The Study of Developing Innovation on Technology-Enabled Design Process

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Abstract. The worldwide industries are pondering how to redefine the domain they belong to. The industry, by taking views from functional approach, has shifted from "What equipment is doing" to "What equipment is representing?" Therefore, from the status of the equipment itself, the instant visibility of the design, to the data of the first-draft, etc., all these elements are required to be united, communicated and innovated. The philosophy behind this study is "technology alignment, product innovation, and service integration." It will introduce research and development applications such as interconnection with 3D software, etc., which means to apply the "Virtual-design System" as its conceptual foundation and to reach cross-domain applications in conventional industries with animation tools, such as iClone and Clo 3D. Hence, it allows free communication between science and technology, humans and machines, people and people. With the help of the cutting-edge equipment of digital process in production line, it innovates design process. To save time and cost of design and creation, by applying technology alignment and verification, the innovation process will become a complete medium for just-in-time customization. The design will no longer be fettered by complicated and tedious techniques. Designers can realise his original contents by utilize various materials and technology to express their ideas more effectively and efficiently. Further, the conclusion by the applications with Clo3D and iClone technology, accelerates design innovation mechanisms, speeds up production and delivery while instantly meets customer satisfaction with "Virtual communication production;" therefore, enhances the design services.

Keywords: Virtual-design · Digital process ·
The instant visibility of the 3D design · High customization

1 Introduction

1.1 Fashion Industry Status

Innovative design and management are common in international fashion brands. Development models constructed in response to the trends and difficulties in the

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fashion industry are not limited to application solely in fashion design fields. Focusing on creating original interdisciplinary products on the basis of the brand's image and value, international fashion brands are integrating art, technology, and culture to customize services and reach out to consumers through diverse methods. This approach not only impresses consumers but also enhances brand value.

Although fashion products are rich in cultural and artistic elements, fashion design is time-consuming and complex. However, designers have to produce collections twice a year to keep up with trends. From the setting of a theme to fabric planning, product planning, pattern development, style development, and series sampling, innumerous iterations of the process of trying on, adjusting, resampling, and readjusting are required. When the designs of the garments have been finalized, processes including promotion, photographing, dynamic and static exhibition, order receiving, stock preparation, production confirmation, and shipment are required for the final product to reach consumers. Despite stagnant global economies, fashion designers must still launch a new collection every season, which is highly costly. Designing apparel can itself deplete a designer's resources. Moreover, designers have to market their products and increase their popularity by holding fashion shows or attending international fashion shows [1] in addition to selling their products through consignment, online shops, and brick-and-mortar shops. Because of the environment and their limited resources, designers worldwide are confronted with the challenge of survival and development. Therefore, solving the problem of lengthy and costly development processes is a critical issue for the global fashion industry.

1.2 Emerging Virtual Design Technology

Fashion design and the practice of making garment samples is a highly professional field that requires interdisciplinary techniques. Computer-aided design (CAD) systems and computation technologies for fashion design have long been developed. In 1990, the first accurate garment simulation application was developed, with many complementary technologies being considered in addition to fabric simulation [2]. Among the technologies used are body modeling and animation [3] and fabric layers [4]. One study used geometrics to process grid positions and speed [5]. In recent years, each specific system has been successfully integrated into separate stages of product design processes. Three-dimensional (3D) virtual simulation software has advanced to the point that it can simulate realistic effects of products to reduce or eliminate lengthy time spent sampling and without needing to create actual garments. The simulation software provides an opportunity to view a design or produced pattern in a 3D environment immediately during virtual garment sampling and fitting [6].

