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Digital Display Design of Children's Wear Based on Meta-Verse Technology

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Abstract

The meta-verse utilizes the integrated development of various new technologies to strengthen the fusion of real life and virtual reality, promote the digitization of real-world scenarios, and make life more efficient and convenient. At present, consumers have generated information needs that surpass those displayed in traditional online shopping models. To cater to the pursuit of fashion by consumers in the new era and satisfy their expectations for digital visual experiences, the introduction of digital technology for innovation and the use of metaverse technology to digitize and display children's clothing can meet the actual needs of consumers. This paper conducts a rational analysis of the realistic opportunities for the digitization of children's clothing. Through a deep analysis of the technical dimensions and application perspectives of the meta-verse, it conducts an analysis and design practice of the digital application of children's clothing from a consumer perspective. Finally, it summarizes the application value of meta-verse technology in the digital design of children's clothing, verifies the feasibility of the UE5 engine in virtual clothing displays, and provides an outlook for future research and applications.

Keywords: Meta-Verse Technology, Digitization of Children's Clothing, 3D Display

With the rapid development of emerging digital technologies such as big data, blockchain, and artificial intelligence, the digital economy has become an important global economic form, bringing new opportunities, new formats, and new directions to the apparel industry. As the continuous integration of meta-verse technology and life promotes the digitization of more and more real-life scenarios, it subtly changes the way of life of the public and makes consumers have new pursuits for online shopping experience. The apparel industry needs to actively explore digital transformation, combining intelligent manufacturing, smart factories, and digital technology innovation to gradually improve production processes and achieve data-driven and digital operations. This transformation will promote the rapid integration and development of new-generation information technology and the textile and apparel industry, enabling enterprises to better cope with market challenges. Through digital transformation, apparel enterprises can improve production efficiency, optimize supply chain management, achieve personalized customization, and improve consumer experience, thereby achieving sustainable development of the industry. This has gradually integrated factors such as personalization, technology, and environmental protection into the fashion industry. Meanwhile, with the rise of the "Meta-verse" concept, the fashion industry has begun to gradually form the basic prototype of its virtual fashion environment.

Many well-known apparel companies are leveraging cooperation with electronic games and virtual social platforms to create, promote, and sell products. Important breakthroughs have been made in areas such as the interactive transformation from 2D to 3D, digital simulation technology, and virtual reality technology, driving the digitalization of product and brand marketing, reducing production costs, and establishing the brand's own differentiated advantages.

1.Opportunities for the Digitization of Children's Wear

The 52nd "Statistical Report on the Development of the Internet in China" shows that as of June 2023, the number of online shopping users in China has reached 884 million, an increase of 38.8 million from December 2022, accounting for 82% of the total internet users. Online shopping has brought great convenience to consumers. However, when shopping for clothing online, online merchants usually only provide flat model try-on images and text descriptions, with less involvement in special human body data models such as pregnant women, the elderly, and children, which cannot meet the consumption needs of such users and has become one of the reasons for high return rates and low customer

satisfaction. Meanwhile, the apparel industry is facing a series of problems such as insignificant brand differences, weak core technologies, and insufficient innovation.

Traditional design, R&D, and production methods can no longer meet the needs of apparel enterprises, brands, and customers. Therefore, to address these issues, the apparel industry needs to actively explore digital transformation, combining intelligent manufacturing, smart factories, and digital technology innovation to gradually improve production processes and achieve data-driven operations. This transformation will promote the rapid integration and development of new-generation information technology and the textile and apparel industry, enabling enterprises to better respond to market challenges. Through digital transformation, apparel enterprises can improve production efficiency, optimize supply chain management, achieve personalized customization, and enhance consumer experience, thereby achieving sustainable development in the industry. This has led to the gradual integration of personalization, technological advancement, and environmental protection into the fashion industry. Concurrently, with the rise of the "metaverse" concept, the fashion industry is gradually forming the basic prototype of its virtual fashion environment. Many renowned apparel companies are leveraging collaborations with video games and virtual social platforms to create, promote, and sell products. Significant breakthroughs have been made in areas such as the interactive conversion from 2D to 3D, digital simulation technology, and virtual reality technology, driving the digitization of product and brand marketing, reducing production costs, and establishing the brand's own differentiated advantages. By leveraging metaverse technology to digitize children's clothing, consumers can experience three-dimensional, realistic try-on effects without leaving their homes, significantly reducing consumers' trial and error costs and time, thereby enhancing their shopping experience.

