

# MASTER OF SCIENCE IN COMPUTER SCIENCE

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## UTILIZATION OF A VIRTUAL ENVIRONMENT FOR COMBAT INFORMATION CENTER TRAINING

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Recent fiscal and personnel cutbacks have placed significant restrictions on surface ship training opportunities. As a result, additional methods of training must be established in order to maintain current operational readiness. This thesis research investigates the use of a workstation-based shipboard virtual environment (VE) as complementary training for naval personnel, in particular, in the combat information center (CIC).

The approach taken was to extend the Naval Postgraduate School's Shiphandling Training Simulator (SHIPSIM) and shipboard Virtual Environment Trainer to include a combat information center virtual environment system (CICVET). Using the NPSNET IV framework, the system provides two levels of training; the first reflects the dynamics of real-world warfare theaters with the capability for distant entities to interact, while the second allows for the team training of shipboard personnel, possibly in separate locations, within the same virtual CIC.

To achieve our goal we built a real-time, distributed, interactive shipboard environment for combat information center training. It consists of a three-dimensional CIC model, containing functioning consoles for information display, sensor management, and weapons control.

## CROSS MODEL ACCESS IN THE MULTI-LINGUAL, MULTI-MODEL DATABASE MANAGEMENT SYSTEM

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Relational, hierarchical, network, functional, and object-oriented databases support its corresponding query language, SQL, DL/I, CODASYL-DML, DAPLEX, and OO-DML, respectively. However, each database type may be accessed only by its own language. The goal of M<sup>2</sup>DBMS is to provide a heterogeneous environment in which any supported database is accessible by any supported query language. This is known as cross model access capability.

In this thesis, relational to object-oriented database cross model access is successfully implemented for a test database. Data from the object-oriented database EWIROODB is accessed and retrieved, using an SQL query from the relational database EWIROODB. One problem is that the two interfaces (object-oriented and relational) create catalog files with different formation, which makes the cross-model access impossible, initially. In this thesis the relational created catalog file is used, and the cross model access capability is achieved.

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The object-oriented catalog file must be identical with the relational one. Therefore, work yet to be done is to write a program that automatically reformats the object-oriented catalog file into an equivalent relational catalog file.

### **INVESTIGATION OF EFFECT OF DIFFERENT RUN-TIME DISTRIBUTIONS ON SMARTNET PERFORMANCE**

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This thesis investigates, using in-line simulation, the effect of non-deterministic runtime distributions on the performance of SmartNet's schedule execution using the Opportunistic Load Balancing (OLB) Algorithm, the Limited Best Assignment (LBA) Algorithm, an  $O(mn^2)$  Greedy Algorithm, and an  $O(mn)$  Greedy Algorithm. Smart-Net is a framework for scheduling jobs and machines in a heterogeneous computing environment. Its major strength is its use of both current machine loads and predicted job/machine performance when generating schedules. Schedules are built to meet various Quality of Service requirements using the above algorithms among others. We enhanced SmartNet's simulator so that the runtime distributions could be used for experimentation. The distributions were generated using derivations from our study on NAS Benchmarks. Experiments were run for various categories of job/machine heterogeneity to compare the algorithms which account for both load and expected performance (the Greedy algorithms) against OLB and LBA.

For all categories of heterogeneity, the greedy algorithms outperformed the other two algorithms for both truncated Gaussian and exponential distributions. For these same distributions, the  $O(mn)$  Greedy algorithm performed as well as the  $O(mn^2)$  Greedy algorithm when the heterogeneity of jobs and machines was high.

### **VIRTUAL ENVIRONMENTS AND WAYFINDING IN THE NATURAL ENVIRONMENT**

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The purpose of this study was to determine if a Virtual Environment (VE) model of a natural environment could provide familiarity training transfer. The methods used included aspects from sport orienteering. Fifteen male participants comprising three ability groups participated within three treatment groups. The treatment groups were comprised of a map study, map and VE study, and an actual environment study.

The results indicated that navigational ability had a more pronounced effect on performance than did treatment group. However, among the treatment groups, the intermediate ability group seemed to benefit the most from the VE. Within the VE treatment, the beginner ability group seemed to suffer from excess workload, while the advanced group found the VE treatment only useful for pinpointing the location of the marker.

The results indicate that a properly designed VE can, through training, impart a familiarity with a selected natural environment area, better than map study for all except the most sophisticated land navigators. Further study is needed to examine aspects of the VE, how they need to be represented, and what other refinements or features could be included in such a VE in order to maximize training transfer,

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### **A COMPUTER SIMULATION STUDY OF SINGLE RIGID BODY DYNAMIC MODEL FOR BIPED POSTURAL CONTROL**

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Existing kinematics models for humans cannot simulate movement beyond geometric constraints. On the other hand, complex dynamics models are computationally expensive for real-time computer graphics applications in Virtual Environments(VE). To be able to create a more realistic, real-time, and computationally efficient human model, a simple dynamic model needs to be developed.

The approach taken in this thesis was to develop a single rigid body dynamic human model with massless legs. Instead of a Lagrangian model, which complicates the calculations exponentially as the complexity of the system increases, the Newton-Euler method was chosen to derive system differential equations. Linear state feedback was used for postural and gait control. As part of this research, a previous realistic looking human model is further developed.

