1995

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þÿ L e n t z , F r e d C . , S h a f f e r , A l a n B . , P r a t t , D a v i d R . , F a l b y , J o h n S . a n d Z y
þÿ N a v a l T r a i n i n g I n t e g r a t i o n , i n t h e P r o c e e d i n g s o f t h e 1 3 t h D I S W o r k s h o
1995, Orlando, Florida, pp. 107- 112.

http://hdl.handle.net/10945/41552

NPSNET: NAVAL TRAINING INTEGRATION

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KEYWORDS
Virtual reality, Naval training in a DIS synthetic environment.

ABSTRACT

The NPSNET Research Group has begun to investigate the integration of Naval forces into the NPSNET/DIS synthetic environment. These efforts continue our long-standing work at producing low-cost, workstation-based virtual environments. Recent work includes the development of a portable visual shipboard simulator, a damage control virtual environment trainer (DC-VET), an LA-class submarine trainer, and an SH-60B ASW helicopter trainer. The presentation describes our work with these systems and the emerging requirement for a networking protocol allowing multiple workstations to be utilized as a single weapon's system.

NAVAL TRAINING IN THE FACE OF SHRINKING RESOURCES

With the ongoing reductions in Defense spending, Naval training funds have become smaller and smaller, yet the need for increased readiness is now more important than ever. In the past, this argument fed the need for large-scale training facilities throughout all communities of the Navy. The idea was that, while it was prohibitively costly to conduct all training on-board actual shipboard or aircraft evolutions, it was relatively cheap to allow officers and enlisted men in the training syllabus to hone their skills in a trainer. After all, fuel and maintenance costs were not a factor, and more importantly, the trainee could make mistakes early on, without the risk of an accident. To some extent, though, even those days are falling by the wayside. As with actual shipboard training availability, trainer facilities are becoming less available, and the cost of building and maintaining them higher and higher. There is now a great need to augment the training conducted at shore-based facilities, and it must be accomplished without significant impact on the current training budget.

At the Naval Postgraduate School (NPS) in Monterey, California, the Computer Graphics and Visual Simulation track of the Computer Science department is working toward a solution to the above problem through the use of Virtual Reality. The objective of our research effort is to build systems that meet the training needs of the Navy as realistically as possible, outside the context of an actual ship bridge or aircraft cockpit. Virtual Reality provides a means of inserting a trainee into a simulated environment via computer hardware and software alone, and allows him the opportunity to conduct either stand-alone training, or training with others over a network. Several projects are currently ongoing, including systems to provide shipboard OOD training, shipboard walkthrough and damage control training, submarine operations training, and naval ASW helicopter flight training. All of these projects are being built exclusively by students at NPS. The great benefit to the fleet is that these systems can be obtained for the cost of hardware alone; all software can be obtained free of charge, since it has all been developed at a U.S. government facility.

PORTABLE VISUAL SHIPBOARD SIMULATOR

In recent years, the Navy has initiated a number of strategies to aid in alleviating the problem of providing real training opportunities for junior officers undergoing OOD training. One such strategy has been to crossdeck (or temporarily transfer) junior officer watchstanders to other units either preparing to deploy or involved in at-sea operations, to facilitate their gaining some of the necessary underway bridge watchstanding time which is crucial to the development of their shiphandling skills. A problem frequently encountered with this strategy has been that the host ship sponsoring the training must at the same time provide adequate shiphandling training opportunities for its own junior officer watchstanders. When faced with limited underway time, as well as significantly reduced opportunities to conduct such training, this can present a conflict. Often, the transferred junior officer may reap only limited benefit from the training opportunity at significant monetary cost.

Another strategy involves the use of full-scale shiphandling training simulators which make use of three dimensional computer graphics. These full scale facilities provide a very realistic view of the world as seen through the bridge windows. The use of simulators makes possi-

ble an infinite variety of potential scenarios involving shiphandling, to include getting underway from and mooring to piers in a variety of environments, formation steaming, underway replenishment, piloting in narrow channels, and transits through restricted waters and crowded shipping lanes. Currently, however, there are only two such shiphandling training simulators available to the Navy, located in San Diego, CA and Newport, RI, making their availability very limited.

