An Augmented Reality-based simulation guide for apparel assembly

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Abstract— Augmented Reality (AR)-based technologies have revolutionized prototyping and manufacturing operations in many industries despite limited applications in the context of apparel. Currently, digital technologies are demanded in the process of apparel 'design to manufacturing' to improve efficiency while maintaining the product defects to a minimum level. This study proposes an AR-based tool to educate sample machinists to assemble even a complicated new product to meet the exact design specifications. Such guiding device overcomes product defects which occurs due to misinterpretations of design details. This study was carried out in two phases. During the first phase, qualitative research methods were utilized to analyze the impact of new product failures which occur due to misinterpretations of prototyping instructions. Also, this phase was utilized to analyze their perceptions of AR-based guiding tool, along with the suggestions to develop such system to support product assembly. The second phase proposes relevant guide to develop the new AR tool and presents the acceptance of such tool from the focus group consists of potential users. Future work will include creating relevant contents based on the proposed screen images. Then it will be useful tool to train sample developers to produce the prototypes right first time.

Keywords— apparel industry, augmented reality, design for assembly, prototyping

I. INTRODUCTION

Apparel markets are dynamic, and customers always seek new products to match with their complex lifestyle needs. Apparel manufacturers usually follow market intelligence and trend information from their retail buyers to develop new products [1]. Usually, product designers advise design ideas to product developers and product developers forward specifications to the manufacturing team. In doing so, styles are frequently changing and, conventional approaches in the flow of information within the process is not adequate for new product success [2]. Most importantly, organizations had to focus more on quality of the products rather efficiency when developing such complicated products to delight the customer [3].

Prototyping was identified as the most crucial task within the new product development (NPD) process. Most of the prototyping errors happen due to miscommunication and misinterpretation of technical information related to product assembly at the initial stage of NPD [4], [5]. Furthermore, the prototyping tasks are even complexed when the new product consists of value-added functionality and higher level of performance. These situations will be challenging for the product development team and it will lead to NPD failures and it will also cause to multiple sample iterations with amendments. This will lead to high NPD cost and subsequently, product price will be increased accordingly.

Therefore, advanced digital technologies are demanded to establish legitimate information system to minimize product design to manufacturing errors [6]. Out of which, Augmented Reality (AR) applications are utilized in complex assembly, maintenance, expert support systems, quality assurance and automation [7]. The integration of digital and physical experiences is creating new ways for different manufacturing disciplines to proliferate their productivity and effectiveness [8].

The apparel development phase begins with the receipt of initial tech pack from the product designers and ends at the commencement of manufacturing [9]. In the export apparel manufacturing business, mostly, product development team receives the design details from the buyers. This includes material specifications, size specification, basic patterns and construction details, trims, and labels. Over the years, apparel exporting countries have excelled their manufacturing expertise and they tend to acquire very complicated products with higher efficiencies. Sri Lanka is one of the examples for such countries, it is on the verge of introducing new products to the global market using their technical expertise acquired over the years. Therefore, the companies were encouraged to invest on new technologies and implement new processes for innovations and currently intends to carry out product design to manufacturing [6]. The embrace of digital technologies by the apparel sector will greatly improve its overall success.

Apparel manufacturing process characterizes four main phrases: designing/pattern generation, fabric cutting, sewing, and ironing/packing [10]. Out of which, sewing is considered as one of the most crucial activities as it consists of critical product assembly, value added sub-processes, deployment of different technologies/ advanced machineries, and different levels of skilled labour [10]. Various causes for product development failures were identified in the published literature. Mainly, production plans in the product development department are frequently changed. These issues effect for the production learning curve and reduce line performance in the product development department. Another shortcoming was incomplete information provided to the manufacturing team even after the product development stage. In certain instances, bulk production commenced without complete approval due to delivery schedule pressure [11]. Those issues lead to higher NPD cycle time, low quality products, higher sample rejection rate, higher material wastage, higher production cost and poor customer satisfaction. Therefore, advanced manufacturing support systems are essential to educate sample machinists to minimize the production errors. This study suggests a method to create an AR based tool to assist sample machinists to create the first apparel proto sample accurately. Moreover, this study was intended to analyze the requirements of developing such AR tool to minimize the prototyping errors that happened due to misinterpretations of technical information. This proposed wearable AR glass will provide more visualized technical guide at each sampling operation. There is no such study published in the context of apparel manufacturing using AR technology. This concept of virtual technical guide in NPD can be further developed to commercial wearable glasses in future. In this study, researchers focus on sample making activities and present necessary guide to create contents by computer scientists. This study can be further used to develop similar training devices in future.

