Real Time Physical Force-Driven Hair Animation

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Summary
Hair animation is one of the elements that contribute to realistic character animation which is widely used in animation, games and movies. Simulating realistic hair with physical properties always becomes a challenge where the hair strands are being manipulated with the forces. This paper proposed physical forces of gravity and wind to be applied into hair animation in real time based on wisp model and verlet integration technique. Initially, the hair strand will be extended from hair scalp then each joint of hair scalp will be updated through verlet integration. Afterward, the physical forces will be applied into each hair strand. The result of experiment show promising behavior where straight type hair style able to produce a realistic motion with acceptable frame per second. However, the rise of hair strand with physical forces will affect the computational cost significantly. The 2250 generated particles will require 0.017s of time step value, while 36750 needs around 0.070s, this mean 24% of extra time step value required when hair strand particles rendered. The current technique still can be improved by apply tessellation technique to reduce excessive use of resources and not only straight-type hair model such as curly or frizzy.

Key words:
Hair animation; Physical forces; curly hair.

1. Introduction

Hair is one of the human body parts that are created by God in order to fulfill the perfection of human appearances. As hair is the human traits that make them one perfect creature ever created, animators have been continuously struggling to make human hair movements and its physics having a realistic look in many ways it could. From that of 2-Dimensional (2D) animation to 3-Dimensional (3D) animation, we could observe the differences in hair motions animation. As of today, as the technology in 3D animation production advances, more animators took opportunity to improvise their own animation products, in way that they could mimic real human movements as in the real world, perfectly.

Toy Story from Pixar Studio, an animation film that was produced and released in Year 1995, had successfully presented an animation in 3D format, and as of this success, it has brought changes to animation industry that existed during that period. This 3D animated film also has been a stepping stone to many animators, in the entertainment media industry, to produce more that of 3D animations with better quality. The presence of new technology also has helped the animation industry to seek more opportunities in order to produce animation products with better and advanced graphics performance. As of hair animation, we could observe that 3D animations that have been produced still unable to reach the realism of human motions, especially in realistic hair motions. This is caused by limited animation techniques in terms of the calculations in the human hair physics that considers the gravitational force and wind force that must be applied to human hair.

2. Related Works

Particle-based dynamic simulation technique is a technique commonly used in hair simulation. This technique is preferred by researchers because it allows hair strands to be produced by linking the particles easily. Particle-based dynamic simulation technique is a technique that is used by Oshita, M. (2007), by combining this technique with dynamic hair generation technique in his research on hair simulation with the use of graphics processing unit (GPU) along with the dynamics wisp model in real-time[1].

Oshita,M. used the wisp model technique by grouping hair strands that possesses similar orientations. This technique, used by Masaki Oshita is adopted from Plante et al.'s (2002) technique, developed in his previous research, and then it is continued by Kelly W. et al. By using particle-based dynamic simulation techniques, that is, hair model with a series of tiny particles, hair motion simulation can be generated based on the forces applied to all the particles [2,3]. Fig.1 shows the dynamic Wisp model for hair strand creation.

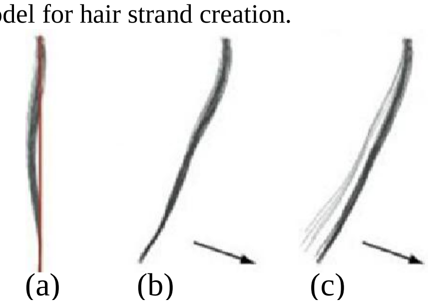

Fig.1 Dynamic Wisp Model. a) Generated wisp. b) A Moving static wisp. c) A moving dynamic wisp[1]

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In addition to dynamic simulation, hair-hair interactions, which is the collision that occurs between hair strands was also studied by Hadap and Magnenat-Thalman. Their research has helped further studies because this hair—hair interactions is an important factor in the production of animation or hair simulation [4]. Collisions that occur between the hairs strands are needed to generate hair movements [2]. The diagram of envelope wisp and skeleton is described by Fig.2.