		Number of people	proportion
Satisfaction with translation quality	Very satisfied with the translation.	18	36%
	quite satisfactory.	11	22%
	In general	8	16%
	Quite dissatisfied	10	20%
Credibility of translation	Very high	15	30%
	Quite high	13	26%
	In general	14	28%
	Quite low	5	10%
	Very low	3	6%
Does the English translation meet shopping needs?	can fully meet the need.	7	14%
	can meet most of	16	32%
	Satisfy a part of	20	40%
	Quite dissatisfied	4	8%
	dissatisfied	3	6%

Table 1: Translation of Respondents' Shopping Experience and Demand Situation

		Number of people	proportion
Is the effect real	Yes	30	60%
	No	6	12%
	Uncertain	14	28%
Is there a variety of purchasing channels available	Yes	30	60%
	No	9	18%
	Uncertain	11	22%
Is there a comprehensive display of clothing	All of them	10	20%
	Most of them have	15	30%
	Half of them have	12	24%
	A small portion has	10	20%
	None of them	3	6%

Table 2: Online Store Service and Display Situation

2. Methods of Digital Design for Children's Clothing

2.1. Visual Design Based on Online Shopping Aesthetics

Traditional online shopping primarily relies on two-dimensional visual information such as text, images, and videos to display relevant product information on web pages, aiming to attract consumers. However, existing images and videos are often captured using studio or real-world photography methods, resulting in flat images or scenes tailored for models. This approach is time-consuming, economically costly, and has significant limitations. The significance of visual design lies in guiding consumers to associate products with themselves, stimulating their consumption awareness and impulses. Leveraging the technology layer of the metaverse, relevant software for simulating and digitally constructing comprehensive environments can be employed. Through 3D scene construction, spatial computation, and rendering techniques, virtually realistic scenes can be created. Models can then be synthesized into one or multiple scenes, for example, combining a children's clothing model filmed in front of a green screen with a challenging and unattainable snow-capped mountain scene (as shown in Figure 1). In this way, we can transcend the limitations of physical space for clothing display, save time and costs, and create scenarios and atmospheres that align with or transcend consumers' daily lives. This, in turn, stimulates consumers' desire to purchase, thereby achieving the purpose of visual design on the display page.

Figure 1: Combination of Studio Shooting and Virtual Scenes

2.2. Display Scenario Design Based on User Needs

The original intention of display scenario design is to better convey information, showcase products, and cater to consumers' actual needs when shopping online. Therefore, when designing display scenarios, it is essential to first gain a deep understanding of users' needs and habits. For children's clothing consumers, the current two-dimensional display of online shopping has failed to meet people's shopping experience demands. Consequently, constructing a virtual scenario that simulates a three-dimensional real-life setting and placing 3D clothing within it allows consumers to more intuitively and quickly understand how children's clothing behaves under different lighting conditions in a real environment. This significantly enhances the authenticity and trustworthiness of online shopping, thereby stimulating consumers' interest in and willingness to purchase children's clothing. The design of virtual scenarios should possess a certain degree of flexibility, adapting to various occasions suited for different types of children's clothing. By designing display themes, spaces, and timings based on the age group, season, and style of the children's clothing, and adopting a modular design approach, consumers can freely combine and adjust these elements to create highly customized virtual scenarios that perfectly match their needs, ultimately achieving optimal display effects.

2.3. Dynamic Display Design Based on Children's Wear Promotion

The ever-changing technology makes it increasingly difficult for static texts and images to capture consumers' attention. Dynamic displays that integrate 3D animation technology with digital children's clothing models represent an innovative approach that can not only effectively attract consumers' attention but also provide a more comprehensive understanding of the detailed characteristics and dynamic effects of children's clothing. Additionally, the dynamic display design based on digital avatar virtual images creates a unique visual identity for children's clothing brands, enhancing brand recognition and memorability, thereby improving their market competitiveness.

The virtual dynamic display design based on digital avatars transcends traditional webpage advertising formats. Instead, it actively explores the integration with new technologies, presenting "interpretive" advertisements across various platforms. This not only boosts product exposure and awareness but also captures the market among young consumers, strengthening their purchase intentions and loyalty.

