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WATERFALLS NEW MEDIA DESIGN PHASE I

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ABSTRACT

The waterfalls new media project is a design focused on delivering a new means of media distribution. The College of Imaging Arts and Sciences (CIAS) at the Rochester Institute of Technology (RIT) intend the project for use, so that they may explore new means of exposing their media.

The idea for this project was to develop a continuous waterfall that would provide a fluid curtain capable of acting as a projection screen by a high performance projector. The waterfall machine needs to be mobile and able to run for long periods of time. The user needs to be able to manipulate the fluid curtain produced by the waterfall machine by using solenoids and small dams that can be raised and lowered allow fluid flow over the waterfall lip in eight different sections. A computer interface controls the solenoids and any patterns that the user wishes to define. However, the primary purpose for this machine is to provide a sustainable curtain surface to project images against.

Since this project is only phase I the CIAS will be able to use, modify and manipulate the waterfall machine for their own use. The CIAS will also be able to continue development for the waterfall machine by either aesthetically manipulating or redesigning certain aspects of the device.

INTRODUCTION AND BACKGROUND

The waterfalls new media project (P11301) is only a phase I project and has not been explored by any prior projects. The motivation for creating a project like this was to provide a new mode of delivering projected images or media created by CIAS students. For the current project terms (20101, 20102) the main objective was to design and build the machine so that it is operational and able to be aesthetically modified by the customer.

Today, the standard means of projecting media is limited to simply a projector and a static projection screen. Standard white projection screens do not allow for the best image projection quality. Also, projection screens are static, meaning that there is no dynamic manipulation of the projection. The inspiration for the waterfalls media project came from the desire to have a more dynamic projection system. By using falling fluid to project images and media on, there exists many more opportunities to dynamically modify and change the projected media. A waterfall provides many natural fluctuations and deviations that will provide a much more immersive experience.

The design of the waterfall provides a curtain that will fit the standard 16:9 aspect ratio of width to height that most projectors have. This means that the waterfall machine could be applied at many different locations and with many different projection setups. The fluid that is being used for the waterfall curtain has to be opaque enough so that images can clearly be projected on it but not so thick and viscous that it clogs and blocks the pump that powers the waterfall.

It is important to understand all the aspects involved with making a mobile waterfall machine. Along with providing a surface for an image to be projected upon, it is also necessary to move a large volume of liquid while reducing total weight so that the waterfall can be mobile. The waterfall is also one piece when it is fully assembled so there is no need for any disassembly when the machine needs to be moved. Part of having a dynamically shifting projection apparatus is ensuring that it can easily be applied to a number a scenarios; therefore the need to be easily mobile and adjustable is critical.

The idea for a dynamic projection media is not original. There are many systems that have already been applied in a number of scenarios. Theme parks use waterfalls as a projection screen for some of their attractions. Also, flags blowing in the wind have been used many times as a form of projection media. However, developing a completely mobile self-contained waterfall projection screen is something a bit different. It could be argued that the idea for something like this is completely original, however, since this project is just a phase I design it is still open to many more future developments and modifications.

PROCESS (OR METHODOLOGY)

For the initial thought and design of the waterfalls media project, the idea was to incorporate a design that would incorporate an almost perfectly laminar flow to the fluid curtain. This would have been achieved by demonstrating a relatively small fluid curtain as to minimize the final velocity of the fluid. Also, this could have been achieved by designing a curtain that would have a glass back for fluid to drip down, which would provide a viscous means to slow down the fluid. However, after discussions with the customer, it was decided that a free falling large waterfall would be preferred. This meant sacrificing the perfectly laminar flow water curtain for something that would be a bit more turbulent but would also provide a larger curtain size.

