AWARENESS OF 3D BODY-SCANNING AND PROSPECTIVE UPDATE OF INDONESIAN ANTHROPOMETRY FOR VIRTUAL FASHION DESIGN

Markus Hartono*[1], Brian Kurniawan Jaya[2], Dian Prianka[3], Christabel Annora Parung[3], Viviany[3]

[1]Department of Industrial Engineering, Faculty of Engineering, University of Surabaya
[2]Product Design and Management Program; Faculty of Creative Industries, University of Surabaya
[3]Fashion Design and Lifestyle Product Program; Faculty of Creative Industries, University of Surabaya

Abstract

It is a challenge for the designer and user in compromising a perfect fit of fashion. This study addresses the awareness of users and development of two different methods for the fitting of a fashion product. The first one, it is an individual anthropometric measurement, whereas the second one is assisted anthropometric measurement. Based on the Focused Group Discussion (FGD), it showed that the virtual fashion technology was perceived as something new and prospective in the future fashion industry. Through the virtual prototyping using CLO3D, it was found that the result had relatively the same as the manual measurement. The virtual one has reduced measurement and lead time significantly. In other words, the virtual measurement is deemed to be a time-saving process, promoting "fitting the product to the user" principle. This study supports a good communication bridge between users and designers through the 3D virtual clothing process, and also contributes to Indonesian anthropometry updates.

Keywords: *virtual fashion; CLO3D; Indonesian; anthropometry*

1. Introduction

Anthropometry deals with the concept of human factors engineering which is to fit the job to the human physically (Kroemer & Grandjean, 1997). The job includes work, product, task, and the component of a system which is controlled and used by the user. Due to complicated and various demographic factors, the interaction between man and the job can be complicated. At least, it is urgent for product designers to consider the important human body dimensions in product design and development process especially in making prototypes. Appropriate and perfect fit is highly expected. Hence, anthropometry should be considered. Anthropometric data are critical in obtaining effective design for high user performance and productivity (Klamkay et al., 2008). Lack of anthropometric data inclusion may potentially cause musculoskeletal disorder, discomfort, dissatisfaction, or even physical injuries. The main challenge of studying anthropometry is the consistency of measurement. It refers to the validity and reliability of measurements related to the appropriateness of tools, methods, and procedures. Still, there was a potential discrepancy between anthropometric information and their applications for planning ergonomic products and applications (Dianat et al., 2018). The study of anthropometry incorporating special groups (e.g., the elderly, children, and people with disabilities) and advanced technology is of highly interest.

How to obtain valid and reliable data with minimum acceptable errors is highly expected. In the garment industry, it is imperative to tackle some possible drawbacks related to human body dimensions such as bad fitting, lack of individualization, and over inventory in terms of waste of materials.

Clothing can be said to be like human skin which is aimed to provide comfort (e.g., protection and warmth) for humans. In fashion, people need personal and individual clothing styles. Mass production-based fashion styles are somewhat insufficient representing the overall people's needs. Most probably, the customized clothes based on the personal characteristics and design will be highly preferred. It needs information technology to fill the gap. The expected platform is a system capturing human body dimension, collecting the database, and utilizing them to be virtual display. Thus, it will shorten the material cost, production cost, and communication process between customer and designer. Indeed, it helps designers execute fashion products which are more in line with the customer's needs.

With the rapid growth of high technology, there is a mixture and fusion between fashion design and technology. It leads to the rising demand of selling and buying experience. It is a challenge for the designer and user in compromising a perfect fit of fashion. In line

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*Correspondence Author.

E-mail: markus@staff.ubaya.ac.id

with this, a principle of ergonomics of fitting the product to the man is highly recalled. The regular steps for finalizing a prototype of a fashion product are as follows. It starts with generating some concepts followed by the development of technical specifications, identifying the materials, patternmaking, building a prototype, checking, fitting, and adjusting the prototype or pattern rectifications. Once it is done, a duplicate is prepared, which is making the second prototype. We need to check, fit, and adjust it once more. If there is no significant difference, it can be said that the prototype and pattern is acceptable for production ramp up. While in 3D-based virtual prototyping (such as CLO3D software), the regular steps are reduced. They include generated concepts followed by technical specifications, pattern, virtual prototype with the sample taken from digital mannequin, and the adjustment of patterns. Once the digital prototype is confirmed, the physical one is provided. Through 3D-based virtual fashion design, it supports better communication between user and designer, so that it may avoid the requirement of prototyping sets. Even the number of physical prototypes can be reduced up to 80%.

Major various and updated 3D-based anthropometric studies have been conducted and published. Study by Kuehnapfel et al. (2016) addressed the contrast between 3D laser and conventional anthropometry. Their study highlights that anthropometric amount are broadly utilized in epidemiologic investigate as conceivable confounders, hazard components, or results. 3D laser-based body filters permit assessment of handfuls of amounts in brief time with negligible physical contact between spectators and probands. The point of this think about was to compare 3D body measurement with classical manual anthropometric evaluations with regard to achievability, unwavering quality, and legitimacy.