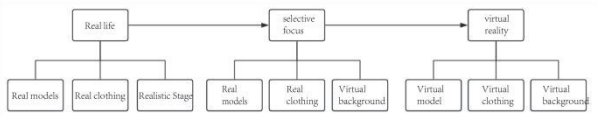


Figure 2: The Emergence of Virtual Clothing Presentation

3. Digital Design Framework for Children's Clothing Based on Metaverse Technology

3.1. Basic Technology Layer

• Holographic Projection Technology

Holographic projection technology utilizes the principles of optical projection to project dynamic images onto projection media through specialized light sources, enabling viewers to immersivity appreciate the images in space1. In fashion shows, holographic projection technology projects virtual images onto the actual stage and integrates them with stage design to create unique visual effects. Through holographic projection, designers can showcase the details, texture, and fluidity of clothing, allowing viewers to more intuitively experience the beauty and design concept of the clothing. Additionally, it enhances the three-dimensionality and sense of space and time on the stage, creating a stage atmosphere that blends reality and illusion. For example, in the 2008 spring-summer fashion show in Florence, the Diesel brand utilized holographic projection to create a blue fantasy space (as shown in the figure). Objects magically transformed their shapes, and models walked in this virtual space, as if wandering in a surreal dream. These imaginative designs not only showcased the brand's philosophy but also provided viewers with an audiovisual feast in a surrealist style.

Figure 3: Diesel Brand 2008 Spring/Summer Fashion Show

• Green Screen Compositing Technology

Green screen compositing technology is one of the commonly used techniques in the field of film special effects production. It involves designing a green or blue background at the shooting location and then replacing this background with other images or video materials during the post-production process to achieve the desired virtual effect. In fashion shows, the green screen technology is utilized to replace the background of the model's runway walks with a virtual background, such as simulating different environments to showcase dynamic scenes that match the theme of the clothing. In 2022, "Suihuan Technology," an organization in China's art history, staged a digital fashion show on various platforms (as shown in the figure). This show leveraged green screen compositing technology to recreate a cosmic space scene, allowing audiences to experience the space environment virtually, diversifying and bringing the clothing presentations to life, while also adding a narrative and immersive element to the fashion display.

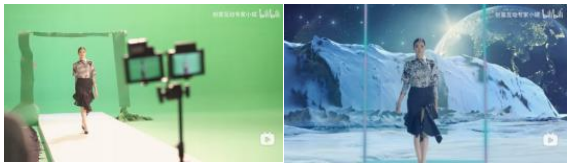


Figure 4: "Suihuan Technology" Digital Clothing Exhibition

• Digital Special Effects Technology

Digital special effects technology encompasses two major components: visual effects and sound effects. Visual effects include digital animation, particle dynamics, visual rendering, etc., used to enhance atmosphere and drama. Sound effects are often used to simulate special sound effects that do not exist in nature, in order to enhance the atmosphere and drama. In fashion shows, digital special effects are usually combined with holographic projection and green screen synthesis technology to create virtual space content, build abstract environments and virtual backgrounds, and further enhance the atmosphere and appeal of fashion shows.

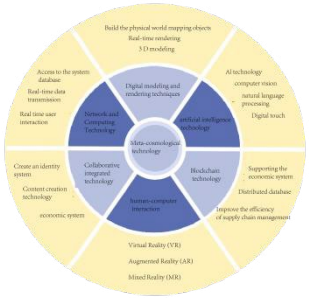


Figure 5: Metaverse technology related to children's wear digitization

3.2. Interactive Tool Layer

Based on the technology layer, the interactive tool layer emerges. By collecting relevant data on physical children's wear, the software serves as a foundation to digitize these physical garments, enabling their entry into the virtual space. Simultaneously, children's wear information and user data are integrated and mapped onto a virtual platform, providing a data source for scene setup2, children's wear display, user access, and more. Combined with hardware devices, this layer focuses on new-dimension interactive experiences rooted in metaverse technology, facilitating the seamless integration of physical children's wear and users into the virtual realm.

3.3. Rule Definition Layer

The rule layer explores the reconfiguration of the attributes and relationships among "people, objects, and scenes" in the display of children's wear in the metaverse. It transforms the customer's one-way browsing, selection, and purchasing behavior on web platforms into an interactive relationship in the virtual space where customers can interact with products and even actively create them. "People" refers to customers themselves. Through the mapping and creation of body dimension data, each individual obtains a corresponding character image in the virtual space. "Objects" refer to children's wear, and the reconfiguration of "objects" involves mapping existing information from the real world into the metaverse to reproduce the styles3, materials, sizes, and other information of physical children's wear in the virtual environment. "Scenes" refer to the usage contexts of children's wear. There are two ways to construct scenes in the metaverse: one is to design virtual spaces that are free from real-world constraints in an ideal manner, and the other is to reference reality and reproduce scenes from the physical world4. To immediately observe the real-life performance of virtual children's wear during try-ons, the second approach of reproducing real-world scenes should be chosen to build virtual scenarios. This achieves the reconfiguration of "people, objects, and scenes" from customers to virtual models, physical children's wear to digital children's wear, and real-world scenes to simulated scenes.

