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Reverse Engineering For Textile Manufacture Using Artificial Intelligence Methods: A Review"

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Abstract

Modern artificial intelligence technology is developing quickly, and as it integrates gradually.The use of artificial intelligence technologies in the textile business, together with the spinning sector make the manufacture of textiles ever more accurate, quick, and efficient. By collecting and analyzing big data, artificial intelligence systems can improve production processes, reduce costs, improve quality, and increase productivity. AI methods that can identify patterns in photos have performed remarkably well in object recognition, materials, and image processing in particular in recent years. These algorithms provide precise and quick data-driven solutions, which successfully improve operations' efficacy and efficiency. Textiles can provide valuable information that can be extracted using AI techniques like computer vision, deep learning, and machine learning, which are used to analyze images, videos, and other sorts of data. Reverse engineering is the process of dissecting a system or product to determine its design and functionality. Reverse engineering is a method that can be applied in the textile industry to analyze and dismantle existing textile products in order to make them better or more identical. This article reviews discusses artificial intelligence techniques used in reverse engineering processes within textile production.

Keywords

Artificial intelligence (AI), Reverse engineering, Textile industry, Image processing, Deep learning .

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Introduction

The goal of artificial intelligence (AI), a broad field of computer science, is to create intelligent machines that can carry out tasks that ordinarily call for human intelligence.(1) Since artificial intelligence is an interdisciplinary subject with many different applications, developments in machine learning and deep learning in particular are revolutionising almost every area of industry technological progress and bringing artificial intelligence into the workplace. Artificial intelligence (AI) increases worker productivity, reduces time spent on tedious tasks, and improves the customer experience in general. (2)
With the use of artificial intelligence (AI), machines can mimic or even surpass human mental powers. Artificial intelligence enables software to automatically learn from patterns or features in the data by combining massive amounts of data with quick, repeated processing and clever algorithms.(3,4) An artificial intelligence (AI) algorithm is a more advanced form of machine learning that instructs the computer on how to become self-sufficient. As a result, the machine keeps learning in order to enhance procedures and perform jobs faster than a human being with intelligence.(4)
One of the fascinating and widely applicable fields in computer science at the moment is artificial intelligence. When a computer is able to think, listen, and solve issues, artificial intelligence is developing. The creation of an autonomously

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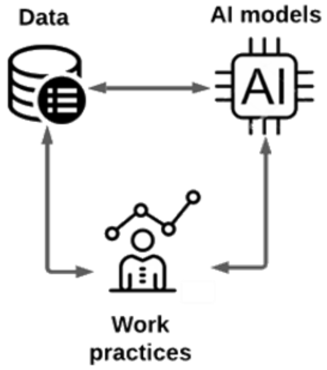
thinking computer is the aim of artificial intelligence. Intelligence comprises various components, including learning, perception, problem-solving, reasoning, and language. (5)

The textile sector is one of those that has the most impacts on the standard of living of people worldwide. Among the necessities of life for humans is clothing. Innovation is one of the most important tactics the textile business uses to remain competitive in the market. In the worlds of fashion, sports, uniforms, and items, new techniques, the use of computer intelligence, and the production of sustainable materials are becoming more and more prevalent. Important capabilities have been brought about by the technological advancement of fabrics, which might set them apart in this kind of business. The process of manufacturing textiles and apparel has undergone updates, encompassing everything from selecting raw materials to production techniques. (6)

In the textile industry, where knowledge of fabric compositions and structures can improve product replication, quality, and process efficiency, reverse engineering is particularly useful. AI's use in reverse engineering not only speeds up these procedures but also makes automation possible, lowering the need for manual inspection and enabling accurate examination of material qualities, fiber properties, and textile patterns. There are solutions and opportunities provided by artificial intelligence in transforming traditional textile production methods, especially reverse engineering, which includes extracting fabric densities and textile compositions, to push the industry towards a more developed and efficient future.(7)

