. Section 4 presents the description of the AI used techniques and in section 5 there are presented some future work proposals based on existing identified gaps and challenges. Finally, in Section 6, final remarks are enunciated.

2 Artificial intelligence in textile industry

Artificial Intelligence (AI) is a branch of computer science dedicated to the study of computational activities that requires intelligence when performed by humans. "Intelligence" is the computational part of the ability to achieve goals. [3]

The main purpose of AI systems is to perform functions that, if supposed to be performed by a human being, would be considered intelligent. It is a very broad concept, and one that receives so many definitions when we give the word intelligence different meanings. [3]

Machine Learning is a subfield of Artificial Intelligence (AI) and its main approach is to learn through experience to find patterns in a data set. It involves teaching a computer, through examples, to recognize patterns instead of programming it with specific rules.[4]

In Machine Learning there are three main classifications with respect to the algorithms used and the type of learning of the same, namely:

- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning

The choice of which of the three methods will be used will depend on the data set you have and the problem you want to solve.

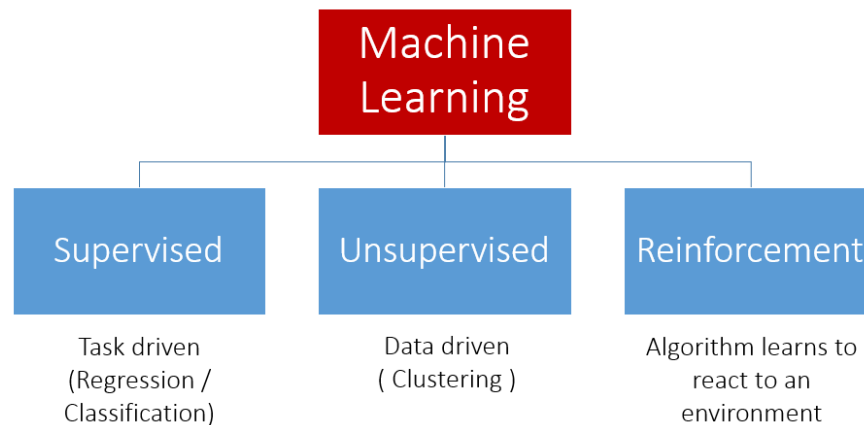


Fig. 2. Types of Machine Learning [4]

Most machine learning practices use supervised learning. In supervised learning, a set of data is provided and we know what the correct result should be, as there is a relationship between the input and the output, that is, it has the inputs (X) and the outputs (Y) and uses the algorithm to map the learning function that will image the input (X) to the output (Y) ($Y = f(X)$). [4]

The goal is that, when you have a new input (X), you can predict what the output (Y) is, based on the model produced containing the rules learned with the learning function. [4]

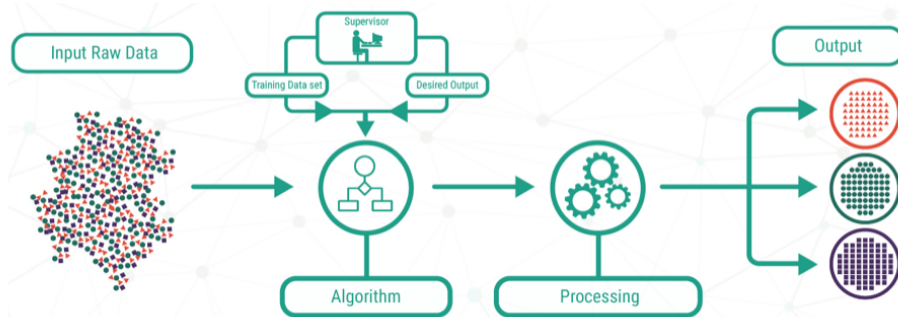


Fig. 3. Supervised Learning [4]

In Unsupervised Learning, there is only the input (X) of data and not the corresponding output (Y). The objective in this case is to model the underlying structure or distribution of the data to learn more about it. Unsupervised Learning is called that, because there is no feedback based on the prediction results as in the previous case, in fact there is no way out and there is no teacher. The algorithms are left by their own mechanisms to discover and present the data structure, this allows us to approach problems with little or no idea about the results.

