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AI in the Apparel and Textile Industry

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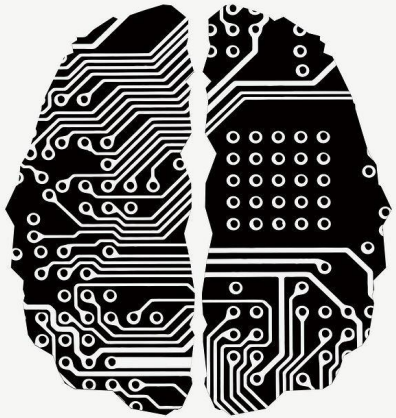
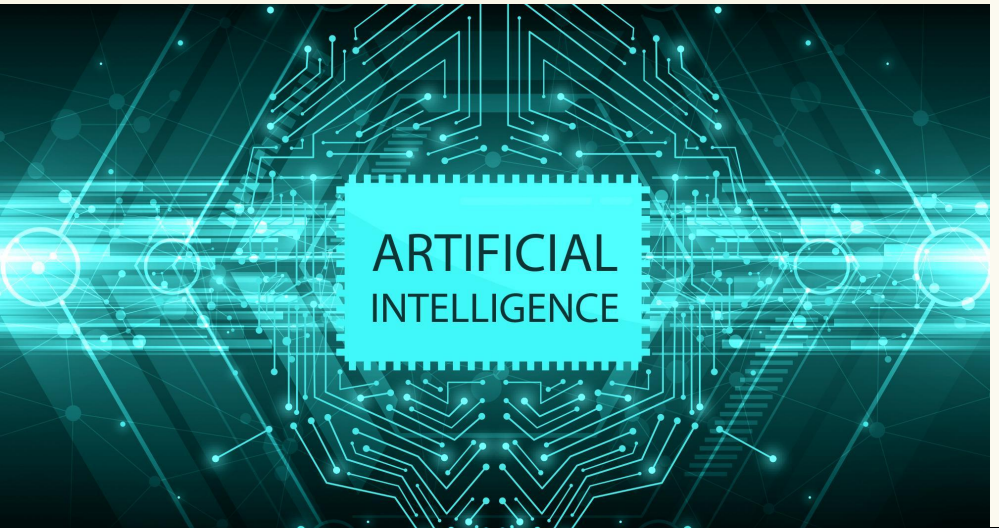




AI in the Apparel and Textiles Industry

Article 1/4: Artificial Intelligence and Explainable Artificial Intelligence for Visual Quality Assurance in Manufacturing

Article 2: A Ubiquitous Service-Oriented Automatic Optical Inspection Platform for Textile Industry

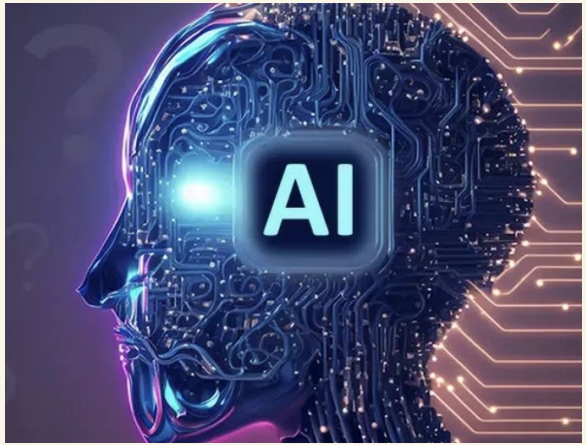
Article 3: The power of 4th industrial revolution in the fashion industry

Article 5: A greener world through Collaborative Consumption of Apparel: An Exploratory Study of consumers' perception and preferences

Artificial Intelligence and Explainable Artificial Intelligence for Visual Quality Assurance in Manufacturing

Explainable AI Versus AI

- XAI addresses the "black box" nature of traditional AI by promoting transparency and interpretability.
- Enhances understanding of the relationship between input variables and quality outcomes, aiding in identifying root causes of quality
- AI is developed to simulate human intelligence, focusing on problem-solving, pattern recognition, and decision-making issues.



