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Siper-Virtual Reality Simulator of Periscope

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Abstract: In this paper an application designed to simulate the environment seen in a periscope by means of a virtual reality environment is presented. The application allows full viewing of all objects visible from the periscope, sea, ships, airplanes, etc. With the appropriate hardware (3D mouse and tracking systems) it is possible to navigate into the virtual world and interact with the elements. Each of the objects that appear in the navigation environment has been reproduced in the simulation model, including the behavior laws associated with it, so the complete functionality of the all objects can be simulated. This module is built into a larger and more complex computer system composed of the actual submarine simulator, with all its characteristic components (except the periscope) and the functional system, which simulates all the external signals that are captured by the submarine. The application automatically updates in the virtual environment any changes to the environment navigation and allows access, from this environment, to information on every component the same way as is done from a real periscope. The virtual reality application has been implemented in a hardware configuration and has the same interface as that used in the real periscope. In this way, the system developed can be integrated into a replica of the submarine emulating a real periscope, it being able to fully interact with the global system and allow totally real situations to be simulated.

Key words: Training Systems · Simulator · Immersive system · Virtual environment · Real time simulation · 3D models

INTRODUCTION

The goals of educating in Virtual Reality include training individuals to operate complex machinery, to respond appropriately to rapidly unfolding events, or to function in environments that would otherwise be too expensive or hostile to be used on a day to day basis [1]. Such established uses of Virtual Reality are becoming both more widespread and more compelling, prompting investigation of its application to training enhanced critical decision-making skills.

The flexibility of virtual environments can be used to enhance those features of the environment that are specific to the targeted tasks at the expense of those which are not. Prior research in Virtual Reality and education has described a number of variables of interest to Virtual Reality based decision making training [2][3].

Especially in situations where there is an abnormal operation and the goal of training is to respond to worst rather than a normal day's operations [4]. A crucial element of the approach is to provide opportunity for repeated practice under operational conditions similar to those likely to be encountered in the real-world settings.

A variable widely accepted as being positively related to enhanced learning and performance in Virtual Reality and therefore highly desirable is 'presence' [5]. It is well established that meaningfulness and coherence of a stimulus set promotes learning and in Virtual Reality, presence has been identified as a key requirement in achieving this [6].

In order to appropriately simulate a virtual world, technologies such as realistic graphics and dynamic simulation with real-time calculations must be used [7]. Peripherals must be used for the system to interact with the user. Immersion comes as a result of stimuli to sight, hearing and touch [8][9]. It is possible, therefore, to produce immersion in the system by providing visual, tactile and acoustic feedback to the user.

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This paper describes the development of a simulator for training operators in typical periscopes situations (a.k.a. Siper-Periscope Simulator). The simulator was implemented using a georeferenced scenario editor [10] and the graphics engine Impromptu [11], which was created by this group. This engine was successfully used in various applications based on simulated environments [12][13].

Simulator Objectives: The fundamental objective is to develop a simulator for operations at periscope. These types of operations can be considered high-complexity activities for the people performing them. Therefore, the use of simulators for training can be particularly beneficial.

To giving the simulator the highest possible degree of realism, it has been equipped with the following features:

- Represent a periscope. This implies designing three-dimensional geometrical models of all the elements, which make up the periscopes.
- Interactive. Interactivity is obtained by the system responding through the peripherals to user-initiated events.
- Immersive. For the user to feel he or she is inside the virtual environment and visual feedback must be provided through the hardware, with the objects of the environment presented in 3D display.
- The system must replicate, as closely as possible, the actual functioning of the periscopes. To that end, the functioning logic of the installation has been be coded into the system, so that objects react to user input with the appropriate movement and behavior. Furthermore, all objects must strictly adhere to the physical laws governing their behavior; in this case, the laws of movement affecting three-dimensional objects and the physical principles of movement which, logically, define the behavior of a periscope. This means that the system includes mathematical algorithms, which simulate the movement of objects simultaneously with the behavior of periscope variables.
- Finally, the system has been incorporated into an external simulator, so that it becomes a multi-user system where the users can simultaneously input into the same virtual environment, following defined behavioral rules.

Interconnecting the different hardware and software elements has attained these objectives. The following section describes how these elements work and their relationship.

