Fitting Simulation Based on Mobile Body Scanning for Wheelchair Users

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Abstract

Clothing of wheelchair users is one of the problems that hinder their social participation and social return. The types of clothes worn by wheelchair users are often limited in number owing to the physical form and limitations of the physical functions of these users. In addition, they also face other problems such as difficulty in wearing clothes owing to their disability. To resolve such problems, we are working on a sustainable research project for manufacturing ideal clothes for wheelchair users while simultaneously improving functionality, design, and economic efficiency.

As a core part of this project, we have developed a virtual fitting application that enables virtual trial fitting in a seated position and that collects body measurement data of wheelchair users. Mobile RGB-D cameras mounted on current smartphones are utilized for measuring body shape without any direct contact. The measured body shape data are sent to a dedicated fitting server. Then, accurate fitting simulations based on the measured body shapes are performed. After completing the fitting calculations, the fitting results can be downloaded by the client. This system is designed for providing a virtual fitting experience to wheelchair users and for collecting body measurement data required for manufacturing their garments.

Keywords

Fitting simulation, garment manufacture, wheelchair users, sitting position, mobile body scanning, RGB-D camera.

Introduction

Fitting simulation for wheelchair users

Clothing is one problem that hinders the social participation of wheelchair users and social return. The types of clothes worn by wheelchair users are often limited in number owing to the physical form and limitations of their physical movements. In addition, wheelchair users face other problems such as difficulty in wearing such clothes.

To resolve such problems, we are working on a research project for sustainable manufacturing of ideal clothes for wheelchair users while simultaneously improving functionality, design, and economic efficiency. The developments made in this project with respect to functionality, design, and economic efficiency are summarized in Figure 1. For functionality improvement, we have developed a special material and pattern for wheelchair users, a dummy robot for garment evaluation based on body movement replication and data sensing while wearing garments, and an e-textile garment that exhibits measurement functionality such as extension and clothing pressure. For design improvement, we have endeavored to enrich the quantity of the garments worn by wheelchair users and to share pattern and body shape data to garment manufacturer. For improving economic efficiency, we have developed a sustainable framework to reduce production cost for custom-made garments for wheelchair users.

To achieve development in all aspects, a virtual fitting application has been developed in this study. The objective of this application is to realize simulation garment functionality and its design in the virtual space. By enabling 3D measurement through an RGB-D camera and virtual trial fitting based on measurement data provided by a smartphone, economic efficiency is also improved. The application can also facilitate e-commerce and virtual pre-production of garments.