2. The mechanism work of artificial intelligence

The main goal of artificial intelligence is to teach computers to carry out and excel at jobs that people accomplish. With interest in AI now on the rise, manufacturers are aiming to attract consumers by showcasing how their products and services employ AI. Often, they just make references when people refer to a particular facet of artificial intelligence, like machine learning. AI requires a base of specialized hardware and software to develop and improve machine learning algorithms. There are a few popular programming languages, like Python, R, and Java, but no single language is only related to artificial intelligence. Artificial intelligence systems frequently consume vast amounts of labelled training data, which they then examine for connections and patterns before applying these patterns to forecast future states. An image recognition programme may learn to recognize and describe objects in photos by analyzing millions of examples, just like a chatbot that is shown examples of text chats may learn to have realistic interactions with people. It is essential to comprehend each component of artificial intelligence in order to comprehend how it functions.(8) Three components account for the revolutionary potential of AI systems in the workplace: creating predictive and descriptive models, using big data, and altering work procedures as shown in figure 1.(9)



Figure(1)Three intertwined elements, defining AI performance in work context(9)

3. Classification of artificial intelligence

There are three different forms of AI :

Narrow AI: artificial intelligence (AI) tools that are tailored to perform specific tasks or commands are referred to as narrow AI, weak AI, or artificial narrow intelligence (ANI). One example of narrow AI is natural language processing, which is limited to recognizing and responding to voice instructions.(10)

Artificial General Intelligence (AGI): refers to the fictitious intelligence of a machine that is capable of learning or comprehending any intellectual work that a human being is capable of. (10,11)

Artificial super intelligence (ASI): t is a fictitious artificial intelligence (AI) system that runs on software and has a higher level of intellect than a personThe idea behind artificial superintelligence is that it will eventually be able to understand human intelligence and be able to experience time.(10,12)

4.The major subfields of artificial intelligence

Artificial Intelligence is a broad field of study that includes many theories, methods and technologies, as well as the following major subfields:

4.1 Machine Learning

A form of artificial intelligence called machine learning creates predictions through algorithms that learn from data. These forecasts can be produced by computers using unsupervised learning, which finds broad patterns in data, or supervised learning, which identifies patterns from already-existing data. Machine learning is an area of research in artificial intelligence that focusses on creating and analyzing statistical algorithms that can accomplish tasks without explicit instructions by learning from data and generalizing to new data Machine learning has become an essential technique for finding patterns, deriving insights, and drawing predictions from massive amounts of data due to the exponential rise of data.(13)

4.1.1 Machine learning procedure

Four steps are involved in machine learning, which are listed below (as shown in figure 2):

- First, extracting features
- Second, choosing an appropriate machine learning algorithm
- Third, training and assessing the effectiveness of the data model
- Four, making predictions with a trained model(14)

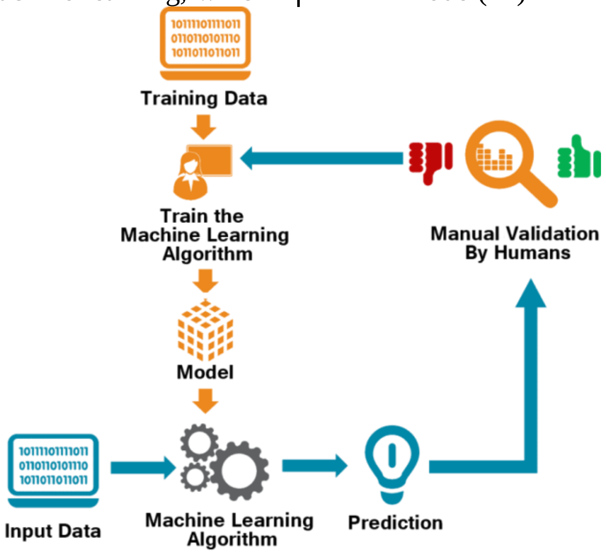


Figure (2) Machine learning model(15)

4.2 Deep Learning

Deep learning uses massive neural networks with multiple processing layers to identify intricate patterns in large data volumes using advanced training methods and increased processing capacity.Voice and picture recognition are two common uses. A collection of machine learning methods known as "deep learning" use numerous layers, each of which corresponds to a different degree of abstraction. There are other hidden layers in addition to the input and output layers. Voice synthesis, image processing, object detection, handwriting recognition, prediction analytics, and decision-making are among the applications for it. Three major categories can be used to categorize deep learning as shown in figure 3.(16,17)