Another previous similar study by Kouchi & Mochimaru (2011) was performed in which 40 subjects were stamped five times in add up to by one profoundly talented marker and an amateur marker. Quantitative information on the intra and inter-observer landmarking mistakes within the display think about may be valuable as a reference when assessing and comparing the execution of computer program for calculating point of interest areas for 3D anthropometry.

A study by Lee et al. (2018) highlights that the 3D-based anthropometric measuring investigating framework created within the ponder provides examination capacities of a measuring framework and agent confront models by considering a target item, a target populace, the number of estimate categories, and key anthropometric measurements based on the head estimations.

Related to fashion and apparel products, a study by Yu & Kim (2020) addressed the problem that most Korean attire companies need reasonable dress shapes for the diverse body sorts of middle-aged Korean ladies. Their study investigated the Korean anthropometric characteristics of ladies in their 40s and 50s using 3D-based mechanisms. Moreover, as women's upper body changes are critical, another study on woman's anthropometry through 3D modeling was continued and deemed to be highly interesting. According to a study by Song et al. (2022), shape and pose contrasts were evaluated concurring to four age bunches based on 47 estimations prepared into 27 shape-related factors; six foremost components (such as, acromion slant, upper body incline, neck slant, bear point, upper back ebb and flow, and back bulge tallness) were investigated.

Inherently, a critique has been raised. The 3D-based prototype is potentially reducing the need of the work force so that it may cause the increase of unemployment rate. However, it is not. The 3D-based design actually supports the automated processes which require a large number of resources including the labors, materials, and energies. Indeed, it promotes sustainability of business and environment. As a result, the 3D-based design deals with the ergonomics principle of fitting and sizing incorporating various human body dimensions. Thus, a lot of product returns may be significantly avoided. Related to the entire product design and development processes, the 3D-based process saves the confirmation and consolidation of sample prototypes. The spending time to check and fit the physical prototype will be highly reduced as the potential adjustments are made immediately. It saves the development lead time. Hence, the required review time will be less. Moreover, utilizing social media for promoting virtual products will be beneficial to get feedback from the customer quickly.

Mostly, in the last 15 years, the recent study of Indonesian anthropometry focused on the update of anthropometric data through manual static measurements. It experienced the limited number of body dimensions measured, time consuming process, more effort in measurement protocols, adjustment of potential discrepancy, and huge variation in measurement. There are 36 body measurements often utilized (Hartono, 2018). The update of Indonesian anthropometric data has been published, covering Indonesian adults, children, and elderly (see Hartono (2018); Tan et al (2010)). Considering a more specific demographic factor which is the ethnic group, study by Widyanti et al. (2015) addressed the update of Indonesian anthropometry comprising Javanese, Minangkabau, and Sundanese characteristics. It is time consuming, and not in the specific context of data utilization.