In view of these limitations, we set out to develop a virtual simulation system with several goals in mind: development and implementation of a deployable three-dimensional virtual world shiphandling training simulator; design and development of terrain database for virtual world simulation (to include cultural structures, shoreline, aids to navigation, ships at anchor, and moving vessels); and, modeling of ships and other maritime vessels, as well as modeling of real-time hydrodynamic forces acting upon those maritime entities within the virtual world environment. Additionally, we wanted to develop a training system to provide greater training availability for more junior officers, who normally do not receive exposure to land-based full scale training simulators until later on in their naval careers.

The design objective of the portable visual shiphandling simulator was to provide realistic shiphandling training scenarios provided by the full-scale simulators utilizing a single, high-speed graphics workstation as a host, preferably a Silicon Graphics Inc. Reality Engine series model equipped with a monitor, keyboard and mouse pointing device. The purpose of hosting the portable simulator on a single workstation was to allow its placement either aboard a deploying vessel or in the immediate vicinity of one that was in port. This close proximity provides easy access to any shipboard personnel desiring shiphandling practice without the need for numerous support and technical personnel normally associated with running the training scenarios in the full-scale simulator.

Limited to a single monitor, the training exercise is displayed in a split screen configuration with the display of the ship and its surrounding scene (tactical viewing area) occupying the upper three quarters of the display and the ship's controls (provided by a simple graphical user interface) occupying the lower quarter (Figure 1 shows the 3D display only). For more enhanced training, the portable shiphandling simulator also has the capability to operate in a distributed network configuration, thus providing multiple ship, multiple user interaction and scenarios, wherein different portable shipboard simulators on the network could act as different ship entities.

When designing the portable simulator, the task of modeling the movement of the ship was not the only problem. The ability to place the conning officer onto a virtual bridge with only a single monitor available and allowing freedom of movement among specific conning stations or viewing locations also needed to be considered. In addition to moving about the bridge, a form of head movement needed to be implemented where the conning officer could observe a desired viewing angle off the bow or raise and lower the view with respect to the horizon. The approach to solving these problems was to attach the conning officer's viewing position to one of three possible locations on the ship model -- the pilot house, the port bridge wing or the starboard bridge wing. Movement between these positions is accomplished through inputs from the control panel. In essence, the conning officer is immersed into the scene by "riding" the ship model as it moves through the terrain database. When viewing forward, in line with the bow or off the beam, the conning officer will sense forward motion as the ship moves forward.

While "underway" in the virtual environment, adjusting the ship's course and speed is easily accomplished through the use of rudder and engine controls located on the control panel immediately below the tactical display area. To add more realism to the scenario, a second person acting as a helmsman could operate the controls in response to voice commands passed by the conning officer. With this arrangement, a more experienced conning officer could give instruction to the less experienced one as the exercise progresses.

To further enhance training, the conning officer is allowed to detach himself/herself from the ship and view the entire exterior of the ship from different external viewpoints while moving through the water. This added feature was developed to provide better visualization feedback to the conning officer as to what the ship looks like during various maneuvering evolutions. Furthermore, the conning officer can fly ahead of the ship to view the maneuvering evolutions of other ships being reported over the network as well as viewing anticipated turning points. Additionally, controls are provided to adjust both the local time of day and the local visibility by manipulation of lighting and fog levels.