The major conclusion of this thesis is that a single rigid body dynamic model can be used for simulation of postural control. The simulation results contained in this thesis show that such a modeling technique could be used to cause a detailed kinematic representation of a human figure to move in a smooth and realistic way without resorting to complexity of a multi-link dynamic model.

### **DOCUMENTATION FOR CAPS USER INTERFACE AND GRAPHIC EDITOR**

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The Computer-Aided Prototyping System (CAPS) is an integrated environment, comprised of an integrated set of software tools, aimed at rapidly prototyping hard real-time embedded Systems. The problem with the current CAPS software development environment is the absence of a CAPS User's Manual (How to Use ...), which provides CAPS users with step-by-step guidelines on how to use the CAPS tools.

One solution to this problem was solved by designing, developing, and creating on-line documentation for the CAPS User Interface and Graphic Editor Reference Manuals for CAPS Release 1.1. Such an approach provides accessible visual, graphical, and textual step-by-step illustrations for CAPS users when interfacing, interacting, and manipulating, commands and options within the CAPS User Interface subsystem and Graphic Editor tool. In addition, this approach includes a glossary which helps CAPS users to understand the meaning of the difficult or specialized terms used in this environment.

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### **SIMULATION FOR SMARTNET SCHEDULING OF ASYNCHRONOUS TRANSFER MODE VIRTUAL CHANNELS**

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Critical to the success of future battlefield commanders is the rapid retrieval of relevant, time sensitive information. Some of this information will be available locally while the remainder is stored in the United States. DARPA's Battlefield Awareness and Data Dissemination (BADD) program attempts to deliver heterogeneous data to the battlefield using the Asynchronous Transfer Mode (ATM) protocol. ATM was originally designed to implement dynamic virtual channels over duplex, high-speed, high capacity, fiber optic cabling. The problem addressed was to determine which algorithm best schedules calls on BADD's ATM network that uses static virtual channels over simplex, error prone, long delay, satellite links. Because the BADD project uses ATM in such an unusual way, and because of the need to determine a schedule for transmissions over the heterogeneous static channels, we modeled BADD using the state-of-the-art network simulation tool, Optimized Network Engineering Tools (OPNET). We determined several modifications that must be made to existing network simulators to allow them to model next-generation networks. Our simulation shows that a greedy algorithm yields a 53% decrease in the overall completion time and a 46% increase in average bit throughput over FIFO scheduling.

### **CHANNEL CAT: A TACTICAL LINK ANALYSIS TOOL**

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The Tri-Service Tactical (TRI-TAC) standards for tactical data links mandate a terminal data rate of 32,000 bits per second. As greater demands for data throughput are placed upon tactical networks, it will become imperative that the design of future client/server architectures do not exceed the capacity of the TRI-TAC networks. This thesis produced an analysis tool, the Channel Capacity Analysis Tool (Channel CAT), designed to provide an automated tool for the analysis of design decisions in developing client-server software.

The analysis tool, built using the Computer Aided Prototyping System (CAPS), provides designers the ability to input TRI-TAC channel parameters and view the results of the simulated channel traffic in graphical format. The size of data, period of transmission, and channel transmission rate can be set by the user, with the results displayed as a percent utilization of the maximum capacity of the channel.

Designed using fielded equipment specifications, the details of the network mechanisms closely simulate the behavior of the actual tactical links. Testing has shown Channel CAT to be stable and accurate. As a result of this effort, Channel CAT provides software engineers an ability to test design decisions for client-server software in a rapid, low-cost manner.

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### **BUILDING A DYNAMIC WEB/DATABASE INTERFACE**

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This thesis examines methods for accessing information stored in a relational database from a Web Page. The stateless and connectionless nature of the Web's Hypertext Transport Protocol as well as the open nature of the Internet Protocol pose problems in the areas of database concurrency, security, speed, and performance.

We examined the Common Gateway Interface, Server API, Oracle's Web/database architecture, and the Java Database Connectivity interface in terms of performance and flexibility. Oracle's approach was found to be the most robust and best performing approach currently in use, although the Java Database Connectivity interface has not yet been widely implemented.

Based on our research and experience implementing a prototype, we conclude that Web/database technology is currently only appropriate for read-only type applications such as Decision Support Systems and Information Delivery Systems. The database access methods presently available cannot support more advanced capabilities of client/server type applications including client-side data validation, sophisticated user interfaces, and concurrency among multiple users.

### **DATABASE ACCESS FROM THE WEB**

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Determining the best method for granting World Wide Web (Web) users access to remote relational databases is difficult. Choosing the best supporting Web/database link method for implementation requires an in-depth understanding of the methods available and the relationship between the link designer's goals and the underlying issues of Performance and Functionality, Cost, Development Time and Ease, Serviceability, Flexibility and Openness, Security, State, and Session.

This thesis examined existing methods for enabling Web-client access to remote relational databases and found that most fall within the general categories of Common Gateway Interface scripts, Server Application Programming Interfaces, Web-enabled Database Management Systems exporting query results in Hypertext Markup language, and independent client-based processes such as Java applets. To determine the best database access category we compared each one to the underlying link issues and conducted a case study for the IEEE Signal Processing Society.

The results of this thesis are: (1) a taxonomy of existing Web/database linking methods, (2) a thorough listing and examination of the underlying issues as they relate to each link method, and (3) recommendation and specification of the proper link method and hardware/software support system for the case study linkage problem.

