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AI in Textiles: A Review of Emerging Trends and Applications

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Abstract: ***The integration of Artificial Intelligence (AI) in the textile industry is driving significant advancements across various domains, including manufacturing, design, quality control, and sustainability. This review explores how AI technologies, such as machine learning, computer vision, and predictive analytics, are transforming traditional processes to enhance efficiency, reduce waste, and offer innovative solutions for smart textiles and wearable technology. AI-driven automation is optimizing production workflows, while AI-powered quality control ensures higher accuracy in defect detection and fabric inspection. Additionally, AI is enabling predictive analytics in supply chains, helping manufacturers anticipate demand and manage resources more effectively. The review also highlights AI's role in sustainable textiles, where it supports eco-friendly practices by minimizing waste, promoting resource efficiency, and enabling circular fashion. Despite its transformative potential, AI implementation presents challenges, such as ethical concerns, data quality, and integration with traditional systems. This article discusses the current trends, applications, and future directions of AI in textiles, underscoring its pivotal role in reshaping the industry's future.***

Keywords: Artificial Intelligence (AI), Textile Industry, Predictive Analytics, Smart Textiles, Sustainability

I. INTRODUCTION

Artificial Intelligence (AI) has increasingly become a transformative force across industries, and the textile sector is no exception. The integration of AI in textiles is revolutionizing traditional manufacturing, design, and consumer interaction. From automated production processes to smart textiles and personalized fashion, AI is enhancing efficiency, innovation, and sustainability in the textile industry. One of the key reasons for AI's adoption in textiles is its ability to process large amounts of data and make intelligent decisions that optimize various stages of production and design. This technology is not only streamlining tasks such as fabric inspection, pattern recognition, and defect detection but also enabling more precise predictions in supply chain management and consumer demand forecasting.AI is also playing a crucial role in sustainability efforts within the textile industry. By utilizing predictive models, manufacturers can minimize waste, optimize resource usage, and explore new avenues for recycling and circular fashion. Additionally, the emergence of smart textiles fabrics embedded with sensors and computing capabilities is opening new frontiers for wearable technology and functional garments, further underscoring AI's potential to reshape the textile landscape. In this review, we explore the current and emerging trends of AI in textiles, examining its applications across manufacturing, design, quality control, and sustainability, as well as the challenges and future directions of this rapidly evolving field.

II. AI-DRIVEN TEXTILE MANUFACTURING

The application of Artificial Intelligence (AI) in textile manufacturing is transforming traditional processes by enhancing efficiency, reducing errors, and optimizing production workflows. AI-driven technologies, such as machine learning, computer vision, and robotics, are being integrated into various stages of textile production, enabling manufacturers to automate complex tasks, reduce waste, and increase productivity.

The review article "A Survey on AI-Driven Digital Twins in Industry 4.0: Smart Manufacturing and Advanced Robotics" by Huang et al. examines the integration of digital twin (DT) and artificial intelligence (AI) technologies in the context of Industry 4.0, highlighting their role in enhancing smart manufacturing and advanced robotics. The survey analyzes over 300 manuscripts from the past five years, discussing the developments and current state of AI integration within these fields, including applications in metal machining, industrial automation, 3D printing, and human-robot interaction. The authors emphasize the importance of domain-specific expertise for effective implementation and explore the advantages of AI-driven DTs in promoting sustainable development, while also addressing practical challenges and future prospects. The paper outlines a pathway for integrating AI with multiscale data sources in DTs, aiming to improve decision-making and operational efficiency in manufacturing processes. [1].

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Emerging AI technologies are driving innovations in the e-textiles sector, which integrates smart textiles with advanced computational capabilities inspired by biological neural networks. The paper discusses the significance of neuromorphic computing and spiking neural networks (SNNs) as key elements that can enhance the functionality of e-textiles, enabling applications such as real-time health monitoring and advanced data processing. It explores the evolution of smart textiles from basic electronic integration to the development of textiles with embedded AI intelligence, capable of performing complex tasks. The authors emphasize the importance of understanding the architectural elements of artificial neural networks to inspire future research and applications in e-textiles, highlighting potential use cases in healthcare and beyond, while also addressing the challenges and opportunities presented by these technologies in creating more intelligent and responsive textile products. [2].

The article "A New Perspective on the Textile and Apparel Industry in the Digital Transformation Era" by Akhtar et al. examines how the textile and apparel industry is evolving due to digital transformation, particularly through innovations by Amazon. It highlights a shift in consumer preferences towards digital fashion that transcends traditional economic value, emphasizing the impact of artificial intelligence (AI) and cloud computing in shaping new business models and enhancing customer experiences. The study analyzes Amazon's initiatives in digital fashion, such as advanced digital fashions (ADFs), on-demand manufacturing, and the supra-omnichannel platform, which integrates stakeholders and fosters real-time visibility in operations. As a result of its significant investment in research and development, Amazon has emerged as a leader in the fashion industry, adapting to the demands of a non-contact society while promoting a culture of experimentation and user-driven innovation. The findings suggest that Amazon's approach could serve as a framework for future advancements in the fashion industry, providing actionable insights for companies seeking to thrive in a digitally transformed environment. [3]. This research paper examines the transformative role of artificial intelligence (AI) in the textile and apparel industry, particularly focusing on demand forecasting for weaving materials. It highlights various AI applications, including demand forecasting, process innovation, sustainable manufacturing, and defect detection. The study utilizes methods like artificial neural networks (ANN) and support vector machines (SVM) to enhance forecasting accuracy and operational efficiency. It identifies strong correlations between demand for finished fabrics and gray fabrics, emphasizing the importance of accurate demand predictions for optimizing production and resource utilization. Additionally, the paper discusses the need for continuous improvement in AI integration to enhance sustainability and operational performance in the textile industry. Future research suggestions include exploring dynamic demand forecasting models and the environmental impact of AI-driven practices. [4].

The study by Xiaopei Wu and Li Li investigates the application of generative AI, specifically Generative Adversarial Networks (GANs), in creating knitted textile designs for fashion. Recognizing that previous AI applications focused more on broader fashion elements and less on textile specifics, the researchers aimed to fill this gap by generating new textile images and assessing their aesthetic quality through a survey of over 200 participants. The results indicated that the GAN-based method effectively produced creative and practical textile designs, demonstrating comparable aesthetic qualities to real textiles, thus highlighting the potential of generative AI to enhance creativity and efficiency in the fashion design process while reducing waste and development costs. This study not only contributes to the theoretical understanding of AI in design but also proposes practical applications for the fashion industry, such as digital swatch design generators. [5]. The article presents an innovative IoT-based and cloud-assisted monitoring platform designed for smart manufacturing, focusing on anomaly detection and risk classification to enhance production efficiency. Developed by a team from the University of Naples Federico II, the platform is structured in five modular layers, with a central Cloud Cyber layer that employs a novel AI-driven algorithm, integrating control charts, autoencoders, long short-term memory (LSTM), and fuzzy logic to identify defects and their causes. Experimental validation on a solar thermal high-vacuum flat panel production system demonstrated the platform's effectiveness in providing real-time insights into production anomalies, enabling human operators to respond proactively. This approach aligns with Industry 5.0 principles, emphasizing human-machine collaboration, resilience, and sustainability in manufacturing processes, and aims not only to detect issues but also to facilitate timely interventions, thus promoting a zero-defect manufacturing strategy. [6].

The article discusses the development and implementation of an AI-based clothing design process in a fashion design class at a South Korean university, aimed at enhancing student engagement and practical skills in the fashion industry. The research involved three phases: organizing the class, applying the AI process, and gathering student feedback. Collaborating with Samsung C&T Fashion Group, the study integrated AI technologies, including supervised learning and creativity support tools, into the curriculum. Student evaluations indicated a high satisfaction rate of 4.7 out of 5, highlighting the effectiveness of the instructional methods and communication.

