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METHODS, IMPROVEMENT AND CHALLENGES ON CLOTH AND HAIR ANIMATION

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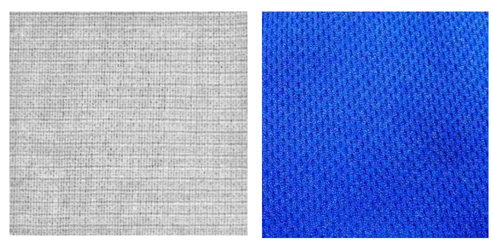
ABSTRACT

Animation may create the illusion that something is moving by taking a succession of drawings and displaying them one after another. This phenomenon is known as the illusion of movement. The generation and control of movement is a significant obstacle in both hair and clothing animation. The purpose of this study is to investigate the techniques utilized in hair and clothing animation, as well as how these techniques have changed over time and what obstacles they currently face. For this study, a systematic literature review (SLR) method was used, and 47 manuscripts from various databases between the years of 1987 and 2022 were found. According to the study, continuum model and clump mode were used for hair animation while geometric model and physical model were used for clothing animation. As technology has advanced, improvements in seams, wrinkles, blonde hair, and shading have made it easier for animators to animate clothing and hair. The animated item or character also looks better and more realistic as a result of this improvement. The precision, estimation of human shapes and sizes utilizing various devices and various fabric materials are the final obstacles for clothing animation, although it is still challenging to produce realistic hair animation in interactive applications.

Keywords: *Cloth Animation, Hair Animation, Methods, Improvement, Challenges*

1. INTRODUCTION

In this study, cloth and hair will be explored in terms of real life and in animation. Cloth and hair work similarly in the two scenarios, however, there are differences in terms of visualization. Cloth in real life, is a woven fabric that can be made from wool, cotton and fiber. Cloth can be used for different purposes, such as our clothes, curtains, tablecloth, handkerchief, and even cloth mask [1]. In real life, there are different types of cloth, we can touch and feel the texture of the cloth: some can be smooth, some can be rough, some is soft, and some get crumpled easily. People can choose the types of cloth that they want for different purposes. For example, dry-fit cloth is suitable for sports wearing, silky cloth can be made for women's clothing, and stretchable cloth can be used to design free size clothing. Besides, the pattern of threads in the cloth can also be observed by eyes. For example, dry-fit material, based on author's observation, the thread looks like many micro "holes" on the cloth as illustrated in Figure 1(a). Another example will be cotton cloth. From what the author observes, cotton cloth looks like it is being built by multiple tiny squares as shown in Figure 1(b).



(a) Dry-Fit Cloth (b) Cotton Cloth
Figure 1: Type of Clothes

In animation, cloth normally can be seen on the characters' clothing. People are trying to make the cloth to look as realistic as it is in real life. In animation, the texture of the cloth cannot be felt and touched. It only can be viewed and the impressions that it gives to the audience [1].

For 2-Dimensional (2D) cloth animation, it does not really talk much about the cloth. It may talk about the status of the cloth for example, Winnie the Pooh is wearing a red shirt (Figure 2). However, people would not know the material of the cloth: people would not know if the cloth was soft, or if it was knitted just by looking at the picture. Thus, it may not be very realistic.

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Figure 2: Winnie the Pooh With Its Red Shirt

However, in 3-Dimensional (3D) cloth animation, people are trying to make the cloth as realistic as possible. Giving an example, Elsa' clothing in Frozen 2 [2] as shown Figure 3, the details of the clothing are being drawn out and it can somehow give people the impressions of the clothing. Refer to this image (Figure 3), the cloth is likely to be knitted as the pattern of the threads can be seen clearly. By looking at the pattern of the threads, the authors could know that the dress is most likely made of cotton material.

Figure 3: Elsa's Clothing in Frozen 2

Hair is something that every human being has. Hair can be on the head, hand or leg, can be eyebrows, and moustache. Not only human beings, but there is also hair for animals too, that is known as fur. Animal fur covers their body to keep themselves warm. There are many characteristics of hair such as long or short, curly or straight, very light and can be different colors. Besides, hair can be designed into different hairstyles, for example ponytails, buns, braids, gelled and even curly-ponytail hairstyle as shown in Figure 4.

In the animation, there is hair for human and animal characters as well. In 2D hair animation, the hair is not being drawn in detail. As the author observed, hair can be very neat, that might not look realistic. For example, this Simpsons character has curly long hair (Figure 5). However, in real life, the hair cannot be very neat as there will be some strains of hair that will come out. Thus, the hair of the character does not look realistic.

Figure 4: Curly-Ponytail Hairstyle

Figure 5: Simpsons Character

As compared in 3D animation, the author observed that the hair of the character may be drawn as detailed as possible. The purpose is to make the character look as realistic as possible. Figure 6 shows the transformation of Remy, a character in Ratatouille. From the transformation, the authors could clearly see that the last form looks realistic, which the hair of the rat has been drawn in detail and just like a rat in real life.