The Portable Visual Shipboard Simulator was developed by LCDR Joseph Nobles and LT James F. Garrova as their Masters Degree thesis research at NPS. The system currently used to construct this trainer is the Silicon Graphics Onyx Reality Engine 2. While this system represents the state-of-the-art in graphics rendering hardware, the trainer can also run quite nicely on the Silicon Graphics Power Series Reality Engine I, with some slight degradation in frame rate (a computer graphics measure of the number of frames per second that can be displayed to the user). Silicon Graphics is planning the release of a new system that has the capability of the Power Series Reality Engine I for about $29,000 by quarter four of 1995. This new system would be ideal for shipboard deployment from the parent command simply because of its real-time graphics capabilities, low material support and overall low cost.

DAMAGE CONTROL VIRTUAL ENVIRONMENT TRAINER (DC-VET)

The Damage Control Virtual Environment Trainer (DC-VET) is an excellent system to demonstrate the

training capabilities of virtual reality. Basic shipboard familiarization and damage control skills can be learned from the virtual representations of a ship. The damage control trainer is also designed as a networked environment using the computer network communication protocols, which allow multiple people to train together in the same virtual environment.

The DC-VET is designed to allow a novice sailor to acquire ship familiarization by allowing him to move about the ship model in a realistic fashion. By visiting key points of interest within the ship model, the sailor can later associate the virtual world with the real world. A trainee can also review shipboard fire-fighting techniques while fighting a simulated fire in the engine room compartment. The team aspect is also an important part of damage control training, and we have addressed this fact in the DC-VET. With the use of network communications, multiple people participate in team training over an Internet connection. One can participate actively, or as a silent observer watching others react in the simulation. The latter role would be ideal for the training instructor or evaluator. The limit to the number of players is based only on the limitations of the participant's workstation.

Figure 2 shows a typical networked damage control scenario being conducted in the DC-VET. The observed view is that of one player on the network watching another fight a fuel fire in the ship's engine room compartment. The pipe in the lower-right of the screen represents a fuel line, with a shut-off valve approximately midway down the pipe. Upon instructor initiation, a fuel leak occurs at the left end of the pipe, and the trainee is given twenty seconds to shut off fuel flow at the valve before a fire ignites. The trainees must then work together to access the water nozzle and extinguish the fire. During this time, the scene gets steadily darker to simulate smoke filling the space. Once the fire is extinguished, a vent control switch can be accessed to vent the compartment of residual smoke. Also in this virtual environment are the ship's boiler, main fuel pumps, and main fuel booster pumps, which can all be seen in the figure.

In addition to the damage control training capabilities of the DC-VET, shipboard familiarization training is also provided. The entire virtual environment is comprised of eight multi-level compartments, including a CIC compartment, Comm Shack, HT Shop, and other miscellaneous spaces. A trainee can navigate throughout the virtual ship to familiarize himself with a typical layout. As well, in each of these compartments, the trainee can "grab" various pieces of gear and will be shown textual information to describe such things as operating specifications and parameters.

The basic design of DC-VET was developed by LCDR Tony King and LT Perry McDowell as their thesis research at NPS, and continued upon by LT Jim O'Byrne in his thesis work. In its current version, the DC-VET database represents a typical shipboard layout; in the future, data from actual fleet combatants can be implemented to provide more realistic training environments. As with the Portable Shipboard Simulator, DC-VET uses the Silicon Graphics Onyx Reality Engine family of systems.

LA-CLASS SUBMARINE TRAINER

One of the major projects being conducted at the Graphics Lab is the Naval Postgraduate School Networked Vehicle Simulator IV (NPSNET-IV). NPSNET-IV, now in its eighth configuration, is a low-cost, student written, real-time networked vehicle simulator that runs on commercial, off-the-shelf workstations (the Silicon Graphics IRIS family of computers). The simulation reads and writes DoD-Standard DIS protocol data units (PDUs), and utilizes formatted terrain and model databases. NPSNET is an ongoing project, used as a test bed for new areas of work within the NPSNET Research Group. One of these new areas is the implementation of an LA-Class Submarine Trainer. Figure 3 shows an external representation of the submarine, as well as the SH-60 ASW Helo described later.