### **PARALLEL PROCESSING PERFORMANCE EVALUATION OF MIXED T10/T100 ETHERNET TOPOLOGIES ON LINUX PENTIUM SYSTEMS**

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The intent of this thesis is to answer the question as to whether real-time battlefield visualization, once requiring high-speed Unix workstations and specialized parallel processors, can now be performed on relatively inexpensive off-the-shelf components.

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Alternative network topologies were implemented using 10 and 100 megabit-per-second Ethernet cards under the Linux operating system on Pentium based personal computer platforms. Network throughput, processor and video performance benchmark routines were developed to assess the hardware's potential for parallel application in a distributed environment. Code was first ported to the Linux environment. Benchmark routines were then developed and tested on various machines.

Dual 200 MHz Pentium Pro processor performance exceeded the dual processor 50 MHz SUN and 40 MHz SGI Unix workstations currently used for terrain generation by a factor of 30 using a simple ray trace algorithms as a basis for comparison. The Intel Pentium Pro personal computer proved to be a capable platform for generating six to ten frame-per-second terrain simulations. However, Fast Ethernet throughput averages only 2.5 megabytes-per-second, thereby limiting the usefulness of a distributed approach designed to increase performance by dividing workload across the network.

### **DESIGN OF A HIGH ASSURANCE, MULTILEVEL SECURE MAIL SERVER (HAMMS)**

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Computer Systems employed in the Department of Defense (DoD) for processing classified electronic mail (e-mail) generally operate at the highest classification level of the data being processed. These *system high* implementations cause two significant problems: all users must be granted unnecessarily high security clearances, and separate, incompatible workstations and networks exist for users to process classified data at different security levels. To solve these problems a System/Subsystem Specification (SSS) and a System Security Engineering (SSE) approach has been used to design a High Assurance, Multilevel Secure Mail Server (HAMMS).

This thesis presents the architecture, mailing capabilities, and required design characteristics necessary to develop a high assurance mail server. Existing high assurance and information security systems are analyzed to identify related design advantages and disadvantages for a high assurance mail server. Also included is the initialization, adaptation, and employment of a media encryption device and associated software that will be adapted to extend secure mail operations to a Commercial-Off-The-Shelf (COTS) workstation.

The result of the research is a system design that can be employed to provide a high assurance multilevel e-mail server and a reduction in the number of workstations, incompatible networks, and user clearances required in secure environments. In the future, the HAMMS design can be used as the basis for other high assurance server applications.

### **A MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS (MSHN) SECURITY ANALYSIS**

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A team of interdisciplinary experts funded by DARPA is in the process of developing a Resource Management System termed MSHN (a Management System for Heterogeneous Networks). MSHN's primary function is to accept a sequence of jobs, and intelligently determine what jobs should be executed on which machines and when. It is designed to take both machine affinity and loads into account, thus providing superior performance and Quality of Service (QoS). The current prototype of MSHN does not provide protection against the threats of inadvertent disclosure and corruption of sensitive

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information and resources. A rigorous security analysis of MSHN is the first step required to successfully incorporate security into the MSHN project.

The approach taken was to analyze MSHN's architecture, information flow diagrams and user interfaces and explain how fundamental security concepts may be applied to MSHN. By exercising the MSHN simulator, this work was able to expose many security weaknesses and outline conceivable methods of exploitation.

As a result of this effort, a security policy tailored to MSHN is proposed, a functional breakout process based on the principle of least privilege between common user interface capabilities and administration capabilities is provided, and finally design recommendations for the incorporation of security into MSHN are presented.

### **RE-ENGINEERING PORTABILITY OF THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)**

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The Computer-Aided Prototyping System (CAPS) currently runs only on SPARC workstations running SunOS version 4.1.3. This limits the usefulness of CAPS, since Sun Microsystems has publicly announced that they have no interest in continuing support for SunOS version 4.x. A solution to this problem is to port CAPS to a PC platform running the Linux operating system.

Toward this end, the graphical editor portion of CAPS was ported onto a 100Mhz Pentium, with 32 MB of RAM, Linux 3.0, running Motif 2.0 on Xwindows. Modifications to both, the Makefile and the graphical editor source code were required for a successful compilation. These modifications were items such as having to compile using various compilers, providing pointers to the Motif and Xwindows Libraries needed to produce the static builds of the graphical editor, and a number of recompilations of the Linux kernel.

As a result of these efforts, the graphical editor, a functional component of CAPS, was successfully ported to this system. The software database, project control and execution support components still remain to be ported as a future development.

### **VISUAL FEEDBACK FOR A STUDENT LEARNING LANGUAGE PRONUNCIATION**

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The learning of language pronunciation can be a frustrating and time-consuming process. Traditional methods require feedback from another person, usually an instructor or another student, or use of a self-assessment technique such as the listen-record-and-compare technique. These techniques have flaws. Human factors such as self confidence, shyness, fatigue, hearing ability, vocal tract agility, and confidence in the instructors fairness and competence all influence how rapidly a student acquires new pronunciation skills. A new technique to replace or augment existing techniques needs to be explored.

This thesis proposes the use of a computer to provide visual feedback to both complement auditory feedback to a student and lessen the detrimental impact that these human factors have on learning pronunciation. A computer shows no bias and provides an environment that affords privacy and the ability to practice whenever the student is willing. Additionally, the

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use of a computer to provide visual feedback helps a student to better understand exactly what portions and in what areas the pronunciation attempt is incorrect.

