Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-016

SUMMARY OF RESEARCH 2001

Department of Computer Science
Graduate School of Operational and Information Sciences

LCDR Chris Eagle, USN
Acting Chair

Neil C. Rowe
Associate Chair for Research

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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13. ABSTRACT (Maximum 200 words.)

This report contains project summaries of the research projects in the Department of Computer Science. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.

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THE NAVAL POSTGRADUATE SCHOOL MISSION

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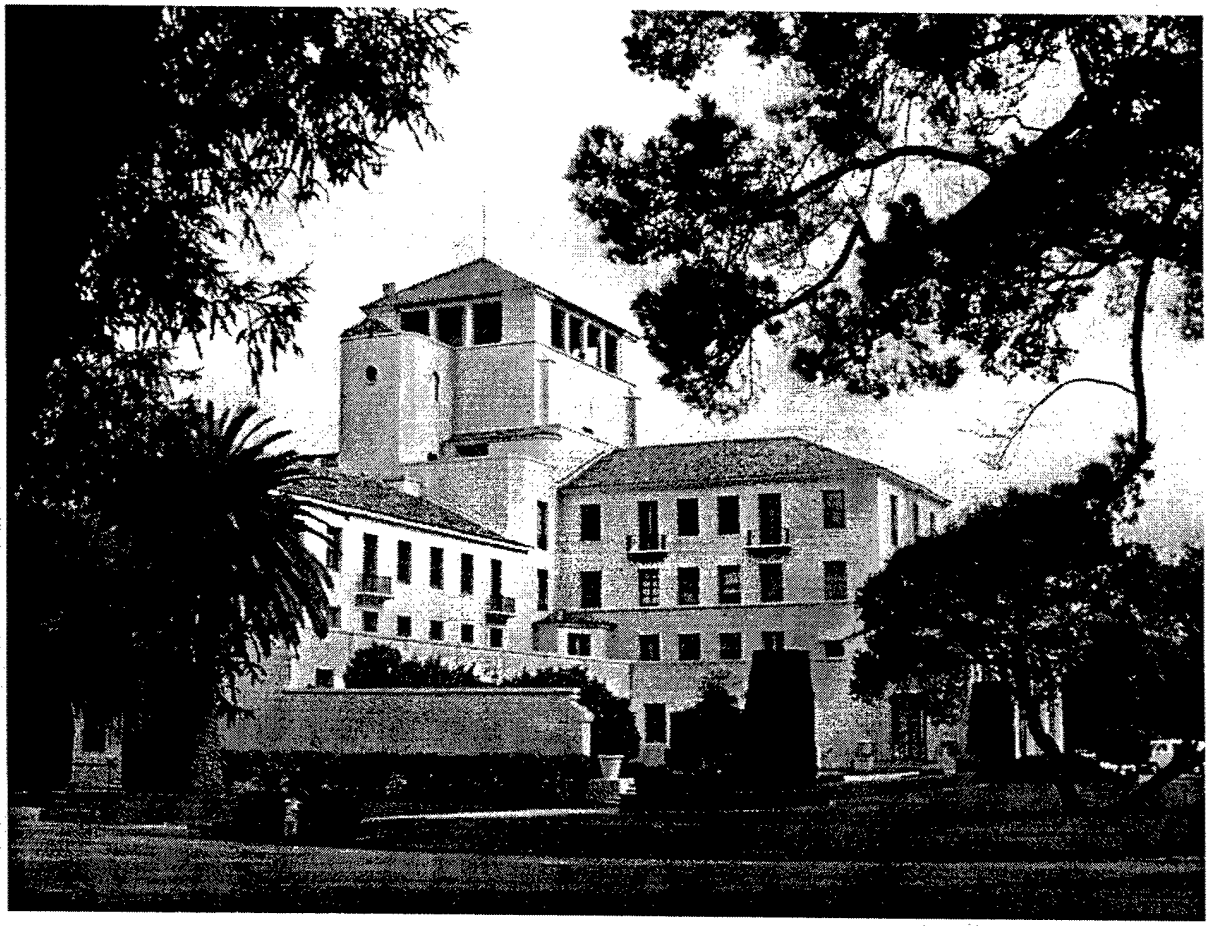

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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Computer Science during 2001. The summary also contains thesis abstracts for those students advised by Computer Science faculty during 2001.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil/~code09/

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research*: A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research*: An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
http://web.nps.navy.mil/~code09/publications.html.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, and maintains the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.

- Naval Postgraduate School Institutionally Funded Research (NIFR) Program: The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2001, the level of research effort overall at the Naval Postgraduate School was 148 faculty work years and exceeded $48 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2001, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2001 is provided in Figure 1.

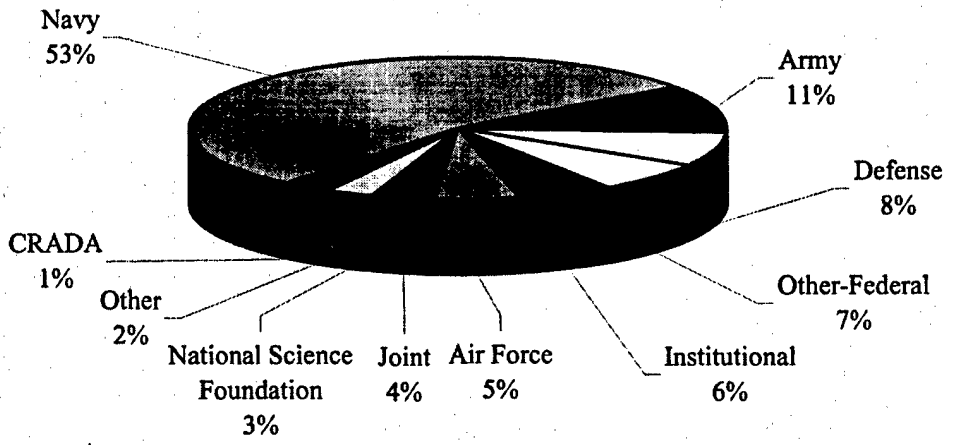


Figure 1. Profile of NPS Research and Sponsored Programs ($52M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2001 is provided in Figure 2.

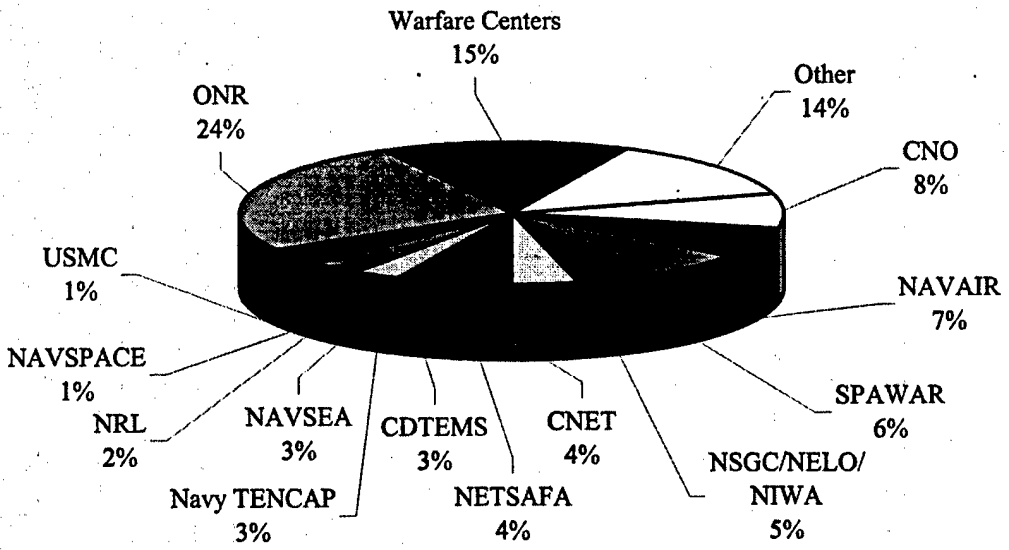


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs ($29M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

September 2002

DEPARTMENT OF COMPUTER SCIENCE

LCDR CHRIS EAGLE, USN
ACTING CHAIR

DEPARTMENT SUMMARY

OVERVIEW:

The Department of Computer Science provides graduate training and education in major areas of computer science. Thus, both basic and advanced graduate courses are offered. Course work and research lead to either the degree of Master of Science or Doctor of Philosophy. The requirements to complete either program are rigorous and are comparable to those of other major universities.

CURRICULA SERVED:

- Computer Science
- Software Engineering
- Modeling, Virtual Environments, and Simulation

DEGREES GRANTED:

- Master of Science in Computer Science
- Master of Science in Software Engineering
- Master of Science in Modeling, Virtual Environments, and Simulation
- Doctor of Philosophy in Computer Science
- Doctor of Philosophy in Software Engineering
- Doctor of Philosophy in Modeling, Virtual Environments, and Simulation

RESEARCH THRUSTS AND FACULTY EXPERTISE:

- Software Engineering:
  Professor Luqi, Professor Valdis Berzins, Professor Ted Lewis, Associate Professor Man-Tak Shing, Military Instructor CDR Deborah Kern, and Military Instructor LCDR Chris Eagle
- Databases:
  Associate Professor Thomas Wu, Research Assistant Professor Wolfgang Baer, and Professor Robert McGhee
- Information Security:
  Associate Professor Cynthia Irvine, Lecturer Daniel Warren, and Lecturer Paul Clark
- Artificial Intelligence:
  Professor Robert McGhee, Professor Neil Rowe, and Assistant Professor Chris Darken
- Modeling, Virtual Environments and Simulation (MOVES) Institute/Computer Graphics:
  Professor Michael Zyda, Assistant Professor Rudy Darken, Lecturer Eric Bachmann, Research Professor John Hiles, and Research Professor Michael Capps
- Networks:
  Associate Professor G. M. Lundy, Assistant Professor Geoffrey Xie, and Associate Professor Bret Michael
- Programming Languages:
  Associate Professor Dennis Volpano

RESEARCH FACILITIES:

- Computer Science Academic Laboratory
- Artificial Intelligence and Robotics Laboratory
- Computer Systems and Security Laboratory
- Computer Graphics and Video Laboratory
- Microcomputer Systems Laboratory
- Modeling, Virtual Environments, and Simulation Institute
- Software Engineering Laboratory

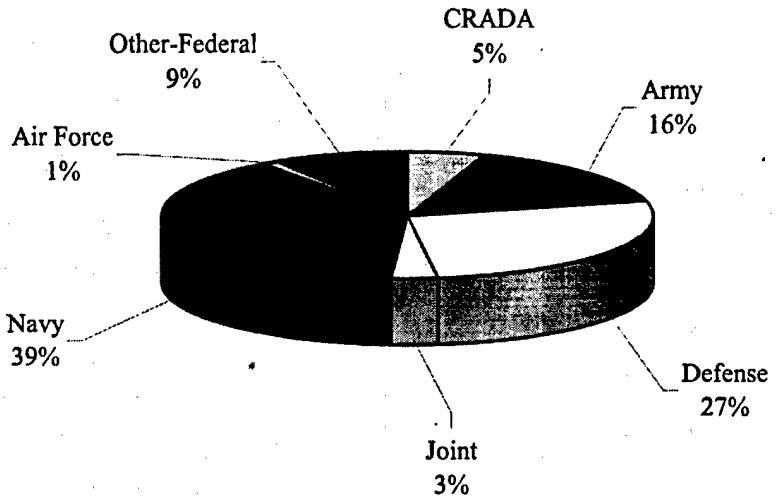
- Visual Database and Interface Laboratory

RESEARCH CENTERS:

- Center for Information Security (INFOSEC) Studies and Research (CISR)
- Software Engineering Center

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Computer Science is provided below:



Size of Program: $2550K

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BATTLEFIELD DATA PROCESSING COURSE DEVELOPMENT

Wolfgang Baer, Research Assistant Professor
Department of Computer Science
Sponsor: Unfunded

OBJECTIVE: Develop a Course and Research Capability to Support Integration of Virtual Reality and Battlefield Sensing.

SUMMARY: Closing the loop between battlefield sensors and military computer systems in a timely and accurate manner is one of the key requirements for information superiority in 21st century military operations. Future command centers will integrate virtual reality technologies with real-time battlefield sensing systems to support battlefield decisions and data product generation. It is imperative that the future commanders understand the concepts, limits, and capacities of such systems.

The course planned for development focuses on the generation of virtual environment data bases. Emphasis will be on the techniques, data sources, and active research areas which produce realistic representations of geographic areas of military interest.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Computing and Software

KEYWORDS: Virtual Reality, Battlefield Sensing

HIGH RESOLUTION TERRAIN DATA GENERATION SUPPORT

Wolfgang Baer, Research Assistant Professor
Department of Computer Science
Sponsor: U.S. Army TRADOC Analysis Command

OBJECTIVE: Identify and Construct 3D Terrain Feature Models.

SUMMARY: Provides a tool to automatically recognize, measure, and model three-dimensional surface features for addition to one meter resolution terrain database. The database is initialized using standard elevation models (DTED). It then integrates higher resolution ortho-rectified photo imagery and higher accuracy elevation data from a terrain patch of interest. Finally the tool will recognize terrain feature classes such as trees, bushes, rocks, etc. and perform a 3D model fit. The tools also provides for interactive editing of the terrain database in order to allow cosmetic and high fidelity corrections. The tool was delivered in FY 2001 in order to support a 64x64 km database construction at Ft. Hood, TX.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: 3D Terrain, Database

SISO INTRINSIC EARTH SURFACE MATERIAL CLASSIFIER SYSTEM PHASE II

Wolfgang Baer, Research Assistant Professor
Department of Computer Science
Sponsor: U.S. Army TRADOC Analysis Command

OBJECTIVE: Build the infrastructure for the construction of such an earth surface material database at one meter resolution.

SUMMARY: The Simulation Interoperability Standards Organization (SISO) Intrinsic Earth Surface Material Classifier System project will develop the definition of a Standard Surface Material Code (SSMC). To a modeling and simulation program, such a code acts like a pointer to a list of intrinsic earth surface material parameter values that define the physical and radiometric properties of the surface over a broad wavelength range. This information will reside in the Surface Materials Standards list - RESOLVE (Radiometric Earth Surface Observables for Land Visualization Events), which includes materials based on

the global abundance of naturally-occurring, man-made, and non-realistic materials, their significance (e.g. importance) to a user community, and availability of spectral data sources to support extraction of intrinsic surface properties. The standard will also include reversible surface rendering and atmospheric propagation equations to allow a traceable connection between measurement and database content. Tools for extracting intrinsic properties of material from remotely required data are basically nonexistent and the suites of surface rendering tools currently available are limited in scope; in other words, they cover an abbreviated wavelength range or include only a limited set of material types. The goal of our effort is to build the infrastructure for the construction of such an earth surface material database at 1meter resolution.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Standard Surface Material Code, Simulation Interoperability, Standards Organization, SISO

XML TECHNOLOGY ASSESSMENT

Valdis Berzins, Professor
Department of Computer Science
Sponsor: Joint C4ISR Battle Center

OBJECTIVE: The Joint C4ISR Battle Center (JBC) needs an assessment of technical issues related to the use of XML to achieve data interoperability in military systems. An XML schema should accommodate controlled change to enable incremental approaches to implementation that add one system at a time. If changes are done according to the least effort for each individual data interchange connection between legacy systems, eventually become a severe maintenance problem. The NPS Software Engineering Group proposes to evaluate and assess different methods for alleviating this problem.

SUMMARY: The use of XML has been investigated for achieving data interoperability between DoD legacy systems from several points of view: methods for integrating XML schemas covering data interchange between pairs of systems, methods for using XML to transfer data between heterogeneous databases, and XML for data interchange between real-rime systems. The capabilities of commercial tools have been assessed related to XML and XML interfaces to the commercial database systems used in the systems of interest to JBC. Methods have also been assessed for translating between different XML representations of the same real-world data, corresponding to the different views of that data as modeled in different legacy systems.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: XML, Legacy Systems, Software Engineering

MV-22 CREW TRAINING FOR DEPLOYED EXPEDITIONARY FORCES: MARINE CORPS AIR TO GROUND OPERATIONS

Rudolph P. Darken, Assistant Professor
CDR (sel) Joseph Sullivan, USN, Military Instructor
Sponsor: Office of Naval Research

OBJECTIVE: To design and construct a deployable training system for the Navy and Marine Corps helicopter and rotocraft aviation communities focusing on team tasks, specifically air to ground operations.

SUMMARY: This project involves the development of a deployable training device for the MV-22 platform and helicopters capable of performing air to ground operations. The trainer will be deployable, interoperable with other trainers, cost effective, reconfigurable, and the investigators will also conduct training assessment evaluation to assure positive training transfer. A rudimentary task analysis has been completed which will need to be redone more thoroughly next year. A fully implemented prototype system that uses a bluescreen (Chromakey) solution for mixed modes of display is available.

PUBLICATIONS:

Darken, R., Kempster, K. and Peterson, B., "Effects of Streaming Video Quality of Service on Spatial Comprehension in a Reconnaissance Task," *Proceedings of I/ITSEC*, Orlando, FL.

Peterson, B., Boswell, J. and Darken, R., "Collaborative Navigation in Real and Virtual Environments," *Proceedings of I/ITSEC*, Orlando, FL.

THESIS DIRECTED:

Boswell, J., "User-Centered Iterative Design of a Collaborative Virtual Environment," Masters Thesis, Naval Postgraduate School, March 2001.

Hennings, C., "Designing Realistic Human Behavior into Multi-Agent Systems," Masters Thesis, Naval Postgraduate School, September 2001.

Mert, E. and Jilson, E., "Modeling Conventional Land Combat in a Multi-Agent System Using Generalization of the Different Combat Entities and Combat Operations," Masters Thesis, Naval Postgraduate School, September 2001.

Norlander, K., "Emergent Leadership on Collaborative Tasks in Distributed Virtual Environments," Masters Thesis, Naval Postgraduate School, September 2001.

Unguder, E., "The Effects of Natural Locomotion on Maneuvering Task Performance in Virtual and Real Environments," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Human Systems Interface, Modeling and Simulation

KEYWORDS: Training, Virtual Environment

AN EXECUTIVE LEVEL INFORMATION TECHNOLOGY EXPLOIT DEMONSTRATION

Cynthia E. Irvine, Associate Professor
MAJ Michael VanPutte, USA
Department of Computer Science
Richard Harkins, Lecturer
Department of Physics
Sponsors: Headquarters, Department of the Army

OBJECTIVE: This proposal is in the development of an executive level demonstration of information security vulnerabilities and exploits. The purpose is to open the eyes of non-technical DoD leaders to the risks that are inherent in current information technology systems, so they can understand and make policy.

SUMMARY: This report is interim and describes and ongoing effort. The purpose of this effort is to develop an executive level stand-alone demonstration of current computer security threats and exploits. The demonstration will consist of a "worst case" scenario presentation of various (unclassified) cyber threats and vulnerabilities, illustrating the skills required to exploit the vulnerabilities and, where available, courses of action to reduce those threats. The intent is to present to non-technical military and DoD leaders an executive demonstration of current Information Assurance threats, risks, and countermeasures. The demonstration will include not only trivial attacks that can be mounted by "ankle-biters" or that result from careless or inadequate procedural measures on the part of authorized users, but will also illustrate attacks that are preferred by state-sponsored or other well-funded professionals. Thus, the demonstration will provide decision makers with the information that they need to *understand* and make high level policy in the area of computer and network security and the risks associated with information technology.

An unclassified "sand box" laboratory is being developed to produce the highest level of realism and accuracy in the demonstration. Areas include network infiltration and exploitation, wireless infrastructure

threats, malware threats, Trojan Horses, trap doors, and PDA threats. Each of the attack or exploitation areas is being explored for vulnerabilities and attack scenarios have been hypothesized. This is followed by test or implementation. When possible, methods to mitigate vulnerabilities are identified. Both the attacks and a discussion of techniques to thwart them are being incorporated into the demonstration.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Information Assurance, Vulnerability Exploitation, Threats

HIGH ASSURANCE MULTILEVEL COMPUTING ENVIRONMENT, PHASE II

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Navy Engineering Logistics Office

OBJECTIVE: This research is to continue work in support of a high assurance distributed multilevel computing environment, building on recent work accomplished on the Naval Postgraduate School High assurance label processing mail service prototype undertaken during Phase I. Areas of study include applicability to collaborative environments, extension of label processing, trusted path extensions, and supporting policy adaptations.

SUMMARY: The prototype High Assurance system functionality was extended in the following ways: (1) Modifications to the Trusted Path Server, Secure Session Server, 'sendmail' daemon and HTTP server on a high assurance platform were finalized, (2) An initial Java prototype of a generic client TCB Extension was produced; high assurance server functionality was ported to the Linux operating system base. This work permits a multilevel version of Ethernet support as well as dynamic instantiation of protocol services in conformance with client security attributes. (4) A similar port to the Open BSD operating system was started. (5) The design of a PDA-based trusted path mechanism to be used in the context of a contemporary server (e.g. Linux or OpenBSD) was begun. The client trusted path device is envisioned to be a hand-held component juxtaposed between the client workstation and the server.

Preliminary sketches of an architecture for self-protecting data were prepared. An option in this design is to use a specialized reader device. The use of Intelink/CAPCO metadata tags to support visual labeling of paragraph markings, as well as access control to XML/HTML documents was investigated.An initial study of security vulnerabilities associated with the use of popular applications on the connectionless User Datagram Protocol (UDP) was conducted. This included examination of several Voice over IP (VoIP) suites. It was found that for a number of the most popular products ensuring performance was paramount and that security was turned off when VoIP was turned on.

Based upon the need to provide standard commercial-grade productivity applications as the general purpose user interface to high-assurance data processing environments is compelling in the context of "trusted" systems, the problem of integrity in architectures comprised of both traditional trusted components and less trusted components was explored. Some of these systems were characterized as a class of architecture. This lead to the development of a general integrity property that systems can only be trusted to manage modifiable data whose integrity is at or below that of their interface components. The analysis led the effect that in terms of integrity high-assurance systems cannot be composed of a combination of high assurance policy-enforcement components and low assurance commercial interface/application components. Another effect is that this type of these hybrid-security systems are only applicable to processing environments where the integrity of data is consistent with that of low-assurance software.

PUBLICATIONS:

Irvine, C.E., Levin, T., Wilson, J.D., Shifflett, D. and Pereira, B., "A Case Study in Security Requirements Engineering for a High Assurance System," *Proceedings of the 1st Symposium on Requirements Engineering for Information Security*, Purdue University, Indianapolis, IN, 5-6 March 2001.

Irvine, C.E. and Levin, T., "Data Integrity Limitations in Highly Secure Systems," *Proceedings of the International Systems Security Engineering Conference*, February 2001.

Irvine, C.E. and Levin, T., "A Cautionary Note Regarding the Data Integrity Capacity of Certain Secure Systems," Fourth International IFIP Working Conference on Integrity and Internal Control in Information Systems, Brussels, Belgium, 15-16 November 2001.

THESIS DIRECTED:

Glover, M., "Integrating a Trusted Computing Base Extension Server and Secure Session Server into the Linux Operating System," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information Assurance, Multilevel Security, High Assurance

MSHN: MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: Research and design effort directed at solving the fundamental problems associated with and creating a distributed metacomputer.

SUMMARY: Phase I of the MSHN Project was completed in 2000. This report provides s a summary of project research and additional publications emerging from the project.

The accomplishments of the project include a peer-to-peer architecture composed of the following components: client library, scheduling advisor, resource requirements database, resource status server, MSHN daemon, application emulator. The architecture supports the execution of many different client applications, both new and previously unencountered.

Mapping algorithm research supported the MSHN scheduler and resulted in the development of a "toolbox" of mapping techniques from which the scheduler can select the most appropriate algorithm for a given heterogeneous computing and application environment. A unified mapping framework was developed addressed two mapping problems: mapping with advance reservation and data replication, and mapping with resource co-allocation requirements.

MSHN produced a resource model that allows the system to make mapping decisions. Monitoring is needed to ensure that model represents the resources available. Strategies were developed to permit monitoring to be performed at each client. A number of techniques and tools were explored to permit the monitoring and modeling of communications resources.

The research explored the problem of distributed communications in an environment requiring transfers of large quantities of data. A uniform framework for developing communication schedules for collective communication patterns was introduced. The schedules were adapted at run-time, based on network performance information.

Performance metrics were developed so that the success of MSHN as a resource management system could be measured. A multidimensional performance measure was developed that included: priorities, task and data versions, deadlines, situational modes, security, and other dependencies.

Security was an integral part of the MSHN project. A multi-domain cryptographically enforced security architecture was developed that provided authentication and confidentiality for MSHN components. The notion of Quality of Security Service was introduced and developed as part of the project.

PUBLICATIONS:

Kim, J.K., Kidd, T., Siegel, H.J., Irvine, C., Levin, T., Hensgen, D.A., St. John, D., Prasanna, V.K., Freund, R.F. and Porter, N.W., "Collective Value QoS: A Performance Measure Framework for Distributed

Heterogeneous Networks," *Proceedings of the 15th International Parallel and Distributed Processing Symposium*, pp. 810–823, 2001.