Visual Quality Assurance

- **Quality Assurance (QA)**: A systematic approach ensuring products, services, or processes meet or exceed quality standards, focusing on all stages of development.
- **Quality Control (QC)**: A subset of QA, focusing on inspecting and testing finished products to meet quality standards.
- **Visual Quality Assurance (VQA)**: A specialized subset of QA focusing on the visual aspects of products and services. It ensures visual consistency and quality throughout all development

Which Industry sectors are using AI approaches to provide VQA manufacturing?

This figure highlights clusters of selected studies across various industry sectors and their corresponding AI and XAI approaches. The "Component Inspection" sector emerges as the leader, with the highest number of studies, followed closely by "Electronics" in second place, and "Additive Manufacturing" in third. These sectors are particularly AI-driven due to the high volume of products they generate, making automation critical. By integrating AI, especially in quality control and early defect detection, these industries can significantly reduce costs, optimize resources, and enhance production efficiency. This explains why they lead in AI adoption compared to others.

Table 4. *Cont.*

Study	Industry Sector	VQA Practices	AI/XAI-Approaches	AI Method	XAI Method
[41]	AM	PO	Seg., Est.	CNN	
[70,71]	AM	VQC	Class.	RF, CART	
[72]	AM	VQC	Class., Model-Sp.	CNN, SVM	Smooth IG
[32,35]	AM	VQC	Class., Model-Sp.	CNN	GradCAM
[25]	AM	VQC, PM	Class., Est.	CNN, CPH	
[73]	AM	VQC	Est.	CNN	
[74]	AM	VQC	Class.	BPNN	
[33]	AM	VQC, RCA	Class., Intrinsic	CART, RF, XGBoost	Interpretable model
[75–80]	AM	VQC	Class.	CNN	
[39]	AM	VQC, PO, RCA	Est., Intrinsic	Multi-Otsu, RF, DT	Interpretable model
[81]	AM	VQC	Seg.	CNN	
[14]	AM	VQC	Est.	LR, GR, SVM	
[82–86]	Electronics	VQC	Class.	CNN	
[10,87]	Electronics	VQC	AD	CNN	
[23]	Electronics	PM	Class.,	DLNN	
[88]	Electronics	VQC	Class.	CNN, LSTM	
[28]	Electronics	VQC	AD	osPCA, OnlinePCA, ABOD and LOF	
[89]	Electronics	PM	Est.	GAF, CNN	
[90]	Electronics	VQC	Est.	LogR, RF, SVM	
[91–93]	Electronics	VQC	Class.	SVM, k-means, GMM, KNN, RF	
[94]	Electronics	VQC	Seg.,	CNN	
[95–99]	Electronics	VQC	OD	CNN	
[13,100]	Electronics	VQC	Est.	CNN	
[101]	Electronics	VQC	OD	CNN	
[102–104]	Machinery	VQC, PM	Class.	CNN	
[105]	Machinery	VQC	OD	CNN	
[106,107]	Machinery	VQC	Class.	CNN	
[108]	Machinery	VQC	Seg., OD	Otsu, CNN	
[109]	Machinery	PM	Est.	CNN, LSTM	
[16]	Machinery	PM	Est., Model-Ag.	CNN	LIME, SHAP
[16]	Machinery	PM	Est., Model-Sp.	CNN	LRP, Grad-CAM, ISCSal
[110]	Machinery	VQC, PM	AD	CNN	
[40]	Machinery	PO	Est.	CNN, LSTM	
[111]	Forming	VQC	Est.	CNN, RNN	
[112]	Forming	VQC	Class.	SVD, RF	
[113,114]	Forming	VQC	Class.	CNN	
[59]	Forming	VQC, PO	AD, Est.	CNN	
[115]	Forming	PO	Est.	CNN	
[116–118]	Textile	VQC	Class.	CNN	
[119]	Textile	VQC	OD, Class.	CNN	
[38]	Textile	VQC	Est.	MLP	
[120]	Textile	VQC	Seg.	CNN	