This thesis identified three required areas of pronunciation feedback—phoneme, stress and intonation—and integrated them into a single interface. An object-oriented LISP implementation is presented to display the visual feedback and a design for digital speech processing is proposed to analyze the pronunciation and supply the interface with data.

### STATIC SCHEDULING OF CONDITIONAL BRANCHES IN PARALLEL PROGRAMS

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The problem of scheduling parallel program tasks on multiprocessor systems is known to be NP-complete in its general form. When non-determinism is added to the scheduling problem through loops and conditional branching, an optimal solution is even harder to obtain. The intractability of obtaining an optimal solution for the general scheduling problem has led to the introduction of a large number of scheduling heuristics. These heuristics consider many real-world factors, such as communication overhead, target machine topology, and the trade-off between exploiting the parallelism in a parallel program and the resulting scheduling overhead.

We present the *probabilistic merge heuristic*—in which a unified schedule of all possible execution instances is generated by successively scheduling tasks in order of their execution probabilities. When a conditional task is scheduled, we first attempt to merge the task with the time slot of a previously scheduled task which is a member of a different execution instance.

We have found that the merge scheduler produces schedules which are 10% faster than previous techniques. More importantly, however, we show that the probabilistic merge heuristic is significantly more scalable—being able to schedule branch and precedence graphs which exceed 50 nodes.

### REALISTIC INTERFACE AND CONTROL OF A VIRTUAL SUBMARINE MODEL IN NPSNET

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The current NPSNET submarine simulator is not a viable training tool because it utilizes a control panel which runs as a separate process and includes three separate tabs, one each for the Officer of the Deck, Helm, and Weapons Officer. Besides lacking immersion qualities, most of the control icons and prototypes are not functional.

Our approach is to mount human entities to the submarine that can control and maneuver the submarine entity by interacting with various objects onboard the submarine. These human entities represent key members of the submarine control party including the Officer of the Deck, Diving Officer of the Watch, Chief of the Watch, Helmsman Planesman, and a second Planesman. The submarine model was improved by building a 3D Control Room and adding manipulable visual cues to represent an actual submarine control room.

As a result of this work, a group of human entities can operate a submarine in NPSNET, acting together as a watch team and maneuvering the submarine through the virtual environment. Realism has been improved by immersing a user into the virtual environment as a virtual human entity.

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### **A COMPUTER SIMULATION STUDY AND COMPONENT EVALUATION FOR A QUATERNION FILTER FOR SOURCELESS TRACKING OF HUMAN LIMB SEGMENT MOTION**

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Current methods of tracking the human body within virtual environments (VE) are hampered by problems due to interference which occurs from using artificially generated source signals. In recent years, the miniaturization of self-contained inertial tracking systems has made them a viable alternative. They are impervious to external interference but require filtering in order to give accurate orientation data. Filters for this purpose using Euler angles are common, but are limited by their inability to track through the vertical axis. A filter based on quaternions would not have this limitation.

This thesis presents an implementation of a quaternion filter in Lisp. The filter was tested with a computer simulated inertial tracker. Also presented is a quantitative and qualitative assessment of an existing inertial tracker, Angularis, which uses a filter based on Euler angles.

This effort resulted in an improved filter based on quaternions which allows objects to be tracked through the vertical axis making it a more desirable option for body tracking applications. The evaluation of the Angularis inertial tracker yielded generally good results when tested on a tilt-table at various rates of motion through 45 degrees of rotation. Specifically, orientation errors measured were typically less than one degree for smooth motion. However, when moved rapidly through large orientation angles, it was found that the nonlinear characteristic of the proprietary filter resulted in large steady state errors.

### **ON THE ROLE OF THE WORLD WIDE WEB AND WEB TECHNOLOGY IN EDUCATIONAL COURSEWARE**

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There are many types of computerized training systems available today ranging from text-based "quizzers" to interactive multimedia "edutainment." However, each system is proprietary to the platform for which the binary executable is compiled. Additionally, when the information in the training material changes, a new copy must be created, distributed and installed before it is available to the end user.

This thesis explores the use of the Java programming language as a fundamental element in the creation of interactive courseware deployable through the World Wide Web. Java is used to add interactive, executable content to Web pages in the form of simulations and complex demonstrations of educational concepts.

Complete on-line materials were developed in support of the initial offering of CS2973, a Java programming course. Following that success, a prototype interactive on-line exam system, using a Java applet and file server, was developed. This prototype foreshadows a complete virtual classroom environment supported by a Courseware Creation Interface. Both of these have the distinct advantage of being cross-platform by virtue of being created in the Java programming language, thus usable on a majority of operating systems and platforms through Java enhanced Web browsers.

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### **ANALYSIS OF A 3-TIER DISTRIBUTED ARCHITECTURE FOR THE SECTOR ANTI-AIR WARFARE CENTER**

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The Marine Air Command and Control System (MACCS) is composed of a collection of legacy, stovepipe Automated Information Systems (AIS), each of which contain functionality which is widely duplicated throughout the MACCS. A proposed alternative architecture, the Common Air Command Control System (CAC2S), would leverage the investment currently being made in Command, Control, Communications, Computing, and Intelligence (C4I) systems which provide a robust set of functional services common to a wide range of mission critical applications. A plan for migration from the MACCS architecture to the CAC2S architecture is a required component for a successful transition.

