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Research on Developing a Production Preparation Model Applying Industry 4.0 Technology Platform in Garment Enterprises

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Abstract

The study was conducted to develop a smart production preparation model for industrial garment enterprises. In this research, a questionnaire survey and interviews were used to collect data from 100 garment enterprises in Vietnam. The survey aimed to assess the current status of applying Industry 4.0 achievements and technologies such as radio frequency identification (RFID), artificial intelligence (AI), and 3D technology in various production preparation stages (including material and accessory preparation, sample development, and preparation of technical and technological documentation). Based on the findings, a smart production preparation model is proposed, incorporating the full application of these technologies and analyzing the interrelationships among the model's components. The results also reveal several challenges and the feasibility of applying these technologies in different parts of the smart production preparation model for Vietnamese garment enterprises. The study also provides several recommendations to support the effective implementation of this model, directed at both the government and enterprises.

Keywords: Garment technology, Industry 4.0, pre-production.

1. Introduction

The Fourth Industrial Revolution is unfolding with technologies such as the Internet of Things (IoT), Radio Frequency Identification (RFID), wired and wireless sensors, additive manufacturing with 3D printing, cloud computing, artificial intelligence (AI), connected robots, self-integrating and network-interacting software, big data analytics, and interactive virtual reality [1]. These technological solutions have the potential to create breakthroughs in the textile and garment industry's production and business activities, covering all stages from product design, raw material supply, manufacturing, export, and marketing.

Nowadays, the garment industry is facing increasing global competition and unpredictable fluctuations in production demand. These pressures force garment enterprises to continuously improve the efficiency of their production processes within the shortest possible time and at the lowest production costs. Therefore, enhancing the competitiveness of Vietnamese garment enterprises by applying the achievements of the Fourth Industrial Revolution (Industry 4.0) and integrating advanced technologies/software into production is essential.

The research conducted by author L. T. Truong *et al.* has made some predictions about the potential application and impact of Industry 4.0 technology platforms in the textile and garment industry [2]. Additionally, H. X. Hiep *et al.* introduced the Lean 4.0 model, which provides forecasts on the potential application of Industry 4.0 technology platforms in traditional Lean model tools [3]. Studies predicted the use of connected software tools for production management, mobile devices for control, and applications of IoT, AI, sewing robots, RFID, etc., in the garment. Many domestic and international studies focus on the application potential of individual technological elements in specific aspects of industrial garment production, for example the application of 3D technology in design, the use of foundational technologies like IoT and RFID for product management in manufacturing and clothing business [4], and the use of sensors to measure workers' performance through energy consumption [5].

The industrial garment production process consists of two main stages: production preparation (PP) and production execution. Production preparation includes activities such as material preparation, sample preparation, and the preparation of technical and technological documentation. Meanwhile, production execution involves cutting, sewing, and finishing processes. Among these, the PP stage plays a crucial role, impacting production time, product quality, and delivery schedules. Several studies have addressed various aspects of PP in the garment industry [6, 7]. However, these studies primarily describe the general PP process without analyzing or evaluating a PP model that integrates Industry 4.0 advancements and modern technologies. It can be defined that the intelligent production preparation model is an integrated system that leverages advanced Industry 4.0 technologies, such as AI, big data, IoT, and automation, to optimize the production preparation process in garment enterprises.

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Therefore, the objective of this study is to develop a PP model that applies the achievements of Industry 4.0 and advanced technologies. Additionally, it aims to assess the applicability of various elements within the model based on a survey of the current state of 100 garment enterprises in Vietnam.

2. Experimental

This study employs a combination of two research techniques: quantitative research, through a mass survey using questionnaires, conducted with 100 Vietnamese garment enterprises; and qualitative research, through in-depth interviews conducted at 10 enterprises. A total of 100 questionnaires were distributed across the three regions of Vietnam: 40 in the North, 30 in the Central region, and 30 in the South. The study combines several sampling methods, including regional sampling, stratified sampling, and convenience sampling to select over 100 industrial garment enterprises for the survey. The rules are as following.

- Industrial garment enterprises are stratified based on labor size: small, medium, and large. A corresponding number of enterprises from each group will be selected to ensure the results are representative of the entire population.

- Convenience sampling was employed to select industrial garment enterprises that were readily accessible and demonstrated a willingness to participate in the survey, without the application of randomization criteria.

