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THE GRIFFISS INSTITUTE SUMMER FACULTY PROGRAM

GRIFFISS INSTITUTE

MAY 2013

FINAL TECHNICAL REPORT

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AIR FORCE RESEARCH LABORATORY
INFORMATION DIRECTORATE

■ **AIR FORCE MATERIEL COMMAND** ■ **UNITED STATES AIR FORCE** ■ **ROME, NY 13441**

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Griffiss Institute (GI), has facilitated the management of the Air Force Research Laboratory Information Directorate Visiting Faculty Research Program and Summer Faculty Fellowship Program. The GI will place highly qualified and motivated faculty members and graduate students (M.S. and Ph.D.) in science, technology, engineering and mathematics (STEM) disciplines as well as other recognized technical and newly emerged interdisciplinary areas to provide intellectually stimulating summer environment for the visitors to have enriched and rewarding experiences.

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1. INTRODUCTION

The Griffiss Institute (GI), has facilitated the management of the Air Force Research Laboratory Information Directorate Visiting Faculty Research Program and Summer Faculty Fellowship Program. The GI will place highly qualified and motivated faculty members and graduate students (M.S. and Ph.D.) in science, technology, engineering and mathematics (STEM) disciplines as well as other recognized technical and newly emerged interdisciplinary areas to provide intellectually stimulating summer environment for the visitors to have enriched and rewarding experiences.

2. FACULTY & RESEARCH AREAS

2.1. 2011 Summer Faculty

Timothy E. Busch - A Study of the application of game theoretic approaches to cross layer optimization in communications networks; Electrical and Computer Engineering Department, State University of New York Institute of Technology

Network centric warfare is a term that was coined in the mid 1990's to describe a shift from a focus on war fighting platforms and their individual capabilities to seamlessly integrating their use. The synergy brought about by this networking would greatly enhance our capability, increase our flexibility, and potentially reduce costs. The ability to collect, process, and share information to decision makers at all levels of the enterprise has been the goal of this transformation. While network centric warfare was not primarily focused on communication systems, they are an essential component.

The Air Force Vision for Aerial Layer Networking in 2024 expresses the fundamental goal of the aerial network as "to extend and augment space and surface networks to connect, reconnect, and enable collaboration of warfighters executing specific missions and tasks." The document goes on to say that "Aerial layer networking connectivity, capacity, interoperability and management gaps exist today and will find further potential exposure in the coming years due to the demands of dynamic missions." Expected growth in the number of airborne systems, users, and sensors will add to the demand. At the same time, the primary resource for wireless devices, spectrum, is in much greater demand. In fact, the United States government has sold off blocks of spectrum that was previously reserved for military use. This leads to significant technology challenges in closing aerial networking gaps.

Spectrum is currently allocated by international treaty and national regulatory bodies. Changes to its use come very slowly. Likewise for operators and equipment developers, static frequency allocation provides a measure of stability. There are frequently situations where spectrum has been allocated but is under used. For example 470-512MHz has been allocated to broadcast television channels 14-20 in the United States and is reserved for this purpose regardless if there is a local station or not. So while static allocation eases spectrum management issues it has the potential for wasting precious bandwidth. The situation is much more complicated for deploying military forces that have to coordinate and share spectrum with a variety of communication, radar, navigation, and other systems that are dynamically changing.

The Air Force Research Lab contributed significantly to the development of software defined radios which were aimed at improving connectivity and interoperability and gave rise to the notion of cognitive radios. A cognitive radio is defined as "a radio that is aware of its environment, and constantly utilizes this awareness to adjust its operating characteristics and behaviors to provide effective performance in a wide range of environments" DARPA programs such as the neXt Generation (XG) and Wireless Network after Next (WNaN) have demonstrated that cognitive radios can be used to dynamically use spectrum that has been allocated to another user (called the primary user) but not in use at the time. Dynamic spectrum access (DSA) will improve both network connectivity and capacity.

Kyoung-Don Kang - Towards High-Performance Processing of Cloud Auditing Data using GPGPU Many-Core Parallelism; Department of Computer Science, State University of New York at Binghamton

As the demand for cloud computing is increasing fast, it is realized that cloud computing has many security threats and vulnerabilities. Even though the success of cloud computing largely depends on security, supporting cloud computing security is challenging. To tackle the challenges, the CyberBAT team at Air Force Research Laboratory, Rome, NY led by Dr. Keesook Han is exploring cloud auditing – a key fundamental building block for cloud computing security. A major challenge for cloud auditing is dealing with massive real-time and stored traffic data. In this project, we explore how to leverage massive hardware parallelism provided by many-core GPGPUs (General Purpose Graphics Processing Units) to support high performance processing of traffic data for cloud auditing. Existing tools for network traffic data analysis such as Wireshark provide limited performance and scalability due to the design based on outdated computer architectures. Hardware-based solutions using, for example, FPGAs (Field Programmable Gateway Arrays) is expensive and inflexible. In this project, we take an initial step towards high performance traffic data analysis by taking advantage of tremendous hardware parallelism provided by GPGPUs that are inexpensive and easily programmable using CUDA (Compute Unified Device Architecture) similar to C programming language.

Vladimir V. Nikulin - Propagation of Quantum Encrypted Signals Over Practical Free-Space Atmospheric Links; ECE Dept, SUNY-Binghamton

Optical communication has proven to be the lowest cost and most scalable technology for keeping up with increasingly large bandwidth demands. It is viewed as a technology that offers unsurpassed advantages over traditional radio frequency (RF) systems: intrinsically high bandwidth, absence of channel contention, low probability of detection and interception, and resistance to jamming [1] – [3]. However, based on practical issues such as antenna size and pointing errors, there is still a risk of interception by unauthorized parties. In this case, privacy and security of information can be significantly enhanced by data encryption. The extent of this enhancement depends upon the mechanism used by the system. Perfect information-theoretical security is achieved when the content of an encrypted message is statistically independent of the cipher text in which the message is embedded. This implies that analysis of an intercepted sample of a cipher text does not reveal any information about the hidden message. A search for the "holy grail" of cryptography has led to the application of quantum mechanical principles in optical communication networks. The basic element of a quantum system is a "qubit," or a quantum bit, which could be in one of two possible states, such as the electron spin +1/2 and –1/2, the photon polarization, orbital angular momentum, or other quantized values of photons. Quantum processes at the physical layer of encryption could be used to facilitate ultra-secure quantum communications (QC) with very competitive performance characteristics. The ultimate range of applications for QC systems spans from fiber-based to free-space links and from secure banking operations to mobile airborne and space-borne networking. Just like any laser communication technology, free-space QC links are affected by channel distortions. Under practical conditions, atmospheric turbulence creates spatial and temporal fields of the refractive index along the propagation path and can alter the optical wave front characteristics, including

phase and polarization. If quantized values of photons are used to encrypt the signal, its integrity may suffer as a result of these distortions.

As part of the 2008 Visiting Faculty Research Program, we focused on the optical connectivity issues associated with free-space quantum communications. In the summer of 2009, we performed a simulation study of phase encrypted links paying special attention not only to the power of the detected signals, but also to the received wave front patterns. In 2010, a wave front sensing approach was developed and used for coherence experiments in a practical quantum communication link. Within the framework of this project we studied integration of a quantum key distribution (QKD) system into an existing optical link and use previously developed atmospheric models and experimental data to assess propagation of the encrypted signals. This project complements other AFRL-funded research efforts in this area, including the design of optical communication transceivers and the development of encryption systems.

Qinru Qiu - Architecture Design and Enhancement for Autonomous and Intelligent Text Recognition; Department of Electrical Engineering and Computer Science, Syracuse University

Autonomous and intelligent recognition of printed or hand-written text image is one of the key features to achieve situation awareness. The Intelligent Text Recognition System (ITRS) harnesses the TeraFLOPS computing power of the HPC (High Performance Computing) cluster at AFRL Rome laboratory to mimic human cognition in printed text understanding. It learns from what has been read and, based on the obtained knowledge it forms anticipations and predicts the next input image (or the missing part of the current image). Such anticipation helps the system to fight with all kinds of noises that may occur during recognition.

The ITRS is divided into 3 layers. The input of the system is an image of text. The first layer performs the character recognition based on the *Brain-State-in-a-Box* (*BSB*) model. It tries to match the input image with stored images of English alphabet. If there is noise in the input or the image is partially damaged, multiple matching patterns will be found, which results in ambiguities. The ambiguity can be removed by considering the word level and sentence level context, which is achieved in the second and third layer where word and sentence recognitions are performed using *cogent confabulation* models. These models fill in the missing characters in a word and missing words in a sentence.

The focus of this summer research project is to investigate potential techniques that may improve the performance and accuracy of the ITRS. Two major directions have been explored and the potential enhancement techniques have been evaluated. First, the image correction algorithms have been studied in order to improve the accuracy of character recognition by using better input images. Second, the potential of using parts-of-speech tagging to improve the quality of sentence confabulation has been evaluated. The experimental results show positive improvements.