This thesis describes the messaging and database methodology, the ongoing efforts to identify common data types and processes, and a proposed three-tier distributed object architecture, which will guide the MACCS migration to the CAC2S. A Software Engineering tool, the Naval Postgraduate School Computer Aided Prototyping System (CAPS), is used to model a component of the MACCS, the Sector Anti Air Warfare Center (SAAWC), in an effort to more precisely identify the critical data type representations and data processing requirements needed to properly specify the CAC2S.

As a result of this effort, a blueprint has been created to describe the methodology and analysis required to effect the migration from the MACCS architecture to the CAC2S vision.

### **MULTIVARIATE MOTION PLANNING OF AUTONOMOUS ROBOTS**

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A problem of motion control in robot motion planning is to find a smooth transition while going from one path to another. The key concept of our theory is the steering function, used to manipulate the motion of our vehicle. The steering function determines the robot's position and orientation by controlling path curvature and speed. We also present the—neutral switching method—algorithm that provides the autonomous vehicle with the capability to determine the best leaving point which allows for a smooth transition from one path to another in a model-based polygonal world.

The above mentioned algorithm is thoroughly presented, analyzed, and programmed on a Unix workstation, and on the autonomous mobile robot Yamabico. The research data indicate that neutral switching method improved the transition results for polygon tracking, star tracking motion, and circle tracking. Moreover, neutral switching method enhances robot control and provides a more stable transition between paths than any previously known algorithm.

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### **QUALITY NETWORK LOAD INFORMATION IMPROVES PERFORMANCE OF ADAPTIVE APPLICATIONS**

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The Joint Task Force Reference Architecture requires a Comms Server to aid client applications in adapting to changing network loads by apprising them of current and expected loads. The current Comms Server implementation estimates the network load by sending various sized packets and reporting raw performance statistics to the client. This implementation presents three problems: (1) clients interpret the statistics autonomously, (2) statistics are inaccurate due to the instantaneous collection procedure, and (3) clients also require the state of other resources to make informed decisions concerning adaptation. Development of a new Comms Server design, which solves these problems, is needed

This thesis develops a new Comms Server design and determines, through simulation, whether providing a more accurate estimate of the load could permit users of adaptive applications to obtain better performance. Simulations were run using many different situational parameters. Both the average size of the data successfully transmitted, and whether an application met its deadline, were recorded.

The results of these simulations show that clients of the existing Comms Server perform much better because they adapt, but in some cases 14% to 30% of the messages do not arrive by their deadline. However, a better design that more accurately estimates loads could deliver at least 96% of the messages on time.

### **AMPHIBIOUS OPERATIONS IN A VIRTUAL ENVIRONMENT**

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**Master of Science in Computer Science-March 1997**

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John S. Falby, Department of Computer Science**

More than 80 percent of recent, real world, naval operations have taken place in the littoral; over half have employed amphibious units. However, up till now, no simulation developed at the Naval Postgraduate School had the capability to exercise any type of naval amphibious operation. Previous simulations lacked the necessary amphibious ship and landing craft models. Second, a method for nesting mounted entities did not exist.

The approach taken was to develop a general algorithm for dynamically mounting, unmounting, and nesting entities. Secondly, amphibious ship and landing craft models were developed incorporating a simple hydrodynamic model for use with the LPD-17 and Landing Craft Air Cushion (LCAC) vehicles. Finally, real-time collision detection was implemented to ensure realistic interaction between all entities.

The result is a stand-alone, 3-D, virtual environment (VE) which simulates landing craft embarkation operations between a mother ship (LPD-17 class) and an LCAC, and allows embarked entities to walk through the 50,000 polygon LPD model in real-time (7-15 frames per second). The simulation is further enhanced by realistic wave response, based on the Pierson-Moskowitz spectrum, by all ocean borne vehicles. Lastly, the use of the high level EasyScene 3.0 API allowed the application to be written in approximately 30 percent fewer lines of code than otherwise possible.

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### **FRONT LOADED ACCURATE REQUIREMENTS ENGINEERING (FLARE): A REQUIREMENTS ANALYSIS CONCEPT FOR THE 21st CENTURY**

**Anthony E. Leonard-Captain, United States Army  
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**Master of Science in Computer Science-June 1997**

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**Valdiz Berzins, Department of Computer Science**

**Second Reader: Michael J. Holden, Department of Computer Science**

This thesis focuses on ways to apply requirements engineering techniques and methods during the development and evolution of DoD software systems in an effort to reduce changes to system requirements. The major goal of this thesis is to provide a feasible course of action (COA) that reduces changes to requirements caused by the turnover of DoD decision-makers.

We demonstrate a distributed requirements engineering environment using computer aided software engineering tools linked together with electronic mail. We create this distributed requirements engineering environment using Netscape Communicator, Microsoft's Internet Explorer, Microsoft's Access97 database, Rational Corporation's Rational Rose, Matt Wright's FormMail, and Thompson Software Products' ObjectAda.

We propose a COA to reduce requirements changes caused by the turnover of decision-makers that is based on the use of specialized requirements engineering teams composed of active duty officers by the geographic and functional Commanders in Chief. These teams use the distributed requirements engineering environment described above to assist in the rapid elicitation of requirements and to increase user participation in the requirements engineering process.

