Game-based Interaction Technology for Informal Education in Public Settings

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1 Introduction

Modern science museums use highly interactive exhibits to engage their visitors. However, other informal education centers such as zoos and aquaria suffer from the problem that direct interaction with their specimens is undesirable. While the interest from visitors in interacting with living creatures is evident by the popularity of touch-tanks and petting-pens, visitors must be protected from the specimens, and specimens from the visitors. The question therefore is how to introduce the benefits of interaction to assist informal education in a setting where direct tactile interaction is unfeasible (c.f. Figure 1)?

Figure 1: Reaching out to touch is typical in an exhibition.

In this paper we present the Interactive Aquarium project [Stephenson et al. 2005]. The aim of the project is to develop the interaction capabilities of aquaria and other informal science centers where a necessary physical separation between the exhibit and the visitor prohibits the direct physical interaction and exploration of the exhibited objects and specimens. This approach is aimed to improve the educational value of an aquarium visit, since research in cognitive sciences has proven a potentially strong relationship between the amount of elaboration with learning content and long-term memory retention [Greenleaf 2000]. From a cognitive perspective, the scenario of a visitor who is interested and engaged in an exhibit bears important potential for successful creation of memory, since visitors mostly reside in a state of emotional curiosity and alertness, as well as cognitive involvement. The success of memory creation and retrieval can depend upon encoding factors such as emotional significance, the amount of personal elaboration, and cues used for the search [Schenck 2003]. The more personally significant, the easier it can be for the user to recall information, even for a long time after the learning experience [Given 2002].

In order to support a highly interactive game-based experience that can be personalized according to the visitor's individual preferences, the Interactive Aquarium system (c.f. Figure 2) comprises a range of subsystems, which can be used individually or in combination to customize the richness of the experience. The subsystems currently include the Virtual Aquarium [Wetzstein et al. 2004], a virtual and augmented reality system for aquarium environments, a Dynamic Interaction Panel [Czyzewicz et al. 2005], which combines a personalized kiosk-style interaction and information panel, and a Mobile Interaction Panel based on a wireless Personal Data Assistant (PDA) [Stephenson et al. 2005] that acts as a remote control, mobile data store and mobile group activity panel. As an example of an activity facilitated by the system, we also present a game-based simulation of a deep-ocean environment based around a hydrothermal vent [Lecrenski & Stephenson 2005]. The game allows visitors to explore the environment and to interact with the deep-sea creatures.

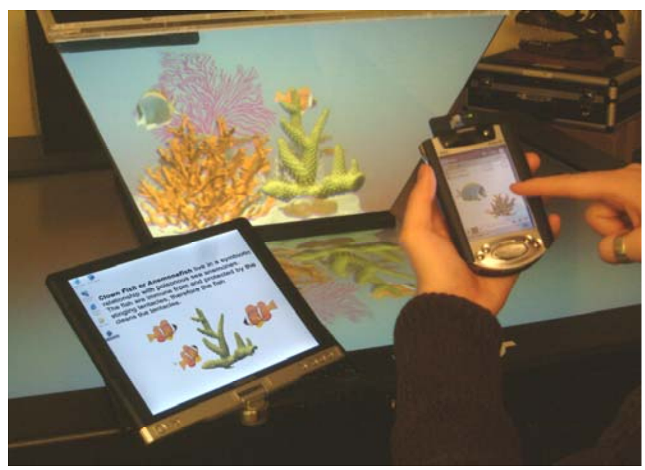

Figure 2: Example configuration of the Interactive Aquarium system.

2 Related Work

The use of technology to introduce interactive experiences is becoming commonplace. Disney has been heavily engaged during the past decade to integrate interactive virtual reality experiences into their theme parks [Mine 2003]. Most of the systems are based on head-mounted displays (HMD) or projection technology and

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are specially designed to work for large audiences such as one would find in a museum setting.

However, informal education centers tend to have limited budgets. Efforts have been made to reduce costs for VR installation such as the NAVE [Pair et al. 2000], an inexpensive surround-screen projection environment, and low-cost stereo projection walls [Pape et al. 2002].

The Virtual Oceanarium was part of the world exhibition EXPO 1998 in Portugal [Fröhlich 2000]. A cinema-like stereoscopic projection-based setup provided an immersive virtual reality experience for several hundred viewers. The Virtual Oceanarium provided no head tracking, thus the generated images were not viewpoint-dependent and only allowed for constrained interaction with the environment in the form of a professional presenter who navigated a virtual submarine through various fish tanks. This approach of presenting virtual content allows many viewers to participate, but due to limited interaction possibilities, it does not assist smaller museums building out existing exhibitions.

