IPRO 341: Developing a Prototype Display for the Prenatal-to-Newborn Blood Flow System

Final Project Report Spring 2005

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Introduction

In today's society, we acknowledge the birthing process as a 'miracle' of sorts. Bringing a new life into the world has long been thought of as one of the most amazing capabilities of the human body. At the same time, the actual physiological processes that the mother's body and fetus undergo remain a mystery to the majority of the world's population. Most people consider the birth of their child as one of the most important events in their lives, yet most do not understand what is actually happening at the physiological level.

Background

The Museum of Science and Industry (MSI) is currently developing a number of new displays to help better educate the general public on the relationships between physiology, pathology, and medical technology. Our IPRO team is working with the MSI to help promote public awareness of medical knowledge by developing a bench-top working model as well as an educational computer animation that demonstrates the change in blood flow from fetus to newborn.

The idea to work with MSI originated through a biomedical undergraduate student during October of 2003. The student developed the initial relationships with MSI through Dr. Barry Aprison, the director of science and technology at MSI. Originally, the biomedical engineering department hoped IIT would be able to help update one of their exhibits. Faculty members from the Biomedical Engineering department met with Dr. Aprison and Dr. Patricia Ward, the museum curator, about the department becoming involved with the museum. Initially the museum was interested in working with IIT in the area of biomaterials. After considering the needs of the museum and, more importantly, the public, it was decided that the neonatal section of the museum needed updating. More specifically, MSI wanted to work with IIT to help the general public understand how pressure and blood flow are related; MSI wanted the importance of pressure and blood flow during birth to be

illustrated, as an engineer would envision it. Thus, through displaying the importance of the changes in the circulatory system, the public could be educated about how pressure and blood flow are interrelated and change at birth, which could, also indirectly educate them on the complications involved with abnormal blood pressures during adult life. Because of this opportunity MSI agreed to use our help in inventing a novel exhibit. Consequently, Dr. Paul Fagette compiled an IPRO request at the end of the 2003-2004 school year to have an IPRO with the project of developing the neonatal exhibit concerning the changes in the circulatory system that occur at birth. The IPRO team is currently maintaining the relationship with MSI by working with museum curator, Patricia Ward.

In the past, MSI formed relationships with students from colleges in the area, such as Northwestern and University of Chicago. Most of the students the museum works with are at the graduate level. Previously a graduate student from Northwestern worked on a similar project IPRO 341 has attacked this semester of showing how blood flow changes from fetus to newborn. The model this student developed was simple, but informative. By analyzing her work, IPRO 341 expanded her ideas to create a more involved and detailed model and presentation.

The students in Spring 2005 IPRO 341 were recruited from a variety of majors, mostly having a strong background in biology. Students with ECE, and CS backgrounds were also recruited for their ability to help produce the visual presentation and model.

Last semester, the group was able to complete an interactive Flash presentation. The presentation had a base run time of around 6.5 minutes. The presentation included many sub-layers, which the user could explore based on individual interest, in addition to animated illustrations, (flowing blood, moving lungs, toolbars, timelines) and audio throughout the base layer. The computer subgroup also created the website including the meetings minutes, pictures and biographies of the group members, the Flash presentation, and the Final Power Point Presentation.

The Model Group, during the fall semester, assembled a prototype of the circulatory system. Clear acrylic containers represented the significant circulatory organs. Rubber Tygon tubing represented circulatory vessels, and stopcocks represented various valves of the pre-natal circulatory system, which could be closed to represent the post-natal circulatory system. These components were all positioned to represent the changes occurring at birth in the circulatory system of the fetus.

Purpose

The purpose of the IPRO this semester was to further develop the prototype of a cardiovascular display for the prenatal to newborn blood flow system for the Museum of Science and Industry. The museum's main goal was to have a display that would emphasize the changes in pressure within the body before, during, and after birth. To accomplish this, the group decided the goal of the semester was to recreate a visual presentation, which could

ultimately be on a touch screen monitor, and bench-top model as the display. In addition to the creation of the prototype, it was then brought to the museum for testing.

To continue work on the bench-top model as well as the educational presentation, a significant amount of alteration on the model and the flash presentation had to be done. In order to use our time in the most efficient manner, we divided the group into four teams: the model group was responsible for reworking the previous prototype, the narrative group was responsible for editing the text to make it more understandable and shorter, the computer group was responsible for adapting the flash to the new more concise text, as well as the IPRO website, the animation group was responsible for finding images to be used in the flash presentation.