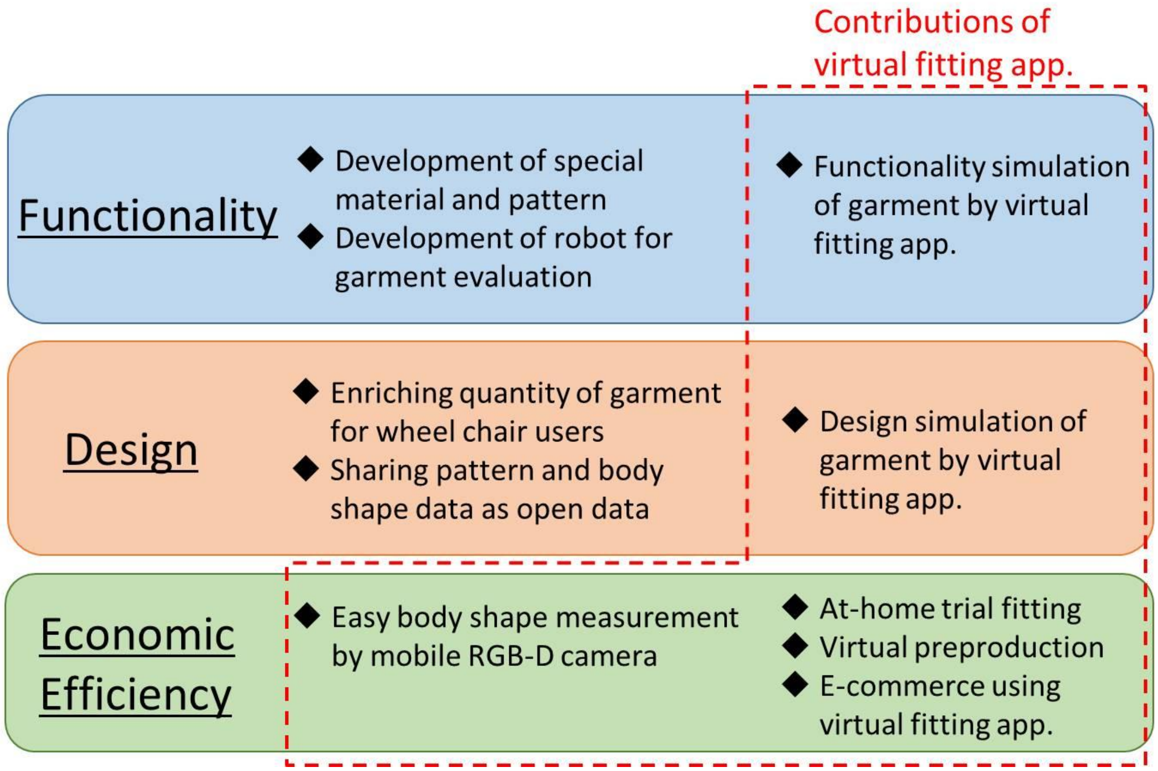


Fig. 1. Development aspects in the project.

The virtual fitting application has the following features:

1. Ability to allow wheelchair users to try clothes virtually while they are in a seated position (i.e., in the wheelchair)
2. Ability to realize automated and accurate fitting simulation using examples pre-loaded to a standard model
3. Ability to realize three-dimensional physical measurement function using a common mobile device
4. Ability to verify fitting results by three-dimensional visualization using a common mobile device
5. Ability to develop a form database by collecting the results of three-dimensional measurements on a server

6. Ability to support reliable data required in the garment manufacturing industry (computer-aided design (CAD) data, etc.)

Related Works

While functions for three-dimensional fitting of a two-dimensional pattern by computer graphics are being introduced into more recent CAD software in the apparel industry, most of these functions target a standing position using a pre-defined torso or a standard human body.

Virtual fitting has been studied in the field of computer graphics. (Stefan et al.) performed a fitting simulation by micro-adjusting pre-measured clothing data, while (Igarashi et al.) studied a case in which clothing parts are interactively fitted onto a CG character. Nonetheless, there are no cases that enable automated measurements of the body form and posture when wheelchair users remain in a seated position to realize automated fitting and verify the fitting results.

Virtual fitting experiences have been investigated using augmented reality and mixed reality (MR) in actual points of sales for apparel (Hilsmann et al.) (EON Interactive Mirror). In most cases, these virtual fitting experiences were investigated by utilizing applications for sales promotions that do not actually involve rigorous body measurements. We had proposed a real-time MR fitting situation based on measurement data obtained using an RGB-D camera (Ichikari et. al.). However, that approach emphasized on the simulation of the outward appearance, thus failing to perform strict measurements of the body shape or coordinate with apparel CAD data. The virtual fitting application used in this study does not track the user in real time, but it measures the stationary user carefully in detail in client side and performs accurate fitting calculations at server side. The accurate fitting calculation is based on “Digital Mannequin” which resembles the users’ body form measured by three-dimensional measurement with mobile devices such as smartphone or tablets. The virtual fitting application also enables collecting body form data, which are very important for garment manufacturing