Study	Industry Sector	VQA Practices	AI/XAI-Approaches	AI Method	XAI Method
[121]	Textile	VQC	Class.	KNN	
[122]	Packaging	VQC	OD, Seg., Est.	CNN	
[123,124]	Packaging	VQC	Class.	CNN	
[125]	Packaging	VQC	AD	CNN	
[126–128]	Packaging	VQC	OD	CNN	
[27,129]	Packaging	VQC	Seg.	CNN	
[67]	Packaging	VQC	OD, Est.	CNN	
[130–132]	Food	VQC	Class.	CNN	
[130,132–138]	Food	VQC	Class.	KNN, SVM, DT, CART, RF, Fuzzy, PLS-DA, LDA, QDA, NB, AdaBoost	
[139]	Food	VQC	Seg.	Otsu, MBSAS	
[140,141]	Food	VQC	Class.	ANN	
[142]	Food	VQC	Est.	SVM, RF, GBM, M5, Cubist, LR	
[143–146]	Wood	VQC	OD	CNN	
[147]	Wood	VQC	Seg., Est.	CNN	
[148,149]	Other	VQC	Class.	XGBoost, SVM, KNN, LR, RF	
[62,148]	Other	VQC	Class.	ANN	
[150,151]	Other	VQC	Class.	CNN	
[152]	Other	VQC	Class.	CNN, SVM, RF, DT, NB	
[153]	Other	VQC	Class., Model-Sp.	CNN	GradCAM, ScoreCAM
[154]	Other	VQC	OD, Class.	CNN	
[155]	Other	VQC	Seg., Class.	Clustering, LogR, NB, CART, LDA	
[156]	Other	VQC	OD, AD	CNN	
[157]	Other	VQC	AD	CNN	

Industry Sector	VQA Practices	AI/XAI-Approaches	AI Method	XAI Method
Component Inspection	VQC	Class.	CNN	
Component Inspection	VQC	Seg.	CNN	
Component Inspection	VQC	OD	CNN	
Component Inspection	VQC	Est.	CNN	
Component Inspection	VQC	Class.	RF, DT, NB, SVM, KNN, AdaBoost	
Component Inspection	VQC	Class., Model-Ag.	CNN	SHAP
Component Inspection	VQC	Class., Model-Sp.	CNN	CAM
Component Inspection	VQC, PM	Est.	CNN	
Component Inspection	VQC	AD	CNN	
Component Inspection	VQC	OD, Est.	CNN	
Component Inspection	VQC, PO	OD, Est.	CNN	
Component Inspection	VQC	Class.	KNN, DT, RF, SVM, NB	
Component Inspection	VQC	Seg.	MLP	

[26]
[68]
[69]

Which AI and XAI methods are used for VQA in manufacturing?

Machine Learning(ML): The study of learning algorithms that enable computers to learn from experience and improve performance on tasks.

- Supervised Learning
- Unsupervised Learning
- Semi-supervised Learning
- Reinforcement Learning

Models: The computer program that has been trained is called a model. ML models are computational algorithms and statistical techniques designed to enable computers to learn and make predictions or decisions without being explicitly programmed.

Metrics: What each AI method should accomplish

- Identity
- Separability
- Stability
- Selectivity
- Coherence
- Completeness
- Congruence
- Acumen

VQA Practices in manufacturing that cover AI and XAI approaches

- **Visual Quality Control (VQC)**: Monitoring quality during production to enhance service quality.
- **Process Optimization (PO)**: Regulating production parameters to maintain quality.
- **Predictive Maintenance (PM)**: Regularly maintaining equipment to prevent quality loss.
- **Root Cause Analysis (RCA)**: Identifying defects' root causes to implement preventive measures.