II. EXISTING AR-BASED TECHNOLOGIES

AR is a novel human–machine interaction that enhances virtual computer-generated information on a real environment [12]. AR is widely available as mobile devices, and creates interface that explore new ways of interaction between actual and virtual world at the same time. More precisely, AR technology has shown the potential ways to train the workers during their prototyping mainly in product assembly. For an example, AR enabled Microsoft's HoloLens were used at Volvo manufacturing firm to visualize their design experiments during their assembly lines [13]. In this study, AR applications were reviewed and brainstormed the utility in training related applications.

For an example, luxury watch brand 'Tissot' has joined with Selfridges to create AR based mirror-like display that tracks customer feedback online for a variety of its product aesthetics and functional attributes [14]. AR technology has further developed with next-generation wearable devices such as Google Glass, which deploys cameras and wireless connections to project information through eyeglasses. Many VR and AR related applications can be experienced in some other innovative industries; for an example IKEA (the Swedish home furnishings retailer) use VR to realize their product ideas in their early concept development phases, marketing and promotional purposes. IKEA provides virtual shop visits with semantic product information with a visualization to their customers. Such platforms enable the user to walk through the virtual shop and choose products with better understanding of the product [15].

Augmented reality system coordinates real images and virtual images and enables real-time interaction [16]. 'LEGO' implemented AR kiosks and product demonstrations to enable more product visualizations to their customers, located in different geographical areas [8]. Mitsubishi Electric developed maintenance-support technology using AR-based on a 3D model that enables users to confirm the order of inspection with the aid of an AR display, subsequently entered inspection results with their voice [13]. According to Kocic [13], AR technology via telepresence, can be effectively used to train technicians or machinists compared to conventional training methods. These examples demonstrate the applicability of AR technology in different manufacturing processes at different stages. AR is emerging in most of the manufacturing industries, and very limited applications can be identified in the apparel industry [7], [17]. One of the successful implementations of AR was AR fashion mirror in apparel retail business [2]. Augmented Reality enabled 'Magic mirror' revolutionized the apparelretail by providing convenience for users by assuming the role of a professional fashion coordinator, providing an appearance presentation [18]. It uses a depth camera to capture the figure of a user standing in front of a large display screen. The display shows fashion concepts and various outfits to the user, coordinated to user's body. This system has currently established at leading fashion stores to support a customized method for clothes shopping.

Nevertheless, apparel industry adopts these state-of-the-art technologies in very slow phase [7], this study fills that gap by initiating the use of AR to improve the quality of overall product development process.

III. OBJECTIVES

The researchers inspired the related AR technology applications from other manufacturing disciplines and planned the relevant AR tool in the context of apparel. The main aim of this study was to create a guide, to design an AR-based tool to train sample makers to minimize prototyping errors. This kind of tool is essential to follow exact product specifications designed by the design team based in different geographical areas. The study was completed in two phases. The objectives of the first phase were to, (1) analyze the impact of new product failures which occur due to misinterpretations of prototyping instructions, (2) analyze the potential users' perceptions of AR-based guiding tool, (3) collect and analyse the users expectations develop such system to support product assembly. As such, this research suggests that users' perceptions and experiences matter in showing the potential impact of these technology applications. The objectives of the second phase were to, (1) propose a guide to develop the new AR tool, (2) present the acceptance of such tool from the focus group consists of potential users.

IV. METHODOLOGY

Qualitative research approach along with the appropriate data analysis methods were used for the study. Qualitative interviewing was used in the first phase of the study to explore the existing situation and requirements analysis. Focus group discussion was carried out to validate the proposed AR-based tool and receive feedback for future developments.

Sri Lankan apparel industry was selected for the data collection based on the convenience in data collection and validation of the results. In particular, one of the leading intimates manufacturing organizations was selected for both phases of the study. Digital technologies have grown in importance in this organization and currently, implemented digital garment creation process effectively. They adopt virtual apparel design, digital pattern making system, and virtual fit-on technology. Since, the workers are familiar with novel digital technologies, it was feasible to explain such technology tools to them. However, participants viewed a short video, images with the brief introduction of AR technology applications before starting the data collection. Purposive sampling methods [19] were applied to select relevant participants for the study, including fashion designers, product development technologists, technical managers, and sewing technicians. There were 41 participants included in the first phase of the study and Table 1 describes the sample composition.