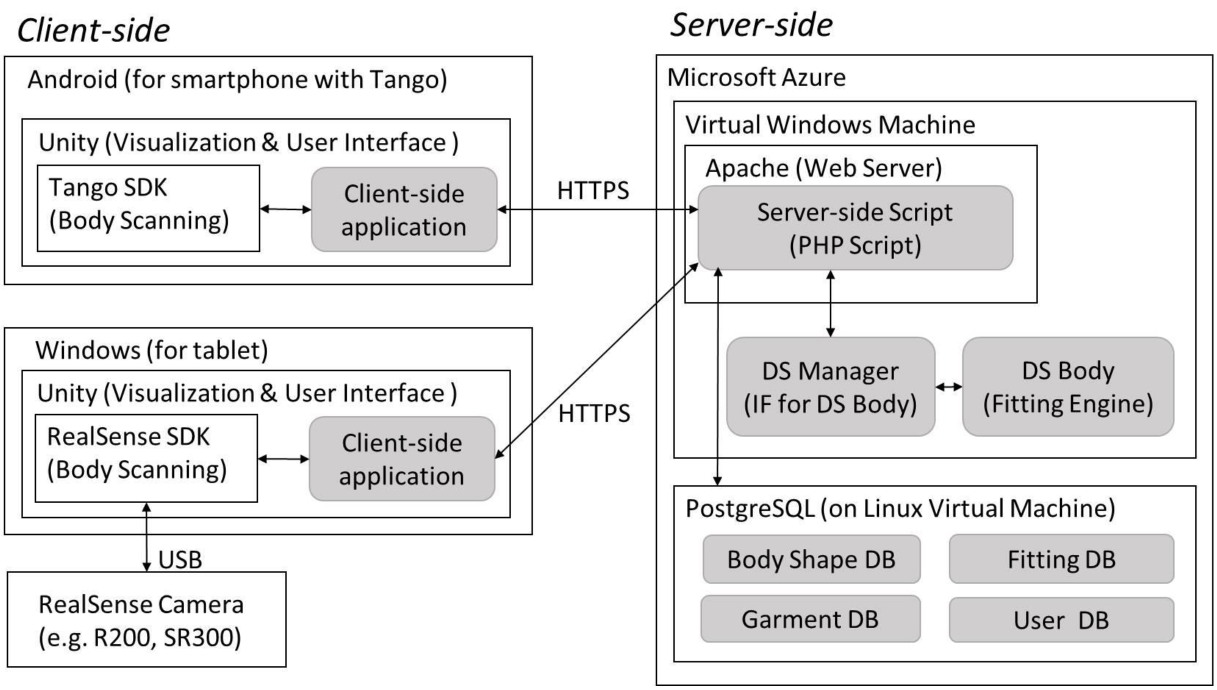


Fig. 2. System configuration

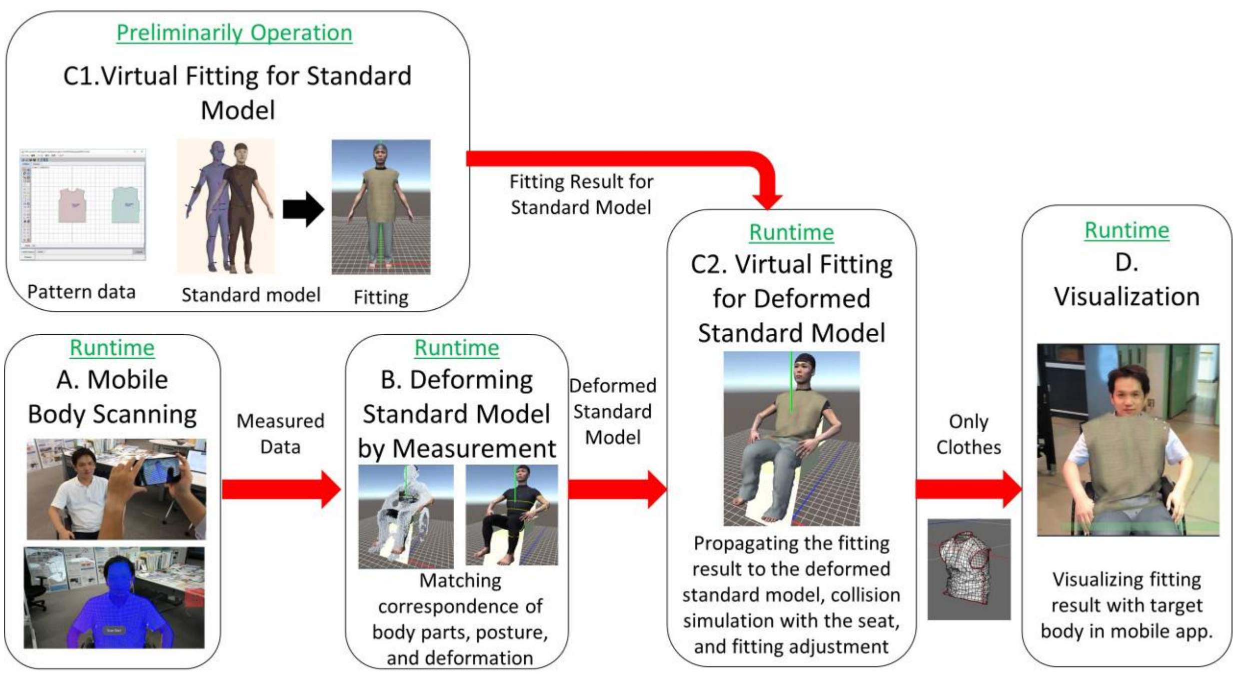


Fig. 3. Workflow of the virtual fitting application

Discussion

System Design and Implementation

System overview

The major functions of this virtual fitting application are as follows: realizing body measurement through detailed three-dimensional visualization and providing a physically accurate virtual fitting result based on the measured data. To achieve these objectives, the system comprises a client-side application for performing three-dimensional measurements and visualization on the mobile device and a server-side application for performing the fitting simulation as shown in Fig. 2. The client-side application is installed on mobile platform such as Android or Windows using the Unity game engine. In order to utilize the-dimensional measurement functionality, Tango SDK is used in the case of Google Tango; and RealSenseSDK is used in the case of Windows tablet devices. The server-side application is implemented on a cloud using Microsoft Azure. The server-side application including the simulation engine is running on a virtual Windows machine on the Azure platform. The Apache web server is also running on the virtual machine for exchanging data with the client devices. On the server side, PostgreSQL server is also running on anther virtual machine for managing measurement data, garment data, and client identification data.

A detailed workflow of the virtual fitting application is shown in Fig.3. Each element of the flow is described below.

Mobile scan of the human body

In recent years, three-dimensional measurements on mobile devices such as smartphones and tablets have become possible owing to services such as Tango by Google and RealSense by Intel. This has enabled measurements of the size of a human body in a seated position without any direct contact with the user (via a mobile client). In this approach, seated positions of the wheelchair users are considered as measurement targets. Measurements were taken using the three-dimensional object scanning function that utilizes a distance camera provided by technologies such as Tango and RealSense. To use this function, the user was photographed by capturing the images of the body from various angles. Measurement results were obtained as a point cloud.

A. Correspondence between a standard model and the measured model

The human body shape used in the simulation needs to be combined by a homology model with defined topology and number of vertices and the measured point cloud is converted to a homology model. Through this conversion, the removal of holes and duplications in the measured point cloud and deletion of duplicate data become possible.

For the homology model, a standard human body character model called Dhaiba was used (Mochimaru et al.), which is provided by the Digital Human Research Group at the National Institute of Advanced Industrial Science and Technology (AIST). By using a human evaluation integrated environment that uses a digital human model called DhaibaWorks, Dhaiba models that are adapted to the form and posture of various height, weight, and landmark point sets can be produced.