Technical Basis of the Application: To arrive at the functionality indicated in the objectives, several software tools have been used. The core of the application consists of pascal/object pascal code, which accesses the OpenSceneGraph [10] graphical libraries APIs. This aspect of the application allows the user to work with a physical mechanism within a virtual reality environment.

In the next phase, 3D models of the different components of the environment have been constructed. To this end a graphic engine has been used [14]. The software allows the insertion of repeated elements, so that identical geometrical models (i.e., ships) need not be duplicated.

Too much detail in the geometrical modeling means an increase in the time needed to render it, so that it can become impossible to offer real time experiencing. The rendering has been improved by applying textures to the 3D model. This greatly simplifies the rendering without loosing realism.

The geometrical models are imported by the virtual reality application, which applies to each object properties such as interference, object collision detection and preset trajectories. To increase the realism of the whole, colors, transparencies, labels and lights have been added to the geometries. Once the geometrical and operational data have been loaded, the virtual environment of the periscope can be manipulated.

In order to view the mechanism in real time, a scene graph with hierarchical object structure is created. The nodes, that is, the elements which include information on geometry, position or light, are the elements which make up the scene graph. Geometrical, position and light information is stored in geometry, transformation and light nodes, respectively.

Siper's Characteristics: The operation of a submarine involves handling a few instruments, such as passive sonar, active sonar, depth control, rudder and plans controls, control of engine power and of course, the periscope.

The periscope simulator (Siper) developed was incorporated into the ADITACSUB submarine simulator, located in the Submarine School of the Armada Argentina.

The ADITACSUB simulator has all the basic instruments that are in a real submarine and the signals it receives each of these components are simulated with computers, achieving an acceptable degree of realism.

Siper was adapted on the carcass of a real submarine periscope. The adaptation replaced the actual optical periscope for a virtual-reality helmet on which is displayed a three-dimensional environment generated in real time.

The operations and movements performed on the periscope are converted into digital signals and then are entered into the simulator to replenish the visual model. These operations are:

- Rotation of 360°
- Change of optical (three levels of magnification).
- Elevation control between-10° and 60°.
- Change of filters (three filters to reduce light intensity received).
- Lighting reticulum control (illumination for night vision).
- Phase shift of the stadimetric reticulum (splits the image to estimate distances).

All these signals are collected and incorporated into the computer by serial and parallel ports. In addition, the system receives from the direction of exercise (another computer) the location and speed of targets (ships and aircraft in the scenario) in each time. This information together with the characteristics assigned to the stage (coast, sea state, wind direction, visibility, weather conditions, etc) is the data required by the system to define the image to be sent to the periscope. To be realistic feel is necessary maintaining a rate of 15 frames per second.

Simulated Effects: To achieve the balance between realism and performance was necessary to use different kinds of tricks to get the desired effect. Below are the most important requirements and how they were implemented:

Sea Waves: Five sea states were considered with sea waves ranging from 10 cm. to 6 m. It was simulated with a triangulated surface of 70 km in diameter with a texture moving in the wind direction. This surface is a semi-sphere for modeling the curvature of the earth. Figure 1 shows that the surface has been generated for take small elements near the center (position where there is always the periscope) and large elements on the horizon.

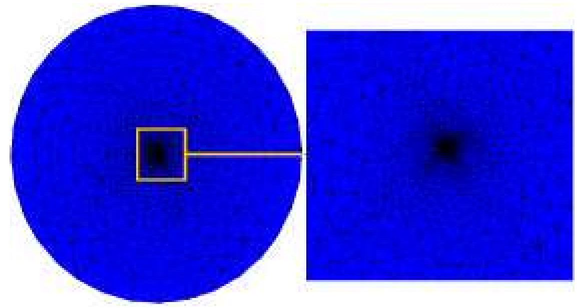

Fig. 1: Sea surface state.

The size ratio between the small and large elements is 1/10000. The points of the triangulation are displaced vertically at 10 times per second of rate to simulate the waves.

Ships: They are three-dimensional models with fewer than 10000 polygons. These models are displaced (proper motion) and rotated (rocking and pitching) 10 times per second. The system may keep 15 ships at the scene at same time.

