Builder Bob: Interactive Learning Simulation System for Flood Management in Museums and Science Centers

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ABSTRACT
Flood Management is a crucial topic discussed globally. In this paper we describe a learning simulation system for flood management and collaborative planning skills of the users during a crisis. Builder Bob is a museum exhibit that focuses on the design decisions taken by the users, applying the basic concepts of civil engineering, logistics and imagination. We expect Builder Bob to communicate information about flood disaster and the means to mitigate the effects. We developed a scaled down version of the concept to address the design rationale where users interact with the system using tangible inputs. This paper effectively describes the museum model and the implementation of our prototype on a small scale.

Keywords
Tangibles, museum exhibit

INTRODUCTION
Digital technologies and multimedia have become an important alternative for physical specimens in museums and galleries. The gap between real and virtual world is significantly diminishing, enhancing the user experience and interaction. The inclusion of multimedia makes the exhibits interesting and engaging. Learning in museums and digital exhibits emphasize on learning from objects rather than about objects and on strategies for discovering information rather than the information itself [2]. Museums have enhanced the interactive experiences for the users adopting digital technologies and educational experiences.

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Technology has evolved from restricting itself within exhibits and installations to more pervasive uses of technology and multimedia creating interactive experiences for visitors throughout a museum. With the help of museum education visitors get a chance to move at their own pace, decide their choices and control their decisions. Today museums want people to learn and engage themselves in evocative objects and experiences.

Our concept encompasses a wide variety of technologies including multimedia, simulations and visual graphics. This learning model not only facilitates long established learning tasks but also critically, it permits activity that would otherwise be impossible. The flood management model is a simulation of a flood scenario. The model of the terrain is based on pre-determined test cases that were thoroughly considered and the best scenario was selected [5]. The system uses a physical 3-D model. The users have tangibles like miniature models of dams, sandbags and levees to be placed over the terrain. The flood is simulated after a time lapse based on the location of tangibles and the result is evaluated and a feedback is provided to the visitors.

RELATED WORK
There are many projects and models related to risk management and simulation. The systems use different techniques, system supports and user interfaces. Our paper mainly focuses on projects that provide a strong backbone to our model including rich multimedia and strong features.

Various projects have explored the visualization of geographical terrains and flood simulation using simulation and virtual reality. The Maryland Association of Floodplains and Storm water management created a 3D flood simulation model with the aim of using it to create awareness about flood disaster and water management in schools [11]. Another project used a game engine to render a scenario using a three dimensional terrain with objects and information retrieved from a geographical information system (GIS) to explore flood simulation in case of a Dam Break Event [6], while another project has used laser altimetry to acquire high resolution digital elevation models and hydrographic chart datum to model flood extent [12]. We have thoroughly reviewed the project [6] on flood emergency and visualization that helped us to determine our scoring system and terrain elevation graphs to determine various test cases.

For the desired target visitors, we studied various aspects to determine our museum model and gain knowledge on the desired exhibit effect. For our model it was necessary to learn about the expected age and statistics of general population who will interact with our model [3].

BACKGROUND

Flood modeling is an important task for decision making in the field of natural risk management [7]. Therefore designed tools and simulations are required as physical models, in order to evaluate the risk and calculate proper measures.

The visitors are provided knowledge about the functionality of tangibles before they can interact with the flood management system. This interactivity leads to learner participation, contributing to the museums exhibits that involve feedback and digital storage of images and performance. The model is not only a learning experience but focuses on user activity and level of interaction with the simulation. Learning through museums and science galleries is a variant of imparting information in a more fun filled, self-determined manner. The simulations and multimedia add new dimensions that keep the visitors engaged and interested in gaining knowledge.

There are not only museum curators but also scientists, designers and innovators involved in different scientific simulator models. A new set of relationships is emerging among objects, learners and digital technology, in which museums are, above all, places of exploration and discovery. Technology innovation is reshaping the role and mission of museums as educational hubs, imparting contextual information in best of forms and user experience [2].

Interactive exhibits offer visitors the opportunity to explore real and sometimes simulated scientific phenomenon and state of the art technology. Visitors tend to use technology based exhibits more frequently for a longer period of time. Museums not only hold the history but also spark an ignition to the innovative future and technology. The Flood Simulation Model has the evident potential for providing a framework for understanding a calamity in a social, cognitive, kinesthetically and aesthetically rich manner.

THE MUSEUM MODEL

Role of museums have changed and grown dramatically [1]. After reviewing several articles on the educational role of the museum we proposed the Builder Bob learning system for a museum exhibit. The central goal of the museum exhibit is to arouse interest and provide intellectual interaction that pertains to flood management.