This study has been conducted as a response to the rapid development of the digital world. It is especially important as the fashion industry is believed to be the biggest contributor to world pollution. According to Hudd (2022), the fashion industry used huge amounts of water, energy, and natural resources, and generated up to 10% of global CO_2 emissions. Therefore, the development of digital fashion is promoted as a solution to the problem of waste and added value of fashion products. Digitalization including the fashion industry may provide more value added to the product. In the post-pandemic retail, the digital fashion industry may shorten the production
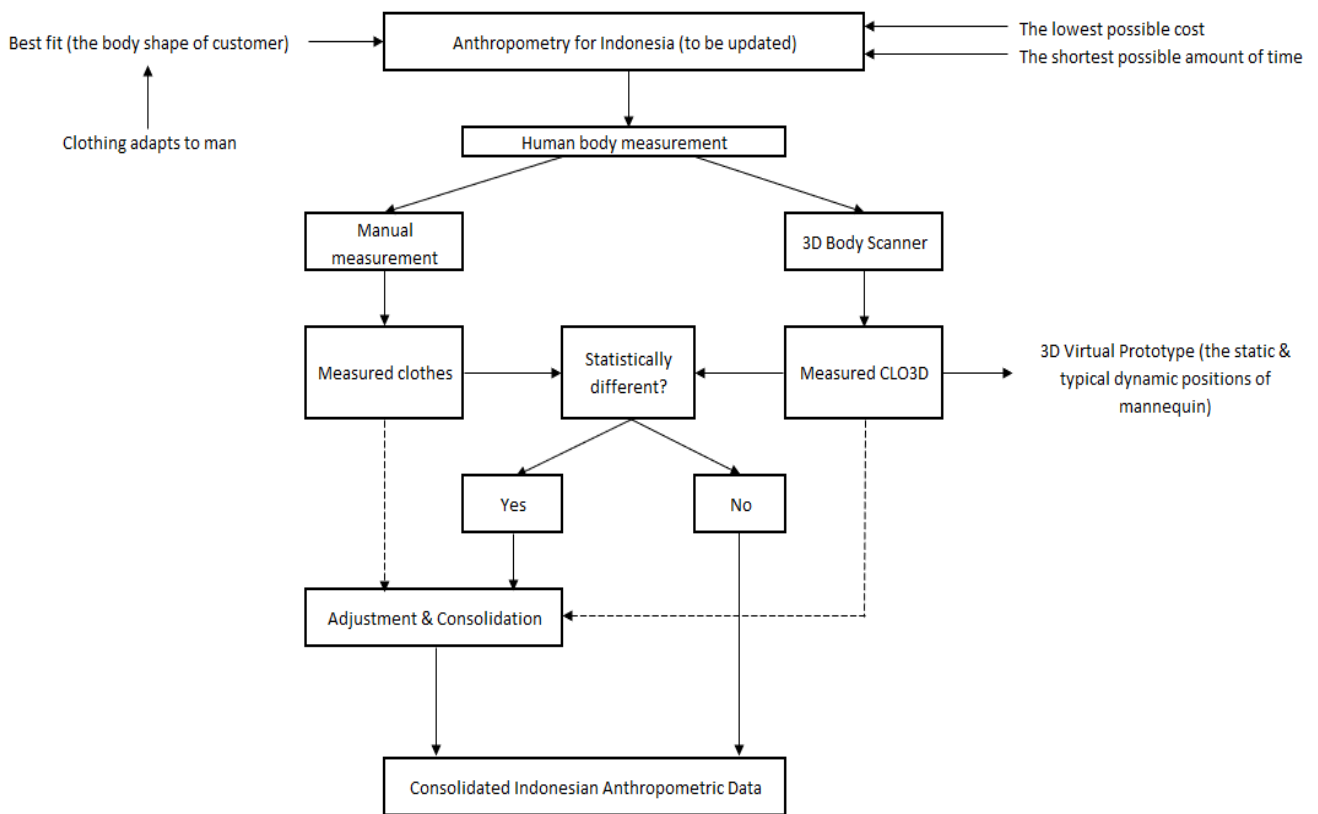
Figure 1. Framework of Human Body Measurement Through Manual and CLO3D for Potential Update of Indonesian Anthropometry
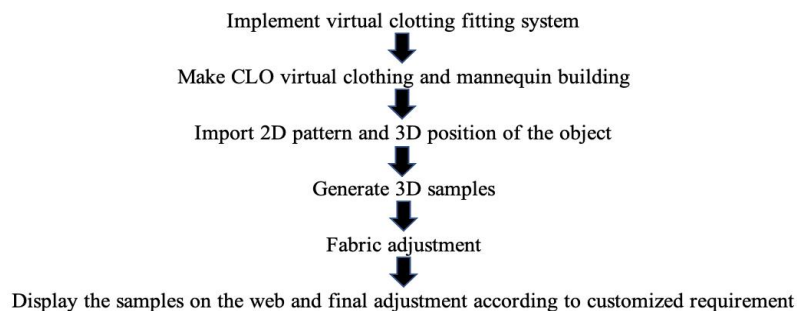

Figure 2. Virtual 3D Body Scanning System Process

chain and increase the effectiveness, and lead to the expansion of marketing reach. This study aims to present the awareness of virtual fashion design and update of Indonesian anthropometry through the 3D body-scanning for virtual fashion. The result of virtual measurement will be compared to the self-manual one, to check and analyze the potential discrepancy.

Hence, as a novelty, this study is proposed to explore to what extent the awareness of fashion designers, enthusiasts, and customers toward the importance of 3D-based fashion design using 3D software incorporating the principal issues of sustainability is (e.g., time and material-saving process, less pollution, and user fitting). Moreover, it provides an alternative way in updating Indonesian anthropometric data directly related to fashion designs. Since this study provides a generic framework of human body measurement through manual and CLO3D for fashion design; it may be potentially utilized for different design settings such as shoe design, cap design, and so on.

2. Method

This study utilized focused group discussion (FGD) and experiment in data collection. It starts with the exploration of how the respondents perceive the virtual fashion product design concept and implementation. Afterward, it continues the human body measurement using manual and 3D body scanners (supported by the CLO3D software) (see **Figure 1**). Manual measurement is done using meter-tape. There will be a statistical or non-statistical comparison between manual and computerized 3D-based measurement. Once there is a significant discrepancy between those measurements, adjustment and consolidation is required. Otherwise, the result is deemed valid, and it contributes to the updated anthropometric data for Indonesian.