The Submarine Trainer, currently a project in the works, is designed as a real-time hydrodynamic model with full freedom of movement in the virtual environment. The goal in designing the submarine model has been two-fold. First, it needed to appear realistic from an external standpoint in that, within the simulated world of NPSNET, it must look and act like a submarine. This concept is important in providing realism to other network players that interact with the sub. Second, it needed to represent a realistic submarine virtual environment from within to provide as believable a training experience as possible for the user.

While the emphasis of the Shipboard Trainer mentioned above is on shiphandling, the Submarine Trainer emphasizes both submarine warfare training and shiphandling. The submarine model can fire torpedoes and missiles in a battle scenario, and can be driven in a shiphandling scenario. This provides the submarine warfare community a more complete training environment.

An NPSNET-IV submarine simulation optimally consists of three stations operating one virtual submarine: a helmsman/planesman, a weapons coordinator, and an OOD. Each of these submarine stations can be individually controlled from separate computer workstations, or they can all be controlled by one individual on a single workstation. Interaction is accomplished through the use of computer network communication protocols over the Internet via user interface panels. Each user has an interface panel displayed on his computer screen specifically tailored to the function that he is performing. For example, the OOD will have a display that shows the overall status of the submarine to include weapons available, locations of contacts of interest, and heading/attitude/depth information, among other things. He can also get a view of the external virtual environment by looking through a "periscope". Similarly, the weapons coordinator will have access to any weapons information he needs, while the helmsman/planesman will view shiph-

andling information. Information is passed between stations over the network, allowing users to coordinate their actions and fight a more realistic battle simulation.

One of the biggest benefits of NPSNET-IV is that the user panels described above can be interchanged among computer workstations, and the workstations themselves do not need to be in the same geographic location. This allows the maximum amount of training flexibility for crew members. For example, consider a scenario where three submarine warfare crew members are in training at different locations of the country, each having a computer workstation capable of running NPSNET-IV. By being connected via the Internet, trainees can each control one individual aspect of the same submarine model in a single simulation, then switch modes with one other to receive training in another position. As submarine warfare officers, these users receive training in all of these aspects of submarine warfare.

Another benefit of NPSNET-IV is realized when members of different warfare communities participate in one simulation. This allows members of the submarine warfare community to receive training by conducting simulations against actual anti-submarine warfare assets using the SH-60B ASW Helicopter Trainer described below. This type of scenario benefits all participants by providing exposure to tactics used by members of other communities, as opposed to the case where a single community must simulate both sides of a prosecution. And the networking benefits of the system can be applied here as well. For instance, the submarine crew and ASW forces can be physically located in distant geographic areas, yet still operate in the same virtual environment over the Internet.

The LA-Class Submarine Trainer in NPSNET-IV is currently being developed by LT Daniel Bacon as his Masters Degree thesis research at NPS. The system is being developed and operated on the Silicon Graphics IRIS family of low-cost computer workstations.

SH-60B ASW HELICOPTER TRAINER

NPS is also conducting research on development of a helicopter anti-submarine warfare trainer. When NPSNET-IV is configured to represent a helicopter in the virtual environment, the program adopts the look and feel of a helicopter flight simulator. When operated in conjunction with the LA-Class Submarine trainer described above, an environment is created where helicopter anti-submarine aircrews can conduct training against actual submarine warfare crews. This is accomplished in a virtual environment, and is significantly less costly than the current method of training, which involves an actual submarine operating on a training range with numerous aircraft overhead conducting anti-submarine training. This latter type of training is significantly more costly, more difficult to coordinate, and more inherently dangerous than operating computer workstations over a network. A virtual environment warfare scenario is also more realistic than the scenarios presented to aircrews training in current helicopter flight simulators, since the submarines path modeled in the latter is either scripted, or controlled by other pilots conducting the training. The best training environment is one in which actual flight crews can train against actual submarine crews. NPSNET-IV provides that capability.