Next, Verlet integration technique (Verlet Integration) used to calculate the trajectories of particles in molecular dynamics simulations is also used in previous studies [5]. Verlet integration techniques adopted by some researchers in the production of cloth simulations and particle movements. This technique provides better stability on the movement of the particles used. Following is the equation of Verlet integration as described in equation 1:

$$P_k = (P_k^{-1} - P_k^{-2})\Delta t + g\Delta r^2 + \frac{|w \times t_k|}{|w|} w\Delta r^2 \; \ldots\ldots (1)$$

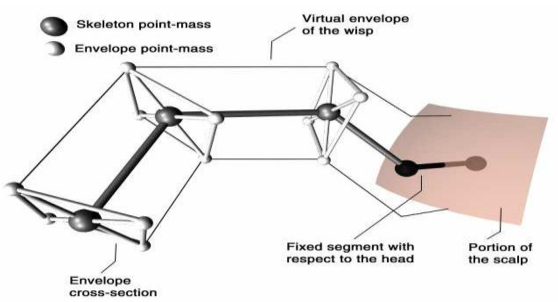


Fig.2 Elements that define the skeleton and envelope wisp, and its configurations[2].

Previous researchers also studied the hair style and involve the statistical wisp model for the hair style generation approach. The hair style is still denoted by collision behavior between strands to maintain the realism of 3D virtual human or animal hair [6-7]. Besides the hair animation, researcher also tried to track the object features without marker to boost the realism in augmented reality[8-11]. It can be extend to emergency assistant in crowded environment during panic situation[12]. Brain computer interface with facial expression also affect the virtual human realism and increase the interactivity between user and virtual human. It will revealed the inner emotion of human to be expressed deeply in the virtual human[13-19]. The interaction between users and system also can be handled via gesture with natural interaction through finger or hand movement[20-21].

Hair wisp model is the most important component in the development of this simulation system as it is to fulfill the goal of this study. This module also acts as the cornerstone of this study as well as the development of system. Existing hair wisp model is used in this study, improvised and updated with appropriate additions and tweaks. The objective of the implementation of this module is to produce hair model by using generated particles, and to group the hair strands to form the hair wisp model.

3 Methodology and Experiment

The modules used in the system development process of simulation system include the hair wisp model generation module, head model generation module, the implementation of Verlet integration module, and the implementation of gravity and wind direction over hair model. These modules have been implemented in a proper way during the development of the hair simulation system process to avoid the occurrence of major technical errors.

Subsequently, generation of head model module leads to the production of head model will be used as one of the constraints to the movement of the hair. It is also produced to meet the needs of the constraints to the implementation of Verlet integration techniques. The implementation of Verlet integration module is a very important component in this study because the process of storing, computation, and updating particle positions are done in this module. The generation of hair wisp model and head model are related because this technique is implemented in order to create a constraint to the hair movement. Gravity and wind module is a module that holds the main objective of this study. This module includes gravity and wind direction (drag) input over the hair model. Fig.3 shows the process of the implementation of this module.

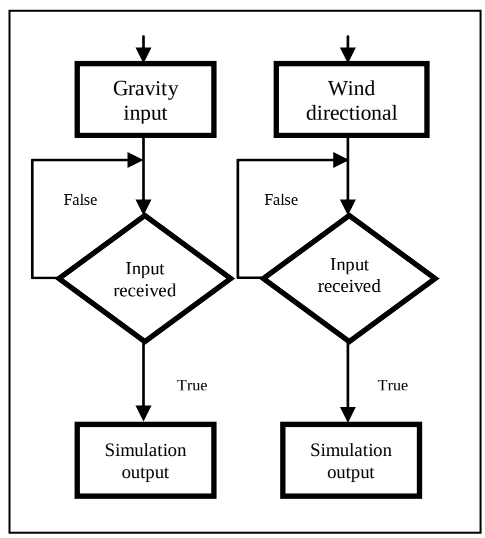


Fig.3 Flow chart of the implementation of gravitational force and wind drag force.

Implementation phase will be focused more on implementation process of the modules stated in previous section. The process existed in the stated modules will be elaborated more in this section.

3.1 Generating Hair Model

Hair model will be produced by using particles as they are easy to manipulate due to its flexibility nature. Next, each particles generated will be linked together in parallel to form a hair strand. This process is repeated until desired amount of hair strands are generated to produce a group of hair strands. Afterwards, the process of gathering and grouping all the hair strands is performed. Each hair strands will be grouped equally and the process are repeated for all hair groups. Then, every hair strands found in each group will be bind together to form a wisp model. Fig.4 shows the framework of the process of generating hair model.

3.2 Generating Head Model

Head model are produced using C + + programming language and is aligned with DirectX 9.0. Primitive objects are considered, such as primitive lines which are then make up the triangle meshes, in order to produce the head model. Triangle meshes that are generated are then linked to form the wireframe of human head model.

