What RAMS Means to M&S

David Hetrick
Group Leader, Modeling & Simulation Group

Computational Sciences and Engineering Division

December 3, 2008

RAMS Students Mentored by Modeling & Simulation Group

RAMS 2008

- Cedrick Collins (mentors: Lee Hively & Jim Nutaro)
- Brandon Davis (mentor: Andy Loebl)
- Jillian Gauld (mentor: Kara Kruse)
- Sara Haque (mentor: Kara Kruse)
- Chris Lanclos (mentor: Andy Loebl)
- Abigail Snyder (mentor: Jim Nutaro)
- Katelyn Swift-Spong (mentor: Richard Ward)
- Jessica Travierso (mentor: Vickie Lynch)
- Sara Wezensky (mentor: Kara Kruse)

RAMS 2007

- Elizabeth O'Quinn (mentor: Kara Kruse & Richard Ward)
- Abigail Snyder (mentor: Kara Kruse)
- Jessica Traverso mentor: Vickie Lynch)

RAMS 2006

- Paul Donnelly (mentors: Mallikarjun Shankar, Phani Teja Kuruganti, David Resseguie)
- Erin Lennartz (mentors: Kara Kruse & Richard Ward)
- Elizabeth O'Quinn (mentor: Kara Kruse & Richard Ward)
- Angela Reedy (mentor: Kara Kruse & Richard Ward)

RAMS 2005

- Jennifer Marie Bennett (mentor: Richard Ward)
- Rowena Ong (mentor: Kara Kruse)
- Elizabeth O'Quinn (mentor: Kara Kruse)
- Kenroy Williamson (mentor: Jim Nutaro)

RAMS 2004

- Gary Atkins (mentor: Richard Ward)
- Coslough Harrison (mentor: Robert Sanders)
- Veranda Victoria Moffett (mentor: Glenn Allgood)
- Rowena Ong (mentor: Kara Kruse)

RAMS 2003

- Talisha Haywood (mentor: Lee Hively)

Decreasing Artificial Attenuation of the RCSIM Radio Channel Simulation Software

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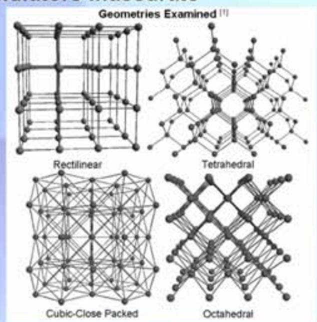
Research Alliance in Math and Science
Computational Sciences and Engineering, Oak Ridge National Laboratory
Mentor: Jim Nutaro, Ph.D.

http://www.ccs.ornl.gov/Internships/rams_08/a_snyder

Oak Ridge National Laboratory is currently improving the accuracy of the radio channel simulation software RCSIM by reformulating the scattering junctions that it uses to propagate a simulated radio wave. Radio waves naturally experience path loss (attenuation) as they move outward from the signal source. However, there is a certain level of artificial attenuation in computer simulations of radio wave propagation. The goal is to increase overall accuracy of the RCSIM software in part by decreasing this artificial attenuation.

Background

- Radio waves naturally experience path loss (attenuation) as the wave moves outward from the source
- In computer simulations of radio waves, artificial attenuation occurs in relation to the geometry of signal scattering junctions, making simulators inaccurate

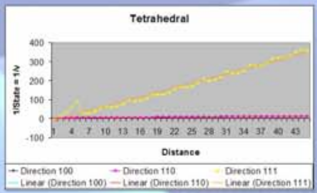


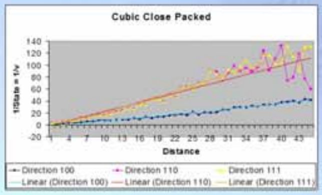
Research Objective

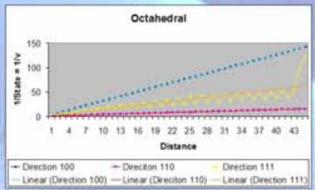
- Find a geometry that will decrease artificial attenuation in the RCSIM software by more closely mirroring the natural sphere shape of actual path loss