While the groups were each responsible for different aspects of the prototype, weekly meetings ensured that all groups had input into the prototype on the whole. In these meetings we could discuss ideas, problems, and museum requirements. Preliminary trips were made to the museum to try to understand how the average visitor interacts with museum exhibits. This would help us to determine how to best create our prototype.

Research Methodology

While most of the research on how the prenatal circulatory system works was completed last semester, the research involved for this semester included improvement aspects needed for museum iterations, better options to enhance the bench top model, and pictures to better illustrate our main points in the flash presentation.

The narrative group primarily used the original "Flash" Presentation text from the previous semester's IPRO to re-write the presentation to be more user friendly. When further information was required than contained in the original presentation, *Grays Anatomy, Textbook of Fetal Physiology, Fetal and Neonatal Physiology and Guyton Medical Physiology* were used for reference. Through the first testing at the museum, much was learned about how to make the text and flash more user friendly.

The model group needed to research many different components in order to rebuild the model. The biggest change from the previous semester was the addition of lighting to show flow. It was proposed to use flashing lights to show the direction of flow. However, through further research it was determined that "moving" lights were not going to be cost or time effective. Thus, other lighting options were examined. While LEDs were purchased for testing the problem of how to attach the light to the board behind the tubing was still a major problem. An alternative, electroluminescent wire was chosen as the final lighting option, as it could easily be attached to the tubing and it came in several colors. In changing the model from a purely mechanical to an electromechanical system we also needed to research power sources, computer interface options, wiring aspects, and electrically controlled valves. A 12V DC AC wall adapter was the best option for power as it can plug into any electrical outlet and all the DC electronic components chosen required a supply from 9-24 VDC. To interface the

model to the computer, a DIY Kit 108 Serial Isolated Input/Output Module was chosen because it has the ability to independently switch 8 outputs and respond to 4 isolated inputs. The serial interface was chosen over the Kit 74 parallel option since it is much more adaptable and has widespread compatibility. Also, the Kit 74 lacked the ability to take inputs, which could later be used to allow control of the model beyond the keyboard and mouse of the computer. The solenoid valves, Miniature (direct acting) Solenoid Valves (McMaster-Carr #799K56) were chosen because they had the smallest form factor and being direct acting required no minimum pressure differential for correct operation. Our other option was an external solenoid pinch valve that operates by pinching shut the tubing. This was not chosen due to the large size and extreme cost. Because of the lighting behind the tubing we no longer needed to use a colored fluid; therefore we decided on silicone oil and some aluminum oxide particles. Through empirical research we determined that the particles began to fall out of suspension after a short period of time, and did not do much to show the direction of flow as desired. So we decided to create a water oil mix, wherein the bubbles would show the direction of flow.

The computer group researched color options as well as the creation of a time line in order to make the presentation more understandable and eye catching. The animation group completed many different searches in order to find specific images to use in the reformatted flash presentation. Due to copyright law it was also their responsibility to get un-copyrighted material ready for the computer group's use.

Assignments

Sub-Groups:

Model Group
Jenn Barta
Ryan George
Suruchi Thakore
Christopher Tuthill
*Grace Lin
*Armando Perez

The model group worked on the bench-top model of the prototype of the pre-natal to post-natal circulatory system. After extensive research and advice, the model group decided to use a roller pump, plastic tubing, acrylic containers, EL wire, solenoids, a clear fluid and shrink-wrap to simulate the circulatory system. The plastic containers serve as basic representations of each of the important organs: placenta, heart, brain, lungs, liver, and the lower half of the body. The tubing represents the blood vessels; the colored lighting behind the tubing was used to show the oxygen level of the blood, as well as the changes in the two systems. The flow was shown using an oil and water mix. Solenoids were used instead of mechanical valves to change the flow through the computer system and the flash animation.

The model was an integral part of the prototype we were asked to build by the museum. For this semester it was our job to rework the model and add the electrical component. At the start of the semester we decided to hold group meetings on Tuesday nights. In these meetings we decided what needed to be done, who was to do it and how we were going to accomplish our goals. During the first few weeks of the semester we decided that we were going to rework the model.