The Massachusetts Institute of Technology developed the iQuarium [Wasserman et al. 2004], a virtual reality fish tank that simulates and visualizes hydrodynamics of swimming fish. The iQuarium is part of the Hart Nautical Gallery at MIT museum.

3 The Interactive Aquarium

The Interactive Aquarium system is a suite of technologies designed to engage visitors and to assist them in exploring ideas and information otherwise difficult to communicate to audiences using traditional techniques. The system comprises a range of components that can be used individually or combined to build a more complex and integrated exhibit. The subsystems currently comprise:

- The Virtual Aquarium, which can be used in a purely virtual mode displaying a totally virtual environment or used to augment virtual elements on a prosthetic or live aquarium.
- The Dynamic Interaction Panel, which combines a Kiosk-style touch-screen interaction and information panel. The panel can be personalized based on a visitor's cultural and motivational preferences and abilities.
- A Mobile Interaction Panel based on a wireless Personal Data Assistant (PDA) that acts as a remote control, mobile data store and group activity panel.
- An interactive game-based simulation of a deep-sea environment to assist the personal exploration and discovery of such an extreme setting.

4 Virtual Aquarium

The Virtual Aquarium component of the Interactive Aquarium project (c.f. Figure 3) was built using the Virtual Showcase® [Bimber et al. 2001], an optical see-through augmented reality display that allows multiple users to observe and interact with the augmented physical content. It has an ideal form for an aquarium and a cost effective configuration suitable for exhibitions has been field-tested.

The Virtual Aquarium component currently displays a stereoscopically rendered aquarium environment containing virtual coral and fish. In a purely virtual aquarium, animations describing various biological and geological processes and behaviors can be visually explored and explained without the restraint of our natural time scale. For example, life cycles can be accelerated and replayed, virtual creatures dissected in situ, visualizations of flow dynamics and climatic conditions created, and the structure of coral and the locomotion of creatures explored.

Figure 3: The Virtual Aquarium component.

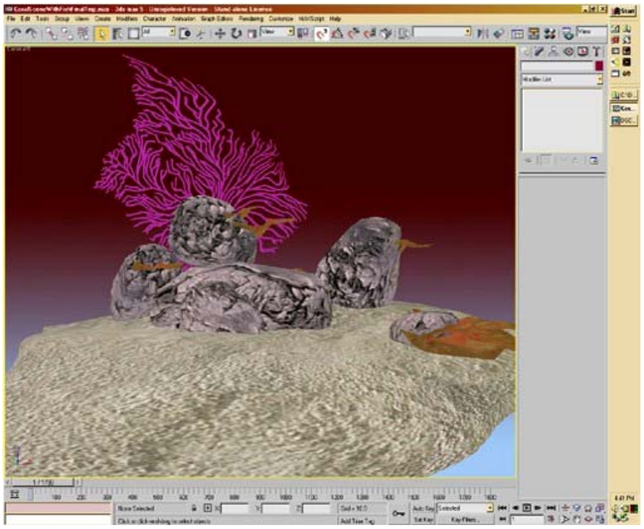
The Virtual Aquarium also has the capacity of augmenting virtual elements on the physical aquarium. Because the virtual elements are externally blended onto the physical scene by the use of a half silvered mirror, an aquarium could be maintained within the showcase. Virtual elements could then be used to populate the physical aquarium. The first step would be to augment prosthetic coral with virtual elements. Ultimately, the goal is to augment a fully living aquarium with virtual elements. While the concept has been proven for prosthetic corals, use in a living tank is more difficult due to the effect of the water on casting Occlusion Shadows [Bimber & Fröhlich 2002]. At the very least we will be able to help visitors identify the position of static and moving specimens in the living tank and will switch to a virtual reproduction for animation and story telling phases.

5 Designer Oriented Workflow

A significant development undertaken within the project for the production of content for the Virtual Aquarium is that the environment and models can be created by a designer using off-the-shelf modeling software such as 3D StudioMax® and Maya® (c.f. Figure 4a). Previously content creation for virtual environments has typically required the involvement of programmers.

Previous efforts to develop standards to create non-linear stories have been made at the Vienna University of Technology. The Virtual Showcase Modeling Language (VSML) [http://studierstube.org/virtualshowcase/details/vsml.html] is an XML-based description of interactive stories that uses modeled geometry to define a story. The Augmented Presentation and Interaction Authoring Language (APRIL) [http://studierstube.org/april/] is also an XML-based scene and interaction description language. Both offer the opportunity to define interactive stories but require programmers.