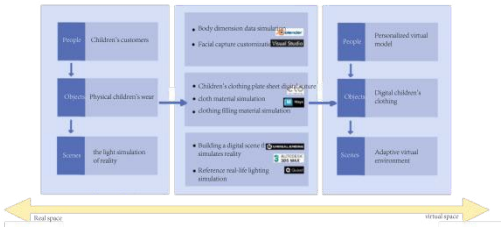


Figure 6: Diagram of the Transformation Relationship Among "People, Objects, and Scenes"

3.4. Creative Layer and Application Scenario Layer

The creative layer and application layer incorporate the inspiration of designers and consumers on top of defined technologies, tools, and rules, blurring the boundaries between consumers and designers. Fischer believes that the introduction of metaverse technology expands the boundaries of design, changes the division of labor in design, and defines the design and technological environment as living entities5. This implies that while metaverse technology facilitates consumers to try on virtual children's clothing online more conveniently and immersivity, it also enables designers to observe the overall appearance of the garment before completing the physical children's clothing, converting 2D design drawings into 3D virtual children's clothing, which is more conducive to the adjustment and improvement of children's clothing.

The current serial state of "buying clothes by looking at pictures" during online shopping for physical children's clothing and virtual children's clothing should be changed to a parallel model of purchasing "physical products + digital collectibles". Virtual children's clothing will exist permanently in consumers' online wardrobes in digital form, and can be easily accessed and paired with existing or intended purchases for observation. Furthermore, with the support of metaverse technology, the traditional model where designers solely undertake design work is altered6. Encourage users to become co-designers of content by utilizing system functions7. The engagement of users in virtual children's

clothing can be enhanced through a "customizable" approach, allowing them to mix and match different ready-made virtual children's clothing options during shopping. This immersive styling experience transforms customers' purchasing desires from "individual pieces" to "complete outfits." By presenting a range of children's clothing elements, colors, or materials within reasonable limits for consumers to choose from, we can significantly satisfy customers' demands for merchandise and their pursuit of personalization.

4. The Path of Digital Children's Wear Design Based on Metaverse Technology

The advantage of children's wear design based on metaverse technology lies in creating a new business model, shifting the limited two-dimensional online shopping model into the three-dimensional space of the metaverse; expanding the design and display of children's wear, breaking through the real space and the constraints of existing virtual fitting rooms on equipment; and endowing new commercial value by making digital content a part of the product, thereby giving it a certain value and significance. The design based on metaverse technology can be divided into five levels from bottom to top, namely, the technology layer, the tool layer, the rule layer, the creative layer, and the application layer8.The technology layer serves as the foundation for children's wear design and presentation based on metaverse technology, providing technical support for other layers, enabling personalized design of virtual models, production of virtual 3D clothing, and construction of virtual scenes. The tool layer emerges from the content generated by the technology layer, focusing on new dimensions of interactive experience, helping designers and consumers transition from physical to virtual spaces. During the transformation between real and virtual spaces, the rule layer arises, redefining "people, objects, and scenes," encompassing the shift from real human models to customized virtual models, from physical children's wear to virtual children's wear, and from real scenes to virtual scenes. The creative and application layers blur the distinction between designers and consumers, allowing consumer participation. Consumers can utilize the finished children's wear provided by designers to coordinate outfits on customized virtual models and view the overall effect.

This open access makes online shopping more akin to offline experiences, fostering consumption and transforming consumers' desire to purchase individual items into a desire for complete outfits. Users can leverage designer-provided elements for personalized customization, creating children's wear within reasonable bounds that better aligns with their preferences, significantly satisfying consumer needs.

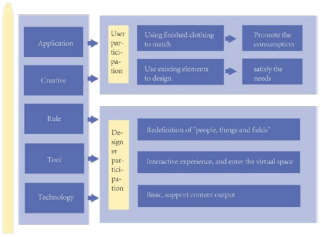


Figure 7: Vertical Hierarchical Relationship of Digital Design of Children's Clothing Based on Metaverse

4.1. Enhancing the Experiential Value of Digital Children's Wear from the Perspective of User Needs

The focus of technical services lies in serving the target audience. The digitization of children's wear aims to optimize customers' online shopping experience. Therefore, when creating virtual children's wear, it is crucial to avoid enhancing the true effects of the garments through technology. Instead, we should utilize metaverse technology to objectively present the authentic effects of children's wear in the real world within the virtual space, emphasizing the satisfaction and enhancement of consumers' online shopping needs. With the aid of CLO3D, we can conduct isometric stitching of children's wear patterns and fill the garments, simulating the authentic thickness and gravitational pull-induced drape in a physical environment. Finally, by assigning corresponding material effects to different fabric types, we complete the creation of virtual children's wear, offering a shopping experience that is more convenient than in-store and more authentic and reliable than traditional online shopping.