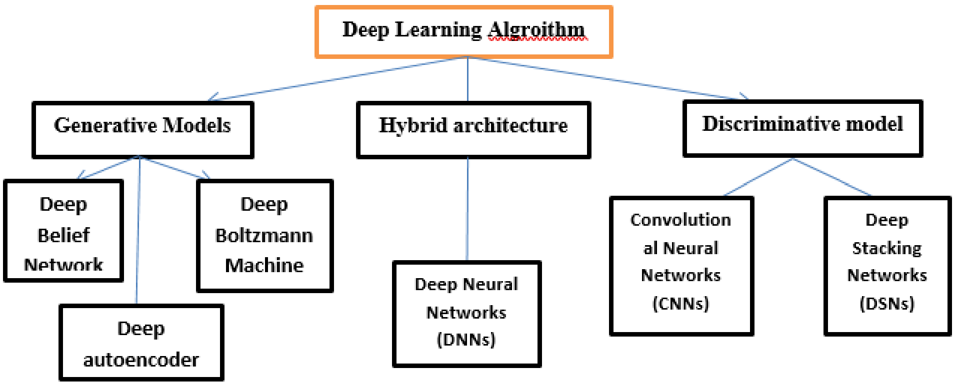


Figure (3) Deep learning(15)

4.3 A neural network

Neural networks, a subset of machine learning, are composed of interconnected components called neurons that process information by passing information amongst each other and responding to external inputs. Mathematical models known as neural networks are roughly modelled after the structure of the human brain. Within a neural network, every neuron is a mathematical function that receives input, processes it into a more readable format, and outputs the result.(18)

4.4 Computer vision

Deep learning and pattern recognition are the two main tools used by computer vision to identify objects in images and videos. Machines that possess the ability to process, analyze, and comprehend images will be able to record films in real time and comprehend their environment. With the aid of CV, systems are able to comprehend and interpret their visual environment and take appropriate action. It teaches computers how to read and comprehend visual data.(19)

4.5 Natural language processing (NLP)

Natural language processing is the use of computational methods to the study of linguistic data, usually in the form of textual data like articles or papers. Using linguistic insights, natural language processing aims to create a representation of the text that gives the otherwise unstructured natural language some structure.Systems biologists utilise natural language processing to create apps that combine data from the literature with information from other biological data sources. (20)

5. The applications of Artificial intelligence

People frequently receive personalised recommendations from artificial intelligence, based on things like past searches, purchases, and other online activity. AI has a significant impact on commerce: maximising goods, organising stock, and handling logistics as shown in figure 4(21).

The following are a few uses for artificial intelligence such as:

Gaming: AI has revolutionized games like chess, using powerful algorithms to analyze many possible moves. (22)

Heavy industries: Robots powered by AI handle dangerous tasks.(23)

Weather forecasting: AI models use neural networks to predict weather patterns.

Expert systems: These systems use logic and data to answer questions. (24)

Data mining: AI helps find hidden patterns and relationships within large datasets. (25)

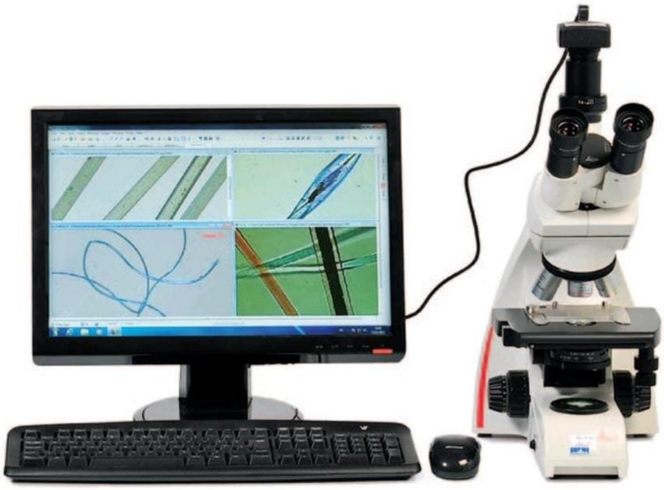
Figure(4) AI Applications(26)