The workflow we have built allows designers to create, edit and preview scenes as they appear in the Virtual Aquarium (c.f. Figure 4b) using nVidia's CgFX plugin and the industry standard modeling software (c.f. Figure 4a). Differences in the appearance of a modeled scene when it is finally exported to the final display devices are a constant source of frustration for designers. The Virtual Showcase contains a renderer for the nvb portable shader format, to which we export the scene. Essentially what we have constructed is a WYSIWYG modeling tool for the Virtual Aquarium.



(a) Modeling environment.

(b) Virtual Aquarium.

Figure 4: Coherence of the appearance of the environment in the modeling environment and the Virtual Aquarium.

6 Dynamic Interaction Panel

Printed information panels, audio guides and video programs are standard tools for providing information to visitors of aquaria and museums. These media suffer several limitations:

- Graphics panels are typically unattractive to most visitors.
- The audio and visual programs and graphics panels are static and offer no interaction.
- Altering or updating the information is difficult and costly.
- The information is kept general because the information is intended for many different people.
- The real estate or time needed to present information dictates that only a fraction of the material available can be offered.
- Information panels are physically separate from the exhibit.
- The graphics panels can only depict generalizations of the referenced specimens, which makes it often difficult to recognize the specimens in the exhibit from the graphics panels.
- It is not possible to accommodate for significant differences among visitors' culture, ability and motivation.

The Dynamic Interaction Panel (c.f. Figure 5) component of the Interactive Aquarium system offers a solution to many of these problems. The interaction panel fulfills the same role as a graphics panel in presenting information on the specimen, however altering the information as the specimens in the aquarium are moved is straightforward. The interaction panel can also present multimedia information.

The panel permits interaction with the specimens in the aquarium, albeit vicarious. The interaction panel can be linked to the video stream of a camera that images the aquarium. Hotspots are placed over the video stream such that the visitor can simply touch the coral or other immobile specimens in the video stream to receive information about them. For moving specimens such as fish, a tracking system has been developed to place a moving hotspot over the creature in the video stream.

The information and interaction capabilities of the system offer new possibilities for visitors. To designate which specimens they are interested in, a specimen can be chosen from a list, information about that specimen is presented and the specimen highlighted in the video stream. If a visitor wants to know about a specimen in the video stream but cannot identify it, they just have to touch it. This answers one of the problems in information retrieval in aquaria, in which the visitor is left to determine the species of the specimen from a list of static images, which often don't look like the specimen at all.

7 Interaction Panel Personalization

Each day more than 2.3 million people visit museums in the U.S., and given the diversity within e.g. American society, it is often difficult for informal education centers to accommodate the diversity of their visitors. The 2000 Census shows that of the U.S. population aged five and older, 22.6% belongs to a racial and ethnic minority, therefore cultural diversity is a significant factor among museum visitors, and includes aspects such as language differences, gender biases and preferred learning methods. Other important differences among museum visitors also exist, including their ability to understand certain information and to perform certain tasks. For example, age, experience and education level of visitors varies considerably [Kelly 2002]; and considering that 19.2% of the U.S. population has a long-lasting condition or disability, accessibility to museum information and exhibits may also vary. In addition to differences in culture and abilities, variations in motivation for visiting exist; while the primary goal of visiting a museum for some people is to learn and to be challenged, others are seeking an entertaining leisure activity [Kelly 2002].

Figure 5: The interface of the Dynamic Interaction Panel.

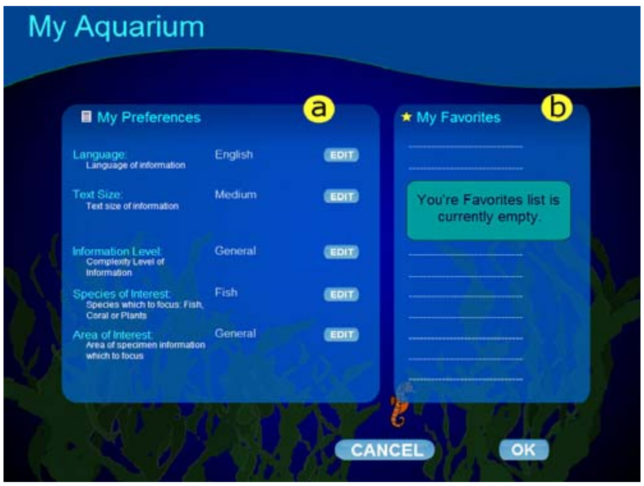


Figure 6: My Aquarium - The user profile screen.