THESIS DIRECTED:

Drake, T., "Design and Implementation of a Real-Time Distributed System Emulator," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Heterogeneous, Distributed Computing, Data Staging, Metacomputing

MSHN: SECURITY ARCHITECTURE AND QUALITY OF SECURITY SERVICE FOR RESOURCE MANAGEMENT SYSTEMS

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Projects Research Agency

OBJECTIVE: This is an extension of ongoing work in the area of quality of security service (QoSS) and security architectures for resource management systems (RMS). The theory of QoSS was broadened and the QoSS framework extended through experimentation with mechanisms to provide QoSS in the context of a RMS. Security requirements of RMS applications will be identified to further refine needed architectural and QoSS support.

SUMMARY: A method for articulating network security functional requirements, and for measuring their fulfillment has been developed. Using this method, security in a quality of service framework (QoSS) is discussed in terms of variant security mechanisms and dynamic security policies. It was also shown how QoSS can be represented in a network scheduler benefit function.

This research continued to address the problem of how users and administrators can easily interact with the wide range of security resources and mechanisms. A method for translation of a simplified user abstraction of security to detailed underlying mechanisms was further refined.

An approach for representing the level of resources consumed by jobs under the control of a resource management system was extended. This work continued to show how this measurement of resource usage can be combined with a notion of user preferences to reflect a restrictive resource-usage policy for network management.

Based upon a preliminary security service taxonomy defined to provide the resource management system with potential resource utilization costs, a demonstration of our framework was developed for defining the costs of various network services. Using IPSec in OpenBSD, a demonstration of Quality of Security Service was constructed. Based upon environmental conditions, security associations between peer systems are selected according to a predefined policy. Environmental conditions relating to the network mode and user security requirements may change. When this occurs, security associations are broken down and re-established.

PUBLICATIONS:

Irvine, C., Levin, T. and Sypropoulou, E., "Security as a Dimension of Quality of Service in Active Service Environments," *Proceedings of the International Workshop on Active Middleware Services*, San Francisco, CA, 6 August 2001.

THESIS DIRECTED:

Agar, C., "Dynamic Parameterization of IPSec," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Information Assurance

NAVY INFORMATION WARFARE/INFORMATION SECURITY/INFORMATION ASSURANCE SUPPORT PLAN FOR NPS CISR

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Chief of Naval Operations (N643)

OBJECTIVE: The aim of this research is to provide support for the Naval Postgraduate School Center for INFOSEC Studies and Research (NPS CISR) in an integrated approach to INFOSEC research and education. The program will focus on network and platform security problems of importance to DoN and DoD.

SUMMARY: Several ongoing projects intended to support the emerging DoD public key infrastructure (PKI) were started. These included an examination of the feasibility of the use of the PKI in tactical situations. Another study involved configuration management issues for deployed PKI components. A third research effort is explored metrics for the service level agreement (SLA) for operational services relating to the PKI that are required for the Navy Marine Corps Internet.

PKI training within the DoD was examined and found unable to provide all of its users with an adequate level of general understanding of the system as a whole, or of the implications and ramifications that their individual actions may have upon the system. A decentralized, segmented, and inconsistent approach to PKI training will result in a lack of trust within the PKI. The initial requirements and design for a coherent web-based training framework for the DoD PKI were developed. A prototype was developed for further testing and evaluation.

Human factors in the perceived and actual level of security awareness was the topic of another investigation. A survey was developed to assess security awareness within the U.S. Coast Guard. this was followed by analysis and a plan to improve security awareness was recommended.

Highly trustworthy user interfaces for an open source operating system constituted another area within the scope of this research. The objective was to identify all of the mechanisms within the keyboard interface that represent trap doors in the open source system and to modify the design of the input subsystem so that a trustworthy secure attention key was possible. Additionally, this work resulted in the development of a state representation of the interface that could be used for subsequent design of a trusted path interface.

Using the Situational Influence Assessment Module (SIAM), classical risk analysis was expanded to increase visualization of choices that impact the security of a system, in this case a firewall. By providing a comparative analysis of system attributes communications between decision makers and technicians is encouraged. This increased understanding of the impact of investment choices has the potential to increase the security posture of existing systems.

The implications of the use of human microchip implants to permit radio frequency identification of personnel were investigated. This work included a survey of current technologies for enhanced user identification, focusing on human implant approaches and a summary of security, privacy, social and ethical issues that may arise from the use of these technologies in the U.S. Navy. It was found that the collateral social issues are complex and far-reaching. Potentially intractable technical, morale and legal issues must be avoided by the U.S. Navy. The results of this exploratory work show: 1) technology must be examined in the context of its social impact, and 2) there is a valid need for future research and analysis of human microchip implants.

Research into platform architectures and their ability to support secure systems involved examination of the Intel IA-64 platform. Hardware protection mechanisms were examined and included mechanisms for: privilege levels, access rights, region identifiers and protection key registers. It was found that proper use of the TLB-based hardware protection features permits some protection in the IA-64 architecture.

In addition, the Intel IA-64 architecture was analyzed for virtualizability with respect to the three classical virtual machine monitor definitions and their hardware requirements. Although the IA-64 architecture meets the three hardware requirements, the IA-64 instruction set contains 18 sensitive

unprivileged instructions. These instructions prevent the IA-64 architecture from being used for a Type I VMM.

A study of Windows 2000 configuration for NPS was conducted with the objective of describing a secure configuration as well as the rationale for its settings. This work resulted in: (1) brief overview of the Microsoft Windows 2000 security architecture, (2) a description of the Windows 2000 Security Configuration Tool Kit and how to configure security settings, (3) a discussion on security policy and how it effects security configurations, (4) recommendations on how to translate the Naval Postgraduate School's Security Policy into Windows 2000 security settings, and (5) recommendations on a pre-configured, security template for all students attending NPS.

PUBLICATIONS:

Irvine, C.E. and Levin, T., "Teaching Security Engineering Principles," in Armstrong, H. and Yngstrom, L., eds., *IFIP TC11 WG 11.8 Second World Conference on Information Security Education*, Perth, Australia: Edith Cowan University, pp. 113-127, July 2001.

Clark, P., "Supporting the Education of Information Assurance with a Laboratory Environment," *Proceedings of the 5th National Colloquium for Information Systems Security Education*, May 2001.

THESIS DIRECTED:

Brock, J., "Supporting the Secure Halting of User Sessions and Processes in the Unix Operating System," Masters Thesis, Naval Postgraduate School, June 2001.

Brodhun, C.P., "Prioritization of Information Assurance (IA) Technology in a Resource Constrained Environment," Masters Thesis, Naval Postgraduate School, September 2001.

Gumke, R., "Navy Marine Corp Internet Information Assurance Operational Services Performance Measures," Masters Thesis, Naval Postgraduate School, June 2001.

Jubert, L., "Implications of User Identification Devices (UIDs) for the United States Navy," Masters Thesis, Naval Postgraduate School, September 2001.

Karadeniz, K, "Analysis of Intel IA-64 Processor Support for a Secure Virtual Machine Monitor," Masters Thesis, Naval Postgraduate School, March 2001.

McGovern, S., "Information Security Requirements for a Coalition Wide Area Network," Masters Thesis, Naval Postgraduate School, June 2001.

McKinley, D., "Implementing the Naval Postgraduate School's Security Policy Using Windows 2000," Masters Thesis, Naval Postgraduate School, September 2001.

Stocks, A., "Requirements for the Deployment of Public Key Infrastructure (PKI) in the USMC Tactical Environment," Masters Thesis, Naval Postgraduate School, June 2001.

Unlamis, B., "Analysis of the Intel IA-64 Processor Support for Secure Systems," Masters Thesis, Naval Postgraduate School, March 2001.

Whalen, T., "Human Factors in Coast Guard Computer Security -- An Analysis of Current Awareness and Potential Techniques to Improve Security Program Viability," Masters Thesis, Naval Postgraduate School, June 2001.

Zembia, M., "A Training Framework for the Department of Defense Public Key Infrastructure," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information System Security, INFOSEC, Information Assurance, Network Security

NPS CISR SCHOLARSHIP FOR SERVICE: SCHOLARSHIP TRACK

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: The objective of the proposed work is to provide Master's level education in the science and practice of Information Assurance to selected students who would subsequently be available and obligated to perform two years of Federal service in the same field.

SUMMARY: Students with undergraduate computer science degrees will be placed into a specially designed two-year computer security track within the Center for INFOSEC Studies and Research (CISR) at the Naval Postgraduate School. This four-year Scholarship for Service program will initiate a stream of ten students per year for the first three years, graduating the final set of ten students at the end of the fourth year.

Through courses involving extensive laboratory exercises and projects, student will learn how to design, build, configure, and manage systems and networks securely. During their two years of study, the program will provide students with a firm grounding in the foundations of computer science and the concepts and techniques for understanding modern information assurance.

The program is intended to have a significant effect toward filling the current personnel gap in Information Assurance for the national information infrastructure.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information Assurance, Critical Infrastructure Protection

PUBLIC KEY INFRASTRUCTURE (PKI) LABORATORY EQUIPMENT - FY01
PUBLIC KEY INFRASTRUCTURE (PKI) LABORATORY SUPPORT AND EXTENSION

Cynthia E. Irvine, Associate Professor
J.D. Fulp, Lecturer
Department of Computer Science
Sponsors: National Security Agency and Office of the Secretary of Defense

OBJECTIVE: (1) This proposal is for Laboratory equipment in support of the Public Key Infrastructure (PKI) Laboratory operated by NPS CISR. This laboratory will support information Assurance (IA) education and a forthcoming cyber defense exercise. (2) This proposal is for laboratory equipment in support of the Public Key Infrastructure (PKI) Laboratory operated by NPS CISR. This laboratory will support Information Assurance (IA) education and a forthcoming Cyber Defense Exercise.

SUMMARY: The NPS CISR PKI Lab provides students and research faculty with the necessary system resources to study implementation and security issues relating to PKI. Issues include, but are not limited to: 1) Implementation of the various PKI functional components (e.g., Certificate Authority/Server, Registration Authority/Server, Certificate Revocation List, Key Archival and Recovery, etc.), 2) Interoperability among DoD users, 3) Interoperability between DoD and non-DoD users, 4) Public Key enabling of applications, and 5) Certificate Trust Hierarchies and Relationships.

Equipment for the PKI lab was initially provided in February of 2001 under the auspices of the DoD PKI Program Management Office (PMO). An equipment upgrade was funded by the PMO in September of 2001. To provide a more interesting and dynamic venue for the introduction of PKI to DoD Service component student officers, the PMO and Service School representatives embarked on a plan to wrap the usage of PKI inside a student run IA exercise – the "Cyber-Defense Exercise" (CDE).

The first CDE was conducted in April of 2001, though the compressed procurement-to-implementation timeframe did not allow integration of PKI into the exercise. NPS was judged the un-official winner of the 2001 CDE based upon the judgment of IW professionals from the NSA, USAF, and US Army (collectively the "Red Team") who conducted a week long barrage of offensive exploits against each school's network. The "un-official" win status is due to NPS' unique status as the only postgraduate competitor in the exercise.

Planning for the 2002 CDE has been ongoing and will culminate in the actual attack/defend phase during the week of 22 April. PKI will be utilized for the signing and encrypting of daily situation reports from each school to White Team (referee) participants at Carnegie Mellon University. The situation reports will document the status of each school's network following each day's eight-hour attack period. The reports will also list any offensive intrusion exploits that were logged or otherwise identified by the defending team. The winner will be chosen based upon two criteria: 1) The accuracy and specificity of the situation reports, and 2) The relative resistance to, and ability to recover from, Red Team exploits.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Network Security, Public Key Infrastructure (PKI), Authentication

SECURITY-ENHANCED WINDOWS CE

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsors: Microsoft Corporation

OBJECTIVE: The objective of the Secure Windows CE project is to examine the data protection and self protection features of the Windows CE Operating System and to develop structural modifications and enhancements to the Windows CE operating system that would increase its level of self protection. As a result users would have greater confidence of the ability of Windows CE devices to withstand attempts to penetrate or subvert them, and consequently to have greater confidence in the ability of Windows CE to protect data entrusted to it.

SUMMARY: In the absence of source code, preliminary studies of the Windows CE system in the form of black box analysis. Documents from the open literature as well as existing systems were used as the basis for two analyses.

In the context of general security redesign of operating systems the applicability of such redesign to the Windows CE operating system was explored. The operating system was critically examined for externally visible security weaknesses, especially in the Input/Output subsystem area. Recommendations were made for improving the self-protection of Windows CE.

Threads and processes in WinCE, as well as authentication, and public key infrastructure (PKI) support were examined. It was found that *Talisker*, the next generation of WinCE, supports Kerberos an authentication protocol, and it also supports PKI (a key management system) components. Using selected applications and configuration management security on a Talisker platform can be significantly enhanced beyond that usually supplied in "out of the box" systems.

THESIS DIRECTED:

Burns, T., "Analyzing Threads and Processes in Windows CE," Masters Thesis, Naval Postgraduate School, September 2001.

Pereira, B., "Analyzing Input/Output Security in Windows CE," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information System Security, INFOSEC, Information Assurance, Network Security

SIM SECURITY

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Chief of Naval Education and Training

OBJECTIVE: The purpose of this research is to create a distance learning lab to support hands-on learning, working with or without distance learning modules, focusing on the subject of information assurance (IA).

SUMMARY: This project is ongoing. The following summarizes project objectives. The purpose of this effort is to create a distance learning lab to support hands-on learning, working with or without distance learning modules, focusing on the subject of information assurance (IA).
The lab will be based on existing course material that meets NSTISSC Standard 4011 as well as all or part of the other NSITISSC Standards pertinent to Information Assurance.

SimSecurity will package an Information Assurance laboratory in the form of an interactive computer game in which players may perform various roles involved in IA: manager, security administrator, attacker, etc. Through the use of agent-based software techniques, the laboratory will adapt to the decision or omissions of students, providing them with a customized learning experience. The agent-based software underlying this laboratory facilitates extensions as new threats and countermeasures in the real world IA landscape evolve.

The laboratory will support both IA Training and IA Education. It can be used in an ad hoc fashion to teach users IA concepts and vocabulary. When used as a self-contained laboratory it provides an introduction and tutorial providing a basic introduction to IA concepts and their application. When combined with a course, students navigate through the IA lab in a systematic program. When used in conjunction with learning modules and courses, such as those developed by the Center for INFOSEC Studies and Research at the Naval Postgraduate School, students progress through a rigorous sequence of labs and lectures to a NSTISSC-based certification and/or course credit from NPS.

A model of Information Assurance and a series of scenarios for the simulation have been developed. Additional details of the model and scenarios will be developed. Initial artwork has been created to provide backdrops for several scenarios.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Education, Information Assurance, Simulation

ASSESSMENT OF DEFENSE MODELING AND SIMULATION OFFICE (DMSO) CONCEPTUAL MODELS OF THE MISSION SPACE

Luqi, Professor
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Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: The objectives of this project are to provide a quantitative assessment of the value-added due to the DMSO data engineering and Conceptual Models of the Mission Space (CMMS) products and to provide useful measures of the health and the status of work in progress. Ongoing NPS faculty and graduate students' efforts on software requirements analysis and risk reduction were leveraged to address these objectives.

SUMMARY: The assessment addressed the value added by DMSO data engineering concepts and tools, as well as metrics to support cost estimation, scheduled planning, status of work in progress, conceptual model complexity, and software defect evaluation. In FY01, we focused our assessment efforts in the following areas: (A) effectiveness of software risk assessment models, (B) enhancement to the functional description of the mission space resource center, (C) the use of XML and Wrapper-based translators for heterogeneous DoD databases, and (D) metrics for systematically evaluating and selecting automated testing tools.

A. Quantitative risk assessment for software development: Investigation continued on formal risk assessment models for the evolutionary software process and their application to DMSO projects. The methods and tools were analyzed and improved to assess the risk and the duration of software projects automatically, based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. These metrics eliminate the subjectivity issue characteristic of previous research. Any decision-maker will arrive at the same estimates, independent of his or her expertise. The approach enables a project manager to evaluate the probability of project success very early in the life cycle. For more than twenty years the estimation standards (COCOMO 81, COCOMO II, Putnam) have been characterized by the common limitation that the requirements should be frozen in order to make estimations. Our models remove this limitation, facing the reality that requirements are inherently variable. The effectiveness of the models was validated by comparing the results of the models against data collected from 16 simulated projects and 3 large, real projects.

1. Sixteen Simulated Projects: The simulations showed that the three risk factors observed during the causal analysis (efficiency, requirements volatility, and complexity) have compound effects over the three parameters of the Weibull distribution. The results of the models were illustrated against 16 simulated projects. Each model derives an increasing degree of accuracy based on: metrics from the three risk factors, Weibull cumulative density function, and the derivation of the time.
   - Models 1-2: Model 1 can be used when the requirements volatility is small. Model 2 considers the three factors (EF, RV, and CX), but neglects the combined effect of EF and RV.
   - Model 3: Model 3, illustrated in Figure 2, considers the three factors as well as the combined effects of EF and RV. The analysis of variance shows that the samples obtained from the simulations and the samples obtained from the estimates using Model 1, 2 or 3 cannot be statistically differentiated.

     Another interesting result is that the errors remain in the range of (15% for all of the scenarios. This result is interesting if we compare it with the results of COCOMO ((20% in the best cases). Barry Boehm in reference to the validation of COCOMO said, "In terms of our criterion of being able to estimate within 20% of projects actuals, Basic COCOMO accomplishes this in only 25% of the time, Intermediate COCOMO 68% of the time, and Detailed COCOMO 70% of the time."
   - Model 4: Model 4, can be used for any range of complexity and requirements volatility, and considers the three factors, their combined effects, and the following a priori assumptions:
     * A project with 0 LGC will take 0 days
     * (, (, and (> 0
     * If RV increases the p(x<=t) decreases
     * If CX increases then p(x<=t) decreases
     * If EF increases then p(x<=t) increases

     The scatter plot derived compares the simulated times versus the estimated times. Most of the errors are overestimations and the duration of the project has no effect over the percentage of error. Model 4 is conservative. The maximum overestimation error was less than 16% and the maximum underestimation was less than 4%.

     Model 4 gives a good estimation for projects between 4,000 and 20,000 LGC (128 and 640 KLOC of Ada). The estimation seems to be too optimistic for projects smaller than 1000 LGC but it is quite good for larger projects.
2. Uruguayan Navy Project: Model 4 was on a war-gaming simulator with 75,240 lines of code. The software was made up of 1836 LGC and was developed in 1.5 years by the Uruguayan Navy. Model 4 predicts 17 months instead of 18 months, the actual development time.
3. U.S. DoD Project A: This project used an Evolutionary Spiral lifecycle model. It used Object-Oriented methodology and was composed of five computer software configuration items written in Ada. It was real-time embedded, and used Rational Rose as a Computer Aided Software Engineering tool with the developer operating at SEI level 3. In addition, software metrics from three builds over a period of three years had been kept.

   Model 4 was used to calculate the probability of completion curve for the project. For consistency, we used working days, defined as 22 days per month, the same as used in the original Nogueira model.

The model predicted that the minimum time, in days, necessary to have a probability of completion of 100% is approximately 260 working days. When compared to the actual time it took, which was 336 working days, the model predicted completion sooner. The model predicted 76 working days less, or a 22.6% delta: (1 - (260 / 336)) (100) = 22.6%.

At this point, with 22.6% variability, we decided to investigate and see what the original estimated completion date was from project records. The original estimation was 200 working days, with the project schedule slipping 136 working days for build 3. The developer missed the original completion estimation by 40.5%: (1- (200 / 336)) (100) = 40.5%.

The Nogueira model missed the developer's original estimate by 23.1%: (1-(200 / 260)) (100) = 23.1%. This data point leaves us with an inconclusive position as to the validation of the model against the first project. It appears that there is a difference when using projects with real data versus simulated project data, reflecting what the real world is - unpredictable.

4. U.S. DoD Project B: This project originally used an incremental build lifecycle model and not an evolutionary model. It originally used Functional Decomposition methodology and was composed of six Computer Software Configuration Items. Written in ADA and assembly language, it was real-time embedded. It did use upper CASE tools, like Requirements Traceability Matrix (RTM), however did not use lower CASE tools such as Rational Rose. The development effort initially was performed in an ad-hoc manner with little software process involved and had experienced extreme volatility and poor metrics early in its development. However, due to a major restructure and overhaul of the project, and a shift of focus to institutionalizing software processes, (SEI CMM level 3 certification), the project migrated to ADA, and began using a modified Incremental Build lifecycle model. In addition, suitable software metrics from two recent builds were available. We used Dr. Nogueira's Model 4 to calculate the probability of completion curve for Build 2 using; BR=2.59, DR=3.04, RV=5.63, O=2544, D=4010, T=1003. The model predicted Impossible.

   Actual time for build 2 took from 4/24/00 until 7/10/00 or 68 working days at 22 working days a month. We believe this inconsistency is due primarily to the calculation for the LGC count being based on all six Computer Software Configuration Items (CSCI). Core functionality on three CSCIs; CSCI-A, CSCI-B, and CSCI-C had been previously developed and validated. However, the builds during this period, involved addition of functionality to the following CSCIs: CSCI-D, CSCI-E, and CSCI-F. That is, build 2 was modifying only a portion of the total software system code, but the LGC data gives a view of all six CSCIs combined.

   The available data was not broken down into separate CSCIs, nor did it, post-mortem, identify the code that was being worked in a previous software release. We cannot fault the developer for not collecting metrics for research concepts that they are not aware of, nor do we believe that this type of data collection is a requirement of CMM level 3.

   A finding of this research is the need to adjust the CX when applying the Nogueira model to evolved projects that are developing or enhancing only a portion of their CSCIs.

   As previously stated, this project did not utilize a lower case tool such as Rational Rose. We believe use of such a tool is essential when attempting to apply the Nogueira formal model, as it provides the capability to collect detailed information, over the software development lifecycle. The data can later be extracted and used for input to the Nogueira model metrics.

B. Analysis and enhancement to the functional description of the Mission Space Resource Center: DMSO developed the Functional Description of the Mission Space (FDMS) Resource Center under the guidance of DoD 5000.59-P, DoD Modeling and Simulation Master Plan. The FDMS Resource Center provides a controlled repository for modeling and simulation (M&S) data and promotes data standardization and reuse. The FDMS Resource Center is currently functional and on-line at http://38.241.48.9.

Use of the FDMS Resource Center is voluntary on the part of DoD M&S organizations, although maximum use of the Center is paramount if standardization and reuse synergies are to be realized. In an effort to encourage more use of the Resource Center's capabilities, we analyzed the Resource Center, interviewed the Center's principals, and developed a set of recommendations governing screenshots appearance, data workflow control, and privilege permission selections to simplify and clarify the Center's user process:

1. The FDMS libraries will refer to the digital files in its repository as "products."

2. The Design and Create Documents screen will clarify the difference between "register" and "submit."
3. The Register New Products screen will clearly inform the user of his options regarding creating registration elements or registering products.
   - The screen will present the user with two options: to register a product or to create a registration element.
   - The screen will briefly define "registration element" so that the user can make an informed decision.
4. The FDMS system will control the creation of registration elements.
   - The Producer will not be able to use a registration element and it will not be visible to users other than the Administrator until it is approved by the governing Sponsor.
   - The FDMS system will overtly notify the governing Sponsor and Producer during the various steps in creating a registration element.
   - The Create Registration Element screen will clearly inform the user how to create a registration element. The screen will have a clear header and definition, will not have misleading underlining, and its top "Register" button will be labeled to reflect its true "go back one screen" function.
5. The FDMS system will control the submission of products for approval.
   - The system will overtly notify the governing Sponsor and Producer during the various steps in the submission of products for approval.
   - The top "Register" button on the Register Product(s) screen will be labeled to reflect its true "go back one screen" function.
6. The Product/Registration Element Approval screen will be clear.
   - The screen header will be correctly labeled.
   - The headers of the first and second columns of the approval table will read "Product/Registration Element" and "Sponsor", respectively.
7. The headers of the second and third columns of the approval table in the Product Endorsement screen will read "Sponsor" and "Endorsed", respectively.
8. A Sponsor will be able to define groups and assign privileges to those groups.
   - A Sponsor will be able to create and modify groups. Each group will have a unique name. The Sponsor will have the option to add notes or explanatory comments about a group. The system will display the names of users so that the Sponsor can select user names from the display to be members of his group. A Sponsor will have the option of allowing other users to use his group or of restricting all other users from using his group.
   - A Sponsor will be able to assign FDMS privileges to a group in the same manner as he would to an individual user.

The implementation of these recommendations into subsequent versions of the FDMS Resource Center will significantly improve the usability of the web-based repository and novice user's understanding of the organization and functionality of the FDMS Resource Center. This, in turn, will encourage members of the DoD modeling and simulation community to exploit the Resource Center by registering and analyzing their own products in the repository and by reusing other registered products. This anticipated synergy will directly support the first and fourth objectives of the draft DoD Modeling and Simulation Master Plan.