4.2. Enhancing the Application Value of Digital Children's Wear from the Perspective of Integration of Virtual and Real Worlds

4.2.1. Design and Presentation of Virtual Models

With the support of metaverse technology, the integration of physical and virtual spaces has deepened further, making the seamless fusion of virtual and real an inevitable trend in the development of digital children's wear. The purpose of digital display of children's wear is to utilize metaverse technology to present products during online shopping in a more authentic and reliable manner, enabling consumers to purchase satisfactory physical children's wear. Therefore, virtual children's wear cannot merely remain in the virtual space but must ultimately return to reality to satisfy consumers' demands in the physical world. Consequently, it is essential to integrate real-life scenarios with virtual children's wear, breaking down the fourth wall between them. To achieve seamless integration of virtual products with real-life scenarios, providing consumers with the experience of trying on clothes in a physical space from the comfort of their homes and enhancing their overall user experience, we can leverage Unreal

Engine's real-time rendering capabilities to create simulated real-world scenarios. Alternatively, we can scan real spaces and recreate them in the virtual world, allowing customers to select virtual clothing and view its appearance in various environments with different spatial layouts, times of day, lighting conditions, and so forth. This approach addresses the limitations of traditional online shopping, where two-dimensional displays cannot fully satisfy the need for a comprehensive understanding of clothing. It also resolves the issue of limited display space in physical stores, which cannot simultaneously showcase a sufficient variety of merchandise.

Furthermore, it tackles the problem faced by both traditional online shopping and physical stores, where customers cannot view the true appearance of clothing in natural environments.

Virtual models belong to the category of virtual digital humans. They serve as a carrier for showcasing fashion designs, and their appearance and performance directly affect viewers' perception of clothing9.It is necessary to design the appearance, body shape, skin color, and pose of virtual models according to the requirements to ensure that they can showcase the characteristics and design concepts of clothing. The expressiveness and realism of virtual models are crucial to the overall display effect. As one of the important carriers of clothing display, virtual models are virtual images synthesized through virtual 3D modeling, animation driving, and rendering technologies, which can replace real models in performing the duty of clothing display.

They play a significant role in subsequent clothing styling and design.

• Key Technical Points of Virtual Model

To achieve a realistic effect, we need to conduct a thorough analysis of the production technology and process of digital character models. This covers four crucial aspects: modeling, rigging, animation, and rendering (as shown in Figure 8). Based on the analysis results of each aspect, we select the technical solutions that best align with the UE5 engine and are feasible, to better apply them in subsequent practical creation and design, aiming to realize the dynamic display effect of "virtual model" dressing.

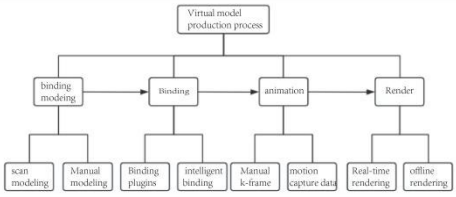


Figure 8: Flowchart of Virtual Model Production

• The production method of virtual models

Before creating virtual children's clothing models, it is necessary to conduct a three-dimensional analysis and design of the required human body. Based on factors such as gender, age, occupation, and body shape, the appearance characteristics that match the character should be designed. At the same time, it is necessary to have a certain knowledge of human physiological structure, including bone structure, muscle distribution, and morphology, to ensure the authenticity of the virtual model's body proportions and movement expressions. In software specifically designed for fashion design, such as CLO3D, Style3D, and Marvelous Designer, users can obtain virtual models from the official marketplace and are allowed to modify their height, weight, hairstyle, and other data, as well as select their own expressions and movements for the virtual models. However, this method is not conducive to modifying the characters and does not allow for personalized customization of the characters.

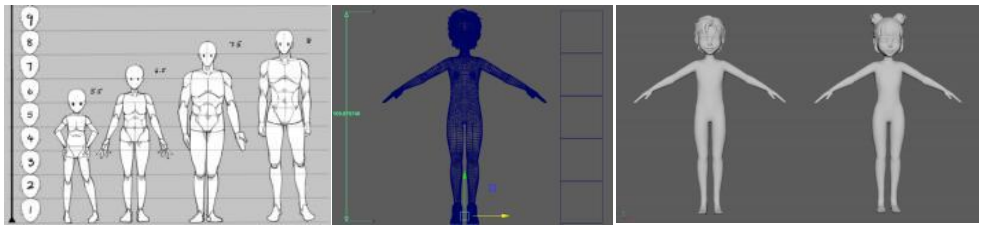


Figure 9: Model Design for Boys and Girls

The application of 3D scanning technology in 3D modeling is a modeling technology achieved through a non-contact measurement method. The advantage of using 3D scanning for human body modeling is that it is convenient, fast, and accurate in obtaining data, but the disadvantage is that it is expensive and difficult to promote and popularize10.Furthermore, ordinary scanning instruments have limited scanning accuracy, resulting in models with suboptimal precision and numerous broken surfaces. Consequently, manual secondary repairs are still necessary, necessitating the use of expensive equipment to achieve satisfactory results. In summary, both methods have their respective strengths and weaknesses. However, for stylized characters, three-dimensional scanning