In the virtual 3D body scanning process (see **Figure 2**), it starts with the preparation of a virtual clothing fitting system (Wang & Liu, 2020). Through the CLO3D software, independently manually, the user or customer may measure his or her anthropometric
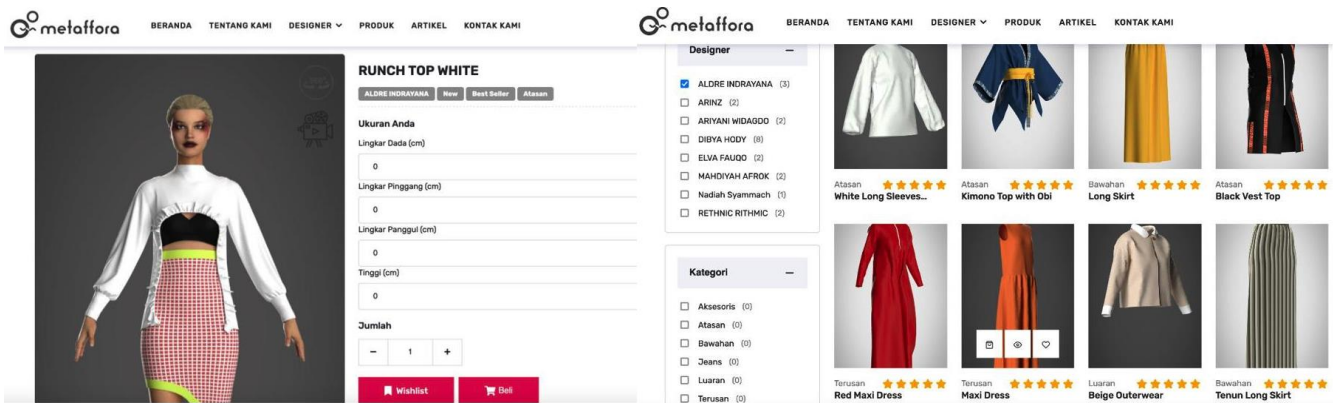
Figure 3. Independent Anthropometric Data Input Into 3D Web-Based Software

data using meter-tape and input them into web-based software (see **Figure 3**). After that, it is to create virtual clothes designed by designers and evaluate the suitability and comfort of the clothes. Afterwards, it is to change and adjust the clothes. Then, it needs to post the customized clothes on the web. This will include detailed diagrams or dynamic videos. Users can see all relevant information about clothing on this page. When they are not satisfied with the style of clothing, they can communicate directly with online designers to make promptly and accurately potential changes.

3. Result and Discussion

The FGD session on digital fashion was conducted involving respondents from 5 practitioners (aged 25 – 50), 5 educators (aged 24 – 35), and 5 university students (aged 19 – 21). Purposive sampling method was applied. The spoken-up responses were captured. This study utilized qualitative research in discussing a hot issue on fashion design using 3D models and technology. The results of FGD are shown in **Table 1**.

According to the FGD process above, we were able to explore more the genuine responses of participants, and their visual expressions and gestures. In general, most of the participants were already familiar with the term of virtual fashion design. Direct manual and conventional body measurement for fashion design is still highly favorable and expected. Here the subjects may ask for adjustment directly so that they feel comfortable and confident. Direct touch with the material and direct communication with the designers help the users requesting any changes or adjustments. It was understandable since all subjects tended to have the same experiences with clothing design and adjustment.

Table 1. Response and Summary of FGD

No	Question Asked	Respondent's Response (Set as Pure Responses from The Subjects)	Keywords	Summary
1	Are you familiar with virtual fashion products?	● *Virtual fashion products are virtual 3D clothes designed with humans and avatars in mind.* ● *I've never heard of it, except in the office recently.* ● *I just heard about virtual fashion products.* ● *Online shopping? So, we can see the stuff online?* ● *Maybe a virtual fashion product exhibition?* ● *In my opinion, virtual fashion products are fashion products that are packaged in such a way in 3D. The virtual fashion product that I imagine that sticks the most is the result of CLO3D.*	Avatars, 3D clothes	Most of the participants were already familiar. It is divided into several definitions, such as virtual exhibition fashion products, fashion products packaged in 3D (animation, photos, or videos) which are then sold online.
2	If you think, the product is a photo or what?	● *You can make a video, maybe it's like a game.* ● *You can take a photo or video. In 3D I have never seen it so far.* ● *Photos and videos are possible.* ● *Virtual fashion products, in my opinion, are like selling fashion online, either in the form of photos or videos.* ● *I have seen it in the metaverse, maybe the fashion is shown in the metaverse like that.*	3D, animation	
3	Do you think clothing measurements should be	● *You can measure it independently.* ● *Actually, you don't have to, but it's better to go straight because sometimes you measure yourself and it still doesn't fit your clothes.*	Direct measurement	Most of the female participants said it should not be measured directly. A