6. Artificial intelligence and its applications in textiles

Fibre categorisation, yarn property prediction, textile inspection, and dye colour prediction are just a few of the uses of artificial intelligence (AI) in the textile production process. The apparel sector can also benefit from the application of artificial intelligence (AI) in pre-, production, and post-production procedures. Fabric flaws lower the worth of textile goods. Artificial intelligence approaches, such as Artificial Neural Networks (ANN), are used for defect identification in textile industry fabric inspection as a solution to this issue.(25) Features are taken out of the acquired image and then combined with older features to create a new, smaller feature set using the feature selection method, which reduces the dimensionality of the feature set. (27,28)

6.1 Computer Vision on fiber characteristics

A high-performance computerized artificial intelligence system has been developed to quickly and easily analyze fiber qualities. Determine the proportions of each type of fiber in the combination and examine the compositional percentage. It can also assess the toughness of nonwoven textiles and count the threads and yarns in a Dtex or den as shown in figure 5.(27) It is possible to recognize and assess fiber characteristics including length, diameter, and curl using computer vision. Analysis of the characteristics of the fiber, particularly its shape, is another use for it. (29) The steps that are usually taken are broken down as follows: 1-Image Acquisition: take high-resolution images of the fibers: cameras and microscopes are used to take high-resolution images of the fibers. 2-Preprocessing the Image. 3- Feature Extraction: Measure characteristics such as aspect ratio, curvature, fiber length, and breadth (diameter). 4-Classification and Identification: utilize methods like pattern matching or machine learning algorithms to categorize fibers according to their morphological traits that have been retrieved. 5-Validation and Quality Control. 6-Reports summarize the morphological qualities and fiber characteristics. (30)



Figure(5)Fiber morphological identification(27)

6.2 Machine Learning on yarn spinning

To guarantee a dependable production process and high/constant quality of semi- and final products, modern concepts of computer-based information systems supporting yarn engineering/optimization of fiber blends, as well as for collection and processing of data, relevant for the entire spinning process, have to be used.(31) AI and machine learning can optimize cotton fiber blends to enhance quality, consistency, and performance. By using large-scale cotton fiber data, including physical attributes like length, fineness, and strength, machine learning models can improve textile manufacturing efficiency, reduce waste, and produce superior, customized materials. The models rely on data such as fiber composition, environmental factors, and production methods to optimize the blending process.(32) Based on the input features, machine learning models are constructed to forecast the ideal composition of the cotton fiber mix. maximizing yarn strength and minimizing production costs by utilizing a genetic algorithm to determine the ideal combination of short- and long-staple cotton fibers. Machine learning algorithms, once trained, use new input data (fiber qualities, mix ratios) to forecast the quality and performance of different blends of cotton fiber.(33)

6.3 Machine Vision and Image Processing on yarns quality and defect detection

A brand-new method for evaluating yarn quality based on diameter, hairiness, and defects has been introduced. Machine vision and image processing serve as the foundation for this method. Analysis is done on the detection experiments' results. The following are the advantages of the proposed method over the existing one.(34) There is a technique based on machine vision and image processing to identify flaws, hairiness, and yarn diameter. Figure 6 depicts the suggested method's flowchart. And the following describes the equivalent algorithms. Image preprocessing is used to enhance image quality and increase measurement accuracy of the yarn diameter. Greyscale transformation and picture filtering are the two fundamental phases in image preprocessing. Grey-scale transformation is an easy way to turn colour photographs into greyscale images. Because of the influence of the imaging environment and settings, picture noises cannot be avoided. It is possible to treat the image noises as a type of ambiguous information. Neutrosophic Set (NS) has been effectively used for ambiguous information processing in recent times. The yarn images are processed using an indeterminacy filter. The purpose of the measuring system is to measure the yarn diameter, hairiness, and flaws. To prevent stray light disturbance, the image-capturing platform in the system is enclosed. In order to get rid of shadows and reflected light, milky white diffused glass is employed. To improve simulation, yarn motion driver and tension controller are also utilized. The integrated structure of this system is displayed in figure 7.(35,36)