The museum exhibit is a blend of modern technology and interactive craftsmanship. The entrance to the exhibit is an arched walkway to the activity area; the user experiences a lifelike scenario of flood and gushing waves around him. The walls of the walkway lined with modern display and sound technology indulge the visitor. The activity is introduced by a narrative element that we call as the mayor of the city who guides the visitors about the scenario. The debriefing session begins by mayor stating the flood problem followed by the richness of their land and measures required to save the city. The mayor promises the visitors an incentive if they succeed in helping him through this calamity.

As the activity progresses into the next phase, the visitor gathers information about the dams, levees and sandbags. We do not expect the visitors to have any prior knowledge of the resources and strategies to place the tangibles. It is not the set-up or the interface on its own that provides engaging experiences. The content or the appeal of topic and installation play a role as well [3]. Full wall length interactive screens around the activity area showcase the information in the form of audios and visuals. Readings and articles on museum learning taught us that most visitors were overwhelmed with too much text and would prefer to find Information next to exhibits. The distribution of population and economy is exhibited through respective maps that the user can access to strategize and position the placement of tangibles.

The activity is designed to be performed in a group (varying from 3 to 5). Keeping in mind the magnitude of the activity and the play area, the time can vary from 5 to 7 minutes, during which the visitor has to gather all the information, strategize and place the tangibles. The activity area with the terrain size will be (20ft x 20ft). The maximum height is no more than (4ft) so that the visitor can easily move around and navigate the space. The virtual terrain and water is projected on the transparent acrylic glass model of the physical terrain. Rear projection is used for simulating water. The tangibles are (2.5ft x 2.5ft) and weighs no more than 2 pounds made out of recyclable material. The terrain has weight sensors that would sense the varying weight of the tangibles and the central system maps the location of the tangibles to the virtual world. After the activity timer runs out, the visitors are able to witness the effect of the simulated water on the terrain.

The visitors are provided with the printed feedback including an advice and critique about their performance. A calculated score report, based on the actual and the optimal location of the tangibles and the best score is available to the visitors as a means to retrospect and improve in the future. A snapshot/video of the visitors engaging in the activity is also available as a feedback. The museum visit is time-constrained and visitors want an engaging experience with useful information to take back home so that they could reflect back or keep the memories alive.//and also have a memory of the experience

TARGET POPULATION

For the purpose of Simulation System Flood Management Model the target population is geared towards general museum visitors like families, school trips and field trips. We expect people of ages seven and above to be part of the interaction. It was important for our model to gather information about the predicted visitors, their age and interests due to safety and interest differences.

In recent years, museums and galleries have begun to research seriously on the responses of the visitors. These responses are both specific to the individual and also susceptible to patterning according to different expectations and requirements of the visitor. There is now a targeted differentiated audience [8].

The simulation is available to children who might not have any information prior to the game play, and thus read the assistive screens for some knowledge and divulge in their own strategy. While the parents and the senior visitors are given a chance to revise their knowledge using the provided information and apply their analytical intelligence to play with tangibles.

Nationally, museums have a fairly old visitor profile compared to the population as a whole. Around 13% of museum visitors nationally are aged 24 or under, whilst 27% are aged 55 or over [13].

The main aim is to keep the interaction simple and easy. Our model does not expect a proper knowledge of the tangibles and flood management techniques. The simulation wants to provide an experience and education in an interesting manner. Audience will include interaction between variable ages e.g. A father having a conversation with his son about his ideas or a schoolteacher giving instructions to the student where he can actually place the tangible. Hence the model is a well-considered platform for cognitive thinking and mutual planning.

Korn further states that young adults crave an environment that invites them to be social, feel comfortable and to learn and share ideas as a group [8].

DESIGN AND IMPLEMENTATION//THE PROTOTYPE

In this section, we describe the design of our selected model and its implementation. In design section our main goal is to introduce the model and list the rationale for which we picked this concept. In addition we explain the reasons to choose this technology and the benefits in comparison to other design alternatives. Next, we describe the technology and devices used to facilitate the model design.

Design

To achieve the maximum out of our design selection for flood management model, our prototype is restricted in terms of number of users and implemented technology. It is not the quality of the collection which is the main factor for potential visitors when deciding to visit a museum or gallery. It is the environment as a whole and the interaction with the collection that proves to be the key factor [10].

We chose Builder Bob as a design because firstly, it is always difficult to model a large-scale calamity on such a restricted area in order to evaluate and control the flood inundation risk (Figure 1). Secondly we give an opportunity to the user to play with tangibles like dams, levees and sandbags and strategize on the solutions. Thirdly we expect that the physicality of our model will help naïve users to better grasp and understand the system. The model emphasizes on reusability, easy set- up and scalability with respect to difficulty level.