C. Evaluation of XML and Wrapper-based translators for heterogeneous DoD databases: In today's combat environment, the US military and its allies find themselves in the midst of the information age they helped to start. This information and applied systems abound in all parts of the services and at locations throughout the globe. To influence decisions, commanders and their respective staffs need the most up-to-date information available. This information comes from various sources, but especially from computer systems, many of which were developed over the last few decades before interoperability became a concern. These stovepipe systems cannot pass information to each other because they use incompatible message sets. We developed an object-oriented model for a "wrapper-based" translator to resolve the representational differences between heterogeneous systems which include: (1) an integrated development environment for users to create such models, (2) methods for determining object correspondence during system integration,

and (3) the use of the Extensive Markup Language (XML) as a means for establishing interoperability between multiple DoD databases.

D. Metrics for measuring the effectiveness of software testing tools: The levels of quality, maintainability, testability, and stability of software can be improved and measured through the use of automated testing tools throughout the software development process. Automated testing tools assist software engineers to gauge the quality of software by automating the mechanical aspects of the software-testing task. Automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Evaluating available tools and selecting the most appropriate suite of tools can be a difficult and time-consuming process. We proposed a suite of objective metrics for measuring tool characteristics as an aide in systematically evaluating and selecting automated testing tools for both procedural and object-oriented source code.

The proposed metrics for evaluating testing tools include:

1. Human Interface Design (HID) - This metric measures whether the tools have well designed human interfaces to enable easy, efficient, and accurate setting of tool configuration. A large HID indicates the level of complexity in learning the tool's procedures and the likelihood of errors in using the tool over a long period of time.
2. Maturity & Customer Base (MCB) - This metric measures the maturity of a tool, as indicated by the customer satisfaction in the tool's ability to adequately test their software.
3. Tool Management(TM) - This metric measures the ability of Automated testing tools to provide for several users to access the information while ensuring proper management of the information.
4. Ease of Use (EU) - Ease of use accounts for the learning time of first-time users, retainability of procedural knowledge for frequent and casual users, and operational time of frequent and casual users.
5. User Control (UC) - This metric measures the ability of the testing tools that provide users expansive control over tool operations. It enables testers to effectively and efficiently test those portions of the program that are considered to have a higher level of criticality, have insufficient coverage, or meet other criteria determined by the tester. UC is defined as the summation of the different portions and combinations of portions that can be tested.
6. Test Case Generation (TCG) - This metric measures the ability of the test tools to automatically generate and readily modify test cases, either based on parsing the software under test or on modification to the software under test.
7. Tool Support (TS) - This metric measures the degree of technical support provided by the vendor.
8. Estimated Return on Investment (EROI) - This metric measures the estimated gain in productivity, software quality, and testing cost reduction against cost of tool investment.
9. Reliability (Rel) - This metric measures the average mean time between tool failures.
10. Maximum Number of Classes (MNC) - This metric measures the maximum number of software classes that may be included in a tool's testing project.
11. Maximum Number of Parameters (MNP) - This metric measures the maximum number of parameters that may be included in a tool's testing project.
12. Response Time (RT)- Time required to conduct a test case on specified size of software.
13. Features Support (FS) - This metric measures features like extensibility, database availability, integration with software development environment, and summary report generation.

These metrics were applied to the three testing-tool suites. During the process, we discovered that several of the metrics are quite difficult, if not impossible, to calculate without having additional information supplied by the tool vendor. For example, if a vendor has not conducted a study on the tool's operational retainability by its users, experiments would need to be designed and conducted to evaluate the performance of users in applying the tools. If a vendor does not have statistics on its average response time to customer support requests, calculating the measure would be impossible. Success was achieved in applying several of the metrics including HID, TCG, and reporting features (RF). HID measurements were calculated for each testing tool based on the sub-metrics of average keyboard-to-mouse switches, average input fields per function, average length of input fields, and button recognition when applicable. The sub-metrics demonstrated non-coarseness (different values were measured), finiteness (no metric was the same for all tools), and non-uniqueness (some equal values were obtained). The HID measurements were all unique, indicating that the measurement could be useful in comparing tools during the evaluation and

selection process. TCG measurements also provided unique measurements for each tool. Sub-metrics measuring levels of automated test-case generation and test case reuse functionality demonstrated the qualities of non-coarseness, finiteness, and non-uniqueness. RF measurements were also successful. It is simple to determine whether a tool automatically generates summary reports (SR) that are viewable without the tool application running (e.g., HTML or ASCII text document). The RF metric is non-coarse, finite, and non-unique. However, because each tool earned a SR score of one, additional testing should be conducted to determine SR's level of non-uniqueness.

PUBLICATIONS:

Murrah, M., Johnson, C. and Luqi, "Enhancements and Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of the 14th International Conference on Parallel and Distributed Computing Systems*, Dallas, TX, 8-10 August 2001.

Young, P., Berzins, V., Ge, J. and Luqi, "Use of Object Oriented Model for Interoperability Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

THESIS DIRECTED:

Johnson, C. and Piirainen, R., "Application of the Nogeuria Risk Assessment Model to Real-Time Embedded Software Projects," Masters Thesis, Naval Postgraduate School, June 2001.

Nelson, P., "A Requirements Specification of Modifications to the Functional Description of the Mission Space Resource Center," Masters Thesis, Naval Postgraduate School, June 2001.

Kwang Kin, B., "A Simple Software Agents Framework for Building Distributed Applications," Masters Thesis, Naval Postgraduate School, March 2001.

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Pugh, R., "Methods for Determining Object Correspondence during System Integration," Master Thesis, Naval Postgraduate School, June 2001.

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DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Conceptual Modeling, Simulation and Specifications, Risk Assessment, Computer Software

DYNAMIC ASSEMBLY FOR SYSTEMS ADAPTABILITY, DEPENDABILITY, AND ASSURANCE (DASADA) PROJECT

Luqi, Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: For NPS to support DARPA's efforts with the DASADA project in software technology and development for future adoption in military systems. The expected benefits of the proposed effort are to facilitate the transition of DASADA technologies to military applications, to prepare young officers for technical missions involving such technologies, and to lower barriers between warfighters and technologies. It is an investment for the training of out future admirals

SUMMARY: Important results accomplished in 2001 include:

- Conducted critical study and review of the 19 DASADA projects,
- Educated DoD engineers and military officers on DASADA technologies via distance learning,
- Conducted in-depth case study of one the EDP programs,
- Developed checklist and template for DASADA technology evaluation,
- Developed a guide to help DoD managers to select software metrics in acquiring new technologies for weapon systems software.

A review of the DARPA functional requirements listed in the request for proposals as well as various DASADA briefs, white papers, periodicals, and other DoD on-line resources was conducted. In addition, analysis generated from the DASADA program conference held at the Naval Postgraduate School, Monterey, CA from 31 January-2 February 2001 was completed. An in-depth analysis of the 19 DASADA technologies was conducted during the DARPA-sponsored demonstration held in Baltimore 4-5 June 2001.

An in-depth study of the Managed Information and Network Exchange Router (MINER) program was performed and a template was developed to ensure standardization and serve as a metric for approval or disapproval of the implementation of the DASADA technology in a specific software system. The template diagrams the software architecture, the system components, desired functionality, and logical relationship among components with respect to the DASADA technologies.

During the fact-finding efforts at the "DASADA Demo Days" in Baltimore, Maryland, a significant amount of insight into the development status of each of the projects as well as comprehensive information into each of the technologies was attained. It was observed that some of the projects were aggressively coordinating with other technologies as well as working with an Experimental Demonstration Project (EDP). Several projects just recently matured their technology to the point where they were going to contact one of the EDPs in the near future for demonstration purposes. Lastly, there was a hand full of projects that were not even close to the development level to demonstrate their projects much less than working with an EDP in the near future. It was found that the technologies, which are currently coordinating with industry on the development of embedded software systems, are the most applicable to the original spirit of the DASADA Program. These technologies include:

- MetaH (modeling, timing analysis),
- UNCLE (constraint consistency gauges),
- QRAM (resource allocation gauges),
- IMPACT (system load tracking and visualization),
- Proteus (run time and design time gauges for alternate architecture deployment).

This analysis also concludes that there are particular web and network-based systems that in all likelihood will prove to be of considerable benefit to DoD. These technologies include:

- SIM-TABASSCO (component interoperability gauges),
- Kinesthetics eXtreme (probes and gauges for runtime monitoring of web-based systems),
- Venice tool (design time component assembly tool).

There were two aspects of the DASADA program that warrant mentioning due to their success; the first being that DARPA deemed the best method to achieve the program objective was to merge academia with DoD projects so that the developing technologies had readily available real-world projects to demonstrate their advanced technological capabilities. The second aspect was the exposure to DoD engineers of the state-of-the-art software engineering technology that the DASADA program exemplifies during the DASADA Winter Principal Investigator (PI) Meeting in January 2001. To facilitate the transfer

of DASADA technologies to DoD users, we hosted the Winter PI meeting at the Naval Postgraduate School and arranged over 40 DoD engineers and military officers attended the meeting via distance learning.

A guide was also developed to help DoD managers on selecting the most effective set of software metrics to help DoD managers in acquiring new technologies for weapon systems software. The guide will be useful in helping DoD Managers to acquire future DASADA technologies.

THESIS DIRECTED:

Mandak, W. and Stowell, C., "Dynamic Assembly for System Adaptability, Dependability and Assurance (DASADA) Project Analysis," Masters Thesis, Naval Postgraduate School, June 2001.

Ramgolam, R., "A Guide to Selecting Software Metrics for the Acquisition of Weapon Systems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, DASADA

ENGINEERING AUTOMATION FOR RELIABLE SOFTWARE

Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: This research addresses the problem of how to produce reliable software that is also flexible and cost effective for the DoD distributed software domain. Current and future DoD software systems fall into two categories: Information systems and Warfighter systems. Both kinds of systems can be distributed, heterogeneous and network-based, consisting of a set of components running on different platforms and working together via multiple communication links and protocols. It was proposed to tackle the problem with a "wrap and glue" technology that is based on a domain specific distributed prototype model. The key to make this approach reliable, flexible, and cost-effective is the automatic generation of glue and wrappers based on the designer's specifications. Glue and wrappers are software that bridge the interoperability gap between individual COTS/GOTS components. Research was proposed on enabling technologies for this approach including prototyping, automatic program generation, inference for design checking, reliability assessment, and reliability improvement.

SUMMARY: The work focused on "wrap and glue" technology based on a domain specific distributed prototype model. The key to making the proposed approach reliable, flexible, and cost-effective is the automatic generation of glue and wrapper software based on a designer's specification. The proposed "wrap and glue" approach allows system designers to concentrate on the difficult interoperability problems and defines solutions in terms of deeper and more difficult interoperability issues, while freeing designers from implementation details. The objective of our research is to develop an integrated set of formal models and methods for system engineering automation. These results will enable building decision support tools for concurrent engineering.The research addresses complex modular systems with embedded control software and real-time requirements.

The longer-term goals are to construct an integrated set of software tools that can improve software quality and flexibility by automating a significant part of the process and providing substantial decision support for the aspects that cannot be automated. The resulting development environment should be adaptable to enable (1) maintaining integrated support in the presence of business process improvement, (2) incorporation of future improvements in engineering automation methods, and (3) specialization to particular problem domains.

In FY01, models and methods were investigated for solving the integration and interoperability problems in component-based distributed heterogeneous systems development.

The work resulted in models and languages for specifying the architecture of distributed heterogeneous systems and components, as well as technologies and tools to automate the integration of distributed heterogeneous software component via the automatic generation of glue and wrappers from specifications.

An object-oriented model for a wrapper-based translator was developed to resolve the representational differences between heterogeneous systems; an integrated development environment for users to create such models; methods for determining object correspondence during system integration; and the use of the Extensive Markup Language (XML) as a means for establishing interoperability between multiple DoD databases. Techniques were also developed for decision support for optimizing distributed object servers utilization, as well as the use software decoys to improve the security of distributed heterogeneous systems.

In addition, formal risk assessment models were investigated for the evolutionary software process. Methods and tools were formulated to assess the risk and the duration of software projects automatically, based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. The effectiveness of the models was validated by comparing the results of the models against data collected from 3 large real projects and 16 simulated projects.

Investigators worked with the U.S. Army TACOM to develop formal models and methods to assess the maturity/risk of emerging software technologies and to assist managers to size the software technology infrastructure.

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DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Engineering Automation, Reliability, Glue and Wrapper Technology, Computer-Aided Decision Support

IMPROVED SOFTWARE TECHNOLOGY FOR THE NEXT GENERATION AIRCRAFT CARRIER

Luqi, Professor
Department of Computer Science
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of the proposed project is to improve software technology in areas of concern to NAVSEA, and to apply the results to software issues arising in future aircraft carriers such as CVX. For example, we will investigate better ways to achieve software interoperability among aircraft carrier systems, and to identify and mitigate software-related risk factors in the early stages of the project, when requirements are fluid and detailed designs are not yet available.

SUMMARY: A. XML and Wrapper-based translators for system interoperability: In today's combat environment, the U.S. military and its allies find themselves in the midst of the information age they helped to start. This information and applied systems abound in all parts of the services and at locations throughout

the globe. To influence decisions, commanders and their respective staffs need the most up-to-date information available. This information comes from various sources, but especially from computer systems, many of which were developed over the last few decades before interoperability became a concern. These stovepipe systems cannot pass information to each other because they use incompatible message sets.

An object-oriented model for a "wrapper-based" translator was developed to resolve the representational differences between heterogeneous systems, which solves the data and operation inconsistency problem in legacy systems based on an Object-Oriented Model for Interoperability (OOMI). A Federation Interoperability Object Model (FIOM) is defined for a specific federation of systems designated for interoperation. The data and operations to be shared between systems are captured in a number of Federation Interoperability Classes (FICs) used to define the interoperation between legacy systems. Software wrappers are generated according to the FIOM that enable automated translation between different data representations and operation implementations. We also studied the use of XML-based message translation for implementation of the proposed model. The capability provided by the XML family of tools coincides nicely with the requirement for data and operation representation capture and translation.

B. Interoperability model for re-engineering legacy software: Legacy software systems in the Department of Defense (DoD) have been evolving and are becoming increasingly complex while providing more functionality. The shortage of original software designs, lack of corporate knowledge and software design documentation, unsupported programming languages, and obsolete real-time operating system and development tools have become critical issues for the acquisition community. Consequently, these systems are now very costly to maintain and upgrade in order to meet current and future functional and nonfunctional requirements.

A new interoperability model for re-engineering of old procedural software of the Multifunctional Information Distributed System Low Volume Terminal (MIDS-LVT) to a modern object-oriented architecture was developed. In the MIDS-LVT modernization acquisition strategy, only one Computer Software Configuration Item (CSCI) component at a time will be redesigned into an object-oriented program while interoperability with other unmodified CSCIs in the MIDS-LVT distributed environment must be maintained. Using this model, each legacy CSCI component can be redesigned independently without affecting the others. Lessons learned from this re-engineering effort will benefit future integration of legacy software in CVX and other DoD systems.

C. Quantitative risk assessment for software development: Formal risk assessment models and methods for the evolutionary software process and their application to CVX and DoD projects were investigated. The methods and tools to assess the risk and the duration of software projects automatically were analyzed and tested, based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. These metrics eliminate the subjectivity issue characteristic of previous research. Any decision-maker will arrive at the same estimates, independent of his or her expertise. The approach enables a project manager to evaluate the probability of project success very early in the life cycle. For more than twenty years the estimation standards (COCOMO 81, COCOMO II, Putnam) have been characterized by the common limitation that the requirements should be frozen in order to make estimations. The models remove this limitation, facing the reality that requirements are inherently variable. The effectiveness of the models was validated by comparing the results of the models against data collected from 16 simulated projects and 3 large, real projects.

1. Sixteen Simulated Projects: The simulations showed that the three risk factors observed during the causal analysis (efficiency, requirements volatility, and complexity) have compound effects over the three parameters of the Weibull distribution. The results of the models were illustrated against 16 simulated projects. Each model derives an increasing degree of accuracy based on: metrics from the three risk factors, Weibull cumulative density function, and the derivation of the time.
   - Models 1-2: Model 1 can be used when the requirements volatility is small. Model 2 considers the three factors (EF, RV, and CX), but neglects the combined effect of EF and RV. Figure 1 illustrates the results of the models that were calculated using 95% of confidence (p=0.95). Note the errors as vertical segments between the estimated and real values.
   - Model 3: Model 3, illustrated in Figure 2, considers the three factors as well as the combined effects of EF and RV. The analysis of variance shows that the samples obtained

from the simulations and the samples obtained from the estimates using Model 1, 2 or 3 cannot be statistically differentiated.

Another interesting result is that the errors remain in the range of ±15% for all of the scenarios. This result is interesting if we compare it with the results of COCOMO (±20% in the best cases). Barry Boehm in reference to the validation of COCOMO said, "In terms of our criterion of being able to estimate within 20% of projects actuals, Basic COCOMO accomplishes this in only 25% of the time, Intermediate COCOMO 68% of the time, and Detailed COCOMO 70% of the time."

- Model 4: Model 4, Figure 2, can be used for any range of complexity and requirements volatility, and considers the three factors, their combined effects, and the following a priori assumptions:
  * A project with 0 LGC will take 0 days
  * (, (, and (> 0
  * If RV increases the p(x<=t) decreases
  * If CX increases then p(x<=t) decreases
  * If EF increases then p(x<=t) increases

  The scatter plot derived compares the simulated times versus the estimated times. Most of the errors are overestimations and the duration of the project has no effect over the percentage of error. Model 4 is conservative. The maximum overestimation error was less than 16% and the maximum underestimation was less than 4%.

  Model 4 gives a good estimation for projects between 4,000 and 20,000 LGC (128 and 640 KLOC of ADA). The estimation seems to be too optimistic for projects smaller than 1000 LGC but it is quite good for larger projects.

2. Uruguayan Navy Project: Model 4 was applied on a war-gaming simulator with 75,240 lines of code. The software was made up of 1836 LGC and was developed in 1.5 years by the Uruguayan Navy. Model 4 predicts 17 months instead of 18 months, the actual development time.
3. U.S. DoD Project A: This project used an Evolutionary Spiral lifecycle model. It used Object-Oriented methodology and was composed of five computer software configuration items written in ADA. It was real-time embedded, and used Rational Rose as a Computer Aided Software Engineering tool with the developer operating at SEI level 3. In addition, software metrics from three builds over a period of three years had been kept.

   Model 4 was used to calculate the probability of completion curve for the project. For consistency, we used working days, defined as 22 days per month, the same as used in the original Nogueira model.

   The model predicted that the minimum time, in days, necessary to have a probability of completion of 100% is approximately 260 working days. When compared to the actual time it took, which was 336 working days, the model predicted completion sooner. The model predicted 76 working days less, or a 22.6% delta: (1 - (260 / 336)) (100) = 22.6%.

   At this point, with 22.6% variability, we decided to investigate and see what the original estimated completion date was from project records. The original estimation was 200 working days, with the project schedule slipping 136 working days for build 3. The developer missed the original completion estimation by 40.5%: (1- (200 / 336)) (100) = 40.5%.

   The Nogueira model missed the developer's original estimate by 23.1%: (1-(200 / 260)) (100) = 23.1%.

   This data point leaves us with an inconclusive position as to the validation of the model against the first project. It appears that there is a difference when using projects with real data versus simulated project data, reflecting what the real world is - unpredictable.
4. U.S. DoD Project B: This project originally used an incremental build lifecycle model and not an evolutionary model. It originally used Functional Decomposition methodology and was composed of six Computer Software Configuration Items. Written in ADA and assembly language, it was real-time embedded. It did use upper CASE tools, like Requirements Traceability Matrix (RTM), however did not use lower CASE tools such as Rational Rose. The development effort initially was performed in an ad-hoc manner with little software process involved and had experienced extreme volatility and poor metrics early in its development. However, due to a major restructure and overhaul of the project, and a shift of focus to institutionalizing software processes, (SEI CMM level 3 certification), the project migrated to Ada, and began using a modified Incremental

Build lifecycle model. In addition, suitable software metrics from two recent builds were available. We used Dr. Nogueira's Model 4 to calculate the probability of completion curve for Build 2 using; BR=2.59, DR=3.04, RV=5.63, O=2544, D=4010, T=1003. The model predicted Impossible.

Actual time for build 2 took from 4/24/00 until 7/10/00 or 68 working days at 22 working days a month. We believe this inconsistency is due primarily to the calculation for the LGC count being based on all six Computer Software Configuration Items (CSCI). Core functionality on three CSCIs; CSCI-A, CSCI-B, and CSCI-C had been previously developed and validated. However, the builds during this period, involved addition of functionality to the following CSCIs: CSCI-D, CSCI-E, and CSCI-F. That is, build 2 was modifying only a portion of the total software system code, but the LGC data gives a view of all six CSCIs combined.

The available data was not broken down into separate CSCIs, nor did it, post-mortem, identify the code that was being worked in a previous software release. We cannot fault the developer for not collecting metrics for research concepts that they are not aware of, nor do we believe that this type of data collection is a requirement of CMM level 3.

A finding of this research is the need to adjust the CX when applying the Nogueira model to evolved projects that are developing or enhancing only a portion of their CSCIs.

As previously stated, this project did not utilize a lower case tool such as Rational Rose. We believe use of such a tool is essential when attempting to apply the Nogueira formal model, as it provides the capability to collect detailed information, over the software development lifecycle. The data can later be extracted and used for input to the Nogueira model metrics.

D. Metrics for Weapon Systems Acquisition: Modernization of Department of Defense (DoD) weapon systems has resulted in an ever-increasing dependence on software. Despite technological advances in the software field, software development remains costly and one of the highest risk factors on most weapon system programs. The use of software metrics is a methodology for mitigating this uncertainty so that software development progresses under informed decision making. Software metrics are essential tracking tools used by program managers to monitor and control risk areas. However, the choice of metrics for a program is critical to their usefulness. We developed a guide to acquisition managers on selecting the most effective metrics to use in management of weapon system software. The study identified key issues in the use of software metrics experienced by program managers, and recommends a revised set of metrics and improvements to the use of metrics based on innovations and improvements in the software field as well as software estimation tools that facilitate the use of these software metrics.

E. Electronic maneuvering board and dead reckoning tracer decision aid for the Officer of the Deck: The U.S. Navy currently bases the majority of our contact management decisions around a time and manning intensive paper-based Maneuvering Board process. Additional manning requirements are involved on many Naval Ships in order to accurately convey the information to the OOD and/or the Commanding Officer. When given situations where there exist multiple contacts, the current system is quickly overwhelmed and may not provide Decision-Makers a complete and accurate picture in a timely manner.

A stand-alone system was developed that provides timely and accurate contact information for decision-makers. By creating a reliable, automated system in a format that is familiar to all Surface Warfare Officers we will provide the Navy with a valuable decision-making tool, while increasing ease of data exchange and reducing current redundancies and manning inefficient practices.

The software design is based upon the Unified Modeling Language (UML). UML allows us to construct a software model that is supported by the ADA programming language. Our design is based upon these fundamental tenants: Non-Operating System dependent, Non-Hardware System dependent, Extensible and Modular design. ADA provides a certified compiler, making our code robust and assuring the "buyer" that the program does what we advertise it to do.

F. Metrics for measuring the effectiveness of software testing tools: The levels of quality, maintainability, testability, and stability of software can be improved and measured through the use of automated testing tools throughout the software development process. Automated testing tools assist software engineers to gauge the quality of software by automating the mechanical aspects of the software-testing task. Automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Evaluating available tools and selecting the most appropriate suite of tools can be a difficult and time-

consuming process. We proposed a suite of objective metrics for measuring tool characteristics as an aide in systematically evaluating and selecting automated testing tools for both procedural and object-oriented source code.

The proposed metrics for evaluating testing tools include:

1. Human Interface Design (HID) - This metric measures whether the tools have well designed human interfaces to enable easy, efficient, and accurate setting of tool configuration. A large HID indicates the level of complexity in learning the tool's procedures and the likelihood of errors in using the tool over a long period of time.
2. Maturity & Customer Base (MCB) - This metric measures the maturity of a tool, as indicated by the customer satisfaction in the tool's ability to adequately test their software.
3. Tool Management(TM) - This metric measures the ability of Automated testing tools to provide for several users to access the information while ensuring proper management of the information.
4. Ease of Use (EU) - Ease of use accounts for the learning time of first-time users, retainability of procedural knowledge for frequent and casual users, and operational time of frequent and casual users.
5. User Control (UC) - This metric measures the ability of the testing tools that provide users expansive control over tool operations. It enables testers to effectively and efficiently test those portions of the program that are considered to have a higher level of criticality, have insufficient coverage, or meet other criteria determined by the tester. UC is defined as the summation of the different portions and combinations of portions that can be tested.
6. Test Case Generation (TCG) - This metric measures the ability of the test tools to automatically generate and readily modify test cases, either based on parsing the software under test or on modification to the software under test.
7. Tool Support (TS) - This metric measures the degree of technical support provided by the vendor.
8. Estimated Return on Investment (EROI) - This metric measures the estimated gain in productivity, software quality, and testing cost reduction against cost of tool investment.
9. Reliability (Rel) - This metric measures the average mean time between tool failures.
10. Maximum Number of Classes (MNC) - This metric measures the maximum number of software classes that may be included in a tool's testing project.
11. Maximum Number of Parameters (MNP) - This metric measures the maximum number of parameters that may be included in a tool's testing project.
12. Response Time (RT)- Time required to conduct a test case on specified size of software.
13. Features Support (FS) - This metric measures features like extensibility, database availability, integration with software development environment, and summary report generation.

