TRAINING ROV PILOTS WITH A VE-BASED INTELLIGENT TUTORING SYSTEM

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ABSTRACT

Remotely operated vehicles (ROVs) are widely used in military and commercial applications such as mine countermeasures, search and salvage, offshore oil and gas production, and structural inspection. Due to the expense and logistics involved with operating actual vehicles, training and practice is often difficult to obtain in other than an "on the job" fashion. The Training for Remote Sensing and Manipulation (TRANSoM) program, sponsored by the Office of Naval Research, has developed and demonstrated a virtual environment (VE) based system for training ROV piloting skills. This system is a unique combination of an Intelligent Tutoring System (ITS) within a VE simulation which offers individualized instruction in a self-paced, guided-practice learning environment. It has been prototyped and tested extensively over the past three years. Verification and validation tests have demonstrated the fidelity of the simulation when compared to an actual ROV system. Transfer tests have demonstrated the system's training effectiveness, indicating that practice with the simulation based system yields comparable piloting performance to practice with the actual ROV. Skills learned under simulation were also transferable to other related tasks. System enhancements currently in process include development of a curriculum to teach situation awareness, development of mission planning and rehearsal tools, and porting to a PC-based platform.

AUTHORS' BIOGRAPHY

Barbara Fletcher

As Senior Systems Engineer at Imetrix , Ms. Fletcher has been involved in a wide variety of systems applications. She is the Co-Principal Investigator and the Project Manager for the ONR program *Training for Remote Sensing and Manipulation* (TRANSoM), developing the application of virtual environment technologies for ROV operations and training. She has been the Principal Investigator for 2 SBIR Phase 1 efforts: *Autonomous Power Generation,* and *Stand Alone ROV Trainer (START)*. She was also the project manager for the development of tracking and control for the Naval Surface Warfare Center Advanced Hull Maintenance Vehicle. She has been responsible for delivering Integrated Navigation and Control Systems, including systems for General Electric Nuclear Energy and Hydro-Quebec dam inspection. Prior to coming to Imetrix, she spent ten years at the Naval Ocean Systems Center (NOSC), specializing in areas of underwater security, mine countermeasures, deep submergence and surveillance. She is a licensed Professional Engineer, with a B.S. and M.S. in Mechanical Engineering from Stanford University.

Bruce Roberts

Mr. Roberts is a member of the Learning Technologies Department at BBN, and has been responsible for developing numerous AI systems. His current projects include building an operational tutor for teaching flight line troubleshooting to Air Force technicians and a virtual environment based tutor for teaching piloting of remotely operated underwater vehicles. His involvement in the development of Intelligent Tutoring Systems extends back to some of the earliest work incorporating simulation, computer graphics, and expert systems in training systems. Past projects have focused on applications of AI to support the design and analysis of complex systems; for example, telecommunication networks, chemical plants, and protein biology. His research interests include knowledge representation and the knowledge acquisition process, the qualitative modeling of complex systems, and the development of human-computer interfaces that utilize speech, text, and graphics, as well as knowledge of user's task, to communicate naturally and effectively.

Prior to coming to BBN, Mr. Roberts was a member of the MIT Artificial Intelligence Laboratory, where he participated in some of the earliest work in knowledge representation, expert systems, and applications of computers in education. He was one of the developers of FRL, one of the earliest knowledge representation systems. His primary research interest was in constructing computational models of Piagetian psychological phenomena.

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OVERVIEW

Military and Commercial Requirements

The Navy is currently using or investigating the use of remotely operated vehicles (ROVs) in a wide variety of applications including search and salvage, hull husbandry, and mine countermeasures [Fletcher 96]. Due to the high value of the vehicle and associated systems, it is difficult for operators to receive sufficient hands-on training. The critical nature of the missions performed also require the most experienced operators possible, further limiting the training time available. For effective utilization of these systems, tools are required to both train operators and provide for mission rehearsal and planning. The system described in this paper provides a variety of these tools in a system designed for ready use in a desk top computer.

TRANSoM Program Background

Started in 1995, *Training for Remote Sensing and Manipulation* (TRANSoM) is sponsored by the Office of Naval Research. It is a collaborative effort of four organizations, each of which contributes a key component to the effort: *Imetrix Inc.* the prime contractor and expert in ROV systems and operations; *BBN Technologies,* developing the intelligent tutor system, *Massachusetts Institute of Technology,* providing the lead in human/machine interaction research, and *The Boeing Corporation,* leading the training transfer studies*.*

The objective of this program is to design, develop, and evaluate a prototype remote platform pilot training and mission rehearsal system incorporating Intelligent Tutoring System techniques within a Virtual Environment [Pioch 96]. The system being developed, as well as many of its component parts, is seen as an answer to some of the training requirements for effective ROV operations [Fletcher 97a].