Figure 7: The personalized interface.

In this section we describe a solution for accommodating diversity amongst museum visitors through personalization of the Dynamic Information Panel. The personalization architecture and interface implemented for this system offers support for visitor differences in culture, abilities and motivation with the following features: various languages including English, Spanish, and German; visual adjustments of text size; a range of information complexity and sophistication; customizable topics of interest; and personalized information collection management.

Personalization of dynamic information systems is currently a leading research agenda in industry. For the application of search engines, Khopkar et al. [2003] found that 13% (8 from the 60 analyzed) of search engines had some personalization features for retrieving information. The most recent addition is Google's personalized search engine, which offers tailored results to a user's particular interests as well as a slider component to control the degree at which personalization is applied.

Personalization has also become an integral component of customer relationship management systems within e-commerce websites helping to attract customers and maintain their loyalty [Khopkar et al. 2003]. For example, Amazon's personalization strategies are based on user profiles, interaction history and collaborative filtering. The user profiles allow Amazon to match and display products relevant to each customer's interests.

The personalization system implemented within the Interactive Aquarium project allows specimen information to be presented according to each visitor's culture, abilities, and motivational interests. The personalization features implemented were based on the differences among visitors in those three categories, and also considering security issues, time scenarios and ease-of-use.

Specimen information may now be presented in English, German or Spanish. Accessibility features include customizable size of display text, and color-blind friendly images and interface color schemes. Variety in education backgrounds, experience and age differences among the visitors is supported with the information complexity feature of the system – specimen data may be presented at a basic, general, or scientific level. To accommodate for the differences in visitor interests, a feature to specify desired specimen and information types is offered to decrease navigation time and present relevant data to each visitor; in addition, visitors can keep track of specimens of particular interest through navigation with the personalized collections management feature.

At any time the Create My Aquarium button may be selected, which brings the visitor to the User Profile Screen (c.f. Figure 6). My Aquarium Preferences are displayed on the left of this screen and initiated with their default values: the language is English, text size is "Medium", complexity level of the information is "General", specimen of interest is "Fish", and the specimen information category is "General" (c.f. Figure 6, section a). By selection its accompanying edit button, each preference can be changed through a pop-up dialog listing its options. The right side of the My Aquarium screen displays the information collection management as My Favorites – specimens selected as a favorite by the visitor during navigation (c.f. Figure 6, section b).

Figure 7 shows the Information Panel interface after a visitor set their preferences to Spanish as the language, "Coral" as their interest area, and "Large" text size display. This caused all content to be displayed in "Spanish", with large text and the "Coral" category to initially display.

8 Mobile Interaction Panel

The mobile interaction panel maintains all and more of the information functions of the stationary panel except for the video stream of the aquarium. A simple, familiar and easy-to-learn interface can therefore be created for the entire exhibition and between the stationary and mobile interaction devices.

The only significant differences between implementing the information system on the stationary and mobile interaction panels are the extremely small form factor of the display of the mobile device (c.f. Figure 8) and defining how to attach the mobile device to a particular exhibit. To attach the mobile interaction panel to a particular exhibit, the device registers on approach to an aquarium via an infrared emitter (IrDA Beacon) and the Personal-Interfaces-to-Go (PI2Go®) [Tesch et al. 2002] communications system. The information and the learning experience presented on the mobile device are based on the visitor's preferences and profile stored within the mobile device.

Figure 8: The information system of the Mobile Interaction Panel.

Because the visitor carries the mobile panel, it is natural for the panel to have a map and be used as an exhibition guide. The map feature also allows the visitors to find the locations of exhibits of interest based on their stored profile (c.f. Figure 9).

Figure 9: Map and exhibition guide.

The mobility of the device also opens up possibilities for individual and group activities to help educate visitors about different processes and systems that link several exhibits. For example, a Tamagotchi-style game is presented in which the visitor is set the task of maintain a simulated ecosystem within the device. They must go to different exhibits to collect samples to build their own aquarium. If the ecosystem is out of balance, feedback is supplied to the visitor as to why and directions are provided to fix the problem.

9 Game-based Simulation and Interaction

Due to the problem of maintaining the extreme environment found at 4,000 meters beneath the sea surface, public aquaria have a difficult problem creating a live deep-sea exhibition. Deep-sea creatures cannot exist at surface pressures due to their unique anatomy; therefore exhibits typically comprise preserved specimens with supporting information, which limits the educational experience that can be achieved. The museum visitors cannot experience how the creatures move, behave, and interact with their environment.