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This innovative approach not only improved students' understanding of AI's role in the design process but also provided them with valuable, data-driven insights, bridging the gap between theoretical knowledge and practical application in the rapidly evolving fashion sector. [7]. Summary of "A Review of Artificial Intelligence Applications in the Apparel Industry" The article by Abid Noor et al. provides an overview of the applications of artificial intelligence (AI) in the apparel industry, highlighting the challenges and limitations faced by manufacturers in a competitive global market. As the industry grapples with fluctuating demand and the necessity for efficient production processes, AI techniques such as neural networks, genetic algorithms, and fuzzy logic have been increasingly explored to enhance decision-making, from design to supply chain management. Despite various applications, research remains limited, particularly regarding the integration of AI in solving complex issues like production planning, sales forecasting, and fabric selection. The authors emphasize the need for further research and collaboration between AI experts and industry professionals to optimize AI applications in apparel manufacturing, thereby improving efficiency, reducing costs, and addressing consumer needs effectively. [8].

AI is revolutionizing textile manufacturing by improving efficiency, minimizing errors, and streamlining production workflows through technologies like machine learning, computer vision, and robotics. A review by Huang et al. highlights the integration of AI with digital twins in Industry 4.0, emphasizing smart manufacturing and robotics while analyzing over 300 studies. Innovations in e-textiles are driven by neuromorphic computing and spiking neural networks, enhancing functionality for applications like health monitoring. Akhtar et al. discuss digital transformation in the textile and apparel industry, with a focus on Amazon's influence on digital fashion and consumer preferences. AI applications in demand forecasting and process innovation are crucial for optimizing production and sustainability. Wu and Li's study showcases the use of generative AI for creating knitted textile designs, highlighting its potential in fashion design. Additionally, an IoT-based monitoring platform enhances production efficiency through anomaly detection, while a South Korean university's AI-based clothing design curriculum improves student engagement. Overall, the landscape of AI applications in textiles demonstrates significant potential for enhancing creativity, efficiency, and sustainability in the industry.

III. AI-POWERED QUALITY CONTROL IN TEXTILES

AI-powered quality control in textiles has revolutionized how defects and inconsistencies in fabrics are detected and managed. Traditionally, quality control in textile manufacturing involved manual inspection, which was time-consuming and prone to human error. With AI-driven solutions, textile manufacturers can now use advanced computer vision, machine learning, and deep learning algorithms to automate and enhance the inspection process.

The article by Dr. Govind Bhargava discusses the transformative role of artificial intelligence (AI) in the textile industry, highlighting its potential to enhance efficiency, reduce costs, and improve quality across various manufacturing processes. It emphasizes the shift from labor-intensive tasks to automated systems that utilize AI technologies such as genetic algorithms, fuzzy logic, and neural networks for applications like fiber grading, fabric defect detection, and dye recipe forecasting. The text outlines the evolution of the textile sector towards Industry 4.0, where digital integration and data-driven decision-making optimize production and quality control. Moreover, it points out that AI can support the entire manufacturing cycle, from pre-production to post-production, while addressing challenges faced in developing countries. The potential growth in the smart textiles market is noted, underlining the need for the industry to adopt AI technologies to remain competitive and responsive to market demands. [9].

The article discusses the potential of artificial intelligence (AI) to enhance the Tunisian textile industry, which is vital for employment and economic growth. It highlights how AI can provide a competitive edge through improved automation, data analysis, and decision-making processes. The authors outline AI use cases, including automatic quality control, AI-powered design, forecasting, and smart marketing, demonstrating the current limitations within the industry such as manual processes and a lack of data utilization. Recommendations for stakeholders include fostering collaborations between textile companies and AI specialists, enhancing educational opportunities in AI for students, and establishing government initiatives to support AI adoption. The article aims to be accessible to a diverse audience while advocating for a transition towards an Industry 4.0 framework in Tunisia's textile sector. [10].

The thesis by Marina Russo explores the strategic evaluation of AI-powered solutions for optimizing archives in the fashion industry, highlighting the transition of fashion archives from mere repositories to valuable assets that inspire innovation. The research presents a methodology to integrate Visual AI functions—automated garment identification, description, and image generation—specifically applied to the Gianfranco Ferré Research Centre Archive, which houses over 30,000 digital photos.

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It reviews the current state of AI applications in fashion archives, discusses advancements in object detection, image captioning, and image generation, and outlines the theoretical foundations of these technologies. The proposed five-step methodology includes digitization, data analysis, design, enrichment, and final usage scenarios, aiming to enhance archive accessibility and functionality. The findings demonstrate the strengths and limitations of existing AI tools while emphasizing the need for tailored training to improve performance, ultimately envisioning a new interactive relationship with fashion archival structures to unlock their full potential. [11]. The article "Integration of Artificial Intelligence & Its Practices in Apparel Industry" by Dr. Bharati Rathore discusses the transformative role of AI in the fashion and apparel industry. AI technologies are increasingly used to automate production processes, enhance product design, predict customer demand, and improve supply chain efficiency. This integration leads to reduced labor costs, increased accuracy in manufacturing, and enhanced customer experiences through personalized recommendations and virtual fitting tools. The research highlights the potential of AI to revolutionize the industry by optimizing operations, ensuring quality, and providing insights into consumer preferences, ultimately leading to greater competitiveness and customer satisfaction. The article emphasizes that as AI continues to evolve, its application in the fashion sector is expected to grow, making it an invaluable tool for businesses aiming to adapt to rapidly changing consumer demands and market trends. [12].

This pilot study explores an AI-powered, contactless measurement system developed by The PS Collective to facilitate a decentralized production process for digital fashion designers. The technology allows designers to obtain reliable size measurements remotely by having customers submit two full-body images, which the AI processes to provide 24 measurements. This approach aims to streamline the design process, reduce waste, and promote sustainability by enabling small-batch designers across various geographic regions to create customized garments quickly. The pilot involved five designers who provided 3D digital designs tailored to customer sizes, with production and tailoring taking place in Accra, Ghana. Feedback from designers indicated a positive reception of the technology, with many expressing satisfaction with the fit and quality of the garments produced. The study emphasizes the potential for remote measuring technology to enhance sustainability in fashion while ensuring inclusivity and responsiveness to consumer demands. [13].

AI-powered quality control in textiles has transformed defect detection and management, moving away from manual inspections prone to errors. Dr. Govind Bhargava's article highlights AI's role in enhancing efficiency and quality in the textile industry, utilizing technologies like machine learning and neural networks for tasks such as fabric defect detection and dye forecasting, marking a shift towards Industry 4.0. It also discusses AI's potential in the Tunisian textile sector, advocating for collaborations and educational initiatives to boost AI adoption. Furthermore, Marina Russo's thesis emphasizes the application of AI in fashion archives to enhance their accessibility and innovation potential. Lastly, Dr. Bharati Rathore's research showcases AI's impact on production automation and customer personalization in the apparel industry. Overall, the integration of AI technologies is poised to increase competitiveness and sustainability in textiles and fashion.

IV. SMART TEXTILES AND WEARABLE TECHNOLOGY

Smart textiles and wearable technology represent one of the most exciting intersections of artificial intelligence (AI) and textile innovation. These technologies incorporate electronic components, sensors, and AI algorithms into fabrics, enabling the development of intelligent garments that can sense, react, and adapt to environmental and physiological conditions.

This article reviews the advancements in smart textiles for wearable technology, focusing on the fabrication processes of conductive fibers and their applications in soft sensors. Smart textiles are designed to monitor environmental interactions, operator safety, and physiological parameters, utilizing materials such as metal, polymeric, and carbon fibers to create resistive sensors. The paper discusses the electrical properties of these fabrics, emphasizing the significance of fiber composition and structure on resistance and sensor performance. It highlights the development of a piezoresistive sensor for a smart training shoe that monitors step rate, interfacing with a smart watch for data display. The challenges of integrating electronics with smart textiles and ensuring effective connections are also addressed, pointing to ongoing research in the field of wearable technology. [14]. The paper discusses the transformative impact of smart textiles and wearable technologies on sportswear, emphasizing their integration into everyday activities and their ability to create dynamic, interactive clothing. Conducted at the Politecnico di Milano's Sportswear Studio Lab, an educational workshop tasked students with designing advanced sportswear concepts that leverage smart textiles. The design process involved understanding the purpose, applicable technology, context, and wearability of their products. Notable student projects included a glowing sweatshirt for ice skaters, a tracking safety kit combining illuminated shoes and communication bracelets, and a lightning glove featuring a heart rate monitor.