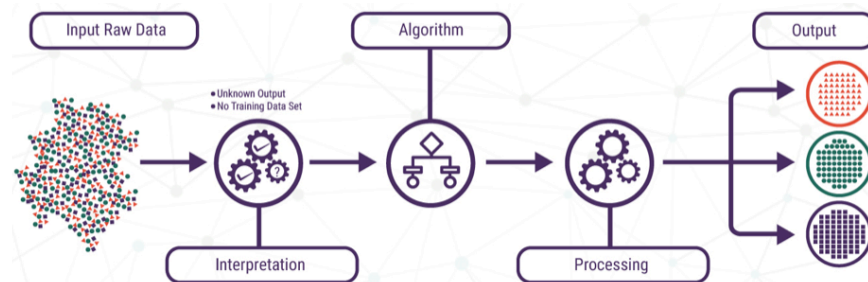


Fig. 4. Unsupervised Learning [4]

Reinforcement Learning is a trial-and-error method. Their approach is similar to that of a baby who is learning new things. The machine knows nothing at first. She will then try something and, depending on the results, decide whether it was a good decision or a bad decision. After countless attempts, if the model is well learned, the machine will become better and better and, eventually, it will only make good decisions. The difficulty lies in the fact that the actions taken by the agent can change the environment, and the agent can obtain his reward long after his action. So, it becomes difficult to know which actions led to which reward.

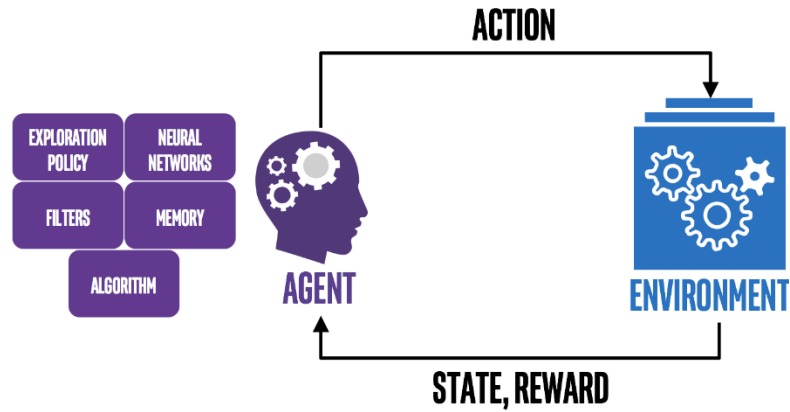


Fig. 5. Reinforcement Learning [4]

Several sectors of activity used AI including robotics, artificial vision, comprehension, artificial neural networks and a branch of AI denominated “expert systems”. AI has been particularly useful in solving a number of problems in different areas of the textile industry. [4] Expert Systems, Fuzzy Logic and Artificial neural networks will be covered in the following subsections.

2.1 Fuzzy Logic

One of the techniques used in textile industry is the neuro-fuzzy. The neuro-fuzzy hybrid system is a combination of fuzzy and neural network techniques. A neuro-fuzzy system (SNF) is a type of embedded hybrid system consisting of the combination of two well-known modeling techniques such as ANN (Artificial Neural Networks) and FL (Fuzzy Logic). At present, SNFs are of great interest as they bring benefits from both ANN and FL systems, thus eliminating individual disadvantages by combining common features. In addition, different SNF architectures have been researched in various application areas, especially in industrial process control. [5][6]

Fan et al. (2001) have employed an adaptive neuro-fuzzy system for the prediction of cotton yarn strength from HVI (High Volume Instrument) fiber properties garment drape and forecasting circular knitting machine parameters. However, the neuro-fuzzy systems are yet to be applied in the field of yarn property prediction [7].