No	Question Asked	Respondent's Response (Set as Pure Responses from The Subjects)	Keywords	Summary
	taken directly?	● *In my opinion, it doesn't have to be like that, because usually, for example, I buy clothes online, like we can measure ourselves using a tape measure at home, then we run out of size, we immediately send it to the seller, after that the seller can make the clothes or adjust the existing size. That's it, so you don't have to meet in person.* ● *Yes, directly if possible. Because in my opinion so far, I believe in the tailor's measuring skills. This is if I make clothes on request.* ● *It depends on the clothes you want. If you need precise accuracy, you may have to measure it directly because getting the right size on your body will be difficult if you go online. But if the clothes you want are looser/oversized, maybe it can be done indirectly.*		small part if it can be measured directly for the accuracy of the size of the clothes to be used. All male participants said it was better to be measured directly.
4	What are the obstacles if e-commerce/on line stores use virtual fashion products as product examples?	● *Maybe you can't feel it right away, so it's like the texture or something. It's been explained in detail, people want to feel the physical touch. Perhaps, giving a photo can describe it? Yes, if you want to physically touch it, but if you imagine it abstractly, you can, for example, 'chiffon fabric, oh yeah, have you ever seen it, have you ever been to a fabric store and felt chiffon'.* ● *In my opinion, for example, for 3D, maybe people can't enjoy it. It's like we sometimes buy online, for example, sometimes we also have trust issues. The item may not, it doesn't come as pictured. We even though the goods already have a model like that, right. So what if it's 3D like that, what kind of thing do you have to imagine yourself? What is the fabric like?* ● *I, as a consumer who buys products directly (seeing real products), usually spends a lot of time thinking. If, for example, this is a virtual product, it doesn't really matter, but it increases my time to think when shopping takes longer.* ● *I don't think 3D is a problem, because it's pretty good to see the curves of the clothes. But it's also better if there's a photo/video display when the model is worn, so there's an idea when it's worn on the body.*	Physical model, suitability	Most of the participants had doubts about the suitability of the original goods and those displayed in e-commerce. It will add time to rethink when making choices because of the picture factor that is too perfect so that you are afraid of not meeting expectations.
5	Do you think virtual fashion products can help consumers in getting a real product picture?	*Reaction after seeing the picture:* ● *Yes, if you can get this far, it means that I think it can help us to imagine what the materials are like.* ● *It depends, for example, if it's a dress design that has never existed before, it really helps. In terms of cost, it could also be lower.* ● *I hope that's the case, from the example, it's really good and consumers are helped. I can even visualize the material/texture of the clothes.* ● *From the point of view of a 3D seller, this is profitable because it can attract consumers because the visuals are much better. However, from the consumer side, it's a bit confusing, especially for ordinary people.*	Helpful, real	Most of the participants were helped, because they could see the details of the material, clothes fell on the model because of the realistic 3D rendering. Some say it depends, if there are pieces of clothing that are new models, it will really help consumers in wearing them, but it can also confuse ordinary consumers to buy products.
6	Is it better	● *The one with the avatar.*	Avatar,	Most of the

No	Question Asked	Respondent's Response (Set as Pure Responses from The Subjects)	Keywords	Summary
	without or with avatars attached?	● *The one with the avatar because it can be seen falling on the body.* ● *I prefer the one with the avatar, the visualization is better, but it's back to the imagination of each consumer.* ● *I think it's the same, because when it comes to our bodies, the fall will be different. In the middle, if we can see, the body is already in shape. If it's used on the body, I think it's just a matter of skin colour.* ● *If there is an avatar according to the body shape desired by consumers (e.g.: us), it will be more attractive.* ● *For me, because sometimes there are confused about the meaning of the designer. Rich example is the photo on the far right. It can be confusing for some people if it's just a product photo, but there are also people who want to know only the product.*	person-like attachment, body shape	participants chose an image with an avatar, especially if we could adjust the avatar according to the consumer's body shape.
7	Do you often have trouble imagining you wearing the clothes you see in the product photos of an e-commerce/online store?	● *Yes, it's difficult, because sometimes the model who wears clothes has a different body shape from us.* ● *I often find it difficult, because my body is a bit big, while the models are usually ideal.* ● *Yes, it's often difficult, because the model or body shape of the model is very different from ours.* ● *Sometimes it's difficult, because the model in the photo has a different weight from us when we look at the review, so it's different from the one in the model.* ● *It's possible, but often it doesn't match expectations, such as lighter colours online, darker when received.* ● *It's hard, because sometimes every clothing model, every clothing, in every store the size is different.* ● *I think it's back to the previous suggestion that we can get the avatar, so when we try online, we can imagine that.* ● *If every dress could be worn by a model with a different skin colour and body size/body shape. If it's virtual, maybe you can use a virtual model with different body sizes and skin colours.*	Body shape, match	Participants have difficulty in imagining using products from e-commerce because it often happens that expectations are not met (incorrect size, inappropriate colour, poor material).
8	What do you think if you could see yourself (in terms of body size and shape, maybe without a face) wearing the clothes you want to order in an e-commerce/online store? Will it help the buying decision?	● *It would be very helpful.* ● *It will be very helpful. It saves time and maybe even more consumptive?* ● *It helps for sure.* ● *It's cool if you can do that. So far, I have tried on virtual cumin lipstick products.* ● *It saves time, you don't need to go to the store to try it directly, but it already fits on the body via virtual.*	Helpful, useful, timesaving	It is very helpful because it can save time.
9	In your opinion, if you choose clothes, are you more	● *From the new style and material size.* ● *The price is first, then the style, size, and then the comfort of the dress.* ● *The first thing to look at is the model and the size, but then again, look at the price. But if the quality of the material*	Style, size, material, price.	Everyone has their own main interest in the selection of clothes.