These metrics were applied to the three testing-tool suites. During the process, we discovered that several of the metrics are quite difficult, if not impossible, to calculate without having additional information supplied by the tool vendor. For example, if a vendor has not conducted a study on the tool's operational retainability by its users, experiments would need to be designed and conducted to evaluate the performance of users in applying the tools. If a vendor does not have statistics on its average response time to customer support requests, calculating the measure would be impossible. Success was achieved in applying several of the metrics including HID, TCG, and reporting features (RF). HID measurements were calculated for each testing tool based on the sub-metrics of average keyboard-to-mouse switches, average input fields per function, average length of input fields, and button recognition when applicable. The sub-metrics demonstrated non-coarseness (different values were measured), finiteness (no metric was the same for all tools), and non-uniqueness (some equal values were obtained). The HID measurements were all unique, indicating that the measurement could be useful in comparing tools during the evaluation and selection process. TCG measurements also provided unique measurements for each tool. Sub-metrics measuring levels of automated test-case generation and test case reuse functionality demonstrated the qualities of non-coarseness, finiteness, and non-uniqueness. Reporting features (RF) measurements were also successful. It is simple to determine whether a tool automatically generates summary reports (SR) that are viewable without the tool application running (e.g., HTML or ASCII text document). The RF metric is non-coarse, finite, and non-unique. However, because each tool earned a SR score of one, additional testing should be conducted to determine SR's level of non-uniqueness.

PUBLICATIONS:

Young, P., Berzins, V., Ge, J. and Luqi, "Use of Object Oriented Model for Interoperability Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of the 14th International Conference on Parallel and Distributed Computing Systems*, Dallas, TX, 8-10 August 2001.

Murrah, M., Johnson, C. and Luqi, "Enhancements and Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

THESIS DIRECTED:

Bossuyt, B. and Snyder, B., "Software Testing Tools: Metrics For Measurement Of Effectiveness On Procedural And Object-Oriented Source Code," Masters Thesis, Naval Postgraduate School, September 2001.

Christie, B. and Young, P., "Integrated Development Environment (IDE) for the Construction of a Federation Interoperability Object Model (FIOM)," Masters Thesis, Naval Postgraduate School, September 2001.

Davis, D., "Evaluation of the Extensive Markup Language (XML) as a Means for Establishing Interoperability Between Multiple DoD Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Frantzen, J. and Ehresman, K., "Electronic Maneuvering Board and Dead Reckoning Tracer Decision Aid for the Officer of the Deck," Masters Thesis, Naval Postgraduate School, September 2001.

Halle, R., "Extensible Markup Language (XML) Based Analysis and Comparison of Heterogeneous Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Kwang Kin, B., "A Simple Software Agents Framework for Building Distributed Applications," Masters Thesis, Naval Postgraduate School, March 2001.

Johnson, C. and Piirainen, R., "Application of the Nogeuria Risk Assessment Model to Real-Time Embedded Software Projects," Masters Thesis, Naval Postgraduate School, June 2001.

Moua, T., "Application Programmer's Interface (API) for Heterogeneous Language Environment and Upgrading the Legacy Embedded Software," Masters Thesis, Naval Postgraduate School, September 2001.

Pugh, R., "Methods for Determining Object Correspondence during System Integration," Masters Thesis, Naval Postgraduate School, June 2001.

Ramgolam, R., "A Guide to Selecting Software Metrics for the Acquisition of Weapon Systems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software, Computer Technology, Interoperability, C4ISR, Combat Systems, CVX

MONTEREY WORKSHOP 2001 - ENGINEERING AUTOMATION FOR SOFTWARE INTENSIVE SYSTEM INTEGRATION

Luqi, Professor
Department of Computer Science
Sponsors: Office of Naval Research, Defense Advanced Research Projects Agency, U.S. Army Research Office, U.S. Air Force Office of Scientific Research

OBJECTIVE: This workshop is aimed at the dissemination and integration of recent research results related to the production of reliable cost-effective software for DoD in heterogeneous environments. A major goal for this workshop is to help the software engineering community focus on issues that are vital to improving the state of software engineering practice. This workshop focuses on all topics related to supporting engineering automation of reliable cost-effective integrated distributed software development processes. The purposes of the workshop are to assess current research efforts in this area, to identify results and directions that can increase the degree of automation, to aid tool integration by building a common understanding, and to increase the practical use of formal methods.

SUMMARY: The 2001 Monterey Workshop on Engineering Automation for Software Intensive System Integration is the 8th in a series of International workshops. The workshop was held in Monterey, California during 18-22 June 2001. The general theme of the workshop has been to present and discuss research works that aims at increasing the practical impact of formal methods for software and systems engineering. The particular focus of this workshop was "Engineering Automation for Software Intensive System Integration." Previous workshops have been focused on issues including, "Real-time and Concurrent Systems," "Software Merging and Slicing," "Software Evolution," "Software Architecture," "Requirements Targeting Software," and "Modeling Software System Structures in a Fast Moving Scenario."

A major goal for this series of workshops is to encourage the software engineering community in general to improve interaction between researchers and engineering practitioners. The workshop has long established itself as a summit where researchers from academics and industries can exchange recent results, assess their significance and earn motivation for transferring the relevant results to practice. This indeed is a forum where software engineers may communicate current problems in engineering practice to researchers and help focus to bridge the gap between the theoretical and practical sides of the subject.

It is no longer the case that theoretical foundations for computing are lacking. However, keeping in mind the challenge to put these results to work, the formal aspects of computing cannot be studied in isolation in the context of software engineering. The need to ensure that the assumptions on which formal models are based are consistent with the situations encountered in practical applications puts interdisciplinary requirements on researchers and lends importance to interactions between experts from heterogeneous backgrounds.

This year, apart from the distinguished panel of invited speakers, we have accepted contributed papers mainly to encourage the emerging researchers in software engineering. This has widened the scope of discussion and the sessions were highly interactive and rich with intellectual frictions in opinion from a broad range of experts. Members of the academic, government, military and commercial world exchanged their vision, insight and concerns on many important issues. The workshop has provided another step to reduce the gap between theory and practice of software engineering.

PUBLICATION:

Luqi, "Engineering Automation for Software Intensive System Integration," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, Automation, Research Assessment, System Integration

PERFORMANCE MEASUREMENT OF THE METCAST SERVER

Luqi, Professor
Department of Computer Science
Sponsors: Fleet Numerical Meteorology and Oceanography Center, and Space and Naval Warfare Systems Center – San Diego

OBJECTIVE: To measure the performance of the metcast server under real loads. Discover characteristics of the metcast connection loads and compare with business-to-consumer loads. Develop a benchmarking tool that reproduces metcast loads. Use the tool to micro-benchmark the server and suggest areas of improvement.

SUMMARY: Important results accomplished in 2001 include:

- Configured Metcast (the server and the obs decoder) on several Linux boxes. Used one box to run a set of performance texts. The other two Linux boxes serve as a development Metcast server.
- Developed a new version of Metcast Channels, which supports product attributes and has many performance enhancements. The version is backward compatible. The new version has been thoroughly documented.
- Participated in a Joint METOC Data Standard meeting and contributed to the development of Joint METOCV XML standard. Developed a draft JMGRIB format to markup gridded data

PUBLICATIONS:

Kiselyov, O., "Distributing Weather Products through an HTTP Pipe," 1 February 2001, http://zowie.metnet.navy.mil/~spawar/JMV-TNG/

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, Automation, Metcast Server

SYSTEM ENGINEERING AND EVOLUTION DECISION SUPPORT

Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: The objective of this effort is to develop a scientific basis for system engineering automation and decision support. This objective addresses the long term goals of increasing the quality of service provided by complex systems while reducing development risks, cost, and time. The effort focuses on decision support for designing operations of complex modular systems that can include embedded software. Emphasis areas include engineering automation capabilities in the areas of design modifications, design records, reuse, and automatic generation of design representations such as real-time schedules and software.

SUMMARY: Focused was on automation of design activities that appear in an evolutionary approach to system development. Decision support for design synthesis, reuse and evolution is emphasized. This research extended recently developed formal methods in system engineering to construct a cohesive set of formal models. These models are used to create and to connect automated processes for computer aided prototyping, requirements validation, and design synthesis. Mathematical models for implementing a set of automated and integrated engineering automation tools were also developed. Work combined very-high-level specification abstractions and concepts with: (1) formal real-time models, (2) automated management of system design data and human resources, (3) design transformations, (4) change merging, (5) automated retrieval of reusable system design components, and (6) automated schedule construction. We have created automated methods for: (1) generating real-time control programs, (2) generating simulations of subsystems, and (3) coordinating concurrent work by engineering teams. Work will ensure design consistency and alleviate communication difficulties.

The significance of the work is to:

- improve system effectiveness and flexibility,
- increase engineering productivity, and
- reduce system maintenance costs.

This was achieved by providing a higher level of engineering automation coupled directly with requirements validation facilities. The work will broaden the scope of engineering decision support to include concurrent whole-system engineering, requirement determination, and system evolution. Automated decision support will ensure system quality by decreasing the human effort required. This, in turn, will minimize the incidence of human error. The trial use of operational system prototypes linked with software simulations of selected subsystems enables users to provide feedback for validation and refinement of system requirements prior to detailed design. Maintenance costs can be minimized by reducing the need to repair requirement errors after system deployment. Methods for process and system re-engineering at minimal cost were provided This was achieved by: (1) regenerating new variations of designs from high-level decisions. (2) combining changes, and (3) propagating the consequences of design modifications. These engineering capabilities will enable the Army to improve and integrate its complex systems with reduced costs. Improved systems can reduce Army manpower needs while strengthening information warfare capabilities.

Specific tasks accomplished include:

- Formal models, architecture and tools for software evolution: A new relational hypergraph model, architecture and tools for the computer-aided software evolution process was developed. The new model provides an integrated framework for integrating software evolution activities with configuration control, maintaining the consistency of an evolving system, organizing and coordinating the activities involved in the evolution of large systems. The model also serves as the basis for organizing the repository of configurations. The effectiveness of the model was illustrated via a case study involving C4I systems evolution.
- Formal model for software project risk assessment: Formal risk assessment models for the evolutionary software process, and methods and tools were developed to assess the risk and the duration of software projects automatically based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. The effectiveness of the models was validated by comparing the results of the models against data collected from 3 large real projects and 16 simulated projects.
- Architectures and automated retrieval methods for software reuse: Formal models and methods to automate the search and retrieval of software components from software reuse repositories were developed. Models to support reuse in product line approach were also developed.
- The use of Computer Aided Prototyping in Software Re-engineering: The effective use of computer-aided prototyping techniques were studied for re-engineering legacy software via a case study involving the development an object-oriented modular architecture for the existing US Army Janus(A) combat simulation system, and validating the architecture via an executable prototype using the Computer Aided Prototyping System (CAPS). The research showed that prototyping can be a valuable aid in re-engineering of legacy systems, particularly in cases where radical changes to system conceptualization and software structure are needed.
- Automation support for distributed heterogeneous systems engineering: Models and methods for solving the integration and interoperability problems in component-based distributed heterogeneous systems development were investigated.

  The work resulted in models and languages for specifying the architecture of distributed heterogeneous systems and components, as well as technologies to automate the integration of distributed heterogeneous software component via the automatic generation of glue and wrapper from specification.

  An object-oriented model for an interoperability wrapper-based translator was developed to resolve the representational differences between heterogeneous systems, an integrated development environment for users to create such models, methods for determining object correspondence during system integration, and the use of the Extensive Markup Language (XML) as a means for establishing interoperability between multiple DoD databases.

Techniques were also developed for maximizing the network infrastructure and provide decision support for optimizing distributed object servers utilization, as well as the use software decoys to improve the security of distributed heterogeneous systems.

- Formal models for Technology Transition: Investigators worked with the U.S. Army TACOM to develop formal models and methods to assess the maturity/risk of emerging software technologies and to assist managers to size the software technology infrastructure.
- Technology transfer via Software Engineering education: To allow corporate and Department of Defense (DoD) software leaders and practitioners to effectively utilize the technology available to them, two Software Engineering graduate degree programs were developed to address the issues and needs unique to DoD software development. The Software Engineering program at the Naval Postgraduate School offers M.S. and Ph.D. degrees in Software Engineering to both in-residence and distance-learning students, to equip software leaders and practitioners with the tools needed to achieve information superiority. The Ph.D. Program is the first-ever doctoral program in Software Engineering. It is designed to satisfy the great and growing demand within the Department of Defense for Ph.D. level leadership to direct software research and development projects and to develop policies regarding software requirements and processes for design, evolution, reuse and management.

PUBLICATIONS:

Auguston, M., "Visual Meta-Programming Notation," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of the 14th International Conference on Parallel and Distributed Computing Systems,* Dallas, TX, 8-10 August 2001.

Kiselyov, O., "Subclassing Errors, OOP & Practically Checkable Rules to Prevent Them," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Luqi, Berzins, V. and Shing, M., "The Use of Computer-Aided Prototyping for Reengineering Legacy Software," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Luqi, Berzins, V., Ge, J., Shing, M., Auguston, M., Bryant, B. and Kin, B., "DCAPS - Architecture for Distributed Computer Aided Prototyping System," *Proceedings of the 12th IEEE International Workshop on Rapid System Prototyping (RSP2001),* pp. 103-108, Monterey, CA, 25-27 June 2001.

Michael, J. and Riehle, R., "Intelligent Software Decoys," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Murrah, M., Johnson, C. and Luqi, "Enhancements and Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Raje, R., Auguston, M., Bryant, B., Olson, A. and Burt, C., "A Unified Approach for the Integration of Distributed Heterogeneous Software Components," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Ray, W. and Berzins, V., "Optimization of Distributed Object-Oriented Servers," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Saboe, M. and Luqi, "A Software Technology Transition Engine," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Young, P., Berzins V., Ge, J. and Luqi, "Use of Object Oriented Model for Interoperability Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

THESIS DIRECTED:

Kwang Kin, B., "A Simple Software Agents Framework for Building Distributed Applications," Masters Thesis, Naval Postgraduate School, March 2001.

Davis, E., "Evaluation of the Extensive Markup Language (XML) as a Means for Establishing Interoperability Between Multiple DoD Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Halle, R., "Extensible Markup Language (XML) Based Analysis and Comparison of Heterogeneous Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Johnson, C. and Piirainen, R., "Application of the Nogueira Risk Assessment Model to Real-Time Embedded Software Projects," Masters Thesis, Naval Postgraduate School, June 2001.

Mandak, W. and Stowell, C., "Dynamic Assembly for System Adaptability Dependability and Assurance (DASADA) Project Analysis," Masters Thesis, Naval Postgraduate School, June 2001.

Nelson, P., "A Requirements Specification of Modifications to the Functional Description of the Mission Space Web-based Tool," Masters Thesis, Naval Postgraduate School, June 2001.

Pugh, R., "Methods for Determining Object Correspondence during System Integration," Masters Thesis, Naval Postgraduate School, June 2001.

Windhurst, W., "An Application of Role-Based Access Control in an Organizational Software Process Knowledge Base," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: System Engineering, Decision Support, Evolution, Concurrent Engineering

WEAPON SOFTWARE SAFETY PROGRAM IN NPS SOFTWARE ENGINEERING AUTOMATION CENTER

Luqi, Professor
Department of Computer Science
Sponsors: Naval Sea Systems Command

OBJECTIVE: For Software Engineering Automation Center at the Naval Postgraduate School to support instructional effort for Software Engineering Courses on weapon software safety in software engineering curriculum, and to establish a weapon software safety chair and computer/telecommunication support.

SUMMARY: Modern weapon systems rely on software for virtually all aspects of their functionality. Software controls almost all aspects from the detection and classification of threats to launching the ordnance, guiding it to the threat, and, in some cases, initiating the explosive warhead. An error or failure in any of the software modules controlling the weapon system could have catastrophic results from

misidentifying a friendly track as hostile to initiating the warhead while still in close proximity to the launching platform.

The Navy needs highly trained individuals capable of developing and assessing the software for modern weapon systems to ensure that it can reliably perform its mission without posing an unacceptable risk to the fleet. Weapon Systems Software Safety is a discipline that integrates Systems Engineering, System Safety Engineering, and Software Engineering into a cohesive discipline that provides the knowledge and skills necessary to perform this risk assessment. The discipline is Software Engineering intensive due to the complexity of the software in modern weapon systems however; it uses a true Systems Engineering approach to address the issues. The proposed curriculum will provide a cadre of individuals trained in the development of critical software with the fundamental knowledge necessary to develop software that provides and acceptable level of risk in the system and operational context without sacrificing mission effectiveness or functionality. Key courses in the curriculum will also provide individuals with the knowledge and skills necessary to perform the required design, analysis, testing, and risk assessment to verify the safety of the software in the system context.

Software Engineering and Information Technology are rapidly evolving disciplines. The Naval Postgraduate School is at the forefront of both disciplines. To be effective, the Weapon Systems Software Safety must evolve with these disciplines and provide the direction necessary to maintain both the effectiveness and safety of the associated technology as it is applied to Navy weapon systems. NPS is in an enviable position to accomplish that mission. Qualified individuals must also perform both the theoretical and applied research necessary to provide the Weapon System Safety community with the tools and techniques necessary to assess the risk associated with the introduction of new technologies, the integration of existing technologies with our existing systems, as well as the integration of existing system into systems of systems. The students at NPS have backgrounds directly relevant to the discipline: many have first hand experience with the software developed for modern weapon systems. Therefore, NPS has a cadre of highly skilled individuals available to conduct this vital research.

The student body consists of individuals who will be managing weapon system programs involving software, managing the development of software for future weapon systems, or perhaps even developing the software themselves. The position will allow the direction of thesis and research topics to provide the necessary tools and techniques to evaluate software in complex weapon systems. The position will also allow direct access to research conducted at NPS and other universities in Software Engineering and Information Technology and evaluate its application, or possible impact, on the safety of modern weapon systems. Evaluating this research gives the Navy the opportunity to address these topics before they become a part of a Navy weapon system.

THESIS DIRECTED:

Brown, M., "Modeling and Reasoning about Safety Properties for Systems Interoperability and Systems of Systems," draft dissertation, Naval Postgraduate School.

Williams, C., "A Formal Application of Safety and Risk Assessment in Software Projects," draft dissertation, Naval Postgraduate School.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, Weapon Systems Software Safety, Automation

FY01 IO/IW RESEARCH ON INTELLIGENT SOFTWARE DECOYS

Bret Michael, Associate Professor
Department of Computer Science
Sponsor: Naval Information Warfare Activity

OBJECTIVE: Further investigate the technical feasibility of an intelligent software decoy architecture for use in information warfare.

SUMMARY: The notion of an intelligent software decoy was developed, providing both an architecture and initial description of an event-based language for automatic implementation of decoys. The decoys detect and respond to patterns of suspicious behavior, and maintain a repository of rules for behavior patterns and decoying actions. In order to illustrate our concept and approach, a model was constructed of system behavior from an initial list of event types and their attributes in the interaction between computer worms and an operating system. The model represents patterns of suspicious or malicious events that the software decoy should detect, and specific actions to be taken in response. The approach explicitly treats both standard and nonstandard invocations of components, with the latter representing an attempt to circumvent the public interface of the component.

At present various decoying strategies are being explored and the decoying action language is being expanded with the aim of supporting information operations and warfare. We are also implementing the event-based language, with the aim of running experiments using the language to test decoying strategies, and conduct performance analyses with the aim of determining the amount of overhead that will be generated by the decoying mechanism.

PUBLICATIONS:

Michael, J.B. and Riehle, R.D., "Intelligent software decoys," *Proceedings of Monterey Workshop: Engineering Automation for Software Intensive System Integration*, pp. 178-187, Naval Postgraduate School, Monterey, CA, June 2001.

PRESENTATIONS:

Michael, J.B., Auguston, M., Rowe, N.C. and Riehle, R.D. "Software Decoys: Intrusion Detection and Countermeasures," *Proceedings of Info Assurance Workshop*, IEEE, West Point, NY, June 2002, in press.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Behavior Modeling, Computer Security, Computer Worm, Event Trace, Software Decoy, Intrusion Detection, Intrusion Tolerance

TESTING OF LARGE SOFTWARE-INTENSIVE SYSTEMS

Bret Michael, Associate Professor
Department of Computer Science
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of the research project is threefold: (i) To provide expertise to SPAWAR corporation in the area of software testing, and more generally, formal verification and validation, in both overseeing and participating in the Defense Systems Test and Productivity Initiative (DSTPI). This objective entails two tasks: identifying key areas of research and technology transfer that the DSTPI should address and overseeing the research performed by the University of South Florida as part of the DSTPI to ensure that the research is relevant to the needs of SPAWAR, the Department of the Navy (DoN), and the Department of Defense (DoD). (ii) To integrate the outcomes and general deliverables of the DSTPI, as appropriate, into the computer science and software engineering curricula at the Naval Postgraduate School to SPAWAR, as well as to transfer the results of the curriculum development and research by faculty and students at the School to SPAWAR, the DoN, and DoD. The transfer of outcomes and general deliverables to the curricula will assist the School in preparing naval officers to return to the Fleet with the latest theory and knowledge of best practices to specify and acquire software that is testable, of known pedigree, and maintainable. In the other direction, the faculty and students can transfer their research result on testing, and more generally, formal verification and validation of software-intensive systems, to the other participants in the DSTPI. In order to facilitate the exchange of technology and influence the direction of the DSTPI, Dr. Michael will participate as a member of the Advisory Board of the DSTPI. (iii)To perform research on a novel approach to testing large software-intensive systems. Dr. Michael, along with Dr. Neil Rowe and a team of graduate students, are investigating the technical feasibility of testing policy and system requirements with the goal of detecting gaps (e.g., inconsistencies in policy or requirements) prior

to refining policy into requirements, and requirement into lower-level system artifacts (e.g., architectures, designs, code, documentation) [2,3]. We believe that our approach to testing systems can significantly improve the ability of the DoD to both acquire and maintain high-quality software for large systems. This work is based on the concept of a policy workbench [5]: an integrated set of tools for specifying policy and requirements, testing policy and requirements, refining policy and requirements into executable or interpretable specifications, and maintaining the policy, requirements, and other system artifacts.

SUMMARY: A suite of objective metrics was developed for measuring the characteristics of automated software-testing tools, as an aid for systematically evaluating and selecting automated testing tools. The metrics are independent of architectural frameworks and lower level software system artifacts. Such metrics are needed because automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Decision makers can use the metrics to select amongst alternative automated software testing tools, matching the suite of tools to the needs of a particular software-development project. Experiments were constructed to test the feasibility of generating the test metrics for different versions of a medium-sized software system: one version implemented using a semi-structured procedural design with known faults, and a second version implemented using a well-structured object-oriented design. It was found that we could generate most of the metrics, while other of the metrics would be difficult to compute due to a lack of data or an inability to extract such data about the performance of the tools. Present investigations focus on the validity of the suite of metrics. The investigator is conducting similar research using a larger software testbed, and incorporating additional commercial-off-the-shelf (COTS) tools into the study.

In addition, a rapid prototyping tool was invented, as part of a policy workbench, which automatically tests the logical consistency of policy. A policy workbench supports the rapid prototyping of systems in support of reasoning about policy prior to both committing updates to a policy base and refining policy into requirements and other artifacts of an information system. The approach to testing policy is novel in that test cases and scripts are generated automatically based on the detection of patterns extracted from structural models of policy, which are represented via Unified Modeling Language (UML) class and collaboration diagrams. The automatic classification and detection of patterns is based on temporal, counting, and sequence properties of policies, in addition to the relationships between policy objects. Investigators experimented with our testing-tool component, along with other tools of the policy workbench, using as input to our tools a set of security policies from a well-known published case study.

The investigator served on the Interim Government Advisory Board (GAB), providing oversight and guidance to the federally funded National Institute for Systems Test and Productivity, located at the University of South Florida, Tampa, Fla.

THESIS DIRECTED:

Sezgin, M., "A Pattern-Making Approach for Automated Scenario-Driven Testing of Structured Computational Policy," Masters Thesis, Naval Postgraduate School, September 2001.

Bossuyt, B.J. and Synder, B.B., "Software Testing Tools: Analyses of Effectiveness on Procedural and Object-Oriented Source Code," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Automated Testing, Computer Security, Metrics, Policy Workbench, Software, Test Patterns, Testing Tools

DETECTION OF CHANGES OVER TIME IN LINEAR FEATURES IN AERIAL PHOTOGRAPHS

Neil C. Rowe, Professor
Department of Computer Science
Sponsor: Navy Engineering Logistics Office

OBJECTIVE: A prototype system to find changes between aerial photographs of the same terrain at different times will be developed.