To reach our design the team discussed few ideas about virtual reality. We also took into consideration real water, light and sound effects to simulate a flood atmosphere. Finally we took a stand on implementation of tangibles and front projection. The main thought is focused on using Tangible User Interface [4] instead of Full Immersion Virtual Reality [9] ,so that user can interact and manipulate the parameters and move beyond screen communication. Water was too messy to be handled and difficult to be implemented in a reusable model.

Figure 1: Interactive Learning Simulation System for Flood Management in use.

Figure 2: Screenshot of virtual terrain created using Unity Engine.

Figure 4: The white plastic painted terrain.

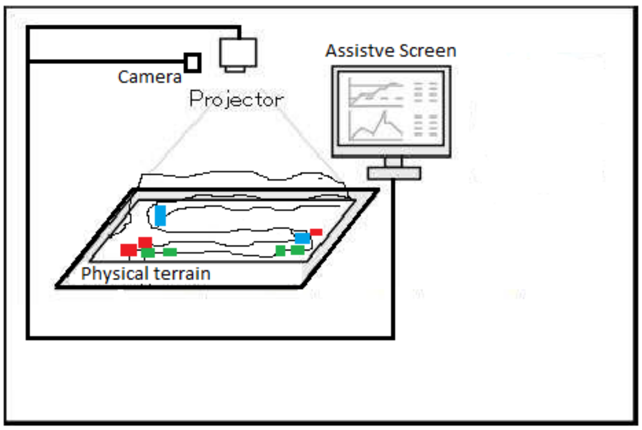


Figure 3: System Architecture

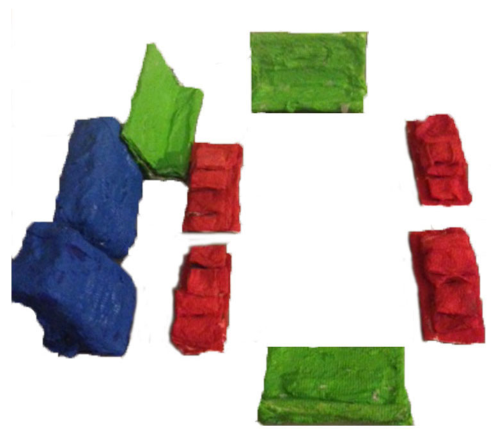


Figure 5: Appearance of tangibles.

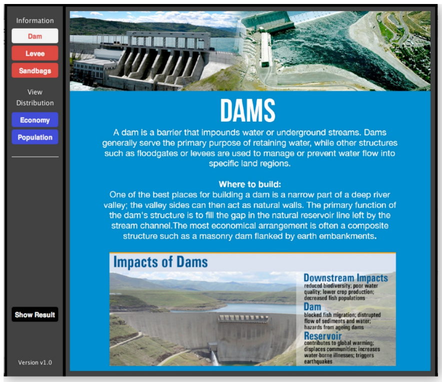
Implementation

The Builder bob system is implemented as a physical model. The cardboard base of the terrain measures (3ft x 3ft x 0.3ft). The model rests on a tabletop large enough to allow multiple people to interact with the system simultaneously. A 3M Pocket Projector MP150 mounted on the ceiling projects virtual terrain created using Unity Game Engine, on the white terrain base to give an aesthetic feel and lifelike presentation (Figure 2). A Logitech HD webcam C270 mounted in parallel to the projector allows remote sensing of the tangibles that uses computer vision to distinguish and determine the location of the tangibles (Figure 3). The physical model of terrain and tangibles are built out of waste material like newspaper, toilet paper and glue to make the model lighter, economic and reusable.. The terrain is painted with white plastic paint to give a strikingly sharp and accurate representation of the projected virtual terrain and water (Figure 4). The dams are painted with blue (0.13ftx0.16ftx0.3ft), levees with green (0.16ftx 0.19ftx0.06ft) and sandbags with red plastic paint (0.16ft x0.09ft x.06ft) that makes them easily recognizable by the camera (Figure 5).