SYSTEM DESCRIPTION

The TRANSoM ROV pilot training system uses virtual environment techniques and technologies to create a realistic simulation of the ROV and its operating environment. An Intelligent Tutoring system is implemented within this environment, providing the guidance required for training the critical tasks.

The Virtual Environment (VE)

The VE is the foundation of the training system. It serves four main functions: modeling of the operational world in which the training takes place, modeling the vehicle, presenting sensor displays comparable to those found in actual ROV systems, and presenting instructional aids which, although not found in standard ROV systems, enhance and accelerate the learning process. Figure 1 shows a representative set of the TRANSoM training system displays.

Creating a sufficiently realistic environment is essential for the training of ROV piloting skills. The VE incorporates a full range of environmental models, including not only the physical objects in the marine environment but also environmental conditions, such as currents, visibility, and particulates, which affect ROV operation.

In addition to world models, the VE simulation incorporates visually and dynamically realistic vehicles. Key dynamic characteristics of the vehicle are modeled, including inertia, response time, drag, and maximum speeds. The system can be configured to depict a wide variety of vehicle types, ranging from small inspection systems to large work vehicles. This results in a versatile training system which is not tied to any single ROV type or configuration.

Along with the vehicle configuration and dynamics a variety of sensors are modeled and presented to the student. The most common sensor is the video display from a camera mounted on the front of the ROV. The TRANSoM video simulation includes realistic lighting effects and accurately captures a full range of visibility conditions. A vehicle status display provides the standard data of the vehicle depth and heading, camera tilt and zoom, and the amount of tether paid out. The navigation plot presents an XY plot of the vehicle position, including the vehicle heading and the path followed. A simple scanning sonar has been modeled, providing mouse-driven controls of selecting range, sector width, and training angle. The cursor can be used to report range and bearing to a target.

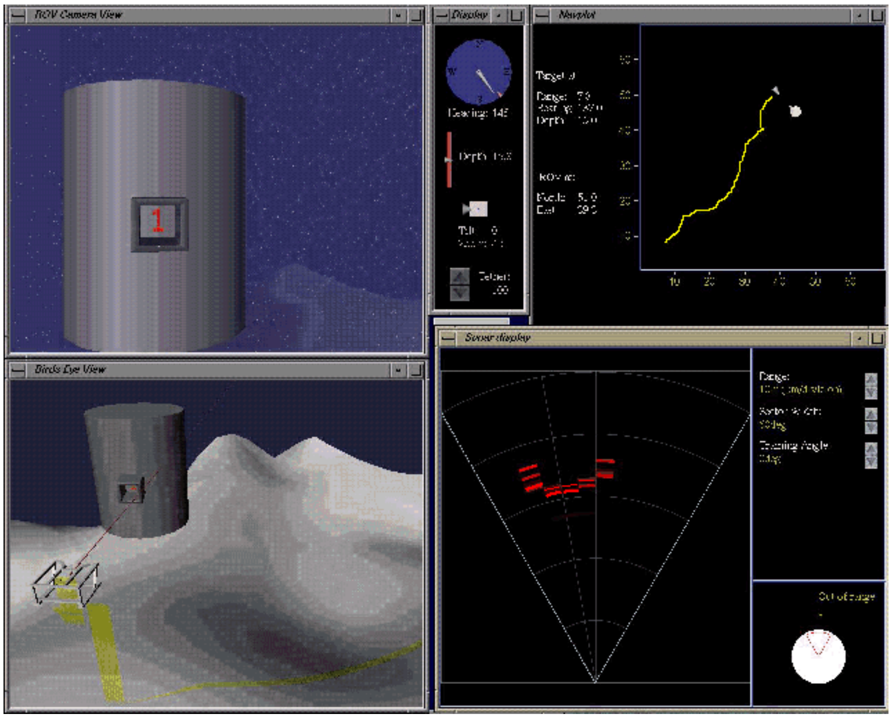

Figure 1: TRANSoM Training System Displays

Use of the VE also offers a unique ability to provide the operator with a variety of viewpoints augmenting that of the simulated ROV camera view that would not otherwise be available. These are provided to the trainee both upon request and during the review phase to provide him with an overall sense of his location and situation. They are then removed, so as to avoid fostering dependence on them.