Table I: Sample Characteristics

Designation	No of Participants	No of years of experience
Fashion Designers	16	3 – 8
Product development technologists	10	3 - 7
Technical managers	3	3 - 6
Sewing technicians	12	3 - 10

For the exploratory type of first phase, a semi-structured questionnaire was constructed and tested before using them at the proper interviews. The questions were planned to investigate the existing information flow of new product development process, drawbacks of written form of the technical file, process monitoring systems, current involvement of the sewing technicians, product defects due to misinterpreting the design specification. The later part of the same questionnaire focused to review the perceptions of such AR-based tool which can be used to receive the digital technical instructions to stitch the sample. Also, includes few questions to collect their requirements when designing such system. Subsequently, face-to-face, in depth interviews were carried out with each participant during the period of May - July 2018 and lasted for 30- 40 min.

Then researchers have planned the AR tool and designed some user screens to present the proposed tool. Importantly, the researchers referred similar AR-based technology solutions when designing the proposed conceptual ideas which are used in similar end-use.

The second phase of the study was utilized to present the know-how of the proposed AR-based tool and measure the acceptance of such system from the potential users. This focus group of participants have been selected from the first sample based on their knowledge on the entire process and awareness of the AR technology. Likewise, there were 6 senior employees including 3 senior fashion designers and 3 product development technologists were included in this focus group discussion. Open ended questions were included in the questionnaire instrument to feedback on relevant images of user-screens. Questions were planned to discuss the following aspects; applications of QR codes for panel identifications, check the cut-kit, user interfaces of the tool, real-time error detection, feasibility and limitations of the proposed tool. This focus group discussion was carried out for 45 minutes at the same organization. At the end of the discussion, participants highlighted the areas for further developments.

V. ANALYSIS AND RESULTS

Qualitative data analysis methods were used in both study phases. Each interview was transcribed and stored systematically for the data analysis. As explained by Macqueen [16], the structural coding method was applied to extract and segment the essence of data with reference to specific research objectives. The codes and sub-codes were generated to highlight the responses to the aforementioned research objectives and to utilize as 'constructs' for the proposed AR tool development.

Currently, product developers receive manufacturing instructions in the form of a written technical package from the designer. In early stages of NPD process, product developers receive design sketches which consisted of basic details. In the early prototyping stages, sample machinists also follow these basic specifications to produce the first prototype. Consequently, machinists interpret the technical details incorrectly in most of the instances. Due to that, the final product differs with the initial product design. Furthermore, such ambiguity in providing detailed information leads to NPD failures. Moreover, more visualized NPD tools are needed as sample machinists need much supervision to understand the written information mentioned in the existing technical package.

Currently, more labour involved in the process to carry out product assembly and supervision. According to the most experienced participant in the sample, explained the reasons for current product defects mostly due to wrong interpretations of the design sketches. Their recent study pretended, even though, the organization increased their manpower, it was able to reduce the defect rate by 7.7%. Therefore, the participants highlighted the need of advanced technologies to educate the machinists in each operations of product assembly to mitigate the prototyping errors. The key findings of the interviews were discussed in the following paragraphs.

Participants explained the severity of the product design defects are depending on product complexity. Sample machinists had different competency levels in sample production. They always depend on the verbal instructions received from the sewing technician. Those instructions are also subjected to frequent changes according to the understanding of the sewing technicians. In this situation, printed tech-packs were not practical, and some important instructions were mis-communicated.

Almost all the participants mentioned that, they consumed more time at the pre-product development meetings for each style to guide relevant value-chain partners. Almost all the designers and 96% of other participants confirmed that close supervision was expected by the sample machinists during the sample production. According to the findings, only 4% of the samples were made at right first time. There were 93.75% designers and 60% development technicians stated that the main reason for those product errors was, lack of instructions provided at the beginning of each operation.

In the first phase of the study, there were 64% of the participants proposed to recruit more supervisors to assure product quality, however they showed the same interest to adopt to AR based tool after demonstrating the proposed concept of such tool. At the second phase of the study, all the designers and 88%of the other participants, showed their interest on adopting the proposed AR tool and they believed it will be an appropriate technical guide to each sample machinist to minimize prototyping errors. Table II depicts the features suggested by the research participants.