The workshop highlighted the need for a multidisciplinary approach, combining fashion design with engineering to effectively utilize emerging technologies in creating innovative wearable systems. The positive student engagement underscored the potential of smart textiles in enhancing sportswear functionality and user experience. [15].

This review article discusses the advancements in wearable electronics and smart textiles, specifically focusing on electronic textiles (e-textiles) which integrate electronics into fabrics, allowing for flexibility and less visibility of components. E-textiles can adapt to various computational and sensing requirements, making them suitable for applications in health monitoring, safety, and smart clothing. The article categorizes smart textiles into three groups: passive (sensing only), active (reacting to stimuli), and very smart (able to adapt behavior). It highlights various fabric-based sensing technologies for monitoring physiological signals such as ECG, EMG, and temperature. The review also addresses the fabrication techniques, such as conductive fibers and coatings, conductive inks, and stretchable sensors, while emphasizing the challenges of integrating electronics into textiles, such as maintaining comfort and flexibility. Overall, the authors outline the potential of smart textiles to enhance daily life by seamlessly integrating technology into clothing, providing benefits across multiple fields including healthcare, military, and sports. [16]. The article "Overview of Wearable Electronics and Smart Textiles" by Mozhdeh Ghahremani Honarvar and Masoud Latifi discusses the evolution of textiles from traditional protective and aesthetic functions to incorporating intelligence through wearable electronics or smart textiles. It highlights the integration of electronic components within fabrics, allowing them to sense and respond to environmental changes, with applications in military, healthcare, sports, and consumer fitness. The paper reviews advancements in smart textiles, focusing on materials and manufacturing processes, including electrically conductive fibers and coatings, and emphasizes the importance of improving usability for future research. Various techniques for creating e-textiles, such as conductive inks and polymers, are explored, indicating a significant shift towards multifunctional, interactive textiles that combine technology with traditional fabric characteristics. [17].

The review article by A. Ivanoska-Dacikj and U. Stachewicz discusses the significant role of smart textiles and wearable technologies in combating pandemics, particularly in light of the COVID-19 crisis. It highlights how the pandemic has exposed vulnerabilities in healthcare systems and emphasized the importance of non-pharmaceutical measures, including the use of personal protective equipment (PPE) such as face masks made from advanced textile materials. The authors analyze the effectiveness of these materials, particularly cotton and polypropylene, in preventing virus transmission and suggest that smart textiles could enhance PPE by incorporating features such as breathability and antimicrobial properties. The article also explores the potential of integrating smart textiles in telemedicine, which enables remote patient monitoring and better healthcare delivery while minimizing direct contact. Furthermore, it addresses challenges faced in the production and usage of PPE and advocates for the development of innovative, comfortable, and effective protective gear for future pandemics. [18]. The white paper by Ohmatex, authored by Christian Dalsgaard and Rachael Sterrett, provides a comprehensive overview of the smart textile market, highlighting the growth and commercialization of wearable technologies. It emphasizes the increasing intersection of smart textiles with wearable tech, noting a significant market expansion projected to rise from USD 289.5 million in 2012 to over USD 1,500 million by 2020, particularly in military, sports, and healthcare applications. The paper discusses the emergence of smart textiles for personal protective equipment, physiological monitoring, and lighted garments, as well as the growing presence of conferences and networks supporting industry development. Key market drivers include the demand for advanced athletic performance tracking, the aging population's healthcare needs, and public funding for research and technological innovations in smart textiles. Overall, the document underscores the potential of smart textiles in various sectors while recognizing ongoing challenges in standardization and commercialization. [19].

The review discusses the integration of fiber optic technology into wearable smart textiles, highlighting their applications in communication, sensing, and healthcare. It introduces various functions of wearable fiber optics, including fashion, vital signal monitoring, and disease treatment, summarizing key working principles like side emission and wavelength modulation. The review also covers textile fabrication techniques such as weaving and knitting that embed optical fibers into fabrics, enhancing comfort, usability, and functionality. The flexibility and compatibility of polymer optical fibers (POFs) make them ideal for use in wearable devices, capable of monitoring physiological parameters and providing therapeutic benefits. Overall, the merging of optical fibers with textiles has garnered significant interest, with ongoing developments promising advancements in wearable technology for both aesthetic and medical purposes. [20].

The article by Chika et al. discusses the emergence and development of smart fabrics, which are textiles embedded with electronic components, making them flexible and adaptable for various applications. These smart textiles can sense and respond to environmental stimuli, thus enhancing wearability and functionality in contexts such as health monitoring, sports, and fashion.

The piece categorizes smart textiles into passive, active, and ultra-smart types, based on their capabilities. It highlights significant advancements in manufacturing techniques, such as incorporating conductive materials and developing flexible electronic circuits. The authors note the growing interest and investment in smart textiles across multiple sectors, emphasizing their potential to improve social welfare and create innovative solutions in everyday life. Future advancements depend on interdisciplinary collaboration among fields like material science, engineering, and design, aiming to address challenges related to durability and wearer comfort. [21].

The article “Smart Textiles and Nano-Technology: A General Overview” Smart textile are innovative fabrics designed to sense and respond to environmental stimuli, integrating technologies such as sensors, actuators, and controlling units. These textiles have various applications, including health monitoring through garments that track biometric data, enhancing athletic performance, and providing safety solutions in military and industrial settings. The development of smart textiles has evolved from traditional fabrics to advanced materials that can adapt to changing conditions, offering functionalities like temperature regulation, health monitoring, and aesthetic enhancements such as color changing and light-emitting properties. The integration of nanotechnology and new materials has further enhanced the capabilities of these textiles, making them applicable in various fields, including healthcare, sports, and fashion. With growing demand and ongoing research, the market for smart textiles is expected to expand significantly, driven by innovations and increasing applications across different industries. [22].

Smart textiles and wearable technology are at the forefront of integrating artificial intelligence with textile innovation, enabling the creation of intelligent garments that can sense and adapt to different conditions. Recent advancements focus on the development of conductive fibers for soft sensors that monitor environmental interactions and physiological parameters, while applications include smart training shoes and multifunctional sportswear designed by students. The integration of electronics into textiles, such as e-textiles, allows for various sensing technologies and categorizes smart textiles into passive, active, and very smart types. This evolution highlights the potential of smart textiles in healthcare, military, and sports, emphasizing the need for interdisciplinary collaboration to address challenges in usability and comfort. Additionally, the COVID-19 pandemic has underscored the importance of smart textiles in enhancing personal protective equipment and healthcare delivery. With significant market growth projected, ongoing research continues to drive innovations in this field, aiming to improve daily life through the seamless integration of technology in clothing.

V. AI IN TEXTILE DESIGN AND FASHION

Artificial Intelligence (AI) is transforming textile design and fashion by revolutionizing the way designers create, customize, and produce clothing and fabrics. From generating unique patterns to predicting fashion trends, AI is reshaping the industry, offering creative tools, improved sustainability, and personalized fashion experiences.