Figure 6: Transformation of Remy

From the above explanation, the authors define that cloth and hair should be animated as realistic as possible like in the real world. Therefore, this study is to seek answers to the following questions, 1) What are the methods used in cloth animation and hair animation? 2) How have cloth animation and hair animation improved over the years? and 3) What

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are the challenges in cloth animation and hair animation?

2. METHOD

This study was performed using systematic literature review (SLR) method. It is a process for identifying, assessing and translating research materials to answer several research questions [3] based on several defined stages [4] as illustrated in Figure 7.

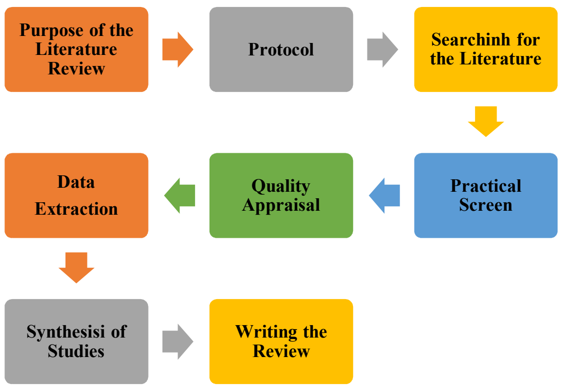

Figure 7: Stages in SLR Process

The following is an explanation of how each stage are being carried out.

Stage 1: Purpose of the Literature Review

This is the first step, which is to identify the purpose and goals of this study. In this study, it is aimed to understand cloth and hair animation. Throughout this study, it is aimed to answer the following questions:

i) What are the methods used in cloth animation and hair animation?
ii) How have cloth animation and hair animation improved over the years?
iii) What are the challenges in cloth animation and hair animation?

Stage 2: Protocol

In this stage, it is recommended by Xiao and Watson [5], that a protocol should be developed in advance and the protocol acts as a guideline throughout the study. In this study, PICOC model [6] was adopted as guideline which comprises Population, Intervention, Comparison, Outcomes, and Context. Referring to Table 1, the summary of PICOC is made on the population of students involved in programming in colleges and universities.

Table 1: Summary of PICOC

Population	Researchers in Cloth animation and hair animation.
Intervention & Comparison	Cloth and hair animation - methods used, improvement over the years and the challenges.
Outcomes	Methods used in cloth and hair animation; improvement of cloth and hair animation over the years; and the challenges in cloth animation and hair animation.
Context	Cloth animation and hair animation.

Stage 3: Searching for the literature

Journals and articles are being identified related to this study using Google scholar, EBSCO, ResearchGate, ScienceDirect and IEE Xplore database as well as other conferences and journals.

Stage 4: Practical screen

After searching for journals and articles, it is important to decide which should be considered and included in the study. In this stage, the abstract of articles will be screened through and decided if it is useful. If there is doubt in including certain articles, these articles will be excluded. The screening process is based on PICOC model which illustrated in Table 1.

Stage 5: Quality appraisal

In this phase, the articles and journals are being filtered out based on the criteria. The criteria are

i) The articles are published in journals or conferences.
ii) The articles are related to cloth and hair animation.

The following articles criteria was excluded:

i) The articles which only has abstract without content available.
ii) The articles do not focus on cloth animation and hair animation.
iii) The articles that are not published in English.

Stage 6: Data extraction

In this stage, 47 manuscripts were extracted based on PICOC mode (Table 1) from year 1987 to 2022.

Stage 7: Synthesis of studies

Once the articles have been screened, chosen, filtered and extracted, the information was combined and produced a comprehensive study. At this stage, the findings were discussed according to the question stated in stage 1.

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Stage 8: Writing the review

At the last stage, a review or conclusion is written to sum up the whole study. This is also to ensure that the study has been done systematically and smoothly. This can also ensure that the goal of the study has been fulfilled.

3. RESULT AND DISCUSSION

In this study, there are 3 research questions that have been set. The following sections are the result and discussion for each question.

3.1 Research Question 1: What are the methods used in cloth animation and hair animation?

3.1.1 Methods Used in Cloth Animation

Animation is not concerned with accuracy but concern the believability [1]. In order to make the animation look realistic, laws of science will be taken into consideration [7]. There are 2 fundamental methods that were identified, geometric model and physical model.

3.1.1.1 Geometric Model

Geometric modelling is the classical method. It is widely used in for cloth modelling as it is simple and intuitive [8]. It provides mathematical tools that can describe the objects in nature and used in designing [9]. In 1986, a geometric method was proposed to show a hanging cloth [8]. In this method, there is a grid consisting of vertices, and the shape of cloth is generated from the catenary curves between the hanging points as illustrated in Figure 8. Catenary curve is the curve which an ideal thread follows naturally when suspended by 2 points. The model creates the underlying shape out with the several hanging points. There are lines that may pass in between the curves and create new constraint points. Thus, the lowest curve will be eliminated to avoid computational complexity. With this method, it is efficient to generate stationary hanging cloth.