Our first goal was to make the flow more clear. We decided to lengthen the model to allow for more room so that the ductus arteriosus and the foramen ovale could be put in their correct places. The model from last semester had these out of place due to space. The first few weeks we spent, redrawing the schematics, figuring out what we needed to purchase, and deciding on a lighting source.

The lighting was the biggest problem we had to overcome. While we were looking at lighting sources we initially found two options. They were LED's or LED light bars. While it was our initial idea to have the lights flash to show the direction of flow, we found that under our cost and time restraints this would not be possible. Mid-semester we found a product known as EL wire. This is a coaxial cable whose wires are separated by an electroluminescent coating that illuminates when an alternating electrical current is run through it. This seemed like out best option, it was small enough to attach to the back of the tubing so that the flow would be made clearer. While the EL wire did not flash, we were able to get both blue and red wire to show the difference between oxygenated and deoxygenated blood.

Once we decided on all of the products we were going to use, we sent out an order and began work on the building of the model. The first step was to detach the model from the previous semester and rework it using our larger plexiglass and tubing. We decided to go with a larger tubing size to accommodate for the lighting. We first cut the plexiglass into the sizes and shaped needed, and then used tape to attach the boxes which act as organs. The next step was to test the lighting and flow components. We decided to go with a black background, with pictures of the organs on it so that people might better understand what each box stood for. In order to work on the lighting we first needed to decide what was going to be red or blue and what the differences in the fetal and postnatal lighting schemes were going to be. Based on these decisions we began to cut and solder the wire as required. This was a long process as each wire needed to be soldered either to another wire or to a common point to create a full circuit. The lighting and solenoids took the longest to put together out of all of the aspects of the model.

Once the system was attached and working, we glued the plexiglass together to create a freestanding model. The flow was retested at this point using the Silicon Oil. In order to see direction of flow we decided to add some water to the oil and create a system of bubbles. These bubbles were able to show the direction of flow in a much better way than the particles. Once the model was completely assembled and working, codes were sent to the animation team to be integrated into the flash, so that the animation could control the flow of the model. The last aspect of the model group's job was to take it to the museum and set it up. This was a challenge because the model had to be transported and then set up at the museum. Upon arrival at the museum the lighting had to be messed with a little as one of the connections had come loose, it also took a few minutes to get the flow into the system and flowing in the correct direction. Following the 1st iteration at the museum, little could be done to the model and so members of the model team helped other groups get what they needed to accomplish done.

*These members joined later in the semester when extra help was needed

Computer Group

Mike Slone

Michael Wright

The technology subcommittee, part of 'IPRO 341 – Development of a Pre and Post-Natal Fetal Heart Model for the Museum of Science and Industry', has been hard at work in the spring 2005 semester.

The technology committee was originally formed during the first general IPRO 341 meeting on September 2, 2005, and was composed of Justin Ram, Eric Dunaway, and Michael Wright. The intent of the subcommittee was to create a flash animation that contained all the factual information of the project, and was to supplement a working 3D model. By the end of the fall semester, the group had created the first version of the flash presentation and gave the spring 2005 Technology Subcommittee a great basis. It was the job of the subcommittee at the end of the fall semester to recruit a flash animator for the spring semester. Mike Slone was recruited and his skills have brought the flash animation to a whole new level.

In the first half of the semester, the Technology Subcommittee took new text, audio files, and pictures generated by their respective subcommittees and implemented them into the flash presentation, creating a second version. The committee also made improvements on the layout, color, and frame spacing. The second iteration being bolder, more streamlined, and easier to manipulate.

The IPRO 341 group as a whole decided that we were going the wrong direction with our flash presentation. We re-focused and decided that the flash animation is supposed to supplement the model, not be the main attraction (which was the aim of our committee when it was originally formed). We decided to cut the majority of the researched information out of the presentation and slim it down from 8 minutes to 2 minutes. It is well connected with the bench-top model, and we now think that the two interact well with each other. This version is simple, to the point, and should test well on the general public.

The third and final iteration of the flash presentation is now in its final testing before it is given to the Museum of Science and Industry. All feedback we get will go directly to the Museum curator, Patricia Ward (our sponsor).