Posture and form of the models are transformed by specifying rough mapping points in the Dhaiba model and measured scan. Blend shape transformation of several Dhaiba models and local deformation are performed so that the Dhaiba model is transformed to be close to the measured scan. Through this approach, the form of the Dhaiba model is transformed to match the measured model while preserving the homology. Through the alteration of forms, variation in forms among wheelchair users, such as thinning of the lower body, can be modeled. The Dhaiba model transformed by measured form data is delivered to the server-side application for calculating fitting results and collecting form data of the wheelchair users.

B. Fitting of the clothes to a standard model and the measured body

This study employed Dressing Sim Body (DSBody), a fitting simulation engine developed by Digital Fashion Ltd. DSBody can realize rigorous fitting simulation that considers gravity, frictional force, and cloth material characteristics. Human shape model as OBJ format, pattern data as DXF format, and suture line data are provided as inputs to.

Suture results for the human shape model can also be transmitted to another human shape model with homology in DS body. By using this function, simulation results can be automatically reflected onto another human body model with shared homology. First, calculations for the suture of clothes are performed for a standard Dhaiba model in standing position for clothing data at Stage C-1. Next, fitting simulation for the Dhaiba model that is transformed to another posture and form sent by the client can be performed at Stage C-2.

C. Verification of the virtual fitting results

Once the fitting simulation is completed on the server side, the results are sent to the client device as CG data limited to the clothing parts. On the client side, the fitting results of the user can be verified as a three-dimensional visualization.

Because the positions of the cameras at Stage (A) can also be recorded as a byproduct of three-dimensional measurements, the camera position and posture are used to superimpose and synthesize on to the real image from body scans offline. The perception of the user that he has physically tried the clothes is enhanced by the image of the user. By using the same homology model at all stages and by performing fitting calculations against all created clothes data, the user is able to choose from multiple clothing choices and try them when required.

Graphical user interface for garment selection

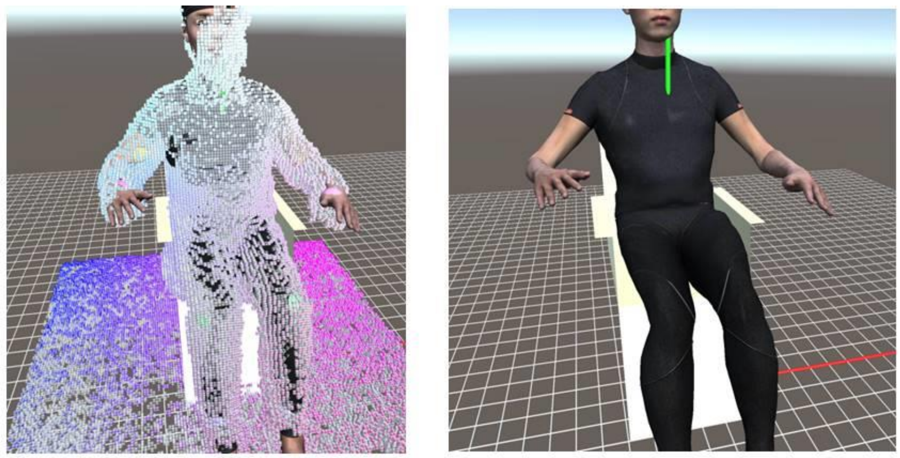
An example of the graphical user interface (GUI) for selecting garments is shown in Fig.4. Multiple choices of the garments are categorized into types of garments such as pants, skirt, jacket, and t-shirt. If the user selects a category, the choices in that category are visualized as small thumbnail icons with manufacturers' logo. Image of the focused item is enlarged with the attribute information such as the uniform resource locator (URL) of manufacturers' website for reviewing the item in detail. If multiple sizes are provided for the selected item, a size can be specified in this phase. If the user presses the "OK" button, the focused item is displayed in the right column as a selected item. The fitting calculation can be started by pressing "Start dressing" button. The status of progress is shown as the percentage during the calculation.