modeling, which is relatively limited to the reproduction of real objects, is not an ideal choice. For children's virtual models, the advantages of flexible manual modeling capable of crafting cartoon-style designs are more prominent. In this project, manual modeling allows for better control over the appearance and characteristics of the characters, enabling the creation of virtual models that align with brand aesthetics and requirements.

Additionally, it better showcases individuality and creativity. The flexibility and humanistic nature of manual modeling will enhance the quality and expressiveness of character creation, offering more possibilities for realizing cartoon-style character designs.

• Skeleton Binding Technology

The display of virtual models requires a series of dynamic poses such as walking and turning to simulate the movement trajectories of real-life models, which necessitates the support of skeleton binding technology. Skeleton binding is an essential branch in the field of computer graphics and animation, used to control the motion performance of digital characters while simultaneously associating digital clothing fabrics with virtual models. This ensures the fit and expressiveness of virtual clothing on the models, laying the foundation for the vivid, natural, and realistic representation of digital characters. After creating the digital model, it needs to be imported into Maya or 3DMax to create virtual bones. The overall skeleton system mimics the skeletal structure of humans or other creatures, consisting of multiple interconnected virtual bones. The virtual bones are connected through joints, simulating the flexibility of biological joint movements. From the root joint, it progresses layer by layer to form a complete skeletal sub-chain that encompasses various parts such as the chest, arms, thighs, neck, and so on (as shown in Figure 10).

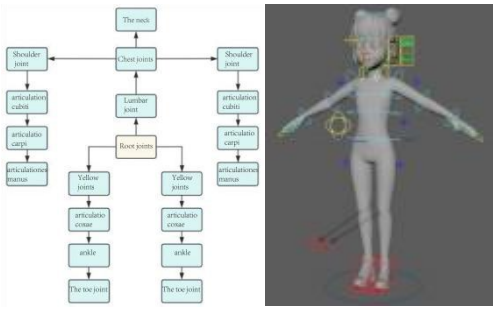


Figure 10: Hierarchical Structure Diagram of Character's Virtual Skeleton and Binding of Virtual Character's Skeleton

Weight distribution is the focus of this technology, and its high degree of logic leads to an overall cumbersome process, but it ensures that the polygon mesh vertices on the surface of the virtual model are tightly connected to the skeletal system. Each vertex on the virtual model will be associated with one or more virtual bones, and appropriate weight values are assigned to determine how these points bend, stretch, or shrink as the bones move. This weight binding is critical to achieving model motion, as it simulates the effects of muscles and bones on the appearance. In addition to manually building bone chains, Maya software can also introduce plugins to quickly build bone chains. ADV (Advanced Skeleton) bone binding tool is a relatively mature binding plugin, widely used in film, game, and animation production fields, and is considered an efficient and reliable bone binding tool. Although plugins can provide help, they still have certain limitations, such as in weight distribution, which cannot be perfect and still requires manual secondary weight painting.

Currently, AccuRIG software and the Mixamo online platform are popular intelligent binding tools that have similar functions. Both can import custom character models and use the provided automatic binding tools to add a skeletal system to the character models.

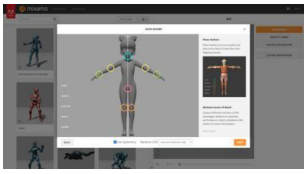


Figure 11: Mixamo Online Platform

However, there are also some limitations to smart binding tools, particularly in terms of animation and expression creation, where they may appear relatively insufficient. Therefore, by analyzing the advantages and disadvantages of both manual and smart binding methods, the author believes that combining these two methods can fully leverage their respective strengths to improve binding efficiency. Initially, the character model should be imported into the smart binding system, allowing it to automatically set up a virtual skeleton and assign weight values. This bound model can then be imported into Maya, where the ADV plugin can be used to

create a new set of virtual bones. The weight values from the smart binding can be transferred to the ADV virtual skeleton through the weight copy function, effectively resolving weight distribution issues and providing a solid foundation for subsequent animation production.