The Intelligent Tutoring System (ITS)

An ITS has been integrated with the VE to create a standalone self-paced learning environment, which is not dependent on the availability of an instructor. The ITS employs a collection of performance metrics to adapt its feedback and advice to the instructional needs of each student.

Based on an extensive task analysis [Harris 96], a curriculum has been developed to teach essential ROV piloting skills. These are taught through a collection of trials in which the student pilot practices a variety of tasks — descent, transit, hover, orbit, and dock — under the guidance of a computer coach. These individual tasks are assembled into lessons that become increasingly more difficult as the trainee progresses through the curriculum.

The general lesson framework is to demonstrate the mission, allow the student to practice it, and then review the student's performance.

- The *demonstration* features an expert flying the mission accompanied by a talk-through of the important aspects of the mission. It is an opportunity to present explicit strategies for control (e.g., dealing with currents) and information assessment (e.g., how to use the displays).

- During *practice* the student can solicit help in the form of reminders about goals and how to achieve them. Various "bird's eye" views of the ROV and its path are available to reorient the pilot. Unsolicited coaching is triggered by monitors that assess the student's progress and deviations from expert performance, such as drifting too far from the prescribed path. This feedback is delivered verbally in order to minimize the workload impact on the student, whose visual attention is already divided among several displays.
- During the *review* phase, the student can replay portions of the mission, see a summary of measures compared with expert performance such as a view of the actual path and an expert's path, and re-fly segments of the mission where errors occurred.

The practice environment includes several visual and aural features that act as instructional scaffolding and invite the student's own interpretation of what went wrong and how to improve performance. They provide extra information to improve awareness of a) the vehicle in its environment, b) the consequences of pilot actions, c) the effects of external forces, and d) information available in the normal ROV displays.

SYSTEM VERIFICATION AND VALIDATION

The validity of the simulation had to be established before the effectiveness of the training could be properly evaluated. Prior to any of the training transfer experiments, extensive verification and validation efforts were carried out to insure that the system provided an accurate and useful depiction of reality. The Imetrix Talon ROV system [Fletcher 1997b] was built and modeled for use in system verification and training transfer tests (Figure 2), enabling direct comparison between the simulation and physical systems.

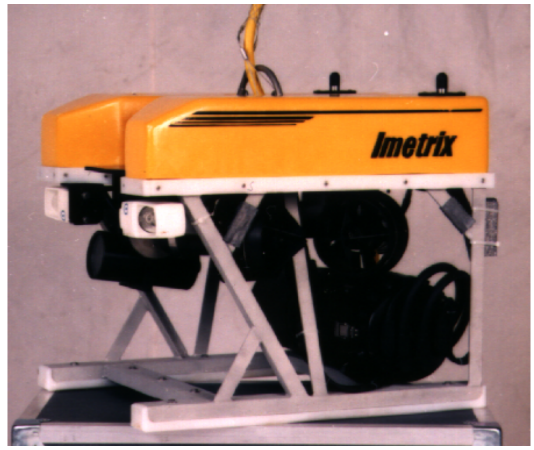

Figure 2: The Imetrix Talon ROV

Human Machine Interface

The TRANSoM user interface design was based on actual ROV displays typically found in the field. The design of the simulated displays was validated both by review of expert pilots and the extensive testing performed as part of the training transfer experiments. The system was found to be a good representation of existing systems as summarized in Table 1.

Component	Design	Expert Assessment
Displays	Modeled on actual	"Effective" or "highly effective"
Controls	Same controls used for both VE and actual systems	"Highly effective"
Vehicle	Modeled on actual system parameters	"Effective" or "highly effective"

Table 1: System Validation Results

Vehicle Dynamics

In addition to the qualitative assessment of the system described above, quantitative comparisons were made between the simulation and the actual system. The steady state behavior of the simulation was comparable to that of the actual vehicle, as shown in Figure 3. The time response of the simulation was measured as faster than the vehicle, but it was generally perceived as slower by the operators. This result may be due to the slower update rate of the visual rendering available in the simulation. Cross coupling effects, shown in Figure 4, were also well matched between the simulation and the actual vehicle.