Methodology

- Build free-space simulators for each geometry using C++
- Choose points for each direction from the displacement (100, 110, 111)
- Compare maximum states for each data point to determine error values







Comparison of K Values

	K Direction 100	K Direction 110	K Direction 111	K Average
Rectilinear	7.4162	4.0941	1.8167	4.44
Tetrahedral	0.2062	0.2043	8.1007	2.83
Cubic-Close Packed	0.9579	2.5612	3.0537	2.19
Octahedral	3.141	1.3634	0.3295	1.61

Conclusions

- Error value for tetrahedral scheme is better than that of rectilinear scheme, it's directional dependencies are too great for practical use
- Error value for octahedral scheme is best. Although it experiences inaccuracies in the 111 direction as the edge of the space is approached
- Error value for cubic-close packed scheme is close enough to that of the octahedral to make it practical to implement as well and compare, though there is less consistency in the data from the cubic-close packed scheme.

Future Research

- Implement octahedral scheme into RCSIM software to determine overall improvement to results
- Consider implementing the cubic-close packed scheme into the RCSIM software to determine improvement to overall results

[1] Campos, G.R. and Howard, D.M., "On the Computational Efficiency of Different Waveguide Mesh Topologies for Room Acoustic Simulation," *IEEE Trans. On Speech and Audio Processing*, vol. 13, pp. 1063-1070, September 2005

The Research Alliance in Math and Science program is sponsored by the Office of Advanced Scientific Computing Research, U.S. Department of Energy. The work was performed at the Oak Ridge National Laboratory, which is managed by UT-Battelle, LLC under Contract No. De-AC05-00OR22725. This work has been authored by a contractor of the U.S. Government, accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

Special thanks to Jim Nutaro, Kara Kruse and Richard Ward for their guidance. Thanks to Debbie McCoy and Jacki Isaacs for their organization and order.

Analysis of the Negative Effects and Possible Contingencies Of the Northeastern Blackout in 2003

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Research Alliance in Math and Science
Computational Sciences and Engineering Division, Oak Ridge National Laboratory
Mentor: Dr. Andrew Loebl

https://wiki.ornl.gov/sites/rams/b_davis/Pages/default.aspx

Abstract

The Northeastern black out of 2003 demonstrates what will keep occurring in the future, if the electrical grid is not understood in more detail. In order to address this issue, the physics limitations as a result of infrastructure failures must be understood and automatic settings continuously updated. We intend to understand parameters of the dynamics of the grid and explore numerical understanding and bases determining the effectiveness of grid command and control. The study was completed using the North American Electrical Reliability Corporation Technical Report (NERC) as the basis, to gain understanding pertaining to the events leading to and causing the black out. An analysis of the report, formal texts on electricity flow in the United States and other resource tools to see at what key points the electrical grid began to fail and then to understand interactive effects of those failures. The analysis of the NERC report with information from different sources such as: text books, internet sources, and research reports allowed for a better understanding of the systems involved with the eventual cascade. Furthermore, this allowed for different conclusions to be drawn. After assessing the report, key events leading to the black out were narrowed down to the critical few of several different events. These few events should or could have been prevented, but there appears to be a lack of understanding of the affected infrastructure and its limits in Ohio and by the Independent Systems Operators and the NERC region personnel. Supervisory Control and Data Acquisition (SCADA) systems were not collecting the right information often enough, or the events were either ignored, not known to operators, or not understood to the point where mistakes were made. Thus, it can be hypothesized that an important key problem is that there is an inherent misunderstanding of how the physics of the electrical grid operates in different instances, which lead to black outs and may be regulated improperly and operated through poor standards and procedures.

Background

- Voltage 'instability' due to power demand
- Not direct cause ('limited to Cleveland Akron Area')
- Area systems 'Fragile' beginning ~0800 hrs
- The Eastern Interconnect of the United States was vulnerable to a failure no later than 1303 hrs

Fig. 1 Progression of electrical flow of the black out over the course of the blackout

- Area remains functional but at Emergency Level of operations: Cannot accommodate any subsequent forced contingency, regardless of loss of situational awareness experienced

Objectives

- Empirically understanding of the electrical grid
- Understand the physics that dictate the flow of electricity
- Compare what the NERC report said was done to was is actually the correct method

Methods

- Reference the electrical distribution flow principles
- Review Literature after action report for the blackout including: reports, text books principles, continuation
- Understand system efficiencies system and inefficiencies
- Mathematical and empirical relationships among parameters
- Reanalysis of consequences preceding and following blackout

Analysis of Events

Fig. 2. 'Power wheeling' indicates lack of technical & operational understanding.