2.2 Artificial neural networks

Artificial neural networks are created from algorithms designed for a particular purpose and basically resembles the human brain at two points: knowledge is obtained through learning steps, and synaptic weights are used to store knowledge.

Synapse is the name given to the connection between neurons and the connections are assigned values, which are called synaptic weights. Thus, artificial neural networks

have in its constitution a series of artificial (or virtual) neurons that will be connected to each other, forming a network of processing elements. [8]

Defects in yarn reduce the value of textile products. In order to try to eliminate this problem, Artificial Intelligence techniques, such as ANN, are applied to identify defects in textile inspection of fabrics. This principle is based on obtaining images that are analyzed in the image acquisition system and saved in the relevant standard format (JPEG, PNG, among others.). Resources are extracted from the acquired image and the image analysis method is used to reduce the feature set dimensionality by creating a new smaller size feature set, which is a combination of older features. [8]

2.3 Expert Systems

This is a technology derived from the family of artificial intelligence, being one of the main practical applications based on knowledge. The specialists seek to apply the knowledge of an expert in the systems and generate actions inherent to the human being to bring innovative solutions and thereby advance in the field or area of application. An expert system is a computational system that tries to imitate human specialists, applying methodologies of reasoning or knowledge about a specific area. [9]

The components that make up expert systems are:

- Knowledge base: rules, facts and heuristics corresponding to the knowledge of specialists in the domain on which the system was built;
- Development team: composed of one or more experts who are in charge of the knowledge base, who translate the knowledge described by the experts into a set of production standards;
- Development environment: also known as AI shells, they are user-friendly development environments, which quickly and efficiently generate user interface screens, capture the knowledge base and manage search strategies in the standards base.

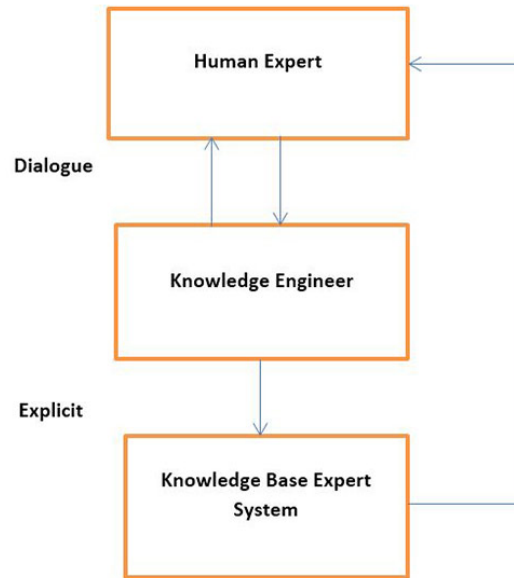


Fig. 6. Expert System Concept [9]

One of the applications of the Systems of specialists in the textile industry, is the verification of the coloring in textiles in terms of finish. The work carried out by the systems of specialists in production management is of fabric machines, aided by computer, is evaluated elsewhere.

One of the applications of the expert systems was in the company Sandoz AZ. This company developed an expert system called Wooly. This has been applied in textile dyeing, where it can predict the performance of solidity in a wide range of tests on patterns and colors in textile fabrics and provides corrections to the fabric such as, better dyeing methods, suitable dyes and is able to interact with a color matching system.

In the next chapter, one of the techniques used by expert systems, in color detection, which is the Kubelka-Munk theory, is discussed.

3 Yarn analysis solutions using AI

3.1 Yarn identification using image processing

This section describes the various methods that exist in the analysis of textile yarn, using artificial intelligence. Three methods using artificial intelligence are described, the first using image processing, the second method identifies patterns using artificial neural networks and the third method verifies the correspondence of textile colors using ANN and the Kubelka-Munk theory.

In the textile industry, there are automatic and manual inspection systems, in which these are the most used in determining the quality of the textile yarn, such as uniformity and impurities. The manual inspection method has several disadvantages, such as solving time-consuming and complex problems. This type of inspection will cause tiredness, lack of attention and errors on the part of the operator, which would cause the unreliability of the products obtained and also the inaccuracy of the results obtained.