Lei Yu - Embedded Incremental Feature Selection for Reinforcement Learning in Continuous Action Spaces; Department of Computer Science, Binghamton University

Applying reinforcement learning techniques in domains with continuous action spaces is a challenging problem that must be faced in order to scale these technologies to realworld applications. Irrelevant and redundant perceptual inputs about the environment significantly

magnify this challenge. Such unnecessary input features often hinder the learning of a good policy for the training environment. Moreover, they can cause the learned policy to overfit the training environment and generalize poorly to similar but unseen environments. In this work, we explore an incremental feature selection algorithm for reinforcement learning. The algorithm embeds a sequential forward selection procedure within the neuroevolutionary policy search algorithm NEAT. We show that feature selection not only enables the discovery of better policies, but that these policies have better generalization properties than those learned without the benefit of feature selection. Specifically, we empirically demonstrate on a complex racing simulation that policies learned on one track can generalize well to other unseen tracks.

2.2. 2012 Summer Faculty

Lynn Abbott - Interleaving Acquisition and Analysis for 3D Sensing; Bradley Department of Electrical and Computer Engineering, Virginia Tech

This report concerns the use of information-theoretic measures to aid in the reconstruction of three-dimensional scenes using multiple camera views. The high-level goal of multiview stereo (MVS) is to construct a detailed representation of a scene automatically, by analyzing images that have been obtained from cameras at two or more viewpoints. Recent work by many researchers has led to impressive results, including large-scale reconstructions involving thousands of images. Most existing systems, however, make no attempt to guide the acquisition of new images based on an evolving scene representation. This report describes a framework for actively selecting new camera positions to support MVS reconstruction. This new approach applies the concept of entropy reduction to viewpoint selection. Results are preliminary, but suggest that improved reconstruction is possible as compared to the case of uniformly spaced cameras.

Yang Cai - Semantic Object Detection; Visual Intelligence Studio and Instinctive Computing Lab, Carnegie Mellon University

The CMU team has worked with the VMR team in RIGC on object detection from images and video sound tracks. It is a continuation of our previous work for DIA/NMEC's project "Visual Media Forensics Toolkit" for analyzing massive images and videos from handheld cameras smartphones and online media such as YouTube and Flickr.

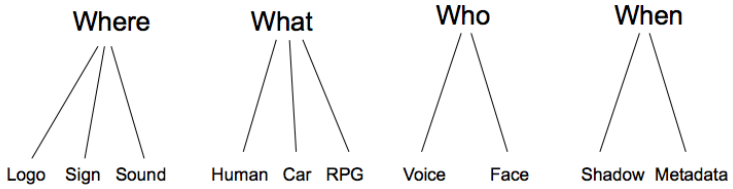

Figure 1: Visual Media Forensics Toolkit

We have studied on the low-resolution, shaky and noisy video data that was a challenge to video analytics. We have developed algorithms for multimodal video analytics, including logo detection, background sound classification, vehicle detection and human detection functions. The

logo detection algorithm was implemented with SURF (Speed Up Rapid Feature) and RANSIC models. Our early experiments showed that the logo detection algorithm works well for the logos with rich features and the algorithm can tolerate scaling and rotation. The car and human detection algorithm is based on Histogram of Gradient (HOG). Early test results showed that the algorithm detects cars and humans from very low-resolution images and videos with a reasonable accuracy (according to NMEC's Binary Object Index Manual). Our background sound classification algorithm was tested with over a hundred sound effect clips. With Short Time Fourier Transform (STFT) and Gaussian Mixture Model (GMM).

We have developed a preliminary algorithm for RPG head detection and studied the correlations between vehicle sounds and vehicle visual detection. So far we have some initial results. The two students will continue to work on that and provide updated results.

We have delivered the logo detection software to support the software viability evaluation. The software was written in GCC on Linux and it is easy to be ported to other platforms.

Yu Chen - Development of Data Collection and Visualization Tools for Android Smartphone Cloud Auditing; Department of Electrical and Computer Engineering, Binghamton University

Applications on Android smartphones are becoming increasingly popular. It is widely recognized that stronger security is required due to the sensitive information attached to a person's smartphone and it is critical to protect the interests of government agents. User-centric security solutions are highly expected because of the close correlation between the information assurance and user behaviors. On the other hand, the capability of auditing the functionalities and behaviors in the Android smartphone cloud environments is essential to provide more intelligent defense. To achieve this goal, efficient and effective traffic analysis is required to capture features of user behavior. In this project, we have developed data collection and visualization tools on the Android smartphone cloud platform.

Wireshark is one of the world's foremost network protocol analyzers. While it is a useful tool, graphical analysis features are not sufficient within the protocol analyzer. In this project, two tools have been developed to enhance Wireshark with the capability to generate visuals. One tool takes advantages of

3D WebGL visuals that allow researchers to visualize traffic properties in a 3D geolocation manner. To demonstrate the practicality of the application, captured Wireshark content is processed using Hadoop, and then rendered as a 3D WebGL website. The second tool is an Android application for real-time user geo- location tracking and traffic analysis. At the smartphone side, a lightweight agent pushes PCAP files to a central server. The server stores PCAP files and geolocation information based on the Android device's ID. The system designed to allow users to join cloud at will and a HTML webpage provides easy to use interface for analysis.

A. Ege Engin - Novel Metal-Semiconductor TSVS In 3D ICS for Improved Electrical and Thermal Performance; Department of Electrical and Computer Engineering, San Diego State University

Parasitic RC behavior of VLSI interconnects has been the major bottleneck in terms of latency and power consumption of ICs. Recent 3D ICs promise to reduce the parasitic RC effect by making use of through silicon vias (TSVs). It is therefore essential to extract the RC model of TSVs to assess their promise. Unlike interconnects on metal layers, TSVs exhibit slow-wave and dielectric quasi-TEM modes due to the coupling to the semiconducting substrate. This TSV behavior can be simulated using analytical methods, 2D electrostatic simulators, or 3D fullwave electromagnetic simulators. In this project, a methodology was developed to extract parasitic RC models from such simulation data for interconnects in a 3D IC. The extracted model was then used to estimate latency and power consumption in 3D ICs. Finally, the developed methodology was applied to estimate the electrical and thermal performance of a novel metal-semiconductor TSV.

Sanjay Madria - Event Detection from Click-through Data; Department of Computer Science, Missouri University of Science and Technology

The approximate size of today's indexed World Wide Web is at least 45.93 billion pages as per existing estimation [1] and is a rich collection of all the real world objects. The Web is a great source of knowledge to be mined to learn about topics, stories, events etc. Event detection is becoming increasingly popular because of its applicability in several diversified areas. Therefore, the interpretation of "event" definition is context-dependent. An event can be associated with reporting how many people/cars have entered a building/freeway, web access logs, security logs, object trajectory in video surveillance and business activity monitoring for business intelligence etc. In our perspective and from the viewpoint of the Web, an event can be understood as some real-world activity that stirs a large scale querying and browsing activity. That is, it is of more interest to users over a sizable window period which is unusual relative to normal patterns of querying and browsing behavior.

Web is the collaborative work of many people; a few publishing, and all of them querying and retrieving the information. Search engines record these activities in Web logs called the click-through data and reflect the query and clicks activities of users. Click-through data is more or less in the format shown in the Table 1 below:

Table 1: Sample click-through data

AnonID	Query	Query Time	Item Rank	Click URL
7	Easter	2006-03-01 23:19:52	1	http://www.happy-easter.com
7	Easter eggs	2006-03-01 23:19:58	1	http://www.eeggs.com

To briefly explain the fields in Table 1, we begin with AnonID, the anonymous User ID from whom the search engine received the request, followed by the query issued by the user, the time the search engine received the request, the rank of the page item clicked, the page clicked in response to the result among the set returned by the search engine. Note that the click-through data format varies slightly from one search engine to the other.

Three Web data types identified in previous [2] efforts are: content (text and multimedia), structure (links that form a graph) and web usage (transactions from the web log). Web data mining encompasses a broad range of research topics like improving page ranking, efficient indexing, query clustering, query similarity, query suggestions, extracting semantic relations and event detection etc. All these areas are inter-related and many use the click-through data as a starting point for their analysis. The seamless flow of advancement in developing better approaches in individual areas can be pipelined to improve existing techniques in other inter-related fields. Our effort in this paper is to integrate three Web data types and achieve the overall objective of event detection via query clustering.