No	Question Asked	Respondent's Response (Set as Pure Responses from The Subjects)	Keywords	Summary
	concerned with size or style? Maybe there are other aspects to pay attention to, what are they?	*and style is good, it's worth it if the price is a bit expensive.* ● *Price, size, style, material.* ● *Price, style, size, convenience, functionality of the clothes.* ● *Style, price, and then decide.* ● *Both are important. The size is sometimes right, but if the style doesn't match the pear shape/inverted triangle/apple body shape, it's the same thing.* ● *Style, material, size, price.* ● *I am confused about which to choose. I guess size is more important, then.*		
10	In your opinion, how important is the aspect of proper size (anthropometry) for the manufacture of clothing for its users?	● *It's very important.* ● *it's important because if it's not enough, it can't be used.* ● *It's very important, because I happen to often fail in size because it's often too big.* ● *It is very important especially due to my small body size. It really affects my body shape.* ● *It's very important, because the human body varies. Sometimes it's the same as large size (L) but maybe the one and the others are not the same size in the arm or something.* ● *It's very important. The problem is that if the size does not fit, it's free. It can affect the comfort of the dress.* ● *It's important, but if it's about the size, it's acceptable because it can be reduced, if it's too small, it's impossible.*	Fit, anthropometry, convenience, comfort.	The importance of the right size (anthropometry) for the manufacture of clothing so that the clothes made are suitable for the user.
11	How to get exact/fit the user size?	● *Direct measurements can be done on clothes such as dresses or coats, if you can, you should take measurements from a professional because many clothes are made based on foreign sizes, so many clothes that should be good but when you try them on, they are too big or too long.* ● *If you measure yourself, maybe you can manually measure it, for example, how to measure the length of the arm from shoulder to wrist or something like that, so there are manual methods like that.* ● *It can be done by explaining the size of the clothes, then we measure ourselves, for example from the size of the chest, waist, sleeves, or the length of the clothes. If it's from the avatar, it's also good if we can enter our size, so just try on the clothes using the avatar earlier.* ● *For general clothing such as t-shirts, the sizes may be equalized, such as L, XL, but for personal clothing such as suits or dresses, the measurements must be made according to each person so that they are more fit on the user's body.*	Manual measurement, expert, do-it-yourself measurement.	Getting the user's size that is right/fits can be done in many ways, such as asking an expert to measure the body or someone who knows how to measure the user's body. However, it can also be done manually by viewing videos/pictures and written instructions to facilitate manual measurement.
12	Manual measuring with video?	● *Agree with the opinion of the brothers who think that a manual is given if you can, the manual is in the form of a video.* ● *In my opinion there is a picture guidance, but it would be better if it was completed with a video.* ● *Incidentally I've tried to measure personally by looking at the written manual & photos but it's still a bit unclear.*		
13	What weaknesses have you encountered in the measurement	● *If the manual uses the meter, sometimes it slides unconsciously, once it misses 2-3 cm, so that it doesn't fit.* ● *I once edited my favorite band's t-shirt in one place (confidential). At that time the shirt I bought was too long, my intention was to cut it a little so that the length was just right, but it turned out to be too short.*	Too short, sliding, user's size.	Some errors and weaknesses of some people in measuring so that the user's clothes do not match the user's size.

No	Question Asked	Respondent's Response (Set as Pure Responses from The Subjects)	Keywords	Summary
	process so far?	● *I measured and chose according to the size description, but when it arrived it still didn't fit, for example, it was like a shoe. I measured it according to the instructions and chose the size, but when it arrived it still didn't fit.* ●		
14	If given the equipment and procedures for self-measurement of clothing for users, what do you think?	● *I don't understand how to measure my body independently.* ● *It will be very helpful, maybe it will become consumptive, especially if the price is affordable.* ● *There is a video tutorial that is more efficient and very helpful.* ● *If the tools are the same, the possibility of being inappropriate is smaller.* ● *I agree with you, sometimes different tools are slightly different in size.* ● *It is helpful. Because it's easier for us to measure. Maybe by helping the video can be more appropriate than the standard size that has been found.*	Measurement equipment, procedures.	By providing the user with the right equipment and procedures for measuring clothes independently, it can make it easier and help users who want to measure manually.
15	In your opinion, what is the ideal process for fitting clothes for users?	● *For fitting, I prefer to come directly to the tailor. Because later if there is a revision it will be easy.* ● *I think you should come directly. So, you have to take the time because I don't think you can if you don't do it directly.* ● *Done manually with the support of digital technology. That's just right.* ● *Actually, the most ideal fitting is directly done. But if you go online, maybe you can use videos. The help of the avatar was enough to minimize the incompatibility of the product, in my opinion.*	On the spot measurement, self-manual measurement.	Some think that they can do the fitting manually at home without wasting energy and time. However, on the other hand, some think that fitting should be done directly on the spot by a tailor.