The automatic textile thread inspection systems are a very effective method in the continuous improvement of the quality of the textiles, when inserting the image processing and analysis technique. This allowed for greater efficiency in obtaining defects and in the continuous improvement of the industrial process.

The image processing technique allows to transform the data of an image and convert it to

mathematical values. This technological solution is very reliable and very efficient. Comparatively with existing solutions, such as human visual analysis, this manages to eliminate all the disadvantages of traditional techniques.

There are more and more studies and research in the identification of defects in textile yarn through image processing that have given very promising results.

There is an ongoing investigation, in which a system was developed that extracts neps images (highly tangled cotton knots) [10] and then classifies it, according to a probabilistic neural network (PNN).

When this test was performed in this investigation, a k-fold cross-validation methodology was used, which is a technique to assess the generalizability of a model, based on a data set. Thus, it was possible to measure what would be the performance of the PNN classifier.

The results obtained through this technique demonstrated that the neps classification, which was carried out through image recognition by the PNN classifier, were very good and validate the technique used in this analysis [11].

Vítor Carvalho et al., (2009) presented a paper on how to apply a textile thread analysis tool using AI and image processing techniques, in order to obtain textile yarn characteristics and prediction models [11].

3.2 Pattern inspection using ANN

The importance of product quality inspection is important in companies, as quality defects can significantly reduce the process (for example, in the textile industry, defects can reach 60%). In textile production, online inspection is a slow process due to the slower movement of the fabric out of the weaving machine, making human inspection an inexpensive option. [12]

The patterns of the fabrics can have several aspects, such as fabric, knitting, braids, finishes and prints. Changing the visual inspection at the factory level by inspection based on vision systems, can help manufacturers in the textile industry avoid fatigue and human errors in defect detection. Typically, camera-based inspection systems are installed that feature immense defect analysis images with "OK" and "NOT OK" final results. [12]

Vision systems to analyze patterns in fabrics, first "learn" the pattern of the fabric, the properties of the textile yarn, the colors and tolerable imperfections from these images. This "teaching" time can be a few weeks, after which the platform can potentially begin to detect defects (such as incorrect knitting patterns) in the final textile fabric, saving the human effort of evaluating hundreds of meters of material. Several challenges are inherent to the inspection of textile fabric patterns, such as its shape, complexity, variability and the large number of types of knitwear. [12]

Ajay Kumar et al., (2003) used a feed-forward neural network to segment defects in pattern textile fabric. According to him, "every defect in the textile mesh changes the gray level arrangement of neighboring pixels, and this change is used to segment the defects". [12]

Each pixel acquired from an image is characterized in an information vector. A simplified characterization of the texture of the textile fabric is used based on the connections between the pixels in the neighborhood. [12]

The gray-level values of neighboring pixels form the resource vector for each pixel. This information vectors captures certain local textural properties of the fabric, such as thickness, directionality, regularity, patterns, colors, etc. [12]

3.3 Textile color matching using ANN and Kubelka-Munk theory

The color of a textile fabric can be considered "acceptable" or "not acceptable" or else "very light", "very red" or "very blue". Such analyzes can be done visually or using equipment, based on the difference between an ideal pattern of textile fabric or a sample. [13]

Color tolerance is based on numerical color descriptions through "instrumental tolerance systems". As this method presented very wrong results, compared to the visual checks of the fabric, an AI-based system was developed, presenting results of the Pass / Fail (P/F) type in order to improve the precision and efficiency of the instrumental tolerance and errors committed by the analysis by the human eye. [13]

To solve this problem of the textile industry related to color patterns, several computer-based methods have been presented in the last few years, using artificial neural networks and Kubelka-Munk (K-M) theory. [13]

The color of an opaque material is a function of its absorption and dispersion properties of visible light. While the dispersion changes the direction of the light rays, the absorption converts them into heat. [13]