• Animation Driven Technology

After the bone binding and setup is completed, to make the character move, it is necessary to set keyframes for the bone controllers. Manually setting bone keyframes involves selecting the position of the animation keyframes on the timeline and using Maya's animation editor to set the character's poses and actions at different time points (as shown in Figure 12). Using IK controllers and FK controllers can make it easier to control the character's movements. By manipulating the position, rotation, and scale of the controllers of the virtual bones, various actions can be created, including walking, jumping, facial expressions, and more. Additionally, using the software's built-in motion library can improve the efficiency of animation production.

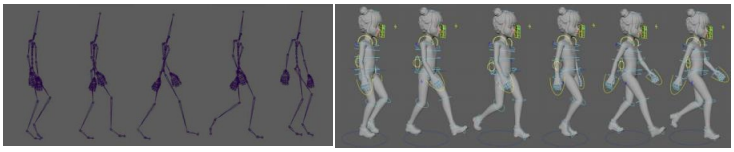


Figure 12: Character Skeleton and Walking Animation in Maya

Motion capture technology can also be applied here. By capturing the movements of the performer, the motion capture data in BVH format file is generated, and the keyframe file is exported from the Motion Builder software to the external software for use.

4.2.2 Design and Presentation of Virtual Children's Clothing

• Technical Essentials of Virtual Children's Clothing Production

Virtual clothing falls within the realm of digital apparel, utilizing computer graphics technology and 3D virtual software technology to create digital simulations of clothing that are typically used in virtual spaces. This process involves comprehensive consideration of clothing patterns, fabric properties, body shapes, human movements, as well as the form and its changes when clothing is worn, followed by digital simulation to achieve the final product.

The production of virtual clothing also adheres to the traditional modeling process, where virtual pattern making and virtual stitching operations are performed within 3D clothing design software to dress virtual models. With the aid of the software's physical simulation system, various fabric textures and realistic wearing effects can be simulated.

• Pattern Making and Virtual Stitching

Pattern making for clothing refers to the process of designing and creating patterns for clothing through computer graphics tools, which is a crucial technology in modern clothing design and production. ET-CAD is a relatively mature software for clothing pattern making, with "ET SYSTEM" representing the current development direction of clothing CAD, covering the entire process from computer-aided intelligent patternmaking, grading, material layout, to work instruction sheet creation (as shown in Figure 13). By importing DXF format pattern files into 3D clothing design software and then performing virtual stitching, the mutual conversion between 2D and 3D can be achieved.

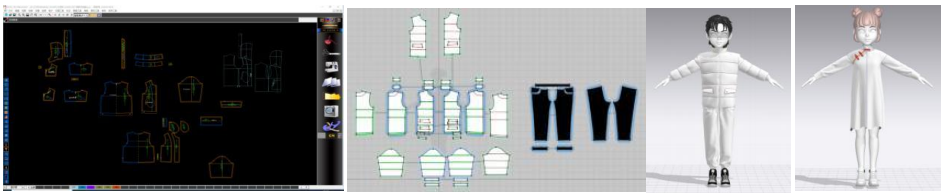


Figure 13: Display of Flat Panel and Stitching Effect

Virtual stitching is a technology that simulates real-life stitching during the process of virtual fashion design. Designers can use computer software to simulate the stitching effects, stitching methods, stitch patterns, colors, and other aspects of different fabrics, thereby providing a more intuitive preview and adjustment of the fashion design effects, improving design efficiency11, and reducing the cost of making sample garments.

• Simulation of Virtual Fabric to Reality

The simulation of virtual fabric is an essential component of the authenticity of virtual clothing. It is a process of simulating the characteristics based on the physical properties of the fabric, including settings such as warp and weft strength, diagonal tension, warp and weft bending strength, deformation rate, deformation strength, density, and friction coefficient (see Figure 14 for details).

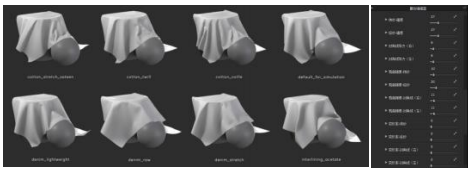


Figure 14: Fabric Simulation of Virtual Clothing

While adjusting properties, the realism of virtual clothing also requires the expression of texture materials. PBR (Physically Based Rendering) is a rendering technology used to achieve realistic lighting and material expression. Commonly used texture maps include albedo maps, normal maps, metalness maps, roughness maps, etc., which are used to simulate different characteristics and light reflection conditions on the surface of fabrics. Taking knitted cotton material as an example, normal maps are particularly important among the three types of texture maps, as they control the concave and convex texture of the fabric (as shown in Figure 15).