The article "Development of Customized Textile Design using AI Technology" discusses how artificial intelligence (AI) is transforming the fashion industry, particularly in textile design. It highlights the emergence of AI tools that enable consumers, especially from Generation Z, to create personalized textile patterns inspired by traditional Korean motifs, such as masks and auspicious symbols. The study details the development process, utilizing AI algorithms to streamline design creation and facilitate both virtual and physical garment production. By applying various color filters and automatic pattern generation techniques, the researchers generated numerous unique designs that maintain high fidelity to traditional aesthetics while appealing to modern consumer preferences. This innovative approach not only enhances individual creativity but also aims to democratize access to fashion design, making it more inclusive for those with limited technical skills. The article emphasizes the potential for AI-driven customization to meet the evolving demands of today's digital generation, paving the way for a new era in fashion. [23]. The article discusses the development of an AI-based automated fashion design system that reflects the work processes of human fashion designers. It highlights the growing integration of artificial intelligence in the fashion industry, emphasizing its potential to enhance efficiency by analyzing vast amounts of data and generating designs. The research aims to identify the similarities and differences between existing AI garment design tools and human designers’ processes, leading to the creation of a new system that incorporates fashion domain knowledge. This system, based on StyleGAN2, is designed to assist designers in generating and modifying garment designs while maintaining brand identity and seasonal concepts. The study concludes that while AI can support designers, it cannot fully replace human intuition, stressing the importance of integrating domain knowledge into AI systems for practical application in the industry. [24].

This paper examines the integration of artificial intelligence (AI) into daily life and its effects on human creativity, particularly in the fashion and textile design sectors.

AI, aimed at emulating human cognitive processes, raises concerns about sedentary lifestyles and the potential loss of reasoning skills due to reliance on machines. It categorizes AI into human-like and rational machines and discusses the growing use of smart textiles that can change based on environmental cues. While AI can enhance design efficiency and facilitate innovative ideas, it cannot replicate the depth of human creativity or moral reasoning. The article emphasizes the necessity for a collaborative approach where AI serves as a tool to augment human creativity, alongside addressing ethical implications like privacy and social manipulation. Ultimately, it asserts that maintaining a human-centered focus is essential for leveraging AI's potential while preserving the uniqueness of human expression in fashion. [25]. The 13th International Scientific-Professional Symposium on Textile Science and Economy, held in Zagreb, Croatia, on September 18, 2020, focused on the transformative role of Artificial Intelligence (AI) in the fashion industry. The symposium highlighted how AI influences various aspects of fashion, from design and production to sales and consumer behavior, emphasizing its importance in adapting to the fast-paced changes in consumer demands and trends. As the industry moves towards digitalization and the adoption of Industry 4.0 and 5.0 technologies, the application of AI raises critical questions regarding sustainability, cultural relevance, and the creative process in fashion design. While AI can enhance efficiency and predict trends through big data analysis, concerns persist about its ability to maintain the artistic and humanistic values intrinsic to fashion. The symposium underscored the necessity for a balanced approach to integrating AI while preserving the cultural and aesthetic quality of fashion. [26]. The report "fashion after fashion" from The Hong Kong Polytechnic University explores the role of artificial intelligence (AI) in the fashion industry, analyzing its potential as a disruptor. It categorizes AI applications in fashion into seven groups: Overview, Evaluation, Basic Tech, Selling, Styling, Design, and Buying, based on 521 research papers published over the past decade. The findings reveal a significant growth trend in AI research related to fashion, particularly in Selling and Design, with a projected increase in market spending on AI in fashion from USD 229 million in 2019 to USD 1,260 million by 2024. The report highlights the challenges and opportunities of integrating AI technologies, emphasizing the need for further research to bridge gaps between existing studies and industry needs, and showcases various AI applications that enhance customer experiences and operational efficiencies in fashion retail. [27].

The study by Jung and Suh explores the integration of soft skills training in sustainable fashion textile design education through the use of generative AI, demonstrating a multifaceted approach that combines empirical, quantitative, and qualitative methods. It identifies key soft skills essential for students to thrive in contemporary fashion design workplaces, such as digital competence, problem-solving, and communication, and proposes a curriculum guide incorporating AI technology. The findings reveal significant improvements in participants' soft skills as they engaged in Design Sprints, collaborating in teams to create textile designs through AI tools like Deep Dream Generator and Wow Pattern. The study emphasizes the necessity of balancing traditional and digital design education while preparing students for the evolving demands of the fashion industry, underlining the role of AI as a valuable resource for enhancing creative output and soft skill development in a sustainable context. [28].

Artificial Intelligence (AI) is significantly transforming the textile design and fashion industry by enhancing creativity, customization, and production efficiency. It enables consumers, particularly from Generation Z, to create personalized designs inspired by traditional motifs, as discussed in the article "Development of Customized Textile Design using AI Technology." AI tools streamline the design process and help generate unique patterns while maintaining traditional aesthetics. Additionally, AI can assist designers by analyzing data and generating designs, though it cannot replace human creativity entirely. The integration of AI also raises ethical concerns and emphasizes the importance of collaboration between AI and human designers to preserve the artistic values of fashion. Recent reports indicate a growing trend in AI research within fashion, highlighting challenges and opportunities for enhancing customer experiences and operational efficiencies, as well as the need for education that balances traditional skills with AI technology.

VI. SUSTAINABLE FASHION AND MATERIAL INNOVATION

AI contributes to sustainability in fashion by optimizing material use and reducing waste. AI algorithms can help designers select eco-friendly materials and suggest fabric combinations that minimize environmental impact.

The article "Future of Textile: Sustainable Manufacturing & Prediction via ChatGPT" by Dr. Bharati Rathore discusses the integration of ChatGPT technology in the textile industry to enhance sustainable manufacturing practices. It highlights how ChatGPT can optimize production processes, automate customer support, and provide personalized recommendations to enhance the shopping experience, thereby improving efficiency and reducing costs without compromising quality. The research emphasizes the historical context of sustainability in textiles, tracing its evolution from traditional methods to modern practices focused on environmental protection and social equity.

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ChatGPT is presented as a tool for minimizing waste, tracking sustainability goals, and identifying areas for improvement in resource utilization, energy efficiency, and overall operational performance. The article ultimately advocates for the adoption of advanced AI technologies like ChatGPT to drive sustainable growth in the textile sector, ensuring a balance between economic success and environmental responsibility. [29]. This article explores the significance of data analytics in fostering sustainable practices within the fashion industry amidst escalating environmental concerns and a growing consumer demand for eco-friendly products. It identifies key challenges such as data inconsistency, lack of standardization, and technological limitations that hinder sustainability efforts. The authors highlight the potential of innovative technologies, including blockchain, artificial intelligence, big data analytics, and the Internet of Things, to optimize production processes and enhance material sourcing. Additionally, the piece emphasizes the importance of collaboration among stakeholders to leverage these advancements for a more sustainable fashion future. Sustainable fashion is framed not only as an environmental imperative but also as a strategic business decision, with consumers increasingly favoring ethically produced and environmentally responsible products. The text advocates for comprehensive data-driven approaches to predict trends in eco-friendly textiles and improve overall industry practices, ultimately calling for a collective effort to drive meaningful change in the sector. [30].

The article by Bharati Rathore examines the intersection of fashion sustainability and artificial intelligence (AI), highlighting both the opportunities and challenges that arise in marketing sustainable fashion. It discusses how AI can drive innovations in the fashion industry by enhancing marketing strategies, improving supply chain management, and personalizing consumer experiences. With growing awareness of the environmental and social impacts of fast fashion, there is a pressing need for brands to adopt sustainable practices. The study reviews current literature and case studies to illustrate how AI can facilitate this shift while also addressing ethical, technical, and operational challenges involved in integrating AI within the sustainable fashion framework. Ultimately, the paper provides valuable insights for industry stakeholders to help navigate the complexities of sustainable marketing in the AI era. [31]. The paper presents an innovative autonomous AI-enabled industrial sorting pipeline aimed at improving textile recycling processes in response to the increasing global textile waste crisis. Traditional manual sorting methods are inefficient and error-prone, highlighting the need for automation. The proposed system leverages robotics, spectral imaging, and AI-driven classification to enhance sorting accuracy, efficiency, and scalability. A Digital Twin system is integrated to evaluate the technical and economic feasibility of the sorting process, providing insights into accuracy and reliability. The framework is designed around Industry 4.0 principles, consisting of five interconnected layers for seamless data exchange. Preliminary results indicate the system's potential to significantly reduce environmental impact and promote sustainable practices in the textile industry. [32].

