

POSITIONING AND CONTROL OF NOZZLES AND WATER PARTICLES IN DECORATIVE WATER CURTAIN AND WATER SCREENS

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Abstract:

LED and LCD displays, laser show devices and animators, musical fountains, water curtains and artificial waterfalls, etc., are decorative instruments. Some of them were developed for intelligent pouring of water droplets as particles in a space (particle screen). They have nozzles in the line that generates pattern with programmed on or off of its valves. This article introduces an improvement of water curtain (waving pouring water) and water screen (stenciled water screen by use of on-off valves), and combines them together.

Keywords: water nozzle, curtain, decorative, simulation, OpenGL.

1. Introduction

Decorative and special effect equipments are used everywhere – in hotels, airports and public places, etc. Many years ago water curtain and water screens have born as a decorative equipment for information or funny multimedia screens. Smoke screens [9] and then recently fog screens [10] emerge after that. Smoke screens reveal laser or light beam projected to a curtain generated by use of smoke particles as a screen. Fog screens do something like that, but they use small water droplets instead to accomplish it. Water curtain is simply a curtain but its brother, water screen, is an intelligent machinery to produce patterns as a media. Single in line (2D) water screens can generate patterns with placing particle (water droplets) in a plane. At the 2006 virtual reality conference a paper was proposed about making 3D patterns with water drops [1], after that scientists pursued to study of this type of screens. Then modifications and improvements in usage [4] or in development [5] (used as computer interface and similar usages [7]) were being proposed in the literature. Finally, Peter C. Barnum, Srinivasa G. Narasimhan, Takeo Kanade at 2010 proposed a “multi layer display with water drops” [8]. This article introduces an improvement of water curtain and water screen, and combines them together.

2. Machine at the simulation and study phase

Simulation software can be the first step in development to investing reality requirements, problems and abilities of a machine or process which will be designed. Here it will be used to design surface generated with the machine physically.

In this article we show how it has been used to design and simulate a set of nozzles in a line (say x axis) and

each of them can move in cross direction (say y axis) which each of them have on/off valve to control pouring the water or not. In the design process it should impose restriction of nozzle movements in real world to imaginary world. A snapshot of the developed software using OpenGL in C++ is viewed in the Figure 1.

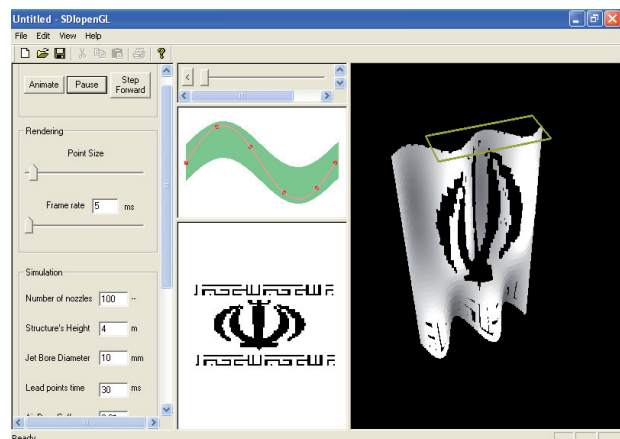


Figure 1. Simulator Snapshot

Some other views of the simulated curtain and cut logo can be seen in the Figure 2.

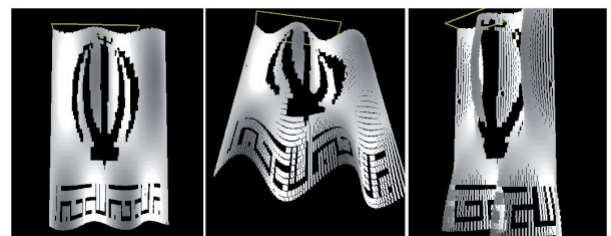


Figure 2. Other views of the simulated curtain

Control panel can be seen in the left most of the window. At the middle of it design pane are placed. And simulation animated preview at the right most.

2.1. Design toolbox

Design toolbox is in middle vertical section of the snapshot above. It can be seen at the top of the design portion we have a time line. Below of its nozzle position a design pane and then On/Off design pane placed.

A user defines position of nozzles in each step of motion, and intermediate steps will be interpolated. We can say in each frame because in simulation these positions are used to make animation. Application imposes restrictions to position definition of nozzles. For example, if a nozzle is going to the positive direction with +20 velocity at

the origin, next position of the nozzle can be extremely at, for example, +40 and only -10 because of negative acceleration needed to stop and go back in negative direction. These restrictions make a legal zone to definition of nozzle positions. It shows to the user with a green zone, and user has to define and adjust control points in that area. Movement restriction defines based on acceleration restriction of nozzles which depends on manufacturing of the machine and will be defined in next development steps.

User can define intermediate frames. An application generates jumped frames accordingly with interpolation. It maybe seems a user-friendly approach to design. It can improve in next versions with a 3D design medium approach.

At the bottom of the design section On/Off pane can be seen. In this section a pattern draws or loads from a bitmap file. This pattern will be ended with the watery curtain. Corresponding nozzles at appropriate steps of time Offs if corresponding point is black or make it On if it's white. Then the pattern designed as a black region will produce as a cavity in the generated surface.

2.2. Physical simulation

Here a particle based simulation is used. A number of water drops injected to the air with nozzles in each step of time and simulate its motion till receives to the ground. Height of water and many other parameters can be controlled *via* control panel in the left most of the window (depicted above).

We use dynamic relations to simulate movement of water drops including gravitation force, air drag, and cohesion between water drops. Look at the Figure 3.