The SH-60B ASW Helicopter Trainer is modelled like a helicopter flight simulator. Flying the helicopter inside of the virtual environment, the pilot enjoys the same type of control that he would get if he were flying the actual aircraft in the real world. A pilot sitting at a workstation can control his helicopter with the same type of flight controls used in a real helicopter, using a joystick, throttle, and rudder pedals. The view of the world presented to him on the computer screen is the view from the cockpit of the helicopter. The pilot has complete control over the flight path of the aircraft and can change his viewpoint without changing the heading of the helicopter, i.e., scan the horizon.

As all helicopter anti-submarine aircrews know, however, flying the aircraft is only part of an anti-submarine scenario. The other major ingredient is the tactics needed to locate, identify, track, and attack a submarine threat, along with the aircrew coordination required to successfully prosecute that threat. With the SH-60B ASW Helicopter Trainer in NPSNET-IV, a pilot can fly his helicopter from one workstation, while another, for example an Airborne Tactical Officer (ATO), controls the tactical portion of the mission. He can launch sonobuoys, track a subsurface contact, and launch torpedoes against the threat just as he would if the mission were real. The ATO is presented with an interface panel on his computer screen which shows the tactical picture - where the sonobuoys are located, how his tracking is progressing, and the best locations for attack. For crew coordination, the panel also presents the ATO with the current status of the helicopter's flight, including altitude, airspeed and heading of the aircraft. This allows the ATO to "back up" the pilot in the flying portion of the mission.

Since the ATO and pilot in a real helicopter need to pass data back and forth, that same capability needs to be present in the Helicopter Trainer. In NPSNET-IV, the ATO makes inputs via his interface panel to the pilot to assist in directing the helicopter to the correct location needed to continue prosecuting the submarine. That input is repeated to the pilot on his own workstation in a simplified form, telling him where to fly or what action to take. The networking capabilities of NPSNET-IV allow for this communication between workstations in digital form, just as in the real helicopter.

In addition to the above single helo-single submarine scenario, NPSNET-IV also has the capability to conduct larger scale simulations without significant degradation of realism. In this scenario, multiple helicopters can simulate prosecution of multiple submarines. Through the use of network communications over the Internet, aircrews from different squadrons in different locations can operate in the same virtual environment without their be-

ing geographically co-located. And like the Submarine Trainer previously described, members of the aircrew don't need to be geographically co-located. They can control the same virtual vehicle from computer workstations located across the Internet from each other.

The SH-60B ASW Helicopter Trainer in NPSNET-IV is currently being developed by LT Frederick C. Lentz, III as his Masters Degree thesis research at NPS. The system is being developed and operated on the Silicon Graphics IRIS family of low-cost computer workstations.

CONCLUSIONS

All of the tools mentioned here are meant to supplement actual training currently used in the fleet. Nothing can replace the benefit of real-world training in the areas of ship handling, damage control, submarine and anti-submarine warfare, and flight training. However, in today's world of defense budget cutbacks, such real world training is becoming less and less available. To help make up for this lost training, the solutions listed here allow the members of the fleet to continue their high professionalism and readiness by being able to conduct valuable training on computer workstations at a much higher frequency than can be conducted in real world scenarios, and at a fraction of the cost.

In today's military environment, joint operations are becoming more and more necessary. Joint training and preparations for such operations, however, becomes increasingly difficult, both from a logistics standpoint and from a cost standpoint. This is partially solved in NPSNET-IV, which currently contains functionality for ground forces like tanks or even dismounted infantry. By combining the Naval forces being simulated in the descriptions above with simulated ground forces, low-cost joint training is possible. Units participating in the simulation can get a much better idea of what to expect from all other forces involved in an operation before that operation actually starts. Since NPSNET-IV also has the capability to model real world terrain data, the simulations can come as close to the actual operation as possible without the need for participating units to leave their home bases. And the training conducted can be as valuable, because it can be conducted in real-time in a virtual representation of actual geographic locations with the actual units that will be involved in the operation, whether they be sea-based naval forces, ground-based army forces or amphibious marine forces.