The collected survey questionnaires will be processed and entered following a strict procedure to minimize errors. The survey content includes questions about the application of Industry 4.0 advancements and various technologies/software in different departments of production preparation, including: Raw material preparation department; Pattern design; Grading and marker making; Sample marking and finished sample; Sample sewing; Jig/fixture department; Material consumption standardization; Technical standards; Color chart/color matching; Production line design.

In addition, thirty interviews were conducted at ten enterprises to clarify issues, including the advantages and challenges, in applying Industry 4.0 achievements and technologies/software in the PP process.

3. Results and Disscution

3.1. The Current Application of Industry 4.0 Advancements and Technologies/Software in the Production Preparation of Vietnamese Garment Enterprises

3.1.1. The current application of Industry 4.0 advancements and technologies/software in material preparation

The material preparation process in industrial garment production includes tasks such as material receiving, unpacking, inspection, storage, and distribution. The survey results on the application of Industry 4.0 advancements and technologies/software in the raw material preparation of Vietnamese Garment Enterprises are presented in Table 1.

Table 1. Survey results on the application of technologies/software in raw material preparation by Vietnamese Garment Enterprises (Source: Survey data)

No.	Tasks	Technologies/Software Used (Percentage of Total Surveyed Enterprises)								Total (%)
		Excel	QR code/ Barcode	ERP Software	RFID	Transport Robot	Electric Forklift	Automatic Fabric Inspection Machine with Manual Error Detection and Marking	Fabric Inspection Machine with Camera Scanning for Automatic Defect Detection and Marking	
1	Material receiving	80	7	8	-	-	5	-	-	100
2	Unpacking	80	7	8	-	-	5	-	-	100
3	Check	-	-	-	-	-	-	99	1	100
4	Storage	80	7	8	-	-	5	-	-	100
5	Distribution	80	7	8	-	-	5	-	-	100

The results show that 80 enterprises still use Excel for management records. Only 7% of enterprises use a QR code/barcode system, and 8% have adopted ERP software for material receiving, unpacking, storage, and distribution. No enterprises have implemented transport robots or RFID technology.

The application of Industry 4.0 advancements and technologies/software in material preparation remains limited. This is partly due to the high investment cost of an integrated management system, as many enterprises are not yet willing to make a significant financial investment in technology.

The use of barcode/QR codes for material management simplifies storage, tracking, and distribution processes, reducing errors and eliminating the need to search for or confuse different product codes. When multiple product codes are awaiting entry, barcode systems help minimize waiting time and prevent mix-ups. Barcodes are commonly used to store product information such as the place of manufacture, company name, and customer details. By scanning a barcode, users can easily access the origin and details of raw materials. Nowadays, many mobile applications are available for scanning QR codes and barcodes.

The survey results in Table 1 show that up to 99% of enterprises use a fabric inspection model with an automatic fabric inspection machine, where a worker manually checks and marks defects. Only 1% of enterprises use fabric inspection machines equipped with camera scanning for automatic defect detection and marking. After inspection, fabric rolls that meet quality standards are labeled with a barcode/QR code at the roll's end and placed in the staging area for distribution. AI techniques such as fuzzy logic, neural networks, and genetic algorithms are commonly used in fabric defect detection methods.

3.1.2. The current application of Industry 4.0 advancements and technologies/software in sample preparation

Sample preparation in garment enterprises includes tasks such as pattern design, grading, sample sewing, marker making, and preparing production guide samples. The survey results on the technologies/software used in sample preparation in industrial garment enterprises are presented in Table 2. The results indicate that most enterprises use Lectra, Gerber, and Optitex software, with 86% applying them in pattern design and 97% in grading and marker making. No enterprises rely on manual design.

Only 9% of enterprises use CLO 3D software for design. This software is primarily adopted by enterprises engaged in OBM/ODM production to simulate virtual sewing during the design and sample-making process. CLO 3D provides designers, manufacturers, and retailers in the fashion industry with tools for designing, simulating, and producing garments. It enables users to create 3D garment models, simulate fabric properties, textures, and stitching, and review and modify designs before production. This virtual sample sewing process helps reduce the number of physical sample iterations.