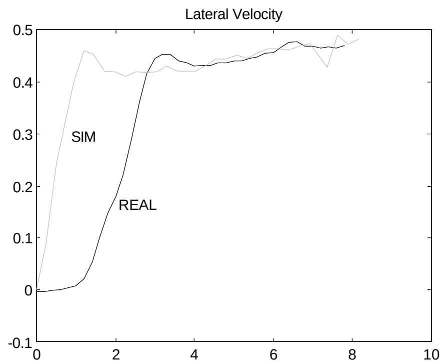

Figure 3: ROV vs. Simulation Response

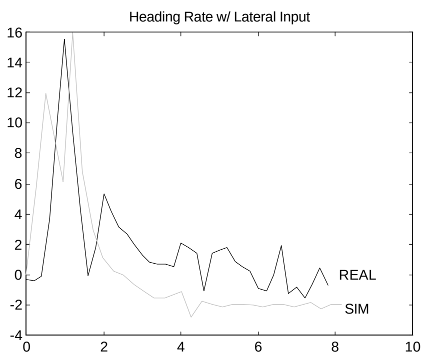

Figure 4: Cross Coupling Effects

FORMATIVE STUDIES

A number of formative studies have been performed in the development of the TRANSoM program. These have included evaluation of individual system components, such as the use of alternate viewpoints, and task performance analysis to determine evaluation criteria.

Viewpoint Assessment

The virtual environment basis of the system provides many opportunities to use VE techniques to support and supplement the training process. Among these include the use of alternate viewpoints, providing the student with a wider view of the world than is available via the sensor displays. Experiments were performed to determine if this sort of visual feedback aided in the training process without causing adverse effects when removed.

Procedure

Three different viewpoint conditions were constructed for the test: 1) no additional VE view beyond the standard sensors, 2) a ROV-centered view, unobstructed by visibility conditions, and 3) an external “Stadium” view, providing a clear view of the vehicle and the target. Six different training conditions were tested: 1) no training, 2) no VE view, 3) ROV-centered view for 50% of the training, 4) ROV-centered view for 100% of the training, 5) Stadium view for 50% of the training, and 6) Stadium view for 100% of the training. After practicing a sequence of manuevers under the different training conditions, the subjects were tested on their performance in the simulation with no additional viewpoints beyond the standard sensor displays.

Results

Positive results were seen from use of the VE viewpoints. During training, performance benefited from use of all the VE viewpoints. Overall, the Stadium view appeared to provide the most useful information during the practice sessions. When the VE viewpoints were removed during the final test, no negative effects were seen. This indicates that while the subjects found the viewpoints useful, they did not become dependent on them. This is important in training the ROV-piloting task, as a key skill is being able to operate the system with limited sensor information.

Expert Skills Assessment

In order to set the performance criteria used by the ITS, a formative study was carried out in which expert and intermediate pilots performed the tasks through all levels of the curriculum.

Background

As part of the mission review, the tutor summarizes a student’s performance for each phase across several skill areas. The scores are presented in a matrix of five phases (Descent, Transit, Hover, Orbit, Dock) by six skills (Stay On Course, Steady Progress, Drive Smoothly, Face the Target, Avoid Collisions, Snapshots), with green, yellow, or red colors denoting good, fair, or poor scores respectively. These scores are derived from data collected during the session by a collection of sensors. Each sensor periodically computes and records its own type of performance measure, such as deviation between heading and target bearing, at least once per second. At the end of a session, sensors compute summary analyses, such as RMS error, minimum and maximum error, and percentage of time outside a given threshold. Combinations of one or more of these summary values are used to compute the scores for each cell in the review phase matrix. The following are sensors currently used by the system:

- *Path Sensor* - This sensor keeps track of horizontal deviation from a path in meters.
- *Bearing Sensor* - Monitors angular deviation (in degrees) between the ROV's heading and the true bearing to the target.
- *Depth Sensor* - Using the same expert path as the path sensor, this monitor finds the closest X-Y point on the expert path and computes the difference between the expert path depth at that point and the ROV's actual depth.
- *Hover Sensor* - Using the ROV position at the time the sensor was turned on as a "hover-point", this sensor then computes the straight-line distance between the ROV's current position and the hover-point.
- *Range Sensor* - This computes the deviation in meters between the horizontal range to the target and a pre-specified range (such as orbit distance).
- *Speed Sensor* - Monitors the speed of the ROV in meters per second. This sensor uses two thresholds, a lower and an upper speed.
- *Control (Smoothness) Sensor* - Computes the variance of the commanded thrust over a time window. Also records zero crossings and stick reversals in each dimension (fore/aft, lateral, vertical, yaw).
- *Progress Sensor* - During transit, this sensor computes the magnitude of the component of the ROV's velocity in the direction of the target.