Limited Adoption with AI in Manufacturing

Despite the benefits of AI, the article found that its adoption in manufacturing remains limited. Only 8% of the studies employed XAI methods, with most using black-box deep learning models due to their superior accuracy in tasks like defect detection. This low adoption rate may stem from several factors:

1. **Complexity**: XAI methods are often more complex and resource-intensive to implement.
2. **Lack of Awareness**: Many practitioners may not fully understand the potential benefits of XAI, as it is still a relatively new field.
3. **Perceived Trade-offs**: Organizations may be hesitant to adopt XAI if they believe it sacrifices model performance for interpretability.

To promote the broader adoption of XAI in VQA, several steps are recommended:

1. **Education and awareness**: Raising awareness about XAI's benefits among industry practitioners and researchers.
2. **Research and development**: Encouraging further research into XAI methodologies to make them more accessible and efficient.
3. **Guidelines and standards**: Establishing industry guidelines and standards for implementing XAI in manufacturing.
4. **User-friendly tools**: Developing tools and frameworks that simplify the integration of XAI into existing workflows.
5. **Collaboration and knowledge sharing**: Facilitating collaboration between academia, industry, and practitioners to share insights and best practices.

AOI in the textile industry

Industries struggle to reduce defects in their products because traditional inspections done by humans -

- take a lot of time
- can be inaccurate
- and are physically tiring for workers.

Recently, Automatic Optical Inspection (AOI) has become popular for detecting defects more efficiently. This report introduces a defect detection system for the textile industry that uses DL (deep learning), computer vision, and location tracking to improve quality control and monitor operations in real time.

Key Innovations

1. it processes large amounts of data in real-time to spot even the smallest of defects
2. it supports Industry 4.0, improving quality control processes.

What's industry 4.0?

Industry 4.0 is the idea of using new technology to improve how factories and industries work. It's called the fourth industrial revolution because it's bringing big changes, just like previous revolutions in manufacturing did. Industry 4.0 connects machines, computers, and devices so they can work together more efficiently and with less human help.

How it works

1. Image Acquisition (IAC) - the process of capturing or obtaining digital images from a source, such as a camera, scanner, or other imaging devices, for further processing or analysis.
2. Defect Detection (DDC) - the process of identifying and locating flaws or irregularities in materials, products, or systems to ensure quality and functionality.
3. Defect Classification (DCC) - a system or methodology used to categorize and prioritize defects or issues in a product or process based on their severity, impact, and nature, to facilitate effective resolution and quality control.
4. Message Broker (MBC) - software that helps different applications or services communicate by receiving, sending, and organizing messages between them in a reliable way.
5. Visualisation Interface (VIC). - a user-friendly platform or tool that enables users to interact with and analyze data or information through visual representations, such as charts, graphs, and maps.