Table 2. Survey results on the application of technologies/software in sample preparation by Vietnamese Garment Enterprises (Source: Survey data)

No.	Technologies/Software	Pattern Design	Grading/Marker Making	Sample Sewing	Jig Manufacturing
1	Manual	-	-		29
3	Lectra	26	41		
4	Gerber	38	44		
5	Optitex	22	12		
6	Clo 3D	9	-	9	
8	Adobe illustrator	2	-		
12	Other	3	3		
13	Programming equipment			91	
14	Using CAD/CAM systems integrated with pattern data from design and grading software (Gerber, Lectra, …)				71
15	Total (%)	100	100	100	100

Table 3. Survey results on the application of technologies/software in technical documentation preparation by 100 Vietnamese Garment Enterprises (Source: Survey data)

No.	Technologies/Software	Technical Standards	Accessories Consumption Standardization	Materials Consumption Standardization	Production Line Design
1	Word/Excel	76	96		73
2	Other software (corel, illustrator…)	24			
3	Sewing Thread Consumption Standardization Software		4		
4	Lectra			38	
5	Gerber			47	
6	Optitex			12	
7	Others			3	
8	GSD system for work analysis support				9
9	Software for automatic work analysis via video				0
10	Standard time data bank				17
11	Using AI for process database extraction				1
12	Total (%)	100	100	100	100

3.1.3. The current application of Industry 4.0 advancements and technologies/software in technical documentation preparation

The preparation of technical documentation in garment enterprises includes tasks such as developing technical standards, calculating material consumption, and designing production lines. The results of a survey on the application of Industry 4.0 technologies and software in technical documentation preparation in Vietnamese Garment Enterprises are presented in Table 3.

The results show that a significant number of enterprises still rely on Word/Excel for technical documentation (76%), raw material consumption standardization (96%), and production line design (73%). Only 4% of enterprises use specialized software for standardizing sewing thread consumption, and just 1% apply AI for the automatic extraction of technological processes. Material consumption is typically calculated based on marker-making results from software such as Gerber, Lectra, and Optitex. In practice, most enterprises continue to use Word/Excel for documentation and calculations, with work quality primarily depending on the experience and skills of technical staff.

3.2. Analysis of the Feasibility of Applying Industry 4.0 Technology Elements to the Stages of the Production Preparation

From the literature review, survey results, and 30 expert interview at enterprises, it is evident that several Industry 4.0 technologies have been researched and applied to various stages of the garment production process, including RFID, transport robots, sewing robots, 3D, and AI. The applicability of technologies to small, medium, and large enterprises will mainly depend on financial resources, infrastructure, and the types of products being manufactured.

3.2.1. The applicability of radio frequency identification

RFID is a technology that identifies objects using radio waves. An RFID device consists of two main components: a reader and a tag with an embedded chip. The reader is equipped with an antenna that transmits and receives electromagnetic waves, while the RFID tag is attached to the object that needs to be identified. Each RFID tag contains a unique identification code that does not overlap with any other tag. The commonly used RFID frequencies are 125 kHz or 900 MHz. RFID has various applications such as in retail and payment systems, healthcare and medical services, electronic toll collection, and product lifecycle management. RFID is considered highly effective for warehouse management. The RFID system enables easy classification of materials and products in storage by attaching RFID tags to fabric rolls, bags, or containers, which are then scanned by RFID readers.

Warehouse data such as location, quantity, and classification is collected through the RFID system and transmitted to the warehouse server for storage and display. As a result, inventory operations, including material issuance and receipt, become faster and more efficient.

Advantages of RFID in Material Warehouse Management

- No need to establish a line of sight: The RFID tag remains in place, and the reader captures the code without concerns about the line of sight;
- Easily rewriting or modify tag data;

- Enhanced real-time visibility;

- Easy inventory management [8].

Disadvantages of RFID

- RFID is more expensive [8] and complex than barcodes.

- Most trading partners do not use RFID. To fully benefit from RFID in manufacturing, suppliers and consumers will need the ability to tag goods or read RFID tags in their facilities.

- RFID tags provide more data than barcodes, so businesses need a system to manage that data.

3.2.2. Applicability of robots

A robot is a type of machine that can perform tasks automatically under the control of a computer or programmed electronic circuits. It is a mechanical, artificial, or virtual agent, typically a mechatronic system. Robots have many applications; however, in the garment industry, they are mainly used in two areas: first, for transporting raw materials in warehouses, and second, for using robotic arms to assemble components.