In order to manipulate the curtain, the original plan was to use angular actuators to disrupt the fluid flow over the pouring lip of the machine. Initially, it was thought that the flow rate of the waterfall was only going to be approximately 6 to 7 gallons per minute. However, after prototyping, it was discovered that a more stable and effective curtain could be established with a much higher system flow rate of about 50 gallons per minute. Due to the higher flow rate the angular actuators were switched to linear servo actuators that would be able to lift a relatively large gate, which would allow more fluid to be stopped at a single time. For the final design it was decided that the waterfall would manipulate 16 servos to operate eight different linear gates across the length of the waterfall lip.

The structural aspect of the waterfall went through many design iterations and variations. Since the actual machine parts would remain largely static there was no need for many analytical calculations. The original design for the waterfall included one large aluminum box beam, which would act as the pouring/ upper trough, six support legs and a large wooden catch trough that would support a large volume of the waterfall fluid.

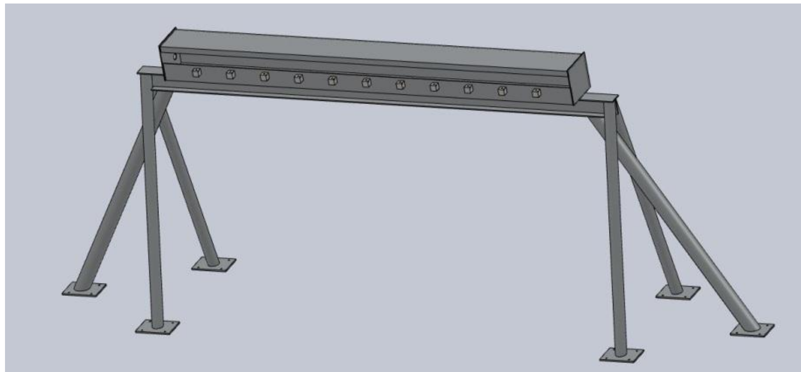

Figure 1: This shows the original design for the upper trough and structural supports. The six symmetrical support legs were attached by welding to the support I-beam underneath the box beam.

The upper trough design stayed relatively consistent throughout the length of the project. However, the support for the trough changed quite a bit. The original design for the support structure was to include the use of six pipes as support legs and an aluminum I-beam to be affixed underneath the pouring trough. This would allow the six support legs, which would be arranged for three on each side of the waterfall, to be welded directly on to the support I-beam. This made for a large 6' width for the waterfall machine and an unobstructed view of the curtain. The design was eventually revised in an effort to reduce the overall size of the machine. This meant eliminating the aluminum I-beam and two of the legs from the support.

$$y = \frac{wx}{24EI}(l^3 - 2lx^2 + x^2)$$

Equation 1: this equation demonstrates the position (y) of the beam vertically as the distance horizontally (x) varies. The load is a distributed weight (w). The modulus of elasticity for the beam (E), the moment of inertia (I) and total beam length (l) are all part of the function of deflection.

$$\delta_{max} = \frac{5wl^4}{384EI}$$

Equation 2: This equation demonstrates the maximum deflection of the beam under the distributed load (w).

Figure 3: This shows how the final design of the upper trough and support structure turned out after a majority of the construction was completed.

The catch trough was another part of the waterfall that underwent much revision. The original design was essentially a large 13' long by 30" wide and 12" tall rectangular tub. This tub would hold the waterfall's fluid before being pumped up to the pouring trough. The tub would also serve as a foundation for the six support legs. Since the bottom surface was a large flat bottom the weight from the fluid would have been immense and would have required many casters to support the bottom. This design was abandoned in favor of a much lighter and smaller sloped basin design. The new total dimensions are 10' long, 30" wide and 12" tall. This means that a majority of the fluid from the pouring trough is poured on to a large sloped flat surface, which is directed to a deep basin about 2 feet long where the pump is located. This greatly reduces the amount of fluid required to operate the waterfalls, therefore reducing the weight by a great deal. The support legs are screwed to the sloped surfaces in the trough providing more height for the upper trough without needing the support legs to be longer.