The article "Consumer in Sustainable Textiles: A Scientometric Review" The study by Can Cui and Nazlina Shaari, published in the Textile & Leather Review, examines the relationship between consumers and sustainable textiles through a scientometric analysis of literature from 2014 to 2023. It identifies 1,010 relevant articles, highlighting key areas of research, including consumer behavior, sustainability, and product design within the textile industry. The analysis reveals that while brands are adopting sustainable practices, effective communication of these efforts to consumers remains a challenge. The study emphasizes the importance of understanding consumer psychology in driving sustainable behaviors and recommends interdisciplinary approaches and the integration of advanced technologies like big data and AI to enhance sustainable practices in textiles. Furthermore, it provides insights into research trends and international collaborations in the field, aiming to guide future studies and industry efforts towards achieving sustainability in textiles. [33].

The article "Green Innovations: Artificial Intelligence and Sustainable Materials in Production" The study by Shahrukh Khan Lodhi and colleagues investigates the transformative potential of combining artificial intelligence (AI) with sustainable materials in manufacturing, showcasing case studies from companies like Adidas, Tesla, Unilever, and IKEA. It highlights how AI can enhance the creation of recyclable products, improve material efficiency, and streamline supply chains, thereby reducing the environmental impact of production. The research emphasizes the necessity for robust regulatory frameworks to ensure the ethical and equitable use of AI in this context, addressing challenges such as data privacy and workforce implications. The authors argue that AI can drive sustainable manufacturing by facilitating resource optimization, predictive maintenance, and the innovation of eco-friendly materials, ultimately promoting a circular economy. They conclude that while the integration of AI and sustainable materials offers significant opportunities for a more sustainable manufacturing future, careful management of associated risks and ethical considerations is essential for achieving desired outcomes. [34]. The article "Towards Sustainable Textile and Apparel Industry: Exploring the Role of Business Intelligence Systems in the Era of Industry 4.0" discusses the integration of advanced technologies in the textile and apparel (T&A) industry to enhance sustainability and competitiveness amid the challenges of Industry 4.0.

The study emphasizes the importance of Business Intelligence Systems (BIS) in addressing sustainability issues, as previous research has primarily focused on big data without considering BIS's role. Utilizing a qualitative approach, the authors conducted interviews with executives from high-end T&A companies, revealing themes including sustainability challenges, the enhancement of value creation processes through leading BI solutions, and obstacles in adopting BIS. The findings indicate that the adoption of BIS is critical for improving efficiency, decision-making, and sustainability within T&A companies as they navigate the complexities of a rapidly changing market, thereby underscoring the need for further empirical research on this topic. [35]. The article "AI and the Future of Ethical Fashion Marketing" by Bharati Rathore analyzes how artificial intelligence (AI) is transforming the ethical fashion marketing landscape by integrating sustainable practices and enhancing consumer engagement. It highlights the shift from fast fashion to more sustainable and ethical approaches, driven by increasing consumer awareness of environmental and social issues. AI's role is explored through its applications in optimizing supply chains, personalizing marketing strategies, and improving transparency in production processes. The paper further discusses the challenges and opportunities presented by AI, emphasizing the importance of consumer engagement in promoting ethical fashion choices. By showcasing real-world case studies, the article underscores AI's potential to revolutionize the fashion industry toward a more sustainable future, advocating for innovative marketing strategies that resonate with eco-conscious consumers. [36].

Artificial Intelligence (AI) plays a crucial role in promoting sustainability in the fashion industry by optimizing material use and reducing waste. Various articles discuss how technologies like ChatGPT can enhance sustainable manufacturing by improving production processes, automating customer support, and offering personalized shopping experiences. Key challenges such as data inconsistency and technological limitations are highlighted, alongside the potential of innovative technologies like blockchain and big data analytics to foster sustainable practices. Research underscores the importance of collaboration among stakeholders and emphasizes that sustainable fashion is both an environmental necessity and a strategic business choice. Furthermore, studies showcase the transformative potential of AI in enhancing supply chains, personalizing marketing strategies, and improving transparency, while also addressing ethical considerations in its application. Overall, the integration of AI and sustainable materials is positioned as essential for driving meaningful change and promoting a circular economy in the fashion sector.

VII. VIRTUAL FASHION SHOWS AND DIGITAL AVATARS

AI enables virtual fashion shows where designers can present their collections in immersive, digital environments without the need for physical runways. These virtual shows offer greater accessibility and reach for global audiences.

1. The study presented at the International Conference on Business Studies and Education explores the evolution of fashion shows in the digital realm, particularly in the context of Malaysia post-COVID-19. It highlights how the pandemic accelerated the adoption of technology in the fashion industry, leading to the emergence of virtual runways that utilize advancements such as AI, VR, and AR to enhance accessibility and engagement. Through qualitative interviews with eight Malaysian fashion designers, the research identifies three key elements of virtual fashion shows: virtual clothing production, virtual runway presentations, and the design of virtual models. Findings indicate that digital fashion allows designers to create collections without geographical constraints, promoting sustainability by reducing the need for physical production. The study underscores the importance for designers to stay updated with technological trends to remain competitive, suggesting that virtual fashion shows will play a crucial role in the future of the industry. [37]. Digital Convergence in IT and Fashion: An Overview The fashion industry is evolving into a knowledge-driven sector, emphasizing design innovation, brand marketing, and advanced technology, leading to the concept of "i-Fashion." This initiative integrates digital services and mass customization, enabling a personalized shopping experience through 3D body measurement technologies. i-Fashion aims to transform traditional mass production into consumer-centered customization, allowing users to create virtual avatars for fitting garments in digital environments. Successful commercialization of i-Fashion technologies has been demonstrated through partnerships with various clothing companies, including the development of digital stores and customized apparel solutions. Looking ahead, these technologies are expected to extend beyond fashion into fields like medicine, furniture, and education, positioning i-Fashion as a key player in merging IT with the fashion industry to enhance consumer experience and create new value. [38].

The article by Dr. Mona M. Nasr's research, published in the International Design Journal, examines how virtual fashion shows can influence women's clothing choices based on their body shapes. It highlights the common frustration women face when purchasing outfits that do not suit their silhouettes, often leading to returns. The study aims to help women aged 25 to 45 identify their body types and make informed fashion choices by showcasing appropriate and inappropriate styles through virtual fashion shows.

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By addressing whether women understand their body types and if virtual shows can assist in selecting flattering outfits, the research concludes that such shows can effectively guide women in finding suitable clothing that enhances their features while minimizing flaws, ultimately promoting a more positive shopping experience. [39]. The study investigates gender characteristics in contemporary virtual fashion design, particularly focusing on avatars and genderless fashion trends among leading brands such as Auroboros, Republiqe, Placebo Digital Fashion House, RTFKT, and Tribute. Utilizing content analysis within a theoretical framework of gender research, the findings indicate a preference for female-type avatars (52%) and an embrace of androgynous aesthetics that challenge traditional gender norms. The study highlights the importance of compromise, sensuality, and playfulness in genderless fashion, with brands integrating elements from both masculine and feminine design, emphasizing inclusivity and experimentation. This shift reflects a broader societal re-examination of gender identity, as virtual fashion allows for creative self-expression and the blurring of conventional gender boundaries, ultimately aiming to foster a more inclusive representation within the fashion industry. [40].