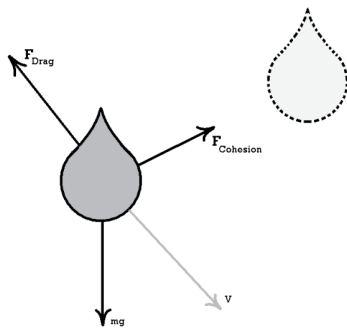


Figure 3. Forces on water drop used in simulation

Components of air drag force with a simple calculation (based on $F=-kV^2$ relation) obtained as:

$$|F_{Drag}|_x = kv_x \sqrt{v_x^2 + v_y^2}$$

$$|F_{Drag}|_y = kv_y \sqrt{v_x^2 + v_y^2}$$

For simulation of cohesion force between water drops we use gravitational force relationship between them. As gravitational force two drops exert cohesion force to each other if they are very near to each other. Then it is proportional to square of distance too:

$$|F_x| = \frac{G^* m^2}{(\sqrt{d_x^2 + d_y^2})^3} (d_x)$$

And F_y like that, which G^* is modified gravitational force constant. By use of these relationships and FBD and knowing kinetics relationships, motion of drops in the air can be simulated.

But each water drop should have a delivery point. Where is that? Drops initially have position of nozzle jet tip coordinate and its horizontal velocity and delivering vertical velocity based on pressure of water in the jet. Then we need simulate motion of nozzle, too. We have positions of nozzle in known time steps as motion descriptor of the nozzle. In real world nozzle has a complicated motion (positive or negative acceleration and...) but we simulate the motion as depicted in the Figure 4.

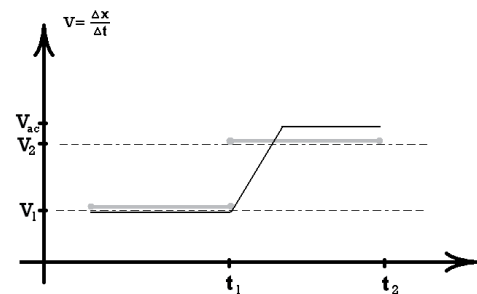


Figure 4. Ideal and simulated velocity-time relations

Which as depicted below traversed distance of two approach (theoretic and simulated reality) is same as depicted in the Figure 5.

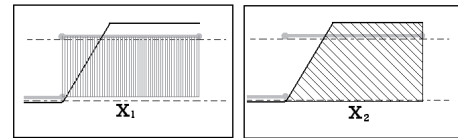


Figure 5. Equal deltaX in ideal and simulated relations

Then "actual velocity" in constant velocity portion is approximated and time of constant acceleration obtained. Now simulation of delivering of water drops done based on this nozzle positioning simulation.

2.3. Water pressure

In vertical movement of drops of water they don't move with constant velocity, they have constant acceleration. Then a stream of water doesn't have a continuous flow line from top to end shape of pattern (when a continuous water flow is emerging). Its shape is as Figure 6.

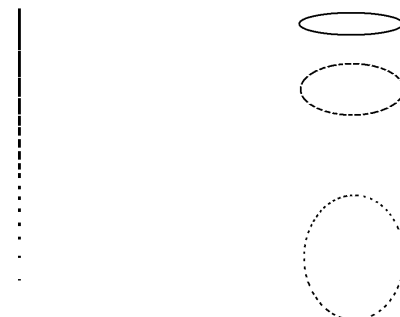


Figure 6. Drops distance increases in vertical movement

Figure 7. Vertical pattern stretching

According to above descriptions on falling of drops of water, it can be seen that generated patterns stretches vertically like Figure 7

This stretching is not linear due to gravity acceleration. We don't have any control on the water after ejection from nozzle. This stretching is inherent of this media but if the initial vertical velocity increases, it can eliminate this effect of acceleration. To increase of the initial vertical velocity we should prepare pressure by use of a pump or height of water in reservoir as in Figure 8.

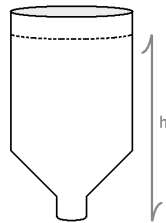


Figure 8. Pressure of water reservoir

$$mgh = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2gh}$$

3. Mechanical implementation

There are many possible approaches to implement of movement of the nozzle. At the first it seems that maybe use of belt and pulley is a good approach as shown in Figure 9.

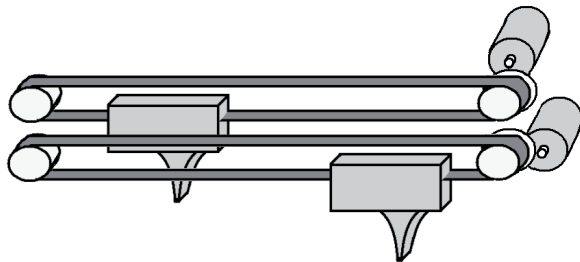


Figure 9. Belt and pulley assembly

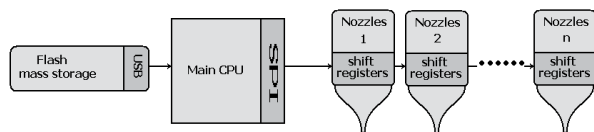


Figure 10. Data transferring to the nozzles

Rack and pinion or simple caret on the rails considered, but they have some drawbacks (e.g. large mass, cost or...) then we didn't mention them here.

The block diagram of the process is depicted in Figure 10. Shift registers can cascade data with high speed (e.g. 300 Mbps theoretically). But any serial connection has a drawback. If an intermediate member lost its connection all others to the end of the chain lost their connections. But it can be developed appropriately.

4. Conclusion

Next step is mechanical development of the machine. It has some challenging aspects. Because of number of nozzles and then number of linear position controllers (belt and pulley assembly and DC motor drivers) cost, electrical power consumption and other aspects of design is important. It may be influence on using which motor, stepper or dc, and kinds of them.

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