Vladimir V. Nikulin – Measurement of Quantum Encrypted Signals Over Practical Free-Space Atmospheric Links Using Coherent States of Light (Phase Encryption); Dept. of Electrical and Computer Engineering, State University of New York at Binghamton

Quantum communication is a laser communication technology that, in addition to very high data rate and low power requirements of the transmitters, offers unprecedented data security. Quantum processes at the physical layer of encryption could be used to facilitate ultra-secure quantum communications (QC) with very competitive performance characteristics. The ultimate range of applications for QC systems spans from fiber-based to free-space links and from secure banking operations to mobile airborne and space-borne networking. Just like any laser communication technology, free-space QC links are affected by channel distortions. Under practical conditions, atmospheric turbulence creates spatial and temporal fields of the refractive index along the propagation path and can alter the optical wave front characteristics, including its phase. If quantized values of photons are used to encrypt the signal, exploitation of quantum communication links becomes extremely difficult. Within the scope of this project, we research measurement approaches based on coherent (homodyne) detection. Simulation studies of the effects of quantum noise on phase estimation are conducted for quantum systems with different number of encryption bases and operating at different power levels. This project complements other AFRL-funded research efforts in this area, including the design of optical communication transceivers and the development of encryption systems, including Alpha-Eta.

Kannappan Palaniappan – Target Tracking Using Likelihood Fusion and Visualization for Wide-Area Motion Imagery; Department of Computer Science University of Missouri-Columbia

Coordinated CETE project activities by working closely with Kitware and AFRL to integrate the University of Missouri tracking algorithms (LoFT and CSURF) within the wide area motion imagery tracking software environment at Kitware. Supervised graduate student and postdoc working at Kitware during the summer on CETE algorithms. A number of software issues related to Matlab Compiler Runtime (MCR) DLLs, multithreading performance, Boost software library compatibility, library signatures, config fies, support for multiple operating systems including Windows (32- and 64-bit) and CentOS were resolved. Some performance improvements to speedup feature computation, median calculation, multiscale Hessian were successfully completed. Three areas of emphasis was to facilitate the rapid integration of the University of Missouri foreground appearance-based tracking algorithms within the Kitware onboard motion imagery processing framework for a CETE project flight demo in 2013,

performance evaluation of tracking algorithms for Information Fusion conference presentation and partial 3D multiview reconstruction. Onboard processing will incorporate car detection and orientation estimation modules to maintain appearance status incorporating a tradeoff between stability and plasticity for optimizing performance.

Algorithm porting of LOFT and CSURF for onboard processing will require integration of the University of Missouri tracking algorithms with the Kitware overall tracking environment and support for managed information objects. The KW-UMO integration process is currently testing V1.0 that is a loosely coupled set of modules. During the summer we worked on a more tightly coupled V2.0 of the KW-UMO integrated tracking system, referred to as the KW-UMO hybrid tracker that combines the foreground appearance based tracking with the detection and prediction modules from KW. The V2.0 software will support restarts on Kitware track initializations (instead of with a _xed set of initializations as in V1.0), and benchmark performance on several datasets including CLIF and ARGUS. The LAIR data will be processed and parameters optimized for testing. The V2.0 software will support a more interactive update process on each frame so that appearance information can be maintained by the UMO tracking modules and shared with the KW modules as needed. I also worked with AFRL and ITT to develop an interface between on-board managed information objects and ground-based information management systems. Mapping of key algorithms (MOKA) that is needed for CETE was discussed with ITT to do performance characterization and scalability on multicore architectures and distributed HPC Condor environment with respect to video processing algorithms such as flux tensor, morphology, connected component labeling.

Testing Kolam-wall on the AFRL video wall display system was very successful but revealed areas for improvement in the current design and implementation of the Kolam-wall network-based asynchronous event communication, Kolam multi-threaded event handling and opengl display processing. We now have a good handle on the cause of the "swimming" effcts we were seeing from different displays not being in sync with the master instance of kolam and different client instances with different temporal lags leading to the adverse performance. Most of the testing and debugging was related to kolam-wall detection of the local graphics hardware cluster topology, user interaction and UDP broadcast performance. Kolam-wall needs to add support for other events supported by the single display kolam tool such as loading sequences and trajectories, 3D rendering, transparency, grid, layer visibility, etc. which are part of work in progress.

The following major tasks were completed:

Transitioned to AFRL a new version of kolam-wall for high performance visualization of gigapixel video on hundred megapixel-sized displays (Mosaic GPU cluster). Forty display screens could be interactively updated with ARGUS-IS, PSS, NASA BlueMarble and other time series imagery. Installed kolam-wall software on Mosaic GPU cluster at AFRL with the assistance from Ryan Luley and Morgan Bishop. Gave presentations to Col. Willis, Dr. Rich Linderman, senior staff, RIEA Branch Chief and branch members on kolam-wall capabilities.

Completed significant improvements in kolam-wall to support higher visualization performance on large WAMI imagery and trajectory data. Identified bottlenecks due to a flood of network packets from user GUI events that were being produced by Qt signaling mechanism and made a number of other improvements as detailed in the following section.

Collaborated with Kitware at their facilities to integrate the Matlab-based wide area motion imagery tracking algorithm (CSURF) developed at the University of Missouri with the C++ based image registration, track initialization, and track validation modules developed at Kitware for CETE. Added track termination criteria to reduce the number false alarms, explicit modeling of turns and improved robustness.

Integrated the Univ. of Missouri LoFT appearance-based foreground tracker within the Kitware wide area tracking framework (KW-MU LoFT v2.0 hybrid tracker) that is being tested at AFRL for CETE as well as BlueDevil programs.

Developed on-board flight test scenarios for CETE in conjunction with Transparent Sky in terms of size, weight, power requirements, Red River SDK libraries, metadata for ight parameters including GPS, IMU, camera parameters, and managing coordinate system transformations. Flight scenarios simulating realistic parameters were identi_ed for orbit radius, sampling rate, camera resolution, color quality, etc. Higher resolution optical imaging camera system was identified for testing. Sample datasets from the Four Hills data collect were processed for visualization using Kolam.

Refined 3D multiview reconstruction algorithm based on a ray casting and voxel-voting scheme. Worked on initial implementation of 3D reconstruction using a synthetic 3D scene with a few buildings incorporating a camera model and realistic flight parameters. Votes accumulated along rays can be interpreted as occupancy or occlusion probabilities combined with a visibility function. This continuous probability interpreation of the vote space will help with extending the results using synthetic models to real image sequences with complex objects and occlusions.

Established collaboration with Naval Research Lab and continuing collaboration with Army Research Lab on WAMI on-board tracking capabilities, architectures and algorithms. Discussion with AFRL on developing an edited book related to WAMI on applications of wide-area imaging and sensor networks.

Presented feature-based HPC target tracking for WAMI and FMV at the NGA Motion Imagery Standards Board meeting in Washington, DC for standards compliant tracking modules. Discussed NGA and DoD standards compliant tracking pipeline interfaces with Jim Antonisse and Scott Randall as part of the Interoperability Working Group activities for plug-and-play architectures.

Visited Army Research Lab (Sean Hu and Alex Chan) to discuss super-resolution algorithms for WAMI and FireFly for web-based annotation of video datasets.

Developed a more integrated connected component labeling algorithm better suited for the Cell/BE architecture by supporting component labeling and statistics on the same SPE processor without moving data across to PPE. Shared algorithm description with ITT for parallel implementation.

Indrajit Ray – Access Control for Cloud Environments: Model Requirements and Proposed Solution; Department of Computer Science Colorado State University

Multi-tenancy, elasticity and dynamicity pose several novel challenges for access control in a cloud environment. Accessing subjects may dynamically change, resources requiring protection may be created or modified, and a subject's access requirements to resources may change during the course of the application execution. Users may need to acquire different permissions from different administrative domains based on the services they require. SaaS collaboration can spread across enterprise boundaries where interactions among entities are often unforeseen and ad hoc. Owing to these characteristics, access control in cloud environments need to be positioned across several layers in the cloud stack and need to be fine-grained. In addition, the access control model for clouds cannot always assume that the access requester is known in advance and can be properly authenticated for access decisions. Consequently, traditional identity-based access control models such as Discretionary Access Control (DAC), Mandatory Access Control (MAC) or Role-based Access Control (RBAC) cannot be applied directly in cloud systems. This is in contrast to access control in most other computing paradigms.

In this work, we investigate the novel challenges for access control in cloud environments. We identify a set of desirable properties for access control models for clouds. We then perform a survey of some of the more important advanced access control models and analyze them against this set of desirable properties. We argue that trust-based access control appears to be the most appropriate way for providing fine-grained access control that is central to supporting tradeoffs between tenant-isolation, inter-tenant communication, and rate limiting in clouds. We then propose a novel trust-based access control model. This model is based on extensions to the widely popular Role-based Access Control Model. We identify the different model elements and the relationships among them. We develop three versions of the model that provide access control under different circumstances. We develop a graph-theoretic semantics of the model to specify how authorization occurs in the proposed model. We also show how to incorporate features such as Separation of Duty. We conclude by discussing extensions of the model.