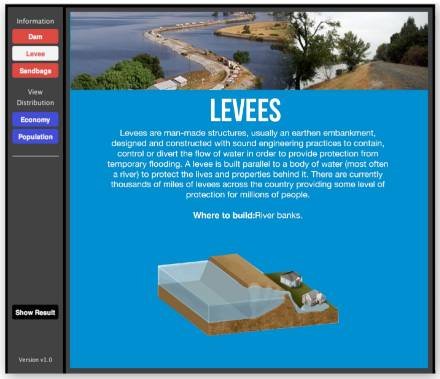
A computer (Intel core i5 @ 1.70GHz 6.00GB RAM, Intel HD 4000 graphics running Windows 7) connected to the camera, senses the tangibles using computer vision. It uses Unity Game Engine to determine the position of the tangibles on the physical terrain, map them from the world coordinates to the virtual coordinates and calculate the result. An assistive application developed using JAVA and processing library runs on the same computer. The application displays the information about the dams, levees and sandbags, the population and economic distribution map and provides a feedback with the score. An email can be send back to the user about the result using the send email option.

THE ACTIVITY

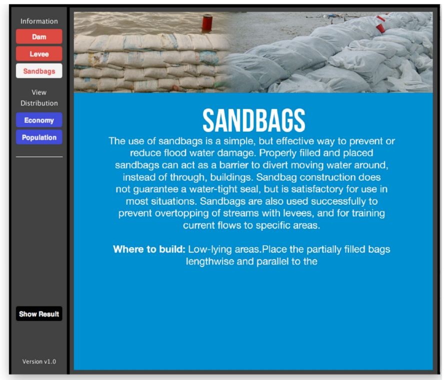
Based on the developed prototype, the activity is designed for the users of all ages from seven and above. The aim of the activity is to gather information about the resources, such as the dams, the levees and the sandbags, and decide upon where to place the tangibles. The ultimate aim is to come up with a strategy that effectively manages the inundation of the river during floods. Activity can be conducted in a group of five to seven people. The individuals collaborate among themselves to find a solution to the problem. This activity requires active participation, effective planning and explorative mindset. The total activity time is decided to be around two minutes.



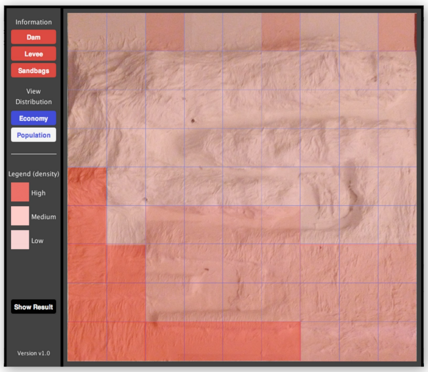
(a) Dam Information



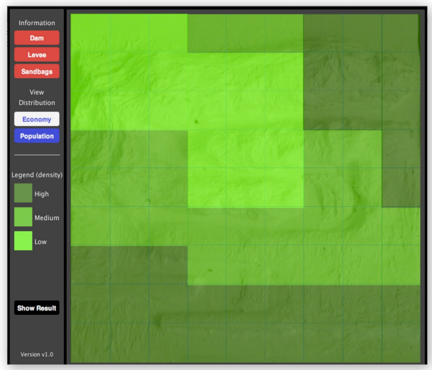
(b) Levee Information



(c) Sandbag Information



(d) Population Map



(e) Economy Map

Figure 6: Screenshot of assistive screen displaying information about tangibles and distribution maps.

Phase 1: This phase of the activity is about gathering information regarding the resources and the terrain. The assistive application displays detailed information about the tangibles along with the economy and population maps representing geological distribution (Figure 6).