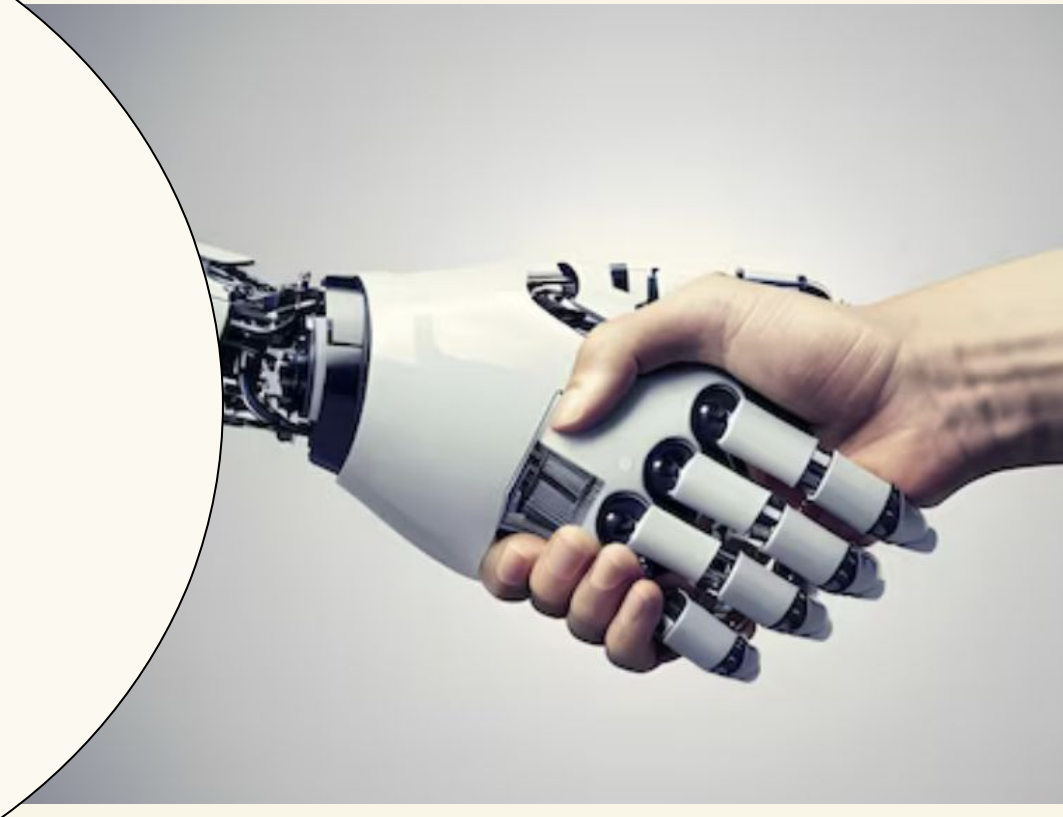
Future of AOI

In the near future, the system will get even better by using an "active learning" method.

This means the machine will keep improving by asking skilled workers to confirm any defects that the system is unsure about.

This will help the platform learn and get more accurate over time.

Machine versus human opinion example in color labs.



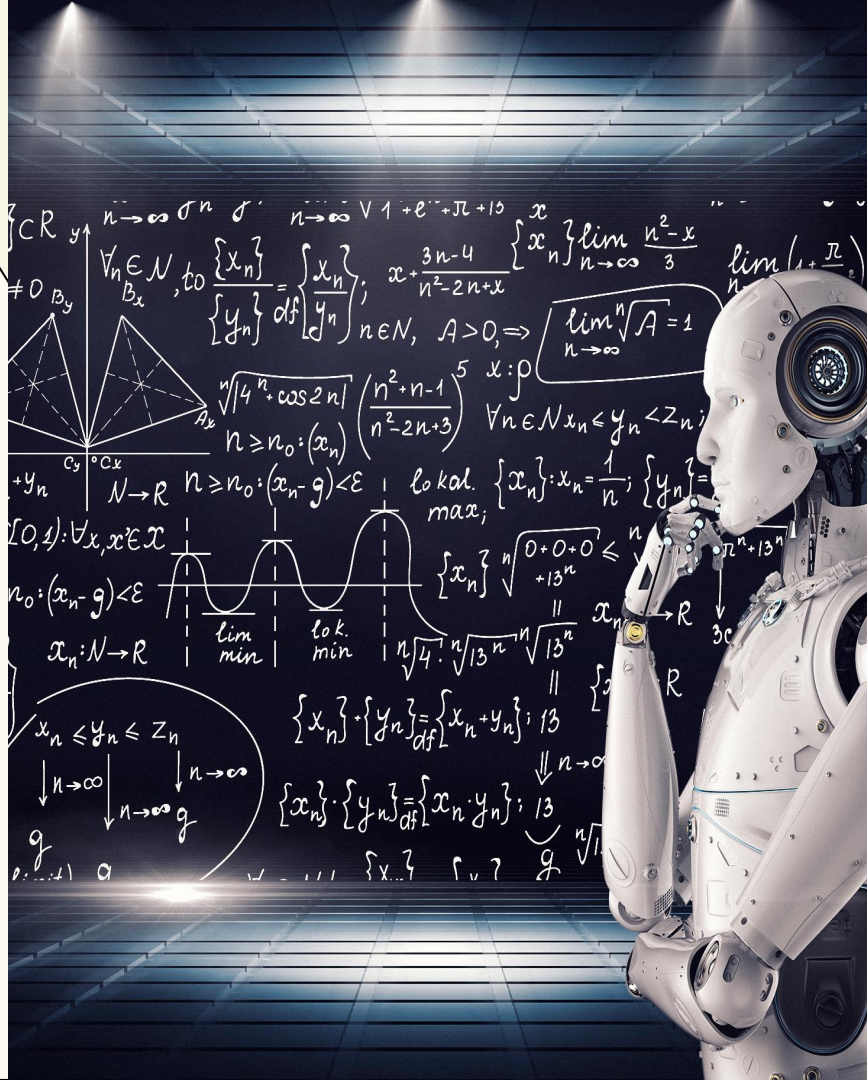
Article 3.