Indrakshi Ray – Query Plan Execution in a Heterogeneous Stream Management System for Situational Awareness; Department of Computer Science Colorado State University

Battlefield monitoring involves collecting streaming data from different sources, transmitting the data over a heterogeneous network, and processing queries in real-time in order to respond to events in a timely manner. Nodes in these networks differ with respect to their processing, storage and communication capabilities. Links in the network differ with respect to their communication bandwidth. The topology of the network itself is subject to change, as the nodes and links may become unavailable. Continuous queries executed in such environments must also meet some quality of service (QoS) requirements, such as, response time, throughput, and memory usage. We propose that the processing of the queries be shared to improve resource utilization, such as storage and bandwidth, which, in turn, will impact the QoS. We show how multiple queries can be represented in the form of an operator tree, such that their commonalities can be easily exploited for multi query plan generation. Query plans may have to be updated in this dynamic environment (network topology changes, arrival of new queries, arrival pattern of streams altered); this, in turn, necessitates migrating operators from one set of nodes to another.

We sketch some ideas about how operator migration can be done efficiently in such environments.

Lei Yu - Machine Learning For Robust Autonomy; Department of Computer Science, State University of New York, Binghamton

This report documents the research effort and results along the direction of machine learning for robust autonomy during the visiting faculty research program (VFRP) from June 11 to August 3, 2012. The research effort is focused on three major tasks: (1) organizing an Armed Forces Communications and Electronics Association (AFCEA) workshop on Machine Learning for Robust Autonomy, (2) improving methods of automated feature selection for experienced based adaptive replanning, and (3) investigating progressive learning and feature extraction for large-scale reinforcement learning. For task (1), outcome of the workshop is documented in this report. For task (2), working methods and positive results are reported. For task (3), algorithm development is still underway, and key issues and basic ideas of the proposed methods are described.

3. CONTINUING RESEARCH PROJECTS

3.1. 2011 Extension Grants

Bharat Bhargava - Active Bundle (Managed Information Object) Security Measures/Properties; Purdue

An Active Bundle (AB) is a data protection mechanism which can be used to protect data at various stages throughout its life cycle by encapsulating the sensitive data with policy data (meta-data) and a virtual machine. Sensitive data itself can have several sub elements with different security levels and only certain users should be able to access them. For example, the data send from UAV can contain general information as well as more sensitive information like the images of the object and its security must be ensured. The active bundle is a robust and an extensible scheme that can be used to disseminate data securely across multiple domains in a publish and subscribe environment.

The focus of this research is to create, implement and demonstrate a prototype for the Active bundle scheme which can demonstrate and allow us to experiment with security properties of a managed information object and add new features beyond what was accomplished in. We have implemented several new features to the earlier prototype. It includes dynamic integrity checks using incremental decryption; dynamic updates on active bundle meta data based on access history; and provide for a controlled access to sensitive data based on the clearance levels of the subscriber. A major task is to emulate a managed information object (MIO) through active bundle and experiment with the security properties of Active bundle scheme through the prototype implementation. The current version of the prototype is designed on cryptographic based methods for protecting data and we have made progress on implementing another version of the prototype without using cryptographic protocols and comparing the security properties of the two systems.

Timothy E. Busch - Scenario Development for a Study of the Application of Game Theoretic Approaches to Cross Layer Optimization in Communications Networks; Electrical and Computer Engineering Department, State University of New York Institute of Technology

Game theory has had some measure of success in applications such as congestion control, network coding, power control and many other network parameters. Game theory offers the potential of automating the dynamic management of a number of network parameters to achieve overall improvement in end to end network performance. In particular, the Nash Bargaining Solution when applied to cross layer optimization for wireless direct sequence code division multiple access networks of visual sensors has advantages over conventional optimization techniques.

Despite the vigorous research in the field, most of the efforts to date have focused on static determination of parameters in somewhat benign environments. Additionally, there is a need to characterize the performance trade-offs related to implementation of game theoretic approaches via centralized versus decentralized schemes.

Over the course of the eight weeks spent at the lab it became apparent that a relevant scenario that employs the Joint Aerial Layer would provide specific parameters that are of interest to the Air Force and would allow much more detailed analysis of suitability of the optimization and game theoretic approaches reviewed this summer. To this end, the current work examines several possible Air Force mission areas and places them in a context that should be useful for such exploration.

A scenario that encompasses both offensive counter air and close air support is presented in the geopolitical context of the island of Pacifica. The operational vignette can be exercised with various communications configurations and determinations made as to which are most effective both from a technology and an operational perspective. One of the motivations for this work is to investigate the military utility of Dynamic Spectrum Access (DSA) and cross layer optimization. But, there is much that still needs to be accomplished before communications experiments can be conducted. Simulation models of the communication network will have to be developed. New link models, such as those that use direct sequence code division multiple access, will have to be introduced into the military environment and interfaces with existing systems worked out. Existing models can be used as a baseline but will have to be extended to accommodate proposed changes to protocols suggested by previous work. Despite extensive libraries of models for military radios and networks that exist in OPNET, the use of OMNET++ is recommended because of its availability to the university community who is conducting much of the current research. The use of this software would not be incompatible with ongoing efforts within AFRL and elsewhere

Yiran Chen - VLSI Implementation of Memristor-Based Synapse and Training Circuit; Department of Electrical and Computer Engineering, University of Pittsburgh

Memristors have shown their potential in neuromorphic computing architecture with their unique properties of high density and recording historic behavior of current and voltage. Memristor-based synapse, which is essential element for neural system, has been proposed to mimic biological system because Memristors can behave like the junctions between neurons in the brain. In this paper, we first designed a CMOS Memristor structure (CMOS-Memristor) with similar characters of memristor. Based on this, we implemented the whole system (training circuit and CMOS-Memristor) with CMOS technology. Finally, we experimentally demonstrated the VLSI system can support important synaptic functions

Baek-Young Choi - Push or Pull?: Towards Optimal Content Delivery on Cloud Storage; University of Missouri

Cloud computing and ’Storage As A Service’ (SaaS) are experiencing a momentous popularity increase via crowd-acceleration. SaaS providers works as an economic alternative of traditional content delivery networks (CDNs), eg. Akamai and Mirror Image by offering economic and flexible content storage and delivery services over large scales. However, existing researches mainly focus only on reducing user experienced latency. A few recent studies address the issue of bandwidth usage in CDNs. Whereas, cloud storage services are charged on both storage space and traffic volume. Therefore, we argue that considering the bandwidth consumption together with delay performance is important for the emerging needs of contents with diverse sizes and user perceived performance. We have formulated the joint optimization problem and proved it is

NP-complete. We then develop an efficient light-weight approximation algorithm toward the optimization problem, and provide its theoretical complexity analysis. Furthermore, in order to promptly react to real time changes, eg. users interests shift, with limited updating to origin server, we further extend the proposed algorithm into a distributed version. The performance bound of the proposed approximation algorithm has been investigated, which shows a much better worst case ratio than those in previous works. Simulation results and experiments on planetlab exhibit that the performance is near optimal for most of the practical conditions.

John L. Crassidis - Introduction to Orbital Dynamics and Tracking; MAE Department, University at Buffalo

This document provides the fundamental theoretical developments to perform orbit tracking using ground-based optical telescopes and radars. It begins by introducing the basics of orbital dynamics, which is followed by a review of estimation theory, in particular the Unscented filter. Then, sensor models are developed. Finally, a simulation study using realistic sensor data to estimate the orbit of an orbiting object is shown.

Chin-Tser Huang - Router-based Rerouting and Filtering Techniques for Traffic Control in Cloud Computing; Department of Computer Science and Engineering, University of South Carolina

Cloud computing has attracted plenty of attentions and interests because it realizes the long-desired goal of on-demand network access to a scalable shared pool of computing resources, such as servers, storage, applications, platforms, and networks. However, along with cloud computing also come security risks and availability concerns. As an Air Force Summer Faculty Fellow, the PI's goal is to enhance the security and performance of cloud computing by developing a router-based technology that when combined with cloud auditing methods will filter malicious traffic early and reroute the excessive legitimate requests to other suitable replicated servers. We had published a paper on a theoretical model to find the best locations for hardware routers in a network to block malicious traffic. We currently focus on developing algorithms to integrate this theoretical model with cloud auditing techniques. In the extension project, we have conducted experiments in order to evaluate the reliable theoretical model and the dynamic programming based algorithm for router-based filtering and rerouting in cloud computing. Our experimental results validate the effectiveness and benefits of our theoretical model and algorithm. We will use an AFOSR grant to purchase more routers and hosts to conduct more extensive experiments, and further extend our published conference paper such that it can be submitted to an appropriate journal for publication.

Sanjay Madria - Incentive Based Approach to Find Selfish Nodes in Mobile P2P Networks; Department of Computer Science, Missouri University of Science and Technology

In a Mobile P2P (M-P2P) network, nodes are expected to not only send their own packets, but also route packets for other nodes. However, selfish nodes in M-P2P can drop packets which affect the efficiency of the whole network. Therefore, we propose a simple and efficient mechanism using virtual currency to identify selfish nodes in the network. Each node issues a receipt to its broker to prove that it has forwarded the data. Based on receipts received each

broker provides well behaved nodes some virtual currency for services provided whereas selfish nodes are punished to make the network more efficient. When compared to other known approaches, our scheme provides real time detection and does not require/assume the presence of any tamper proof hardware at each node. Simulation results show that our scheme is efficient in terms of time to detect selfish nodes, the number of false positives and the number of packets exchanged when compared with others. Our scheme can be integrated with any given routing algorithm for real time detection of selfish nodes. We also propose measures to prevent malicious activity such as spoofing, eavesdropping and replay attacks to make the network more secure.