Over the years, geometric modeling has evolved. Wang, Wang and Yuen [10] proposed a new approach based on geometric cloth modelling which is to construct 3D cloth from 2D sketches on a pre-defined human body feature. Basically, this method will predefine the human body features and draft the 3D cloth template to fit onto it. Then, the profiles of the 3D cloth can be specified and lastly, the 3D cloth template is interpolated and constructing smooth surface. Brouet et al. [11] proposed another method which is cloth transferring for different body-shapes characters. In this method, the adjustment of the 3D cloth is through the combination of proportional scaling method and a constrained gradient-based optimization process.

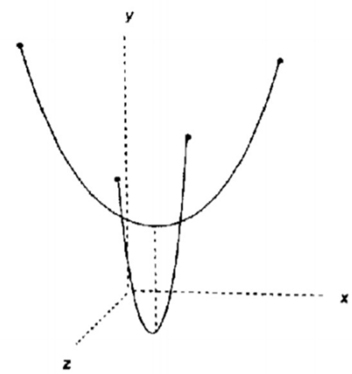

Figure 8: Crossing Catenary Curves

In a nutshell, geometric modelling in cloth animation is effective in constructing the editing the cloth. However, there is limitation such as mimicking the details of dynamic behavior of cloth [8]. Thus, physical models are used to produce dynamic behaviors.

3.1.1.2 Physical Model

In physical modelling, cloth can interact and respond to the environment more realistically [1]. In this model, it involves two methods, which are energy-based method [12], force-based method [13], Mass-Spring model [14], [15] and Particle model [16].

For energy-based method, it is based on the kinematic theory, which is used to calculate the energy of cloth [8]. This method is commonly used in static simulations to determine that the shape of cloth is moving in achieving a minimum energy state [12]. When Terzopoulos et al., [12] proposed this method, it uses the elasticity theory in describing the shape and motion of the cloth. This method is able to calculate and generate shape by simulating the tension and rigidity of the cloth. However, this method is suitable for simple shaped objects, as it is very time consuming to calculate the energy equation for a complex object [8].

For force-based method, it represents the force among the particles in the cloth by using differential equations [13]. By solving the equations, the new position of each particle at every time step can be located. A triangle of cloth element is usually used in dynamic simulation of cloth. Referring to Figure 9, there are 3 stages: a triangle cloth is being defined in 2D (left); the triangle is being deformed into a 3D environment (middle); and the deformation of

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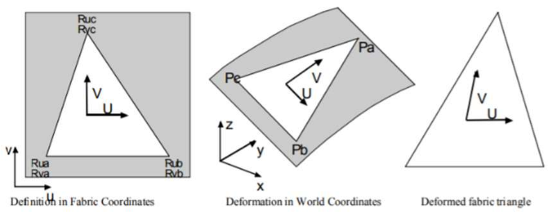
triangle cloth (right). These stages show how the location of vertices have changed on the weft-warp coordinate system with 2 directions (U and V).

Figure 9: 2D Cloth Surface Example



Another physical model, Mass-Spring model, that is improvised from the two methods mentioned earlier (energy-based and force-based methods) [14], [15]. This model is more realistic than the classical methods [14]. Non-elastic properties cloth can use this model to show the deformation and simulation [15].

Particle model is a type of physically based model [16]. The cloth is represented by a set of particles and particles are inter-connected to each other by springs [9]. It is a simple and efficient way to represent the discrete structure of cloth. In Figure 10, it shows a layer of discrete particle grid and some examples when there is internal force applied [17]. With this model, animators can see the particles clearly and know the locations of each particle on the grid.

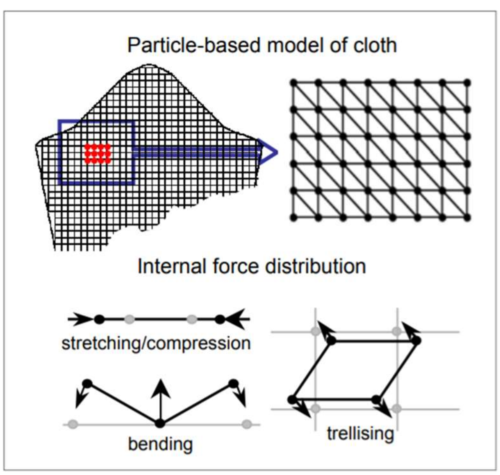


Figure 10: Shows A Layer Of Grid Particles

Basically, physical models use a lot of calculations to get the shape and locations of the cloth. The energy calculation and force calculations will be taken into consideration. This also means that there is heavy computation with physical model.