The Power of the 4th Industrial Revolution

1st- used mechanical production powered by water
2nd- mass production using electrictricity and assembly line
3rd- computer aided design and manufacturing systems
4th- building on past digital revolution and advancing technology using ai, robots, 3d printing, virtual/augmented reality, and more innovative business models

The 3 main challenges that the fashion industry is currently trying to tackle are environmental sustainability, hyper personalization, and productivity.

This article depicts what the major challenges in the fashion industry are, and how the 4th industrial revolution can help fix these problems.



3 Major Challenges in Apparel and Textile Industry Currently

01.

Environmental Sustainability

- Consequence of unmatched demand and oversupply
- Fast fashion has caused a lot of these problems with creating a high variety of products for a low cost
- Looking for ways to effectively source sustainable materials, product labeling, alter purchase behavior, create sustainable business models, and new manufacturing technology

02.

Hyper-Personalization

- Customization and personalization tangible (products) and intangibly (variety)
- Companies are looking for a way to make personalized experience for the customer
- Requires agile demand with smaller quantities and shorter lead times
- Need advanced accuracy and efficiency in forecasting demand

03.

Productivity

- Originally achieved in the industrial revolution, however need to focus on productivity in the decision making process besides creating more products at a lower cost
- Doing thing the “right way”
- Value accuracy and speed and as much as efficiency when producing the items

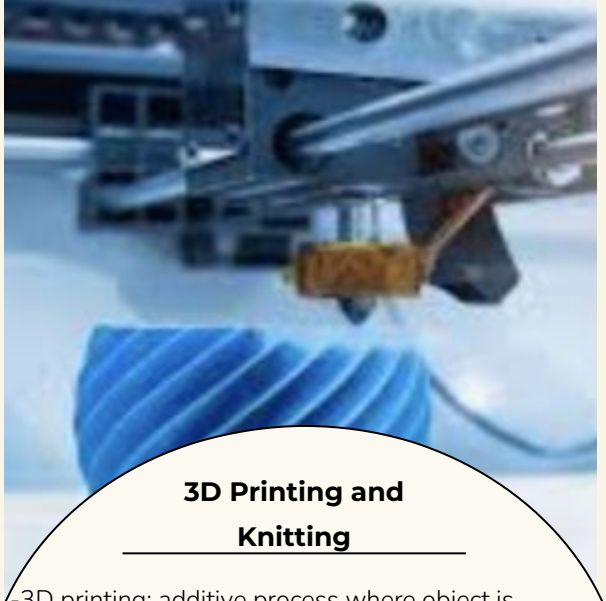
Robots and Intelligent Manufacturing

-More than just high volume production, smart factories can adapt and change demand in real time, have high reliability, and need minimal human intervention