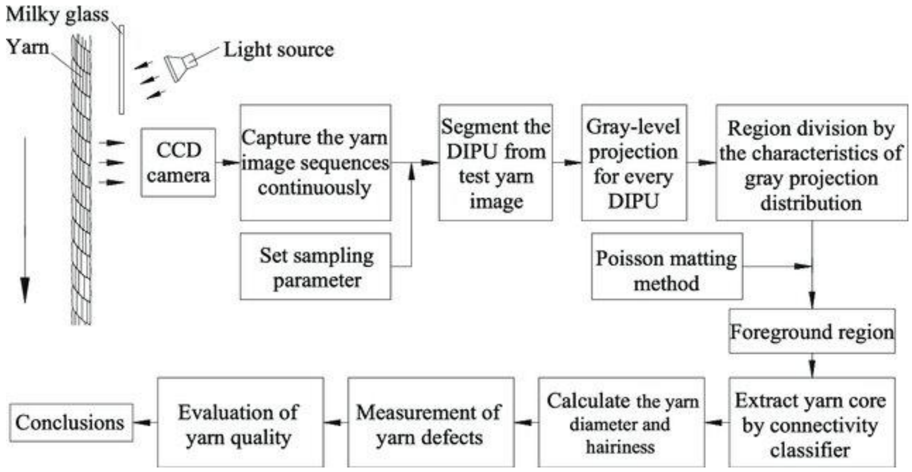


Figure (6) Flowchart of the method to detect yarn parameters and evaluate yarn quality(36)

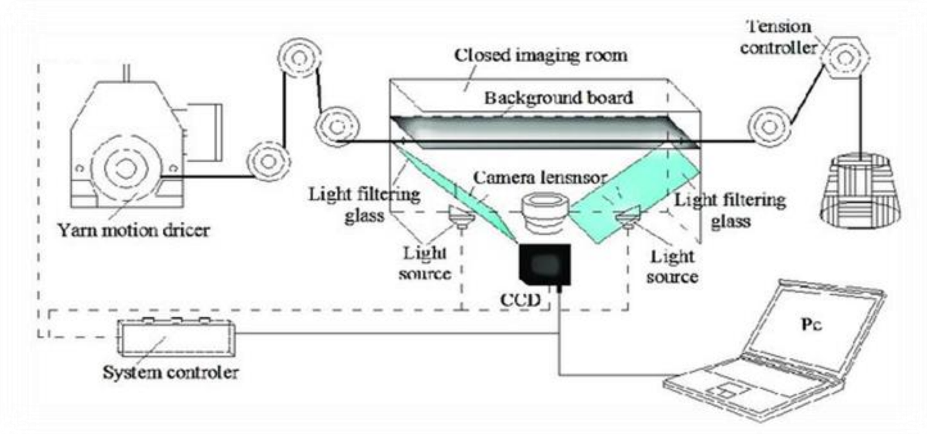


Figure (7) System device to detect yarn parameters.(36)

6.4 Artificial intelligence in weaving process

Even while producers of weaving machines have made strides towards creating digital machines that are prepared for Industry, more work needs to be done. Machines with fully automated style changes, automatic formation of flexible integrated circuits for smart e-textiles, automatic repair of warp breaks, multiphase weaving machines for dobby and jacquard weaving, and variable width/warp density jacquard weaving to surpass the current speed limit of single-phase weaving machines are what weavers are looking for.(37)

The development of robotics to achieve complete automation, the use of Iot to enable machine manufacturers to access and process huge data using AI and analytics to diagnose and predict disruptive issues, and systems to gather and store large volumes of digital data are all necessary steps on the path to Industry. It should be noted that as all data are correlated starting with the fiber and ending with the market, the upstream yarn manufacturing and downstream processes fabric finishing, conversion to products, and marketing should be integrated with weaving. (38)

6.5 Digital image processing and computer vision on fabric quality and defect detection

The term "fabric texture" describes how a fabric feels. It is shiny, silky, smooth, soft, velvety, rough, and so on. The various weaves that are employed determine the fabric's various textures. The textures of many textile materials, including linen, cotton, silk, wool, and leather, vary. Natural and synthetic fabrics make up the two kinds of textile materials. Being relatively new, synthetic materials have developed alongside the textile industry's steady expansion. Defects in fabric can be caused by machine errors, holes, colour bleeding, yarn issues, scratches, and poor finishing.(39,40)

Digital image processing and computer vision have a variety of uses in automated production processes and other applied disciplines. Fabric defect detection is regarded as a difficult problem in the textile industry since the efficacy and efficiency of automatic defect detection determine the price and quality of any textile product. In the past, the textile industry used manual human labour to find flaws in the process of producing fabrics. Digital image processing and computer vision applications can solve the aforementioned issues and constraints. (41)