3.1.2 Methods Used in Hair Animation

Hair animation is like cloth animation. The animators are trying to make the hair as realistic as possible and believable. In hair animation, the models are continuum model [18] and clump model [19].

3.1.2.1 Continuum Model

Continuum model, based on Hadap and Magnenat-Thalmann [18], uses Lagrangian fluid technique to model the fluid forces on the mass/spring system [20]. Lagrangian fluid is a smoothed particle hydrodynamics [20] which can be used to handle the bulk behavior of hair. This continuum approach modeled the individual hair strands explicitly with serial chains of rigid segments [21]. Besides, it glued some particles to each segment. Thus, there are high computational and cost with this model. This approach is also used by Bando, Chen, and Nishita [21] in their studies about using loosely particles to animate hair. They used the idea of continuum model and came out with loosely connected particles approach which can better capture the free particles from the serial chains. Petrovic, Henne, and Anderson [22] also use this approach with Eularian velocity field and level set to animate the hair. The combination of the approaches is aimed to reduce the computational complexity [19].

3.1.2.2 Clump Model

Clumped model is another method in hair animation. It can simulate the hair interactions with a spare set of disjoint guides [20]. In a paper written by Plante, Cani, and Poulin [23], they used clump model with mass-spring model to define more interpolated hair. The hair strands can clump or interpolate between the guides [20]. The clumped parameters can help in modifying large art of clumps simultaneously [24]. This allows animators to change the shape of the hair by adjusting the parameters (refer to Figure 11). Thus, this can produce variations of hairstyles [24].

Furthermore, this model can also be used in real-time hair simulation [25]. Several disconnected strips are used to represent the hair geometries in this model. Dynamics of wisp of hair is simplified to strip motion as strands are only textured on the strips. This model helps to lower the degrees of freedoms (DoFs) of the hair geometry. Thus, this also allows to perform simulation at lower computational complexity [25].

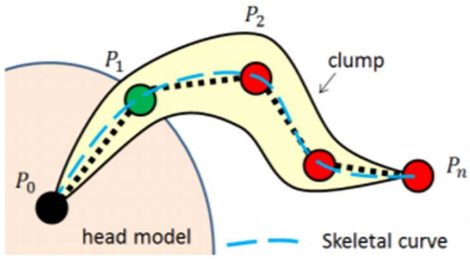


Figure 11: Shows the Example of Clump

3.2 Research Question 2: How have cloth animation and hair animation improved over the years?

In this section, the techniques and tools used in cloth and hair animation will be discussed. Over the years, the techniques and tools have evolved which led to better results in animation such as in film industry [26]. In Pixar company, Menv (Modeling Environment) animation system had been developing for many years to achieve a better result [27]. Besides, there are also other tools and techniques that have been improved.

3.2.1 Techniques and Tools Used in Cloth Animation

Animation in the past was usually done by hand-drawing as the technologies were not that good back then. As the technologies rose, animators started to use computers to animate the characters. Not only the character, but also the garments for the characters. Some popular tools used to animate cloth are fizt [28] and Marvelous Designer [29].

For clothing, there are several designs. There are seam lines for clothing. However, the technique used for seam was not that professional in the past. There was visible undesirable "popping", which is wished to be reduced or eliminated [30].

With the current technology, the techniques and tools used to animate cloth have been improved. Shading seams is a rigorous work in order to make the cloth look realistic. In a Pixar film – Coco, produced in 2017, this technique has helped to create seam texture to lots of garments in the film [31]. This approach extended the method which employs intrinsic frame fields via connection angles [32] and use periodic boundary conditions to handle the closed loops [33]. A powerful tool, AutoSeam, helps to separate the process of authoring seam curves, which allows the animators to do the seam shading more easily [31]. The tool can generate local UVs by thickening the seam curves until the intended thickness is reached. This can help to preserve the arc-length. Besides, the result of seam texture can be done by replicating the input exemplar into the curve parameterization. Figure 12 shows an example of the result using AutoSeam.

Figure 12: Shows the Stitching Textures on the Hoodie Which is the Result by Autoseam [31].

From the results, the technique has been improved and presents a good result in the Coco film. There is not any undesirable "popping". The seam has been fitted nicely and follows the curves that is supposed to be. The shading has also been done so that the hoodie looks more realistic. Thus, from this, it clearly shows the improvement of the technology.

Furthermore, generating wrinkles on cloth is not an easy job. In the past, there was a paper that introduced a kinematic method that could generate wrinkles on cloth for computer-generated characters [34]. However, this method is applicable for tight fit cloth. This is because wrinkles for loose fit cloth is not in the wrinkle database [8]. Another paper introduced a data-driven method to generate fine details, such as wrinkles on the cloth [35]. This method makes use of video footage of wrinkle's distinguishing shape characteristics [35] and produce believable wrinkle shapes. However, this method is limited to the resolution of cloth mesh, which significant amount of detail may be lost during the capturing process.