### **USING ARTIFICIAL NEURAL NETWORKS TO IDENTIFY UNEXPLODED ORDNANCE**

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**Second Reader: Robert B. McGhee, Department of Computer Science**

The clearing of unexploded ordnance (UXO) is a deadly and time consuming process. The U.S. Government is currently spending millions of dollars to remove UXO's from bases that are closing around the world. Existing methods for detecting UXO's only inform the clearing team that a piece of metal is present, rather than the type of metal, either UXO, shrapnel, or garbage. A lot of time and money is spent digging up every piece of metal detected. This thesis presents the use of artificial neural networks to determine the type of UXO that is detected. A multi-layered feed-forward neural network using the back propagation training algorithm was developed using the language Lisp. The network was trained to recognize five pieces of ammunition. Results from the research show that four out of five pieces of ammunition from the test set were identified with an accuracy of .99 out of 1.0. The network also correctly identified that a tin can was not one of the five pieces of ammunition.

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### **SHEPHERD ROTARY VEHICLE: MULTIVARIATE MOTION CONTROL AND PLANNING**

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**M.S., University of Southern California, 1994**

**Master of Science in Computer Science-September 1997**

**and**

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Millions of acres of the U.S. formerly used defense sites (FUDS) are contaminated with unexploded ordnance (UXO) as a result of past military use. The process of returning the land to the civilian sector is sensitive, intensive, and costly (e.g., millions of dollars, and the loss of human life). Hence “clearing” (i.e., site remediation, range clearance, and explosive ordnance disposal) UXO’s from FUDS is a complex problem. Existing clearing methods are inaccurate, dangerous, and labor intensive. This thesis shows that through robotics technology (e.g., “Shepherd” rotary vehicle with three degrees of freedom) and the use of advanced computer technology it is possible to make clearing tasks safer, more cost-effective, and more efficient. An over arching hardware and software architecture was developed for Shepherd (including a self-contained on-board computer system). The software system was developed for timer control, motion control, user interface, and an operating kernel. The hardware and software organization, structure, and interaction provide the framework for real-time control. This research included the use of encoders, digital boards, and a counter board and required the handling of interrupts, electric motor manipulation by servomotor controllers, and communication using RS232 and VMEbus technology. The kinematics algorithms and a real-time operating kernel were implemented using the C language. “Shepherd” research has laid the foundation for the flexible, robust, and precise motion needed for UXO clearing.

### **A SYNTAX DIRECTED EDITOR FOR THE COMPUTER-AIDED PROTOTYPING SYSTEM**

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**Master of Science in Computer Science-September 1997**

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The Computer-Aided Prototyping System (CAPS) is an integrated set of software engineering tools developed at the Naval Postgraduate School (NPS). It is designed to support rapid prototyping of real-time systems. CAPS consists of four major subcomponents; the graphics/text editor, the user interface, the software database system, and the execution support system. Reports from users of CAPS, particularly novices, indicated that the clumsy and unintuitive multi-windowed graphics/text editor present in the system hampered the use of the tool set. This thesis presents the substitution and integration of an efficient and user-friendly syntax directed editor into CAPS. The new syntax directed editor consists of a package of seven Ada95 parsers that recognize the elements of the Prototype System Description Language (PSDL) and an enhanced C\Motif based graphics editor. These modules combine the functionality of all the windows of the graphics/text editor into one window, using pop-up boxes and menus to guide the designer in providing the proper information. During integration, particular attention was paid to ensuring the proper manipulation of data was occurring between modules and the internal consistency was being maintained at the inter-language interfaces. The result is a faster, intuitive, and more efficient designer interface.

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### **EVOLUTION OF A GRAPHICAL USER INTERFACE FOR THE RAPID PROTOTYPING OF REAL-TIME EMBEDDED SYSTEMS**

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The Computer-Aided Prototyping System (CAPS) is an integrated collection of software tools that support the development of software systems utilizing the prototype paradigm. Central to CAPS is the Prototype System Description Language (PSDL). The PSDL Editor supplied in CAPS Release 1 provided a unique combination of a graphical interface for editing PSDL data flow diagrams and an attribute-grammar based text editor to enforce syntactically correct PSDL prototypes. Feedback from CAPS users highlighted on productivity impacts due to the dual user interface as well as the steep learning curve required to become proficient with the attribute-grammar based text editor.

This research initiates the development of the next generation of the CAPS PSDL Editor, focusing on the graph editor. Our approach provides a single graphical user interface with pull-down menus for editing both graphical and text information. Automatic syntax generation and validation as well as limited semantic validation is provided by a background syntax/semantics checker. The result of this research is a working graph editor meeting all the new requirements. When integrated with a the new syntax/semantics checker, CAPS Release 2 will have a PSDL Editor with enhanced capabilities and expected productivity improvements.

### **DESIGN OF A FINANCIAL MANAGEMENT SYSTEM FOR THE ACADEMIC DEPARTMENTS AT THE NAVAL POSTGRADUATE SCHOOL**

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**Master of Science in Computer Science-March 1997**

**Advisor: C. Thomas Wu, Department of Computer Science**

**Second Reader: John A. Daley, Department of Computer Science**

This thesis examines the requirements and design of a financial management system for the academic departments at the Naval Postgraduate School. Existing Systems are difficult to maintain and/or provide out-of-date information. A system is needed that is easy to use, easy to maintain, and provides current account status information so that the academic departments can make intelligent financial decisions.