In material preparation, Automated Guided Vehicles (AGVs) can assist with and perform tasks related to warehouse inbound and outbound processes, as illustrated in Fig. 1. AGV is essentially a guided-movement robot that carries or pulls a significant load while navigating. The goods can be placed in carts or containers for towing or lifting, or they can be loaded directly onto the AGV, which may feature built-in trays, roller conveyors, or PVC conveyors, depending on functional requirements. An AGV can also function as a forklift with integrated automatic lifting and lowering capabilities, handling pallets, rolls of fabric, or boxes. In some cases, AGV is a combination of a robocar and a collaborative robot with the ability to lift, place, and stack goods. The autonomous vehicle is equipped with navigation technology that detects and identifies columns, fixed obstacles, and warehouse walls. Using these fixed reference points, it can position itself in real-time and determine its travel route. There are no limitations on distance, including the number of pickup and drop-off locations.

Fig. 1. Automated guided vehicles (Source: Casun)

Some advantages of AGV robots.

- Enhancing the level of automation in the production process;

- Improving working conditions and preventing personal accidents;

- Reducing labor requirements and facilitating smooth production;

- Increasing the flexibility of the production line;

Several limitations.

- Requires new investment costs;

- Needs improvements to the existing warehouse system and shelving;

- Must be integrated with material management systems using RFID/QR code/barcode for proper operation.

The applicability of robots in sample sewing.

Robots can directly participate in the production process by assembling components of garment products (Fig. 2) [9]. The gripping technology for holding semi-finished products is based on a pneumatic system. The device interacts with the material through a gripping component, which is connected to the pneumatic system. Due to pressure differences, it can hold the material in place. However, this system is not yet widely adopted. Most manufacturers still use semi-automated systems and conventional sewing equipment.

In this system, the fabric pieces float about one inch above the work surface, which is designed like a brush system. This setup allows the robotic arm to rotate 360 degrees to pick up the material and perform sewing operations. However, this sewing technology is still under development and has not yet been commercialized.

There have been several experiments in fully automating garment sewing using robots. One such example is the SewBo robot, which can automatically handle fabric pieces during the sewing process. Invented by Zornow in 2015, SewBo is capable of sewing a T-shirt from start to finish. This achievement marks a significant milestone toward 100% automation in producing a complete garment.

Fig. 2. Robotic arm for garment assembly

SewBo can perform various manufacturing tasks such as fabric cutting, sewing, numbering, labeling, inspection, etc. All these tasks are controlled through a single touchscreen panel.

3.2.3. Application potential of AI

AI is a field of computer science that studies and develops systems and software capable of performing tasks that require human intelligence, such as perception, learning, reasoning, problem-solving, image recognition, and natural language understanding. AI can learn from data, improve over time, and automate tasks that were previously only possible for humans to perform.

- AI integrated for fabric inspection

AI techniques such as fuzzy logic (FL), neural networks (NN), or genetic algorithms (GA) are often preferred for fabric defect classification problems. Neural networks are the most frequently used method for defect classification. Texture features are extracted and ultimately classified based on woven fabric types (plain, twill, and satin). A study using the NN method provided simulation results for defects such as holes, warp defects, weft shortages, and stains. The defective images were classified with an average accuracy rate of 96.3% [10]. Hole defects were identified with 100% accuracy, while other defects were recognized with 95% accuracy [10]. However, applying this system to checkered or patterned fabrics still poses challenges.

- AI in pattern design

With 3D-designed systems integrated with machine learning models, users can find their desired designs by exploring this advanced environment and evaluating designs step by step until they achieve a satisfactory result. The Interactive Genetic Algorithm (IGA) can enhance creativity, allowing users to select a design that appeals to them [11]. The IGA method allows users to participate in the product design process, create new styles, or develop design patterns.

- AI in the marker-making process

The AI technique used in the marker-making process is the genetic algorithm. It has been observed that the proposed algorithm can enhance the efficiency of most marker-making processes for products such as dress shirts, trousers, and other garments. Additionally, neural networks are designed to estimate cutting time based on marker length, the number of fabric layers, cutting blade speed, the number of sizes, and cutting time. The network is trained using the backpropagation algorithm and has demonstrated good performance. Therefore, optimizing the marker-making process with AI techniques can not only reduce workers' manual effort but also significantly improve material utilization and production speed. However, in actual production, for certain product codes, manual marker-making is still used to adjust the positioning of pattern pieces within the permissible technical constraints to optimize marker length.

