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HURRICANE! - A SIMULATION-BASED PROGRAM FOR SCIENCE EDUCATION

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ABSTRACT

We describe the development, testing and fielding of a PC-based instructional program, *Hurricane!*. This program educates students about the effects of hurricane winds on different kinds of residential structures. The effects on the residential structures are physics-based. The program has been developed both for schools and science museums. The format is game-based with realistic graphics and sounds and students see different degrees of damage depending on choices that make. For example, a one story masonry house built to current Florida building code standards, is much less vulnerable than a two story wood structure built before 1985. Therefore, students who make the first choice see less damage. Several tests in middle school science classes have demonstrated that the game is highly interesting and effectively teaches concepts central to understanding how to prepare for a hurricane.

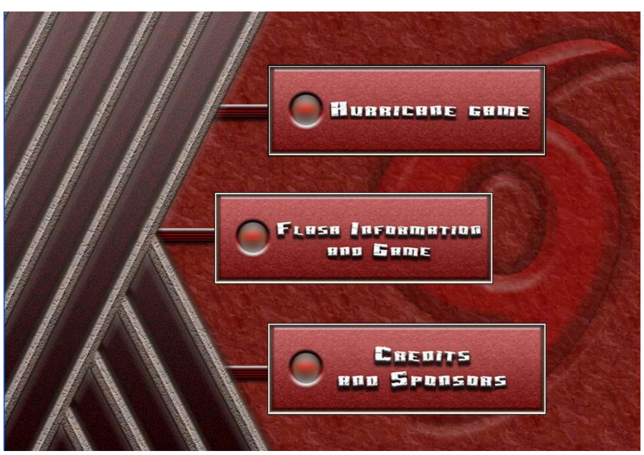

Figure 1: *Hurricane!* opening screen

1 INTRODUCTION

Hurricanes are a continuing threat along the Atlantic and Gulf coasts in the US, particularly in Florida. Not only are they a threat to public safety, but also they pose the potential for huge economic loss. The chance of a hurricane (winds of at least 75 mph) hitting the Miami metropolitan area in any given year is about 10% (predictions of the National Hurricane Center for the 2007 hurricane season). Damage can range from $10 million dollars or less up to $50 billion or more depending on the severity of a hurricane and whether it directly strikes a majorcity. However, there are ways that the public can mitigate loss. One important mitigation technique is to build houses which protect against hurricane wind damage. Our program, *Hurricane!* educates users about this.

Interactive virtual environments have been used for education and training for more than a decade (Luursema and Kommers 2003; Ahmad et al. 1998; Hall and Gordon 1998; Roussou 2004; Lau et al. 1999; Harasim et al. 1996). Gee (2004) stated that the computer and video games can have fundamentally sound learning principles; students in a wide range of learning environments can effectively learn from such games. Educational games with interactive game-like environments demand interweaving of learning content with the play and fun elements of the game (Roussou 2004). *Hurricane Strike*, developed by the University Corporation for Atmospheric Research (UCAR 2008), teaches disaster safety and preparedness with science instruction in an engaging interactive learning environment. For hurricane education, the researchers of the Institute for Simulation and Training, University of Central Florida have created visualization techniques that educate the public in such venues as public schools, and museums. As shown in Figure 1, the interface of this application was made intuitive and easy to use, very much like a PC-based game. User testing, described below, resulted in high marks for the program in this regard. Middle school students recognized and appreciated the game-like qualities of the program, as shown in Figures 1 and 2, and virtually all the students tested began using the program with no instruction.

Figure 2: User interface of *Hurricane!* program

2 PROGRAM DEVELOPMENT

2.1 Visualization Techniques

Several computing techniques were used to realistically show the process of damages to residential building caused by winds during a hurricane. The underline physics uses *Quick Collision Response Calculation*, an iterative method which can tune the accuracy and the performance to calculate collision response between building components. The damage process is designed as a *Time-scalable Process*, and by attaching a damage time tag for each building component, the visualization process is treated as a geometry animation allowing users to navigate in the visualization. *Quick Damage Prediction* is achieved by using a database query instead of using a Monte-Carlo simulation. The database is based on HAZUS® engineering analysis data which gives it validity (Liao 2007).

2.2 Database Development

The main reason for building the database was to use information from it for instructional programs which inform the public and 4^{th} – 10^{th} grade students about hurricane effects. For the development of a hurricane visual database, the emphasis was on the creation of interactive buildings with the aim of representing building components to interact with hurricane force winds and other forces. In addition to visuals, the database contains hurricane sounds and the data taken from HAZUS® for hurricane damage to buildings. The resulting visualization necessitates both physics properties as well as graphics properties. Physics properties included: volume, center points of mass, mass, position and orientation. Graphics properties included: geometry shape, lighting attribute, texture, color, position and orientation. Careful coupling of the physics-based models and the visualizations was necessary including the following characteristics.

- Volume is determined by its geometry shape for graphics. A computation method, "collision detection," is used.
- Position and orientation for the graphics property are determined by its physics. They were computed by an integral equation representing Newtonian law. The input of integral force is a sum of gravity force, wind force and collision force.