SUMMARY: Work in 2001 extended the earlier work that compared linear features between two photographs of the same terrain taken at different times to find important differences in roads and buildings. The new work compared the regions of the picture to detect differences in irregular and curved areas that cannot be detected by just comparing linear features. This did, however, require more complex matching since regions can have many more features than edge segments. Brightness, brightness variation, narrowness, orientation of the major axes, irregularity of the boundary, as well as comparing the largest straight segments along the boundary was examined. A relaxation process is used to find the best matches between regions of the two pictures: First initial matches are rated, then rerated using local consistency of matches of neighboring regions. The result is a more accurate match between the two pictures as well as one that recognizes differences not found by linear matching.

PUBLICATIONS:

Rowe, N.C. and Grewe, L., "Change Detection for Linear Features in Aerial Photographs Using Edge-Finding," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 39, No. 7, pp. 1608-1612, July/August 2001.

Ingram, D.J., Kremer, H.S. and Rowe, N.C., "Distributed Intrusion Detection for Computer Systems Using Communicating Agents," *Sixth International Symposium on Research and Technology on Command and Control*, June 2001.

Michael, J.B., Ong, V. and Rowe, N.C., "Natural-Language Processing Support for Developing Policy-Governed Software Systems," *39th International Conference on Technology of Object-Oriented Languages and Systems*, Santa Barbara, CA, July-August 2001.

THESES DIRECTED:

Alves, J., "Recognition of Ship Types from an Infrared Image Using Moment Invariants and Neural Networks," Masters Thesis, Naval Postgraduate School, March 2001.

Aragon, A., "Agent-Based Simulation of a Marine Infantry Squad in an Urban Environment," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human-Systems Interface

KEYWORDS: Image Processing, Difference Image, Image Registration Aerial Photography, Terrain Databases

MAGMA: MOBILE CODE APPROACH TO SERVER FAULT TOLERANCE

Geoffrey Xie, Assistant Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: Network middleware support for mobile agent based survivable services is being developed.

SUMMARY: Progress was made in the following areas: general system requirements and specifications, and implementation of a system prototype to demonstrate the feasibility of the proposed approach. One M.S. thesis has been produced as a result.

PUBLICATIONS:

Xie, G.G., *Network Protocols for Building Survivable Services*, Technical Report, NPS-CS-02-004, Department of Computer Science, Naval Postgraduate School, December 2001.

THESIS DIRECTED:

Margulis, S., "MAGMA: A Liquid Software Approach to Fault Tolerance, Computer Security and Survivable Networking," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control and Communications

KEYWORDS: Mobile Code, Liquid Software, Fault Tolerance, Survivable Networks

SAAM: NETWORK MANAGEMENT SYSTEM FOR INTEGRATED SERVICES

Geoffrey Xie, Assistant Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: A novel server and agent based active management system for the next generation Internet is being developed.

SUMMARY: Progress was made in the following areas: realistic traffic generation, dynamic bandwidth provisioning, rerouting of real-time flows, survivable SAAM service, best effort traffic engineering, policy-based networking, and application of SAAM concept in underwater acoustic networks.

The SAAM prototype system has been enhanced to incorporate the aforementioned work. Three M.S. theses have been produced as a result.

PUBLICATIONS:

Stone, G., Lundy, G. and Xie, G.G., "Network Policy Languages: A Survey and a New Approach," IEEE Network, Vol. 15, No. 1, pp 10-21, January 2001.

Xie, G.G. and Gibson, J.H., "A Network Layer Protocol for UANs to Address Propagation Delay Induced Performance Limitations," *Proceedings of MTS/IEEE Oceans 2001 Conference*, pp 2087-2094, Honolulu, HI, November 2001.

PRESENTATION:

Xie, G.G. and Gibson, J.H., "A Network Layer Protocol for UANs to Address Propagation Delay induced Performance Limitations," MTS/IEEE Oceans 2001 Conference, Honolulu, HI, November 2001.

THESES DIRECTED:

Turksoyu, F., "Realistic Traffic Generation Capability for SAAM Testbed," Masters Thesis, Naval Postgraduate School, March 2001.

Wright, T., "Fault Tolerance in the Server and Agent-based Network Management (SAAM) System," Masters Thesis, Naval Postgraduate School, September 2001.

Silva, P., "Advanced Quality of Service Management for Next Generation Internet, " Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Command, Control and Communications

KEYWORDS: Network Management, Integrated Services, Asynchronous Transfer Mode (ATM), Quality of Service (QoS), Policy Based Networking, Network Security

CONTEXT MACHINE - A DEVICE TO DETERMINE CONTEXT FROM SYMBOLIC INPUTS

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
Perry McDowell, Lecturer
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The purpose of the Augmented Cognition program is to increase the information management capacity of the human-computer warfighting integral by developing and demonstrating quantifiable enhancements to human cognitive ability in diverse, stressful, operational environments of the U.S. warfighter by several orders of magnitude.

SUMMARY: The MOVES Institute at the Naval Postgraduate School is participating in the DARPA Augmented Cognition Program by creating the Context Machine to explore the notion of "context" in a general way, and to study how such a device might improve future warfighting capabilities. The user's current situation, such as their location, their objectives, and the presence of other people and objects, are inputs to the Context Machine. The machine uses the information to determine context. Based upon this context, it determines the best course of action to achieve the user's goals, which is then conveyed to the user. It is imperative that the assistance supplied by the Context Machine be appropriate to the situation, useful, and wanted.

The first step in this research was to identify those situations in which the Context Machine would prove most useful. Those situations are found when the user:

- Cannot understand information in the environment
- Cannot perceive certain information in the environment
- Does not have time to process information in the environment
- Can process the environment, but does not have time to communicate what has been processed.

The second step was to build a software platform for investigation into varying definitions of perception and cognition. A commercial game engine was selected, because of its ready availability from another project, its broad functionality, the ease with which it can be modified, and its reliance on commercial off-the-shelf hardware and software.

A software prototype was successfully constructed, in which the Context Machine aids an infantryman on a clandestine reconnaissance mission. This demonstration was presented to the DARPA sponsor, as well as to numerous distinguished visitors to the Naval Postgraduate School.

As a result of these efforts, the project has been funded for an additional three years.

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DoD KEY TECH AREAS: Battlespace Environments, Command, Control, and Communications, Computing and Software, Human Systems Interface, Modeling and Simulation .

KEYWORDS: Virtual Reality, Augmented Cognition, Perception Modeling, Augmented Reality

DEPARTMENT OF COMPUTER SCIENCE

2001
Faculty Publications and Presentations

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DEPARTMENT OF COMPUTER SCIENCE

Thesis Abstracts

IMPLEMENTATION OF DATA FLOW QUERY LANGUAGE (DFQL)

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A relational database management system (RDBMS) is a software product that structures data in accordance with the relational data model and permits data manipulation based on relational algebra. There are two widely-used query languages for the relational database management systems (RDBMSs). These are Structured Query Language (SQL) and Query By Example (QBE). Although these languages are powerful, they both have drawbacks concerning ease-of-use, especially in expressing universal quantification and specifying complex nested queries.

In order to eliminate these problems, Data Flow Query Language (DFQL) has been proposed. DFQL offers an easy-to-use graphical user interface to the relational model based on a data flow diagram, while maintaining all of the strengths of SQL and QBE.

The purpose of this thesis is to implement DFQL, allowing the users to login one or more relational database(s) through JDBC, view the structure of the connected databases graphically, and implement inquiries in SQL and DFQL to retrieve the data from the database(s).

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface

KEYWORDS: Structure Query, SQL, QBE, Data Flow Query Language, DFQL, Java, JDBC, Database Structure

BLUETOOTH TECHNOLOGY AND ITS IMPLEMENTATION IN SENSING DEVICES

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Second Reader: Wolfgang Baer, Department of Computer Science

Bluetooth Wireless technology is the world's new short range RF transmission standard for small form factor, low cost, and short-range radio link between portable and desktop devices. This technology does not replace Wireless LANs rather it compliments them. Bluetooth wireless technology has many advantages over other Wireless LAN technologies, which makes it attractive to many applications. One such application is in the area of sensors and gauges on-board ships and submarines. If these are connected wirelessly, a huge amount of cables are eliminated and more user mobility is gained.

This thesis studies the theories and principles of Bluetooth technology and discusses the approaches of connecting Bluetooth to sensors and gauges. Some of the Bluetooth products available in the market were acquired for testing and evaluation. In the course of the study, it was found that the technology was not mainly developed with sensor and gauge applications in mind. However, integrating sensors with Bluetooth modules can be achieved by one of two approaches. One approach requires an expensive Development Kit and is limited to manufacturers integrating Bluetooth technology into their sensor products in compliance with Bluetooth Specifications. The other inexpensive approach requires custom circuit designing and program coding and is preferred by university researchers.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

KEYWORDS: Bluetooth Wireless Technology, Short Range RF Transmission Standard

RECOGNITION OF SHIP TYPES FROM AN INFRARED IMAGE USING MOMENT INVARIANTS AND NEURAL NETWORKS

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Autonomous object recognition is an active area of interest for military and commercial applications: Given an input image from an infrared or range sensor, interesting objects can be found in those images and then classified. In this work, automatic target recognition of ship types in an infrared image is explored. The first phase segments the original infrared image in order to obtain the ship silhouette. The second phase calculates moment functions of those silhouettes that guarantee invariance with respect to translation, rotation and scale. The third phase applies those invariant features to a back-propagation neural network and classifies the ship as one of the five types. The algorithm was implemented and experimentally validated using both simulated three-dimensional ship model images and real images derived from video of an AN/AAS-44V Forward Looking Infrared (FLIR) sensor.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Automatic Target Recognition, Artificial Neural Network, Infrared Image Recognition, Moment Invariants

AGENT-BASED SIMULATION OF A MARINE INFANTRY SQUAD IN AN URBAN ENVIRONMENT

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This thesis research focused on the design, development and implementation of an agent based simulation of a Marine infantry squad in an urban environment. The goal was to design an autonomous-agent framework that could model a combatant's decision cycle. A squad entity comprised of these agents was created to explore the idea of team dynamics and the balance between meeting individual goals and team goals. The agents were placed in a two-dimensional, discrete-state, simulation world with a simple model of urban infrastructure. The squad goal was to patrol through the environment using checkpoints. The individual agent goals were to move to a destination and maintain the squad formation. The critical issues of agent movement were collision detection/avoidance, goal managing and forward planning. Distinguishing the agents by their role in the squad allowed a single agent to act as the squad leader. This agent was given the ability to plan a path to accomplish the squad's overall goal as a series of sub-goals, which was successful in getting the majority of the agents to their checkpoints in squad formation. The design of the simulation program facilitates further research in using autonomous agents to model small-units in an urban environment.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Agent Based Simulation, Two-Dimensional, Discrete State

INERTIAL AND MAGNETIC TRACKING OF LIMB SEGMENT ORIENTATION FOR INSERTING HUMANS INTO SYNTHETIC ENVIRONMENTS

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Current motion tracking technologies fail to provide accurate wide area tracking of multiple users without interference and occlusion problems. This research proposes to overcome current limitations using nine-axis magnetic/angular rate/gravity (MARG) sensors combined with a quaternion-based complementary filter algorithm capable of continuously correcting for drift and following angular motion through all orientations without singularities.

Primarily, this research involves the development of a prototype tracking system to demonstrate the feasibility of MARG sensor body motion tracking. Mathematical analysis and computer simulation are used to validate the correctness of the complementary filter algorithm. The implemented human body model utilizes the world-coordinate reference frame orientation data provided in quaternion form by the complementary filter and orients each limb segment independently. Calibration of the model and the inertial sensors is accomplished using simple but effective algorithms. Physical experiments demonstrate the utility of the proposed system by tracking of human limbs in real-time using multiple MARG sensors.

The system is "sourceless" and does not suffer from range restrictions and interference problems. This new technology overcomes the limitations of motion tracking technologies currently in use. It has the potential to provide wide area tracking of multiple users in virtual environment and augmented reality applications.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Micromachined Sensors, Complementary Filtering, Quaternions, Motion Capture, Networked Virtual Environments, Human Modeling, MARG Sensors, Inertial Sensors, Magnetic Sensors

IMPLEMENTATION OF A HYPERTEXT TRANSFER PROTOCOL SERVER ON A HIGH ASSURANCE MULTI-LEVEL SECURE PLATFORM

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In a client/server environment on a local area network (LAN), a server should provide various network applications including a hypertext transfer protocol (HTTP) server. HTTP is a client/server, request/response application protocol that is used on the World Wide Web (WWW). It provides the definition and means for transferring objects across internets. A server used in the context of a multi-level secure (MLS) LAN should be no exception. A MLS LAN should be capable of providing an HTTP web server that can be used by commercially available web browsers executing on client workstations. This server needs to be aware of the MLS environment and provide clients access to all web pages and objects for which they are authorized.

This thesis implements an HTTP web server running on a high assurance host in a MLS LAN. The web server is based on a commercially available web server application. The commercially available application has been modified and configured to run on the high assurance host. This thesis discusses the details for implementing the web server on the high assurance host.

The result of this thesis is an HTTP web server application that runs on a high assurance host servicing clients on a MLS LAN that are using commercially available web browsers. These clients now have the capability of web browsing at varying levels of classification on one workstation.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Hypertext Transfer Protocol, Web Server, Multi-level Secure, Local Area Network, High Assurance

SOFTWARE TESTING TOOLS: METRICS FOR MEASUREMENT OF EFFECTIVENESS ON PROCEDURAL AND OBJECT-ORIENTED SOURCE CODE

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The levels of quality, maintainability, testability, and stability of software can be improved and measured through the use of automated testing tools throughout the software development process. Automated testing tools assist software engineers to gauge the quality of software by automating the mechanical aspects of the software-testing task. Automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Evaluating available tools and selecting the most appropriate suite of tools can be a difficult and time-consuming process. In this thesis, a suite of objective metrics is proposed for measuring tool characteristics, as an aide in systematically evaluating and selecting automated testing tools. Future work includes further research into the validity and utility of this suite of metrics, conducting similar research using a larger software project, and incorporating a larger set of tools into similar research.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software Engineering, Software Automation

USER-CENTERED ITERATIVE DESIGN OF A COLLABORATIVE VIRTUAL ENVIRONMENT

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Most tasks that are desirable to train in a virtual environment are not tasks that we do alone, but rather are executed collaboratively with one or more team members. Yet little is known about how to construct virtual environment training systems that support collaborative behavior. The purpose of this thesis was to explore methodologies for developing collaborative virtual environments for training. The approach centered on analyzing task or training specific requirements for the simulation environment. User-centered design techniques were applied to analyze the cognitive processes of collaborative wayfinding to develop interface design guidelines. The results of our analysis were utilized to propose a general model of collaborative wayfinding. This model emphasizes team collaboration and interaction in problem solving and decision-making. The model in the field, using cognitive task analysis methods to study land navigators. This study was intended to validate the use of user-centered design methodologies for the design of collaborative virtual environments. Our findings provide information useful to design, ranging from model enhancement to interface development. The cognitive aspects of collaborative human wayfinding and design for collaborative virtual environments have been explored. Further investigation of design paradigms should include cognitive task analysis and behavioral task analysis.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Environments, Wayfinding, Collaboration, Land Navigation, Virtual Reality, User-Centered Design

WEB-BASED TESTING TOOLS FOR ELECTRICAL ENGINEERING COURSES

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This thesis presents a distance-learning tool, which provides a self-sufficient application that allows one to implement online courses for electrical engineering. A major emphasis is placed on replacing simplistic multiple-choice or true-false test questions. A system named, Distance Learning Tools for Online Tests (DLTOT) is designed, modeled and implemented.

The implementation is based on the Java programming language, using Servlets and Java Server Pages (JSP), three-tier technology and Commercial-Off-The-Shelf (COTS) products, namely, an Apache web server, Tomcat Application server, Microsoft Access, Mathematica, WebMathematica and JSP/Servlet technology.

DLTOT is able to control student access, to allow interaction with the student during the course, and to present a challenging test, which is easily graded by the application itself.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel and Training

KEYWORDS: Distance Learning Tools for On-Line Tests, DLTOT

SUPPORTING THE SECURE HALTING OF USER SESSIONS AND PROCESSES IN THE LINUX OPERATING SYSTEM

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One feature of a multi-level operating system is a requirement to manage multiple, simultaneous user-sessions at different levels of security. This session management is performed through a trusted path between the user and operating system. Critical to this functionality is the operating system's ability to temporarily halt dormant sessions, thereby ensuring their inability to perform any actions within the system. Only when a session must be reactivated are its processes returned to a runable state.

This thesis presents an approach for adding this "secure halting" functionality to the Linux operating system. A detailed design for modifying the Linux kernel, the core of the operating system, is given. A new module, allowing an entire session to be halted and woken up, is designed. A new process state, the "secure halt" state, is added. Additionally, the kernel's scheduling manager is modified to properly manage processes in the secure halt state. The research has led to the implementation of the design as a proof of concept.

This research is meant to be used in combination with other efforts to enhance the security of the Linux operating system.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Secure Halt, Trusted Path, Secure Attention Key, Linux, Computer Security

ANALYZING THREADS AND PROCESSES IN WINDOWS CE

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Windows CE 3.0, also known as Pocket PC for palm-sized devices, is becoming increasingly popular among professionals and corporate enterprises. It is estimated that by 2004 Windows CE will have a share of 40% of the marketplace for palm-sized devices. The documented vulnerabilities against a major competitor of WinCE, Palm, and the proliferation of palm-sized devices highlight the need for security for these small-scale systems. This thesis is part of a larger project to enhance the security in WinCE.

This thesis analyzed the threads and processes in WinCE, and discusses authentication, public key infrastructure (PKI) and future technologies as each relates to WinCE. The research discovered that Talisker, the next generation of WinCE, supports Kerberos an authentication protocol, and it also supports PKI (a key management system) components. Results of this thesis show that security can be enhanced in WinCE without requiring a change to its code base.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Windows CE 3.0, Pocket PC, Palm-Sized Devices

INTEGRATED DEVELOPMENT ENVIRONMENT (IDE) FOR THE CONSTRUCTION OF A FEDERATION INTEROPERABILITY OBJECT MODEL (FIOM)

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Advances in computer communications technology, the recognition of common areas of functionality in related systems, and an increased awareness of how enhanced information access can lead to improved capability, are driving an interest toward integration of current stand-alone systems to meet future system requirements. However, differences in hardware platforms, software architectures, operating systems, host languages, and data representation have resulted in scores of stand-alone systems that are unable to interoperate properly.

Young's Object Oriented Model for Interoperability (OOMI) defines an architecture and suite of software tools for resolving data representational differences between systems in order to achieve the desired system interoperability. The Federation Interoperability Object Model (FIOM) Integrated Development Environment (IDE) detailed in this thesis is a toolset that provides computer aid to the task of creating and managing an interoperable federation of systems.

This thesis describes the vision and requirements for this tool along with an initial prototype demonstrating how emerging technologies such as XML and Data Binding are utilized to capture the necessary information required to resolve data representational differences between systems. The material presented in this thesis has the potential to significantly reduce the cost and effort required for achieving interoperability between DoD systems.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Object Orientated Model for Interoperability, OOMI, Federation Interoperability Object Model Integrated Development Environment, FIOM, IDE

DESIGN AND IMPLEMENTATION OF WEB-BASED SUPPLY CENTER'S MATERIAL REQUEST AND TRACKING (SMART) SYSTEM USING JAVA AND JAVA SERVLETS

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In order for decision makers to efficiently make accurate decisions, pertinent information must be accessed easily and quickly. Component-based architectures are suitable for creating today's three-tiered client-server systems. Experts in each particular field can develop each tier independently. The first tier can be built using HTML and web browsers. The middle tier can be implemented by using the existing server side programming technologies that enables dynamic web page creation. The third tier maintains the database management systems.

Java servlets and Java provide the programmers platform and operating system with independent, multi-threaded, object oriented, secure and mobile means to create dynamic content on the web. The Java Servlets Session Tracking API is a potential solution to the problems arising from the fact that HTTP is a "stateless" protocol.

The use of connection pools with database applications provides faster data access, and decreases the use of system resources. Connection pools also offer a solution to the limited number of connections open to a specific database at a given time.

This thesis explores the existing client-server architectures and server side programming technologies such as CGI, ASP and Java Servlets. The thesis also prescribes the design and implementation of a three-tier application using Java and Java servlets as the middle tier, and Java Database Connectivity to communicate with the database management systems.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Database)

KEYWORDS: Software, Database, Structured Query Language (SQL), Common Gateway Interface (CGI), Active Server Pages (ASP), Java Database Connectivity (JDBC) Java Servlets, Java

VULNERABILITY ASSESSMENT OF MICROSOFT EXCHANGE 2000 SERVER SOFTWARE

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LCDR Chris Eagle, USN, Department of Computer Science

E-mail is the dominant utility in use today as a means of issuing directives and sharing information among employees in most enterprises. Although e-mail is typically not classified, many may be personal, private, or often sensitive in nature. Important information can inadvertently be disclosed that may affect a critical organizational decision. Additionally, the sum of several innocuous e-mail messages may allow malicious agents to infer knowledge that might itself be considered confidential. Exchange Server was selected for this research on the recommendation of the Fleet Information Warfare Center (FIWC) and the National Security Agency (NSA) due to its wide use and importance as the enterprise email solution for the Navy-Marine Corps Intranet (NMCI). A vulnerability assessment was needed in order to ensure a high level of integrity and to ensure the application is deployed in a secure fashion within NMCI. Exchange 2000 Server was found to be extremely functional but insecure primarily due to its clear text messaging, its reliance upon security features of the host operating system, and lack of built-in security features. It is recommended that Microsoft create a better setup program that default to a maximum state of security rather than a state of maximum convenience. It is also recommended that administrators make use of encrypted connections (SSL or VPN for example), phase out pre-Windows 2000 machines, invoke the NSA's published security templates and be diligent in applying vendor supplied patches.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Microsoft Exchange 2000 Server Software, Encrypted Connections

WEB-ENABLING AN EARLY WARNING AND TRACKING SYSTEM FOR NETWORK VULNERABILITIES

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The Information Assurance Vulnerability Alert (IAVA) process was established to provide an early warning and tracking capability for protecting Department of Defense (DoD) networks against identified system vulnerabilities. The Navy initially used record message traffic for the information distribution required by the process. This approach was heavily administrative and prone to significant delays in an already time critical process. Additionally, it lacked support for automated data validation, resulting in unreliable vulnerability tracking information. As a result, the process was ineffective, and Navy networks remained highly susceptible to exploitation, even for well-documented system vulnerabilities. For this thesis, web-enabling technology is used to build and deploy an early warning and tracking system for Navy network vulnerabilities. The research sponsor, the Navy Component Task Force for Computer Network Defense (NCTF-CND), has named it the Online Compliance Reporting System (OCRS). It is now being used by all Navy commands and has proven efficient and highly effective in defending Navy networks against known vulnerability exploitations. As a result, the system has gained significant interest from other organizations and the research sponsor is now planning to fund maintenance and future enhancements by the Space and Naval Warfare Systems Center in Charleston, South Carolina.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Information Assurance Vulnerability Alert, Online Compliance Reporting System, IAVA, OCRS, Early Warning

IMPLEMENTATION CONSIDERATIONS FOR A VIRTUAL PRIVATE NETWORK (VPN) TO ENABLE BROADBAND SECURE REMOTE ACCESS TO THE NAVAL POSTGRADUATE SCHOOL INTRANET

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As broadband connections to the home become more prevalent, through Digital Subscriber Lines (DSL) and cable modems, students and faculty will desire to access the NPS intranet via these new means instead of their 56K modems. The introduction of these new technologies will require NPS to re-evaluate how to allow remote access to their internal resources in a secure way, while still allowing for the use of broadband technologies.

This thesis will examine the alternative methods for implementing Virtual Private Networks (VPNs), from simple use of Point to Point Protocols (PPP) to high end specialized internet appliances and gateways. Pros and cons of each will be discussed. A mock-up of the school's network will be created to test each of the discussed methods. Final recommendations will be made for a model that can be used by the NPS to implement a VPN. Also discussed will be how that model may be altered to fit other commands throughout the U.S. Navy who desire similar secure remote access to their internal network resources.

It should be noted that the thesis will concentrate on remote secure access to an internal network from a single remote host more than on the VPNs' additional ability to remotely connect two or more secure networks together, such as can be found in a business to business (B-to-B) environment.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual Private Network (VPN), Remote Access, Public Key Infrastructure (PKI), Broadband Access, and Computer Security

EVALUATION OF THE EXTENSIBLE MARKUP LANGUAGE (XML) AS A MEANS OF ESTABLISHING INTEROPERABILITY BETWEEN MULTIPLE DOD DATABASES

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This thesis evaluates the ability of the Extensible Markup Language (XML) to address the interoperability problem that exists between Department Of Defense (DOD) legacy systems. Due to the different Database Management Systems (DBMS) used within DOD, interoperability is a major flaw. The need for communication between the DBMS within DOD is necessary and this thesis will focus on this problem.