Fig. 4. GUI for choosing clothes from multiple choices

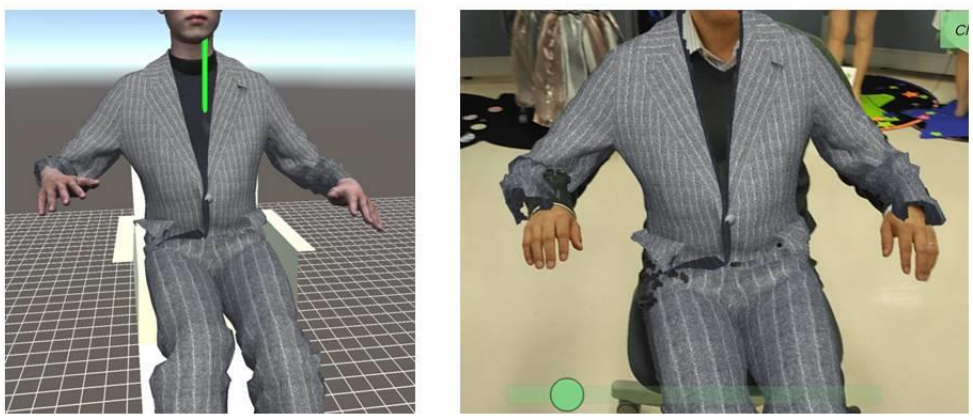
Experimental Evaluation

To test the system operation, the flow of operation from data measurement to simulation calculation and utilization of the simulated results was verified using the prototype system. The flow of the operation to final results was successful in the prototype system (Fig. 5). An example of the values measured at Stage B for chest girth, waist size at seated position, and thigh length is shown in Table 1.

In Fig. 6 and 7, pattern paper data for the clothes used in the simulation are presented. In this study, the authors received pattern paper data for wheelchair users from Bunka Fashion College and Kurashiki School Tiger Clothing Co. Ltd, which engage in clothing development for wheelchair users. Fig. 6. shows the pattern paper data of pants for the normal standing position. Fig.6. shows the pattern paper data of pants for the seated position provided by Bunka Fashion College. As shown in Fig. 6(b), the buttocks of the pants are misaligned, i.e, it appears that the pants are slipping down in the seated position even when they appear to fit in the standing position. Using the dedicated pattern paper data for sitting position, the buttocks are covered appropriately in the seated position as shown in Fig.7.(b). Fig.8. shows another example of fitting result for seated position. This skirt covered buttocks and fitted well during the sitting for avoiding bedsores. Fig 9 shows comparison between results with or without collision simulation with seat. Simulation result can be confirmed in Fig 9(b). By importing actual pattern data for wheelchair users, the effectiveness of the proposed system has been verified.



(a) Transforming the Dhaiba model to be close to the measured scan (b) Transformed Dhaiba model