However, it could be highly acceptable to conduct indirect measurement through 3D modeling and rendering using CLO3D software as mostly addressed by practitioners. They were concerned about the mass-customized clothes which are quite comfortable for the customers. It is called a concept of customer-focus. Their instinct was it had a promising impact and business in the future clothing market. On the other side, most university students and educators promoted that idea 3D-based fashion product attributes such as animation, videos, and photos will support the effectiveness of measurement. It also was well understood. As now is the digital-based era, the knowledge and literacy of IT-based and digitalization are deemed to be basic knowledge and skill in higher education especially for design majors. It is a visual representation of fashion clothing built through computer technology and 3D software. The subjects were deemed helped, because they could see the details of the material and clothes that fell on the model because of the realistic 3D rendering. Even though the potential mismatch between the user expectations and computer 3D-based measurement. It is due to potential incorrect color, inappropriate size, and poor materials. However, once the real anthropometric data of the user is correctly measured and available, the incorrectness of clothing size can be minimized. Hence, practically, through CLO3D software, the additional more fit appropriate measurement can be done manually by viewing videos, pictures, and written instructions. In addition, here the self-manual fitting through 3D-based software conducted will reduce the wasting energy and time. Regarding the visualization of 3D-based fashion design, here is the result of overall measurement (see **Figure 4**).

There were two different measurement methods utilized, namely, manual measurement and 3D-based measurement using CLO3D. Considering an example of individual anthropometric-based measurement data, it was found that there was no significant difference between manual and 3D-based one. It was a one-time measurement taking only 1 subject for a pilot testing purpose. There were 12 body dimensions measured. Since it was a pilot test for comparing the manual and CLO3D measurement, there was no validity and reliability testing. Here is the detail of comparison between two different measurements (see **Table 2**).

According to the percentage of difference values between manual and CLO3D measurement, all values were less than 10%, hence, it can be concluded that there was no significant difference between those two measurements. Somehow, CLO3D is found to be much more flexible and has less processing time. Customers are supposed to select their favorite avatars and models with similar body shapes, or they can upload their own avatars for a more authentic effect. By selecting
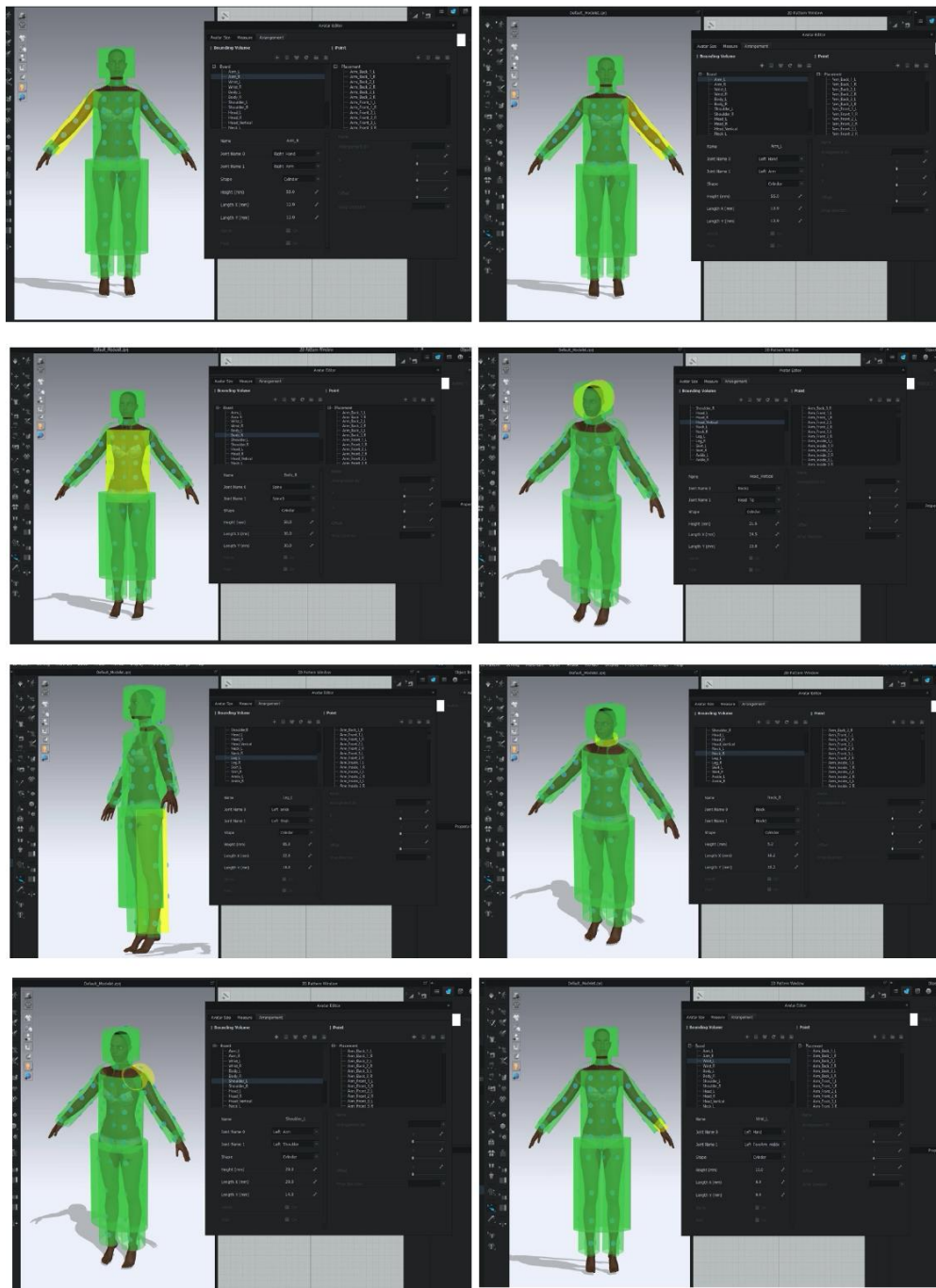
Figure 4. Example of Mannequin Building, Fabric Design, and Transparent Surface of 3D-Based Measurement