The primary goal for the waterfall machine is to create a consistent, sustainable and smooth fluid curtain. In order to achieve this, the pouring lip must be constructed almost perfectly but also be able to be manipulated to ensure a smooth curtain of fluid from the machine. Originally the lip was to be modified by using threaded bolts placed evenly eleven times down the length of the lip. This would allow low spots in the lip to be corrected to exactly match the rest of the lip. However, after prototyping this design it was decided that this was not an effective means for readjusting the shape of the pouring lip. It was then decided that in order to adjust the shape of the curtain the entire machine including, the catch trough needed to be adjustable. This would be achieved by using four scissor jacks at the four corners of the catch trough. This will account for uneven ground and will also act as brakes to keep the machine stationary when it is in use.

Since the fluid curtain is the primary concern for this project, the fluid itself needed to be manipulated so that it would pour to meet customer needs. This meant using a liquid that had the correct viscosity and surface tension. These parameters determine the thickness and cohesion that determine a liquid's properties. The liquid needs to be thick enough so that it does not separate during the pour but not so thick that it clogs and binds in the pump. It was

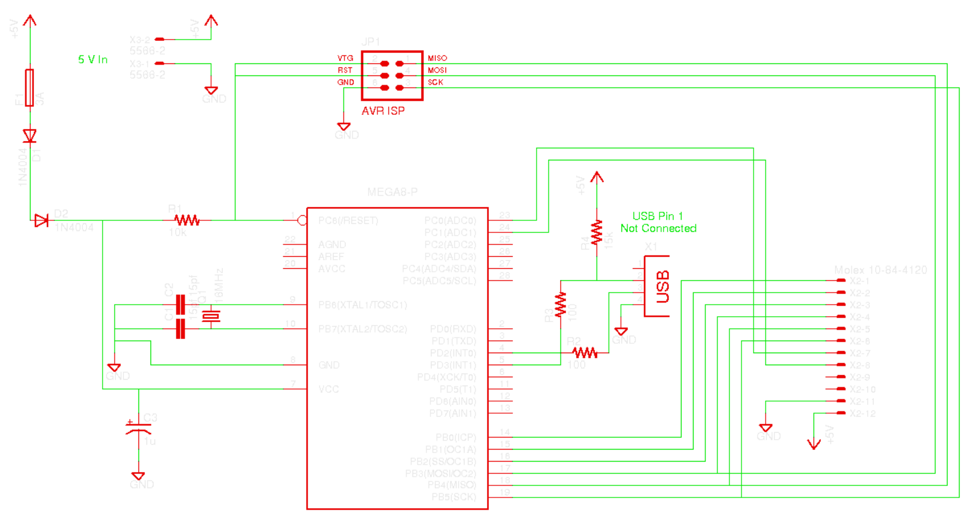

Figure 2: This schematic shows the main board with the main controller.

determined early in the design phase that the best way to determine how to manipulate and pick a liquid would be to do it experimentally once the machine was built.

Electrically, the main tasks in this project were twofold: provide a system and interface for controlling the sections of water flow (by means of solenoids), and power the system. The first task was the subject of much discussion initially, when the size and behavior of the device was still being debated. In particular, it was not known how many sections the user would want to be able to control; as many as 20 had been considered.

As a result, the early plan for the control system involved a master/slave approach, in which a single master controller would broadcast instructions destined to one of many slaves, with the appropriate slave observing the message and taking the appropriate action – energizing or de-energizing its section's solenoid. This method was attractive due to its modularity and theoretical ability to support varying numbers of segments to control. A potential problem with this was its complexity; each slave necessitated its own microcontroller to listen on the control bus for its address. This was along with other complexity associated where wiring was considered worthwhile due to the low cost of the simple controller needed for each slave, as well as the potential for expandability.

Over time, however, it was determined that the price of solenoids made a large number of segments cost-prohibitive. Accordingly, the number was reduced to 8, each one using two solenoids (sharing the same control signal). At first the master/slave method was deemed applicable to this revision, again for the possible future addition of segments or other devices. However, it was soon decided that the simplicity of using I/O from the main controller to switch the segments would be paramount to the perceived benefits of the master/slave method, as now only 8 bits were needed for control.