- AI application in the preparation of technical documentation and technology

AI can predict sewing thread consumption for various products in the garment industry. It can also be applied to establish technical standards for product codes in industrial garment production, provided that a comprehensive input database for this predictive capability is developed. Based on fundamental principles, AI can be effectively used in the development of sewing technical standards, especially when these standards vary significantly depending on product characteristics. These include general technical requirements, seam and stitch standards, assembly standards, buttonhole and attachment standards, and industrial hygiene standards. AI performs better when combined with big data. In other words, big data is the fuel that drives the performance of AI. The more data is fed into AI algorithms, the higher the performance of the model.

3.2.4. The applicability of 3D technology

3D technology allows users to try on clothing to make a preliminary assessment of its shape and the balance between design details. In traditional, non-digital clothing production processes, users need to sew a large number of garment samples and evaluate the results to finalize the design. With 3D technology, the completed garment's shape can be viewed in 3D without the need to cut or sew any fabric. Simple modifications, such as adjusting the size and fit of the clothing or applying a new fabric type, can be done in minutes, allowing users to create more diverse sketches and exchange information more accurately. 3D visualization tools help accelerate the design process and reduce the probability of design/printing/sewing errors, while also showcasing flexible customization options and creative freedom. To use software and virtual garment-making technology, a device with a suitable configuration is required, capable of handling graphics and meeting the software's requirements for rendering. This ensures the simulation of garments with higher accuracy and minimizes the differences between the physical and virtual samples. The input data, including the model's measurements, body shape, curves, and the position of various points on the body, require high-quality input data. If the input data is inaccurate or incomplete, the 3D garment prototyping process will not be precise.

Advantages of 3D technology

- Multiple sample variations can be created and tested before deciding to produce the final product, saving time and costs.

- The product can be viewed from different angles (front, back, side) and the elasticity of the product can be checked on the simulation software, allowing changes in color, material, and size, making the design process more flexible.

- Changes to the sample can be made quickly and easily.

- It reduces the number of sample sewing attempts in industrial garment production. It will be effectively used in companies producing Original Brand Manufacturing (OBM), Original Design Manufacturing (ODM) products or companies with a sample design department. However, Cut - Make - Trim (CMT) manufacturers generally don't need to use it.

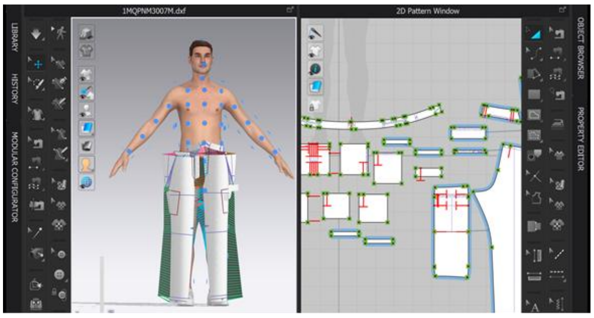

Fig. 3. Virtual sewing with CLO 3D

Disadvantages

- The virtual sample may not resemble the final product due to differences in the production process and materials.

- The design and virtual garment-making software is quite complex and requires time for learning and practice to use effectively.

- Virtual samples may not reflect certain smaller details, such as attachments like buttons or patterns, or the inner side of the product. Some types of materials may not be available in the software for accurate simulation.

3.3. Proposing a Smart Production Preparation Model

From the report analyzing the potential of 4.0 technology elements, including AI, that can be applied to stages in the garment production process, it can be seen that there are four suitable factors that can be incorporated into the smart PP model, including:

- RFID and transport Robot (AVG) used in material preparation.

- Virtual 3D technology is used in the sample preparation stage.

- Artificial Intelligence is integrated to check fabrics, in the sample design process, garment prototyping, and in the preparation of technical documents and technologies.

The proposed smart production preparation model is described in Fig. 4. The model structure is based on the results of the overview study and the survey conducted at 100 garment enterprises. The smart PP model is fundamentally based on the framework structure of the existing model of garment enterprises presented in a previous study [12]. The novelty of this model lies in its upgrade with Industry 4.0 technological components that were not present in the model proposed in study [12], notably, AI and other Industry 4.0 technologies: 3D technology, RFID, and robots.