Because CAD has been an advanced technology in the field of garment design, research institutes and manufacturers worldwide have endeavored to integrate 3D garment virtual simulation software with fashion design, patterning, sewing, printing and laminating, and other production tasks. Computers have been used to simulate the entire garment production process. Well-developed 3D scanning and human body data analysis and processing have been combined with management applications and 3D design of garments. Through the combination of multidisciplinary theoretical knowledge and multiple technical fields and methods, a digitized model has been established

for constructing and simulating fitting and garment demonstration [4, 7]. Virtual garment fit technologies were first developed in western research. Example systems include MIRACloth developed by MIRALab in Switzerland, the virtual garment fitting software developed by the Fraunhofer Society in Germany, the cross-platform system developed by those companies of PAD producer in Canada, the E-Design system developed by lectra in France, and the virtual fitting room jointly developed by Gerber and Browzwear in the United States [8]. Companies in various countries continue to develop advanced 3D software for the virtual garment fitting; for example, PGM 3D Runway in the United States and CLO3D by CLO Virtual Fashion in South Korea. Although the 3D Runway has stronger application functions and more refined settings than other software, CLO3D has easy and intuitive operation to facilitate learning and comprehension; moreover, the garment sizes and virtual contour effects in CLO3D are close to those of real garments [9]. Among the numerous software programs, CLO3D is an outstanding technical software package that provides complete garment simulation, high-quality fabric simulation editing, and technical effects, imitating garment manufacturing [10, 11].

Fashion designing is a charming, diverse, and large industry. During the process of fashion design, each step from patterning to material selection, size measuring, sewing, and sampling requires repeated revisions and approvals, which is extremely time-consuming. In the increasingly challenging global economy, strategies tailored to current market or industrial needs and involving 3D virtual simulation functions are crucial to achieving rapid improvement in the fashion industry. CLO3D virtual design technologies enable simultaneous 2D and 3D simulation. Users can immediately see the effects of pattern, color, texture, and detail revisions [12]. During the design process, software users can examine and revise the style and fit of a garment quickly. This reduces the preparation time required for designs. Existing modules can be used for combinational design. Users may also swiftly design garments on a virtual model to produce garment patterns automatically. This is a near zero cost method and creates numerous possibilities such as the generation of patterns, color set samples, pattern and print alignments, and layouts. Immediate examination of the revisions to 3D garments can reduce the number of unnecessary processes and transportation costs that are required in actual sample creation. A reduction of the production time leads to lower costs. The process from sketching to 3D virtual simulation and the sampling and production of finalized products is illustrated in Fig. 1. The proposed design method not only overhauls the materials (e.g., paper, brushes, and pigment) required from those in traditional design drawing but also considerably reduces the patterning, sampling, and material costs. Using the CLO virtual design technology to develop designs can save time and money and enable fashion designers to create products of higher quality [13]. In addition, options including concept communication, explanation, color, fabric, print pattern, and design styling provide opportunities for fashion designers to innovate and be more creative.