Procedure

A formative study was carried out in which expert and intermediate pilots drove the simulated ROV through missions at all levels of the curriculum. The purpose of the study was to collect data on expert performance so that thresholds could be chosen for "good," "fair," and "poor" performance.

Each session lasted approximately three and a half hours. Subjects were introduced to the maneuvering task by watching a demonstration. They then spent approximately two hours on the main part of the experiment, which involved twelve maneuvering tasks, one at each level of the curriculum. In a second part of the study each subject played the role of a student, deliberately making common mistakes. Subjects filled out questionnaires and were interviewed about their reactions at the end of the session.

Results

As a result of the study, fifty-nine pairs of threshold boundaries for "good" and "fair" performance were established, along with the performance data on which they are based. For many of the subskills, more than one threshold was needed because more than one metric was relevant to good performance (e.g., Stay on Course uses both Path and Depth). Finally, a separate set of thresholds had to be established for the case of currents (averaged across strengths) versus no currents, because this environmental factor greatly affects the difficulty of the problem.

Although the thresholds were decided on the basis of the performance data, no single rule could be used for establishing the thresholds. Judgment was needed because the scores of the experts varied widely and because the novices sometimes did as well as the experts, especially in the easier case of no currents. In general, thresholds were picked that would place either the average or the best expert score in the "good" range and the novice or worst expert score in the "fair" range. A few of the thresholds were subsequently adjusted on the basis of pilot testing in the direction of greater leniency to enable even the slowest learners to make some progress.

TRAINING TRANSFER STUDIES

A key feature of the TRANSoM program has been the ability to evaluate training effectiveness by testing subjects on an actual ROV. The tests described here compared piloting skills under a variety of training conditions. The goals of the testing were to assess the effectiveness of the training system by comparing the performance of operators on standard tasks both before and after training, and to assess its relative effectiveness compared to other forms of available training.

Test Conditions

Two different tasks were used for testing; each was performed under increasingly difficult visibility and current conditions as shown in Table 2.

Trial	Current	Visibility	Task
1	none	3.5 m	Barrel
2	0.07 m/s SW	1.5 m	Barrel
3	0.14 m/s W	1.5 m	Barrel
4	none	1.5 m	Inspection
5	0.14 m/s S	1.5 m	Inspection

Table 2: Training Test Conditions

All testing was performed using the Talon ROV in the pool facility at BBN Technologies, Cambridge, MA. The pool is approximately 6.8 m wide by 10 m long by 4.3 m deep. Use of the pool enabled us to insure that the conditions over the month-long course of testing would be equivalent for each subject. Visibility was altered by mounting a filter on the video camera and by adjusting the lighting level. Varying current conditions were created by imposing a thruster bias in the Imetrix ROV-DP control software. The behavior of the vehicle under the imposed currents was measured and found to be comparable to the currents used in the training simulation.

Two types of tasks were designed to evaluate the maneuvering ability of each subject. The Barrel Task, shown in Figure 5, was comparable to the practice mission used in the TRANSoM training system. The subject performs a sequence of turn, descend, transit, hover, orbit, and dock with a single, barrel-shaped target. These maneuvers were designed to encompass the range of essential operations that pilots are called upon to use in the field.

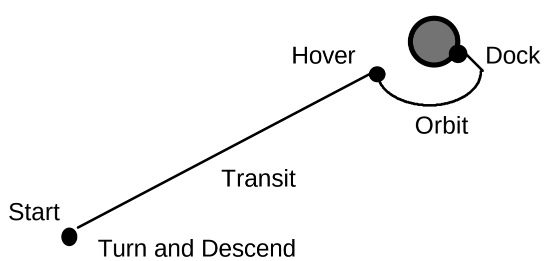

Figure 5: The Barrel Task

The Inspection Task, shown in Figure 6, was modeled after a pipe inspection mission. The subject faces the structure while maneuvering the vehicle along it reading off numbers or letters attached to the pipe at irregular intervals. This task was not included in the training as its purpose was to assess the transfer of the maneuvering skills learned in the trainer to a separate but related task.