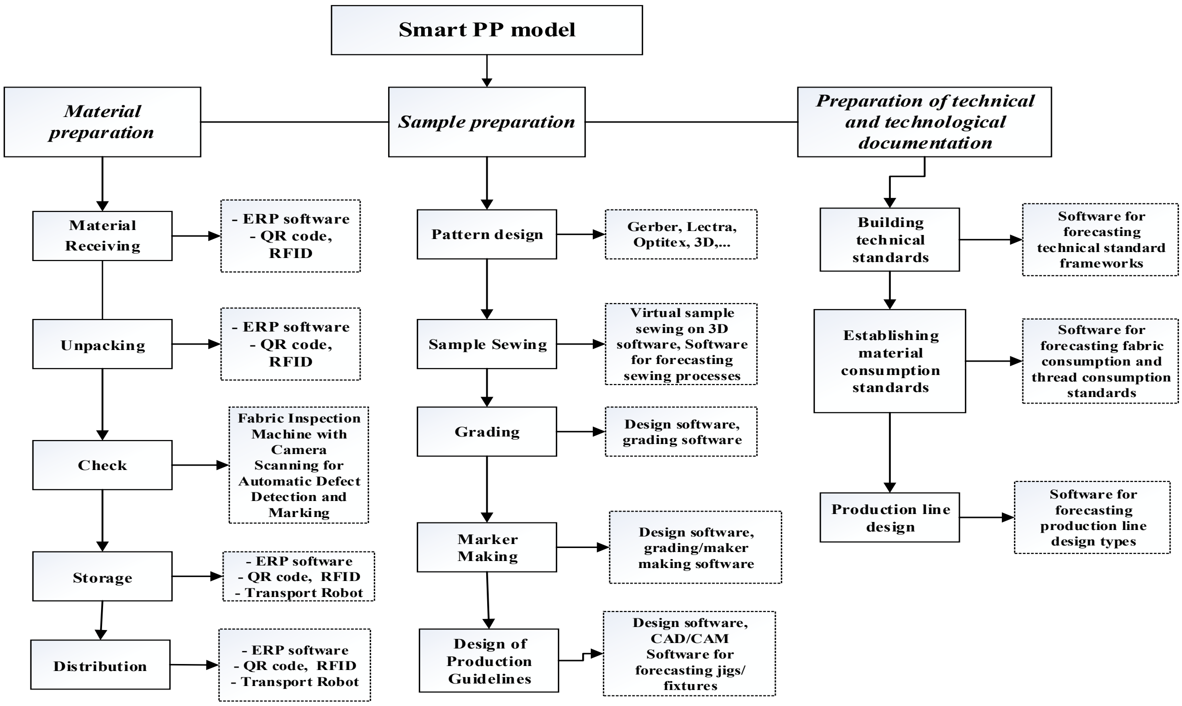

Fig. 4. Smart production preparation model in garment enterprises

3.3.1. Material preparation in the smart production model

1) Input of materials and accessories

The input of materials and accessories is carried out when the shipping invoice matches the delivery invoice. After receiving the materials, the warehouse staff transport the goods to the "temporary receiving" area and record all information in the goods receipt log, including: the date of receipt, invoice number, item name, number of packages, and source of import. For the smart production preparation model, this information can be tagged with a barcode or QR code. Using barcodes or QR codes for material management makes it easier to manage, store, and distribute materials without the need to search for or confuse them with other items. When there are many items waiting to be entered, it prevents waiting time and avoids confusion. The barcode or QR code will be generated and affixed to the ends of fabric rolls, bags, storage boxes for materials, or on the locations of shelves containing the materials.

Companies can use either RFID or QR codes, both of which can be effective. RFID is considered highly effective in warehouse management, as the RFID system is used to easily classify materials and products in the warehouse through RFID tags attached to each fabric roll/material bag, with a card reader required. Actual warehouse data such as location, quantity, and classification will be collected through the RFID system and stored, displayed on the warehouse server system. This allows faster and more efficient control of stock movements. The use of RFID tags requires warehouse management software, whereas barcode or QR code systems may or may not require it. However, when all three systems are applied together, they can be highly effective if accompanied by an enterprise resource planning (ERP).

Additionally, AGVs can be used for the input and unloading of material packages. However, when using AGVs, it is necessary to adjust the layout of the material warehouse and integrate them with barcode/QR code/RFID systems.

2) Fabric inspection

In the smart production preparation model, the company will use an automatic fabric inspection machine that does not require human intervention and is capable of automatically detecting fabric defects. The system can inspect at speeds of up to 300 meters per minute and handle fabric widths of up to 5 meters. The system learns to detect fabric patterns with weights below the normal threshold and identifies size variations. These variations are then analyzed using multiple detection algorithms to separate real defects from random but normal variations in the fabric. After detecting defects, the X and Y coordinates as well as the size of the defect are recorded on the defect map. Additionally, a digital image of the defect is stored for later review by the system operator. The cost of the system depends on several factors such as the type of fabric being tested, the desired speed, and fabric width. The system is currently sold at prices ranging from $100,000 to $650,000. The payback period for the system is typically between 6 months and 2 years.