Table II: Suggested features for the development of AR tool

Areas of the development	User Recruitments
Finish garment measurements	Show how to measure the garment parts correctly (Ex- Waistband, Neckline, Height).
Garment finishing Techniques	Seam corners, Hem construction and finishing methods.
Operation break down	Check cut panels, the sequence of garment assembly, Recognize correct machinery and attachments.
3D visualization of the design	3D visualization before starting the production. Also, 3D visualization of the critical areas of the garment.
Machine settings	Stitch length (no of stitches per inch), Gauge, Stitch tension
Identifying quality points with regards to product assembly and finishing.	Panel attaching, Cutting, Bonding
Tech pack details	Style identification, Design sketch, Materials and trims
Time tracking	SMV (Standard Minute Value) of each operation, time countdown
Value-added construction details	Examples - Bonding and moulding conditions according to the product design
BOM details	Fabric articles, Colors, Store location, Respective merchant

According to the survey findings in the first phase, sample makers prefer more visualized input compared to previous written form of the technical files. With abundant data from multiple user-friendly screens will support customized apparel product development and manufacturing. Moreover, it is contended that there is a requirement of establishing a system to guide sample machinists to minimize errors in production lines. These findings were effectively used to plan the required features of the proposed AR-based tool. The proposed AR tool was visualized using several images to explain the operationalization of the proposed AR tool.

This AR-based tool will develop as a wearable technology and it will contain all the product design and technical details in digital format. Product designer configures relevant information according to each new style. Each operation stores in a data base and the designer and product developer can copy similar operations from previous product development cycles. Following figures illustrate the user-interface screens. According to the emerging trends of this technology, AR will further develop with next-generation wearable devices such as Google Glass, which deploys cameras and wireless connections to project information, on demand, through eyeglasses [20].

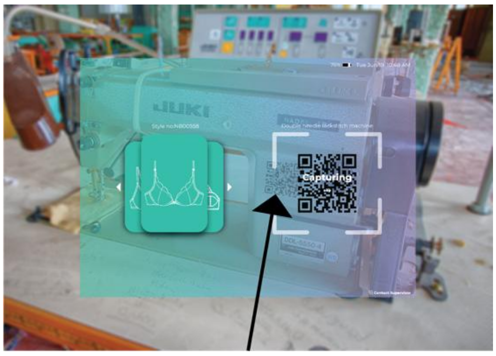
Fig. 1 to Fig. 6 illustrate key activities of a product development cycle which is relevant to a certain style. From Fig. 7 to Fig. 13 illustrate additional features of this AR-enabled tool. When sample machinist wears the AR glass to begin the sewing process, it detects the user with the aid of a facial recognition system. This facial recognition system will be placed in the relevant machine. This will help to track the working hours of the sewing operator to calculate their payroll.

Printed Techpack

Fig. 1. Identifying tech pack details and design

After identifying the operator, the next step is to identify the style and tech pack details. For that, the operator should scan the QR code of the tech pack, or else particular tech-pack can be assigned to an operator by the supervisor using the system. Fig. 1 shows the QR code printed on the tech pack to be recognized using the AR glass. When scanning the QR code on the tech-pack, all the details of the style input to the system to initialize the prototyping tasks. According to the interview data, intimate bras are complexed in assembly, and that will even more complex when it involves several accessories. This AR tool will visualize each operation with the required accessories to achieve the right quality in the first attempt.

After recognizing the style, next step is to identify the relevant machine to be used and set up the machine according to the correct operation. That can be performed by



QR code is printed on the machine

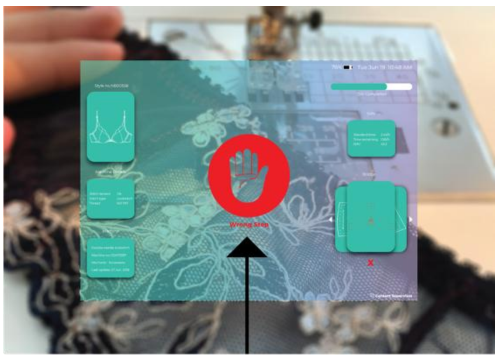
Fig. 2. Machine and machine settings identification

scanning the QR code available on the sewing machines. Fig 2 shows the QR code printed on the machine to be recognized. As such, the operator can adjust the machine according to the requirements of the product design. The machine settings and requirements have already included to the system when scanning the QR code of the tech pack.

