A review on the application of Artificial Intelligence in the Fashion and Apparel Industry

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Abstract: Dressing or clothes is a fundamental need of human beings that do not have a particular gender. Fashion design is a very demanding industry that involves many of the concepts, requirements, and demands of human beings. An area like this, which has a huge involvement of people requires some sort of technology to solve its problems and give the best service to the consumers. So, like every other industry, the fashion and Apparel industry also has some issues such as high production costs, wastage, customer dissatisfaction, and environmental pollution. In order to address these issues, Artificial Intelligence based technologies have been used, including Machine Learning, Decision Support systems, Expert Systems, Optimization, and Image Recognition & Vision. This review presents different research on Artificial Intelligence-based technologies and issues related to the fashion industry. Based on the operational procedures, this study's concerns are also divided into four areas, such as apparel design, production, retail, and supply chain management. In addition to that, Big data helps Apparel e-commerce retailers provide personalized offerings to customers. Machine learning and image processing techniques are commonly used to develop data-driven solutions using product-related data provided by Apparel product manufacturers & designers, and also these technologies help the supply chain to improve business operations.

Keywords: Fashion designing, Artificial intelligence, big data analytics

1. Introduction

Fashion and Apparel is one of the largest growing industries helping the economy, 38% to the Asia Pacific, 22% to North America and 26% to Europe.[1] It has been discovered that Fashion and Apparel industry sales have a growth of 5.5% in Europe and 7.5% in the Asia Pacific.[2] Because of the overproduction and the number of products returns this industry has been named as one of the biggest waste producers globally. The main reason for the customers not being satisfied with the product is dissatisfaction with the colour, size, and style of the product. So, the industry needs to have a good idea of the customer requirements and needs in the manufacturing process. At the same time the manufacturing process should follow steps that do not harm the environment.

So, as mentioned the major problems faced by this industry are high production cost, wastage, environmental pollution, etc. So, to solve these the best solution is to use the latest technology as Artificial Intelligence. There has been a huge growth in the sectors of health, manufacturing and transportation sectors using Artificial Intelligence to solve their problems. When considering the Fashion and Apparel industry consists of a few stages, they are Apparel design, pattern making, forecasting sales production and supply chain management. They have a huge growth with globalization and digitalization. That is essential to improve supply chain processes like Apparel production, fabric selection, fabric inspection, distribution, etc. The speciality in this industry is that it has to be dynamically changed based on the customer demands and fulfilling the customers' requirements. So, it will be really helpful if there is some digital platform for requirement elicitation and collection. For this, we can use technologies such as Artificial Intelligence, big data analytics, machine learning and other available technologies. Even though there is a need for an AI-based solution, some of the companies in the industry still use tools based on classical algorithms. The review conducted demonstrates the categorization of research articles based on four Apparel industry operational procedures, named design of Apparel, manufacturing of Apparel, retailing and supply chain management. The research paper [3] was limited to Artificial Intelligence algorithms, "decision support systems" and "Intelligent systems" in the textile and Apparel supply chain. Another study [4] also considered the Data Mining and Machine Learning approaches used in this industry. But when studying deep inside it is clear that most of the studies conducted in this field have not mentioned the usage of Artificial Intelligence in the Fashion and Apparel industry. Therefore, that is important to have a further study on finding the AI techniques that can be used to improve the business operations in different supply chains. Furthermore, Fashion and Apparel industry supply chain stages have not been defined according to the business perspective yet by none of the studies. However, as AI technology has expanded, the sophistication of commercial operations has increased. The current usage of Artificial Intelligence in the Fashion and Apparel industry comprehends the application of AI technology at various levels of this industry and grasps the use of AI technology from a commercial standpoint.