Dynamic alteration technique is being used by the Pixar company when animating the movie Incredible 2 [36]. With this technique, it can provide a natural way of wrinkles on the cloth for the stylized character [36]. It could help to dynamically adjust the cloth by region, to fit the pattern where the part that is deformed [26]. Besides, with the help of cloth rig, a component that can help to achieve consistency in styling, it allows animators to adjust easily by tweaking the behavior of the cloth on a shot-by-shot level [26]. Moreover, patch-based surface relaxation [37] is being used in order to remove undesirable wrinkles, and not to distort the texture and remove

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unappealing folds [27]. This could result in giving clean lines. This technique can be seen in Incredibles 2 characters as shown Figure 13.

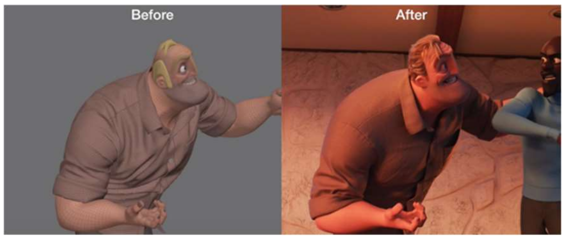

Figure 13: Shows the Use of Dynamic Alterations in Incredible 2 [26]

From the example shown in Figure 13, there are some undesirable wrinkles on the cloth in the picture "Before". With the technique, some undesirable wrinkles have been removed such as the part on shoulder and chest which can be seen in the picture "After". As the shoulder is fitting the clothes, thus the clothes are somehow stretched, and there are no wrinkles. Therefore, it looks more realistic.

From the improvement of technique, wrinkles can be handled more easily. This results in more realistic looking clothes. This technique has greatly helped the animators and film industry to produce realistic and interesting movies.

3.2.2 Techniques and Tools Used in Hair Animation

Hair animation is also an important part in animating the characters with hair. Hair is very light and there are many strings of hair. Besides, hair can be in different styles and colors. Thus, several tools and techniques are being used to animate hair. Some popular tools are 3DS Max plug-ins and Maya Hair [38].

Different characters may have different hair colors. There are characters with light color hair such as blonde hair. In Pixar, they used to use point based subsurface to mimic the light diffusion for the character's hair [36]. There are also other techniques such as dual-scattering simplification [39] and photon spherical harmonics [40]. However, these techniques do not help in producing a realistic blonde hair [36].

Therefore, Pixar team has used renderer to ray trace visibility rays throughout the hair [36]. The renderer can converge to the right color. Besides, they use Bidirectional Scattering Distribution Function model, which they do not have to fake tinted transparent shadows [36]. This allows them to lower the cost of calculating shadows and produce a realistic looking blonde hair [36]. Figure 14 shows the results in Dash's blonde hair (a character in Incredible 2).

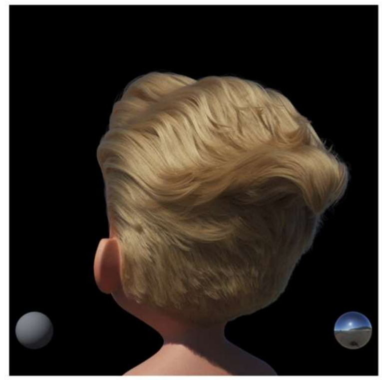

Figure 14: Shows the Result of Blonde Hair.

While the first hair shading model for hair and fur appeared many years ago [41]. However, it is still a challenging problem to shade hair and fur efficiently and accurately [42]. Due to the complexity of fiber assemblies and intricacy of scattered light, this has made control difficult. Most hair shading models in the past were parameterized with the use of material's physical properties. These models make it hard for animators to control and to obtain the desired look immediately. Furthermore, the scattered light creates unintuitive and non-liner relationship between the parameters, which make it hard for animator to control as well [42].

In Toy Story 3, a pink bear called Lots-o-Huggin Bear would not look realistic without the help of global illumination [36]. Global illumination is a technique that is used for shading. It can do fast computation, which could be as fast as ambient occlusion (a shading technique which can be used for shadows from ambient lighting) [43]. This technique could handle complex geometry such as dense polygon, subdivision meshes, and even hair. Besides, a new rigging technique, which can rig the wrinkles, allows a more precise control and presents a realistic character [36]. Figure 14 shows the results after the techniques have been applied to the character.

With the use of better techniques and combination of several techniques, this makes realistic looking hair and fur to be possible. This also allows the film industry to create more interesting furry/hairy characters.

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(a) Rigged wrinkles on Lotso (b) Final render with fur

Figure 14: Shows the Before (A) And After (B) The Techniques Apply on Lots-O-Huggin Bear [36]

3.3 Research Question 3: What are the challenges in cloth animation and hair animation?

There are always challenges in animation. Thus, people are doing heavy research in order to overcome the challenges and improve to produce a better result.