Rocco Furferi et al., (2016) presented a method for accurate estimation of the spectrophotometric response of a textile mixture composed of different colored fibers made of different materials. In particular, the performance of the K-M theory is improved with the introduction of artificial intelligence to determine a more consistent value for the nonlinear function relationship between the mixture and its components. Therefore, a hybrid system composed of K-M + ANN, was developed with the purpose of modeling the color mixing mechanism in order to predict the reflectance values of a mixture. [13]

4 Description of the used AI techniques

This section describes in a more technical way the systems most used in the analysis of textile yarn. In the first system, the YSQ (Yarn System Quality) project that uses image processing to check the quality of the textile yarn was approached. In the second system, the technique on how to carry out the analysis of fibers and spinning using artificial neural networks was discussed. In the third system, an analysis of how to perform color matching in the textile industry was carried out.

4.1 Yarn analysis tool using Artificial Intelligence and image processing

In the last ten years there has been a very significant advance in terms of commercial solutions in obtaining the characteristics of the textile yarn. In this area, USTER Technologies AG has some machines that provide some characteristics but do not obtain all the characteristics of the textile yarn, especially if it is in continuous movement.

There is a prototype, designated as YSQ [14] that obtained some preliminary algorithms in order to obtain a significant amount and variety of characteristics of a textile yarn.

The YSQ prototype [14] consists of an image acquisition and processing system using a microscope attached to a USB camera, which can be subdivided into hardware and software components. At the software level, National Instruments' IMAQ Vision is used to perform image acquisition and processing.

The hardware of this system consists of a USB camera that is in the prototype next to the output plane of an analog microscope. In order to obtain the images, any image processing system needs a light source. In this prototype, a monochromatic light source was used, in order to obtain better contrasts for the relief of the wire geometry (Figure 1).

This system allows to obtain the following characteristics in textile yarn, namely: the orientation and twist of the fibers, the twisting step and the orientation in folded yarns and the number of cables, spun yarns (single cable) or folded yarn (multiple cables). [14]



Fig. 7. Yarn image capture system [14]

4.2 Artificial Neural Network in Fibers and Spinning Analysis

Artificial neural networks are increasingly used to analyze problems in the textile industry. Its use in the textile industry involves the integration of a large number of variables. Due to the high degree of variability of the raw materials, the processing in several stages and the lack of precision in the control of the process parameters, the analysis of the relationship between these variables and the product properties depends on human knowledge. [15]

The ability to predict these properties accurately has become a challenge due to the fact that textile materials have a non-linear behavior. As there is a need to forecast some properties or performances of an industrial process in advance, to minimize the cost of installation and time, it becomes important to use the functions performed with Artificial Neural Networks, since it does not have a constant understanding, but it can be changed dynamically. [16]. An ANN is normally used to predict the composition of the copolymer.

A copolymer is a polymer formed when two (or more) different types of monomers are linked in the same polymeric chain, as opposed to a homopolymer where only one monomer is used. Copolymer refers to a type of polymer that contains two or more distinct repeating units called "monomers". It produces substances of high molecular weight by chemical combination or polymerization of monomers. The final results that an ANN can indicate related to the composition of the copolymer correctly, will depend on the reaction conditions and conversions. Figure 2 shows an intelligent fiber classification system. In this case, ANN is used to identify two types of animal fibers, Merino and Mohair. This ANN model extracts six parameter scales with image processing and the rest using an unsupervised neural network to extract resources automatically, which are determined according to the complexity and accuracy of the obtained model. It can obtain greater precision to the increasing number of colors for learning, since the precision of the ANN depends largely on the selected parameters, this type of algorithm can be used to develop models for previewing and to generate a cotton classification [16].

In [16] it is analyzed the set of elastic properties of the fiber yarn properties. Figure 3 shows an artificial model of neural network for textile thread engineering, developing a "reverse" model of yarn for textile fiber using an ANN.