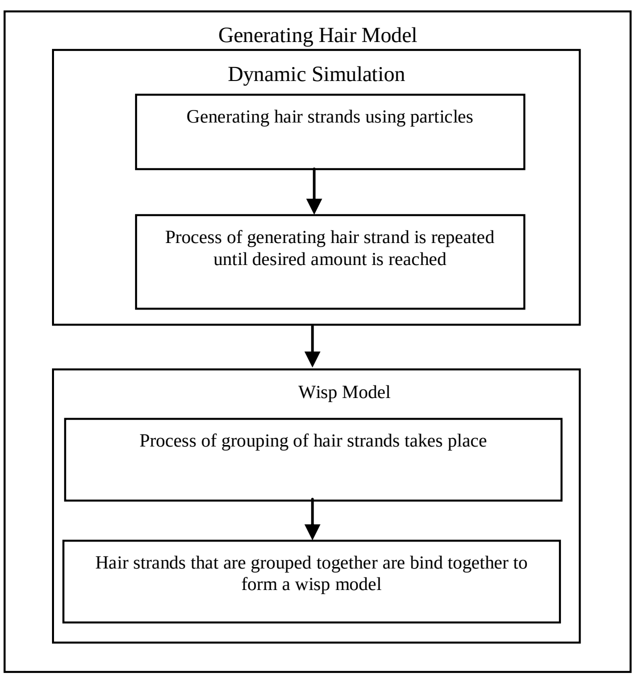


Fig.4 Framework of the process of generating hair model.

3.3Process of Gluing Hair Model onto Head Scalp

Hair strands that were produced using particle-based dynamic simulation are then formed into wisp model and attachment process is done onto the generated human head model. Fig.5 shows the framework of the said process.

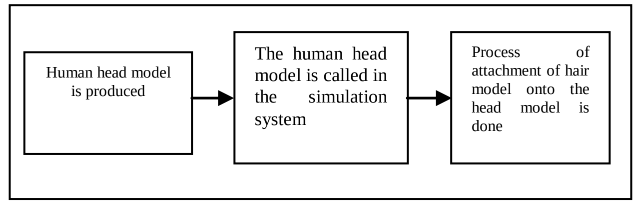


Fig.5 Framework of generating human head model and gluing the hair model onto it

3.4 Implementation of Verlet Integration

Implementation process of Verlet integration is to calculate and determine the motion of particles hair strands. Verlet integration technique is used to define the gravitational force and wind drag force, as outlined in the objectives of this study. Verlet integration allows the motion of hair simulation to be described by particles in rectangular coordinates and changes in velocity is performed by placing constraints on the relative positions of the particles. In each step of the simulation, the forces that acted on each group of particles, and they are used during the process of updating the Verlet integration. After the updating process is done, the relaxation constraint is called. Using Verlet integration method, gravitational forces and wind drag forces are implemented on the hair model. The equation 2 shows the calculation of drag forces, which creates the wind-like forces.

$$F_{drag} = -kv \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where F defines the drag force that acts on every wisp model, which are the gravitational force and wind force, meanwhile k is the controlled or constant variable that is proportional to that of v, which is the velocity of hair motion.

Using the Verlet integration, every current position and the previous ones for the joints of the hair model can be kept. Next, every positions that are kept will be updated if there is any hair motion that is resulted from the gravitational force and wind force (refer to equation 3).

$$P_{current} = 2P - P_{previous} + a\Delta t^2 \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The velocity for every joint for each hair strands are calculated from the current position. This is due to unverified velocity values of every joint of the hair strands. This is a very important matter as the Verlet integration needs to be updated. The whole process of the implementation of Verlet integration is summarized in the following Fig.6.

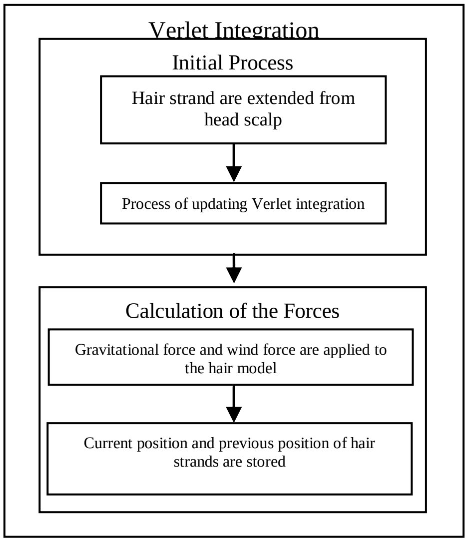


Fig.6 Framework of implementation of Verlet integration

As explained in the previous subtopics, constraints are indispensable factor in producing animated hair motion using Verlet integration. Without proper constraints, the production of hair animation does not seem realistic in terms of motion produced. The constraints that are needed in this process are:

- Gravitational forces
- Wind direction

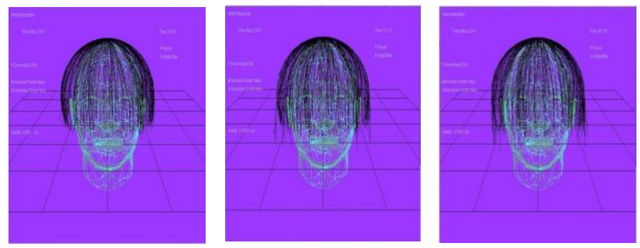
As mention equation (2), which is $F_{drag} = -kv$, F_{drag} is used to calculate and determine these two constraints. This matter proves that Verlet integration is suitable to calculate as it capability in determining gravitational force and also drag force (wind).

4 Result and Discussion

The result that is to be displayed is the hair simulation which considers the changes in gravitational force applied onto the hair model and also the effects of the wind blower on hair model. Testing and observation of the simulation system that has been developed are made and the data obtained are then collected and compared by measuring the performance in hair animation simulation system that considers the gravitational and wind force.

4.1 Applying Gravitational Force

Gravitational forces are applied to the hair wisp model, and the input value given varies in each testing. Gravity input is applied by clicking on the button "Increase Gravity" or "Decrease Gravity". Each value applied is then displayed on the window called "Hair Simulation". Fig.7 shows the resulting output when gravitational forces are applied onto the hair model. Fig.7 a use gravitational force: 9.8ms^{-2}, while Fig.7b:13.8 ms^{-2} and Fig.7c:17.8 ms^{-2}.



(a) (b) (c)

Fig.7 Animation frames of increasing gravitational forces.

Based on Fig.7, we could observe that increasing gravitational force will result in strong pulling forces to act on the hair model and it will be pulled to the ground. As the gravitational force increases, the hair model will be pulled towards the ground and through series of observations, as the gravitational force increases, hair motion will slows down.

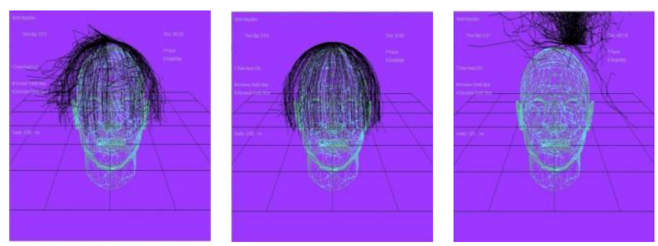
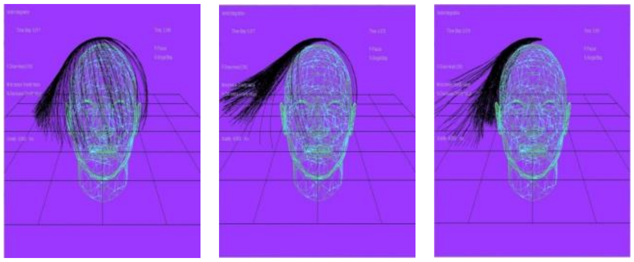


Fig.8 Animation frames of decreasing gravitational forces.

Fig.8 shows that decreasing in gravitational force will result in weak pulling forces on the hair model, and thus makes the hair model to floats upwards. As the gravitational forces decreasing, the hair floats (as in midair) and moves in random directions. Fig.8a gravitational force is set to -1.2ms^{-2}. Fig8b:-0.8ms^{-2} and Fig.8c:-2.8ms^{-2}.

4.2 Applying the Effects of Wind

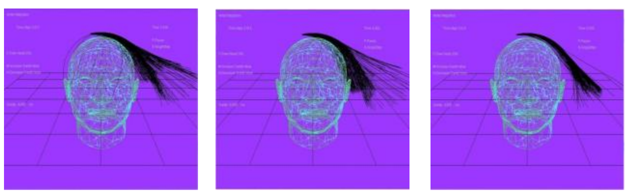
Wind effects are imposed on hair wisp model based on a given input. Fig.9 and 10 shows the output of the hair simulation based on wind direction input. Fig.9a shows the animation frame at 3.346 s, while Fig.9b at 4.670 s and Fig.9 c 5.951 s.