We examined existing methods and tools for designing and building client/server applications. After comparing the traditional waterfall approach to the rapid prototyping approach, we elected to use rapid prototyping in order to develop the system quickly and to help the users determine their own requirements. We decided to use the *Powersoft Portfolio* tool set from Powersoft Corporation because it is scalable, transportable, affordable, and compliant with the Open Database Connectivity standard.

The result of this thesis is a prototype financial management system that users have found easy to use and maintain. The system provides summary and detail information on departmental financial accounts, to include balances and expenditures in the funding categories of faculty and support labor, equipment, travel, and contracts.

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### **AUTOMATIC LAYOUT TECHNIQUES FOR THE GRAPHICAL EDITOR IN THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)**

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The Computer-Aided Prototyping System (CAPS) is a systems engineering tool intended to make the iterative process of software development more efficient. CAPS allows the user to investigate different designs. The simplest way to input and modify a CAPS design is through the graphical editor. When a design is modified over and over, the resultant graphical representation can become difficult to comprehend. Trying to change the graphical representation by hand can be very tedious. By adding automatic layout techniques to the graphical editor, this task is made easier for the user of the system.

Automatic layout techniques for general graphs that maximize all of the aesthetic characteristics of a graph are not possible. One characteristic may conflict with another. By giving the user multiple layout algorithms that emphasize different characteristics over others, the user may choose between different layouts for the graphical representation. When the aesthetic value of the graphical representation is increased, the cognitive process of interpreting the design is lessened.

### **USER INTERFACE OPTIMIZATION THROUGH BREADTH OF DISTRIBUTION ANALYSIS**

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**Master of Science in Computer Science-March 1997**

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**John Daley, Department of Computer Science**

A Java tutorial was developed as a World Wide Web (WWW) site for use in capturing user behavior data. Breadth of distribution analysis was then applied to the data collected in order to characterize the usage of the user interface through the shape, connectedness, and order of traversal of each user in the sample.

The results reveal distinct user groups with different levels of user knowledge and needs in relation to the web site content. The resulting user interface analysis process produces a set of recommendations for optimizing the user interface, including adaptive interfaces for different user sub-groups and optimization of sequential rather than topical presentations.

### **ANALYSIS, EXPERIMENTAL EVALUATION, AND SOFTWARE UPGRADE FOR ATTITUDE ESTIMATION BY THE SHALLOW-WATER AUV NAVIGATION SYSTEM (SANS)**

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**Master of Science in Computer Science-March 1997**

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**Eric Bachmann, Department of Computer Science**

The main problem addressed by this research is the lack of a small, low-cost integrated navigation system to accurately determine the position of an Autonomous Underwater Vehicle (AUV) during all phases of an underwater search or mapping mission. The approach taken utilized an evolving prototype, called the Shallow-Water AUV Navigation System (SANS), combining Global Positioning System (GPS), Inertial Measurement Unit (IMU), water speed, and magnetic heading information using Kalman, low-pass, and complementary filtering techniques. In previous work, addition of a math coprocessor improved system update rate from 7 to 18 Hz, but revealed input/output coordination weaknesses in the software. The central focus of this thesis is on testing and programming improvements which resulted in reliable integrated operations and an increased processing speed of 40 Hz. This now allows the filter to perform in real-time. A standardized tilt table evaluation and calibration procedure for the navigation filter also was developed.

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The system was evaluated in dynamic tilt table experiments. Test results and qualitative error estimates using differential GPS suggest that submerged navigation with SANS for a period of several minutes will result in position estimation errors typically on the order of 10 meters rms, even in the presence of substantial ocean currents.

### **APPLICATION OF THE RAPID COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS) IN THE DEVELOPMENT OF A SUDDEN INFANT DEATH SYNDROME (SIDS) MONITOR**

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**Masters of Science in Computer Science-June 1997**

**Advisor: Luqi, Department of Computer Science**

**Second Reader: John Daley, Department Computer Science**

The main problem addressed by this research is to remove the need for adhesive monitors on sleeping infants who are being monitored for Sudden Infant Death Syndrome (SIDS). The approach taken was to develop the software interface prototype for the Acoustic Monitoring Pad hardware developed by the U.S. Army Research Laboratory to create the SWAM (SIDS Wireless Acoustic Monitor). The Computer-Aided Prototyping System (CAPS) Software Engineering tool of the U.S. Naval Postgraduate School was used to create the SWAM. CAPS allowed us to involve potential users and implement changes to the requirements as development progressed. Using rapid Computer-Aided Prototyping, this research demonstrates the use of acoustic sounds to monitor patients via their cardiac and respiratory sounds in a wireless fashion eliminating the use of adhesive electrodes, monitoring patients.

The results demonstrate that by using CAPS and the iterative design process, a prototype was built in less than eight months that validates the acoustic pad concept. The Unix based prototype was implemented on a laptop PC for portability, which enables other applications including mobile trauma care, in addition to infant monitoring.

### **IMMERSIVE ARTICULATION OF THE HUMAN UPPER BODY IN A VIRTUAL ENVIRONMENT**

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**John Falby, Department of Computer Science**

This thesis addresses the problem that virtual environments (VEs) do not possess a practical, intuitive, and comfortable interface that allows a user to control a virtual human's movements in real-time. Such a device would give the user the feeling of being immersed in the virtual world, greatly expanding the usability of today's virtual environments.

The approach was to develop an interface for the upper body, since it is through this part of users' anatomy that they interact most with their environment. Lower body motion can be more easily scripted. Implementation includes construction of a kinematic model of the upper body. The model is then manipulated in real-time with inputs from electromagnetic motion tracking sensors placed on the user.