This one model is totally different from future models, which predict the properties of the final yarn using the properties of the fiber as input elements. The cost reduction of cotton fiber was ensured with the use of linear programming in conjunction with an ANN algorithm (figure 4). [16]

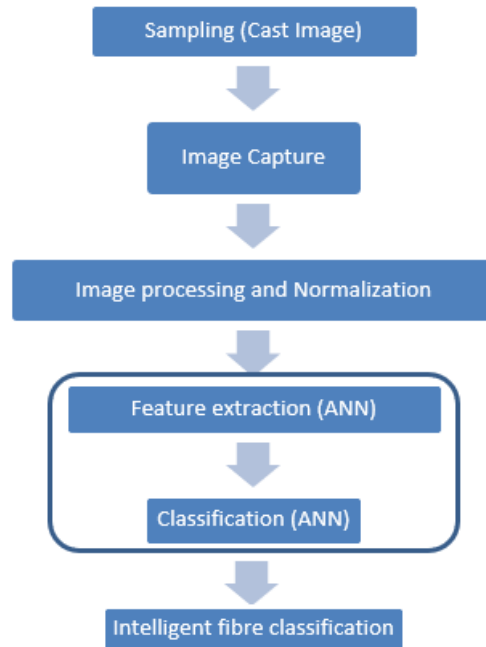


Fig. 8. Intelligent fibre classification system [16]

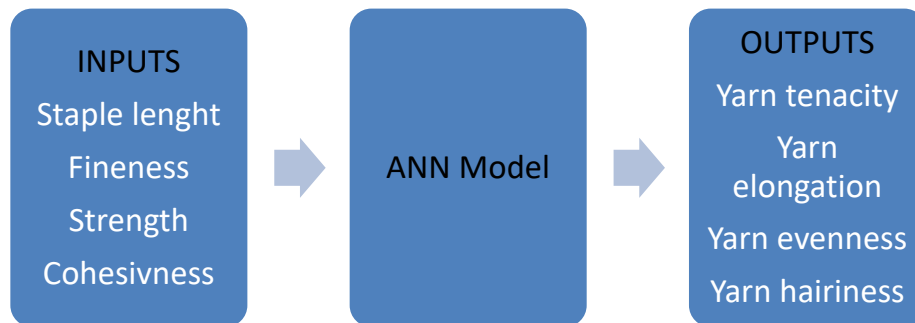


Fig. 9. ANN model for yarn engineering [16]

The Uster fabric scan machine system uses this ANN in the analysis of wrinkled textile fabrics using image processing analysis. Figure 7 shows the artificial neural network model for textile engineering as well as the USTER machine.

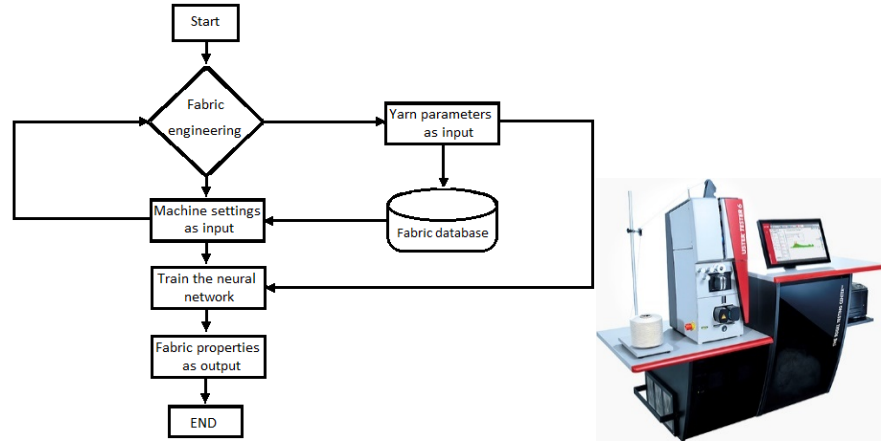


Fig. 10. Artificial neural network for textile engineering (left) and USTER machine (right) [16]

4.3 Artificial Neural Network and Kubelka-Munk (K-M) in color matching Analysis

Rocco Furferi et al., (2016), refers that after a mixture of colors is created, an instrumental comparison is always performed against a defined pattern, with the aim of determining the difference between them.