Aircraft: For airplanes and helicopters will use an approach similar to the ships. In this case only has the movement of the propellers.

Ship Wake: This effect was modeled with a surface with wave shape, whose amplitude is synchronized with the movement of the ship.

Costs: A submarine operates at depths exceeding 30m and it can't get too close to the coast. This restriction permits a very economical 3D representation of the real coast with a texture mapped on a polygon located at the correct distance.

Stadiometric Rang: This function is used to measure distances, creating a double image overlay. Given the height of the target which is known and the overlay angle is possible to calculate the approximate distance between the submarine and the ship. To simulate this effect are duplicate all the objects in the scene and it are presents rotated with a degree of transparency (Figure 2).

Rain, Snow and Hail: These effects were incorporated as textures mapped to a polygon placed in front of the camera. When the periscope up or when a wave hits it, there is a water drop in front of the camera. This effect is simulated as the rain and is activated when the periscope out of the water for three seconds.

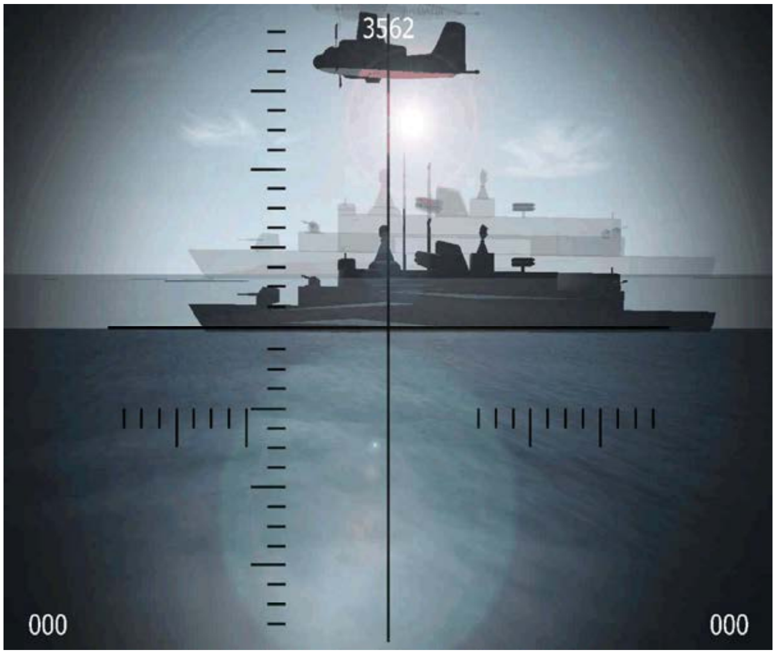

Fig. 2: Stadiometric range.

Fig. 3: Simulation image.

Sky: Three sky states are considered: clear sky, partially cloudy or completely overcast. The clouds are displaced in the direction of the wind. For this purpose the images are applied to polygons used as background. Besides, the sun is represented in the case of cloudless days or the moon and the stars at night. In this regard, particular attention has been the backlights and the effects they produce on the optics.

The Implemented System Required Two Adjustments: first the position information of targets in the scene is sent by the management of exercise at one frame per second of rate. In general the ships do not have large displacements in a short period of time, but under certain circumstances, such as ships to a short distance or with significant velocity, there is an unwanted break. The situation is more serious with the aircraft. Since it was not possible to reduce this interval to less than 0.5 seconds for problems of network overload, we decided to work a backward time step and interpolating between two positions every 0.1 seconds.

The other problem is the high computational cost of water model. The difficulty is that the surface points are displaced every 0.1 seconds, thereby changing the normal of each triangle, requiring a complete recalculation (this does not happen with the rest of the objects in the scene while moving, because they do in rigidly). Furthermore, the texture mapping should be done completely for each time interval. For this reason the adapted surface (Figure 3) must be used, reducing the number of polygons to only 3500.

CONCLUSIONS

In this paper, a virtual reality environment for training users under conditions almost identical to reality was presented. Using low-cost equipment and tools of modern software was simulated in real time a three-dimensional of the observable scene in a submarine periscope. The system was installed at the Submarine School of Armada Argentina and given the information obtained; the model implemented has a degree of realism similar to the best known products.

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