Narrative Group
Grace Lin
Armando Perez
Archita Shrivastiva
Kedari Vasu

This group was formed to meticulously revise the text of the "Flash" Presentation. This was accomplished through editing the text by further researching into the content of the text to add more definitions to terms, and simplifying the language to make the text more people friendly. Also, the text was cut down to be more streamlined to keep the presentation fast paced. The members of the narrative group also analyzed what would help keep the attention of patrons of the presentation and decided to alter the text to be in a more question format manner. Prior to the final edit of the text, members from the IPRO team visited the museum to showcase our product and receive feedback. These visits provided further concrete guiding as to how to best edit the text to serve the public effectively. After all iterations of text editing, the final length was cut from six and a half to two minutes of spoken text.

Between iterations of editing, this group divided and rejoined when further editing was required. Two members joined the model team, while the remaining members began to work on tasks required by the IPRO department.

Animation Group
Sean Pitroda
Anand Vankawala
David Zaboli

Our task within the IPRO group was to find images and make recommendations as to how to integrate them into the presentation. Sean and David were originally tasked with looking for images that demonstrated post-natal development and physiology. Anand was assigned the task of looking for images that showed circulation within a newborn. After each group compiled their images, all three of us met and started to discuss what we thought was best for the presentation. We realized that we had a wide variety of images from which to pull from and we felt the presentation would be better understood if there was consistency amongst the images presented. At this point we found several images that would be able to encompass the majority of areas in the neonate's physiology that we were interested in covering. The computer group received our first set of images and created the first revised animation for this semester. Members of the group tested it during the first iteration at MSI.
The IPRO group determined the animation was too long and needed to be shortened from a running time of seven minutes to about ninety seconds. Therefore, the images had to be changed accordingly to satisfy the needs of the new animation. We also learned from our first trip to MSI that our animation lacked a clear objective. One method to make the animation more focused was to decrease the number of images while focusing on a few that covered the core of the presentation. These were the images of the fetal and adult circulatory systems. We decided that many of the other images were descriptive but were dispensable and had to be removed to accommodate the time constraint.

Obstacles

The IPRO group this semester faced many obstacles. Each sub-group was faced with obstacles on the path to its goal. The model group had several obstacles to overcome. Due to the electrical aspect of our new design we ran into a few issues with the lighting. The first inverter we bought burned out during the initial testing of the lighting. In addition to having problems with the lighting the model group also spent a lot of time waiting for parts to arrive. This meant that when the parts finally did arrive it was crunch time. The narrative group had trouble deciding what text was the most important part and what text was expendable. It took several iterations to get the text down to its final length. The narrative group felt as though all of the information they had obtained was important, and thus it was hard to cut out and dumb down the text. The pictures group had trouble finding clear pictures that were not copyrighted material. The computer animation group had trouble working with the codes designed to work the model. The biggest obstacle our IPRO team experienced was a general lack of communication between subgroups. The individual teams would be doing exactly what needed to be done, but the whole IPRO team would be unaware of this. When it came time to act as a whole, we ran into problems of no one really knowing what was going on, due to the general lack of communication. Once it was realized that that was our biggest problem, we quickly worked through it and began to communicate and work as a whole team.

Results

The IPRO was able to create a new prototype. This prototype used both a flash animation and a bench-top model to display the changes in blood flow in a neonate. The bench-top model took advantage of both a flow system, and an electrical system to show direction of flow as well as changes that occur. During the second half of the semester the prototype was brought to the Museum of Science and Industry for testing. The first iteration produced results with the most common suggestions being:
Shorten the flash animation
Have the flash change the model and tell you when to look at the model to see the changes
Simplify the animation so more could understand it

The necessary changes were made to the flash animation; it was shortened to a little over two minutes; and the text was made much simpler. During the second iteration the prototype tested much better with the visitors of the museum. The final prototype as well as the results we obtained were handed over to the museum. The museum will now be able to take what we learned and create a new exhibit.

Conclusions and Recommendations

The IPRO team was able to accomplish:

1) An interactive computer presentation including animation, text, and audio-visual narration.
2) A working bench-top model representing the changes occurring in the fetal circulatory system at birth.
3) The bench-top model now includes LED, solenoids, and a control system to be in sync with the flash animation.
4) A positive working relationship with MSI.

Recommendations:

1) Build on presentation after conducting marketing research of current prototype.
2) Maintain relations with MSI and work towards final exhibition at the museum.
3) Develop a program to run external of Flash that will control the model based upon the XML socket communication capabilities of Flash.
4) Use input capability of relay board to migrate the manual model controls to physical off screen buttons.
5) Use blocking of the text to make it even more presentable and understandable.

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