With this setup it was initially decided that the microcontroller would send TTL-level control signals to individual control boards for each segment, which would each support an N-channel MOSFET and supporting components (eg, flyback diodes). However, this was again rejected in the interest of simplicity – it would have required distributing power to 8 daughter boards, as well as logic signals. The present scheme uses only two boards, one for the controller and one for the MOSFETS. Opto-couplers are also present to isolate the controller outputs from, as well as to assist in driving the MOSFETS.

The controller board is supplied with 5 volts from an external supply. Through a harness it also supplies 5 volts to the MOSFET board, for running the optocouplers. (Note: The 5 volt supply used also has a 12 volt output for possible future applications; at the moment it is unused.) The MOSFET board is also supplied with 24 volts, which via the MOSFETS drive the solenoids for each channel. Both power runs are fused, and a flyback diode suppresses spikes resulting from the inductance inherent in the solenoids. Due to the design of the optocouplers the logic signal from the microcontroller is inverted, which is a problem corrected in the software configuration.

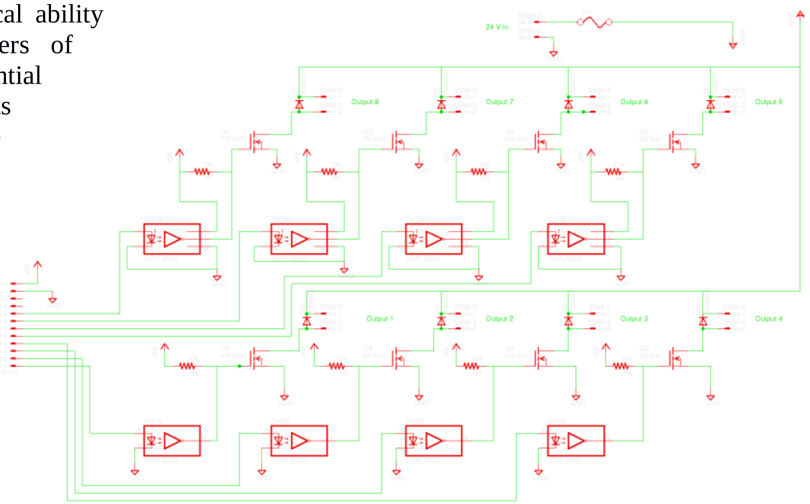

Figure 4: This schematic shows the MOSFETS which are responsible for switching the solenoids on and off.

The microcontroller itself is a member of Atmel's AVR family, the 168p-20pu, clocked at 16 MHz using an external crystal. The controller provides logic outputs through its general-purpose IO ports, while instructions are taken from a host PC via USB. Communication with the host is accomplished via Objective Development's V-USB library, which allows the controller to function as a USB-1.1 device, which is adequate due to the low-bandwidth usage inherent for this application. The software used on the microcontroller is a modified version of an example program from Objective Development's Website.

On the host PC communication with the controller is performed using USB control commands, allowing for easy communication. A simple library for communicating with the controller was developed using the Python scripting language. This was chosen due to the availability of a USB library within the language, ease of programming, as well as the customer's existing familiarity. The library will present a simple interface for controlling segments of the waterfall.

RESULTS AND DISCUSSION

After week 3 of MSD II quarter the prototype testing began. The prototype that was built was only a 24" version of the upper catch trough, excluding all of the electrical components. The prototype was tested by using a small pump to fill the trough with water. The water was then poured out at different flow rates to determine what flow rate would provide the best curtain. After this experimental analysis it was determined that the ideal flow rate for the final design would be approximately 50 gallons per minute (GPM). This was essentially the last parameter that needed to be analyzed before finalizing the bill of materials for pump selection.

Once construction and electrical testing was completed for the entire machine, it needed to be tested in the full arrangement. The machine was tested on the machine shop loading dock. The machine was successfully leveled using the four scissor jacks. The leveling process took approximately two minutes including arranging the electrical wires from the solenoids to the control circuit boards. Once wires were organized the control box was connected to the power strip to energize the solenoids to lift off the pouring lip.