6.6 Deep Learning on textile colour matching

The DLE4FC model enhances color detection accuracy in fabric images using deep learning techniques. The testing dataset comprises 2,000 textile photos captured under various lighting conditions, resulting in 7,757 images. After manual labeling, a balanced dataset of 1,200 photos representing 12 color classes was created. Each image was evaluated by eleven individuals to assign a ground truth color label, with the final label determined by a majority vote.The DLE4FC model significantly improves color detection in fabric photography.(42) Product color may be rated as "acceptable" or "unsatisfactory" in general, or may be rated more specifically as "very light" or " Too red" or "too blue." These decisions are due to an appreciable difference between the ideal product standard and the sample, and can be made visually or analytically.(43) It is possible to improve the precision and effectiveness of automated tolerance by creating an AI-enabled platform with a pass/fail (P/F) function. This platform will function similarly to defect detectionas shown in figure 8 (27,44)

Figure (8) AI in textile colour matching(27)

7. Reverse engineering

Reverse engineering is the process of copying an existing part, subassembly, or product without the use of documentation, drawings, or computer models.. Reverse engineering (RE), the technique of digitally capturing a component's physical entities, is frequently defined by academics in relation to their particular objective.(45) Reverse engineering is widely used in manufacturing, industrial design, and jewelry creation. It allows rival manufacturers to dismantle new vehicles to understand their design and operation. Good source code in software engineering often consists of other good source code. (46)

7.1 Reverse engineering for textile production

The warp and weft yarn densities, fabric structure, colour, coloured yarn array parameters, and other factors make up the weave pattern of woven cloth. Other criteria in modern textile operations still depend on the analysis of specific testers with the assistance of auxiliary equipment, with the exception of the warp and weft count, which is determined by the procedure of sampling, weighing, and calculating. The time commitment, low efficiency, and impact of testers' subjective elements on test results various testers may arrive at different test results are some of the drawbacks of this artificial analysis method. Figure 9 shows the steps for reverse engineering to produce textiles manually and using AI.(47,48)

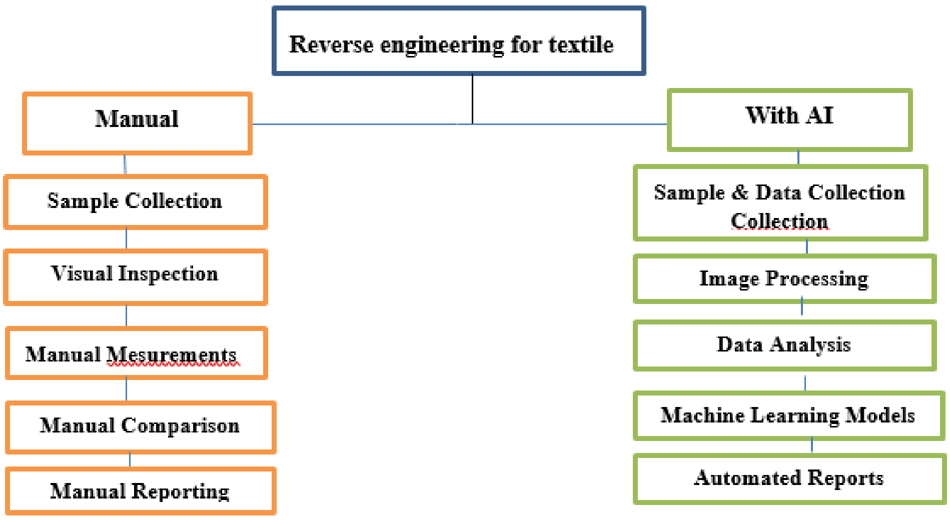


Figure (9) The steps for reverse engineering to produce textiles manually and using AI

Deep learning models called convolutional neural networks (CNNs) are used to examine images of fabric and textile structure in order to extract complex patterns and properties from fabrics. These models are able to predict the effects of certain patterns on the strength, elasticity and appearance of textiles. This facilitates the development of new or modified designs. Deep learning models are trained on enormous libraries of texture pictures to accomplish this. With deep learning, textiles with intricate weave patterns can be identified with a high degree of accuracy. CNNs can automatically identify the spatial relationships between warp and weft threads by analysing high-resolution fabric photographs.(48,49)