The system uses an automatic scanning camera system to detect and mark defects, capable of checking fabric color deviations; automatic labeling; automatic edge alignment; fabric dust removal and wrinkle reduction; measuring fabric length and weight; and generating reports for evaluating the quality of incoming fabric. This system can be applied in companies producing single-colored items, long orders, or specialized products such as jeans/denim or single-colored woven fabrics.

3.3.2. Sample preparation in the smart PP model

1) Design, pattern grading, and marker making in the smart production preparation model

For the smart PP model, design software, pattern grading software, and marker making software will still be used. However, the design process will also incorporate virtual garment prototyping software to speed up the design and sampling process, reducing the number of physical prototypes needed. Virtual garment prototyping software should primarily be applied in ODM/OBM manufacturing companies.

2) Sample sewing

In the sample sewing stage of the smart PP model, virtual garment prototyping software will be used, allowing users to create 3D models of the garment, simulate materials, textures, and seams, and check and modify designs before actual production. Users can simulate stitching and test different options before manufacturing. Once the sample for each detail is created, the precise placement and arrangement of the components on the product must be determined. The software allows for the movement, rotation, and adjustment of the components to achieve the desired fit and organization. It also provides virtual sewing tools to assemble the components together. These tools are used to create virtual stitching on the 3D model, thereby determining how the components are connected and sewn together. After using the sewing tools to join the parts, the designer needs to check and adjust the fit and aesthetics of the result. The software allows users to preview and evaluate the sewing outcome on the 3D model, and make adjustments and refinements as needed.

For the smart production preparation model, the application of artificial intelligence will help propose the processing technology procedures, making the process of researching technology procedures before prototyping faster. Additionally, it will provide forecasts for the garment prototyping process, including: types of defects, types of fixtures, and material characteristics.

3) Designing sample production guidelines

The process of designing fixtures on the CNC system will integrate software such as Template Plotter Cutter for design before milling the fixtures. Additionally, in this model, the design of the components can be taken from the design department using specialized software to quickly adjust the fixture design before milling.

The preparation of fixture types is based on the machining characteristics of the component clusters. Therefore, it can be observed that component clusters that are machined separately will use specific types of fixtures. From this, it can be seen that AI technology can be applied in this stage to store and analyze the use of fixtures in the production of certain component clusters, serving as a basis for shaping fixtures when producing new product codes.

3.3.3. Preparation of technical and technological documentation in the smart production preparation model

1) Technical standards, material consumption norms

When building technical standards, the software can automatically generate cutting, sewing, and finishing standards based on data from previously produced product codes. AI-based software can also be used to forecast the effectiveness of sewing standard development, as these standards can vary significantly depending on product characteristics. Requirements for stitch type and stitch length are determined by the specifics of the product, while other technical standards may remain largely similar.

Material consumption norms refer to the necessary materials required to produce one unit of product following a specific process. Establishing material consumption norms is the basis for determining the amount of materials consumed for a product code, the cost of the product, the allocation of materials to units, and serves as a metric to assess the efficiency of the production process. In the smart PP model, proposing the main material consumption norms will assist in the process of building technical standards by evaluating the alignment of the established norms with the forecasted norms. This allows for analysis and comparison of the alignment of the calculation process. Technical staff can leverage the material consumption norms forecasted by the AI software.

2) Production line design

In this model, the process of line design can be performed more quickly by leveraging the ability to automatically extract technological processes and the line design database for similar product codes previously produced, through suggestions for job step combinations.

The AI application software in the smart production preparation model will be built based on the operational principles as described in Fig. 5.

According to the diagram, the software will contain a database related to the smart production preparation process of several hundred product codes in basic categories such as T-shirts, polo shirts, shirts, pants, jackets, vests, and workwear. These product codes are all export items that have been produced at the garment company. When a new product code needs to be predicted, based on the documentation, the user will input the product's characteristics into the software, such as style, category, specifications, fabric width, etc. The software will then use the data from previously produced items, automatically extracting similar characteristics to suggest suitable data for the product code that needs to be predicted.

