Project EDAN35
Realistic cloth and wind simulation

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***Abstract*—Idea: Simulate how cloth is affected by the wind**
Result: Using collision detection, force distribution, springs and Newtonian physics, the end result was good. The motion was fluid and moved in a realistic manner. Possible improvement includes setting up a better shader to get the visual effect more accurate, but also some more physics, e.g. that the wind particles are affected by the flag and changes direction upon collision.

I. Description

The goal of the project was to simulate a piece of cloth moving with the wind in a 3D environment. To do this, we implemented several methods to manipulate the structure of the cloth object. This included wind particles that would interact with the cloth, tension equations for the vertices and the distribution of force over the surface.

We used several variables in order to experiment with the program and get a desired look. The wind was defined as particles with a certain velocity vector which gives the direction and how fast they moved. How the cloth reacts to the wind particles was determined by variables k and c in 1. Testing would also include generating wind from different directions and with several cloth objects in the scene.

II. Algorithm choices and approximations of physics

There are many ways to set up a structure for the cloth and use it to create movement. We chose to manipulate the actual building blocks of the 3D object, namely it's vertices. When a wind particle hits the surface, the closest vertex is affected by the initial magnitude of force, which spreads over nearby vertices and diminishes. We used a recursive algorithm in order to simulate this type of force distribution:

```
void distribute_force(strength){
  if(strength < LIMIT) {
        return;
  }
  apply_force();
  for(all_neighbor_vertices){
        distribute_force(strength*
            diminishingFactor);
  }
}
```

Furthermore, we wanted the movement of each vertex to affect it's neighbors position in the sense that it ”drags” them with it. To get this effect we used Hooke's Law:

$$m * a = F_{ext} - k * x - c * v \tag{1}$$

which resulted in a movement in the cloth as a dampened harmonic oscillator.

Since the position and velocity is given by

$$x = x_0 + v * t \tag{2}$$

$$v = v_0 + a * t \tag{3}$$

we could compute the new position and velocity of each vertex.

The wind effect was done by using a simple implementation of a wind particle object and sending a large amount of these toward the cloth. A wind particle had a velocity and a position, and applied a force to the cloth when a collision was detected. When colliding with the surface, we used plane equations for the triangles to find which triangle was hit, and then applied force to the closest vertex. We set the direction of the force to be the same as the surface normal, and the magnitude to diminish proportional to the dot product of the normal and the particle travel direction:

$$force_{applied} = direction_{particle} \cdot N * force_{particle} \quad (4)$$

where N is the surface normal.

III. Results

The results were good, the cloth reacted like a curtain blowing in the wind. The motion and reaction were fluid. Furthermore, we could freely change the spring constants k and c in order to simulate other materials than cloth. A high c with low k for instance results in a "heavier" material, almost making it look as if it is hit by bullets. Screenshots are in the Appendix.

IV. Discussion

During the project, we tried different approaches and saw many changes in the result but eventually managed to create a visually appealing effect. Initially we wanted to implement a way for the wind to apply force to the cloth, and quickly settled with the method described earlier in the report. At this stage however, only one vertex was moving and we knew that we needed some way to spread the impact over the surface. That's how we came up with the force distribution algorithm which greatly improved the cloth movement. At this point, nothing was restraining the cloth from stretching too much and moving without any restriction, which is why we needed to implement Hooke's law to actually hold the vertices together. With this implementation, the vertices movement affected it's neighbors by holding them together with a force that becomes greater the further they are apart. However, we made the mistake of replacing the force distribution with Hooke's law, thinking that it was an improvement to do so. Even though the cloth moved nicely, we could easily identify an unwanted behavior in the form of large oscillations. With enough force from the wind it could even create a superposition effect that made the vertices move to infinity. What we later discovered was that by re-introducing the force distribution algorithm and making it work together with the spring equations, the unwanted oscillations disappeared which resulted in a more fluid movement. This was basically our breakthrough in the project.

While we were satisfied with our results, changes could be made to make it more realistic. One thing that our simulation is lacking is a gravity effect, and the reason the cloth is slowly returning to it's normal state when the wind stops is because we defined the Hooke's law equations to make the vertices move toward this position. To get the movement to more closely resemble reality, we would have to redefine the way we use Hooke's law and use a seperate force that simulates gravity.