7.1.1 Reverse engineering in calculating the weft-warp densities in textile fabrics

Traditionally, weaving has been employed in the textile industry to create a fabric by interlacing two different sets of strands that are perpendicular to one another. For the fabric to be both aesthetically pleasing and robust and stable, the warp and weft of the threads must be interlaced in a specific way.(50) Weaved fabric densities, or warp and weft densities, are crucial factors to consider when measuring textile production. Analyzing the vertical and horizontal frequencies from a textile image is the foundation for determining the weft and warp densities in textile woven fabric. These metrics are often counted by hand using a small tool called a "loupe." Thus, the precise density varies from one to individual as shown in figure 10. (51)

Figure (10) calculating the weft-warp densities in textile fabrics manually(52)

7.1.1.1 Reverse engineering in calculating the weft-warp densities in textile fabrics with AI

Fabric density is typically measured by manually removing warp and weft yarns from a sample and counting them with a loop, a process that is labor-intensive, tiring, and prone to errors, leading to decreased productivity and efficiency. As a result, research efforts are focused on developing reliable methods for automatic fabric density inspection. Despite extensive investigations into automated assessment, the textile industry still requires a robust procedure that ensures greater effectiveness and accuracy.(53,54)

There are several methods for automatically calculating fabric density. A strong tool for determining the fabric density in both the temporal and frequency domains is image processing. The technique based on the grey level cooccurrence matrix (GLCM) has been used to determine the density of plain, twill, and broken twill woven fabrics. It is a statistical technique looks at the spatial relationships between individual pixels in a picture to assist identify texture features that are associated with fabric density.(55,56)

In another study, discrete image analysis was used to determine yarn densities in plain, twill, and satin-braided fabrics. The Fourier Transform was applied to measure weft and warp densities, providing valuable insights into the fabric's structural properties. (57) Using the Fourier Transform to transform the fabric's spatial image into the frequency domain. By dissecting the image into its frequency components, this transformation makes it possible to examine periodic patterns. Figure 11 & 12 shows separating warp yarns and weft warns in plain fabrics(58)

Figure (11) plain fabrics(58)

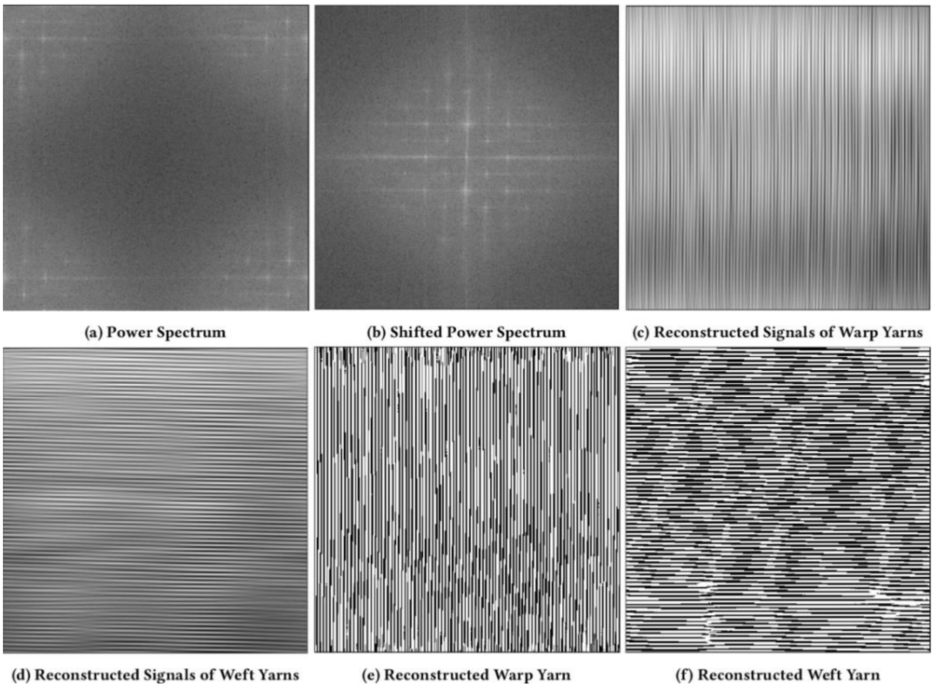


Figure (12) Reconstruction Steps of Plain Fabric Image(58)