2. Research Famework

There are some methods involving the fashion and Apparel industry using Artificial Intelligence Technology. To make the study more reasonable, transparent, and consistent a method known as SLR methodology was used.[5] According to this research method the review process has been done by collecting and processing data from scientific databases. The articles were selected according to five phases known article retrieval, article selection, information extraction, article classification, analysis & funding and finally discussion & conclusion. Then those were taken into classification depending on the three research questions. The three research questions are "What has been the impact of Artificial Intelligence on the fashion industry over the last few decades?", "Where have AI technologies been used in the F&A supply chain?" and "To what extent has research addressed supply chain issues from a B2B and/or B2C standpoint?". There were three researchers known the first researcher, second researcher and expert researcher. The first two researchers are involved in the whole review process while the other is involved in the validation process. The competency of each researcher is mentioned below in Table 1.

Table 1. competencies of each researcher

Researcher	Competencies	
	Major	Minor
First Researcher	Artificial Intelligence, Data Science, Expert Systems, Machine learning	Fashion, Textile, supply chain, management
Second Researcher	Fashion and Apparel supply chain, fashion technology, information technology, data analysis	Machine learning, Artificial Intelligence
Third Researcher	Significant knowledge of both domains (AI and F&A)	NA

The article screening process consists of three main steps known as article retrieval, article selection and information extraction. The first step which is known as article review is the initial step of the selection process. So, it requires selecting the databases to conduct the research. Some of the well-known databases are Scopus and Web of Science. Then the other step is article selection. In this step the

researchers select the most relevant research articles Then they can be used to solve the research problems. This process involves five phases. Those are filtered by document type, Removing duplications, initial screening, the second round of screening and final screening. The selected research papers were based on getting a clear idea of the various Artificial Intelligence classes used in the Fashion and Apparel industry in order to check the types of revenues that can be used to address the above-mentioned research problems. The final step is information extraction which includes collecting articles and then classifying them into the sub-areas such as AI classes, Business to Business, Business to Customer approaches to address research questions, supply chain etc.

So, after the study was done using collected research articles, four main types of information can be extracted. Those are applied AI and algorithm, Business perspective: B2B & B2C, supply chain stage and research gaps. Table 2 below explains the classification of articles used in this review based on the research question.

Table 2. classification of articles used in this review

Article Classification		
Research Problem 1	Research Problem 2	Research Problem 3
Artificial Intelligence Classes	Fashion and Apparel Supply chain stages	
Machine Learning	Design	Business to Business (B2B0
Decision support Systems	Fabric Production	Business to Customer (B2C)
Expert System	Apparel Production	
Optimization	Distribution	
Image Recognition and vision		

According to above Table 2, research question 1 is focused on the overall trend of AI in the fashion and Apparel industry. Therefore, to address that question the techniques of AI has divided into 5 categories. These are Machine Learning, Decision Support System, Expert System, Optimization, and Image recognition & vision. These sub-sections will be discussed later in this review.

Research question 2 is focusing on identifying the various phases of the supply chain where the AI approach was used. As a result, the supply chain stage under consideration was recorded during the information

extraction stage. The supply chain was divided into stages such as Design, Fabric Production, Apparel Production and Distribution to address this question.

Research question 3 seeks to comprehend the scope of business problems that are the focus of research studies. To do this, the identified supply chain phases were further classified as B2B and B2C from a business standpoint.

This classification of research articles was confirmed with the assistance of an experienced researcher who has been actively involved in research, linked to Artificial Intelligence and the financial services industry for the past two decades. Table 1 also mentions the expert researcher's competency.

Table 3. B2B & B2C activities in fashion industry

B2B	B2C
Fashion Design	Fashion Design
Textile Design	Textile Design
Spinning	Dyeing and printing
Weaving and Knitting	Cutting
Dyeing, Printing, Finishing and Inspection	Sewing and Assembly
Cutting	Finished garment
Sewing and assembling	Retailing
Wholesaling	E-Commerce
Retailing	