3.3.1.1 Challenges of Cloth Animation

Cloth animation is not only involved in the film industry. People are trying to use cloth animation in e-commerce, which is a digital try-on system [44]. It is basically a virtual fitting room which allows people to try on clothes. This could bring considerable profit to the economy.

Due to the current outbreak of Covid-19, it is hard for people to shop for clothes physically. However, it is hard for people to shop virtually as well, because people do not know if the clothes are suitable, or they will look good in those clothes. With a digital try-on system that makes use of cloth animation, this will greatly help people to try out the clothes before buying.

However, technology is still far from practical and there is a technological gap between garment fitting in digital and in real life. There are some challenges that are currently under open research issues. This is because machine learning of 3D human body shapes is relatively new, and it is not mature [45].

The first challenge is the accuracy and estimation of human shapes and sizes using different devices [46]. Different people will have different body sizes and shapes. Inconsistency in the system and different garment materials make it hard for people to size the clothes [47]. It may not fit well for some people who tried on the same clothes. Besides, the resolution of device used may also affect the accuracy and estimation. Thus, the accurate estimation of body shape is currently a challenge to animate cloth on human virtually. Another challenge is that different fabric material will also affect the cloth animation [48]. As different fabrics have different characteristics, it will affect how the garments fit and look on the people. The actual material and the digital representation are not well understood, which poses a challenge for cloth animation.

Lastly, fast and realistic motion of garments is also a challenge on the digital try-on system. It might not be a major issue; however, this can provide better user experience. With the current technology, people have tried to improve animation speed with cloud computing. However, improvements will still need to be made as there is a notable technology gap for 3D animation of clothes [45].

3.3.2 Challenges of Hair Animation

Not only there are challenges in cloth animation, but there are also some challenges in hair animation. With the increasing popularity of augmented reality (AR) and virtual reality (VR) applications, it is important to digitize the hair of the virtual avatar [46]. People have put in a lot of effort in making realistic hair animation. The improvements have been made in non-smooth frictions [47], impact and collision [48], and complex hair-liquid interactions [49] in hair animation. These methods could produce highly realistic hair animation. However, these methods do not apply in interactive applications as the cost of computational is very high [50]. Heuristic models such as continuum model and clump model deteriorated the hair details, which are not preferable for interactive application. A data-driven method succeeds in giving visually realistic hairs at interactive speed [51]. However, the method prohibits its generalization to unseen data [52].

A group of researchers has presented a solution by using neural interpolation [53]. However, there are still limitations in their method in producing highly realistic hair animation in interactive applications [54]. More complex mechanics will be needed to improve the method. Thus, having a realistic hair animation in interactive application is still a challenge.

4. CONCLUSION

In conclusion, cloth and hair animations have been discussed in this study. They are important and play a significant role in today's world. Animators are trying their best in making cloth and hair animation as realistic as possible. This is to give better user

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experience to people, and it is a sense of achievement. SLR has been used throughout the study in obtaining valuable and useful information. The three research questions have also been answered in the study discussion. There are several methods used in cloth and hair animation. For cloth animation, geometric model and physical model have been discussed. While for hair animation, continuum model and clump model are the methods that have been discussed in this study. The techniques and tools used for cloth and hair animation have been improving over the years and they have had a significant effect on the results produced. However, there are still challenges in cloth and hair animation. Further research will need to be done to overcome the challenges. Lastly, cloth and hair animation could be improved and widely used in other industries such as ecommerce, AR and VR in the future.

REFERENCES

[1] Parent, R., 2008. Computer Animation. 2nd ed. Burlington: Elsevier Science, pp.235-240

[2] JIANG, Q., & Chung, J. H. (2021). Analysis of the female character and modeling design features of' Frozen 2'. *Journal of Digital Convergence*, *19*(6), 309-314.

[3] Thinakaran, R. and Ali, R. (2015). Work in progress: An initial review in programming tutoring tools. 2015 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), pp.1–2

[4] Rahim, F. A., Ismail, Z., & Samy, G. N. (2014). Information privacy concerns in the use of social media among healthcare practitioners: A systematic literature review. Advanced Science Letters, 20(10-11), 2176-2179.

[5] Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. Journal of Planning Education and Research, 39(1), 93-112.

[6] Thinakaran, R., & Chuprat, S. (2022). Students' characteristics of student model in intelligent programming tutor for learning programming: A systematic literature review. International Journal of Advanced Computer Science and Applications, 13(7). https://doi.org/10.14569/IJACSA.2022.0130778

[7] Zhou, C., Jin, X., Wang, C.C. and Feng, J., 2008. Plausible cloth animation using dynamic bending model. Progress in Natural Science, 18(7), pp.879-885.

[8] Li, W., 2014. Automatic tailoring and cloth modelling for animation characters (Doctoral dissertation, Bournemouth University).