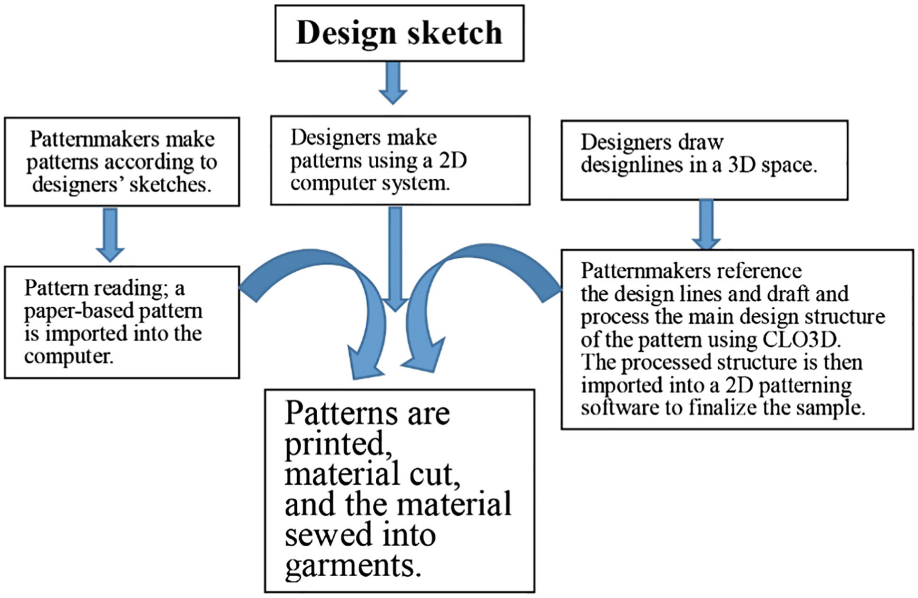


Fig. 1. Process of 3D sampling

1.3 E-Marketing in the Fashion Industry

In October 2018, the 30th anniversary of its founding, the luxury fashion retailer I.T (ithk.com), headquartered in Hong Kong [14, 15], declared for the first time that future digitization of the fashion industry is a keynote idea. I.T requested digital fashion companies to create a new promotional collection symbolic of its 30 years of devotion to the Chinese fashion industry. The promotional collection was designed by brands such as Marques Almeida, Helmut Lang, and Alexander McQueen. Customers can only view digital forms of the products before purchasing them in I.T concept stores. The collection was presented in a 60-s film made by The Fabricant and through static images obtained using CLO3D. This method of presentation indicates that virtual and digital technologies will lead e-commerce in the 21st century. A trend has formed for the use of applications that enable fast communication and visual garment revision by incorporating relevant virtual software. Such applications solve cost and time problems for the fashion industry. Under the momentum of Industry 4.0, design, production, and marketing are commonly being performed using virtual approaches to communicate advanced concepts. The integrated application of CLO3D and other animation software packages has resulted in the novel concept of garment customization within micro factories. The demand for such applications and concepts is increasing [16].

2 Research Process

The research framework had three steps. Step 1 involved a review of the literature to analyze the fashion trends and status quo of digital software in practical operations. Step 2 involved design development based on original themes. Step 3 involved verification of the process from designing to sampling. The benefits obtained using the process and the comprehensive procedural analysis were used to make suggestions for optimizing innovative design and production processes.

2.1 CLO3D and Key Integration Software

The CLO3D, Alembic Importer, and iClone 7 Pro 3D software tools were considered in this study.

CLO3D. This tool has various functions useful for fashion design, including drawing high-quality curves, partial sewing, free sewing, folding, and inserting flexibility effects. The drawing tool can be used along with 3D patterning and cutting. The physical properties of fabric are digitized and parameterized to facilitate the editing of fabric flexibility, cutting, curvature, friction, density, and thickness to simulate the textures of different materials. Various functions, such as examining points of contact and fabric pressure, can be used to measure the fit of a designed garment to a model [9] to achieve accurate fitting.

Alembic Importer. The objective of using this software is to completely display the detailed fabric simulation effects of CLO3D in iClone and further optimize the instantaneous display performance. In addition to fabric simulation, the Alembic format is suitable for processing various types of dynamic and static topological grid information such as fluid and particle effects. Use of this function enhances integration with other mainstream tools of the fashion industry.

iClone 7 Pro. This is a 3D animation software package that can be used to create 3D animations by integrating various fine art materials, movement performance, and lighting effects. It also exports various technological materials for the development of other digital content (e.g., virtual reality and augmented reality).

To clarify the process through which these integrated software tools can be applied, this study analyzed the contexts of the 3D digital software tools. We estimate that during the design and technology application communication process of CLO3D, few scholars have proposed the concept of integrated design, customization, and microfactory production from the perspective of the designer as the innovative organizer. This study employed innovative and practical methods in the design process by importing virtual and digital technologies as a solution to problems in fashion production processes. Table 1 shows the research steps of the design process and software integration application.

Table 1. Steps in the research methods

Research	Steps
1	Literature review of key concepts related to the application of CLO3D and iClone in production processes and product demonstration
2	Learning of software tool application (added-value application) technologies and suitable software integration applications
3	Create the design structure of "real-time virtuality" and actual sampling procedures
4	Verification that original content is convertible into visualized fashion design proposals and innovative sampling processes
5	Concept connection, design simulation, product sampling, demonstration, and experience of interactive virtual reality
6	Construction of innovative work models of the "cyber-design process" serving as the reference for the industry, government, and academia