P=EI

E= IR

P= power (watt) (Generation)
E= (volt)
I=Current (ampere)
Mvar=reactive power

R=Resistance (ohm)
High Load, Low or Constant Generation Ξ Reduced Voltage

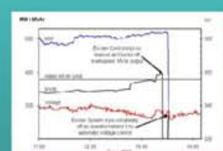


Fig. 3. East Lake Unit 5* goes Offline, 1331 hrs EDT3

Operators addressed low voltage situation by trying to increase voltage (E). Normal response is to decreased current (I).

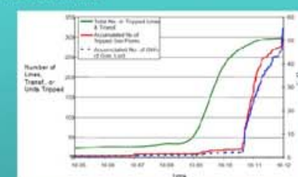
(Cleveland-Akron) *612 MW and 400Mvar

Fig. 4. Graph of subsequent overload failures of four 345kV lines (with one recovery at a non-FE control area @1427 hrs) 1505-1542 hrs

- Reactive power held a>100% for 3-4 minutes before failure.

Results

- Proper methodology to empirically address (in real time) reliability issues within the electrical power system is needed
- Analysis showed missing data on key parameters representing Mvar and its control
- Loop effects evident in cascade of Ohio control area (effects of this nature are notoriously uncontrollable in present SCADA-based environments)
- Empirical representation of fundamental electrical power concepts incomplete and not verifiable



Sammis-Star outage is determined by NERC to be the precipitating event of the New York Blackout of 2003. It is similar in cause and consequence to the Eastlake Unit 5 outage. The difference between the two are only the scale of the consequences. The first incidence affected the Ohio Reliability Control Areas, the latter affected the entire Eastern Interconnect of the U.S.

Conclusions

- Parallelization, which occurred after 16:05:57 hrs has escaped attention. The northern Ohio outages effectively blocked all effective routes for electricity to flow into the 'area'
- If major disturbances in the grid are to be prevented in the future, the measures of performance and conditions must be empirically understood, in detail and monitored continuously
- Anecdotal (post event) After Action Reporting of chronology of events or by summary description such as 'voltage was degraded' or ' system was unstable' is insufficient
- Electric potential overloads the system when a generator suddenly goes off line

The Research Alliance in Math and Science program is sponsored by the Office of Advanced Scientific Computing Research, U.S. Department of Energy. The work was performed at the Oak Ridge National Laboratory, which is managed by UT-Battelle, LLC under Contract No. De-AC05-00OR22725. This work has been authored by a contractor of the U.S. Government, accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

Data and illustrations are from: Technical Analysis of the August 14, 2003 Blackout, North American Electric Reliability Council, Princeton NJ, July 2004

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OAK RIDGE National Laboratory

Parallelization of Nonlinear Application Code

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http://wiki.ornl.gov/sites/rams/c_collins/Pages/default.aspx

Introduction

The objective of this study is parallelization of an existing research-class nonlinear analysis. Parallelization provides an infrastructure to start and run each instantiation of the FORTRAN implementation on separate nodes of the White Oak cluster computer. The infrastructure also returns all of the results in a single output file to the user. Multiple search engines were employed (such as Google, Ask Jeeves, Yahoo, and Livesearch) to research programs, commands, and other scientific processes to gather information needed for creation of the software. The primary result was that the Java code successfully runs by executing independent instantiations of the FORTRAN on 65 nodes of the cluster and then returns the results to the user. It will then use the parallelized version to analyze brain wave data for seizure forewarning for various values of the statistical parameters. The goal is maximization of the total true rate, which is the sum of true positives (correct prediction of a seizure event) and true negatives (no forewarning when no event occurs). This will be used to create an device that forewarns the user of a possible seizure that may occur within the next couple of hours.