Research resulted in an interface that is easy to use and allows its user limited interaction with a VE. The device takes approximately one sixth the time to don and calibrate as do mechanical interfaces with similar capability. It tracks thirteen degrees of freedom. Upper body position is tracked, allowing the users to move through the VE. Users can orient their upper body and control the movements of one arm. Uncorrected position data from two trackers was used to generate clavicle joint angles. Difficulty in controlling figure motion indicates that the sensors used lack sufficient registration for this purpose. Therefore, the interface software uses only orientation data for computing joint angles.

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### MASS DISSEMINATION OF INFOSEC LECTURES VIA THE WORLD WIDE WEB

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**Master of Science in Computer Science-September 1997**

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**Geoffrey Xie, Department of Computer Science**

The Naval Postgraduate School (NPS) Center for Information Systems Security (INFOSEC) Studies and Research (NPS CISR) invites experts in the field of INFOSEC to NPS to lecture on computer security. Other universities, government, and non-government organizations need similar lectures. Two problems arise: experienced security practitioners are few in number and cannot spend a considerable amount of time on the lecture circuit. Also, for many institutions a regular lecture series would be too costly. To solve these problems a method for mass distribution of the NPS security lectures must be designed.

Multi-media tools were used to capture INFOSEC lectures for cost effective mass dissemination. By using the appropriate equipment, computer technology, and software, a tool was developed which can distribute security lectures to an unlimited audience in multiple formats. The resulting product is a tutorial to give content providers a technique to take archived video tapes, digitize them, edit them, and export them. These lectures can be delivered in HTML, compact disk, and video taped formats.

An analysis of the production process yields a set of recommendations for optimizing the user interface and balancing producer and user requirements such as memory conservation, increased product quality, and accelerated remote delivery.

### REMAP TMS: CAPTURING DESIGN RATIONALE AND PROVIDING AUTOMATED REASONING

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**Master of Science in Computer Science-September 1997**

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**John Daley, Department of Computer Science**

The explosive growth of large-scale software systems results in a need for automated software engineering tools to assist in the management of software development and maintenance. Automated reasoning capture is needed to manage the dynamically changing constraints of software design. A prototype developed to manage this problem, the Knowledge Based Software Assistant (KBSA) Advanced Development Model (ADM) software design tool lacks the ability to perform automated reasoning and is unable to capture and display design rationale with different levels of detail and formality.

This thesis takes a current prototype of the REMAP Model (**RE**presentation and **MA**intenance of **P**rocess Knowledge) for representing design rationale and integrates a new truth maintenance system into a prototype called REMAP TMS. This prototype supports automated reasoning and multiple views to maintain the consistency of the rationale knowledge base. The TMS framework supports a forward chaining rule-based system that provides automated inferencing. Three levels of granularity within the Graphical User Interface (GUI) allow the capture and viewing of design rationale at increasing levels of detail.

The REMAP TMS prototype resulting from this work is now incorporated as part of the KBSA/ADM software design tool developed by the USAF and Anderson Consulting.

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### **PROTOCOLS FOR SECURE CLIENT-SERVER APPLICATIONS IN THE JOINT MARITIME COMMAND INFORMATION SYSTEM**

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The new architecture for the Joint Maritime Command Information System, referred to as JMCIS'98, seeks to provide uniform access to tactical and non-tactical information. The goal is to allow access to such information using Wide Area Network technology and Personal Computers running Windows NT in a web environment. This architecture relies on web servers to deliver executable content, such as Java applets, to clients and gateway servers to route requests to the appropriate servers and/or databases.

This architecture raises new security risks which must be addressed. Two of these risks are addressed in this thesis: executing downloaded code from a web server and transmitting sensitive information, such as passwords, to gateway servers.

We investigate three cryptographic protocols to address these risks. The first protocol treats the risk of executing downloaded code from a web server by using digital signatures. The second protocol addresses the transmission of sensitive information to a gateway server by using certificates and symmetric key cryptography. Finally, we explore an alternative approach, that of the Secure Sockets Layer, which provides mutual authentication. We discuss how the first two protocols can be implemented in Java using the Java Developer's Kit (JDK) 1.1 and the Java Cryptography Extension (JCE) 1.1.

### **LOW-COST DIGITAL SIGNAL PROCESSOR (DSP) BASED TORPEDO COUNTERMEASURE WITH AUTONOMOUS TARGET MOTION ANALYSIS (U)**

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**Advisors: Don Brutzman, Undersea Warfare Academic Group**

**Robert B. McGhee, Department of Computer Science**

CLASSIFIED ABSTRACT

### **TECHNIQUES FOR MULTIPLE DATABASE INTEGRATION**

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**Master of Science in Computer Science-March 1997**

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**Second Reader: Mark H. Barber, Department of Computer Science**

There are several graphic client/server application development tools which can be used to easily develop powerful relational database applications. However, they do not provide a direct means of performing queries which require relational joins across multiple database boundaries.

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This thesis studies ways to access multiple databases. Specifically, it examines how a “cross-database join” can be performed. A case study of techniques used to perform joins between academic department financial management system and course management system databases was done using PowerBuilder 5.0.

Although we were able to perform joins across database boundaries, we found that PowerBuilder is not conducive to cross-database join access because no relational database engine is available to execute cross-database queries.