[9] Hasle, G., Lie, K.A. and Quak, E., 2007. Geometric modelling, numerical simulation, and optimization. Heidelberg: Springer.

[10] Wang, C.C., Wang, Y. and Yuen, M.M., 2003. Feature based 3D garment design through 2D sketches. Computer-Aided Design, 35(7), pp.659-672.

[11] Brouet, R., Sheffer, A., Boissieux, L. and Cani, M.P., 2012. Design preserving garment transfer. ACM Transactions on Graphics, 31(4), pp.Article-No.

[12] Terzopoulos, D., Platt, J., Barr, A. and Fleischer, K., 1987, August. Elastically deformable models. In Proceedings of the 14th annual conference on Computer graphics and interactive techniques (pp. 205-214).

[13] Volino, P. and Magnenat-Thalmann, N., 2005. Accurate garment prototyping and simulation. Computer-Aided Design and Applications, 2(5), pp.645-654.

[14] Louchet, J., Provot, X. and Crochemore, D., 1995. Evolutionary identification of cloth animation models. In Computer Animation and Simulation'95 (pp. 44-54). Springer, Vienna.

[15] Provot, X., 1995, May. Deformation constraints in a mass-spring model to describe rigid cloth behaviour. In Graphics interface (pp. 147-147). Canadian Information Processing Society.

[16] Breen, D.E., House, D.H. and Wozny, M.J., 1994. A particle-based model for simulating the draping behavior of woven cloth. Textile Research Journal, 64(11), pp.663-685.

[17] Fontana, M., Rizzi, C. and Cugini, U., 2004, June. Physics-based modelling and simulation of functional cloth for virtual prototyping applications. In Symposium on Solid Modeling and Applications (pp. 267-272).

[18] Hadap, S. and Magnenat-Thalmann, N., 2001, September. Modeling dynamic hair as a continuum. In Computer Graphics Forum (Vol. 20, No. 3, pp. 329-338). Oxford, UK and Boston, USA: Blackwell Publishers Ltd.

[19] McAdams, A., Selle, A., Ward, K., Sifakis, E. and Teran, J., 2009. Detail preserving continuum simulation of straight hair. ACM Transactions on Graphics (TOG), 28(3), pp.1-6.

[20] McAdams, A., Selle, A., Ward, K., Sifakis, E. and Teran, J., 2009. Detail preserving continuum simulation of straight hair. ACM

Transactions on Graphics (TOG), 28(3), pp.1-6.

[21] Bando, Y., Chen, B.Y. and Nishita, T., 2003, September. Animating hair with loosely connected particles. In Computer Graphics Forum (Vol. 22, No. 3, pp. 411-418). Oxford, UK: Blackwell Publishing, Inc.

[22] Petrovic, L., Henne, M. and Anderson, J., 2005. Volumetric methods for simulation and rendering of hair. Pixar Animation Studios, 2(4).

[23] Plante, E., Cani, M.P. and Poulin, P., 2002. Capturing the complexity of hair motion. Graphical Models, 64(1), pp.40-58.

[24] Yamamoto, K., Shimosoyama, T. and Noma, T., 2017, September. NPR Hair Modeling with Parametric Clumps. In 2017 International Conference on Cyberworlds (CW) (pp. 214-217). IEEE.

[25] Jiang, J., Sheng, B., Li, P., Ma, L., Tong, X. and Wu, E., 2020. Real-time hair simulation with heptadiagonal decomposition on mass spring system. Graphical Models, 111, p.101077.

[26] Kutt, A., Kalal, F., Albright, B. and Crow, T., 2018. Collaborative costume design and construction on Incredibles 2. In ACM SIGGRAPH 2018 Talks (pp. 1-2).

[27] Villemin, R., Hery, C., Konishi, S., Tejima, T., Villemin, R. and Yu, D.G., 2015. Art and technology at Pixar, from Toy Story to today. In SIGGRAPH Asia 2015 Courses (pp. 1-89).

[28] Gowanlock, J., 2020. Animating Management: Nonlinear Simulation and Management Theory at Pixar. Animation, 15(1), pp.61-76.

[29] Pinskiy, D. and Gomez Diaz, J.L., 2014, August. Modeling tools at Disney animation. In Proceedings of the Fourth Symposium on Digital Production (pp. 5-5).

[30] Foshee, J.W., 2004. Resolution independent curved seams in clothing animation using a regular particle grid (Doctoral dissertation, Texas A&M University).

[31] Bashforth, B., de Goes, F., Kuenzel, J., Merrell, J. and Xenakis, A., 2018. Automating the handmade: shading thousands of garments for Coco. In ACM SIGGRAPH 2018 Talks (pp. 1-2).

[32] Schmidt, R., 2013, May. Stroke parameterization. In Computer Graphics Forum (Vol. 32, No. 2pt2, pp. 255-263). Oxford, UK: Blackwell Publishing Ltd.