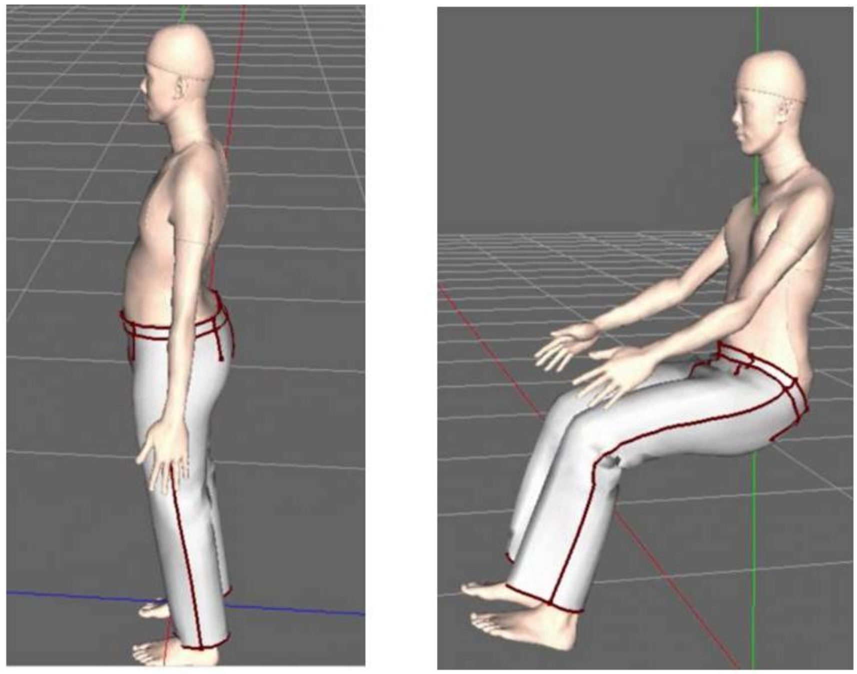


(c) Fitting result (d) Superimposition of the result onto an image of a wheelchair user

Fig. 5. Example of virtual fitting in the prototype system

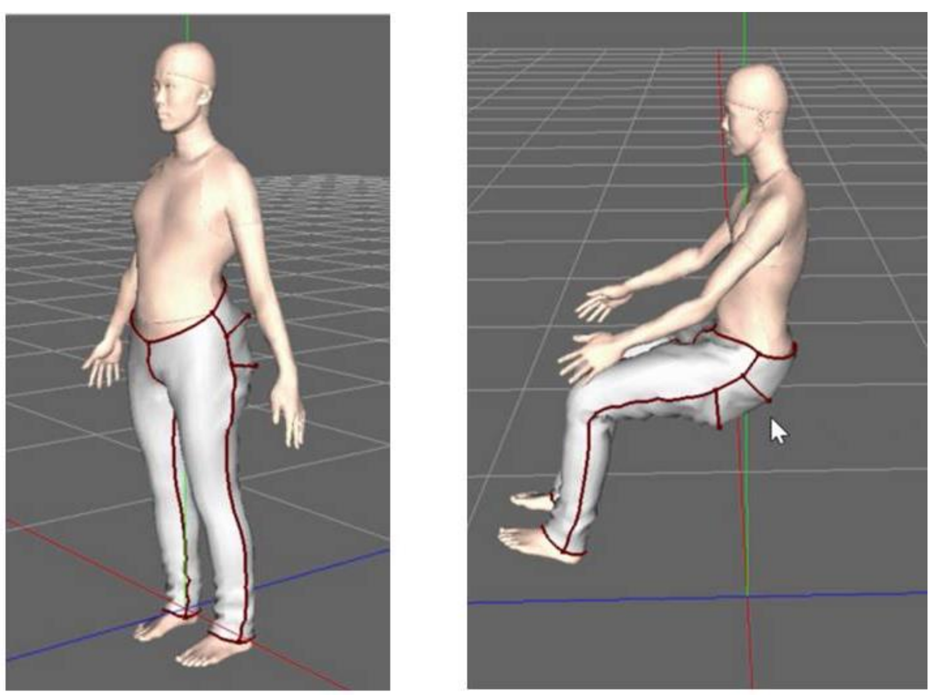
Table 1: Error of automated measurement

Measure area	**Correct**	**Estimated**
Chest girth	97 cm	98.8 cm
Waist	90 cm	86.3 cm
Thigh length	56 cm	53.3 cm



(a) Standing position (b) Seated position

Fig. 6. Simulation results using pattern paper data for jeans for standing position