These tools can provide to our military services the ability to conduct meaningful training with other military units via a virtual environment. With the Internet already in place on a global scale, training simulations can now be conducted across the room, base, state, or continent, or even across the oceans at a lower cost than has ever been possible.

ACKNOWLEDGMENTS

This work would not have been possible without the support of our research sponsors: ARPA, USA ARL, DMSO, USA TRAC.

RESOURCES

All papers from the NPSNET Research Group are available via the NPSNET Research Group's web page:

http://www.cs.nps.navy.mil/research/npsnet

The full source code to NPSNET is also available at that location. NPSNET is currently under configuration management for the DoD by the technical staff of the NPSNET Research Group at the Naval Postgraduate School, Monterey, California. The configuration management efforts are carried out via reimbursable contracts with the faculty of the NPSNET Research Group. Over 100 DoD laboratories and contractors currently utilize NPSNET.

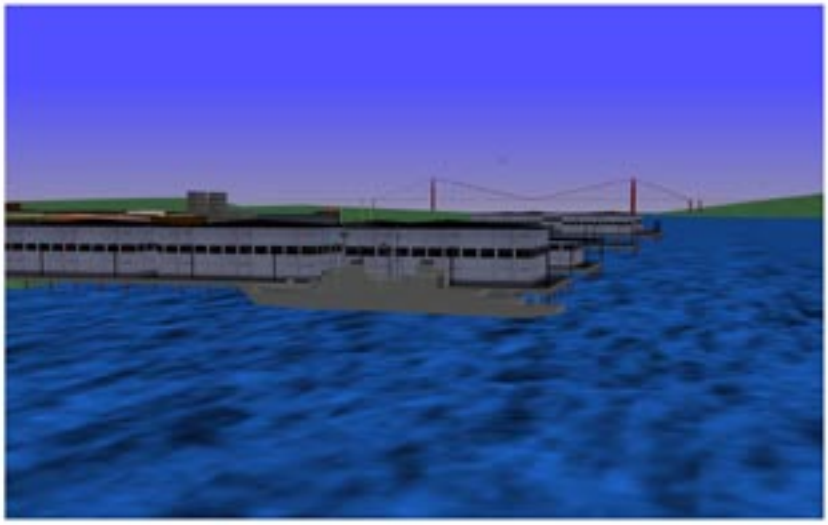

Figure 1 - Portable Visual Shipboard Simulator

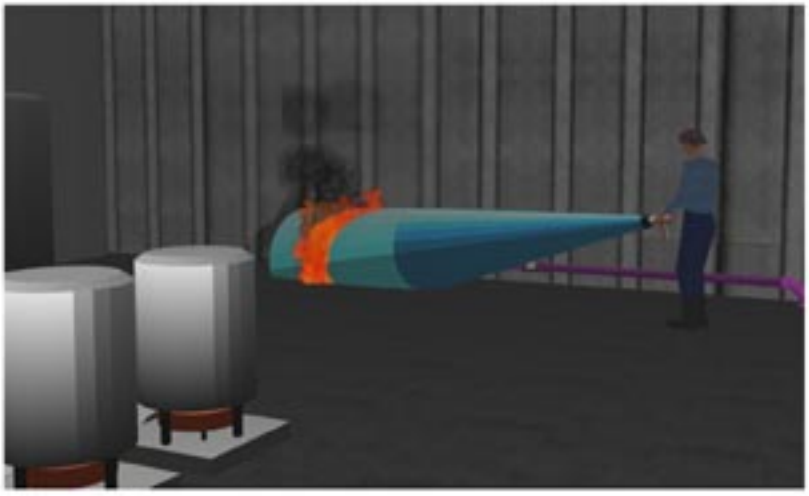

Figure 2 - Damage Control Virtual Environment Trainer

Figure 3 - LA-Class Submarine & SH-60B ASW Helicopter Trainer