Vladimir V. Nikulin - Measurement of Quantum Encrypted Signals Using Coherent States of Light (Phase Encryption); Department of Electrical and Computer Engineering, State University of New York at Binghamton

Free-space optical links offer secure communication channels with low probability of interception and detection (LPI/LPD). However, based on practical issues, such as antenna size and pointing errors, there is still a risk of unauthorized access to information, which can be significantly minimized with data encryption. A search for the “holy grail” of cryptography has led to the application of quantum mechanical principles in optical communication networks. Quantum processes at the physical layer of encryption can be used to facilitate ultrasecure quantum communications (QC) with very competitive performance characteristics. Within the scope of this project, we research measurement approaches based on coherent (heterodyne) detection. Modeling of coherent states of light and noise mechanisms that affect them is performed. Simulation studies of the effects of quantum noise on phase estimation are conducted for quantum systems with different number of encryption bases and operating at different power levels. This project complements other AFRL-funded research efforts in this area, including the design of optical communication transceivers and the development of encryption systems, including Alpha-Eta.

Jing Peng - ShareBoost: Boosting for Robust Data Fusion with Applications to Wide Area Image Exploitation; Computer Science Department, Montclair State University

This paper introduces a novel method for data fusion in target tracking. Target tracking can be posed as a binary classification problem, where target pixels must be separated from background ones based on local image properties. Often, image properties can be described by multiple representations, where a representation (view) corresponds to a specific type of feature or attribute. For example, an image can be represented by multiple wavelengths. Each of these representations provides a partial view about an object of interest, i.e., revealing a particular aspect of data. Thus, one must decide on how to exploit all of the information available, or what features or information sources to use and how to fuse them in order to make effective inferences about potential object of interest characterized with multiple views.

This paper is concerned with feature selection in target recognition, where a large number of features often make the design of a classifier difficult and degrades its performance. This is particularly pronounced when the number of examples is small relative to the number of features. This fact is due to the curse of dimensionality. In such situations, feature selection or extraction methods play an important role by significantly reducing the number of features for

building classifiers. For example, in target recognition the principal modes are often extracted and utilized for description, detection, and classification.

Lixin Shen - Eigenstructure Estimation for Multihub Matrices and Nesterov's Algorithm for the Primal-Dual Formulations of Image Inpainting Models; Department of Mathematics, Syracuse University

This report contains two parts. In the first part, we discuss the eigenstructure of a Gramian matrix associated with a multihub matrix. Our main contribution is that we give a precise mathematical definition for multihub matrices and extend our previous work (which was supported by the 2009 Air Force Summer Faculty Fellowship Program) on single-hub matrices to multihub matrices. In particular, we provide a lower and an upper bound for the leading eigenvalue of the Gramian matrix of a multihub matrix. In the second part, we consider the problem of recovering missing information of data. This part is a continuation of my work which was supported by the 2011 Air Force Summer Faculty Fellowship Program. We propose a new variational model for image inpainting. For the proposed model, we study its dual formulation in the context of convex analysis. The resulting model in the dual formulation allows us to exploit the advanced Nesterov's acceleration technique. The theoretical justifiable algorithm is developed for the proposed model. Our numerical experiments demonstrate the efficiency of the proposed algorithm.

Nary Subramanian - Natural Language Processing-Based Automation of the NFR Approach for Re-engineering Trustworthy Embedded Systems; Department of Computer Science, University of Texas at Tyler

The NFR Approach, where NFR stands for Non-Functional Requirements, can be used for capturing knowledge of a process or a product in a structure called the Softgoal Interdependency Graph (SIG) which permits application of propagation rules of the Approach for further analysis. A SIG consists of many elements: NFR softgoals, operationalizing softgoals, claim softgoals, contributions, and labels. So far the process of developing a SIG has been largely manual wherein information available in a document has been converted into different SIG elements. In this research we employed different NLP (Natural Language Processing) tools to partially automate the process of SIG development; since SIG creation is one of the most time-consuming activities during the NFR Approach, any automation in this phase will significantly help researchers. The tools we considered included OpenNLP, MontyLingua, and the NLTK. We evaluated efficiency of these NLP freeware tools in capturing knowledge using feasibility analysis. Our research indicated that NLTK is perhaps the best amongst these three from an NFR Approach-perspective.

Christopher Thron - Statistical Dynamics of Long-Term Average Activism in Agent-Based Models of Population Behavior; Department of Mathematics , Texas A&M University – Central Texas

The National Operational Environment Model (NOEM) is a strategic analysis/assessment tool that provides insight into the complex state space that depicts today's modern nation-state environment. A key component of the NOEM is its Populace Behavior Module, an agent-based model that describes activist behavior in terms of populace agents' perceptions of hardship and government legitimacy.

The NOEM behavioral model is based on an agent-based model of civil violence developed by Joshua Epstein. Although the model has no analytical closed-form solution we may use analytical methods to estimate the model′s response with a given set of initial parameters. This paper uses probability theory and various statistical approximations to estimate levels of activism associated with different parameters in Epstein′s model.

This study has two important benefits. First, it gives an overall picture of how model parameters are related to model behavior: this knowledge will help us find suitable model parameters that correspond to observed data. Second, it gives insight into the statistical mechanisms that determine levels of activism. This can help us both predict probable trends resulting from changes in social conditions, and can inform policy decisions that will be effective in controlling activism.

Li Xu - Resilient Cross-Layer Detection of Maliciouswebsites: Towards Achieving the Best of Both Static and Dynamic Analyses and Going Beyond; Department of Computer Science & Department of Statistics, University of Texas at San Antonio

Malicious websites have become a major attack tool of the adversary. Detection of malicious websites in real-time can facilitate early-warning and filtering the contents from, and the accesses to, the malicious websites. There are two main approaches to detecting malicious websites: static and dynamic. The static approach is centered on the analysis of website contents, and thus can automatically detect malicious websites in a very efficient fashion and can scale up to a large number of websites. However, this approach has limited success in dealing with sophisticated attacks that include obfuscation. The dynamic approach is centered on the analysis of website contents via their run-time behavior, and thus can cope with these sophisticated attacks. However, this approach is often expensive and cannot scale up to the magnitude of the number of websites in cyberspace. In this paper, we propose a novel cross-layer solution that can inherit the advantages of the static approach while overcoming its drawbacks. Our solution is centered on the following: (i) application-layer web contents, which were typically analyzed in the static approach, may not provide sufficient information for detection; (ii) network-layer traffic corresponding to application layer communications might provide extra information that can be exploited to substantially enhance the detection of malicious websites. Evaluation of our cross-layer detection is based on real-life data that we collected. In order to deal with attacks that attempt to evade our cross-layer detection, we investigate the resilience of our solution against adaptive attacks. We demonstrate that adaptive attacks can easily evade detections that include our own, and propose algorithms for effectively defending against adaptive attacks.

Lei Yu - Embedded Incremental Feature Selection for Large-Scale Reinforcement Learning: Exploring Sample Trajectories for Feature Evaluation; Department of Computer Science, Binghamton University

Scaling reinforcement learning technologies to real-world applications is challenging due to high-dimensional state spaces and continuous action spaces that describe such applications. These environments often include perceptual inputs about the environment which are irrelevant or redundant to the learning task. With many unnecessary state dimensions, the state space grows so large that an agent cannot experience enough states to learn an effective policy. In this work, we explore an incremental feature selection algorithm for reinforcement learning called IFSE-NEAT. The algorithm embeds a sequential forward selection procedure within the neuroevolutionary policy search algorithm NEAT and exploits the sample trajectories of NEAT for feature evaluation. We show that feature selection enables NEAT to cope with high-dimensional state spaces much more effectively than without, and that the additional cost of feature selection is small in terms of both computational and sample complexity. Specifically, we demonstrate the effectiveness of our method on a complex racing simulation as well a double inverted pendulum balancing problem. In these challenging environments we show that our algorithm not only allows NEAT to scale to high-dimensional spaces, but also outperforms a competing feature selection algorithm designed for the same purpose.

Ramesh Karri/N. Memon/J. Rajendran/Huan Zhang - The 2011 Embedded Systems Challenge; Computer Science and Engineering Department, Polytechnic Institute of New York University

Trusted computing relies on dedicated and trusted hardware platforms. The security and trustworthiness of hardware platforms is critical to several applications ranging from credit cards to traffic monitoring systems to missile control. Re- cent attacks on hardware platforms such as tampering, reverse engineering, and malicious circuits insertion highlight the importance of designing secure and trust- worthy hardware.