The article "Evolution of Fashion as Play in the Digital Space" by Juha Park and Jaehoon Chun explores how fashion transcends its traditional roles of decoration and protection to become a form of play within digital media. It identifies four characteristics of play—free activity, departure from space-time, pretending, and order—and analyzes their application in the context of fashion marketing and social media culture. The authors argue that digital fashion facilitates self-expression and enhances emotional connections through playful interactions, such as creating avatars, engaging with fashion memes, and participating in brand platforms. The study emphasizes that fashion, when integrated with digital media, serves as a dynamic playground that satisfies higher-order human needs for creativity and social interaction, ultimately reshaping consumer engagement in the contemporary fashion landscape. [41]. The study published in the International Journal of Internet, Broadcasting and Communication explores the impact of perceived value of virtual fashion in the Metaverse on users' purchase intentions, emphasizing the role of the sense of presence. Conducted with 300 respondents in Korea, the research highlights that a strong sense of presence enhances the emotional, visual authority, and economic value of avatar fashion products, which in turn positively influences users' intentions to purchase. The findings reveal that enjoyment and perceived values significantly mediate the relationship between the sense of presence and purchase intention. This research contributes to the emerging field of virtual fashion marketing by providing insights into consumer behavior in the Metaverse and suggesting implications for marketers aiming to leverage this digital landscape for fashion sales. [42].

The 1st International Conference on Creative Design, Business and Society (ICCDBS) 2023 discusses the transformative impact of digital fashion facilitated by artificial intelligence (AI) and 3D prototyping technologies. Luri Renaningtyas highlights how these advancements revolutionize traditional design processes and enhance consumer experiences by merging physical and digital realms—termed "phygital." The article examines the concept of realness within fashion, analyzing how AI influences representation, trend prediction, and virtual try-ons (VTO) through immersive shopping experiences. The integration of AI allows designers to create and simulate garments digitally, thereby streamlining production and broadening consumer interaction with fashion products. This digital evolution not only redefines design practices but also shapes future trends, emphasizing the growing relevance of AI in the fashion industry and its potential for fostering innovative and inclusive approaches to design and consumption. [43].

The integration of AI in the fashion industry has led to the rise of virtual fashion shows, which allow designers to showcase their collections in immersive digital environments, greatly increasing accessibility for a global audience. Research presented at the International Conference on Business Studies and Education highlights how the pandemic accelerated the shift towards digital platforms in Malaysia, emphasizing the importance of virtual clothing production, runway presentations, and modeling. The concept of "i-Fashion" is emerging, focusing on personalized shopping experiences through digital avatars and 3D body measurements, which can also extend into other fields. Additionally, studies reveal how virtual fashion can assist women in making informed clothing choices based on their body shapes, while the exploration of gender characteristics in fashion design shows a trend toward genderless aesthetics. Digital fashion is also seen as a form of play, enhancing consumer engagement through self-expression and emotional connections. Furthermore, research indicates that a strong sense of presence in virtual environments positively influences purchase intentions, showcasing the potential of AI and technology to revolutionize traditional fashion practices and consumer experiences.

VIII. AI IN FASHION RETAIL

AI helps fashion retailers optimize stock levels by predicting which items will sell more based on current trends, historical sales data, and seasonality.

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The article "A Review of AI Tools and Customer Experience in Online Fashion Retail" examines the transformative impact of artificial intelligence (AI) on e-commerce, particularly in enhancing customer satisfaction and online shopping experiences. It highlights how AI technologies such as machine learning, chatbots, augmented reality, and recommendation engines are being integrated into online retail to provide personalized experiences that foster brand trust and customer loyalty. The paper conducts a literature review of existing research on AI's influence on customer satisfaction, referred to as e-satisfaction, and identifies gaps for future research. The findings suggest that effective use of AI can lead to improved customer engagement, reduced return rates, and increased revenue for e-retailers, emphasizing the necessity for businesses to continuously adapt to technological advancements to remain competitive in the evolving digital landscape. [44]. The article "Artificial Intelligence in Business-to-Customer Fashion Retail: A Literature Review" by Aitor Goti et al. examines the significant role of artificial intelligence (AI) in the fashion e-commerce sector through a systematic review of 219 publications sourced from Web of Science and Scopus. The study categorizes AI applications into computer vision (CV), natural language processing (NLP), and other machine learning (ML) techniques, highlighting their uses such as product retrieval, virtual fitting systems, and customer sentiment analysis. It also discusses how AI enhances profitability and customer satisfaction in the fashion industry and identifies research gaps for future exploration. The findings suggest four key areas for upcoming research: smart city-oriented e-commerce, omnichannel shopping experiences, social network information for marketing, and the matching of fashion products. Overall, the study underscores the evolving landscape of AI in fashion retail and its potential for further advancements. [45]. The article "Implementation of Artificial Intelligence in Fashion: Are Consumers Ready?" by Yuli Liang, Seung-Hee Lee, and Jane E. Workman explores consumer attitudes and purchase intentions towards the AI device Echo Look in the fashion industry. The study, based on a technology acceptance model and involving 313 participants aged 18 to 65, found that perceived usefulness, ease of use, and performance risk significantly influenced consumer attitudes towards AI, which in turn affected their purchase intentions. The results indicate that positive attitudes towards technology lead to higher likelihoods of purchasing AI products, highlighting the need for retailers to understand consumer responses as fashion and digital innovations converge. The findings also suggest implications for both theoretical models and practical applications in the fashion industry, emphasizing the importance of addressing consumer concerns regarding performance risk and enhancing user experience to foster acceptance of AI technologies. [46].

The article discusses the transformative impact of artificial intelligence (AI) on the retail value chain, highlighting how traditional retailers face challenges from new entrants that deliver greater customer value more efficiently. It emphasizes the need for retailers to innovate their value chains by adopting advanced technologies like AI to remain competitive. The authors propose a conceptual framework outlining four key roles for AI in retail: knowledge and insight management, inventory management, operations optimization, and customer engagement. By mapping AI technologies to the retail value chain stages, the article provides managers guidance on prioritizing investments in AI technologies, advocating for a shift from traditional linear processes to a more interconnected, agile approach. The findings aim to assist retailers in leveraging AI effectively to enhance their operations and customer relationships in a rapidly evolving market. [47]. The article discusses the development of an explainable AI-based tool for forecasting new product sales in fashion retail, aiming to enhance decision-making processes among varied stakeholders such as designers, buyers, and financial planners. It highlights the challenges faced by fashion houses, particularly the issue of unsold inventory due to mismatches in supply and demand, especially for new products lacking historical sales data. The proposed tool incorporates explain ability to ensure trust and transparency in AI predictions, allowing stakeholders to understand the factors influencing sales forecasts and make collaborative decisions. By enabling pre-season interventions through what-if analysis and counterfactual explanations, the tool aims to improve product design and development, ultimately contributing to reducing unsold inventory and fostering sustainable fashion practices. The research emphasizes the importance of integrating various data sources and user feedback to enhance adoption and effectiveness within the industry. [48].

Artificial intelligence (AI) is transforming the fashion retail sector by optimizing stock levels and enhancing customer experiences through various technologies. Research highlights the integration of AI tools like machine learning, chatbots, and augmented reality to personalize online shopping, improve customer satisfaction, and foster loyalty. Studies have categorized AI applications into computer vision, natural language processing, and machine learning techniques, emphasizing their roles in product retrieval and customer sentiment analysis. Consumer attitudes towards AI technologies, such as the Echo Look device, are influenced by perceived usefulness and ease of use, indicating that positive consumer perceptions can drive purchasing intentions. The retail value chain is also being disrupted by AI, as traditional retailers must innovate to remain competitive against agile, born-digital brands and new collaborative consumption models.

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Overall, AI's impact on the fashion industry is significant, with a focus on improving decision-making, reducing unsold inventory, and promoting sustainable practices while addressing the evolving demands of consumers.

IX. PREDICTIVE ANALYTICS IN TEXTILE SUPPLY CHAIN

Predictive analytics has emerged as a powerful tool in optimizing the textile supply chain, enabling companies to make data-driven decisions, anticipate market demands, and enhance overall efficiency. In an industry as dynamic and globally distributed as textiles, predictive analytics helps manufacturers, suppliers, and retailers streamline operations, reduce costs, and improve responsiveness.

