IPRO 317 Final Report

Summer 2008

Design & Build Chicago Scale Model for Dynamic Disaster Simulation

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Sponsor: Chicago Fire Department

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1. Abstract

This is the second phase of this project as a continuation of Spring 2008 IPRO 317 and will have a focus for Summer 2008 on the computer program, the user interface, as well as creation of the second geographic area of the scale model.

The objective of this project is to design and construct a 3-D scale model for the second portion of downtown Chicago (downtown Chicago has been subdivided into 6 portions). The model will be used to simulate and test the effectiveness of fire defense strategies to address fire or other catastrophes related to public health and safety. This model will include streets, buildings and detailed information that help the Chicago Fire Department in planning interventions, considering various scenarios and case studies.

The model is being built in phases, with the overall design incorporating a sophisticated, computer-driven illumination scheme built within the model base. The model thus will be able to display animated scenarios of virtually any depth and focus, by means of time-varying color and brightness. CAD Computer-generated images and laser-cutting methods are the main techniques used to design and build the model, but hand craftsmanship is also necessary.

The completed model will be fully modular, designed to transport easily to various facilities. The usefulness of the model thus will extend to many needs of the Chicago Fire Department and City of Chicago, as an educational tool within the department and for community outreach. Possible additional uses for the model will be wind tunnel measurement of pressure distributions to inform building design and City infrastructure needs, as well as the study of urban microclimates and the impact on building energy demand. There is also the potential for this model and its design approach to inform the development of scale models to depict the venues associated with the proposed 2016 Olympics along the Chicago lakefront.

This project will include: (1) Identification of the scale, materials, technologies, and strategies for construction; (2) Physical mapping and computer modeling of the downtown built environment; (3) Design of the physical model and computer/electronic components; and (4) Construction of a reduced-area mock-up for final review and approval by the City of Chicago.

2. Background

A. The project will be advised by Dr. Ahmed Megri of the IIT CAEE Department. The project will be sponsored by the Fire Department of the City of Chicago, under the approval of the Chicago Fire Department Commissioner.
B. This is a continuing IPRO which will focus on refining the model from the spring 2008 semester. Specifically, researching a way for the model to be lighted by a projector with the use of mirrors and lenses built into the base structure, which will illuminate the various acrylic features of the model based on input from a computer interface. Completion of the model also entails the completion of the remaining building models that were left unfinished in the due to time constraints.
C. Manipulation of the base material acrylic plays an important production role in the project and will consume a large portion of energy in completing the first model. Light manipulation and computer technology will have to be researched in order to convey information with clear resolution on the model.

D. The previous semester was unable to complete the acrylic model and the computer interface due to manpower and costs. This semester will focus on using existing resources and new technologies to finish the model in a more efficient manner.
E. The team will face many technological obstacles in order to identify the cost effective interactive physical model.

3. Objectives

A. Completion of the remaining acrylic building models from the Spring 2008 semester
    a. Fabrication of the remaining detailed models
    b. Experimentation on bonding methods for larger models
    c. Determine a method for creating models with greater detail
B. Experimentation with a liquid acrylic – model cast method
    a. Creation of a model using the cast method
    b. Determine the degree of possible details
    c. Determine the rapidity of this manufacturing process
C. Integrate a computer interface into the acrylic model
    a. Obtain a high resolution graphic from the computer onto the model
    b. High illumination so that ambient light does not block information
    c. Ease of interface between the model and a computer
    d. Serviceability of the system due to roughness of use
    e. Maintain a low cost for reproducibility
D. Initial Experimentation
    a. Data displays including LED illumination and projection surfaces
    b. Implementation and design process (after the arrival of materials)

4. Methodology
A. <Work Breakout Structure and Gantt Chart attached separately>
B. Due to limitations in machine availability some aspects of the plan were delayed. Specifically, the high demand for the usage of the Computer Numerical Control (CNC) machine by IIT students, the team, and third party organizations, made the time available for fabricating buildings highly limited. Whereas other machines such as the Selecting Laser Sintering (SLS) machine was available, the trained personnel were on unforeseeable vacations and thus delaying team progress. These events forced an extension of the deadline as more team members were forced to work past the project deadlines. The result is that there was less time and person availability to attend the IPRO Presentation Day workshop and less time to work on deliverables.
C. If available, attach any relevant documents used for research methodology (examples include: surveys, websites, models) The main model incorporates many of the test models as working models were put directly to use because of the limitation in resources and to maximize the presentation of the scale model of downtown. These test models include adhesive bonding, sandblasted buildings, LED circuit boards, illumination techniques, and improvements in projection software.