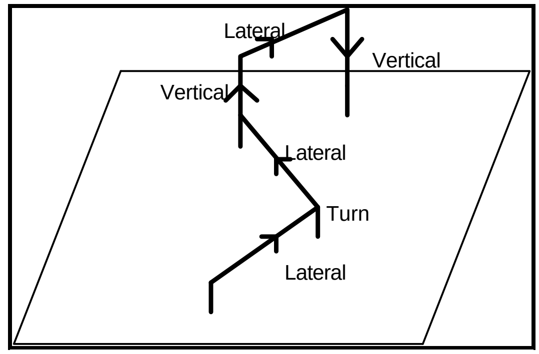

Figure 6: The Inspection Task

Test Procedures

The test procedures were standardized across all experimental groups. Subjects were randomly assigned to one of four treatment groups. They ranged in age from 19-39; 65% were MIT students.

Pre-Test

Prior to any training, all subjects received a pre-brief which included a description of the TRANSoM program, a subject consent form, and a background questionnaire including items about experience with computer games and remotely controlled vehicles, and the subject's age and occupation. Each subject then completed standard tests used to gauge manual dexterity and spatial visualization skills.

Once these were completed, all participants were familiarized with the Talon ROV controls and displays. Each was given a description of the Barrel Task and the general performance goals to be met (accuracy, speed, etc.). They then performed the first two trials outlined in Table 2. These pre-test trials were used to measure both inherent ability and to provide a basis for comparison of the effect of the different training treatments.

Training Treatments

For the training phase of the experiment, subjects were randomly assigned to one of four training treatment groups: 1) Full Training (VE and ITS), 2) practice with simulation only (VE, but no ITS functions), 3) hands-on practice with the real ROV (no instruction), and 4) no training. Eight subjects were tested under each condition.

The Full Training group went through the full TRANSoM training program, consisting of a structured curriculum with computer-based verbal and visual feedback, enhanced viewpoints, and review, replay, and demonstration capability [Pioch 1997]. Training was held over four 1.5 hour sessions, yielding approximately 4.5 hours of actual driving time for each student. By design, progression through the curriculum was both time-constrained and performance-based; as a result, three of the eight subjects did not complete the most difficult levels.

In order to examine the effects of structured instruction versus free play, the eight Simulation Only subjects were allowed to drive the simulation for 4.5 hours over 2-3 days, providing an equivalent amount of stick-time as the Full Training group. There were four levels of difficulty available with varying currents and visibility, to be chosen entirely at the subject's own discretion. Unlike the full training scenario, there was no prescribed progression through the levels of difficulty, no feedback on performance, and no enhanced visual perspectives or other aids to training.

The ROV Only group received training similar to that found in many operational situations; self-directed, hands-on practice with a real ROV. Subjects were provided with the basic task goals, then given the opportunity to practice with the actual ROV in the test tank, under their choice of four difficulty conditions. Stick-time was matched with the full training and simulation only groups at 4.5 hours over 2-3 days. As with the simulation only group, no additional feedback was provided, except in extreme cases of tether entanglement.

The No Training group provided the control for the experiment. These subjects received no training or familiarization with the system other than the pre- and post-testing. Finally, while not an official experimental group, two experienced Talon pilots also performed the test trials to provide an indication of what level of performance might be expected.

Post-Test

The post-test trials were identical for all training treatment groups. Each subject performed all five trials as outlined in Table 2, following identical procedures to those of the pre-test. These provided post-test performance measures for both the pre-test conditions and on a similar task in order to assess transfer of skills. After each trial, subjects were asked to rate the workload of the task, using standard workload estimation guidelines. At the completion of all five trials, subjects completed questionnaires on their training experience and were encouraged to comment on the training, simulation, and ROV system.

Results

The measures used to evaluate the subjects' performance were derived from those skills commonly required in field operations. Key skills included the abilities to maintain a heading facing the target, maintain a given depth, make steady progress towards the goal, hover, and to perform each task as quickly as possible without sacrificing accuracy. For each stage of the tasks performed, various performance measures were recorded. For instance, during the transit phase, bearing, depth, path, and speed were recorded, while during the hover phase, only position and bearing were relevant.

Training Transfer Results

The most significant results of the testing were found in transferring the skills learned in the Barrel task to the Inspection task. All training groups showed significant positive transfer, as shown by the range Root Mean Squared Error (RMSE) and inspection speed measures (Figure 7). The range from the pipe target is seen as a particularly relevant parameter as it indicates the degree of control of the operator. The speed measure was obtained by combining velocity and accuracy in inspecting the pipe, indicating the efficiency and completeness of performing the task. For both performance measures, all training groups showed significantly improved performance over the No Training group, while reporting consistently lower workloads. In addition, all training groups showed performance approaching that demonstrated by the expert pilots.