Background

- Nonlinear approach that indicates condition change in experimental data has been developed and patented
- "R&D Magazine" awarded its prestigious R&D100 Award in 2005 to SeizAlert technology which is
  - Low-cost
  - Compact
  - Prototype PDA device to alert the wearer and medical personnel of an impending epileptic seizure

Research Objectives

- Convert the existing research-class, nonlinear statistical FORTRAN code to a parallelized form
- Analyze brain wave data for seizure forewarning for various values of the statistical parameters
- Find a parameter set that maximizes the total true rate

Methods

- Determined software requirements
- Used Eclipse- software for creating and running the Java Code
- Used FileZila- software for transferring files across a network
- Used Putty- software to login onto the White Oak cluster to run and compile the Java Code
- Used ArgoUML- software to draw the diagrams of how the program was going to run
- Wrote the java code that parallelized the FORTRAN code from scratch using different sources

The Process of the SeizAlert

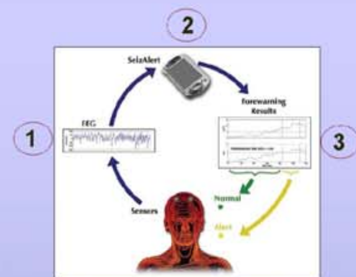

Fig.1. SeizAlert seizure prediction process

1. EEG data gathered and sent to SeizAlert device
2. Artifact removal done and discrete points generated
3. Analysis of dissimilarity
4. Forewarning result

Conclusions

- FORTRAN code runs successfully on a number of nodes on the cluster
- Capability will allow rapid and precise identifications of better parameters
- Will also be used for other forewarning applications
  - Biomedical
  - Industrial applications
  - Complex structures

Future Research

- Other biomedical examples
  - Detection of sepsis onset from ECG
  - Breathing difficulty from surface chest sounds
- Industrial applications provide forewarning of machine failures from motor power to tri-axial acceleration
- Related novel application is forewarning of failure in complex structures, such as bridges and cranes

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The author gives special thanks to God, ORNL family and staff, Dr. Lee Hively and Dr. James Nutaro, and everyone who made it possible for me to be a part of this great opportunity and experience.

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Spallation Neutron Source Data Analysis

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http://computing.ornl.gov/internships/rams/rams08/abstracts/index.shtml

Abstract

The Spallation Neutron Source (SNS) portal was developed to give virtual access to SNS data as well as access to tools to reduce, analyze, and visualize that data. The purpose of this project was to make a graphical user interface (GUI) for a fitting service to be added to the SNS portal. An XML file was written describing the components and features of the GUI. That XML file was then added into the SNS portal where it was read by existing software to create the GUI. When submitted, the GUI will provide input for a fitting code (NL2SOL, NL2SNO, or DAKOTA) which will run on the TeraGrid, a nationwide network of supercomputers. The results will then be sent back to the portal where users can visualize the fit data as well as use the output parameters for a new run. This project is useful for developers and users alike in that the developers can easily modify the XML files in the portal and the users can analyze their data at the push of a button without having to know anything about the TeraGrid, XML, or parallel computing.

Project Goals

- Create GUI for fitting service to be added to SNS Portal
- Make GUI useful and attractive
- Add descriptions for components to make more comprehensive for users
- Incorporate suggestions and ideas from SNS instrument scientists to develop GUI into what users want/need

Creation

- Created by an XML file
- Used examples and software documentation to guide development
- Defaults and other values provided

Fitting Service GUI

Figure 1: Input Parameters Page

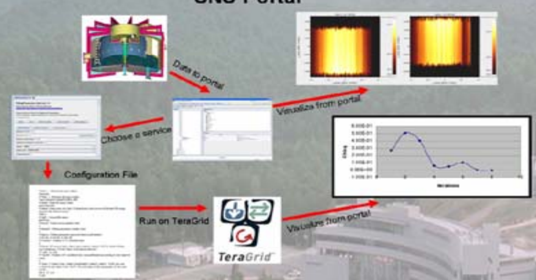
Figure 2: Model Parameters Page

Figure 3: Code Parameters Page

GUI Content

- Figure 1: Input Parameters Page
  - User inputs info about data
  - Selection of instrument (Model) sends values to Model Parameters Page.
- Figure 2: Model Parameters Page
  - User selects number of parameters to use
  - Chisqr is calculated when the program runs and is then returned here
  - User sets max and min and decides whether to vary each parameter
- Figure 3: Code Parameters Page
  - Needed by NL2SOL and NL2SNO
  - Descriptions in tooltips