The annual Embedded Systems Challenge (ESC) focuses on the red-team blue- team approach to assessing the trustworthiness of hardware. Teams are invited to participate in this challenge and attack a target hardware platform. They will discover vulnerabilities in the target platform and exploit them by using their hardware design skills. Such attacks lead to a better understanding of the vulner- abilities in hardware platforms and thereby enable designers to build trustworthy hardware that can thwart such attacks.

Jun Zhuang - Extension Research on Visualizing Interactive and Automatic Wargames Training System; Department of Industrial and Systems Engineering, University at Buffalo, The State University of New York

This report documents a project that was conducted at University at Buffalo. The research is an extension to the PI's summer 2011 project. We transform a paper-based wargame into a computer-based wargame program and provide a flexible wargame toolset using Matlab GUI interfaces. We first provide a model called Stochastic Game for the wargaming process. Since this wargame consists of at most thirty-two turns, the number of stages is "finite," and thus we

propose to solve the game using backward induction. Due to the huge gaming structure, we simplify the game rules and examine a two-player wargame, and extend to six-player wargame. We then (a) introduce the user interfaces for both two-player and six-player wargames; (b) design 2-4 heuristics for each player; (c) calculate the players' best-response functions and the Equilibrium solutions; (d) run the simulation 1000 times for each of the three experiments (for two-player wargame, six-player wargame, and improved six-player wargame); and (e) incorporate the human experiences when designing the heuristics.

3.2. 2012 Extension Grants

Georgios C. Anagnostopoulos – Learning Kernel-Based Approximate Isometries ; ECE Department Florida Institute of Technology

Kernel-based methods have been an intensely researched topic in Machine Learning (ML) over the last ten years. Their popularity stems first from their ability to map data from their native space into a feature space, in which a ML problem may be easier to solve. The map itself is implicitly defined via the choice of kernel. Secondly, they allow the application of many traditional ML approaches to problems dealing with data that are not purely numeric in nature by appropriate constructing kernels for this type of data.

Additionally, Metric Multi-Dimensional Scaling (metric MDS) has been a technique for visualizing data, when only pairwise similarities or dissimilarities between data are available. This type of proximity information is then depicted as pairwise distances in a low-dimensional space, where relationships between data can be visually assessed. Such ability finds important applications, in engineering, social sciences, etc.

In this draft paper the foundations are laid for a new kernel-based Least Squares Multi-Dimensional Scaling (Least Squares MDS) model. Unlike traditional metric MDS approaches, the proposed model is inductive in the sense that new samples can be embedded in a low dimensional space through appropriate interpolation. In specific, an optimal embedding is sought among vector-valued functions of a pre-defined Reproducing Kernel Hilbert Space (RKHS). Secondly, the new model employs Multiple Kernel Learning (MKL) to infer the best kernel via a data-driven approach. The kernel to be learned consists of a set of pre-chosen, convexly-combined kernels. Thirdly, a specific kind of regularization is employed that allows inferring a suitable dimension for the embedding, as well as the importance of training samples with respect to the parsimony of the model.

The paper derives two models, one general and a specialization of it, featuring the aforementioned properties and develops an Iterative Majorization (IM) algorithm to train them. A second version of the algorithm, which is equipped with a non-linear Conjugate Gradient acceleration scheme, is also discussed. Finally, some initial, illustrative experimental results are provided.

Yang Cai – Semantic Object Detection:Visual Media Reasoning and Sound Fusion; Director of Visual Intelligence Studio Carnegie Mellon University

In this VFRP 2012 extended project, we have developed a new RPG detection algorithm based on Generalized Hough Transform. It is a general shape recognition model that can detect the unique diamond shape of the RPG head. Our initial experimental results showed that the new algorithm increases the RPG detection accuracy to 74.5%. The description of the RPG detection algorithm and results are in Part I of the report.

We have also developed the vehicle speed detection method using the correlations of video and audio information. This method can detect vehicles from video and calculate their speeds automatically. For the video-based detection, speed is calculated by moving object detection, using the length per pixel and the time interval. For the audio-based method, reverse square law is employed for calculating rough speed value, which is further tuned by the Doppler Effect method. Experimental results show that the proposed method enjoys high accuracy and low cost. The details about the algorithm are described in Part II of the report.

Mainak Chatterjee – Multi-modal Sensors for Survivability Prediction of Mobile Devices; Department of Computer and Computational Science, University of Central Florida

Commercial off-the-shelf (COTS) consumer devices such as smart phones are supplanting ruggedized military-specific equipment that currently provides war-fighters with similar functionality throughout the DOD. The more fragile construction associated with COTS has spurred the running of GOTS (government off-the-shelf) software on the COTS devices to increase their survivability. Many DOD agencies are moving towards using less expensive and less ruggedized mobile communication devices on the battlefield as the COTS tools are inexpensive, easy to use, and suit the government's communication needs. Knowing when these devices are about the fail is vitally important, but current survivability models do not take into account many mechanical sensor inputs, such as temperature, acceleration, and humidity and rarely take into account sensor data provided from the software that is running on the device.

In this project, we build a prediction model that takes into consideration a set of sensors that continuously sense their designated activities and generate a stream of outputs.

Yu Chen – Unclonable User-Device Connection Identification For High Performance Auditing In Android Smartphone Cloud; Department of Electrical and Computer Engineering, State University of New York at Binghamton

The increasing popularity of Android devices and mobile cloud provides a fertile ground for attackers. For the benefits of both the clients and cloud service providers, a systematical, high performance auditing scheme is expected. While it is widely recognized that monitoring the activities of users is mandatory, there is a missing link that is essential to connect the activities of a user in physical world to that in the cyber space. In this paper, we proposed an unclonable user-device connection identification scheme. Taking advantage of physical unclonable features of the embedded image sensors in Android smartphones and real-time watermarking technology, this scheme creates a unique ID for a user-device pair in the cyber space. Such an ID provides a solid

foundation toward an efficient cloud auditing system. A concept proof prototype has been built and validated through experimental study.

A. Ege Engin – Electrical Model Extraction For Interconnects In 3D ICS; Department of Electrical and Computer Engineering San Diego State University

This project is an extension of the VFRP project with the title ”Novel Metal-Semiconductor TSVs in 3D ICs for Improved Electrical and Thermal Performance” that was performed in Summer 2012. In 2012 summer research, time delay and power consumption of TSVs have been investigated using transistor-level driver and receiver models. We revised the power consumption formula $P=CV_2f$ for 3D ICs and investigated the variation of the effective capacitance in the formula as a function of the bit rate. We also developed a new methodology to extract an RC model of a TSV array based on electromagnetic simulation data for non-circular TSVs. In this model fitting approach, the parasitic RC model for TSVs of general shape were extracted using a prescribed network topology.

In the extension project, we developed a general RC model extraction methodology, where the network topology is not fixed. With this new approach, not only TSVs, but also other interconnect segments such as microbumps and redistribution layers can be accurately modeled. These models are critical in time-domain simulation of interconnects in 3D ICs to analyze latency, power consumption, and noise coupling. The new approach is based on a modification of the vector fitting algorithm to ensure that the resulting equivalent circuit model represents a passive RC network. For one-ports, non-negative least squares method is used, whereas multi-port macromodels are generated using semidefinite programming. It was demonstrated that, even though standard algorithms may provide an excellent fit to simulated data, passivity violations may occur and can be corrected using the presented RC vector fitting approach without sacrificing accuracy.

Yujian Fu – Motion Planning and Stability Analysis of Biped Robots; Department, Department of Computer Science School of Engineering and Technology, Alabama A&M University

Dynamic reconfiguration is a key research topic in the robotics systems. During this extension work, a foot printing problem was identified, studied and implemented based on the summer work result of reconfigurable *PrT* net. Biped robot has more complicated behaviors due to the introduction of two legs. The concerns of coordination, collaboration and stability analysis of biped robotics systems are dramatically increased due to the tasks of two legs and balance. This report presented the work of stability analysis of biped robot motion planning using Reconfigurable *PrT* net (*RPrTN*). First, we introduce an improved version of *RPrTN* by updating some limitations. An alternative verification approach using SPIN will be described and results will be discussed. A case study of humanoid robot will be implemented to validate the above approach on the LEGO Mindstorm NXT ver 2.0 (Alpha Rex). Finally, a conclusion with future work will be presented.

H.T. Kung - Compressed Statistical Testing and Application to Radar; School of Engineering and Applied Sciences, Harvard University

We present compressed statistical testing (CST) with an illustrative application to radar target detection. We characterize an optimality condition for a compressed domain test to yield the same result as the corresponding test in the uncompressed domain. We demonstrate by simulation that under high signal-to-noise ratio (SNR), a likelihood ratio test with compressed samples at 3.3x or even higher compression ratio can achieve detection performance comparable to that with uncompressed data. For example, our compressed domain Sample Matrix Inversion test for radar target detection can achieve constant false alarm rate (CFAR) performance similar to the corresponding test in the raw data domain. By exploiting signal sparsity in the target and interference returns, compressive sensing based CST can incur a much lower processing cost in statistical training and decision making, and can therefore enable a variety of distributed applications such as target detection on resource limited mobile devices.