A. Classification of Fashion and Apparel supply chain stages

Fashion and Apparel is a very large industry that is involving various people across the world. This industry is associated with a variety of raw materials such as dyestuff, fabric, fibre, yarn, and other chemicals. The process related to this is classified into four stages namely, design, fabric production, Apparel production and distribution. The normal practice of the supply chain is to follow a push system. [6] The brand owners or clients supply information to manufacturers such as the design or technical specifications of the fabric/ garment to be manufactured, the volume of products to be produced, and the sizes in which the garment is to be produced. The garment and fabric sector carries out work according to the need of their client and follows the instructions they provide. The raw materials used for the apparel production are the finished fabrics which are being approved by the buyer/client. The final garments are then delivered to a wholesaler or store. There is another party which acts between the client and the wholesaler named the retailer. The retailers use various

channels to sell the garments such as e-commerce sites, department stores, etc. Also, the designers produce their creations based on the current market and analysis of the trends. It is considered that the brand owners have considered under the Business to Business(B2B) category since their primary customer is mostly another company or business. Also, most of the retailers do not own any marketplace or shop. So, retailers are considered under Business to Consumer(B2C) since consumers are their primary customers, unlike B2B. But with the increase the e-commerce sites and mostly e-markets the concepts of B2B and B2Cs are evolved. It is also critical to distinguish between B2B and B2C and how AI might assist in tackling challenges in both segments.

B. Classification of AI applications in the Fashion and Apparel industry

Artificial Intelligence is a well-known technology that can be used to address any kind of real-world problem. In the past few decades, the Fashion and Apparel industry had a huge evolution, especially with the usage of AI technologies. Various advanced machines are used in this industry to ensure the efficiency and quality of the products.[7] At the managerial level, the application of Artificial Intelligence is well explained and classified by operating processes in the Fashion and Apparel industry.[8] But when studying these research papers, the categorization is less. The issues in the operating process of the Apparel industry are explained by the research.[8] The mentioned study has revealed that Artificial Intelligence-related research is contributing to this industry's manufacturing issues by a percentage of 45%. Among them, 9% is about Apparel forecasting and 4.2% is about the recommendation of fashion.

3. Methodology

According to the research [17], which is a comprehensive assessment of classification and clustering techniques used in the F&A market, classification algorithms have been used more than clustering algorithms. On the other side, this study is not focusing on the linear and nonlinear predictive models. Also, it does not include areas such as customer analytics [9], optimization techniques [10], big data analytics, deep learning [11] and customization.

A. AI Technologies

AI is categorized into five broad areas by this research work which is mentioned above in Table 2.

1) Machine Learning: Machine Learning can train computers to perform an assigned task without the involvement of human beings. It uses the data patterns to learn by itself. Future decisions can be made using hidden patterns. These hidden patterns are predicted and found using mathematical models which are built on historical data.[12] Machine learning can be divided into two main

categories named Supervised Learning and Unsupervised Learning.

- Supervised Learning: It's a parametric model with input (independent variables) and output (dependent variable) [36]. Supervised model performance can be increased by iteratively improving model parameters [37]. Depending on the research objective, it could be a classification or regression task, with the dependent variable being categorical or numerical.

- Unsupervised Learning: Unsupervised learning models are made up of solely input attributes and independent variables, and their main goal is to group comparable data points. The process of grouping similar kinds of data patterns is called clustering. This process is used to create their labels.[12] The tasks such as sales prediction, demand forecasting, trend analysis, colour prediction and predicting fabric behaviour using mechanical properties are implemented using machine learning techniques in the fashion and Apparel industry.

The most used technologies under Machine learning were Support Vector Machine (SVM) and Predictive algorithms such as regression. Support vectors are data points that are closer to the hyperplane and have an impact on the hyperplane's position and orientation. By utilizing these support vectors, we increase the classifier's margin. The hyperplane's location will vary if the support vectors are deleted. These are the ideas that aid in the development of our SVM. Predictive analytics is used to make predictions about the future based on data from the past. The predictive algorithm can be applied in a variety of ways to assist businesses in gaining a competitive edge or developing better products, Predictive analytics algorithms either use "boosting" (a technique that modifies the weight of an observation based on the last classification) or "bagging" to try to obtain the lowest error feasible (which creates subsets of data from training samples, chosen randomly with replacement). Bagging is used in Random Forest.