SNS Portal



- Ability to immediately see GUI changes in portal helped with design
- Capability to run on TeraGrid
  - Run thru community account- Jimmy Neutron
  - Sent to another machine if run fails

Future Work

- Test with Gaussian
- Make available on Backscattering Spectrometer when configuration file is completed
- Include more instruments as they come online (see chart above for examples)
- Add more models as they become available
- Use more fitting codes (possibly Bayesian fitting)
- Make improvement to GUI and add more features to software

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The author would like to thank Steve Miller, Jim Kohl, Sudharshan Vazhkudai, and the rest of the neutron science portal development group at the SNS as well as John Cobb, Meili Chen and the TeraGrid/NSF group at Oak Ridge National Laboratory.

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On The Design and Capacity Of Wide Area Sensor Networks

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University of Tennessee-Knoxville

Research Alliance in Math and Science
Computational Sciences and Engineering Division, Oak Ridge National Laboratory
Mentors: Dr. Mallikarjun Shankar, Teja Kuruganti, David Resseguie

http://www.csm.ornl.gov/Internships/rams_06/abstracts/p_donnelly.pdf

Motivation

Rapid and efficient deployment of mobile sensor network systems remains more of an art than a science. A systematic process for deploying wireless sensor networks requires characterizing the environment as well as the infrastructure. We address this need and develop wireless sensor network deployment processes and evaluate the match between theory and practice.

Goals of Approach

Develop a wireless network deployment process:

- cover the target area
- ensure that each RF (radio-frequency) cell has enough capacity to carry the expected network load
- eliminate or minimize the effect of interference

Fig 1. ORNL East Campus Quad: Example wireless sensor network deployment target area

Fig 3. Access point (AP) Actual 802.11b transmitter used during wireless survey

Proposed Process

- Determine the total area of the proposed monitored zone (Figure 1)
- Determine the range of an IEEE 802.11b transmission at maximum power (20dBm)
- Deploy transmitter(s) to spatially cover the target area with maximum data rate
- Measure initial signal coverage area of each AP (Figure 2)
- Modify each individual access point's transmit power to adequately support sensor node connectivity virtually while minimizing interference
- Characterize the terrain between the transmitters and receivers and simulate the effect on the RF signal
- Characterize the noise floor for each proposed network channel
- Compare simulation model of RF/Terrain characteristics with measured values to be able to rapidly alter and simulate deployment scenario if needed
- If values match, modify AP power to prevent dead zones. Otherwise, refine simulation model and iterate over previous steps.

Netstumbler RF Signal Output

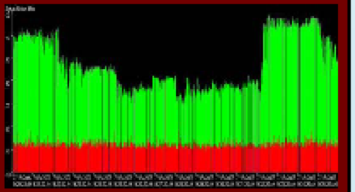

Fig 2. Netstumbler SNR Output:
IEEE 802.11b 2.4Ghz
Channel 11 Data rate: 11Mbs

Conclusions

- Simulation of RF transmission models match (within 10dbm) with measurements
- Multi-path and interference effects due to the environment force multiple iterations of the process
- Interference and path-loss detection tools need to improve to characterize multi-path effects

Future Work

- Develop an algorithm to automate the deployment process
- Develop techniques to characterize the real effect of interference on Data Packet Loss at the Link Layer

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A Simulation Application Programming Interface for Traffic Modeling

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Mentor: Dr. Jim Nutaro
http://www.csm.ornl.gov/Internships/abstracts/kenroyWilliamson.pdf