Another limitation in the program was that the wind particles disappeared once they reached the surface. In reality, wind will of course keep applying force and try to move around the object. A solution would be to let the wind particles move along the surface in some way, but we were not sure how to define which way they would go. In the end we decided that this was not a top priority issue, and not extremely significant for realistic movement.

Overall, we had fun doing this assignment and learned a lot from it. It was interesting to apply mathematical equations in a simulation like this and manipulate the building blocks of a 3D object to create a realistic effect. If we had more time we would probably make it even better and also more computationally effective, but we were satisfied with the end result nevertheless.

V. Appendix

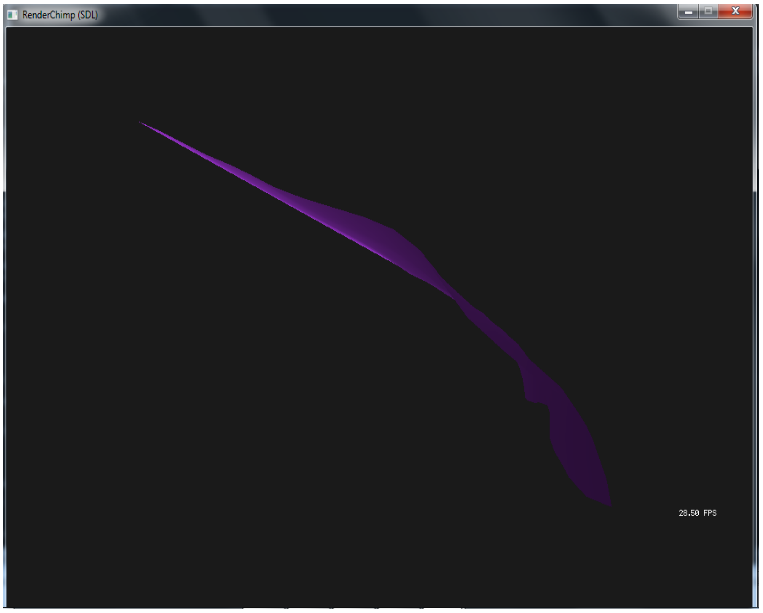

Fig. 1. Reaction from the flag when the wind starts to blow

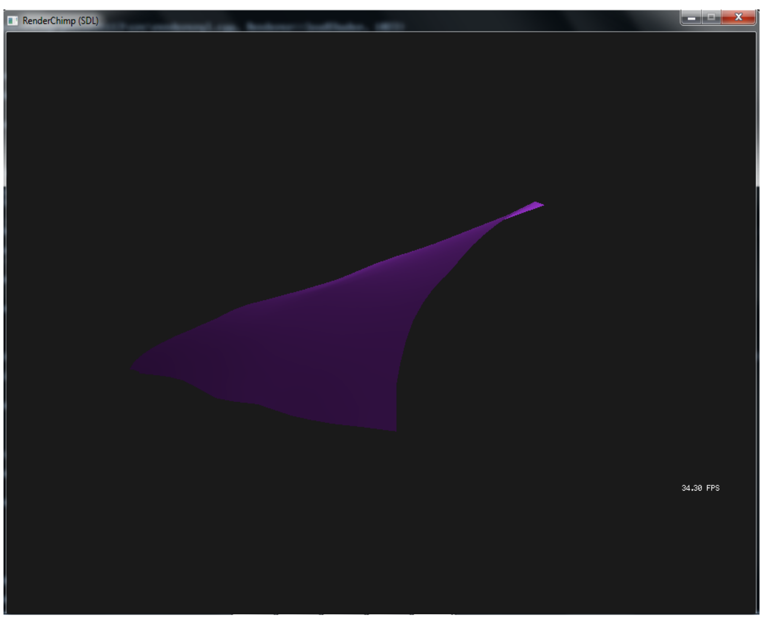

Fig. 2. Reaction from the flag when the wind starts to blow, seen from behind the flag