5. Team Structure

A. Milling sub team
Sub team leader Chance Lebron
Team Responsibilities:
Oscar, Ruben: Completion of the previous Spring 2008 models
Diyanna, Yvonne: Research in proper bonding methods to ensure clarity, strength, and speed of models
Chance: Setup of the model and final touches on all building models

B. Molding sub team
Sub team leader Andrew Seo
Team Responsibilities:
Bogdan, Emmanuel: Research different materials for the molding cast in order to meet temperature requirements, be cost effective, and ease of manipulation
Andrew: Create computer models for use in the molding machine

C. Projection sub team
Sub team leader Matt Claxton
Team Responsibilities:
Meng, Jessica, Jichul: Research possible candidate LED controllers and lamp implementations, while considering scalability, practical application, and prospective computer control methods.
Erick, Matt: Consider applicable projector models in regards to overall practicality and revise existing base design for optimal rear projection performance and durability.

6. Budget

A. <Funding Spreadsheet Attached >

B. The Sparkfun.com, Dick Blick, and Peterson Plastics purchases were made by the third week of the project. The Sparkfun.com purchase with the purpose of building test models from the circuit kits. However, the LED portion of the shipment was delayed past IPRO day due to lack of item in stock and will be predicted to be of use in future semesters. Dick Blick sold a clear cast resin that was used to test the viability of alternate building processes. At Peterson Plastics the acrylic bonding was purchased to complete the larger model buildings for the complete model. The remaining purchases were made at Radioshack to buy required LEDs for the circuit boards due to lack of time and availability of resources on campus due to summer.

C. Actual Spending has been updated on iGroups

7. Results

A. The milling sub team researched different bonding materials between acrylic blocks for the larger buildings in the model. The research was done by consulting various store owners who deal with art supplies including acrylic materials. Another important discovery was that the

light emission through the buildings was best done by sandblasting the buildings.
The molding sub team researched different cast resins and the possible mold materials. This lead to a purchase of a resin cast kit, different materials to construct a mold, and research into different technologies available on campus to cut the molds.
The projection sub team selected lighting the buildings using LEDs controlled by circuit boards. Research was then done into selecting a circuit board based on existing software, price, and size. An improved projector was selected to improve the resolution of images onto the full model.

B. The accomplishments this semester resulted in nearing the completion of the first model. The remaining buildings from last semester were fabricated along with sandblasting of all buildings to allow for the dispersed light of the LED system once it is in place. New test models were made using POR-A-KAST clear casting resin with wood, wax, plastic, and Styrofoam as the mold. Clearly wax was found to be the best mold for the casting process especially when utilizing the clear casting resin. The advantage of using POR-A_KAST casting process was that the time spent on fabricating buildings was a ¼ of the time spent on cutting the buildings from a solid block of acrylic. However, a disadvantage of using the casting process is the inability to manufacture different types of buildings in one fell swoop. The Molding team designed new bases made using the Selective Laser Sintering Machine to be used as bases for the LED lights. The basic structure for the LEDs has been completed with circuit board soldering, the program, and testing completed. There were enough components to show as viable examples in the large scale model
C. The completion of the remaining acrylic buildings from the Spring 2008 semester was done but experiments with increased details into buildings was impossible because of limited availability of CNC machine time. The experimentation of liquid-acrylic was successful in determining properties and processing difficulties. However, the ability to determine details was not accomplished because of limited machine time to create details into the molding material. Integration of the computer interface into acrylic model was accomplished with success to a limited degree. The LED lighting of buildings was successful and is ready for full application. The projector portion remains unchanged from the previous semester because of funding to purchase a better projector and because of the lack of software expertise available for this semester.
D. The unexpected obstacles created pressure to meet deadlines. This placed a risk in creating a product with a loss of quality, due to both lack of time to properly machine the product or the lack of funding to purchase the sufficient quantity or quality of materials.