The article by Hazen et al. discusses the importance of Big Data and Predictive Analytics (BDPA) in enhancing supply chain sustainability, emphasizing the need for research that goes beyond traditional financial performance metrics to include environmental and social sustainability outcomes. While BDPA has become critical for operational efficiency and competitive advantage in supply chain management, its potential impact on the triple bottom line—financial, social, and environmental—is underexplored. The authors propose a research agenda based on established theories to guide scholars in investigating how BDPA can influence sustainability in supply chains. They review eight relevant theories and suggest research questions to encourage future studies that link BDPA initiatives with improved sustainability practices in organizations. The paper aims to inform both academic and practitioner communities about the intersections of BDPA and sustainable supply chain management, advocating for a comprehensive understanding of these critical strategic areas. [49]. The study by Rezaei et al. (2022) explores how data analytics capability (DAC) influences competitive advantage (CA) in the textile industry, specifically focusing on the mediating roles of supply chain resilience (SCR) and organizational flexibility (OF). The researchers developed a conceptual model and utilized partial least squares–structural equation modeling (PLS-SEM) to analyze data collected from 450 respondents across four well-known sleep product brands. Findings indicate that DAC positively affects both CA and the mediating variables, SCR and OF, which, in turn, enhance CA. The study highlights the importance of integrating data analytics with organizational characteristics to achieve sustainable competitive performance, providing insights valuable for top managers within the textile sector. [50].

Predictive analytics is revolutionizing the textile supply chain by allowing companies to leverage data for better decision-making, anticipating market demands, and improving efficiency. The article by Hazen et al. emphasizes the significance of Big Data and Predictive Analytics (BDPA) in not only enhancing operational efficiency but also in addressing sustainability by integrating environmental and social metrics into supply chain assessments. Despite BDPA's crucial role in achieving competitive advantage, its impact on the triple bottom line remains largely unexplored, prompting the authors to propose a research agenda for future studies. Additionally, Rezaei et al. (2022) examine how data analytics capability (DAC) contributes to competitive advantage in the textile industry, highlighting the mediating effects of supply chain resilience and organizational flexibility. Their research underscores the need to align data analytics with organizational traits for sustainable competitive performance, offering valuable insights for leaders in the textile sector.

X. CHALLENGES AND LIMITATIONS OF AI IN THE TEXTILE INDUSTRY

While AI presents vast opportunities for enhancing retail and consumer insights, its success hinges on the quality of data and the ethical use of customer information. Textile retailers must also ensure that AI tools do not alienate customers by over-personalizing the shopping experience or making it too reliant on automation.

The article "A review of artificial intelligence applications in the apparel industry" by Abid Noor and colleagues highlights the increasing need for efficiency in the apparel sector due to global competition and fluctuating demand. It discusses the limited research on artificial intelligence (AI) applications within this industry, identifying challenges in implementing AI technologies across various processes, including apparel design, manufacturing, retailing, and supply chain management. The authors review existing literature on AI techniques such as neural networks, genetic algorithms, and fuzzy logic used to address decision-making problems, improve production planning, enhance design processes, and forecast sales. They conclude that while AI has the potential to significantly benefit the apparel industry by reducing costs and improving quality, further research is necessary to overcome implementation challenges and fully leverage AI capabilities for optimal solutions. [51].

The research article "Implementation of Digitalized Technologies for Fashion Industry 4.0: Opportunities and Challenges" discusses the integration of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, augmented reality (AR), and virtual reality (VR) in the fashion industry, which is a significant contributor to the global economy and environmental issues. The study highlights that the fashion industry must embrace sustainability by adopting these technologies to enhance smart clothing, optimize supply chains, promote a circular economy, and improve consumer experiences.

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It identifies the industry's environmental challenges, including high carbon emissions and waste generation, and emphasizes the need for resilient infrastructure and innovation to achieve the United Nations' Sustainable Development Goals by 2030. The article also provides recommendations for overcoming limitations in technology adoption, such as wider blockchain implementation, advancements in energy storage for smart clothing, and enhanced training for technology use in retail. [52]. This study examines the integration of artificial intelligence (AI) in the ready-made garment (RMG) sector of Bangladesh, highlighting both its potential benefits and challenges. Conducted with twenty designers in Gazipur, the research indicates that AI enhances efficiency, reduces costs, improves productivity, and allows for customization while also predicting trends and promoting sustainability. However, significant concerns arise regarding job displacement, quality control, data privacy, overdependence on technology, and ethical issues. The authors advocate for a balanced approach to AI adoption, emphasizing the importance of human creativity, skill development, and ethical guidelines to ensure the sustainable growth of Bangladesh's garment industry while leveraging AI's capabilities. [53].

The textile industry faces several challenges and limitations in the implementation of artificial intelligence (AI), despite its potential benefits for enhancing efficiency and sustainability. Key concerns include the quality of data, ethical use of customer information, and the risk of alienating customers through excessive personalization. Research indicates a limited understanding of AI applications in apparel design, manufacturing, and supply chain management, necessitating further exploration. Studies highlight the need for the fashion sector to adopt digital technologies like IoT and blockchain to address environmental challenges and improve consumer experiences. Additionally, specific recommendations for the Tunisian textile industry emphasize collaboration among stakeholders to harness AI effectively. In Bangladesh's ready-made garment sector, while AI can boost productivity and customization, it raises issues of job displacement and data privacy, underscoring the need for a balanced approach that values human creativity alongside technological advancements.

XI. FUTURE DIRECTIONS AND INNOVATIONS IN AI-DRIVEN TEXTILES

While AI presents vast opportunities for enhancing retail and consumer insights, its success hinges on the quality of data and the ethical use of customer information. Textile retailers must also ensure that AI tools do not alienate customers by over-personalizing the shopping experience or making it too reliant on automation

The systematic review titled "A Systematic Review of AI-Driven Prediction of Fabric Properties and Handfeel" by Yi-fan Tu, Mei-ying Kwan, and Kit-lun Yick explores the transformative role of artificial intelligence (AI) in enhancing the prediction of fabric properties and handfeel, which are vital for textile quality assessment. Despite advancements in AI techniques, such as machine learning and deep learning, challenges persist in applying these predictions to real-world textile production. The review analyzed 26 out of 811 initially identified papers, focusing on model mechanisms, dataset diversity, and prediction accuracy. It highlights critical gaps in existing research, emphasizing the need for more robust models, better integration of sustainability, and refinement of feature extraction methods. The findings aim to guide future innovations in textile technology. [54]. The article by Yoon Kyung Lee discusses the future of supply chains in the fashion industry, emphasizing the integration of real-time fashion systems (RTFS) that leverage advanced technologies such as artificial intelligence (AI) and 3D design. It introduces a framework for a sustainable and innovative supply chain that enhances consumer engagement through personalized services, allowing customers to co-design products and participate in the manufacturing process. The study highlights the shift towards a consumer-centric model, where technology facilitates customized experiences, thus changing traditional fashion dynamics. Key characteristics of RTFS include real-time operations, direct-to-consumer delivery, and supply chain transparency, which are essential for fostering sustainability and efficiency in the industry. Overall, the article outlines how these technological advancements can lead to a more responsive and responsible fashion supply chain, ultimately benefiting both consumers and companies. [55].

The article "Beyond Trends: Shaping the Future of Fashion Marketing with AI, Sustainability, and Machine Learning" by Bharati Rathore discusses the growing importance of sustainable practices in fashion marketing, driven by environmental concerns and changing consumer demands. It highlights various initiatives such as circular fashion and eco-friendly materials while examining how AI and machine learning can enhance these sustainable practices. The paper emphasizes the role of AI in personalizing consumer experiences and optimizing marketing strategies, as well as the significance of ethical practices in building brand trust. Through a literature review and case studies, the research underscores the potential for integrating these technologies to create a more innovative and responsible fashion industry, while also addressing challenges related to privacy, inequality, and job displacement. [56].