Source: this study

3 Framework for Studying the Virtual Design System

3.1 A Design Services of a Real-Time Virtual Design Model

Using the communication of CLO3D, the author proposed a real-time virtual design system structure that integrates multiple software tools (Fig. 3). The system combines CLO3D, Alembic Importer, Character Creator, and iClone to facilitate product design and sampling and is an example of an innovative fashion production process. The potential users of the system include designers and design customers. Through the real-time virtual effect, users can complete communication and revision without wasting time and money. The proposed system structure focuses on the operation sequence and technologies between the users and software as well as the sequence between software applications and the production processes. The new process improves the development and communication methods in traditional design, providing designers with the ability to customize garments in detail. Designers can thus design freely, unlimited by materials and technologies. Multiple concept generation and real-time communication can enhance the essence of design services, freeing fashion designers from their previous constraints. In future, real-time and effective communication methods can help create new work modes of design in the fashion industry. Advancement of multimedia technologies and interpersonal and human–machine communication and cooperation can promote increasing the application of interactive designs in innovative demonstration.

3.2 Unified Procedure of Design Production and Showcasing

The method used by designers to express an original concept involves their overall conception of the garment. Garment showcasing is a method of presenting a designer's

ideas and is thus necessary for converting designs into fashion products. In addition to having aesthetic value, effect drawings demonstrate a designer's intentions regarding their design. Accurate comprehension of the structure of a fashion design can help turn the drawing into a physical garment. Therefore, creating high-quality effect drawings is a requirement before interaction between designers and customers. Additionally, it is a critical problem in fashion design.

Traditional 2D drawings often neglect the rear and lateral views of garments, as well as the aesthetics when the garment view is turned from the front to the back. The powerful 3D virtual simulation performance of CLO3D enables designers to create complete, 3D fashion designs. The software is also convenient for designers, pattern-makers, and consumers because it can display eye-catching designs created by changes to pattern structures. This study examined how garments are created. The first stage focused on the development planning of original content and established figure model dimensions. The key software technologies and the application of future product showcasing were then evaluated. This study secondly analyzed the functions and technical aspects of CLO3D, CC, iClone animation, and plug-in software tools that facilitate practical learning and operation. The tools were then integrated to form a digital tool for idea conception, design planning, construction and showcasing of 3D patterns, real-time virtuality, and cyber-design processes. As well as, convert into a plug-in for iClone to construct dynamic and static figure models according to the garments' characteristics and styles. (e.g., personality and posture) The unified tool can be further integrated with interactive virtual reality to construct an integral part of the fashion industry ecosystem. The predetermined procedure is illustrated in Fig. 2.

4 Real-Time Design and Work Procedure

The process from virtual fitting and revision to practical sampling emphasizes consensus on humanistic theme exploration, followed by software technology examination. Because CLO3D can simulate garments realistically, designers can revise and design patterns in a 2D right-side view. After pattern revision is complete, the result can be previewed in 3D left-side view instantly. Garment fit is crucial to fashion design; therefore, placing garments on virtual models and viewing from multiple angles can serve as an effective reference for reviewing the designed garments. With 360° observation of a garment, designers, customers, vendors, and technicians can identify more defects in the design. Revisions can then be immediately made to improve the garment design. The steps with which innovative design can be implemented using a unified design and showcasing process are detailed in the following sections.