Figure 15: UV Arrangement and PBR Texturing

By optimizing and adjusting these attributes, it is possible to more accurately preview the performance of fabrics in fashion design, making virtual children's clothing more realistic and in line with expectations. This technology helps designers better explore the impact of different fabric choices on clothing production in a virtual environment, improving design efficiency and reducing trial and error costs.

Figure 16: Comparison of The Effect Between Real Children's Clothing and Virtual Children's Clothing

4.2.3 Purely Virtual Children's Wear Show Simulation

Under the condition of meeting consumers' basic shopping needs, the technological advantages of the metaverse should be leveraged to enable customers to experience the satisfaction brought by exploring, creating, and showcasing digital children's wear. By utilizing purchased virtual children's wear for styling, customers can create within a controllable range and then have virtual models wear these creations on a virtual runway set in an imaginary reality. This process blurs the line between consumers and designers, granting consumers a sense of participation in the creation of children's wear while shopping. Their sense of achievement is fulfilled through the process of styling and showcasing, and the incorporation of gameplay adds enjoyment to the shopping experience that transcends the act of consumption itself, thereby enhancing user engagement and indirectly boosting product sales.

• Concept of Virtual Scenes

Virtual scenes serve as the exhibition space for clothing, enhancing the overall atmosphere of the image by providing better lighting effects, spatial effects, and color palettes for the apparel. They assist in elevating the simulation effect of virtual children's wear, ushering in revolutionary changes in the display of virtual clothing. In the digital age, the creation of virtual scenes has become an integral part of the film, gaming, and fashion industries. This process encompasses various stages such as concept design, 3D modeling, texturing and mapping, lighting setup, animation production, and final rendering, all of which critically impact the final outcome.

Figure 17: Display of Virtual Scene Effects

• Virtual Field Special Effects Technology

Virtual scenes often enhance visual effects and attractiveness by incorporating scene special effects. The most commonly used is the particle system, which can simulate various natural phenomena such as raindrops, snowflakes, flames, and various abstract visual effects such as explosions and particle flows. Secondly, fluid special effects can simulate water flow, waterfalls, waves, etc., with realistic results. In virtual clothing, cloth special effects are frequently used to simulate the real movement effects of cloth materials such as clothing and curtains, including folding, swaying, stretching, and so on.

Figure 18: Simulation cannot be virtualized

• Scene Lighting Layout

In virtual exhibitions, lighting design is crucial for shaping the visual effects of virtual models, clothing, and scenes, significantly enhancing the overall visual quality. The lighting effects on clothing are the key factors determining the outcome and also important criteria for evaluating the realism of virtual clothing. Therefore, when designing and adjusting lighting, it is necessary to consider carefully and coordinate with the theme of the virtual clothing to achieve the best results.

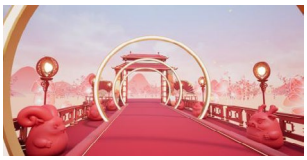
In Maya, commonly used lighting for virtual scenes includes point lights, area lights, and directional lights.

Point Light: A point light is a type of light that emits light rays, similar to a light source located at a single point. It radiates light in all directions, typically used to simulate lighting fixtures or light bulbs.

Area Light: An area light is a type of light with an area, capable of simulating more realistic lighting effects such as windows and light boxes. The light from an area light radiates along the surface direction of the area.

Ambient Light: Ambient light is a light source that is evenly distributed throughout the scene, used to simulate the indirect lighting effects between objects in the scene. Ambient light is often used to enhance the overall lighting effect and reduce the harshness of shadows. Directional Light: Directional light is a type of parallel light rays, similar to sunlight, that enter the scene from the same direction at all points. Directional light is primarily used to simulate distant light sources such as the sun, producing clear shadow effects.

These different types of lights can be combined and their properties and parameters adjusted according to scene requirements and design objectives to achieve the desired lighting effects and atmosphere.



5. Equations

Based on the realistic opportunities faced by the digital development and display of children's wear, this study proposes and practices ideas related to the types, mode frameworks, and development paths of virtual children's wear development leveraging metaverse technology. Currently, the digital research and development of children's wear need further exploration. During the development process, emphasis should be placed on ensuring the authenticity and reliability of virtual clothing, paying attention to consumers' personalized needs, and continuously monitoring the development trends in related fields. It is crucial to analyze potential issues in the digital production and display of children's wear based on metaverse technology from different perspectives and develop corresponding solutions to continue supporting this project. Currently, the digitization of children's wear is still in its infancy, and the development and application of metaverse technology provide broad prospects for it. We should seize this opportunity to promote the continuous advancement of digital work for children's wear based on metaverse technology.

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