The Kubelka-Munk functions is:

$$F(R) = (1-R)^2/2R = k/s = Ac/s \quad (1)$$

Where:

R = reflectance; k = absorption coefficient; s = scattering coefficient; c = concentration of the absorbing species; A = absorbance. [17]

The comparison is evaluated in various color spaces such as CIELAB under a number of standard illuminants, as shown in figure 5. [17]

The hybrid method K-M + ANN used is done in three steps, namely:

1. Definition of the equivalent tissue substrate using the simplified model described in [18].
2. Teach an ANN to infer variations of the recipe in the K-S ratio of the substrate; this proportion is then used to predict the spectral response of the tissue mixture. The sum of steps 1 and 2 will result in a hybrid K-M + ANN system. [18]
3. Derive (from the K-M + ANN method) a practical graph that can roughly replace the ANN software in everyday use. [18]

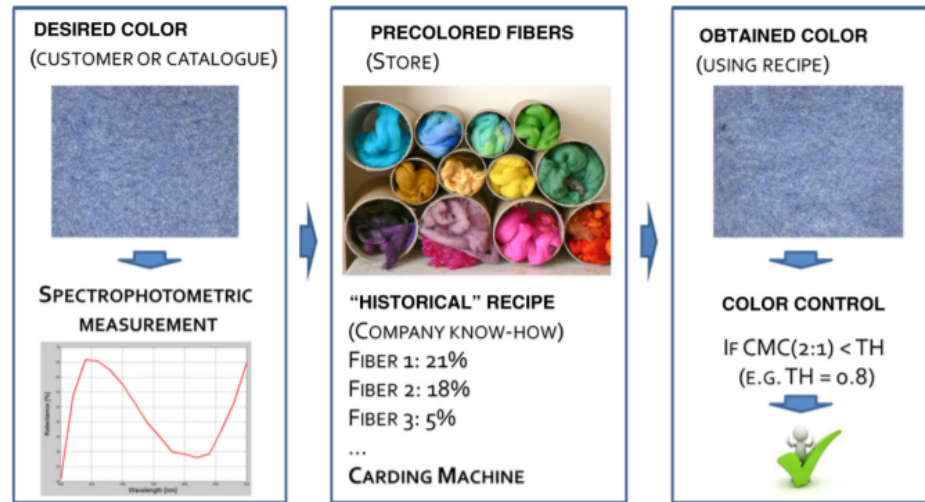


Fig. 11. Recipe-based mixing conceptual process. [19]

5 Future Work proposals based on existing gaps and challenges identified

The commercial use of AI in the analysis of pre-production textile processing appears to be limited to only a few applications today, particularly in the identification and classification of textile fibers and yarns.

The identification and classification of the fiber in terms of color, length, uniformity, among others, may be analyzed with the use of AI and with the possibility that it will be more used and developed in the coming years.

The experience of employees who have acquired a lot of know-how over several years cannot be easily automated. This knowledge is usually lost, unless measures are taken to store knowledge and experience in an appropriate mechanism that allows for easy retrieval and later use.

One way to get around this negative aspect of expert systems is to allow a combination of these in domains familiar with programming languages and available shells, in order to build their own expert systems. For that they should need to ally specialists in artificial intelligence.

On the textile production side, AI can be used, for example, to detect visual defects in shirts or collars, or it can be applied to automatically detect and measure wrinkles in the fabric (figure 12 and 13). The measurement of the roughness of the textile fabric, based on an artificial vein, can help the textile industries to reduce costs and productivity time in the industrial manufacturing process. [20]