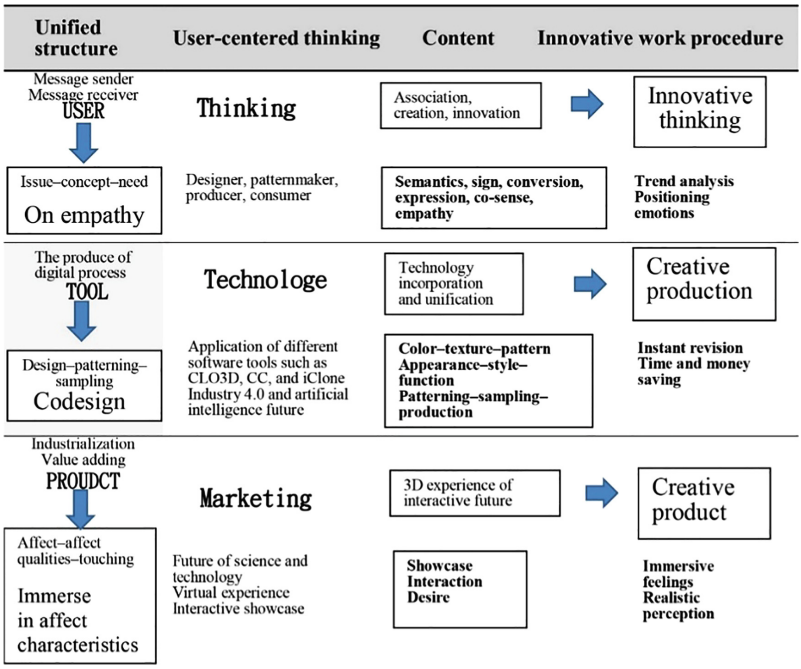


Fig. 2. Unified work modes of cyber-design processes to marketing

4.1 Creative Thinking—Original Content Converted into Design Elements

See Table 2.

Table 2. Thematic elements and patterns

Item	Content
Creative thinking Theme (concept) Color (image) Appearance (pattern form)	1. Taiwanese mountain landscape patterns: Inspired by an old song, *Qing Chun Ling*, which describes birds, red springtime flowers, bees, herbs, and wings. Like the song, the patterns describe the flow of youth and freedom. 2. The graffiti spirit of the youth never dies. From one end of the street to the other, spirits and fashion monsters look for sprouting contexts, becoming the new-generation contexts and textures of Taiwan.  a  b

4.2 Practical Operation of CLO3D Pattern Production Process

See Table 3.

Table 3. Pattern and garment design and print simulation

Item	Content
2.Creative production	1. Sample drawing: 2D garment patterns are drawn in the right-hand window to fit the human model. Digital information is displayed in the steps presented on the left sample. a. In CLO3D, design drawings and 2D patterns are created.  a b. Placement of sample: After completion of sample drawing, "synchronization" is activated. The pattern is displayed in the left-hand window. Users can then select the "point alignment" mode to align surrounding sample pieces. The sample on the left is a better fit to the model. c. Sewing: Smart sewing tools are selected to perform virtual sewing along the shoulder line, lateral line, and segmentation line of the front and rear patterns. d. Revised pattern 2. Pattern sample design: a. Pattern design Photoshop/Ai is used to process and edit patterns [2]. Fashion design requires personalized effects, and fabric pattern design is the key element. When designing fabric patterns, fashion designers tend to borrow from art graphics or modern images, signs, or markings. They then simplify and summarize the patterns. The use of computers can greatly increase their work efficiency. b. Digital print pattern output The designed CLO3D fabric pattern is edited into fabric samples. The density and pattern size of the cloth are edited to sufficiently express the art effect of the garment.  a 3. Print simulation: The left-hand picture is a manual illustration. The picture in the center is the 2D sample, and the right-hand picture is a 3D preview of the garment on the model. In addition, in the virtual garment showcase, the virtual model displays the design effect simultaneously. Discarding unfavorable designs during the design process limits development costs and shortens the development period. Plug-ins and iClone animation software can be used to distribute a virtual showcase through the Internet, facilitating dynamic display of virtual fashion designs and combining design and marketing. This CLO3D intuitive garment showcase method is different from the traditional plan symmetry fabric design in terms of pattern application. Thus, the proposed method is suitable for highly customized designs. The pattern arrangement can be adjusted according to customer preference and at any time.

The author also discovered that when the proportion of the sample in the right-hand window is correct, marking can be used to edit the pattern and position it optimally. Set patterns can be adjusted by changing the pattern size. Thus, pattern designs and print patterns can be printed once to create innovative digital print patterns, thereby saving money, time, and materials. Reflective items, Perler beads, and embroidered accessories can also be appropriately positioned.

a

4. Pattern design and virtual fitting

a.3D pattern design and pattern mapping

Digital print patterns can be arranged in the preferred manner and marked before being printed out.

Source: this study

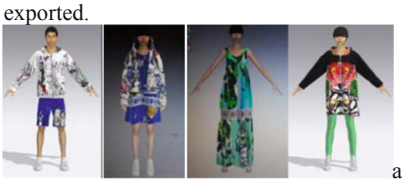
4.3 Creative Product—Simulation Design and High-Order Practice

See Table 4.