8. Obstacles

A. Unexpected obstacles were encountered during the growth of the project. Availability of essential machinery such as the CNC and SLS machine was hindered by the many other users on campus. The smaller support available during the summer made research efforts slower as many professors were unavailable during the summer semester. Funding was drastically limited due to the status of funding with the sponsor for this semester resulting in fewer purchases. Item availability components of test models delayed testing of critical milestones.
B. The team overcame the lack of availability of time on machines by putting extra time into using the machines when they were available. Research efforts were slowed but many innovative breakthroughs were found within the timeframe of this semester. The limited funding resulted in fewer implementations of technology but allowed for a higher quality result for the test models. Item availability of critical components resulted in substitutions with other components and leaving testing of the missing components to next semester.

C. All of the obstacles were unavoidable as the logistics of the younger IPRO project were undefined from the previous semester. By defining the requirements and with proper documentation many of these obstacles can be avoided in future semesters.
D. The funding with the Chicago Fire Department is currently pending final approval at the writing of this documentation. Finalization of the contract would allow for access to materials to fully complete the current model and begin expansion on future models.

9. Recommendations

The following steps are recommended for future semesters following in the steps of this ongoing IPRO:

A. Logistics -
    a) Obtain exclusive usage of the Computer Numerical Control as there will be high demands for usage of the machine and was a limiting factor for this semester.
    b) Confirm funding sources immediately as this project is product based and materials will be needed.
B. Projection –
    a) Obtain a higher contrast ratio, resolution, and brightness projector. Research from this semester showed that the BenQ MP771 DLP Multi-Media Projector would be ideal with a mirror to fold the projection onto the table
    b) Modification to the original model stand to accommodate the new projector and the mirror required
C. Milling –
    a) Ensure that multiple individuals are trained in the usage of the Computer Numerical Control program.
    b) Begin creation of the remaining model files using Rhino based on the CAD file of Chicago
    c) Obtain certification in shop for various tools such as grinder, sandblaster, and other tools to expand fabrication capability
D. LED –
    a) Testing of matrix LEDs that were unavailable due to item availability issues.
    b) Increasing the height of the boxes that encase the circuit board electronics to better fit the components
    c) Integration of the buildings into the boxes to create a more defined look
    d) Integration of the box into the overall model so that the replica is more flush
E. Molding –
    a) Use an opaque cast resin due to cheaper cost and the necessary texture of the model
    b) Testing of the detail obtained by using a wax test mold will be needed
F. Software –
    a) Expansion of the original flash program designed by the Spring 2008 IPRO semester will need some improvements but is very user friendly for the current purpose of testing the model
    b) Usage of another software language other than flash to take advantage of the higher resolution offered by the next projector

10. References

BenQ projector research and pricing: http://www.benq.us/products/Projector/?product=770

Liquid-Acrylic Research: http://www.sunbeltmaterials.com/por_a_kast_chart.htm
http://www.freemansupply.com/video/products/machwax.htm
http://www.freemansupply.com/datasheets/Freeman/MachWax.pdf
http://www.freemansupply.com/brochures/MachWaxBrochure.pdf
Projection Mirror Knowledge Base: http://www.da-lite.com/education/angles_of_view.php?action=details&issueid=28
http://www.interstateplastics.com/detail.aspx?ID=acrylicmirror-SCl013
http://www.eplastics.com/Plastic/Plexiglass_Acrylic_Sheet_Mirrored
LED Research: http://www.sparkfun.com/commerce/product_info.php?products_id=666
Embedded Ethernet Board

11. Resources

Individual hours spent on accomplishing parts of the assignment can be found in the Individual Work Assignment sheets turned in at the end of the semester by each individual. The iGroups timesheet was not used and was not recommended at the beginning of the semester. Filling out the timesheets at this late juncture of the semester would be time consuming and counterproductive.

12. Acknowledgements

Daniel Sochor and Grahm Balkany helped head start the project this semester by providing files from last semester and by providing their personal experience from working on the project last semester.