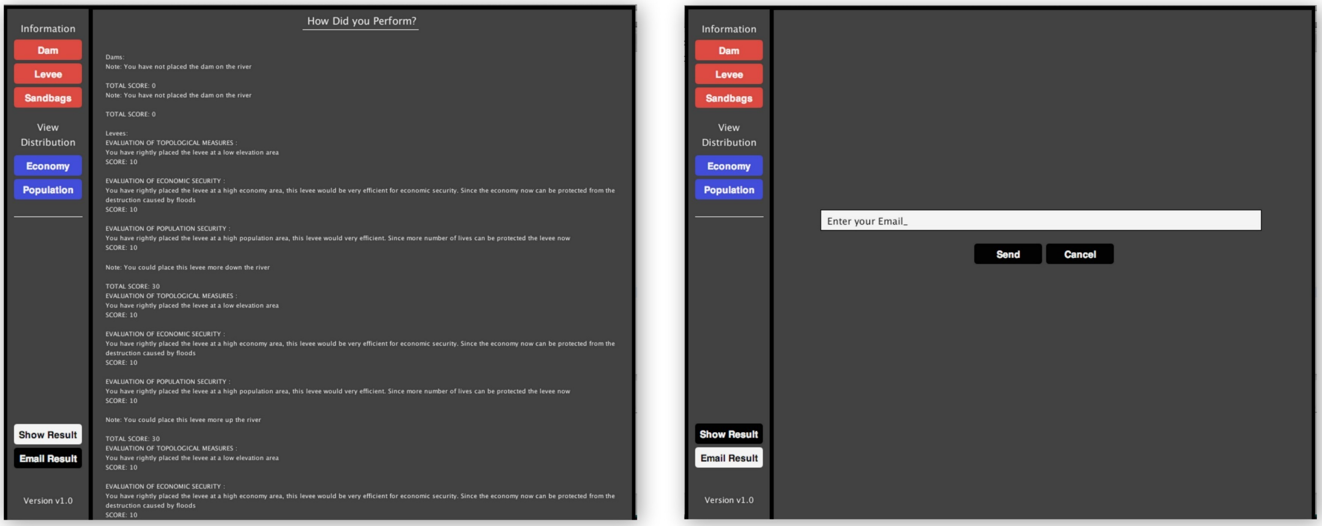
Phase 2: The next phase of the activity is where the user uses his knowledge and the information gathered from (phase 1) to strategize and plan. The individual places the tangibles on the terrain based on the locations that he thinks are most appropriate. The user has the freedom to consult the assistive application for required knowledge and facts during the activity. The system captures an image of the user activity and the scoring algorithm is executed.

Phase 3: The last phase of the activity simulates the river water based on the placement of the tangibles. After the simulation completes, the numerical data is calculated based on the pre-determined optimal solution. The scoring algorithm calculates the results for the user that can be accessed on the assistive application.

SIMULATION RESULT FEEDBACK

The assistive screen provides information about the population and economy of the given geography. It is used to obtain elaborate information about dams, levees and sandbags. After the simulation begins, there are precisely two minutes to place the tangibles on the terrain. When the timer runs out, the camera takes a snapshot of the setup. The terrain projection is turned off and a white image is projected during image capture so that the tangibles and the terrain are easy to identify. The system uses image processing to identify and determine the placement of each tangible. Based on the location of the tangibles, the rise in the level of river water is determined and a scoring algorithm calculates a score for each tangible.

Each tangible has an optimal location for the explained scenario. Based on the position of tangibles, a distance is calculated from the optimal placement to the actual placement of the tangibles. The distance is calculated along the river in the direction of flow of water. The algorithm weighs the distance to determine the score. An advice is also generated by comparing the actual and the optimal placement of the tangibles. The scoring algorithm calculates the score taking into account the placement of the tangibles w.r.t. the optimal best location, the population and the economy distribution around the tangibles' location. The estimated score and the feedback can be accessed through the assistive application that provides extensive analysis and performance ratio (Figure 7).



(a) Feedback and Evaluation

(b) Send e-mail

Figure 7: Screenshot of assistive screen displaying (a) scoring with critique and (b) send email option.

EVALUATION

We conducted a series of evaluation tests during and after the development phase of the prototype. The tests were conducted with varying lighting conditions and various timer values for the activity. During the evaluations, a timer of 2 minutes was found to be adequate to learn about and place the tangibles. We observed the use of this simulation system for the assessment of user performance and best implementation of the learning goals.

Firstly, the user took maximum advantage of the assistive application efficiently to learn about the situation. The user had no previous learning experience with the dams, levees and sandbags. Secondly, most of the user's time was spent in gathering information about the scenario and the given parameters. Placing the tangibles didn't take as much time as expected since the tangibles were easy to differentiate based on color and size and minimal in number. Thirdly, the performance of the user was found to be above average for his first simulation.

After our class demonstration, we had a valuable feedback from few students who found this interface effective and interactive as a flood management-learning tool. This system has a great potential to make such learning processes more enjoyable for participants because of its activity.

CONCLUSION AND FUTURE WORK

The goal of our model is to simulate probable flood inundation damage on a given area depending on several flood scenarios with different intensity, duration and return period. Confronting simulation results assesses model reliability. We have built a model that effectively supports collaborative learning and implementing flood management task. We have performed many preliminary evaluations by conducting the simulation for number of iterations. Our simulation needs enhanced image processing and terrain improvisation.

Our future work includes conducting user experiments with potential users like design experts, risk managers and architects for the museum model. We hope to enhance the simulator and the Tangible User Space to deal with more cases and parameters. We would also like to further study this system in a collaborative learning context to improve the interaction for target visitors. Additional factors are increasing number of tangibles to elevate the complexity, simulating actual geographic locations across the world, including real water, experimenting more complex algorithms for optimal results and enhancing the implementation using high tech sensors, light and sound effects.

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