4.4 Innovative Showcase: CLO3D-Based Fashion Design and Added-Value Application of Digital Animation

Based on the cyber-design system, new digital technologies were explored along with CLO3D, iClone, and other augmented reality and virtual reality software applications. The Alembic plug-in tools are suitable for processing dynamic and static topological grid information [8], such as fluid and particle effects. Import of this function can improve the iClone function as a comprehensive instant animation tool, as shown in figures below. iClone was used to create animal-faced characters, postures, and runway paths for innovative product marketing and showcasing.

Table 4. Virtuality simulation and sampling procedure

Item	Content
3. Creative products High-order 3D practice based on simulation try-on designs	CLO3D offers fast and stable virtual simulation, instantaneous revision and preview, and simulation of the textures of different materials. Different functions can be used to measure garment fit to the model. Designers can draft the design and set model sizes and postures and render the draft in the preview mode. Detailed effect simulation is also available, such as wrinkles, tension, folding, ironing lines, multilayer garments, jackets, and coats. Multilayer garments including hoods, jackets, and stuffed jackets can also be simulated. Because the simulated garments have realistic details, a design can be changed at the last minute if the market or customer demands change. After approval of the design, the sample and printed patterns are exported.  a Simulation  b Sampling

Source: this study

Fig. 3. The design of the runway paths and innovative characters

5 Conclusion and Suggestion

5.1 From User-Centered Thinking to Simulation and the Actual Production Process

In the design and development procedure of the fashion industry chain, design planning and pattern design are the core elements of product development. Although various digital application devices are available, the processes of drawing communication, patterning, printing, and sampling have not been integrated. Interdisciplinary cooperation is common in the fashion industry; however, integration of technology into the industry's production processes is currently primitive. Multiple software technologies

and design practices were integrated with instantaneous virtual design to present products immediately to the customer. This method enables rapid communication, immediate adjustment, and precise revision, thereby reducing the time and cost of repeated communication on colors, shapes, patterns, and sampling and optimizing service applications for high-order customization. Users can be designers, pattern-makers, customers, or customers with customization needs. User operation interfaces are simulations on software applications. With the combination of virtuality and reality, simulated human figure or model forms and the physical properties, style, and print of the garment can be adjusted in accordance with user and designer needs and communication. The size, proportion, and position of the elements can also be adjusted anytime to reduce the time required for sampling, increase the communication efficiency, and improve the existing work sequence. The proposed system can be used by the designer, producer, and user because it combines virtuality and practice. The system conforms with user-centered design thinking. It facilitates barrier-free communication, revisions, and cocreation designing through digital simulation tools. By decreasing the gap between imagination and reality, designers can strengthen their connections with customers and those with customization needs, creating a new market trend.

5.2 Optimization of Highly Customized Service

1. The system reduces the time designers spend on planning drafts and that pattern-makers spend on communicating with customers, effectively shortening the process time.
2. Instantaneous arrangement function combined with print patterns: The 3D garment fitting simulation function facilitates timely revision according to customer needs, optimizing communication over digital prints and the materials used.
3. Instantaneous design assists communication, solves the complex work procedure problem in traditional designing, and improves design processes. Simulated fabric patterns can be placed on animated runways with realistic features (such as garment movement) to help marketing and product showcasing. The innovative process becomes a real-time customization process that enables consumers and developers to satisfy their desire for smart communication in production and customization. The mode can be used in future client-to-client interactions to expedite the development of design innovation and innovative marketing.

5.3 Environmentally Friendly Process Integration

Using the proposed process to create a garment saves one-third of the amount of fabric used in marking. The time saved in the production process was four times that in the traditional process. To ensure the innovative process runs smoothly, the operations of pattern designers, sample makers, and the digital software are required. The traditional process of making a dress from patterning to sampling and production takes approximately one month or longer (depending on the complexity from size measurement to design drafting, patterning, sampling, fitting, revision, and sample delivery). Using

CLO3D, the process took only 27 h from size measurement to 3D design, 3D simulated patterning, 3D simulated sampling, pattern/print approval, pattern export, and sample creation. The sample acceptance rate was 55%, with a sample creation time of approximately 7 days. The proposed method substantially reduced the time designers spent on planning drafts and that patternmakers spent on communicating with customers, effectively shortening the process time.