This thesis focuses in on the problems that exist, and assesses XML as a means of correcting these problems. This thesis uses the Joint Common Database (JCDB) as a means of showing XML to be a viable solution.

DoD KEY TECHNOLOGY AREAS: Battlefield Environments, Command Control and Communications, Computing and Software

KEYWORDS: Extensible Markup Language, Interoperability, Database Management

DESIGN AND IMPLEMENTATION OF ONLINE COMMUNITIES

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There are many claims that building an online community on the Internet is the next big thing for online businesses to enhance their bottom line. Advertising has been the biggest moneymaker on the Internet so far so attention is money on today's Internet. The idea of an online community is to build communication tools into a website to allow visitors to interact with each other and encourage them to return often. By providing visitors with a place to interact with others and talk about their interests companies can better target them with advertising. Certainly a website that brings users back over and over again is very appealing to any organization that is trying to sell goods or get their message heard. But the building of an online community is not as simple as just adding discussion forums and/or chat rooms to a website. In fact, many believe that a successful community is only 10% dependent upon technology and 90% dependent upon people. This thesis takes a look at the principles of successful online communities according to current literature and then analyzes the application of these principles on some popular online communities. It then takes a detailed look at PRESENCE-Lite, an online community built by the author based on the principles of online communities.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Online Community, Internet, PRESENCE-Lite

ANALYSIS, DESIGN AND IMPLEMENTATION OF A WEB DATABASE WITH ORACLE8I

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This thesis represents a model of web-database analysis, design and implementation. An electronic bulletin board for the Naval Postgraduate School is implemented for demonstration. The model includes Oracle8i DBMS as the database, Java (Java Server Pages, Java Script, Enterprise Java Beans, Java Servlets) as the programming language. Apache HTTP Server v.1.3 / Tomcat v.1.2 is used as the Web server and JSP engine. Windows NT4.0 served as the OS environment. From the technical aspect, Database Management Systems, Web-Database Architectures, Server Extension Programs, Oracle8i, as well as several other software and hardware components are reviewed, and some are recommended.

DoD KEY TECHNOLOGY AREA: Other (Web-Database, Oracle8i)

KEYWORDS: Oracle DBMS, Oracle8i, Java Server Pages, Enterprise Java Beans, Web-Database, Apache/Tomcat1.2, Two-tiered Architecture, Multi-tiered Architecture

THERMINATOR 2: DEVELOPING A REAL TIME THERMODYNAMIC BASED PATTERNLESS INTRUSION DETECTION SYSTEM

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A novel system for conducting non-signature based, or patternless, intrusion detection of computer networks is presented. This system uses principles of thermodynamics to model network conversation dynamics. A notion of baseline operating conditions is developed by observing the properties of entropy, energy and temperature within the system. Perturbations in these properties are considered potential intrusions for further investigation. This thesis focuses on the design and architecture of this system. System functions are decomposed into a network sensing device, a real-time processing component and a forensics component. A mechanism for forwarding and storage of sensed data is developed and discussed. Similarly, a novel three-dimensional display technique and the data structure that allows direct access of raw packet information from energy levels within this display is constructed and discussed. A system configuration language is defined and presented and additional tools for follow-on forensic analysis are developed. Finally, examples of valid intrusions and other network perturbations in real traffic collected in Department of Defense network operation center backbones are presented. Preliminary results indicate this system has significant potential for revealing anomalies in large network systems.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Therminator, Patternless Intrusion Detection, Computer Networks

THE DESIGN AND IMPLEMENATION OF A REAL-TIME DISTRIBUTED APPLICATION EMULATOR

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This thesis details the engineering, design and implementation of a real-time, distributed, application emulator system (AE system). The project had two main goals for the tool: emulation of real-time distributed systems, and as a programmable resource consumer. The AE system is currently being used in the HiPer-D test bed to activate a resource leveling tool that monitors several software components for real-time response. The AE system is highly flexible and can be used in the context of a variety of network topologies and system loading options. The results presented show that the AE system also emulates distributed systems.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Emulation, Real-Time Benchmarks

DEVELOPING ARTICULATED HUMAN MODELS FROM LASER SCAN DATA FOR USE AS AVATARS IN REAL-TIME NETWORKED VIRTUAL ENVIRONMENTS

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With the continuing gain in computing power, bandwidth, and Internet popularity, there is a growing interest in Internet communities. To participate in these communities, people need virtual representations of their bodies, called avatars. Creation and rendering of realistic personalized avatars for use as virtual body representations is often too complex for real-time applications such as networked virtual environments (VE). Virtual Environment (VE) designers have had to settle for unbelievable, simplistic avatars and constrain avatar motion to a few discrete positions.

The approach taken in this thesis is to use a full-body laser-scanning process to capture human body surface anatomical information accurate to the scale of millimeters. Using this 3D data, virtual representations of the original human model can be simplified, constructed and placed in a networked virtual environment.

The result of this work is to provide photo realistic avatars that are efficiently rendered in real-time networked virtual environments. The avatar is built in the Virtual Reality Modeling Language (VRML). Avatar motion can be controlled either with scripted behaviors using the H-Anim specification or via wireless body tracking sensors developed at the Naval Postgraduate School. Live 3D visualization of animated humanoids is viewed in freely available web browsers.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Avatars, Virtual Body Representatives, Virtual Environments, VE, Virtual Reality, Modeling Language, VRML

INTERCONNECTIVITY VIA A CONSOLIDATED TYPE HIERARCHY AND XML

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Building a software system that passes any message type between legacy Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) systems is proposed. The software system presents significant cost savings to the Department of Defense (DoD) because it allows continued use of already purchased systems without changing the system itself.

In the midst of the information age, the DoD cannot get information to the warfighter. The DoD still maintain and use heterogeneous legacy systems, which send limited information via a set of common messages developed for a specific domain or branch of DoD. The ability to communicate with one message format does not meet today's needs, though these stovepipe C4ISR systems will provide vital information. By combining these systems, a synergistic effect on our information operations because of the shared information can be had.

The translator will resolve date representational differences between the legacy systems using a model entitled the Common Type Hierarchy (CTH). The CTH stores the relationships between different data representations and captures what is needed to perform translations between the different representations. The platform neutral extensible Mark-up Language (XML) as an enabling technology for the CTH model is used.

DoD TECHNOLOGY AREAS: Command Control and Communications, Computing and Software

KEYWORDS: Interoperability, Interconnectivity, Legacy Systems, XML, Consolidated Type Hierarchy, Information Systems

FEASIBILITY OF THE TACTICAL UAV AS A COMBAT IDENTIFICATION TOOL

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Soldiers maneuvering on the 21st Century battlefield are issued state-of-the-art equipment. Despite this, the tools at their disposal to identify targets as being a "friend" or a "foe" have changed little since Operation Desert Storm. While improved optics on late model combat systems are extending gunners' abilities to identify targets at extended ranges, an optics-vs-ballistics gap remains in the majority of U.S. Army ground maneuver forces. This gap, and other battlefield factors, increases the likelihood of fratricides in combat.

This thesis examines the feasibility of using the Army's Tactical Unmanned Aerial Vehicle (TUAV) as a combat identification (CID) tool for troops at the tactical level. Three scenarios were modeled and multiple simulations run to identify potential problems in using the TUAV as a CID tool, as well as ways to improve the system if it is used in this role. Model considerations included current and planned future datalink bandwidths, system delays, normal vs. immediate taskings, and travel times to mission areas.

The thesis demonstrates that if TUAVs are properly integrated into tactical mission planning and imagery analysts possess the necessary level of vehicle identification training (to include thermal identification training), the TUAV can function well as a CID tool.

DoD KEY TECHNOLOGY AREAS: Other (Combat)

KEYWORDS: Tactical Unmanned Aerial Vehicle, TUAV, Combat Identification, CID

ENHANCING NETWORK COMMUNICATION IN NPSNET-V VIRTUAL ENVIRONMENTS USING XML-DESCRIBED DYNAMIC BEHAVIOR (DBP) PROTOCOLS

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The existing component protocols, as well as new protocols introduced at runtime into NPSNET-V are written in their native programming language. As a result, they require authoring and compiling by a trained programmer. The long time frame required to change or introduce new protocols into NPSNET-V, a dynamically extensible virtual environment, detracts from the dynamics of the virtual environment. Networking optimization thresholds to support NPSNET-V needed to be determined to ensure that the networking is performed efficiently, and system resources to other systems, such as graphics rendering, are maximized. This thesis implements component protocols described using Extensible Markup Language (XML) into NPSNET-V. These protocols are created with different fidelity resolutions for each protocol, which can be swapped at runtime based on the network state. Network testing was performed to find the ideal maximum packet rates based on the impact on CPU utilization and packet loss. By using XML, non-programmers can edit protocols for inclusion in a simulation at runtime.

Important contributions include adding protocols to NPSNET-V with high-resolution and low-resolution versions, described by XML documents. Basic network optimization is added to NPSNET-V to take advantage of the protocols' resolution switching ability. The network testing revealed a linear correlation between the packet sending rate and CPU utilization, and a polynomial correlation between the packet sending rate and percentage packet loss.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: NPSNET-V, Extensible Markup Language, XML, Dynamic Behavior, Protocols

SOFTWARE RE-ENGINEERING OF THE HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM - (MAINTENANCE EXTENSION) USING OBJECT ORIENTED METHODS IN A MICROSOFT ENVIRONMENT

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The purpose of this research is to technically evaluate, refine, and expand two existing aircraft safety management information systems (one military and one civilian). The systems are used in the data collection, organization, query, analysis, and reporting of maintenance errors that contribute to Aviation mishaps, equipment damage, and personnel injury. Both programs implement the Human Factors Analysis and Classification System (HFACS) taxonomy model developed by the Naval Safety Center (NSC) to capture aircrew errors in Naval Aviation mishaps. The goal of this taxonomy is to identify areas for potential intervention by fully describing factors that are precursors to aircraft accidents.

Requirements outlined by Dr. John K. Schmidt of the Naval Safety Center, in conjunction with funding by the National Aeronautics and Space Administration, require that the system utilize a Microsoft Access based implementation. This research focuses on meticulous software engineering to investigate the feasibility of adapting the current "structured" systems to Microsoft-based object oriented architectures ensuring future scalability and increased potential for code-reuse.

Primary research questions investigated in this thesis include: 1) How can a Microsoft Access based implementation provide multi-user access to the same database in a client-server environment while ensuring the ability to scale to a large number (potentially thousands) of users? 2) How can the linguistic discontinuity associated with object-oriented concepts and non-object oriented, flat relational databases be overcome when limited by the requirement for a Microsoft Access based solution? 3) The current military and civilian systems provide similar functionality, but use different database schema. How can object oriented methods be implemented to provide a common interface to both types of data? 4) How should database schema be changed to provide the best performance, scalability, and opportunity for code re-use? 5) In the past, Microsoft has deployed new versions of Microsoft Access and Visual Basic that were not (fully) backwards compatible with previous versions. This caused great discontent among users of applications designed to run under the older versions of these programs. How can our system(s) be designed to isolate them from problems associated with new versions of Microsoft products? Specifically, the pending release of Microsoft Office 2002, the new SQL Server 2000 database engine, and Microsoft Visual Basic.NET.

This thesis describes the use of the Spiral Development Model to create a Microsoft-based solution for the School of Aviation Safety requirements. It is hypothesized that this research produced products that greatly enhance current HFACS-capabilities and provide the means to weather further changes in requirements and application platforms.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Human Factors Analysis and Classification System, HFACS, Naval Aviation Mishaps

STUDY OF A POTENTIAL SINGLE POINT HOUSEHOLD COMMUNICATIONS PRODUCT UTILIZING INTERNET PROTOCOL

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Second Reader: James B. Michael, Department of Computer Science

The future of networking technology and the Internet offer a great deal of promise. The potential is forthcoming as newer hardware technology and higher bandwidth capable protocols are designed and implemented. This thesis investigates the possibility of utilizing existing hardware with presently available software to create a practical communication package for the household. The household communication package or home communicator is the network core of the household linking television, telephone, and web browsing capability into one system. The home communicator would receive an incoming television, telephone and Internet signal via optical fiber from a single service provider.

This thesis investigates Linux as the home communicator operating system with Internet Protocol version 6 (Ipv6) as the network protocol. Linux is examined for its proficiency at being a capable customer oriented operating system. Additional Linux compatible applications are studied to include web browsing, e-mail, chat and simple text editing. Finally, Ipv6 was found to be an acceptable software package for the home communicator. There are several major issues preventing an easy solution. A portion of the functionality must be attained through the Internet Service Provider.

DoD KEY TECHNOLOGY: Computing and Software

KEYWORDS: Linux, Internet Protocol, Ipv6

ELECTRONIC MANEUVERING BOARD AND DEAD RECKONING TRACER DECISION AID FOR THE OFFICER OF THE DECK

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The U.S. Navy currently bases the majority of our contact management decisions around a time and manning intensive paper-based Maneuvering Board process. Additional manning requirements are involved on many Naval Ships in order to accurately convey the information to the Officer of the Deck (OOD) and/or the Commanding Officer. When given situations where there exist multiple contacts, the current system is quickly overwhelmed and may not provide decision-makers a complete and accurate picture in a timely manner.

The purpose of this research is to implement a stand-alone system that will provide timely and accurate contact information for decision-makers. By creating a reliable, automated system in a format that is familiar to all Surface Warfare Officers we will provide the Navy with a valuable decision-making tool, while increasing ease of data exchange and reducing current redundancies and manning inefficient practices.

The software design is based upon the Unified Modeling Language (UML). UML allows us to construct a software model that is supported by the Ada programming language. The design is based upon these fundamental tenants: non-operating system dependent, non-hardware system dependent, extensible and modular design. Ada provides a certified compiler, making the code robust and assuring the "buyer" that the program does what it is advertised to do.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Electronic Maneuvering Board, Unified Modeling Language, UML, Officer of the Deck, OOD

INTEGRATING A TRUSTED COMPUTING BASE EXTENSION SERVER AND SECURE SESSION SERVER INTO THE LINUX OPERATING SYSTEM

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The Multilevel Secure Local Area Network (MLS LAN) Project at the Naval Postgraduate School's Center for Information Security (INFOSEC) Studies and Research (NPS CISR) is building a trusted network system that is both necessary and sufficient to provide a multilevel networking solution for real world use.

The current configuration provides the necessary trusted network services on the TCSEC Class B-3 evaluated XTS-300, which is a combination of the STOP version 4.4.2 multilevel secure operating system, and a Wang-supplied Intel x86 hardware base. The interface for the STOP operating is based on the System V.3 UNIX implementation. System V.3 lacks many of features available in more modern UNIX implementations such as System V.4 and BSD 4.3, and also lacks many of the features in POSIX and ANSI C standards. Finally, the CPU is several generations older than the more current Intel processors. This thesis discusses the port of several MLS trusted network services on the XTS-300 to a Linux operating system running on an Intel Pentium Processor. The new Linux TCBE Server configuration will permit further experimentation with MLS architectural issues in a more modern, flexible and easily modifiable

environment. The port was accomplished by identifying and modifying the necessary software modules needed, to adapt to a Linux environment.

This thesis proves that XTS-300 TCB services can be ported to Linux system without any negative effects on performance thus allowing a move toward a more security enhanced implementation.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Multilevel Secure Local Area Network, MLSLAN, Trusted Network System

NAVY/MARINE CORPS INTRANET INFORMATION ASSURANCE OPERATIONAL SERVICES PERFORMANCE MEASURES

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Communicating in the Department of the Navy (DON) over the Internet is an everyday event. The DON is developing the Navy Marine Corps Intranet (N/MCI) to enhance this communication capability. The security of communicating over the N/MCI has become a concern to the DON. The DON is relying on the N/MCI contractor to provide security for their communications. Key aspects of this secure communication will be provided through the use of a DON Public Key Infrastructure (PKI), which the N/MCI contractor is managing. To ensure the security of the PKI based communications the contract requires the monitoring of four PKI performance measures. This thesis analyzes performance measures, criterion, and standards then uses this analysis to review the contractual PKI performance measures and data collected from commercial PKI vendors. It recommends changes to these performance measures and provides additional performance criteria that should be included in the N/MCI contract. Finally, this thesis analyses how the N/MCI contract, specifically the PKI, impact DON members.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Public Key Infrastructure)

KEYWORDS: Public Key Infrastructure, Public Key Cryptography, Navy Marine Corps Intranet, Service Level Agreements, Performance Measures, PKI, N/MCI

SEMANTIC INTEROPERABILITY IN AD HOC WIRELESS NETWORKS

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Ad hoc wireless networks are decentralized networks whose members join and leave the network in an asynchronous manner and for short periods of time. Each node participating in the network acts both as host and a router

Ad hoc networks in theory, support missions of the Armed Forces in situations in which the infrastructure for wire-bound networks is not dependable, it is impractical to build and maintain the infrastructure, or the missions requires that the nodes have a high-degree of mobility.

Ad hoc wireless networks require some level of semantic interoperability so that nodes in the network can "understand" each other. In this thesis, requirements for semantic interoperability in ad hoc wireless networks are discussed, and a case study is presented of how such requirements could be applied. It was realized during the study that semantic interoperability components and functions are developed mostly for wired networks, and not taking in consideration the wireless issues such as processing, power, and networking limitations. In this thesis, wireless user infrastructure, mobile middleware, and wireless

application protocols as a solution to realize semantic interoperability in wireless ad hoc networks are discussed.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software

KEYWORDS: Ad Hoc Networks, Routing Protocols, Semantic Interoperability, Wireless Networking

EXTENSIBLE MARKUP LANGUAGE (XML) BASED ANALYSIS AND COMPARISON OF HETEROGENEOUS DATABASES

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In the Department of Defense there currently exist multiple databases required to support command and control of some portion of the battlefield force. Interoperability between forces will become crucial as the force structure continues to be reduced. This interoperability will be facilitated through the integration of these command and control databases into a singular joint database or by developing inter-communication schemas to support inter-database communications. The first step in either of these alternatives is the identification of equivalent components among the multiple databases.

This thesis describes how Extensible Markup Language (XML) can be used to facilitate the process of analyzing and comparing multiple databases. Each step of the process is described in detail accompanied by explanations of the XML tools/resources required to execute the step and rationale of why the step is necessary. Detailed graphics and examples are employed to simplify and justify the step by step explanations. The JavaScript code developed as part of the research to execute the XML based analysis is included. This thesis concludes with discussions of the overall value of this XML based analysis and comparison process and of potential future work that could be pursued to further exploit this XML analysis and comparison method.

DoD KEY TECHNOLOGY AREAS: Battlefield Environments, Command Control and Communications, Computing and Software

KEYWORDS: Extensible Markup Language, XML Analysis, Heterogeneous Databases, Database Comparison, Database Analysis, C4I

DESIGNING REALISTIC HUMAN BEHAVIOR INTO MULTI-AGENT SYSTEMS

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As Multi-agent systems advance toward moving virtual humans such as modeled infantry soldiers around a virtual environment for modeling and simulation purposes, an important factor to be considered is how the agent internalizes and reacts to its environment. One method to simulate this sensory perception and the construction of generalized internal knowledge is the symbolic reactive agent architecture. This architecture utilizes symbolic constructive agents to internalize and symbolically represent the outside environment within the agent and reactive agents to decide what course of action will be taken next based on this internal environment. This type of architecture also lends itself well to putting variability and non-homogeneity into different agents by controlling the level of hindrance or interference that the agent utilizes when constructing this inner environment. A simple path finding task was used to determine the overall utility of this architecture with respect to truly representing human performance in cognitive tasks.

Humans as well as different simulated agents were put through the same task in their respective environment and their results were compared. A concept called the bracketing heuristic was also utilized to determine whether the model may translate well to general path-finding tasks.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Virtual Humans, Virtual Environments, Multi-Agent Systems

USING OPERATIONAL RISK MANAGEMENT (ORM) TO IMPROVE COMPUTER NETWORK DEFENSE (CND) PERFORMANCE IN THE DEPARTMENT OF THE NAVY (DON)

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Operational Risk Management (ORM) has been credited with reducing the Navy's mishap rate to all time lows, especially in Naval Aviation. Through the use of a five-step process, ORM has been able to change the decisionmakers' paradigm of day-to-day operations in naval fleet units, making safety the paramount factor that would allow fleet commanding officers to conserve their assets, yet meet the requirement to train in high-risk environments. ORM is a process that mitigates the risk associated with the high-risk environment that naval fleet units operate in.

Not unlike naval fleet units, our computer networks operate in a high-risk environment-the Internet. Crackers are able to penetrate what were thought to be secure networks, and copy, modify, disrupt or destroy valuable information. The risk posed to the Navy's computer network systems is very great. Given the Navy's adoption of "Network-Centric Warfare" and the Navy-Marine Corps Intranet (NMCI), the hazards faced by the possible compromise of these computer network systems are as great as any a fleet unit would encounter in its normal operating environment.

The objective of this thesis is to translate ORM practices into Information Assurance Risk Management (IARM) practices, and demonstrate IARM's utility in identifying, quantifying, and mitigating the security risks associated with computer networks.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Network Defense (CND), Operational Risk Management (ORM), Critical Infrastructure Assurance, Information Assurance Risk Management (IARM), Information Security Policy and Information Assurance

A DISCRETIONARY-MANDATORY MODEL AS APPLIED TO NETWORK CENTRIC WARFARE AND INFORMATION OPERATIONS

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The concepts of DoD information operations and network centric warfare are still in their infancy. In order to develop these concepts, the right conceptual models need to be developed from which to design and implement these concepts. Information operations and network centric warfare are fundamentally based on trust decisions. However, the key to developing these concepts is to develop for DoD is to develop the organizational framework from which trust, inside and outside, of an organization may be achieved and used to its advantage. In this thesis, an organizational model is submitted for review to be applied to DoD information systems and operational organizations.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software

KEYWORDS: Trust Models, Trust Management, Computer Security, Information Operations

AN IMPROVED MAGNETIC, ANGLE RATE, GRAVITY (MARG) BODY TRACKING SYSTEM

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This thesis proposes the design of an improved Magnetic, Angular Rate, Gravity (MARG) Body Tracking System. The current MARG Body Tracking System is limited to tracking three limb-segments. The MARG sensors are physically connected to a desktop computer by cables.

In this thesis, a multiplexing circuit was implemented to allow tracking of 15 limb-segments. Processing was moved from a desktop computer to a wearable computer and wireless communication was implemented using an IEEE 802.11b spread spectrum wireless LAN. The resultant system is able to track the entire human body and is untethered. The range of the system is the same as that of the wireless LAN which can be extended with the use of repeaters. This thesis work will ultimately allow human insertion into virtual environments for training and other applications.

DoD KEY TECHNOLOGY AREA: Computing and Software, Human System Interface, Sensors

KEYWORDS: Human Body Tracking

APPLICATION OF THE NOGUEIRA RISK ASSESSMENT MODEL TO REAL-TIME EMBEDDED SOFTWARE PROJECTS

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This thesis addresses the application of a Formal Model for Risk Assessment to real-time embedded software development projects. It specifically targets the use of existing military and defense software development projects as a way to validate, or refine the formal model. In this case the Nogueira model. Data will be gathered from real projects and analyze through use of the Nogueira model. Selected projects were based on specific criteria, listed later in this thesis. This is, in essence, a "post mortem" of these projects. It gives the ability to compare the model's predictions against what the real data collected from the projects indicated. Results will be reported with our conclusions as to the model's viability for use in determining risk as to probability of completion given the time allowed for the projects. These are data points in the validation of the model and the results, good or bad, cannot be used as a definitive substantiation of the model's fitness for use on other real projects.

DoD KEY TECHNOLOGY AREAS: Other (Project Management and Risk Assessment)

KEYWORDS: Requirements Volatility (RV), Change Rate (CR), Birth Rate (BR), Death Rate (DR), Complexity (CX), Large Granularity Complexity (LGC), Operators, Data Streams, Abstract Data Types (ADTs), Efficiency Factor (EF), Software Engineering, Risk Assessment, Estimation Models, Bi-dimensional Plot, SLIM, Putnam, Function Points, COCOMO, Boehm, Prototype System Description Language (PSDL), Computer Aided Prototyping System (CAPS), Weibull Distribution

ANALYSIS OF INTEL IA-64 PROCESSOR SUPPORT FOR A SECURE VIRTUAL MACHINE MONITOR

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This thesis explores the Intel IA-64 architecture's capability to support a secure virtual machine monitor. The major mission of a virtual machine monitor is to provide an execution environment identical to the real machine environment for virtual machines. A VMM duplicates the real resources of a processor for virtual machines while making a virtual machine think that it is running on a real machine. As a result, a virtual machine monitor allows multiple virtual machines to run concurrently on the same machine.

A secure VMM on the Intel IA-64 architecture would offer several benefits. A secure VMM would ensure that security policy is enforced by constraining information flow between the supported virtual machines. This would provide PC users with a more secure environment in which to run COTS operating systems.