Hongxiang Li - Broadcast and Unicast Hybrid Wireless Network: Enabling Collaborative Spectrum Sharing and Network Convergence; Department of Electrical and Computer Engineering, University of Louisville

Wireless communication networks can be conveniently categorized into two types: broadcasting (BC) used for distribution of common information to all receivers over unknown unidirectional channels; while unicast (UC) means symmetric applications such as voice telephony and data access, which requires a bi-directional network and often the channel state information (CSI) is known by the transmitter via receiver feedback. Due to the inherent differences, these two classes of networks have evolved along different trajectories. For example, the cellular network and over-the-air TV are usually operated over different infrastructure at different frequencies. To increase the spectrum utilization efficiency, this project aims at integrating broadcast and unicast into a single frequency platform based on dirty paper coding (DPC) for interference pre-cancellation.

Sanjay Madria - ECO: Event Detection from Click-through Data via Query Clustering; Department of Computer Science, Missouri University of Science and Technology

In this paper, we propose an algorithm to detect real world events from the click-through data. Our approach differs from the existing work as we: (i) consider the click-through data as collaborative query sessions instead of mere web logs proposed by many others (ii) integrate the semantics, structure, and content of queries and pages, and (iii) aim to achieve the overall objective via query clustering. The problem of event detection is transformed into query clustering by generating clusters using hybrid cover graphs where each hybrid cover graph corresponds to a real-world event. The evolutionary pattern for the co-occurrence of query-page pairs in a hybrid cover graph is imposed over a moving window period. Finally, we experimentally evaluated our proposed approach using a commercial search engine's data collected over 3 months with about 20 million web queries and page clicks from 650,000 users. Our method outperforms the most recent event detection work proposed using complex methods in terms of metrics such as number of events detected, F-measures, entropy, recall, etc.

Warner A. Miller – Toward Estimation and Detection: Integrating Persistence In Homology With Curvature Flow; Department of Physics, Florida Atlantic University

Command decisions in the USAF are becoming increasingly complex, involving high-dimensional relational data sets. Furthermore, the time scales necessary for these decisions is reducing dramatically. Consequently, there are newly-evolving efforts already underway in the USAF to addressing these issues, e.g. (1) the Complex Network program within the Mathematics, Information and Life Sciences Directorate at AFOSR, and (2) the AFRL/RITA's Geometrical and Topological Tools for the Analysis of Complex Systems (GTTACS) program. Central to this effort is to efficiently yield a proper balance between estimation and detection (E&D) for complex systems such as command and control (C2), coherent chemistry, biological networks, etc. Fortunately, there are two newly developed mathematical approaches that bear on a solution to this problem, one approach is persistent homology (PH), the other is Ricci flow (RF). The PH is a branch of applied topology and yields information as to the geometric structure of the manifold, while the RF is a branch of applied geometry and gives information as to the topological structure of the underlying manifold. These somewhat complementary approaches beg to be integrated. The coupling of these two mathematical disciplines is the subject of this research. We are unaware of any mathematical theory coupling these two approaches. We do so here, and apply PH to temporal analysis of a 3-dimensional simplicial dumbbell geometry undergoing a neck pinch singularity through Ricci flow. We used an edge-base filtration with the Perseus PH code on an evolving simplicial geometry driven by our new Regge-Ricci flow (RRF) equations. We find correlations between the geometric evolution and the signatures of the points in the PH birth-death diagrams. We suggest that this approach may provide a new curvature-based filtrations and efficient way to explore, visualize and identify important regions of large complex evolving systems. What we have demonstrated is that we have a clean combinatorial-based description of a higher-dimensional geometry evolving under RF.

Vladimir V. Nikulin – Assessment of Exploitation Vulnerability of Systems With Quantum Signal Encryption; Department of Electrical and Computer Engineering, State University of New York at Binghamton

Quantum communication technology takes advantage of the intrinsic properties of laser carriers, such as very high data rates and low power requirements, to offer unprecedented data security. Quantum processes at the physical layer of encryption are used for signal encryption with very competitive performance characteristics. The ultimate range of applications for QC systems spans from fiber-based to free-space links and from secure banking operations to mobile airborne and space-borne networking where they are subjected to channel distortions. Under practical conditions, atmospheric turbulence creates spatial and temporal fields of the refractive index along the propagation path and can alter the optical wave front characteristics, including its phase. In addition, phase noise of the communication source and photo-detection noises alter the signal to bring additional ambiguity into the measurement process. If quantized values of photons are used to encrypt the signal, exploitation of quantum communication links becomes extremely difficult. Within the scope of this project, we research measurement approaches based on heterodyne detection. Simulation studies of the effects of quantum noise on phase estimation are conducted for quantum systems with different number of encryption bases and operating at

different power levels. This project complements other AFRL-funded research efforts in this area, including the design of optical communication transceivers and the development of encryption systems, including Alpha-Eta.

Rong Pan – Optimization, Robustness and Resilience Analysis of NOEM Outputs; School of Computing, Informatics, and Decision Systems Engineering Arizona State University

The NOEM model, as a nation-state operation environment simulation tool, enables decision makers to study possible outcomes of a policy set and to compare different policy sets. In this report, we discuss the way of conducting sensitivity analysis for gaining insights of the robustness and resiliency of a policy solution. Specifically, we introduce the ImagiNation scenario, and using this scenario, we demonstrate the methods of functional data analysis and kriging metamodeling for extracting useful information from limited simulation runs. As the outputs from NOEM are typically functional outputs, we must pay attention to the definitions of parameters of interests and transfer them to some measureable response variables. We believe that these data analysis techniques can be and should be integrated into the existing NOEM policy set analysis (PSA) tool, and they can become invaluable assets to decision makers.

Indrajit Ray – Trust Based Access Control Model for Clouds Supporting Delegation; Computer Science Department, Colorado State University

Multi-tenancy, elasticity and dynamicity pose several novel challenges for access control in a cloud environment. Accessing subjects may dynamically change, resources requiring protection may be created or modified, and a subject's access requirements to resources may change during the course of the application execution. Users may need to acquire different permissions from different administrative domains based on the services they require. SaaS collaboration can spread across enterprise boundaries where interactions among entities are often unforeseen and ad hoc. Owing to these characteristics, access control in cloud environments need to be positioned across several layers in the cloud stack and need to be fine-grained. In addition, the access control model for clouds cannot always assume that the access requester is known in advance and can be properly authenticated for access decisions. Consequently, traditional identity-based access control models such as Discretionary Access Control (DAC), Mandatory Access Control (MAC) or Role-based Access Control (RBAC) cannot be applied directly in cloud systems. This is in contrast to access control in most other computing paradigms.

Further, in a cloud environment resources are often distributed and managed by different service providers. To support a specific service, there is frequently the need for coordination and interaction between these different providers. Client of one service provider may need to access other providers for getting the relevant service. In such cases, the original service provider needs to act on behalf of the client by making the client's access rights available to the other providers. Delegation is the access control principle that allows such transfer of access rights. Although delegation has been studied in the context of Role-based Access Control, adapting it to a proper cloud access control model is yet to be done.

In this work, we propose a trust-based access control model for providing fine-grained access control that is central to supporting tradeoffs between tenant-isolation, inter-tenant communication, and rate limiting in clouds. This model is based on extensions to the widely popular Role-based Access Control Model. We identify the different model elements and the

relationships among them. The cloud system is very dynamic and allows frequent updates to its RBAC relations. Using traditional RBAC relations to control delegation in such environment is of limited advantage because of the resulting inconsistencies in role hierarchy. We adopt the notion of administrative scope to resolve dynamically any inconsistency involved in controlling delegations. We develop three versions of the model that provide access control under different circumstances. We develop a graph-theoretic semantics of the model to specify how authorization occurs in the proposed model. We also show how to incorporate features such as Separation of Duty.

Indrakshi Ray – Query Plan Execution in Heterogeneous Stream Management System; Department of Computer Science, Colorado State University

Data Stream Management Systems (DSMSs) have been proposed to address the data processing needs of situation monitoring applications that collect data generated from various sources, process them on-the-fly, and take actions in real-time. Traditional approaches rely on a centralized DSMS architecture responsible for collecting the data and executing the continuous queries. However, such architecture may not be suitable for applications occurring over a dynamic and heterogeneous network where the nodes and links differ with respect to their computation and communication capabilities and also their availability at any given point of time. In this work, we focus on the problem of query execution. Good query plans must be generated for efficient query execution in such a resource-constrained environment. We discuss the role and architecture of the query plan manager and give some insights into the constraints involved in query plan generation. We highlight how the query plans can be optimized and adapted when the network topology changes. We present some features of our initial prototype implementation.