6 Recommendation for Innovative Fashion Production Processes

6.1 A Garment Design Database Can Be Established

The interdisciplinary empirical results of this study verify that the proposed innovative design and showcasing process can serve as a reference for the fashion industry and relevant academic collaborators. Designers can use Gerber or Lactra patterning software to input their original concepts into CLO3D and arrange patterns in the correct positions in the 2D window. The design pattern size can be adjusted in the 2D window to determine the visual effect of the garment. In the 3D window, sewing and pattern adjustment can be performed and a preview of the design is displayed. Once the design pattern is approved (a garment design database can be established simultaneously), the pattern to be created is exported. Photoshop/AI image layout software is used to adjust the print pattern and marking. The process not only saves materials used in printing but also enables unified export of products with customized prints, customized patterns, or both. Eventually, the proposed system can provide services for fabric developers, fabric vendors, illustrators, artists, galleries, and customers with customization needs while creating a relevant image database (Fig. 4).

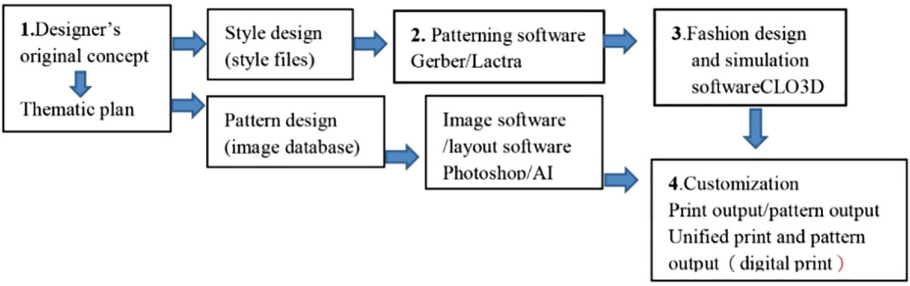


Fig. 4. Fashion design sampling process

6.2 A Digital Marketing Is a Precursor Viewpoints

The second suggestion of this study regards digital marketing and the showcase of fashion concepts. Designers first input their original ideas into Character Creator in iClone 3D to create 3D virtual human characters with varying appearance. The

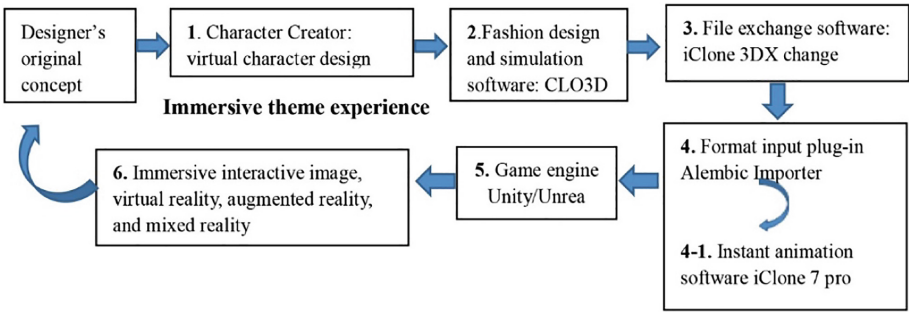


Fig. 5. Process of fashion concept digital marketing

characters are then sent to iClone (with one click) for movement addition. The characters and character movements are sent in .fbx format to CLO3D for garments to be added. The characters with garments then perform movements. The dynamic simulation results (with garments of the designed patterns on the virtual characters) are then calculated. CLO3D is used to export the characters and character movements in .fbx format to 3DXchange*, which then exports the outcome in .iProp item format. CLO3D is then used to export the dynamic simulation results in .abc (ogawa) format. The .iProp item containing the characters, character movements, and garment data is input into iClone. The Alembic plug-in of iClone is used to simulate the dynamic fabric simulation results in the .abc file. The movement and material dynamics of the virtual characters are consistent. The animation resulting from the Alembic plug-in can be used by Unity/Unrea to create immersive interactive virtual reality, augmented reality, and mixed reality images. The service targets can be virtual runway shows, interactive experiences, precursor viewpoints, concept marketing, and other media output related to project proposals, design concepts, expected development, popular projects, animation marketing, event experience, and fashion design (Fig. 5).

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