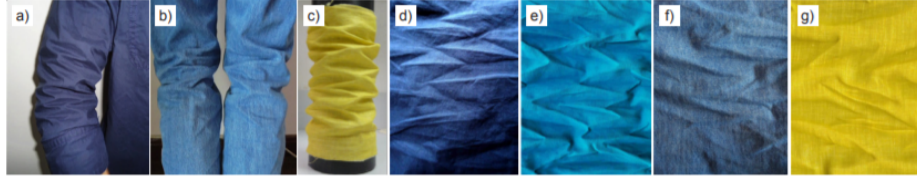


Fig. 12. Comparison of wrinkles in actual wear and those generated by wrinkle simulator; a) wrinkles at the elbow, b) wrinkles at the knee, c) wrinkles in the simulator, d) elbow wrinkles when the coat is spread, e) wrinkles of fabric 3 when it is spread, f) knee wrinkles when the trousers are spread, g) wrinkles of fabric when it is spread. [20]

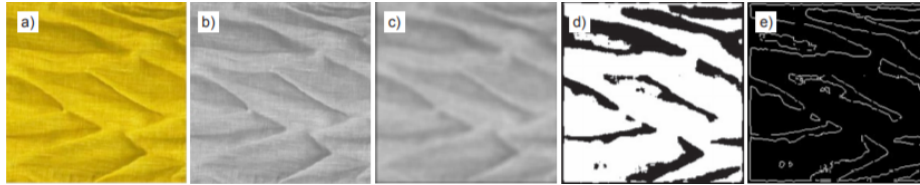


Fig. 13. Image process of wrinkled fabric; a) coloured image, b) grey level image, c) median filtered image, d) binary image, e) edge detected image. [21]

Another application and a challenge for the future is the use of artificial intelligence in the design of the textile industry '3D models' of yarn fibers in their designs and prototypes, that can model the properties of yarns and fibers in an automatic and realistic way, without much effort and intervention by the human being. [21]

For the future, human 3D modeling experts would have to create a yarn from individual 'virtual fibers' and the objective would also be to use a CT (Computed Tomography) scanner, using an AI algorithm in order to convert the data obtained by the CT into a 3D fiber model, as shown in figure 8. [22]

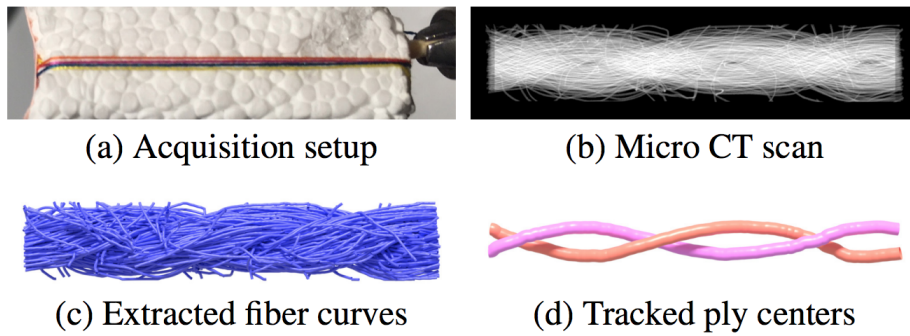


Fig. 14. 3D fiber model. [23]

6 Final Remarks

The implementation of AI in the textile sector is currently relatively low compared to other industrial sectors. Currently, most AI applications in textiles involve the use of artificial vision systems on machines to replace humans. These allow the analysis and detection of errors that, even in some cases, is carried out by humans in textile yarn samples.

Currently, the technology presented in this article leaves many promising aspects and allows analyzing the various research and development activities that are being carried out in universities and other institutions.

AI applications in the textile sector are not yet fully in practice. This is due to the simple fact that cutting-edge AI manufacturing applications are more likely to reach larger and more modern sectors of activity.

In conclusion, the use of AI in the textile industry begins to be widely used and in the coming years it will play a major role in the production and final quality of products, taking into account technological advances and market competitiveness.

The implementation of a new project aims to develop a new technological solution, based on image processing and artificial intelligence techniques, for automatic characterization of the main parameters of a textile yarn, with the highest level of parameterization in relation to commercial solutions. These technologies associated with a new development of a solution to be used "online" at an industrial level in the textile area, will contribute to increase the efficiency of the textile industry and the quality of the final products.

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