2.3 Residential Building Representation

Components of residential building here are simplified as: sheath, shingles, walls, doors, windows and roof.

- Sheath is a cube which height is small. Felt paper textures are applied on XY plane.
- Shingles are organized by roof type. A gable roof type house has two shingle arrays. A hip roof type house has four shingles. Each shingle array are organized as a matrix with starting position, increasing displacement along X axis, increasing displacement along Y axis, number of shingles along X axis and number of shingles along Y axis. They are all specified in a XML format file.
- A wall is a cube with holes for windows and doors, applying textures on XZ plane to represent wall material, like masonry, wood.
- Door or windows is a cube with a hole for glass. Textures are applied on XZ plane to show transparency.
- Roof: A gable roof includes two frames and several rafters. Each rafter is made up of three beams for now (two on the shingle plane and one links the two in the middle).

2.4 Developing Educational Modules

Along with the main simulation program, a hurricane educational package was also developed to deliver general knowledge about the various aspects of hurricanes including their formation and movement, as well as building codes and mitigation methods. Developed using Adobe® Flash®, this interactive package consists of a series of multimedia modules enhanced by sound, video, animations, and simple simulation-based games.

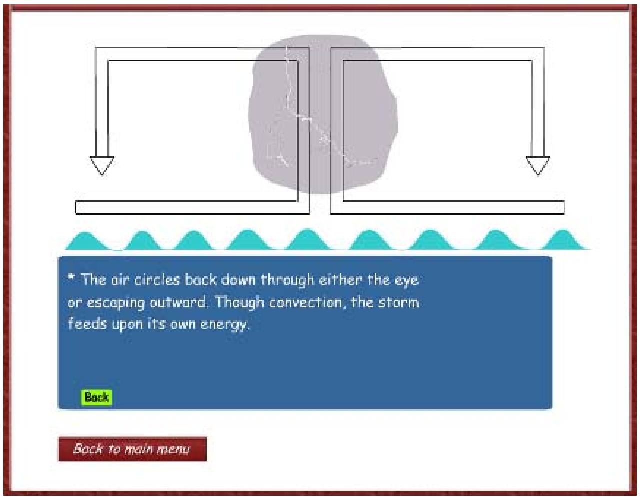

Figure 3: Screenshot from animation showing hurricane formation

Gagné (1985) indicated that attention-gaining animations provide additional ways to ensure selective perceptions of specific presentation features as they are stored and processed in the STM. One of the animations used in this package is a step-by-step user controlled motion showing how the hurricane is formed, which seeks to draw the attention of the users. Figure 3 is a screenshot of this animation.

Simulations and games are playing a more important role in delivering effective instructions. Simulation games place learners in an experimental learning mode, and this mode differs significantly from the more traditional information-processing model (Coleman 1968). In addition, many finds on the effects of simulations suggest that students experience increased motivation, intellectual curiosity, sense of personal control, and perseverance (Ehman and Glenn 1991). Percival (1978) also reported that simulation appeared to improve motivation in children and particularly for those of lower intellectual ability.

The simulation game included in this package was based on a scientific hurricane movement tutorial of *Hurricane Strike*, which was developed by the University Consortium for Atmospheric Research. Users are first presented with the starting location of a hurricane, the low and high pressure area, and three different possible paths that the hurricane may follow. Then the users are asked to choose the right path that the hurricane may follow. Finally, the program reports the user's score. Figure 4 is the screenshot of the simulation game, *Aim a Hurricane*. We revised A*im a Hurricane* (developed by UCAR) to make it better suited as a game. This involved modifying the graphics, adding a voice track, simplifying the user's choices, and posting a score for each user.

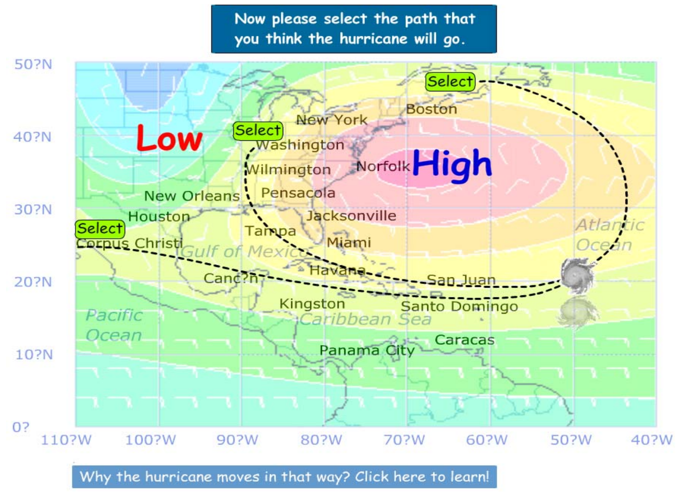

Figure 4: Simple simulation game, A*im a Hurricane*

Other multimedia modules include animated videos from the Federal Alliance for Safe Home (FLASH) showing the destruction of a roof during a hurricane and the tips to prepare the house roof before hurricanes. Figure 5 is the screenshot of one of the animated videos.