James Stine – Design Flow Migration for the Exploration of 65nm/32nm High Performance Low Power VLSI Computer Architectures; Electrical and Computer Engineering Department, Oklahoma State University

This paper discusses a full-featured set of innovative scripts to allow researchers to study designs for targeting silicon CMOS systems at 65nm and 32nm technologies. The designs have been created with three sample designs that utilize elements found in larger silicon systems. Each design allows a user to recreate a complete silicon design using a simple set of keystrokes and Makefiles. This allows a user to rapidly recreate any design while focusing on a specific parameter or engineering design metric. With this new system, an engineer can study various engineering design variables within a design without having to focus on a given set of tool details. Since each design has all the tools scripted by Makefiles, the designs can then be easily studied and recreated in larger designs as opposed to using lengthy Graphical User Interface choices individually. In conclusion, the research presented here makes the case that smaller and fuller features of optimization can be rapidly employed in these sample designs and, thus, transferred to larger systems rapidly and more efficiently than previously hand-based tool integration. Moreover, many of the scripts are debugged to handle many of the advanced Electronic Design Automation Tools without errors and outdated elements.

Chris Thron – Agent-Based Model of Civil Violence Implementation Within the NOEM Behavioral Model; Mathematics and Physics Department, Texas A&M University – Central Texas

This report focuses on the agent-based model of civil violence originally proposed by Joshua Epstein, and its implementation within the NOEM behavioral model. The report provides mathematical and practical descriptions of the model behavior.

The report is organized in two parts: Sections 2-6 deal with the model's mathematical structure, while Sections 7-8 deal with practical application of the model. More specifically,

Section 2 gives a thorough description of the mathematical specification of the model.

Section 3 re-characterizes the model in simpler mathematical terms. This re-expression of the model serves to clarify the model behavior.

Section 4 establishes important general mathematical properties that are consequences of the definition, and explains the consequences of these properties. In particular, the model is shown to be a Markov chain (so that the outburst waiting time distribution is approximately exponential); and the model is shown to express self-organized criticality (so that the outburst size distribution obeys a power law).

Section 5 discusses the effect of model parameter values on model behavior from a theoretical standpoint.

Section 6 presents the results of simulations that support the discussion in Section 5

Section 7 discusses prospects for using the model to simulate a practical system. In particular, it discusses issues relating to the determination of model parameters from practical socioeconomic data. In particular, it shows that model parameters in many cases do not correspond to their nominal significance, but rather are proxies of other system properties. We explain the implications of this of this conclusion

Section 8 introduces some possible modifications to the model which may improve its practical usability.

Section 9 summarizes our conclusions, and in particular our assessment of the limitations of agent-based model of civil violence.

Zhiyuan Yan - Rank Deficient Decoding of Linear Network Coding; Department of Electrical and Computer Engineering, Lehigh University

Since all packets in linear network coding are subject to linear combinations, in all existing network coding schemes, a full rank of received packets is required to start decoding. This requirement unfortunately results in long delays and low throughputs. In this work we propose two classes of rank deficient decoders that work for rank deficient received packets. Within either class, different decoding strategies have been proposed for tradeoffs between delay/throughput and data accuracy. The decoders of the first class take advantage of the sparsity inherent in data and produce the data vectors with the smallest Hamming weight. Since these decoders have high complexities, we propose a class of decoders with polynomial complexities

based on linear programming. Both classes of decoders can recover data from fewer received packets and hence achieve higher throughputs and shorter delays than the full rank decoder.

Lei Yu – Progressive Mining of Transition Dynamics for Autonomous Control; Department of Computer Science, State University of New York at Binghamton

Autonomous agents are emerging in diverse areas and many rely on reinforcement learning (RL) to learn optimal control policies by acting in the environment. This learning generates large amounts of transition dynamics data, which can be mined to improve the agent's understanding of the environment. There could be many uses for this data; here we focus on mining it to identify a relevant feature subspace. This is vital since RL performs poorly in high-dimensional spaces, such as those that autonomous agents would commonly face in real-world problems. This paper demonstrates the necessity and feasibility of integrating data mining into the learning process *while* an agent is learning, enabling it to learn to act by both acting and understanding. Doing so requires overcoming challenges regarding data quantity and quality, and difficulty measuring feature relevance w.r.t. the control policy. We propose the progressive mining framework to address these challenges by relying on cyclic interaction between data mining and RL. We show that a feature selection algorithm developed under this framework, PROFESS, can improve RL scalability better than a competing approach.

4. EXPENDITURES

Under this contract expenses were billed on a faculty/week basis. The rates for the professors were established by the National Research Council for summer research fellows and are as follows.

4.1. Faculty Labor

Assistant Professor	$1,300/week
Associate Professor	$1,500/week
Full Professor	$1,700/week
Faculty Per Diem:	$50/day up to $250/week

*Faculty members whose home residence/university is more than 50 miles from AFRL/IF were entitled to Per Diem

4.2. Other Costs Associated with Program

Round trip travel reimbursement at the start and completion of the project was provided as requested.

5. LIST OF ABBREVIATIONS

2D – Two-Dimensional

3D – Three-Dimensional

3D IC – Three-Dimensional Integrated Circuit

AB – Active Bundle

AFCEA – Armed Forces Communications and Electronics Association

AFOSR – Air Force Office of Science and Research

AFRL – Air Force research Laboratory

ARGUS-IS – Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System

BC – Broadcasting

BSB – Brain-State-in-a-Box

C2 – Command and Control

CDN – Content Delivery Networks

CETE – Center for Educational Testing and Evaluation

CFAR – Constant False Alarm Rate

CMOS – Complementary Metal-Oxide Semiconductor

CMU – Carnegie Mellon University

COTS – Commercial Off-the-Shelf

CST – Compressed Statistical Testing

CSURF – University of Missouri tracking algorithm

CUDA – Compute Unified Device Architecture

DAC – Discretionary Access Control

DARPA – Defense Advanced Research Projects Agency

DIA/NMEC – Defense Intelligence Agency/National Media Exploitation Center

DoD – Department of Defense

DSA – Dynamic Spectrum Access

DSMS – Data Stream Management Systems

E&D – Estimation and Detection

ECE – Electrical and Computer Engineering

ESC – Embedded Systems Challenge

FMV – Full Motion Video

GI – Griffiss Institute

GMM – Gaussian Mixture Model

GOTS – Government Off-the-Shelf

GPGPU – General Purpose Graphics Processing Unit

GPU – Graphics Processing Unit

GTTACS – Geometrical and Topological Tools for the Analysis of Complex Systems

GUI – Graphical User Interface

HOG – Histogram of Gradient

HPC – High Performance Computing

HTML – HyperText Markup Language

ID – Identification

IFSE-NEAT – An incremental feature selection algorithm for reinforcement learning

IM – Iterative Majorization

ITRS – Intelligent Text Recognition System

KW-UMO – Kitware – University of Missouri

LoFT – University of Missouri tracking algorithm

LPI/LPD – low probability of interception and low probability of detection

M.S. – Master of Science

MAC – Mandatory Access Control

MCR – Matlab Compiler Runtime

Metric MDS – Metric Multi-Dimensional Scaling

MHz – Megahertz

MIO – Managed Information Object

MKL – Multiple Kernel Learning

MOKA – Mapping of Key Algorithm

M-P2P – Mobile P2P

MVS – Multiview Stereo

NASA – National Aeronautics and Space Administration

NFR – Non-Functional Requirements

NLP – Natural Language Processing

NLTK – Natural Language Toolkit

NOEM – National Operational Environment Model

NY – New York

OPNET – Application and Network Management solutions that span application performance management, network planning, engineering, operations and network R&D

OMNeT++ – An extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators.

P2P – Person to Person

PCAP – Packet Capture; consists of an application programming interface (API) for capturing network traffic

PH – Persistent Homology

Ph.D – Philosophiae Doctor (Doctor of Philosophy)

PI – Principle Investigator

PSA – Policy Set Analysis

QC – Quantum Communications

QKD – Quantum Key Distribution

QoS – Quality of Service

RBAC – Role-based Access Control

RC – Radio Controlled

RF – Radio Frequency

RF – Ricci Flow

RKHS – Reproducing Kernel Hilbert Space

RL – Reinforcement Learning

RRF – Regge-Ricci flow

SaaS – Storage As A Service

SIG – Softgoal Interdependency Graph

SNR – Signal-to-Noise Ratio

STEM – Science, Technology, Engineering and Mathematics

STFT – Short Time Fourier Transform

SUNY – State University of New York

SURF – Speed Up Rapid Feature

TeraFLOPS – A measure of computing speed equal to one trillion floating-point operations per second

TSV – Through Silicon Vias

UC – Unicast

UDP – User Datagram Protocol

VFRP – Visiting Faculty Research Program

VLSI – Very Large-Scale Integration

WAMI – Wide Area Motion Imagery

WNaN – Wireless Network after Next

XG – neXt Generation