(a) Standing position (b) Seated position

Fig. 7. Simulation results using pattern paper data for seated position

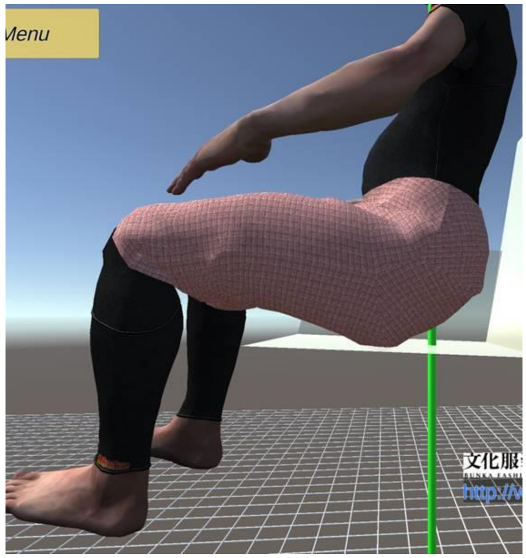
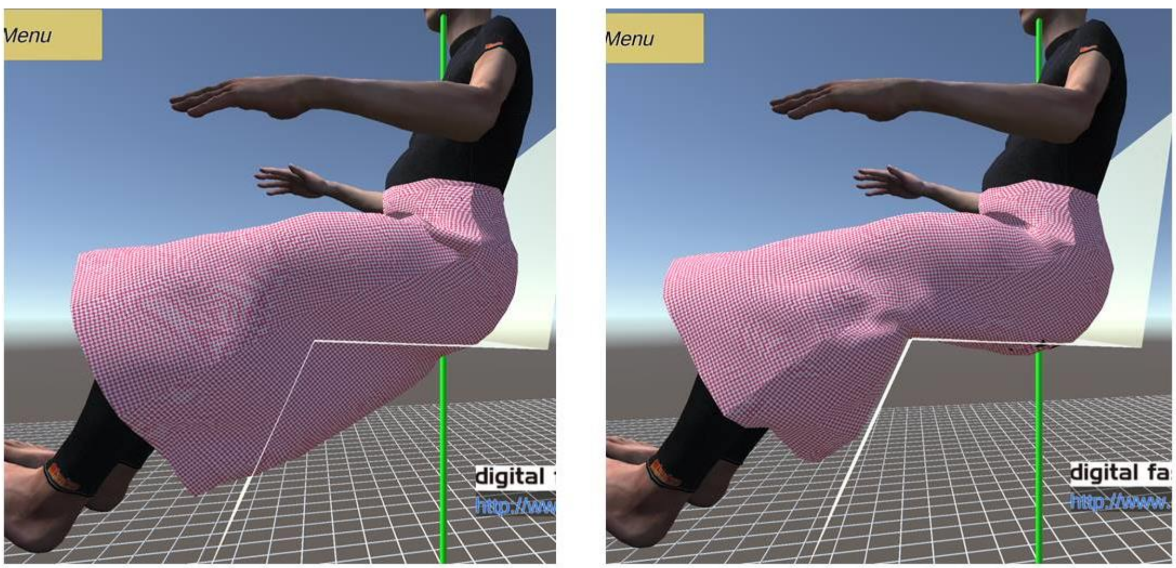


Fig. 8. Fitting result of a skirt designed for seated position



(a) Fitting without collision simulation with the seat (b) Fitting with collision simulation with the seat

Fig. 9. Comparison between results with or without collision simulation with seat

Conclusions

In this study, we propose a virtual fitting application in which wheelchair users can virtually try clothes while they remain in a seated position. The virtual fitting application was developed using a client–server model that comprised an Android device with three-dimensional measuring functionality and a server that realizes a dressing simulation. The users should possess a common mobile device to use this application. By placing a simulation engine on the server side, processing power of the server, which is greater than that of the mobile device, can also be utilized. In addition, there is also a merit in terms of intellectual property since there is no need to distribute a fitting engine to the client side. Therefore, the launch of the proposed application as a service is achievable in real time. Collection of form data necessary for manufacturing clothes has also become possible. Collected data can be utilized as the foundational data for the development of clothing for wheelchair users.

This paper focused on the implementation of the prototype that embodies the proposed concept of a virtual fitting application as well as on the verification of the application's behavior. The final goal is to provide a virtual fitting service by enabling wheelchair users to do trial fitting wherever they want and collecting their form data. Future studies will focus on the enhancement of this service by the automation of the position and posture mapping between measured data and the standard model and on improvements of accuracy of the transformation.

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