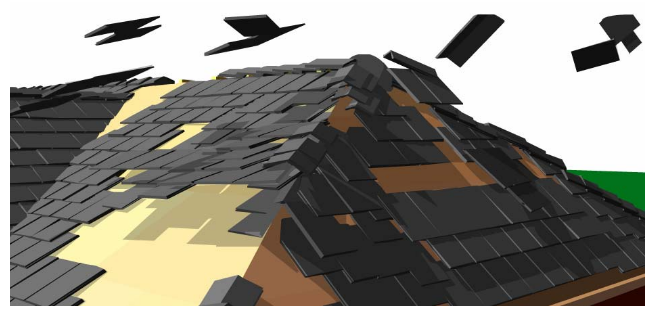

Figure 5: Animated movie clip

3 FIELD TESTING

In April 2006, an initial field test on this hurricane education package was completed at Glenridge Middle School in Orange County, Florida. The primary purpose was to determine if this educational package is suitable for a museum exhibit at the Museum of Science and Industry (MOSI) in Tampa, Florida. Hurricane! was set up as a part of MOSI's comprehensive exhibit on disasters, *Disasterville*. During October 2006, a second field-test on this hurricane education package was done at Lawton Chiles Middle School in Seminole County, Florida, with significantly positive results and reactions from the students.

The school testing also suggested that a 3-5 day period of instruction (one hour per day) was appropriate and that additional homework assignments are also appropriate for hurricane education. The hurricane curriculum fits well into the weather module which is widely taught in the middle school curriculum in Florida as well as the rest of the US. Our plans call for internet posting of our completed curriculum in a format appropriate for both teachers and students.

We compared our version of *Aim a Hurricane* (shown in Figure 4) to the original version of Aim a Hurricane. Both groups of middle school science students preferred our revised version by a significant margin. This simplified version is also incorporated into the museum exhibit.

4 DISCUSSION

Hurricane! is an interactive program for visualizing hurricane damage over different conditions of wind speed, environment, and housing construction. Several field tests in schools demonstrated that the program is intuitive, informative, and easy to use; this was achieved by using a game-like interface. The program was developed for schools (K-12) and the general public to learn about hurricanes, hurricane threats, and emergency preparedness. *Hurricane!* is still part of MOSI's *Disasterville* exhibit and MOSI plans to make the exhibit available to other science museums. For example, *Hurricane!* is being made available as a museum exhibit and traveling exhibit for schools in Trinidad and Tobago under auspices of their National Institute for Higher Education Research, Science and Technology.

Hurricane! contains educational material that has game-like properties, based on physics-based models (e.g., gravity, wind force on different constructions). There are other educational material for classroom use, developed by NOAA and other groups, which when used in conjunction with *Hurricane*! provide a comprehensive program of study about hurricanes appropriate for a 2-5 day module, most appropriate use in the curriculum on weather. The NOAA Education website has a wealth of materials related to weather education (NOAA – CPO 2007). Components of the site particularly good for teaching about hurricanes are shown in the bulleted list below. Grade level of the instruction is shown for each activity.

- Hurricane Strike! is an excellent computer-based learning module on hurricane science and safety for middle school students. It is very well developed with many teaching resources. Registration is free and the entire program, English and Spanish versions, may be downloaded. http://meted.ucar.edu/hurrican/strike/ (UCAR 2008).
- The Eye of the Hurricane - This lesson, produced by National Geographic, introduces students (grades 3-5) to the structure of a hurricane, particularly the hurricane eye. You might want to use it as an introduction to a unit on hurricanes or weather phenomena. It starts with a very interesting movie. It takes 1-2 hours to complete this lesson (National Geographic 2008).
- Stir up a Hurricane This is a science lab demonstration using easily available supplies and should prove very interesting to students in grades 2-7. It can be completed in one class period (National Geographic Kids 2008).
- Interactive storm intensity scale (Appropriate at all grade levels) This animation shows typical damage caused by different wind speeds corresponding to each of the five categories of the Saffir-Simpson Scale (Orlando Sentinel 2008).
- Hurricane Hazards storm surge (which is a good animation) high winds, tornadoes, and flooding (NHC 2007).
- Graphing Hurricane Information (appropriate for grades 7-12) Explore hurricanes and their formation and graph several types of information that meteorologists use when studying hurricanes (NOAA – OAR 2004).
- Multimedia Hurricane Education has a series of movies and web animations; Grades 6-12 (NOAA – CPO 2007).
- NOAA Hurricane Education Materials for teachers (NOAA – Education 2007).

5 CONCLUSION

Hurricane! is an example of a serious game which seems to work well both in the classroom and as a museum exhibit. It was developed for middle school students for use as part of the science curriculum, particular the weather module, and our testing was conducted in middle schools. However, it is appropriate for students from the 4th through 10th grades as part of a school science curriculum.

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