The Intel IA-64 architecture was analyzed to determine if it is virtualizable. Three types of virtual machine monitors and their hardware requirements have been defined. The IA-64 architecture was mapped to these hardware requirements. Analysis showed that the IA-64 architecture meets three main hardware requirements. However, IA-64 instruction set contains 18 sensitive unprivileged instructions. These instructions prevent the IA-64 architecture from being used for a Type I VMM. Several virtualization techniques used in some architectures are discussed to determine if these techniques could be applicable to virtualization of the IA-64 architecture.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual Machines, Virtual Machine Monitors, Intel IA-64 Architecture

A SIMPLE SOFTWARE AGENTS FRAMEWORK FOR BUILDING DISTRIBUTED APPLICATIONS

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The development of distributed systems needs to consider multiple factors such as performance, scalability, resource sharing, and fault tolerance. This thesis proposes a simple agent-based framework to address these concerns when building distributed applications. Agents act as interfaces among processes that interact and cooperate in a distributed environment. These agents encapsulate the implementation details and make the network transparent to running processes. The proposed framework is built on JINI infrastructure. It uses Linda TupleSpace model, a shared network-accessible repository, for different processes to exchange information. Processes are loosely coupled. They discover and linkup with one another by using services residing on JINI infrastructure. Under this proposed model, the correspondent language wrappers such as Java, Ada, C++, C and Visual Basic support multiple programming languages. Information exchange among processes is not restricted to data only. Executable components, leveraging on Java code's portability features, can be sent over a heterogeneous environment and executed remotely.

This framework can further address several important issues on formal specifications of the communication layer, such as partial failure, synchronization, coordination and heterogeneity, by offering properties in our design for operation timeout, and information and service leasing. This framework is to be used in the Distributed Computer Aided Prototyping System (DCAPS) to provide the inter-process communication layer. It simplifies the tasks of designing, binding and analyzing multiple processes of real-time, distributed prototype systems.

The provided interface library shields developers from working on the underlying dynamic and complex network environment. It supports a wide variety of programming languages and operating platforms. Important issues under distributed environment, such as partial failure, synchronization and coordination, have been taken into consideration.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Distributed System, Interoperability)

KEYWORDS: ActiveX, Agent, Distributed Systems, Framework, Interoperability, JavaSpace, JINI, Software, TupleSpace, Wrapper

DEVELOPMENT OF A TARGET RECOGNITION SYSTEM USING FORMAL AND SEMI-FORMAL SOFTWARE MODELING METHODS

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With the shrinking defense budget, the United States Department of Defense (DoD) has relied more on commercial-off-the-shelf (COTS) and contracted software systems. Government contractors and commercial developers currently rely heavily on semi-formal methods such as the Unified Modeling Language (UML) in developing the models and requirements for these software systems. The correctness of specifications in such languages cannot be tested, in general, until they are implemented. Due to the inherent safety requirements for mission critical systems, formal specification methods would be preferable. This thesis contrasts the development of a combat system for the Navy using the formal specification language SPEC with development using the semi-formal method UML. The application being developed is a ship recognition system that utilizes image data, detected emitters, and ship positioning to correlate ship identification. The requirements analysis and architectural design for this system are presented.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Modeling, Requirements Analysis, Formal Specifications, UML, Formal Methods, Semi-Formal Methods, Target Recognition

INTRUSION DETECTION SYSTEMS REQUIREMENTS ANALYSIS: AN EVALUATION OF THE MARINE CORPS' USE OF COTS IDS

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Intrusion detection systems (IDS) have become a major tool in the defense of computer networks throughout DoD. However, in the past, the purchase of these tools has been based on little more than vendor literature. This thesis applies Joseph Barrus' requirements model to the current Commercial-Off-The-Shelf (COTS) IDS deployed on the Marine Corps Enterprise Network (MCEN) and determines if the

current IDS meets the Marine Corps' requirements. To make this determination, this thesis looks at three questions: what are the requirements for an intrusion detection system, how are those requirements measured and can they be measured? This thesis also looks at the MCEN in detail and concludes that the centralized control and management of the MCEN allows the Marine Corps to use other resources to make-up for the deficiencies of an average COTS product. Lastly, the thesis addresses the state of intrusion detection standards and certified evaluations of IDS. Standardization, when approved, gives the Marine Corps more flexibility in selecting security products that complement the MCEN operating environment. Certified evaluations by accredited laboratories ensure that companies and organizations can purchase security products with a greater degree of confidence that they will function according to an established assurance level.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Intrusion Detection Systems, IDS, Marine Corps, Enterprise Network, MCEN

INTERCONNECTIVITY VIA A CONSOLIDATED TYPE HIERARCHY AND XML

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Building a software system that passes any message type between legacy Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) systems is proposed. The software system presents significant cost savings to the Department of Defense (DoD) because it allows continued use of already purchased systems without changing the system itself.

In the midst of the information age, the DoD cannot get information to the warfighter. Heterogeneous legacy systems are still maintained and used, which send limited information via a set of common messages developed for a specific domain or branch of DoD. The ability to communicate with one message format does not meet our needs today, though these stovepipe C4ISR systems will provide vital information. By combining these systems, we will have a synergistic effect on our information operations because of the shared information.

Our translator will resolve date representational differences between the legacy systems using a model entitled the Common Type Hierarchy (CTH). The CTH stores the relationships between different data representations and captures what is needed to perform translations between the different representations. The platform neutral extensible Mark-up Language (XML) will be used as an enabling technology for the CTH model.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software

KEYWORDS: Interoperability, Interconnectivity, Legacy Systems, XML, Consolidated Type Hierarchy, Information Systems

AN EXAMINATION OF POSSIBLE ATTACKS ON CISCO'S IPSEC-BASED VPN GATEWAYS

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Virtual Private Networks (VPNs) are an emerging security solution for computer networks in both the government and corporate arena. IPSec, the current standard for VPNs, offers a robust, standards-based, and cryptographically effective solution for VPN implementation. Because of the immense complexity of IPSec, effective analysis is difficult. In an environment where Information Warfare in general, and computer network attack in particular are becoming more pervasive, it is necessary conduct a critical, independent evaluation of IPSec from a security perspective.

In order to develop an effective evaluation of IPSec VPNs, a Cisco Systems IPSec-based VPN router network is used as an example. A detailed analysis of Cisco's IPSec-based implementation, as well as of the IPSec standard itself is conducted to determine what, if any, attacks or vulnerabilities exist in each.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control and Communications, Electronics, Electronic Warfare

KEYWORDS: Virtual Private Networks (VPN), Internet Protocol Security (IPSec), Computer Network Attack, Computer Security, Computing and Software, Network Security, Encapsulating Security Payload (ESP), Authentication Header (AH), Routers, Information Warfare (IW)

DYNAMIC ASSEMBLY FOR SYSTEM ADAPTABILITY, DEPENDABILITY AND ASSURANCE (DASADA) PROJECT ANALYSIS

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This thesis focuses on an analysis of the dynamic behavior of software designed for future Department of Defense systems. The DoD is aware that as software becomes more complex, it will become extremely critical to have the ability for components to change themselves by swapping or modifying components, changing interaction protocols, or changing its topology. The Defense Advanced Research Programs Agency formed the Dynamic Assembly for Systems Adaptability, Dependability, and Assurance (DASADA) program in order to task academia and industry to develop dynamic gauges that can determine run-time composition, allow for the continual monitoring of software for adaptation, and ensure that all user defined properties remain stable before and after composition and deployment. Through the study, a review of all the DASADA technologies were identified as well as a thorough analysis of all 19 project demonstrations.

This thesis includes a template built using the object-oriented methodologies of the Unified Modeling Language (UML) that will allow for functional and non-functional decomposition of any DASADA software technology project. In addition, this thesis includes insightful conclusions and recommendations on those DASADA projects that warrant further study and review.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computing, Software, Software Engineering, Software Demonstration

VULNERABILITIES ASSOCIATED WITH REMOTE ACCESS TO TIMESTEP VIRTUAL PRIVATE NETWORKS (VPNs)

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As Marine Corps requirements for Internet access continue to increase, so do the concerns about network security. One of the key components in the Marine Corps network security architecture is the employment of TimeStep Virtual Private Network (VPN) products to protect the Marine Corps Enterprise Network (MCEN). These VPN products provide security through authentication, confidentiality, and data integrity. Remote access to the MCEN via TimeStep VPNs provides the flexibility, security, and global connectivity required in today's high operations tempo.

Despite the benefits TimeStep VPNs provide to deployed users, the risks associated with remote access remain unclear. In this thesis, the author begins by identifying and evaluating vulnerabilities associated with remote user access to TimeStep VPNs via dial up modems, cable TV modems, and Digital Subscriber Lines (DSL). After the vulnerabilities have been identified, the author proposes policies and procedures that can mitigate these vulnerabilities. The aim of this study is to provide systems administrators and remote users of the MCEN useful insights into the threats that exist when using TimeStep VPNs and assistance in lessening their impact.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual Private Networks, Computer Network Attack, Computer Security, Computing and Software, Network Security

MODELING CONVENTIONAL LAND COMBAT IN A MULTI-AGENT SYSTEM USING GENERALIZATION OF THE DIFFERENT COMBAT ENTITIES AND COMBAT OPERATIONS

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There are inherent similarities between the numerous ground combat entities and the numerous ground combat operations. In combat entities there exist common characteristics such as the ability to move, shoot, communicate and more. The levels that each entity is able to operate for these characteristics differentiate it from the others. For combat operations, a common characteristic is that all operations have a starting point, objective point and an endpoint. The different operations take on unique properties based on where these points are located, actions enroute to points and what entities do at these points.

The generalized concepts in combat entities and combat operations provide a framework that can assist developers and users to model the majority of combat situations with a single simulation. This thesis uses

three different Multi-Agent System (MAS) combat models to illustrate the generalization framework. Of the three "test" models used, two existed previously and one was developed. The two existing models are Map Aware Non-uniform Automata (MANA), developed for the New Zealand Army and Defense Force, and Archimedes developed by Least Squares Software LLC. The model (GENAgent) was developed based on the redesign of GIAgent, developed by Captain Joel Pawloski, USA, as a thesis at the Naval Postgraduate School.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Multi-Agent System, MAS, Combat Operations, Combat Simulations

THE EMPLOYMENT OF A WEB SITE AND WEB-ENABLING TECHNOLOGY IN SUPPORT OF U.S. MILITARY INFORMATION OPERATIONS

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As a global-based system of information systems, the World Wide Web has the potential to support U.S. Military Information Operations. Presently, there is a lack of established U.S. Military Doctrine or Planning Guidance on how to incorporate the use of a website in support of Information Operations (IO). This thesis proposes suitable uses of a web site within the IO arena as defined by Joint Military Doctrine. Specifically, it is proposed that a web site can support all of the following type of activities: public information, civil affairs, psychological operations, deception and intelligence collection. In addition, the U.S. commercial marketing sector is advantageously employing recent advances in Information Technology and software which have yielded web-enabling features such as interactivity, personalization, customization, and dynamic information publishing, to name a few. The U.S. military can learn a great deal from this. This thesis describes some recent web-enabling technology and then provides a first approximation at mapping web-enabling features to IO capabilities. One product of this thesis is a first approximation of a planning checklist to be used by IO practitioners and web-site developers when considering the use of a web-based IO. Although technology will continue to change, this planning checklist provides a template for integrating web-enabling features within IO.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Information Operations, Website, Web-enabling Technology, Personalization, Dynamic Information Publishing

THE DESIGN AND DEVELOPMENT OF A WEB-INTERFACE FOR THE SOFTWARE ENGINEERING AUTOMATION SYSTEM

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The Software Engineering Automation System (SEAS) evolved from the Computer-Aided Prototyping System (CAPS) developed in the late 1980s and early 1990s to help software engineers rapidly produce working prototypes for hard real-time embedded systems. As software development methods such as the waterfall and spiral methods evolved the requirement for a system to prototype products became clear. CAPS was able to meet the needs of the software engineer, allowing them to edit the project, translate and compile the code, develop the interface, and execute the project. As the requirements change and customer's needs become clearer, the ability to rapidly change the prototype to meet these needs was met

by the CAPS system. Today companies that are developing software systems are global in nature. Development could take place over a vast expanse of several continents. The change in the workplace environment bore the requirement to redesign SEAS to make it accessible globally as well as making it functional across multiple platforms. The envisioned redesign of the SEAS system takes the functionality of the current system and deploys it as a web application on the Internet.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software Engineering Automation System, SEAS, Computer Aided Prototyping System, CAPS, Web-Interface

INFORMATION SECURITY REQUIREMENTS FOR A COALITION WIDE AREA NETWORK

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To achieve information superiority in a coalition environment the U.S. has to seamlessly integrate coalition members, both NATO and Non-NATO, into its command and control processes along all echelons of military operations. In a coalition environment, it is extremely challenging to fuse multinational information systems to achieve seamless integration. This thesis focuses on the security issues that are involved in establishing coalition network interoperability. The coalition environment is defined in terms of purpose, command structure, mission area, and control functions. Network and information protection are discussed in terms of minimizing the threats to information systems security. Coalition information system user requirements are defined and some of the security mechanisms required to meet those requirements are discussed. Current solutions to secure coalition network interoperability are surveyed, followed by conclusions, recommendations and areas for further study.

DoD KEY TECHNOLOGY AREAS: Battlespace Environment, Command, Control, and Communications, Other (Information Assurance)

KEYWORDS: Battlespace Environment, Command, Control, and Communications (3), Information Assurance

IMPLEMENTATION OF A TWO-USER DISPLAY USING STEREOSCOPICS

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The level of presence in a virtual environment depends on the extent to which the real world is shut out, the range of sensory elements the environment simulates, the extent of the panoramic view, and the resolution of the illusion. Many current virtual environment applications effectively address these presence issues for single users, but not for multiple users. Networked virtual environments address multiple user collaboration through real-time interaction of users in a shared environment. These systems provide effective communication between users, but do not address face-to-face collaboration.

To address these needs, this thesis describes a two-user display which fully supports face-to-face collaboration. Each user has independent views of the environment while standing near one another and is able to communicate through voice and gesture. The design of the system includes stereo rendering and magnetic tracking technology. Stereo rendering technology is used to create two separate images that can be viewed independently. A magnetic tracker is used to detect the movement of each user's head. There

are drawbacks, including ghosting, that affect the design's usability. Studies are needed to determine appropriate application mediums for this type of system.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface

KEYWORDS: Magnetic Tracking, Stereoscopy, Virtual Reality

A STUDY OF THE REQUIREMENTS FOR A HEADS-UP DISPLAY FOR USE IN MOTOR TRANSPORTATION IN THE UNITED STATES MARINE CORPS

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In this thesis, the high-level requirements for a concept system, Automated Vehicle Avoidance Identification and Location System (AVAILS) is investigated. The primary goal that this system addresses is the safe operation of large ground vehicles, operated by the U.S. Marine Corps and Army, on both military reservations and public roadways. AVAILS is comprised of an integrated collision warning and collision avoidance system. These two subsystems are used to support both low-speed docking and convoy operations. The objective is to provide the driver with real-time information that will help him or her act to avoid or mitigate the effects of a crash with another vehicle during convoy operations, and with another vehicle or the docking facilities during docking operations.

The high-level requirements for the human-computer interface, AVAILS-HCI, are discussed in the context of the following: the characteristics of the drivers, the nature of their tasks, the environment in which ground-based military vehicles operate, and the doctrine, policy, law, regulations, and procedures which govern the operation of such vehicles on military reservations and public roadways. A high-level treatment is given of the mapping of the high-level requirements for the human-computer interface to in-vehicle display technology, in particular, head-up displays. A limited-function prototype of the system was developed in order to explain and reason about the requirements for the AVAILS-HCI. The thesis concludes with recommendations for future research.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Transportation)

KEYWORDS: Automated Vehicle Avoidance Identification and Location System, AVAILS, Motor Transportation

APPLICATION PROGRAMMER'S INTERFACE (API) FOR HETEROGENEOUS LANGUAGE ENVIRONMENT AND UPGRADING THE LEGACY EMBEDDED SOFTWARE

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Legacy software systems in the Department of Defense (DoD) have been evolving and are becoming increasingly complex while providing more functionality. The shortage of original software designs, lack of corporate knowledge and software design documentation, unsupported programming languages, and obsolete real-time operating system and development tools have become critical issues for the acquisition

community. Consequently, these systems are now very costly to maintain and upgrade in order to meet current and future functional and nonfunctional requirements.

This thesis proposes a new interoperability model for re-engineering of old procedural software of the Multifunctional Information Distributed System Low Volume Terminal (MIDS-LVT) to a modern object-oriented architecture. In the MIDS-LVT modernization acquisition strategy, only one Computer Software Configuration Item (CSCI) component at a time will be redesigned into an object-oriented program while interoperability with other unmodified CSCIs in the MIDS-LVT distributed environment must be maintained. Using this model, each legacy CSCI component can be redesigned independently without affecting the others.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Multi-Functional Information Distributed System Low Volume Terminal, MIDS-LVT, Object-Orientated Database, Computer Software Configuration Item, CSCI

USING NETWORK MANAGEMENT SYSTEMS TO DETECT DISTRIBUTED DENIAL OF SERVICE ATTACKS

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Distributed Denial of Service (DDoS) attacks have been increasingly found to be affecting the normal functioning of organizations causing billions of dollars of losses. Organizations are trying their best to minimize their losses from these systems. However, most of the organizations widely use the Network Management Systems (NMS) to observe and manage their networks. One of the major functional areas of a NMS is Security Management. This thesis examines how the Network Management Systems could aid in the detection of the DDoS attacks so that the losses from these could be minimized. The thesis details the SNMP MIB variables of importance for detecting these attacks and the MIB signatures of the specific attack.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Distributed Denial of Service, DDOS, Network Management System, NMS, MIB, SNMP

A REQUIREMENTS SPECIFICATION OF MODIFICATIONS TO THE FUNCTIONAL DESCRIPTION OF THE MISSION SPACE RESOURCE CENTER

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The Defense Modeling and Simulation Office developed the Functional Description of the Mission Space (FDMS) Resource Center under the guidance of Department of Defense (DoD) 5000.59-P, DoD Modeling and Simulation Master Plan. The FDMS Resource Center provides a controlled repository for modeling and simulation (M&S) data and promotes data standardization and reuse. The Resource Center is currently operational at http://38.241.48.9.

Use of the FDMS Resource Center is voluntary on the part of DoD M&S organizations, although maximum use of the Center is paramount if standardization and reuse synergies are to be realized. In an effort to encourage more use of the Resource Center's capabilities, the author analyzed the Resource Center, interviewed the Center's principals, and developed a set of requirements governing screenshot

appearance, data workflow control, and privilege permission selections which should simplify and clarify the Center's user processes.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Modeling, Simulation, FDMS, DMSO, MSRR, Requirements, Software Engineering, Systems Engineering, Software Intensive

EMERGENT LEADERSHIP ON COLLABORATIVE TASKS IN DISTRIBUTED VIRTUAL ENVIRONMENTS

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Several Department of Defense agencies are currently investigating the use of distributed collaborative virtual environments (CVE) for the training of small dismounted infantry teams. If these systems are to be successful, they will have to do more than simply allow the team members to execute a task. In addition to assuring that essential training in the CVE transfers to the real task, it must be ensured that aspects of team organization also transfer. In particular, this thesis investigates whether or not predicted emergent leadership, as measured by standardized personality tests, holds within a CVE or if aspects of the interface interfere.

For a given "real-world" task domain a leader can be predicted based on personality traits of the individuals within the group. The interface utilized with a CVE may adversely affect these traits. In other words, predictive measures of leadership in the real world may not hold in a CVE.

The study reported here will use this predictability to identify the expected emergent leader within a group and determine how the CVE interface affects the ability of the predicted individual to emerge as the leader. It is theorized that the limitations of CVE interfaces (field of view, realism, etc.) will negatively impact the transfer of leadership personality traits into the virtual environment, but not to a degree that the limitation cannot be overcome. These limitations may impact the group dynamics and the emergent leader may not necessarily be the predicted leader by personality traits.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Collaborative Virtual Environments, CVE, Virtual Environments

AN ARCHITECTURE AND PROTOTYPE SYSTEM FOR AUTOMATICALLY PROCESSING NATURAL-LANGUAGE STATEMENTS OF POLICY

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Organizations are policy-driven entities. Policy bases can be very large and complex; these factors are compounded by the dynamic nature of policy evolution. Thus, comprehension of the ramifications of both policy modification and assurance of the consistency, completeness, and correctness of a policy base necessarily requires some level of computer-based support.

A policy workbench is an integrated set of computer-based tools for developing, reasoning about, and maintaining policy. A workbench takes as input a computationally equivalent form of policy statements.

In this thesis, approaches for translating natural-language policy statements into their equivalent computational form with minimal user interaction are explored. The architecture of a natural-language

input-processing tool (NLIPT) is presented, which was designed to augment a policy workbench. NLIPT components consist of an extractor, index-term generator, structural modeler, and logic modeler.

Experiments were with a prototype of the extractor. The extractor successfully parsed twenty-seven of a sample of ninety-nine of U.S. Department of Defense security policy statements. An additional twenty-one statements were correctly parsed based on the syntactic structure of the input.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control, and Communications, Human Systems Interface

KEYWORDS: Natural-language Processing, Policy, Security, Formal Methods

TRUST AND ITS RAMIFICATIONS FOR THE DOD PUBLIC KEY INFRASTRUCTURE

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Researchers have used a wide variety of trust definitions, leading to a plethora of meanings of the concept. But what does the word 'trust' mean? While most scholars provide their own definition of trust, they are dissatisfied regarding their own lack of consensus about what trust is. Trust is a cognitive function and modeling trust is an attempt to emulate the way a human assesses trust. Models of trust have been developed in an attempt to automate the logic, variables, and thought processes that a human performs when making a trust-decision. This thesis evaluates the various forms of trust and trust models. The results from our research found no such model that incorporates both mandatory and discretionary trust. A new hybrid model will be introduced, the "D-M Model." The motivation for using the model in the context of trust stems primarily from the appropriate use of discretionary and mandatory trust policies in organizations to ensure precision, consistency, and added assurance in trust. The real value of the D-M model, is that it addresses the need to model both of these types of policies explicitly and concurrently. This thesis concludes with the assessment of two practical applications of the D-M trust model as it is applied to DoD's Joint Task Forces.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Trust Models, Trust Management, Public Key Infrastructure (PKI), Computer Security

ANALYZING INPUT/OUTPUT SUBSYSTEM SECURITY IN WINDOWS CE

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In the past few years, mobile handheld devices have emerged as an exciting new tool for accomplishing everyday tasks. Devices with the Windows CE operating system provide flexibility for the designer in the form of customizable modules and components. With wireless capabilities and a familiar user interface, Windows CE devices are becoming popular for such tasks as inventory control and information retrieval. By enhancing the self-protection of the operating system, handheld devices could be used in more demanding environments. This thesis reviews the security redesign of operating systems and explores the applicability of such redesign to the Windows CE operating system. The existing security mechanisms in Windows CE are described, and the operating system itself is critically examined for security weaknesses, especially in the Input/Output subsystem area. Recommendations are made for improving the self-protection of Windows CE. Future work is suggested in two areas: analyzing other Windows CE

subsystems in terms of security, and developing a method of authenticating a Windows CE device to a server.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Operating Systems, Handheld devices, PDA Security, Windows CE

METHODS FOR DETERMINING OBJECT CORRESPONDENCE DURING SYSTEM INTEGRATION

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Object correlation is a semantic comparison of exported entities from one system to imported entities of another. Current research in search algorithms and artificial intelligence methods for pattern matching can aid integrators in finding these matches. This thesis proposes a two-stage correlation process for resolving various kinds of heterogeneity found in legacy DoD systems in order to facilitate interoperability. A prototype built using these methods is explained, results compared to current correlation methods, and recommendations made for further improvements.

The end of the Cold War and the Defense Reorganization Act of 1986, began a new era of unprecedented cooperation among the U.S. military services and our allies. Increasingly dynamic missions have required warfighters to share information quickly and seamlessly while a decreasing defense budget has left few resources to build the infrastructure needed to implement this information exchange in legacy heterogeneous data systems. One possible solution to achieving interoperability of information systems is Young's Federated Interoperability Model. This model allows system designers to advertise the kinds of information they produce and consume and then automatically provides translation services. Before data and services can be shared, however, integrators must resolve exactly what kinds of data they are providing so that other systems in the network can decide if that data is appropriate for their use. That is the purpose of the proposed correlation algorithm.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software

KEYWORDS: XML, Interoperability, Interconnectivity, Legacy Systems, Artificial Intelligence, Correlation

A GUIDE TO SELECTING SOFTWARE METRICS FOR THE ACQUISITION OF WEAPON SYSTEMS

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Modernization of Department of Defense (DoD) weapon systems has resulted in an ever-increasing dependence on software. Despite technological advances in the software field, software development remains costly and one of the highest risk factors on most weapon system programs. The use of software metrics is a methodology for mitigating this uncertainty so that software development progresses under informed decision making. Software metrics are essential tracking tools used by program managers to monitor and control risk areas. However, the choice of metrics for a program is critical to their usefulness.