-Automating sewing cuts manual labor needed by 90% and produces products faster

- Adidas factories can cut and sew a shirt in 4 minutes

-Reduces production time and helps reduce unsold inventory enhancing environmental sustainability



3D Printing and Knitting

-3D printing; additive process where object is created by adding successive layers of materials

- 3D knitting; uses needles to produce knit products in one piece without sewing

- Feetz allows customers to measure feet and send in for custom sneakers -3D knitting used to make sweaters

-Significantly reduces production time, enhances productivity and hyper personalization, less waste, less lead time, and lowers production costs

Virtual/ Augmented Reality

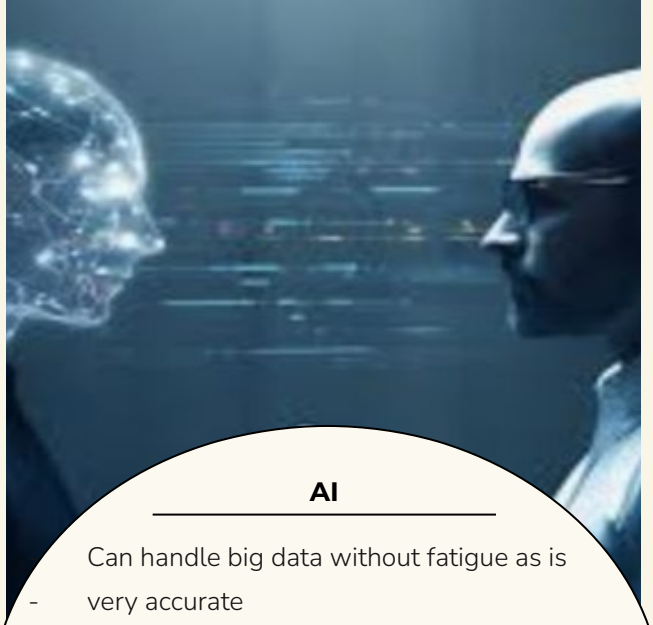
- Utilized in fast fashion, luxury, and contemporary

-Consumers; used in virtual try ons

- Customers can create 3D avatars based on photos and measurements to try on clothes

-Designers; use softwares that allow designers to see how garments look on real people

- Enhances productivity and hyper-personalization, leading to fewer returns and a smaller carbon footprint



AI

- Can handle big data without fatigue as is very accurate
- Can be used for a variety of functions; driving corporate decisions, customer values, setting prices, ai influenced predictions
- Used to analyze consumers interest, best selling products, and cn adjust inventory based on demand
- Helps find personalized items for customers and improves demand forecast, wichhelps with environmental sustainability and hyper-personalization

Business Innovations without the 4IR

- There are other ways to be successful in retail besides using the 4IR
- 4IR helps but is not sure cause for success, it depends on the business model used
    - The Real Real and Rent the runway do not use any technology from the 4IR, however are successful because of their innovative business models

AI & Technology and Chatbots

- AI Technologies are transforming both in-store and online
- AI offers innovative marketing approaches that enhance the customer experience.
- Chatbots are a type of AI-enabled technology that simulate human conversations via voice or text.
- Chatbots can provide customer service when retailers are unavailable.
- AI is often defined ambiguously.
- "Service AI" is defined as the configuration of technology that delivers value in internal and external service environments through flexible adaptation, enabled by sensing, learning, decision-making, and actions.

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Article 5.

Article 5 .

AI in the Luxury Fashion World

- Luxury fashion retailers historically resist technology, viewing it as contrary to the value of luxury.
- Many luxury fashion retailers are now investing in chatbots to enhance customer experience.
- Market and competitor pressures have prompted luxury brands to embrace technological advancements for marketing and customer engagement.
- Dior is one of the brands that has not fully incorporated AI chatbots
- Dior launched the "Dior Insider" AI chatbot on Facebook in 2017.
- The "Dior Insider" service has since been replaced by human customer service, which is not available 24/7..
- Brands that actively use chatbots include Burberry, Louis Vuitton, and Gucci.
- Research indicates that Chanel and Hermès do not use chatbots on their platforms but offer human customer service, which is also not available 24/7.