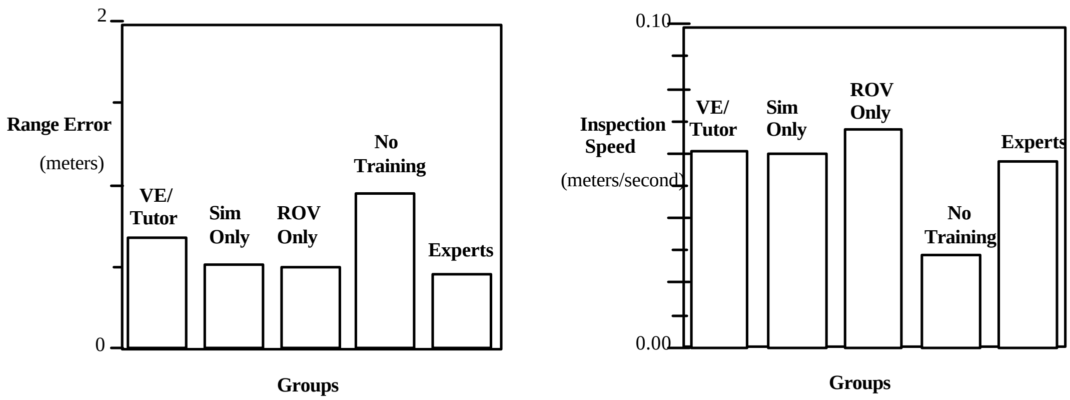

Figure 7: Training Transfer Results

Pre- vs. Post-Test Performance

Comparison of pre- and post-test performance as a function of the training was made across the full range of performance parameters measured. For most of these measures (speed, path, depth), no statistically significant differences were seen between the treatment groups. Several possible reasons have been postulated for this including the limitations on performance in the tank due to the confined space, and the generally rapid initial development of ROV piloting skills.

The one area where significant pre- and post-test effects were seen was in the orbit phase. Here, performance was measured by the bearing RMSE and the range RMSE. This is graphically depicted in Figure 8, showing a comparison between pre-test and post-test errors for the different training groups. For both the bearing and range error measures, both the ROV Only and the Simulation Only groups showed improvement (post-test error less than pre- test error) over the No Training control group. The improvement shown by the No Training control group is attributed to the rapid skill learning (the “practice effect”) over the course of the pre- and post-tests.

What is anomalous is the lack of benefit of the VE/Tutor to those with initial high error; i.e., those with an initial low ability. In this case, the training appeared to have no effect, with the post-test errors equal to the pre-test errors. Two possible explanations are being explored for this effect. First it is possible that the lower ability subjects did not receive sufficient exposure to the higher difficulty scenarios. The curriculum progression scheme followed by the tutor was designed to encourage mastery at lower difficulty levels before recommending harder scenarios. Several of the full training subjects did not complete the curriculum in the fixed time available and therefore were not exposed to the full effects of high current and low visibility. On the other hand, those in the self-directed ROV Only and Simulation Only groups elected to spend the majority of their time in the more difficult scenarios. An alternate explanation may be in the form and timing of the verbal feedback received by the trainees. It is possible that the feedback rewarded inappropriate behaviors for the lower ability subjects, or that they became dependent on it to perform the task.

It should be emphasized that the performance of the Full Training group was much better than the No Training group in the Inspection Task described above. This suggests that the effects noted may be limited to some facet of the orbiting maneuver itself or the specific feedback for this task.