The article "Transformation of the Innovative and Sustainable Supply Chain with Upcoming Real-Time Fashion Systems" by Yoon Kyung Lee discusses how emerging technologies, particularly in real-time fashion systems (RTFS), are reshaping the supply chain in the fashion industry. The study highlights the role of information communication technology (ICT), artificial intelligence (AI), and 3D design in creating a personalized and efficient production process that engages consumers in product customization and co-design. The research emphasizes a shift towards a sustainable supply chain model that relies on real-time data, transparency, and direct consumer interaction, ultimately enhancing product innovation and performance. The findings suggest that as consumers increasingly become "prosumers," actively participating in design and customization, the fashion industry must adapt to meet their evolving needs, leveraging AI and 3D technologies for a more dynamic and responsive market. [57]. The article "Artificial Intelligence-Driven 3D Printing in Pharma: Innovations and Future Directions" explores the transformative impact of 3D printing technology in the pharmaceutical industry, emphasizing its potential for personalized medicine and advanced drug delivery systems. It discusses various 3D printing techniques, such as Powder Bed Fusion, Fused Deposition Modeling, and bioprinting, which enable the production of customized dosage forms tailored to individual patient needs. The integration of artificial intelligence enhances these processes by optimizing manufacturing efficiency, improving drug formulation, and speeding up drug discovery. The review highlights the advantages of 3D printing, including reduced production costs, improved medication adherence, and the ability to create complex drug release profiles. However, challenges such as regulatory compliance, material selection, and potential job displacement in traditional manufacturing are also noted. The article concludes by expressing optimism for future advancements in 3D printing technology and its application in personalized healthcare. [58]. The research paper titled "Artificial Intelligence and Machine Learning Applications in Smart Production: Progress, Trends, and Directions" analyzes the integration of artificial intelligence (AI) and machine learning (ML) in the manufacturing industry, particularly in the context of sustainability and the advancements brought by Industry 4.0. It systematically reviews literature from 1999 to 2019, highlighting key trends, influential publications, and the growing importance of these technologies in optimizing processes, improving resource management, and enhancing product quality. The study employs bibliometric and social network analysis to classify and evaluate 82 relevant articles, revealing significant contributions from the USA and China, as well as identifying collaborative research patterns across various scientific disciplines. The findings underscore the transformative potential of AI and ML in driving sustainable manufacturing practices and suggest future research avenues to further explore their applications across different sectors. [59].

The integration of artificial intelligence (AI) in textiles presents significant opportunities for enhancing retail insights and fabric quality prediction. A systematic review highlights the need for improved AI models and sustainable practices in textile production while emphasizing the importance of ethical data use to avoid alienating customers. Research on real-time fashion systems (RTFS) suggests a shift toward consumer-centric supply chains that enhance engagement through personalization and co-design. Additionally, sustainable practices driven by AI and machine learning are reshaping fashion marketing and manufacturing processes, promoting transparency and efficiency. Overall, these innovations aim to create a more responsive and responsible fashion industry, benefiting both consumers and companies while addressing challenges related to privacy and job displacement.

XII. CONCLUSION

The integration of Artificial Intelligence (AI) in the textile industry is rapidly transforming every aspect of the sector, from manufacturing to retail. AI technologies, including machine learning, computer vision, and predictive analytics, are enhancing efficiency, precision, and sustainability throughout the textile supply chain. By automating complex tasks, improving quality control, and optimizing resource usage, AI is helping manufacturers reduce waste and increase productivity. Additionally, AI's role in the development of smart textiles and wearable technologies is paving the way for innovative applications that can adapt to environmental and physiological conditions.

AI's potential to revolutionize the textile industry is significant, particularly in addressing challenges related to sustainability, consumer demand forecasting, and product customization. However, the implementation of AI comes with its own set of challenges, including data management, the integration of traditional processes, and the need for ethical frameworks to guide AI's application in sensitive areas like personal data usage and labor displacement.

As the industry continues to evolve, the adoption of AI will play a crucial role in driving innovation, promoting sustainable practices, and meeting the changing demands of consumers. Continued research, collaboration, and investment in AI technologies will be essential for unlocking new opportunities and ensuring that the textile industry remains competitive in an increasingly digital and eco-conscious world.

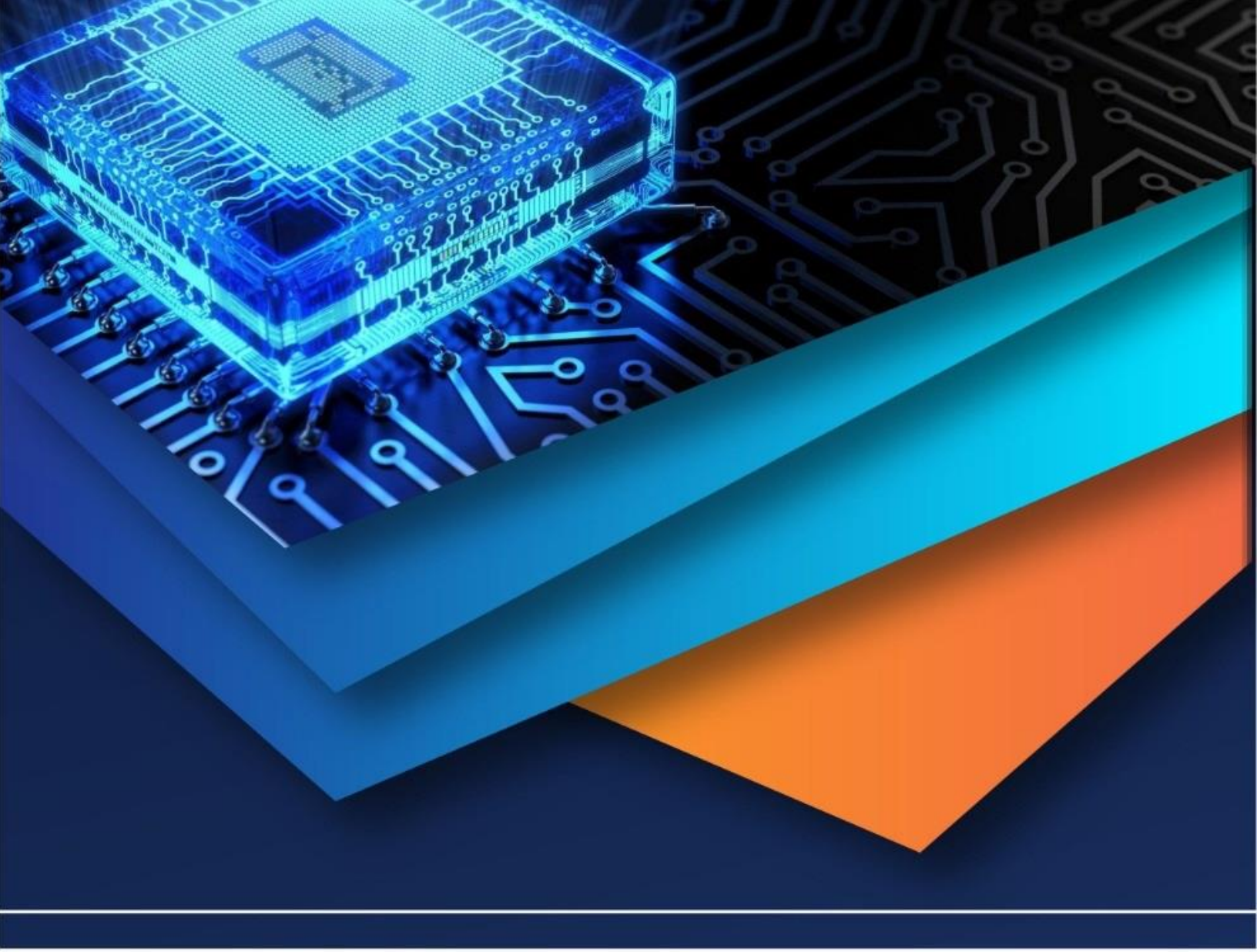
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