ADVANTAGES

- Customers can ask Chatbots shopping-related questions and receive answers in natural language
- Personalization, rather than mobility
- They can sell and process orders directly, reducing the need for human interaction

ADVANTAGES

- Emotional connections with customers enhance engagement
- Chatbots offer efficient assistance during the online buying experience at a lower cost compared to human customer service.

DISADVANTAGES

- Chatbots can impact customers perceived control over interactions leading to dissatisfaction
- Data security/ Confidentiality
- Struggle to understand customer intentions
- Customer satisfaction

Questions

How is AI used in the textile and apparel industry?

AI is used in the textile and apparel industry in a wide variety of ways. AI is helping manufacturers with visual testing like color matching and pattern making. Some manufacturers use it to assist in supply chain management, quality assurance, and monitor/ improve customers' shopping experience through chatbots, virtual styling, AI powered personalization,and virtual try-ons. (AATC)

How is it used in quality assurance and testing in manufacturing industries in general?

AI speeds up the quality assurance process and does not have human error like in manual testing. AI generates a test suite with the data that needs to be used and detects errors that other kinds of tests would not have found. With the utilization of more AI, there becomes less of a need for human intervention, making AI process powered quality assurance testing faster, with less error, and is less expensive. These are a few “ways testers are using AI presently- implementing AI through image based testing, determining whether to run a test script, using AI spidering, monitoring API testing, automating tasks” (Srivastava 1). Accuracy, reliability, and efficiency are all side effects of AI powered quality assurance.

Is it useable to detect defects?

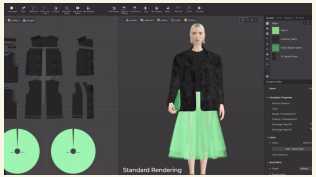
A major reason AI is used in quality assurance is to detect defects with accuracy and efficiency. Different technologies and systems are put in place using AI to detect errors that could have been missed by humans, as well as allow manufacturers to alter their workload based on current time demand changes. Meaning, if demand was forecasted to be one number but ended up being lower than what was predicted, AI allows the manufacturer to slow the production in order to match demand in current time. By being able to detect defects early in the manufacturing process it helps companies save more money and time than if they had to finish the garment before manually checking for any defects. (SCIP)

Questions

Provide case studies/examples of its use.

In Leipzig, Germany a new tactile sensation analyzer has been invented. This tool mimics the sensory of human hands and can measure a textiles surface softness, smoothness, stretch, and recovery in 90 seconds. All information derived from this device is uploaded to the cloud and can be accessed at any time. This invention is far more accurate and efficient than the past TSA hand panel testing.

In Munich, Germany designers are integrating the use of Style3D. Style 3D allows designers to create their knitwear using 3D knitting. In Style 3D there is an avatar that allows the user to “put” the clothing on and style it all virtually. Using AI the software can make digital photoshoots, showrooms, and promote each of the products created. By using 3D knitting it saves costs and shortens lead time. This allows designers and manufacturers to produce smaller batches of items, and not have as much waste. (Borneman)



How do you expect/predict it will be used in testing and quality assurance in the Textile and Apparel industry?

Based on the information from the articles and AATCC journal of research, I think that as AI advances and becomes more common in manufacturing that AI will start to make business decisions based on the information its receiving, rather than humans making business decisions. As AI gets more integrated the need for human intervention will decrease in every aspect from supply chains, to quality assurance, to business decisions. This will make supply chains more efficient and allow factories to adjust to demand in real time, along with being more accurate in forecasting demand and quality assurance than manually. (AATC)

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Thank you!