After leveling, the catch trough was filled with water. Enough water was added so that it started overflowing onto the slanted gutters above the pump trough. Once sufficient liquid was added, the pump was plugged into the power strip to begin fluid flow. Water was immediately transferred to the upper trough much too quickly. The flow was much too turbulent and uncontrollable. This was remedied by limiting the pump's inlet to slow down the flow. This resulted in a surprisingly laminar flow of water off of the pouring lip. The flow was not perfectly centered, most likely due to hasty leveling. This also caused a significant amount of water to miss the catch trough as it was landing. If too much water splashes out it means that the machine could not be run non-stop for eight hours without having to be refilled with liquid.

Even though the flow yielded the desired laminar sheet, the volume of water being moved still needed to be manipulated. The best way to do this was to engineer a throttle bypass system for the pump that did not require limiting the intake of the pump. By using two ball values in parallel with the main hose connected after one of the ball valves, it is now possible to control the volume of water flowing from the pump to the upper trough.

Overall, considering all of the setbacks and design changes to the machine during the construction process, the machine was very successful. The catch trough proved to be a very solid structural component that had minimal leaking and minimal deflection when fully loaded with liquid. The upper trough was also very solid with no noticeable deflection in either the legs or the trough itself. The lip was built well because it produced an excellent water curtain. All of the electrical components, including the USB interface worked because the solenoids could be individually controlled and manipulated from a laptop. As soon as the system is energized (without a computer attached) the solenoids are become engaged and lift out of the way of the water. After modifications to the pump, the pump could also be throttled to control flow, along with the four scissor jacks. The only problem currently facing the project is water splashing when landing on the catch trough. Despite this, the machine worked as it was supposed to and the project should be considered successful.

CONCLUSIONS AND RECOMMENDATIONS

Waterfalls New Media Phase I was a project outlined by very ambitious goals. That being said, it was largely successful. The goal to design, build and test a waterfall machine to provide a dynamic surface to project images was accomplished. However, there were certain aspects of the mission summary that were not completely fulfilled.

MSD I outlined a plan for the designing and construction of the structural and electrical components for the waterfall machine. Customer needs, engineering specifications and risk assessments were all evaluated to eventually come to a detailed design drawing package for the mechanical aspects of the machine as well as the electrical components. The detailed design review also paved the way for an initial bill of materials for the project. It also specified that the fluid selection and testing portion of this project would be done after the machine was built and functional.

During MSD II it was evident that the amount of construction required to build both a prototype and final working machine would push the MSD II project schedule back significantly. Construction was originally scheduled to be complete at the end of week 7 for both mechanical and electrical aspects of the job. This would allow plenty of time for fluid testing and performance tweaking for the machine. However, the actual completion date for construction was Friday of week 9 for the mechanical portion and Wednesday of week 10 for the electrical part. This severely limited the amount of testing that was done for the project.

The reason for being behind schedule was simply due to underestimating the amount of construction that was required for this project in the time prior to MSD I and MSD I. However, the machine was successfully completed but phase I laid out a solid amount of work for phase II.

Waterfalls New Media Design Phase II would be able to continue to develop and refine the design and construction from Phase I. The following recommendations can be made after what has been completed in phase I:

- Fluid selection and testing (Pigment and viscous manipulations)
- Catch trough splash guard and noise dampening
- Solenoid dam reconstruction/ redesigning
- Pump refinement
- Pouring lip refinement for improved curtain quality
- Control system refinement

These phase II ideas would improve the overall quality of the waterfall machine. Phase I provided an extremely solid foundation for future MSD projects.

Waterfalls New Media Design Phase I was successful for a number of reasons. The main reason is because the engineering team was able to design and build a mobile waterfall machine that produces a fluid curtain to customer needs. If construction processes were more refined the finished product may or may not have been more functional but could have been finished earlier in MSD II. Despite this, phase I should be considered a success.

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