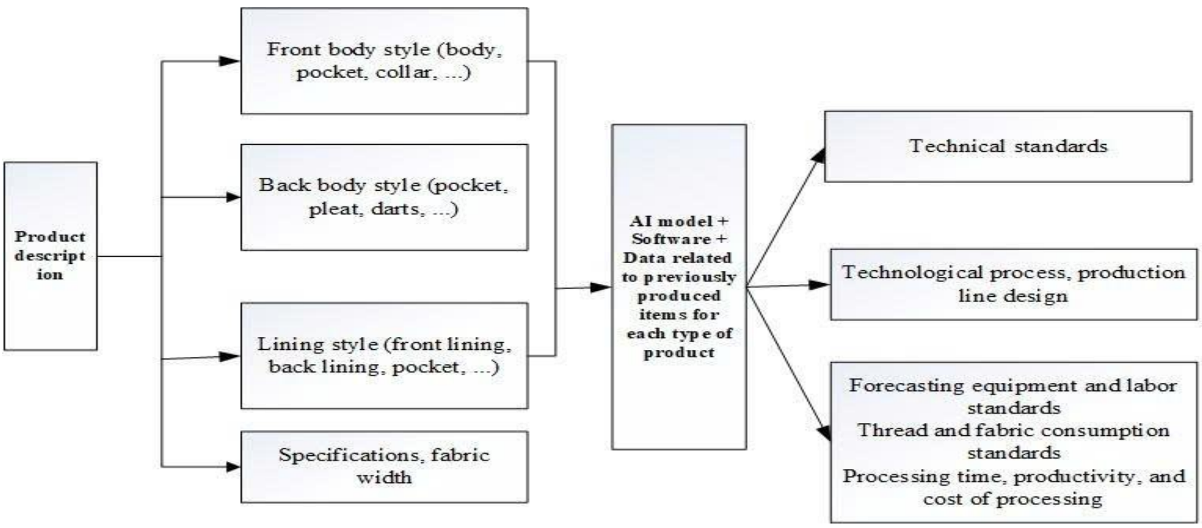

Fig. 5. Diagram illustrating the operational principle of AI application software for forecasting in the preparation of technical and technological documentation

AI models in software incorporate various algorithms. Each algorithm corresponds to either a regression or classification problem, depending on whether the data is qualitative or quantitative. For example:

- Data related to technical standards, technological processes, and line design will use AI models for classification problems;

- Data on equipment norms, labor, thread consumption, processing time, productivity, or processing costs will be handled by AI models based on regression problems;

AI models receive input data on product characteristics and provide corresponding output data as desired.

3.4. Recommendations for Garment Enterprises to Effectively Implement the Model

To promote the implementation of digital technology applications in garment enterprises to enhance productivity, quality, and sustainable development in line with Vietnam's conditions, the government, ministries, and relevant agencies should introduce the following policies and support programs for garment enterprises and research institutions:

- Develop support policies for garment enterprises to actively participate in digital transformation research in general and artificial intelligence in particular.

- Continue to provide greater support for institutes and universities in applying digital technology to contribute to the digital transformation of Vietnamese garment enterprises. This support should be provided through assistance programs, consultancy for institutes, universities, and enterprises in piloting digital technology applications, or specialized training programs for experts in digital transformation, especially in artificial intelligence.

- For garment enterprises, it is recommended that they actively participate in projects initiated by the government, ministries, and research institutes or universities to enhance productivity, quality, and efficiency, while fostering trust in local researchers. In addition, enterprises should join networks established by textile and garment associations to strengthen collaboration within the industry. Furthermore, sharing actual production data is encouraged to support the development of machine learning models and improve prediction accuracy.

4. Conclusion

The application of 4.0 technology platforms in the PP stage of the garment industry mainly focuses on several technologies: RFID, robots, AI, and virtual 3D. Among them, RFID and robots can be effectively applied in material management. The application potential of robots and RFID has not yet been fully realized in sample preparation and technical documentation because textile products are quite complex in structure. Virtual 3D technology can be applied in sample sewing and design. AI can be applied in material inspection, design, pattern plotting, thread consumption prediction, fabric consumption prediction, technological process forecasting, line design, and the development of technical standards. However, there are also many challenges when applying these technologies. In the future, research will be conducted to develop processes for applying the smart production preparation model in a way that is suitable for different types of enterprises, including small, medium, and large-scale businesses. At the same time, the feasibility of selecting and piloting certain elements of the model in specific enterprises will be explored, and the effectiveness will be evaluated.

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