Pattern Pieces

Fig. 3. Verify Cut-kit for missing and incorrect pieces

Fig 3 indicates the next step, that is to verify the cut-kit. In this step, the machinist checks the given cut-kit for missing pieces or incorrect cut shapes and sizes. Subsequesntly, the system will provide the garment costruction details, correct way of assembly at each seams and quality points in AR format. Like wise, AR glass guides the operator and direct for correct prototyping process with least supervision.



Indicating Wrong Steps

Fig. 4. Identifying incorrect operations

Fig 4 indicates the next user screen which guides the correct way of product asssembly, therefore it indicates incorrect operations real-time and guides the operator to correct them.

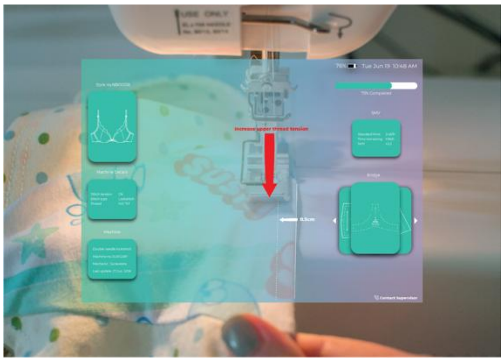


Fig. 5. Identifying quality defects relevant to stitching

Fig 5 shows relevant instructions to educate on quality defects which are relevant to current operation. The system indicates quality points of the seam including misalignments and missed stitches at each operation. At the end sewing, the system guides to review the final sample by indicating necessary quality points. Fig 6 shows an example of certain risk points to be checked by the operator at the completion of the smaple. The quality checker can visualize the check-list of quality points and that will be guide to screen the quality defects of the garment.

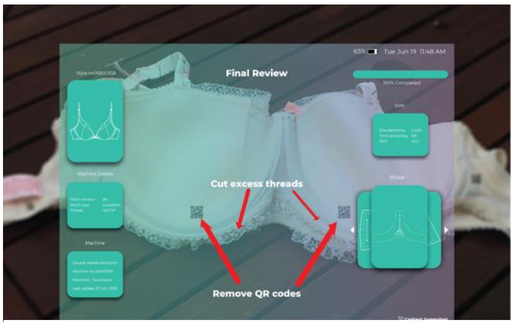


Fig.6. Final review

Design sketch and the style code will be displayed at any stage of the sewing cycle. This will provide an overall picture of the product design and necessary accessories used in the product.

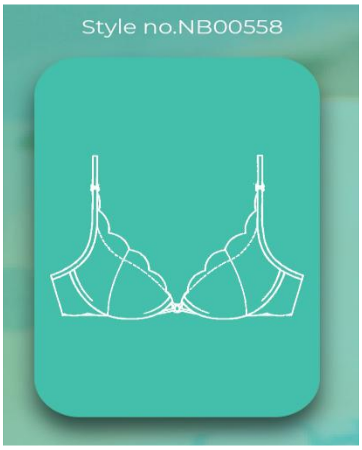


Fig. 7. Design sketch in AR format

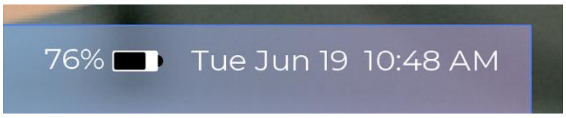


Fig. 8. Battery level, Current date and time

Furthermore, some other screens can be designed (Fig 8) to indicate system settings such as battery level of the device, date, time, and also the the level of completion of the sample. This will help the operator to plan the end time and provide a self-evaluation.

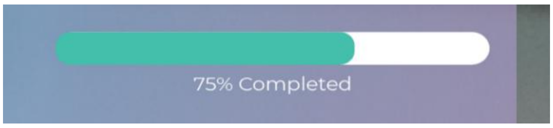


Fig. 9. Level of completion

This component visualizes the piece currently sewing. If necessary the operator can scroll to see the previous piece and the next piece. When the sample is sewing piece by piece this is scrolling automatically and visualize the current piece.