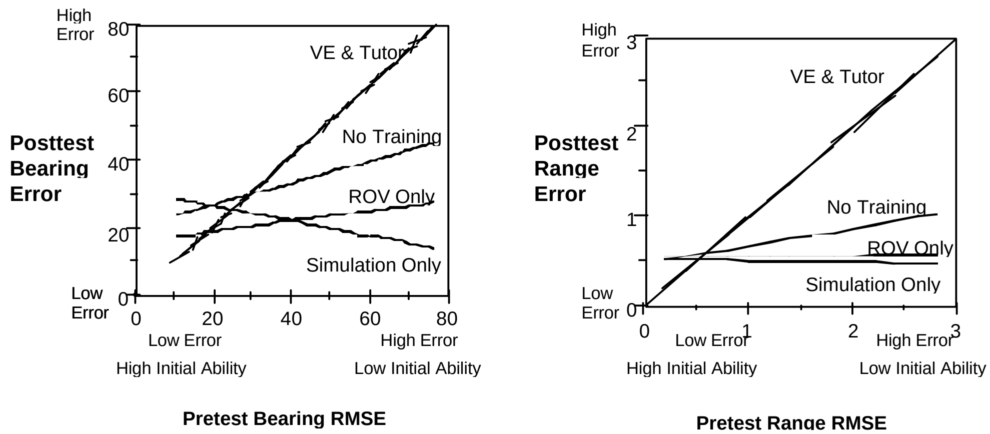

Figure 8: Pre- vs. Post- Test Performance

Aptitude Effects

Visualization, spatial orientation, and manual dexterity aptitudes were measured as part of the pre-test procedures. Differences in visualization aptitude, and to a lesser extent, manual dexterity and spatial orientation, appeared to have markedly different effects on performance depending on the task. For novel tasks, such as the inspection transfer task, individual differences in these aptitudes, particularly visualization, affected the performance of all groups. For the practiced tasks, however, there were notable differences between the treatment groups. The effect of individual aptitude differences were largely eliminated after training for the Simulation only and the ROV Experience groups, while the performance of the Full Training group remained highly correlated with aptitude, as shown by the steep slope in Figure 9. As discussed above, the type and timing of the feedback available (both visual and auditory) may contribute to the effects seen.

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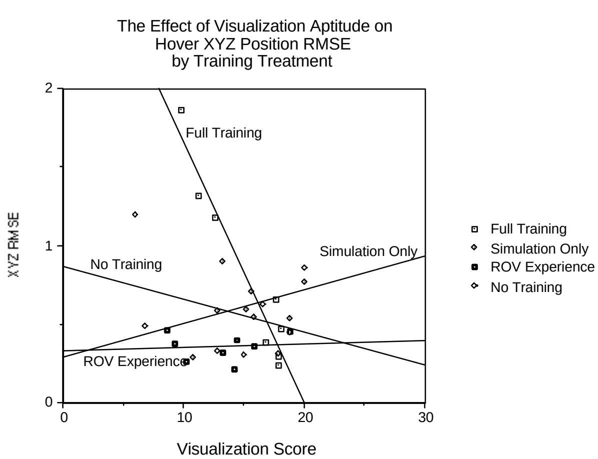

Figure 9: Aptitude Effects

FUTURE EFFORTS

Additional Research

One of the major benefits of the reality-based training transfer testing described here is the ability to direcly translate the findings into system modifications and evaluate the results. The variations noted in performance of the Full Training group suggests several future research avenues. More flexible curriculum progression criteria can be investigated, seeking to increase the performance of the full training group by increasing the amount of learner control. The type and timing of the visual and auditory feedback provided in the full training scenario also bear further investigation. Recent improvements in the system has resulted in an increased visual update rate, providing greatly improved visual feedback to that available during the transfer tests. This may affect the results seen for low-visualization aptitude subjects, as it provides a much more realistic depiction of the maneuvering process. The timing of the verbal coaching and feedback, particularly during fine maneuvers, is also a key area for additional research and refinement.

Situation Awareness Trainer

In addition to the Maneuvering curriculum described here, a curriculum to develop Situation Awareness skills is currently under development. One of the key skills that defines an expert pilot is a superior sense of where he's been, where he's going, where his tether is, and what the general environment around him looks like. The Situation Awareness curriculum will provide instruction and practice in skills such as sensor use and integration, search techniques, navigation techniques, and target identification.

Mission Rehearsal System

The simulation capabilities inherent in the TRANSoM system also provide a strong platform for mission planning and rehearsal. Use of the VE-based system allows development of a wide variety of scenarios for determination of system deployment techniques, optimal path planning, and overall mission rehearsal. In this way, various approaches may be tried without risk to personnel or high value assets.

PC-Based System

The TRANSoM system is currently hosted on a Silicon Graphics O2 desktop computer. To better address Fleet and commercial needs, a PC-based WindowsNT version is currently under development. Advances in PC processors and graphics boards will permit equal or better performance on a cost-effective PC platform and facilitate distributed learning on shipboard and at other remote sites.

SUMMARY

The TRANSoM program has developed and demonstrated a virtual-environment based system for the training of ROV pilots. The system has been verified and validated in comparison with actual ROV systems used in the Fleet and in the commercial arena. System components have been proven through individual formative evaluations. Training transfer tests have demonstrated the effectiveness of the system for training basic maneuvering skills. Future enhancements of the system include the addition of a Situation Awareness curriculum, development of mission planning aids, and porting to a PC-based platform.

Further information may be found on the Web at:

http://copernicus.bbn.com/Transom

http://www.imetrix.com

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