[33] Zhang, E., Mischaikow, K. and Turk, G., 2006. Vector field design on surfaces. ACM Transactions on Graphics (ToG), 25(4), pp.1294-1326.

[34] Cutler, L.D., Gershbein, R., Wang, X.C., Curtis, C., Maigret, E., Prasso, L. and Farson, P., 2005, July. An art-directed wrinkle system for CG character clothing. In Proceedings of the 2005 ACM SIGGRAPH/Eurographics symposium on Computer animation (pp. 117-125).

[35] Popa, T., Zhou, Q., Bradley, D., Kraevoy, V., Fu, H., Sheffer, A. and Heidrich, W., 2009, April. Wrinkling captured garments using space-time data-driven deformation. In Computer Graphics Forum (Vol. 28, No. 2, pp. 427-435). Oxford, UK: Blackwell Publishing Ltd.

[36] Villemin, R., Hu, C.C., Konishi, S., Narita, H., Wrenninge, M. and Yu, D.G., 2018. Art and technology at Pixar: SIGGRAPH ASIA 2018 course notes. In SIGGRAPH Asia 2018 Courses (pp. 1-68).

[37] de Goes, F., Sheffler, W., Comet, M., Martinez, A. and Kutt, A., 2018. Patch-based surface relaxation. In ACM SIGGRAPH 2018 Talks (pp. 1-2).

[38] Bonanni, U., Kmoch, P. and Magnenat-Thalmann, N., 2010. Interaction Metaphors for Modeling Virtual Hair using Haptic Interfaces. International Journal of CAD/CAM, 9(1), pp.93-102.

[39] Zinke, A., Yuksel, C., Weber, A. and Keyser, J., 2008. Dual scattering approximation for fast multiple scattering in hair. In ACM SIGGRAPH 2008 papers (pp. 1-10).

[40] Moon, J.T., Walter, B. and Marschner, S., 2008. Efficient multiple scattering in hair using spherical harmonics. In ACM SIGGRAPH 2008 papers (pp. 1-7).

[41] Kajiya, J.T. and Kay, T.L., 1989. Rendering fur with three dimensional textures. ACM Siggraph Computer Graphics, 23(3), pp.271-280.

[42] Chiang, M.J.Y., Bitterli, B., Tappan, C. and Burley, B., 2016, May. A practical and controllable hair and fur model for production path tracing. In Computer Graphics Forum (Vol. 35, No. 2, pp. 275-283).

[43] Christensen, P.H., 2010, July. Point-based global illumination for movie production. In ACM SIGGRAPH.

[44] Liang, J. and Lin, M.C., 2020. Machine learning for digital try-on: Challenges and progress. Computational Visual Media, pp.1-9.

[45] Liang, J. and Lin, M.C., 2020. Machine learning for digital try-on: Challenges and progress. Computational Visual Media, pp.1-9.

[46] Green, M., Fransen, R., Gray, D., & Kranz, B. (2018). Hair today, cloth tomorrow: automating character fx on peter rabbit. In *ACM SIGGRAPH 2018 Talks* (pp. 1-2).

[47] Li, Y., Du, T., Wu, K., Xu, J., & Matusik, W. (2022). DiffCloth: Differentiable cloth simulation with dry frictional contact. *ACM Transactions on Graphics (TOG)*.

[48] Liu, K., Yang, Q., Lu, Y., Zhang, T., & Chen, S. (2021). Research on the Computer Case Design of 3D Human Animation Visual Experience. *Wireless Communications and Mobile Computing*, *2021*.

[49] Lyu, Q., Chai, M., Chen, X. and Zhou, K., 2020. Real-Time Hair Simulation with Neural Interpolation. IEEE Annals of the History of Computing, (01), pp.1-1.

[50] Daviet, G., Bertails-Descoubes, F. and Boissieux, L., 2011, December. A hybrid iterative solver for robustly capturing coulomb friction in hair dynamics. In Proceedings of the 2011 SIGGRAPH Asia Conference (pp. 1-12).

[51] Kaufman, D.M., Tamstorf, R., Smith, B., Aubry, J.M. and Grinspun, E., 2014. Adaptive nonlinearity for collisions in complex rod assemblies. ACM Transactions on Graphics (TOG), 33(4), pp.1-12.

[52] Fei, Y., Maia, H.T., Batty, C., Zheng, C. and Grinspun, E., 2017. A multi-scale model for simulating liquid-hair interactions. ACM Transactions on Graphics (TOG), 36(4), pp.1-17.

[53] Chai, M., Zheng, C. and Zhou, K., 2014. A reduced model for interactive hairs. ACM Transactions on Graphics (TOG), 33(4), pp.1-11.

[54] Wang, Q., Zhang, L., & Li, B. (2021, December). SAFA: Structure Aware Face Animation. In *2021 International Conference on 3D Vision (3DV)* (pp. 679-688). IEEE.