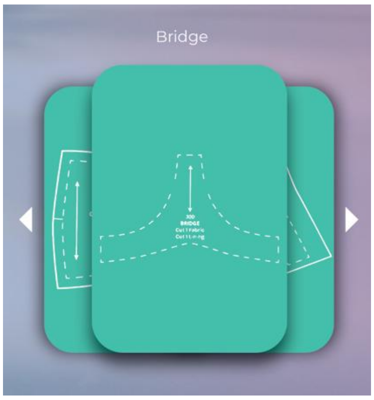


Fig. 11. Current sewing piece

Fig 12 shows an examples of the screen which indicaes machine details. This feature provides the details of the machine currently used. For an example, machine type, machine number, relevant mechanic, last repaired date of the machine. This will facilitate the operator to get the assitance of the machanic whenever necessary. Moreover, a simiar screen can be used to depict the required machine setting. That will guide the machinists to adjust the necessary machine settings correctly by their own.

Fig. 12. Machine Details

Here the system displays the SMV (Fig. 13) relevant to current assembly. This provides the allocated time to sew the sample and the remaining time to sew the sample.

Fig. 13. SMV Display

The interview participants highlighted the importance of a visualized technical guide to demonstrate the required technical details relevant to the product design. This proposed tool is useful in training and development purposes as all the operations are demonstrated with graphics and relevant simulations. This AR tool will be a totally new experience for the relevant NPD value chain partners as there was no such applications exist in the context of apparel. Most of the participants did not realize such tools for apparel manufacturing in the first phase of the study. Nevertheless, they were convinced on the proposed AR tool after seeing the prototypes of the proposed AR guide. This proposed method requires a lack of manual supervision as all the guidelines are provided in the tool. Therefore, prototyping errors will be minimized at the end of the sampling process. Even though this proposed tool focused on product assembly, this can be further developed to other product development activities as well.

In the proposed method, machinery identification and garment component identification will be established using QR codes. Then the proper databases need to be maintained in order to generate QR codes. Graphics and simulations should not distract the user while performing the operation. The user interface should be user-friendly as this tool will be used mainly by sample machinists. Need to include more graphical tools/ icons rather than texts to avoid user-friendliness of the proposed tool. In addition, voice commands can be used to indicate when the operator follows incorrect process steps.

VI. DISCUSSION

The purpose of this study was to introduce an AR-enabled tool to be used by the NPD team and the sample manufacturing team to reduce prototyping errors. With support from this kind of application, the designer will be able to transfer product design and construction details to the sample manufacturing team effectively. As there were no such AR based applications in the context of apparel, researchers inspire such technology from the other manufacturing industries. Also, all the requirements stated by the industry participants have been included in the prototype of the proposed AR tool. Furthermore, the prototype of the AR tool was validated using the second phase of the study. As a whole, such AR tool will be useful to train sample machinists and other direct workers in the organization.

VII. FURTHER RESEARCH AND DEVELOPMENTS

According to the interview findings, some key factors were highlighted for further research and development. Placing QR code to identify the face and back side of the panels can be damaged the cut panels. Therefore, it is better if there is any other mechanism of identifying the face and back side of the cut panels. The graphics and motions using in this system should not distract the sewing operator while stitching. Therefore, user-friendly display screens, non-distracted simulations and graphics should be included in the system. Instead of displaying the full time allocated to sew the whole sample, it is better to divide the whole assembling task into small assembling tasks and display time for each assembling task. Standard notifications and audio guiding system should be included in the system to get the sewing operator`s attention to the incorrect operations and product defects.

VIII. CONCLUSION

This study highlighted the product errors which caused due to miscommunication and misinterpretation of design inputs. Subsequently, the research reviewed the feasibility of applying AR technology to mitigate prototyping failures. Finally, the detailed guide has been developed to create an AR-based wearable technology by the content creators. The proposed AR tool will be a digital tech- pack which provides all the necessary details to the manufacturing team effectively. Therefore, it will minimize the design to manufacturing errors and promise high-quality products. The limitations of the proposed AR tool were identified during the second phase of the study. This proposed wearable technology is not recommended to use while direct stitching period. Before performing actual sewing operation, this proposed tool provides necessary instructions to product assembly. The findings of this study are important to various stakeholders in the new product development domain including product designer, product developer and manufacturer. It is contended that AR technologies will be an enabler for the apparel industry to minimize the failures in the product development process.

In conclusion, this study shows the potential digital applications in the apparel manufacturing to be further developed and equipped in near future.

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