This research provides a guide to acquisition managers on selecting the most effective metrics to use in management of weapon system software. The study identifies key issues in the use of software metrics experienced by program managers. The study recommends a revised set of metrics and improvements to the use of metrics based on innovations and improvements in the software field as well as software estimation tools that facilitate the use of these software metrics.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software Metrics, Acquisition of Weapons Systems

OPTIMIZATION OF DISTRIBUTED, OBJECT-ORIENTED ARCHITECTURES

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Object-Oriented computing is fast becoming the de-facto standard for software development. Optimal deployment strategies for object servers change given variations in object servers, client applications, operational missions, hardware modifications, and various other changes to the environment. Once distributed object servers become more prevalent, there will be a need to optimize the deployment of object servers to best serve the end user's changing needs. Having a system that automatically generates object server deployment strategies would allow users to take full advantage of their network of computers. Many systems have very predictable points in time where the usage of a network changes. These systems are usually characterized by shift changes where the manning and functions preformed change from shift to shift. We propose a pro-active optimization approach that uses predictable indicators like season, mission, and other foreseeable periodic events. The proposed method profiles object servers, client applications, user inputs and network resources. These profiles determine a system of equations that is solved to produce an optimal deployment strategy for the predicted upcoming usage by the users of the system of computers and servers.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Distributed Object Orientated Architecture, Distributed Object Servers

QUALITY OF SERVICE FOR IP-BASED NETWORKS

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In recent decades, the networking community has been looking for strategies to converge over a single common network infrastructure carrying voice, video and data. The pervasive and ubiquitous packet-based IP network provides the most convenient platform for the desirable convergence, where resources can be managed in an efficient and dynamic manner.

The gradual convergence into the IP infrastructure introduces multimedia-rich and interactive applications that are bandwidth-intensive and delay-bound, while more sophisticated data applications are deployed that place new demands onto IP networks. The IP-based network is evolving to satisfy the requirements of traffic differentiation and reliable service. Quality of Service (QoS) mechanisms are introduced to meet the traffic expectations and enhance the basic service model of the network in many subtle ways.

This thesis provides a comprehensive examination of QoS mechanisms and protocols that have surfaced to optimize the utilization of network resources, to provide differentiated treatment of traffic and enforce the appropriate policies. The study proposes a balanced approach of bandwidth increase and integration of robust QoS techniques into existing IP network infrastructure to arrive at a convergent, multiservice and scalable telecommunications network. Findings from this thesis can be incorporated into the design and implementation of an integrated network within a large organization that will deliver accurate services and defined level of performances.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control, and Communications

KEYWORDS: Networking, Convergence, Quality of Service, IP Multiservice Network, Policy-based Network, Traffic Management

A PATTERN-MATCHING APPROACH FOR AUTOMATED SCENARIO-DRIVEN TESTING OF STRUCTURED COMPUTATIONAL POLICY

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Organizations are policy-driven entities. Policy bases can be very large and complex; these factors are in the dynamic nature of policy evolution. The mechanical aspects of policy modification and assurance of the consistency, completeness, and correctness of a policy base can be automated to some degree. Such support is known as computer support for policy. An object-oriented schema-based approach to structure policy was developed. The structural model consists of Unified Modeling Language class and collaboration diagrams. The structural model is used by a suite of testing tools. A case study is presented to illustrate the approach to automated testing of policy. The approach to test-case generation is based on the use of patterns within policy statements and relationships between policy objects. The test spectrum has query-specific tests at one end, and the generic types of tests at the other end. The use of statistical inference to reuse test cases is introduced by determining the patterns that approximate the query-to-be-executed. Query mapping, anytime reasoning and fuzzy logic concepts in policies and their applications are discussed

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer Support for Policy

SOFTWARE ARCHECTURE RECONSTRUCTION METHODOLOGY IN THE CONTEXT OF PRODUCT LINE

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Software common architecture is widely believed to be a promising product-line approach for significantly improving software development efforts, quality control and time-to-market of the software systems. One of the key efforts to meet our goal of software reconstruction of architecture in the US Army Bradley A3 BFIST program was to manage and trace the requirements of the currently existing software architecture and the new requirements developed for the program. Based on the requirement similarities and matching, software components can be identified for reuse. This effort of requirement management and analysis also

gave a clear understanding of the external interface the software components have and the message/data traffic between the components in the system.

This thesis highlights the Software Architecture Reconstruction Methodology of the A3 BFIST program, the programmatic challenges involved, efforts of the Program Managers Office to minimize the project risks regarding the requirements management for software reuse and the lessons learned from the effort. The A3 BFIST Program is a successful project regarding software common architecture reconstruction. Efforts in managing requirements to identify components for software reuse resulted in: Reused software components: 80%; Modified software components: 5%; and New software components: 15 %. The program reduced the risk of cost and scheduling by having this architecture reconstruction process in place.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software

KEYWORDS: Software Architecture Reconstruction, Software Reuse for Product Line, Software Management, Risk Management, Software Process Model

ADVANCED QUALITY OF SERVICE MANAGEMENT FOR NEXT GENERATION INTERNET

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Future computer networks, including the Next Generation Internet (NGI), will have to support applications with a wide range of service requirements, such as real-time communication services. These applications are particularly demanding since they require performance guarantees expressed in terms of delay, delay jitter, throughput and loss rate bounds. In order to provide such quality-of-service (QoS) guarantees, the network must implement a resource reservation mechanism for reserving resources such as bandwidth for individual connections. Additionally, the network must have an admission control mechanism, for selectively rejecting some QoS-sensitive flow requests based on resource availability or administrative policies.

The Server and Agent-based Active Network Management (SAAM) is a network management system designed to meet the requirements of NGI. In SAAM, emerging services models like Integrated Services (IntServ) and Differentiated Services (DiffServ), and the classical best effort service are concurrently sharing network resources. This thesis develops and demonstrates in SAAM a novel resource management concept that addresses the difficulties posed by QoS networks. With the new resource reservation and admission control approaches, the sharing mechanism is dynamic and adapts to network load. It ensures high resource utilization while meeting QoS requirements of network users.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Server and Agent-based Active Network Management, SAAM, Network Management System

ANALYSIS OF ROUGH SURFACE LIGHTING BEHAVIORS WITH OPENGL

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In the physical world, humans gather valuable information about objects through their sight. Information on shape, feel and composition are seen long before the object is touched. This information is generated by light reflecting off the surface of objects. Despite the advancement of computer graphics due to increased

hardware rendering capacity, the fundamental equations, which draw three-dimensional scenes, lack the ability to truly model realistic objects. Whether it is smooth like highly polished metal or rough like the shag of a carpet, it is the reflection of light that tells humans what a surface feels like. The attempt taken in this thesis to implicitly model the roughness of textured surfaces through examination of an explicit model rendered with the OpenGL lighting equation. This approach has the potential to successfully increase the realism of computer graphics without increasing polygon count required for explicit surface generation. Through simulation of an explicitly constructed rough surface followed by the analysis of the behavior of its reflected light, the initial behaviors of textured surface reflections are identified. While these behaviors are not enough to create corrections to the OpenGL lighting equation, they lay the foundation for further development.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: OpenGL, Rough Surface Lighting Behavior

WEB-BASED TRAINING FOR THE HELLENIC NAVY

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The Hellenic Navy is looking to implement new ways of educating its personnel. Continuous training is a key to improve the performance of personnel. Increased operational tasks are preventing participation of a large portion of active military personnel in traditional classroom seminars and courses. Distance learning is a solution, which eliminates the need for the physical presence of a student in a classroom. New means of communication such as computer networks can deliver a large amount of information practically to any place in the world. Those against distance learning methods claim that the quality of distance learning courses is not equivalent to that of a traditionally taught course. In our work, the same course was taught both in a classroom and on the Web. The performance of the students in the classroom was compared to those taking the course online. Specific design principals were used for the Web site in order to achieve the best interface to deliver the course material.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel and Training

KEYWORDS: Continuous Training, Distance Learning, Web-based Training

PRINCIPLES FOR WEB-BASED INSTRUCTION

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This thesis presents a set of principles for web-based instruction based on literature from instructional design, usability engineering, and human-computer interaction. A questionnaire based on usability and instructional design attempts to show that in order to improve web-based instruction, usability and instructional design need to be taken into consideration when constructing long distance courses via the Web. The results show that usability and instructional design are dependent upon each other in order to present an effective on-line course while simultaneously learning from it.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel and Training

KEYWORDS: Web-based Instruction

REQUIREMENTS FOR THE DEPLOYMENT OF PUBLIC KEY INFRASTRUCTURE (PKI) IN THE USMC TACTICAL ENVIRONMENT

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Marine forces are expeditionary in nature yet require the full range of Public Key Infrastructure (PKI) services at deployed sites with limited bandwidth and access to their respective Registration Authority (RA). The development of a PKI solution for the tactical arena is a fluid and complex challenge that needs to be answered in order to ensure the best support of tactically deployed forces. Deployed Marine forces will need the capability to issue and re-issue certificates, perform certificate revocation, and perform key recovery within the command element of the deployed unit. Since the current United States Marine Corps (USMC) PKI was not designed with the tactical environment in mind, the full extent of PKI deficiencies for field operation is unknown. This thesis begins by describing public key cryptography, the implementation and objectives of a USMC PKI, and the components necessary to operate a PKI. Next, tactical issues that have been identified as areas of concern along with their proposed solutions are presented. Supporting material describes design issues, such as scalability and interoperability, and technical challenges, such as certificate revocation lists (CRL), key escrow and management of tokens

DoD KEY TECHNOLOGY AREA: Other (Public Key Management)

KEYWORDS: Public Key Infrastructure (PKI), Computer Security, Navy Marine Corps Intranet (NMCI)

DYNAMIC ASSEMBLY FOR SYSTEM ADAPTABILITY, DEPENDABILITY AND ASSURANCE (DASADA) PROJECT ANALYSIS

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This thesis focuses on an analysis of the dynamic behavior of software designed for future Department of Defense systems. The DoD is aware that as software becomes more complex, it will become extremely critical to have the ability for components to change themselves by swapping or modifying components, changing interaction protocols, or changing its topology. The Defense Advanced Research Programs Agency formed the Dynamic Assembly for Systems Adaptability, Dependability, and Assurance (DASADA) program in order to task academia and industry to develop dynamic gauges that can determine run-time composition, allow for the continual monitoring of software for adaptation, and ensure that all user defined properties remain stable before and after composition and deployment. Through the study, a review of all the DASADA technologies were identified as well as a thorough analysis of all 19 project demonstrations.

This thesis includes a template built using the object-oriented methodologies of the Unified Modeling Language (UML) that will allow for functional and non-functional decomposition of any DASADA software technology project. In addition, this thesis includes insightful conclusions and recommendations on those DASADA projects that warrant further study and review.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computing, Software, Software Engineering, Software Demonstration

WEB DATABASE DEVELOPMENT
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This thesis explores the concept of Web database development using Active Server Pages (ASP) and Java Server Pages (JSP). These are among the leading technologies in the web database development. The focus of this thesis was to analyze and compare the ASP and JSP technologies, exposing their capabilities, limitations, and differences between them. Specifically, issues related to back-end connectivity using Open Database Connectivity (ODBC) and Java Database Connectivity (JDBC), application architecture, performance, and web security were examined. For demonstration purposes, two applications were developed, one with ASP and another with JSP. The user interface and the functionality of these two applications were identical, while the architecture, performance, and back-end connectivity was totally different.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Web Database, Active Server Pages

REALISTIC TRAFFIC GENERATION CAPABILITY FOR SAAM TESTBED
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Traffic modeling is an important component of the design of any communication network. This is even more crucial for emerging networks, which are expected to operate in high speed and high bandwidth environments. As the design of a network depends to a great extent on the types of traffic it is expected to carry, it is essential to characterize the traffic that a network is expected to carry. This is where traffic models are very important. They can be used to produce artificial traffic input that exhibits essential characteristics of real network loads.

This thesis describes a design and implementation of a general-purpose traffic generator for a testbed of the Server and Agent Based Active Network Management (SAAM) architecture. The traffic generator is easy to use and implements the four most important traffic models (Constant Bit Rate (CBR), Poisson, Packet-Train, and Self-Similar). With this traffic generator, the SAAM project now has the capability of simulating and testing the system components in more accurate and more realistic environments.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Traffic Model, CBR, Poisson, Packet-Train, Self-Similar, Next Generation Internet, Networks

ANALYSIS OF INTEL IA-64 PROCESSOR SUPPORT FOR SECURE SYSTEMS

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Current architectures typically focus on the software-based protection mechanisms rather than hardware for providing protection. In fact, hardware security mechanisms can be critical for the construction of a secure system. If hardware security mechanisms are properly utilized in a system, security policy enforcement can be simplified. Systems could be constructed for which serious security threats would be eliminated.

This thesis explores the Intel IA-64 processor's hardware support and its relationship to software for building a secure system. To analyze the support provided by the architecture, hardware protection mechanisms were examined. This analysis focused on the following mechanisms: privilege levels, access rights, region identifiers and protection key registers. Since protection checks are made through the translation lookaside buffer (TLB) during the virtual-to-physical translations, the TLB structure was an area of focus throughout the research for this thesis.

Proper use of the TLB-based hardware protection features permits protection in the IA-64 architecture. It enables the processor hardware and the operating system to collaborate to enforce security policies efficiently.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Protection, Intel IA-64 architecture, Secure Systems

THE EFFECTS OF NATURAL LOCOMOTION ON MANEUVERING TASK PERFORMANCE IN VIRTUAL AND REAL ENVIRONMENTS

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This thesis investigates human performance differences on maneuvering tasks in virtual and real spaces when a natural locomotion technique is used as opposed to an abstraction through a device such as a treadmill. The motivation for the development of locomotion devices thus far has been driven by the assumption that a "perfect" device will result in human performance levels comparable to the real world. This thesis challenges this assumption under the hypothesis that other factors beyond the locomotion device contribute to performance degradation. An experiment was conducted to study the effects of these other factors.

The experiment studied sidestepping, kneeling, looking around a corner, and backward movement tasks related to a building clearing exercise. The participants physically walked through the environment under all conditions. There were three treatments: real world (no display, physical objects present), virtual world (head-mounted display, no physical objects), and real and virtual world combined (head-mounted display, physical objects present).

The results suggest that performance and behavior are not the same across conditions with the real world condition being uniformly better than the virtual conditions. This evidence supports the claim that even with identical locomotion techniques, performance and behaviors change from the real to the virtual world.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human Systems Interface

KEYWORDS: Virtual Environments, Locomotion Devices

EVALUATION OF SURVEILLANCE RECONNAISSANCE MANAGEMENT TOOL AND UTILITY/FUNCTIONALITY TO FUTURE SURFACE COMBATANTS

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This abstract is classified.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Not Available

IMPLEMENTATION OF A MULTI-AGENT SIMULATION FOR THE NPSNET-V VIRTUAL ENVIRONMENT RESEARCH PROJECT

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Traditional networked military simulation systems are technologically frozen the moment they are completed, thus limiting the participants that can interact in the simulation. When training for urgent missions in emerging conflict areas, assimilating new models, threat behaviors, and new terrain environments into the simulators requires lengthy integration, is prohibitively costly, and is non-distributable electronically at runtime. Threat behaviors are pre-scripted, lack organization, and do not accurately portray doctrine or rules-of-engagement.

NPSNET-V is a novel architecture for networked simulations that supports scalable virtual worlds with built-in dynamic entity loading. These advances address each of the above concerns: scalability, entity and environment distribution, and dynamic technology loading. By combining this architecture with a system for creating autonomous, adaptable agents, threat forces can be accurately simulated. This architecture is useful for proposing designs for strategies, tactics, or force packages during the conduct of experiments.

The result of this thesis is a proof-of-concept application demonstrating the utility of these architectural advances. In this application, numerous autonomous agents form complex, dynamic, and adaptable interactions with resident and remote heterogeneous entities. These results define the course for future military models and simulations.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: NPSNET-V, Autonomous Adaptable Agents, Virtual Environments

DYNAMIC SCALABLE NETWORK AREA OF INTEREST MANAGEMENT FOR VIRTUAL WORLDS

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A major performance challenge in developing a massively multi-user virtual world is network scalability. This is because the network over which entities communicate can quickly develop into a bottleneck. Three critical factors: bandwidth usage, packets per second, and network-related CPU usage, should be governed

by the number of entities a given user is interested in, not the total number of entities in the world. The challenge then is to allow a virtual world to scale to any size without an appreciable drop in system performance.

To address these concerns, this thesis describes a novel Area of Interest Manager (AOIM) built atop the NPSNET-V virtual environment system. It is a dynamically sized, geographical region based, sender-side interest manager that supports dynamic entity discovery and peer-to-peer entity communication. The AOIM also makes use of tools provided by the NPSNET-V system, such as variable resolution protocols and variable data transmission rate.

Performance tests have shown conclusively that these interest management techniques are able to produce dramatic savings in network bandwidth usage in a peer-to-peer virtual environment. In one test, this AOIM produced a 92% drop in network traffic, with a simultaneous 500% increase in world population.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Multi-User Virtual World, Area of Interest Manager, AOIM

HUMAN FACTORS IN COAST GUARD COMPUTER SECURITY - AN ANALYSIS OF CURRENT AWARENESS AND POTENTIAL TECHNIQUES TO IMPROVE SECURITY PROGRAM VIABILITY

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The Coast Guard is becoming increasingly reliant upon our nation's information infrastructure. As such, our ability to ensure the security of those systems is also increasing in import. Traditional information security measures tend to be system-oriented and often fail to address the human element that is critical to system success. In order to ensure information system security, both system and human factors requirements must be addressed.

This thesis attempts to identify both the susceptibility of Coast Guard information systems to human factors-based security risks and possible means for increasing user awareness of those risks. This research is meant to aid the Coast Guard in continuing to capitalize on emerging technologies while simultaneously providing a secure information systems environment.

DoD KEY TECHNOLOGY AREA: Command, Control and Communication, Computing and Software, Human Systems Interface

KEYWORDS: Computer Security, Human Factors, Human Computer Interaction, Coast Guard, Trust, INFOSEC

CONCEPTS, APPLICATIONS AND ANALYSIS OF A SUBMARINE BASED WIRELESS NETWORK

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As information technology tools continue to improve, we must take advantage of this wave by developing wise solutions to help automate many daily tasks presented onboard submarines. Java based applications and Commercial-off-the-Shelf (COTS) technology provides us low cost solutions that increase the availability and mobility of the information we seek. Small pen based computers and wireless LANS allow

us to create dynamic and distributable applications that can route paperwork or fight casualties. It is imperative we take full advantage of these technologies in the design of our new submarines as well as in retrofit of our older ones.

This thesis attempts to solve a key task, Damage Control (DC) communications, by designing a Java based application known as SWIPNet (Submarine Wireless Prototyped Network). This virtual grease board application uses multicast sockets to send standard DC and crew reports to all wireless handhelds that participate in a casualty. A proposed Virginia class wireless network, known as the Non Tactical Data Processing System (NTDPS), was then analyzed to determine network efficiency in the presence of SWIPNet and 14 other submarine type network loads. Demonstrations have proven that SWIPNet provides a more efficient way to communicate and can function effectively on the NTDPS.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Computing and Software, Command, Control and Communications

KEYWORDS: Wireless Local Area Network, Mobile Computing, Java, Pen-Based Computing, Pdas, Handheld Computers, Database, OPNET Modeler, Microsoft Access, Damage Control, Multicast Sockets, Wireless Communications

AN APPLICATION OF ROLE-BASED ACCESS CONTROL IN AN ORGANIZATIONAL SOFTWARE PROCESS KNOWLEDGE BASE

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The Organizational Software Process Knowledge Base (OSPKB) is the repository of an organization's software process, product performance, quality metrics, and corporate lessons learned. The knowledge is maintained on a project-by-project basis, as well as by business domain. The OSPKB contains sensitive data and information that needs to be protected from unauthorized disclosure or modification. In this thesis, we address the challenge of controlling access to the data and information stored in the OSPKB. In particular, we investigate approaches to applying role-based access control (RBAC) to OSPKB applications.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Project Management, Software Process Management, Role-Based Access Control, Security

FAULT TOLERANCE IN THE SERVER AND AGENT BASED NETWORK MANAGEMENT (SAAM) SYSTEM

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Interconnected networks of computers are becoming increasingly important. It is the Internet that has spurred the most recent growth in global computer networks. The limitations of the Internet can be blamed on many factors but when determining solutions to these shortcomings the focus has been on replacing the current Internet Protocol version 4 (IPv4) with the new Internet Protocol version 6 (IPv6). Much work has been done and much more work remains to be done in transitioning to and reaping the benefits of this "Next Generation Internet." The Server and Agent Based Active Network Management (SAAM) project is one of many "Next Generation Internet" projects that intend to implement and exploit the enhanced

capabilities of IPv6 to overcome the limitations of the current Internet. The focus of the SAAM project is guaranteed quality of service (QoS). This thesis addresses fault tolerance in a SAAM region with regards to router and link failures. A hybrid link restoration (rerouting) scheme is proposed, in which central knowledge (at the SAAM server) of the network topology is used to develop alternate paths while path switching is done at a local (router) level.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Server Agent Based Network Management System, SAAM, Interconnected Networks, Router and Link Failures

INTEGRATED DEVELOPMENT ENVIRONMENT (IDE) FOR THE CONSTRUCTION OF A FEDERATION INTEROPERABILITY OBJECT MODEL (FIOM)

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Advances in computer communications technology, the recognition of common areas of functionality in related systems, and an increased awareness of how enhanced information access can lead to improved capability, are driving an interest toward integration of current stand-alone systems to meet future system requirements. However, differences in hardware platforms, software architectures, operating systems, host languages, and data representation have resulted in scores of stand-alone systems that are unable to interoperate properly.

Young's Object Oriented Model for Interoperability (OOMI) defines an architecture and suite of software tools for resolving data representational differences between systems in order to achieve the desired system interoperability. The Federation Interoperability Object Model (FIOM) Integrated Development Environment (IDE) detailed in this thesis is a toolset that provides computer aid to the task of creating and managing an interoperable federation of systems.

This thesis describes the vision and requirements for this tool along with an initial prototype demonstrating how emerging technologies such as XML and Data Binding are utilized to capture the necessary information required to resolve data representational differences between systems. The material presented in this thesis has the potential to significantly reduce the cost and effort required for achieving interoperability between DoD systems.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Object Orientated Model for Interoperability, OOMI, Federation Interoperability Object Model Integrated Development Environment, FIOM IDE

NETWORK DEFENSE-IN-DEPTH: EVALUATING HOST-BASED INTRUSION DETECTION SYSTEMS

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As networks grow, their vulnerability to attack increases. DoD networks represent a rich target for a variety of attackers. The number and sophistication of attacks continue to increase as more vulnerabilities and the tools to exploit them become available over the Internet. The challenge for system administrators is to secure systems against penetration and exploitation while maintaining connectivity and monitoring and reporting intrusion attempts.

Traditional intrusion detection (ID) systems can take either a network or a host-based approach to preventing attacks. Many networks employ network-based ID systems. A more secure network will employ both techniques. This thesis will analyze the benefits of installing host-based ID systems, especially on the critical servers (mail, web, DNS) that lie outside the protection of the network ID system/Firewall. These servers require a layer of protection to ensure the security of the entire network and reduce the risk or attack..

Three host-based ID systems will be tested and evaluated to demonstrate their benefits on Windows 2000 Server. The proposed added security of host-based ID systems will establish defense-in-depth and work in conjunction with the network-based ID system to provide a complete security umbrella for the entire network.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Network Security, System Security, Intrusion Detection, Intrusion Detection System, Defense-in-depth

A TRAINING FRAMEWORK FOR THE DEPARTMENT OF DEFENSE PUBLIC KEY INFRASTRUCTURE

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Increased use of the Internet and the growth of electronic commerce within the Department of Defense (DoD) has led to the development and implementation of the DoD Public Key Infrastructure (PKI). Any PKI can only serve its intended purpose if there is trust within the system. This thesis reviews the basics of public (or asymmetric) key cryptography and its counterpart, symmetric key cryptography. It outlines the DoD's PKI implementation plan and the user roles identified within the infrastructure. Because a PKI relies entirely on trust, training for all users of a PKI is essential. The current approach to PKI training within the DoD will not provide all of its users with the required level of understanding of the system as a whole, or of the implications and ramifications that their individual actions may have upon the system. The decentralized, segmented, and inconsistent approach to PKI training will result in a lack of trust within the PKI. Training for the DoD PKI must be consistent, current, appropriate, and available to all users at any time. The author proposes a web-based training framework for the DoD PKI. The basic requirements and design of the framework are presented, and a prototype is developed for further testing and evaluation. Without the proper attention to training, the DoD PKI will be at risk, and may not perform its intended

functions of providing the required authenticity and integrity across the various networks upon which DoD conducts business.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Internet, Electronic Commerce, Public Key Infrastructure, PKI

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