(a) (b) (c)

Fig.9 Animation frames when left directed wind effect is applied onto hair model.

Fig.9 shows the animation frames when left directed wind effect is applied onto the hair model. Based on observations that have been made, animation on hair motion has not encountered any problems as it works smoothly at total particle of 2250, when the left directed wind effect is applied onto it. Similar situation also could be observe in the output of animation frames when right directed and upwards directed wind effect are applied onto the hair model as in Fig.10 and Fig.11.



(a) (b) (c)

Fig.10 Animation frames when right directed wind effect is applied onto hair model. a) Animation frame at 5.936 s. b) Animation frame at 6.602 s. c) Animation frame at 8.550 s.

Fig.11 Animation frames when upwards directed wind effect is applied onto hair model. a) Animation frame at 5.685 s. b) Animation frame at 6.417 s. c) Animation frame at 6.884 s.

Based on the experimental study, it is found that the implementation of Verlet integration technique is very effective in providing the elastic movement of the hair and makes the hair simulation look more realistic. In addition, this technique also allows the gravitational force and wind direction (drag force) implemented on the motion of hair strands by updating each position of the particles that form the hair. However, there are things that should be considered based on the results obtained from the testing. Hair simulation system developed cannot cope with the huge amount of hair strands because the strands are made up of particles that are linked together and due to this reason, the frame per second (fps) of the simulation will decrease if the number of particles are called in a large quantity. This causes the hair animation simulation to slow down and interrupt the system itself. Table 1 shows the computation time of the simulation system based on the amount of particles generated.

Table 1: Computation time of hair strands based on its defined variables

Hair Properties				
m_width	**m_height**	**m_segments**	**Generated number of particles**	**Time-Step Value**
15	15	10	2250	0.017
20	20	15	6000	0.041
25	25	20	12500	0.070
35	35	30	36750	0.070

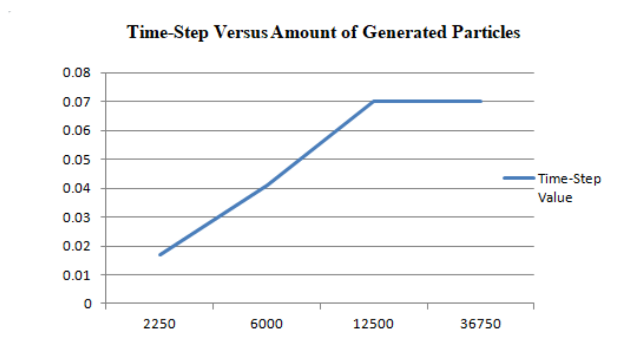


Fig.12 Plotted line of time-step versus amount of generated particles.

Table 1 portray the amount of particles are generated from the specified input value, which means, by setting the input directly, through the variables m_width, m_height and m_segments. From the data gathered through the analysis of the study, which is based on Figure 1.12, the number of point of particles arising from these three variables influenced the computational time of the hair strands generation. As mentioned before, the greater the number of particles generated to form hair strands, the frame persecond of the animation decreases, and cause lag in hair animation. To replace the frame persecond, time-step method is used to determine the computational time of this hair simulation system. Differs from that of persecond frame, increasing the time-step, shows the lagging in the computational time of the system as well as the rendering process of this simulation system

5 Conclusion

In this research, realistic movement of the hair applied with of the gravitational force and wind as constraints in real-time are taken into account. In other words, the physical form of the hair does not play such an important role because the real goal and objectives of the study is to consider the movement of hair, which is straight-type hair style, to be realistic as described above. Hair wisp model that is used in this study fits the objectives of this study. Although the movement of the hair model looks realistic when these forces imposed upon it, frame persecond of the hair animation simulation reduced if the hair strands are produced in large quantity. To reduce such problem in future works, the hair generation technique should be further improved. Tessellation technique helps to reduce the problem of excessive use of resources and it also provides better management of the data set for the generation of hair model. Moreover, this study only takes straight-type hair model into account. Other variations of hair styles are not taken into consideration as the scope of this study is mainly set the straight-type hair model as the controlled variable. As a suggestion for future research, the scope should be expanded and other variations of hair style should be considered as well. This is because every hair style possesses different characteristic and mass, and the different states of mass are able to influence the movement of the hair if the force of gravity and wind imposed on it.

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