Table 2. Measurement of Body Dimensions Using CLO3D and Manual Process

Body Dimension	Measurement (in Millimeters)			
	CLO3D	Manual/Meter-tape Based	Difference	Percentage*(%)
Height	1752.6	1770	17.4	0.98
Width/bust circumference	806.4	830	23.6	2.84
Neck circumference	355.6	380	24.4	6.42
High hip circumference	803.3	820	16.7	2.04
Low hip circumference	955.7	960	4.3	0.45
Across shoulder (curvilinear)	377.8	392	14.2	3.62
Inseam height	841.4	870	28.6	3.29
Thigh circumference	549.3	561	11.7	2.09
CF neck to waist	339.7	360	20.3	5.64
CB neck to waist	381	401	20	4.99
CB neck to wrist	777.9	754	-23.9	3.17
Bicep circumference	254	271	17	6.27

All percentages are less than 10%

different clothes and models, the models also change because the system can analyze and compare the degree of fit according to the size of the human body and the size of the pieces of clothing. This makes it possible to recommend the most suitable style and size for customers. This study used static display. In the static view, the model is equivalent to when the person is standing still and currently, it is convenient to observe the effect of the curtain of the clothes at rest. Whereas the manual one was done by involving a tailor and a customer. Practically, the tailor applied an allowance of up to 4 – 8 centimetres with respect to the types of cloth (i.e., slim fit to regular fit), and finalized it according to the user's approval. Basically, both measurement styles promote flexibility. However, the 3D-based one is more flexible and independent, in terms of timing, parties involved, and personal style. There was no significant difference between the two measurement systems in terms of final clothing designs. The only difference was the time required for virtual clothing design is much less than the manual one, and the flexibility level of adjustment. For instance, once fabric attributes are selected and given desired effect through a particular software such as Photoshop, they will be imported into CLO3D. It is then to adjust the appropriate clothing through the change of relevant parameters, such as color, highlights, brightness, and tightness. In terms of comfort and more human factor consideration, the CLO3D-based fashion design provides an indicator of stress level using color display. For instance, if the color area is dominantly red; it means that the clothing has a more oppressive feeling. However, if the dominant color is green, it means that the clothes have very less pressure on the body. In addition, there is a transparent surface feature; it will be used by designers in judging the overall fit and looseness of the garment.

4. Conclusion and Implication

The pressure of user customization in terms of fashion products is highly increased. In fact, people are pursuing individual users and diverse styles of clothing. Therefore, people are no longer just satisfied with traditional and mass-produced clothing styles. They expect highly fashionable clothes based on their own design styles and adjustments. Due to the personal characteristics, it is usually not suitable for large batch production. Hence, inherently, the virtual 3D-based fashion design is urgently proposed. It will save time, money, materials used, and promote sustainability. This trend and phenomenon have been captured in this study. However, it needs more continuing studies to evaluate its feasibility. On the other side, it has been proven that mass-based production is still relevant in terms of cost efficiency. It is a big challenge to look at the optimal point between 3D-based and conventional mass-based fashion production.

This study is limited in terms of the number of samples involved both in FGD and a pilot testing for measuring 3D- and manual-based measurement. In addition to that, the collected human body measurements are potentially utilized to update the overall Indonesian anthropometry. With less effort, the possibility of updating sufficient anthropometric data will be achieved.

5. Further research recommendation

As there is no significant difference in results between manual and CLO3D measurement, for further study, it is recommended to apply the body measurement through a 3D-based mechanism involving more samples from various backgrounds such as children, adults, and elderly. The results of the upcoming measurement will be compared to the previous published Indonesian anthropometric data and adjusted to update its entire database. In addition, it is important to widen the scope of research and application of 3D-based anthropometric measurement incorporating special populations. Nevertheless, the updates of Indonesian anthropometric data is of high interest, and it is quite urgent to update it through https://antropometriindonesia.org/.

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