2) Decision Support Systems: This technology is used at the commercial level of the organization to get high-level and mid-level decisions. It can be automated, regulated by a human, or a combination of the two. In some studies, the authors have mentioned these decision support systems as software tools while some other mentions that those can be integrated with the business to make intelligent decisions.[3] The mathematical model is combined with the conventional data retrieval methods in Decision Support Systems.[15] It is commonly utilized in the F&A industry to industrialize numerous jobs by streamlining decision-making processes in the supply chain.[16] This DS is very useful for the various stakeholders in this industry to select the most

suitable resources and processes while decreasing the overall costs and at the same time enhancing the performance of the Apparel supply chain.[17]

3) Expert Systems: Expert systems in AI have been used to make decisions without any involvement of human beings. To solve a very complex problem it usually uses a reasoning approach. It is categorized by the "if-then" rules. These expert systems can be classified again as inference engines and knowledge bases. The 'knowledge base' operates based on facts and rules, whereas the 'inference engine' applies the rules to learn the facts and generate new facts. For apparel manufacturing and production and also to select the appropriate equipment and processes these expert systems can be used. The usage of expert systems can help to reduce environmental pollution.[18] Also, expert systems are very useful to the fashion and apparel industry to improve customer satisfaction by the creation of recommendation engines and fashion retailing activities.[19]

Expert System technologies are Genetic Algorithms, Artificial Neural Networks, and fuzzy logic for the modelling purpose of the Fashion industry supply chain problems. An Artificial Intelligence and computing technique known as a genetic algorithm is a heuristic search technique. The theory of natural selection and evolutionary biology is utilized to identify optimum answers to search difficulties. Also, in order for the computer to learn things and make decisions in a way that is similar to that of a human, artificial neural networks are attempts to replicate the network of neurons that make up the human brain. Instead of the traditional "true or false" (1 or 0) Boolean logic on which the modern computer is built, fuzzy logic bases computation on "degrees of truth."

4) Optimization: The Artificial Intelligence can solve complex problems and provide them with numerous smart solutions through the process of intelligent searching. The traditional search algorithm begins with a random estimate and improves iteratively. Some of the methods of optimization are 'Random optimization', 'Hill climbing' and 'Beam search'. Another type of optimization search is an evolutionary algorithm. Some of the most famous genetic algorithms are gene expression programming, genetic algorithms, and genetic programming. GA is widely utilized in the F&A industry to solve scheduling and design layout issues in Fashion and Apparel industry.[20], [21] To improve the fitting services this algorithm has been used.[22]

5) Image Recognition and vision: Computer vision in AI is a scientific area which trains the machine to achieve high-level interpretation of images or videos. These images or videos can be received from any field such as global sensing position, cameras, and medical field. Extraction, pre-processing and creating supervised or unsupervised models and high-dimensional data are the tasks of computer vision

algorithms. These models are using different concepts such as statistics, geometry, and physics to get understanding about the images. This image recognition and vision technology is used by the fashion and Apparel industry to make the industrial applications automated such as inspection and process control.[22] This technique is also popular for virtual Tryon, content-based image retrieval systems and AR (Augmented Reality) in the Fashion and Apparel industry.[23], [24]

B. Artificial Intelligence for fashion in the Bigdata era

Artificial Intelligent can be used to create various methods which will be beneficial for the industry of fashion designing. AI can be used to handle the 3Vs of bigdata which is volume, variety, and velocity.[25] Hence it can handle the variations, uncertainties, and complexities of the market. AI techniques are already used by some of the leading companies, but it has not yet been spread properly among the middle level companies. Implementing these strategies is difficult because to the range of currently available methodologies, models, applications, and data formats. It is sometimes a huge challenge to the fashion companies. Consumer movements, such as the sustainable fashion movement, cause fashion customers' purchasing decisions to be increasingly motivated by a sense of consciousness rather than greed. Nonetheless, it can be argued that people have never consumed as many clothes as they do today, and as a result, the way they do it, has changed.