The Fourier Transform was further studied to find the points of overlap between distinct fabrics, which prevents automatic fabric density detection. Identification of different types of cloth weaves is also possible through analysis of the texture information obtained from these overlapping locations. Feng offered a different strategy that uses image processing in (59,60). He examined how to use the wavelet transform to calculate the fabric density while ensuring the wavelet dimension and binary convention.(59,61)

7.1.2 Reverse engineering in Evaluating Fabric Structure Characteristics

Essentially, textile analysis employs a microscope to identify the weave pattern, the densities of the warp and weft yarns, and most likely the counts of the warp and weft yarns.(62) Traditionally, basic instruments like magnifiers and rulers are used to hand inspect the weave patterns and density of the fabric. Because results can differ amongst inspectors, this method is laborious, time-consuming, and prone to discrepancies. However, more precise and effective digital image processing methods can take the role of manual examinations because to improvements in computer speed and storage capacity. (63)

7.1.2.1 Reverse engineering in Evaluating Fabric Structure Characteristics with AI

To define the fundamental structural elements of a yarn's surface, such as its thickness, hairiness, and twist, other researchers used digital image analysis. The texture of carpets in use was also characterized using digital analysis. When methods became more intricate and specific image processing was needed for a given application, the term image processing emerged. (64) Utilizing an image processing method, the brightness of each channel (Red, Green, and Blue) in a colored fabric image was examined in order to evaluate a fabric surface following pilling. Based on counting the pilled area extracted from the examined image, analytical techniques were utilized to determine the pilling grade for each sample. (65)

Image processing analysis was used to estimate some of the structural characteristics of woven fabric and to identify the weave pattern. The success of such an image processing approach will enable fast and accurate analysis of some of the fabric structure characteristics.(66) It was well known that the conventional method was laborious, time-consuming, and uncomfortable for the inspector's eyes. When the conventional method is replaced with a computer system that records and processes fabric images, all these disadvantages will vanish. A Wiener filter(is a signal processing method that, especially when applied to audio or visual data, lowers noise and enhances signal quality).It is used in an image processing technique that is provided to determine the woven fabric pattern and approximate some of the fabric structural properties. (67)

To recognise and categorise woven materials, a bespoke deep learning model built on the ResNet-50 architecture is suggested. It classifies fabrics into kinds such as satin, twill, and plain after preprocessing fabric photos and utilising data augmentation to extend the dataset. The model proved resilient to variations in illumination, fabric colour, yarn thickness, and spin direction. It is also computationally efficient, which makes it a viable option for the fashion and textile sectors. (68,69)

8. Conclusions

Even in industrialized nations, the use of AI in textile technologies is still relatively new. The textile industries in poorer nations, where issues with production and quality control are persistent, stand to gain much from the prospective applications of AI technologies. The textile sector is increasingly utilizing AI technologies evident since the ability to solve difficult issues fast and precisely is becoming essential for competitiveness. The fabric Manufacturing is a labour-intensive sector where a variety of tasks, such as production and quality assurance, are mostly in the hands of humans. Artificial intelligence is currently being worked into a wide range of tasks, including machine vision, prediction, detection, identification, and inspection. Many weaving operations are laborious and produce erroneous results when done by hand. During the production process, image processing technology is frequently utilized to analyze textile products and raw materials. Although attempts have been made to employ digital image processing for reverse engineering, including calculating warp and weft densities and figuring out fabric composition, it has not always produced correct results in some fabrics. This is because the textile industry has made significant advancements in this area. Although previous research on reverse engineering for textile production using AI techniques have demonstrated encouraging developments and possible advantages such as accuracy and quality of results, speed of data extraction, and reducing errors resulting from fabric analysis by humans.However, there are still challenges and considerations that must be taken into account to improve the process of reverse engineering textiles using artificial intelligence, such as the size and quality of the data. The size and quality of the data set: Access to a large and diverse set of data is crucial to training effective AI models and obtaining higher accuracy in the results. Limited, biased, or low-quality data can lead to poor model performance and unreliable outcomes. Textile science and AI technology expertise are needed for effective reverse engineering, and interdisciplinary teams may not always be available to fill this gap.

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