Assignment 3 : Simulation of Hair Motion with Air Interaction

NAME: JUST

1 INTRODUCTION

In this assignment, I have implemented a simple physical simulation program to demonstrate the dynamics of human hair under the influence of air flow. The system allows users to interact with the head model, and shows the simulation of the hair. The features of the system are listed below:

(1) Add air flow interactively.
(2) Add air flow in the simulation scenario to make hair flutter.
(3) A coupling of air motion and air.

2 IMPLEMENTATION DETAILS

Based on assignment 1 and 2, I create the system(as shown in Figure 1) by Qt 5.8.0.

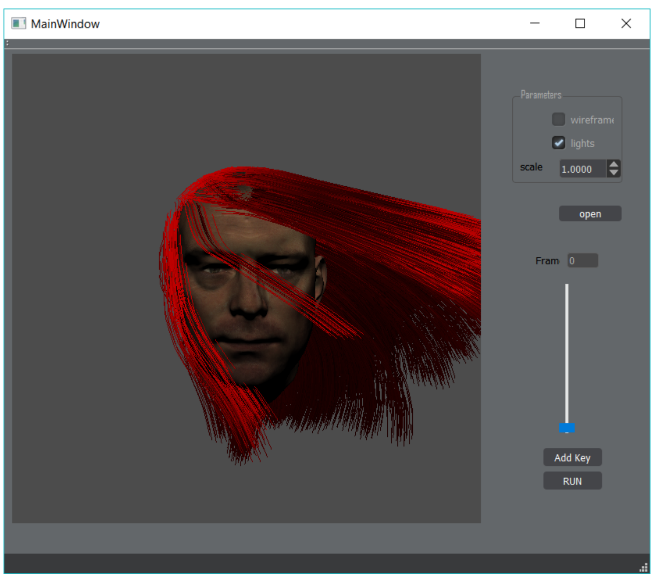

Fig. 1. The interface

2.1 Air flow simulation

Based on Navier-Stokes equations, which describes the motion of viscous fluid substances, we can simulate most fluid flow.

$$\frac{\partial \vec{\mu}}{\partial t} + \vec{\mu} \cdot \nabla \vec{\mu} + \frac{1}{\rho} \nabla p = \vec{F} + \nu \nabla \cdot \nabla \vec{\mu} \tag{1}$$

$$\nabla \cdot \vec{\mu} = 0 \tag{2}$$

But it only admit analytical solutions in very simple cases. Therefore, we usually split it to four simpler equations(mostly using Helmholtz Hodge decomposition[1]):

$$\frac{\partial \vec{\mu}}{\partial t} = F \tag{3}$$

$$\frac{\partial \vec{\mu}}{\partial t} + \vec{\mu} \cdot \nabla \vec{\mu} = 0 \tag{4}$$

$$\frac{\partial \vec{\mu}}{\partial t} - \nu \nabla \cdot \nabla \vec{\mu} = 0 \tag{5}$$

$$\frac{\partial \vec{\mu}}{\partial t} + \frac{1}{\rho} \nabla p = 0 \tag{6}$$

There are many algorithms striving for accuracy and so fairly complex and time consuming. In this assignment, what matters most is that the simulations look convincing and fast(The simulation can be controlled by the user as before). So I used the methods introduced in [2] to make sure the stability and speed of the system. The codes are in **air.cpp**.

The user can press 'W'/'D' to add a force(**Air::AddVelocity**) to the air flow field from bottom/left side to make the air flow. Also, the fluttering hair will disturb the flow field(the video and the next subsection tell more).

2.2 A coupling of air motion and air

Air -> Hair. After the simulation, the system knows the velocity field of the air flow. To make the hair flutter, the system will add an additional force. The steps are as follows:

(1) Calculate the velocity v of the air at the position of p by trilinear interpolation[3] (**Air::trilinearInterpolation**)
(2) Add a force $f\_air = \xi v$ to the hair strand control point p. Where ξ is a constant parameter.
(3) Iterate all hair control points to make the hair flutter.

Hair -> Air. To update the air velocity field, the system needs to interpolate back the new velocities to the grid. I use a Gaussian kernel to produce it. For every grid point, the system calculates the final velocity by:

$$v = \sum_{x \in \Omega} w v_x \tag{7}$$

$$w = e^{-d^2} \tag{8}$$

Where Ω is the sensitive area of each grid point. v_x is the velocity of each hair control point in Ω. d is the square distance from the grid point to the control point.

3 RESULTS

Please watch the demo video to see more features and results.

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Fig. 2. Results

REFERENCES

[1] Jean Bladel. On helmholtz's theorem in finite regions. *IRE Transactions on Antennas and Propagation*, 7(5):119–119, 1959.

[2] Jos Stam. Real-time fluid dynamics for games. In *Proceedings of the game developer conference*, volume 18, page 25, 2003.

[3] Unknown. Trilinear interpolation from wikipedia, 2018.