1) Data mining and fashion sales predicting methods:

Information is considered as one of the most important elements in the todays world which can be useful for so many industrial purposes as well as for the security. The big data environment is always attached to the economy, business life and also our daily life. In the context of Fashion, many sorts of data can be analysed: point-of-sale (POS) data, geographic information systems (GIS) data, social media data, virtual 3D data, sensory data, and textile physical data. Advanced approaches are required to manage the profitable usage of these data. Data mining is also another useful subfield of the Computer Science and Statistics sector, which involves discovering patterns in a large set of data at the confluence of machine learning, statistics, and database management systems. The objective is to extract information using intelligent methods from data sets and then convert them into a comprehensive form for further usage. A target data set must be assembled before data mining algorithms can be employed. For the fashion brand to survive in the industry it is crucial to collect the information and data efficiently. It is difficult to predict the success of fashion brands accurately since it has a very dynamic range of changes every day and the consumer trends might change regularly. It has proved that several AI methods can forecast the performance of fashion sales and

products.[25], [26] Today's fashion industry personnel and trend forecasters rely on the Internet to get information; they spend a large amount of time tracking what is being looked at online and who is looking. New technologies are assisting merchants in inventory management by utilizing AI-powered tools to monitor demand.

2) Virtual Style Assistants and fitting applications:

Forecasting is just one example that shows how AI can be applied in this industry. The fashion industry is almost transformed by AI technologies in the sectors such as designing, manufacturing, marketing, logistics and also sales. According to a WWD magazine article, the world's leading fashion sector sees AI allowing designers, companies, and retailers to develop better products and more appealing shopping experiences.[27] AI has made the shopping experience for consumers easier and more convenient. As an example, the Apparel retailer Gap introduced a "virtual Dressing Room" app in 2018 to assist customers in virtually trying on preferred goods. (Figure 1) [28]

Figure 1. GAP's Virtual Dressing Room shows the outfit on one of five different body types

mechanism is to scan and collect data on a person's foot from thirteen points and then measure the full shape of the foot. This process happens within a few seconds. Then fitting each Nike shoe style using the technology. For this process technologies such as data science, computer vision, machine learning, Artificial Intelligence and recommendation algorithms are being used. (Figure 2) [29]

Figure 2. Scanning application: Nike Fit foot

3) Artificial Intelligence as a fashion Designer:

Fashion experts have a small doubt whether the fashion design done by the creativity of the human being can complete using the computer. Fashion, as a materialization of the human dream concerning the human body, shape of the outfit's silhouette and production of custom beauty, is always an art, an activity aimed at designers and artists. Artificial Intelligence is considered augmented intelligence. Hence that can assist the human thought process in focusing on higher-value decision-making. So, it is proven that AI can become a fashion designer as well. The giant e-commerce

website, Amazon's research facility in San Francisco was opened in 2004. Lab126 has created an algorithm that can recognize specific fashion styles by tracing them on photographs; the technology can then make comparable styles of new goods. A straightforward but competitive AI fashion designer. (Figure 3)

Figure 3. Amazon's fashion algorithm that can develop Apparel by studying a large number of photographs, copying the style, and then applying it to new things

Nowadays AI-enabled features are used by fashion companies in society. They use social media such as Instagram and Pinterest to track the latest fashion trends and interests. The leading companies are powered with smart technologies such as ensuring higher speed while reducing the cost and improving flexibility at every stage of the supply chain. Also, it has got numerous capabilities in the areas such as forecasting and analysing the new fashion trends. Choosing and creating appropriate and sustainable fabric and colour combinations, designing the required cut with minimal waste, and organizing the production process most flexibly and sustainably are all examples of this.

5.   Results

A. The overall distribution of articles over time

Figure 4 depicts the total trend of publications published over three decades (1989–2018). Even though AI technologies were invented in the 1950s the usage of it was realized later in the last decade.
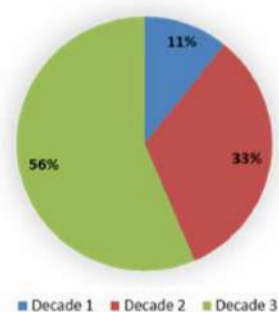

Figure 4. Total trend of publications

For journal papers, research has focused on three AI classes such as optimization, machine learning, and expert systems, although the expert systems are not employed in conference publications. Machine learning, decision support systems, and expert systems are the most utilized AI classes in

journal publications, whereas machine learning and image recognition have received the most attention in conference articles. All AI classes have been widely applied in fabric production, with a particular emphasis on machine learning and expert systems. In addition, image recognition is increasingly being used in fabric inspection, a procedure that falls under fabric manufacture.