While it may be too costly to maintain a living deep-sea environment in a museum, the relative expense to build an equivalent interactive virtual environment is more compelling. Computer games have been proven to be a useful alternative educational resource due to their immersive nature that allows the player to explore at their own pace and seek out personal interests [Rieber 1996; Ryan 2001]. This type of alternative learning strategy has also been found to be particularly useful for female and ethnic students as they can approach the learning process in their own way.

Deep Blue (c.f. Figure 10) is a Virtual Deep-Sea exhibit that presents visitors the opportunity to explore a deep-sea environment of a hydrothermal vent site from within a virtual submarine. The environment includes several creatures such as tubeworms, anglerfish, fang tooth fish, deep-sea crabs and vampire squid. The visitor can navigate anywhere around the environment to seek out and explore the creatures and geology of the environment, which were modeled from video footage.

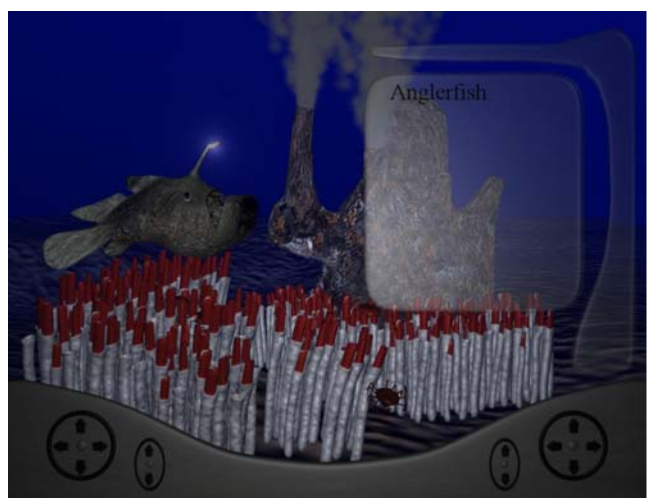


Figure 10: Interface and scenery from the Deep Sea Game.

The navigation interface is positioned in the bottom left and right corners of the console (c.f. Figure 10) so that left and right handed visitors can comfortably use the controls without obscuring the screen. Navigation of the environment includes six basic tasks: moving forward and reverse, turning left and right and tilting up and down. This type of movement was chosen because it is intuitive for visitors to move in these directions.

As the visitor is navigating through the deep-sea environment, they will regularly experience specimens and behaviors of interest. The game allows users to identify specimens, observe behaviors that can be scripted and to gather information. Any part of the environment can be attached to an information source. To identify what is of interest, the visitor simply touches the specimen or object on the screen to bring up an information window. In Figure 10, the screen identifies an Anglerfish in the environment.

10 Conclusions

The Interactive Aquarium project explores novel edutainment approaches for promoting interactivity and cognitive elaboration in the public aquarium setting. The three systems presented here, the Virtual Aquarium, Dynamic Interaction Panel, and Mobile Interaction Panel, can be used to provide: (1) A virtual environment in which a real aquarium can be replaced by a virtual aquarium for story telling purposes. (2) An information system that is interactive, dynamic, personalized, and maintainable. (3) A technique in which natural urges to point and touch things of interest is supported to retrieve information about specimens in the aquarium. (4) An integrated map and exhibition guide that is personalized. (5) An activity system that can be used to tie together concepts and processes across an entire exhibition. (6) A novel educational approach to promote better memorization of facts and constructional knowledge evolvement.

11 Future Work

Several problems still need to be overcome due to the specific requirements of a public environment. The Virtual Aquarium can be used to display a totally virtual environment or to augment virtual elements onto a physical system. While a prosthetic aquarium poses no new challenges, a living aquarium poses several because of the lighting differences required by the Virtual Showcase and used in the tank.

Moving a visitor's personalization profile with them throughout a busy exhibition also poses some system challenges. Having each visitor carry a PDA is an expensive proposition. Magnetic or smart cards used in security applications are cheaper but still more complex than is required. Having the visitor wear a badge or carry their ticket displaying a bar code or other identifying symbol maybe all that is required if each exhibit interaction panel is wirelessly connected.

In addition, we are looking into how to extend the edutainment experience beyond the actual museum visit, so that visitors can recall their personalized experience after their physical visit through the Internet, gather additional information about the specimens exhibited, and we hope, plan their next visit.

12 Acknowledgements

The project has been supported in part by the National Science Foundation (NSF) through the Research Experiences for Undergraduates (REU) program, grant number 0353786.

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