6.   Discussion &Implications

Based on the review carried out following the established study framework and in response to the three research questions, this study identified several deficiencies in the application of Artificial Intelligence in the Fashion and Apparel industry which being discussed below. These deficiencies will direct future researchers on a novel path.

Even though AI technologies and methods existed since 1989, they have been popular among researchers only in the last decade how AI can be used to utilize the Fashion and Apparel industrial problems. Although AI technologies have been analysed by the researchers it is still not in a state to develop industrial-level productions by middle-level companies. The reason for this may be the researchers working in the AI industry might not have good expertise in the fashion industry as well as the industry professionals might not be expertise in Artificial Intelligence technologies. Also, the companies in the industries have less knowledge of how AI and big data can be useful for the betterment of their sector. As a result, they must consider the cost-benefit trade-off to fully realize the potential of AI. This study reveals that most of the researchers have carried out their work focusing on problems related to B2B business whereas a smaller number of research works have been carried out for the B2C business problems. The two major challenges faced by the fashion and Apparel industry are changes in consumer preferences and competition from online and other channels.

The study conducted shows that the widely used AI technologies are machine learning and expert systems. They have been widely used in the areas of the supply chain, fabric production, and distribution. A similar number of research publications have been published on this subject in the decision support systems, optimization, and image recognition classes. The least number of algorithms was observed in the design stage. It implies that less focus has been put into the design-related problems. So, the scope for Artificial Intelligence applications is high at this stage. As an example, Artificial Intelligence can be used to develop systems which are capable of getting the consumer's needs more accurately and efficiently. So, this industry can aim for various market segments. Also, it is possible to analyse the consumer's lifestyle patterns and preferences such as the user's history and social media usage to develop the best suiting products for them.

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7. Conclusion

The main objective of this study was to conduct a systematic review of three main problems identified in the Fashion and Apparel industry with the usage of AI. According to the research area around, 25 to 30 research articles were able to be found in the two popular databases known as Scopus and Web Science. The article screening procedure was divided into five stages. To extract information from these publications and achieve the study objectives, a classification was established that considers AI methodologies and F&A supply chain stages while admitting RQ1 and RQ2. When considering the RQ3 supply chain of the fashion and Apparel industry was classified as B2B and B2C. According to the analysis it is discovered that most of the activities related to the Fashion and Apparel industry using AI technologies happened in the last decade which is from 2009 to 2018. The most applied AI technologies are Machine learning and Expert Systems. The most used technologies under Machine learning were Support Vector Machine (SVM) and Predictive algorithms such as regression. Also, it has been found that the most widely used Expert System technologies are Generic Algorithms, Artificial Neural Networks, and fuzzy logic for the modelling purpose of the Fashion industry supply chain problems. The other AI technologies such as transfer learning and deep learning were not much used. This industry has not discovered the actual benefits of using technologies like big data and other AI technologies to expand their industry. This has been well proven through the research done by various researchers. During the study, it was found that more attention to the usage of AI was applied to the supply chain stages such as Apparel production, Fabric production and distribution whereas less attention towards the designing process. A considerable amount of focus was held on the Business when compared to Business to Consumer. As a result, to provide consumer-oriented solutions to the industry, research must adopt a B2C perspective. This allows the industrial supply chain to transition into a more digitalized and sustainable state. The conclusions and future directions provided in this study will be useful for academic and industrial researchers, as well as industrial practitioners, who wish to make a significant contribution to the field. Despite its importance, this study does have significant drawbacks. Firstly, even though the research articles were extracted only from two databases, there could be various other databases to find articles. Secondly, the other issue is the language barrier, articles from other languages related to the same research field was excluded.

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