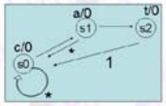
Introduction

This document describes an application programming library for constructing the dynamic pieces of a traffic simulation. It is meant to complement a complete traffic modeling tool set that includes data import and export capabilities, traffic routing algorithms, and visualization tools. This software library provides an abstract framework for constructing event driven models of traffic dynamics. It is based on the DEVS (Discrete Event System) modeling and simulation framework, and will be implemented using *ADEVS* (A Discrete Event System) simulation package. There are three basic elements of a traffic model and they are represented abstractly in the modeling framework. Traffic sources represent locations from which traffic can enter a road network. Traffic sinks are destination locations where traffic can leave a road network. Road segments represent traversable pieces of a road network. A road segment can represent an intersection, a one way street, a multi-lane highway, or any other navigable piece of the road system. The road system is navigated by population units. Population units are characterized by a size (e.g., number of people or number of vehicles) and a destination. Population units originate at traffic sources and are ultimately deposited at traffic sinks. They travel from source to sink through a road segment graph. The paths taken by the population unit, and the time required for a population unit to traverse a road segment, are determined by the user of the modeling framework. The modeling framework provides event scheduling, feedback for modeling congestion, and other time and structure related services that are needed to perform the actual simulation.

Approach

- **Learn** C++
- **Read** *Theory of Modeling and Simulation*
- **Implement** fire spread model in C++
- **Become** familiar with *ADEVS* library

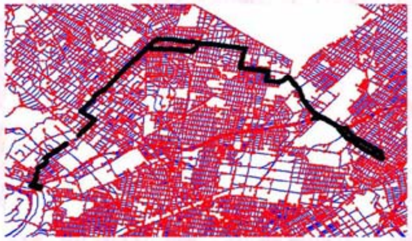
State Trajectories Examples



X	C	A	T	T
S	s0	s1	s2	s0
Y	0	0	0	1

Project

- **Develop** a fire spread model using a generic, systems theory based cell space simulation framework
- **Write** a brief paper describing the principles behind the simulation engine



Map of Philadelphia, the black line is the bus route that is being used to detect movement, the blue lines are city streets and the red dots are nodes that illustrate intersections.

Research Objectives

- **Understand** the fundamentals of modeling and simulation
- **Apply** fundamentals to fire spread model
- **Develop** a software library for constructing the dynamic pieces of a traffic simulation
- **Design** software to be built on the *ADEVS* framework
- **Implement** the software as designed
- **Test** the implementation

Software

- **Cygwin** – used to write program
- ***ADEVS*** – C++ library that program was built on
- **C++** – Language used to write and execute program

Work in Progress

- **Development** of discrete event model that finds the shortest path through a graph

Predicted Results

- Program used to develop high-resolution population distribution model and databases for U.S. metropolitan areas
- Used by the Exposure Modeling and Research Branch (EMRB) at the U.S. Environmental Protection Agency (EPA)

Shortest Path Examples

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I would like to thank my mentor Dr. Jim Nutaro for taking the time to teach me everything I now know about modeling and simulation, software engineering and discrete event systems. Thank you for not judging me. Thanks to my colleagues Jermaine Henry and Dr. Cheng Liu for their assistance. I would also like to thank Dr. Usha Chandra and Dr. Jason Black from Florida A & M University for helping me to get this internship. Finally, special thanks to Debbie McCoy, and all the RAMS students who helped me through out those struggling weeks at work and for helping me to enjoy myself outside of work.

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A Model and Simulation of a DOD Communications Network Based on the Stochastic Process in Real Time

http://www.csm.ornl.gov/Internships/posters04/v_moffett_pa.pdf

Veranda V. D. Moffett
Mississippi Valley State University

Research Alliance in Math and Science
Computational Sciences and Engineering Division
Oak Ridge National Laboratory
Mentor: Dr. Glenn Allgood

Abstract

The Oak Ridge National Laboratory (ORNL) is working on a communication model that will provide information and data among large spatially displaced elements on the battle field. The communication model is associated with latency, and how it applies in the Combat Identification (CID) System. The project was designed to develop the next generation Speed of Service Communication Model relevant to CID. The main task was to develop a Markov Chain and its associated probability that will be calculated in consideration of numerous elements, to include: latency, data integrity, quality of service, and commander confidence. My responsibility was to generate a function that would calculate the total probability for the model. This function will allow the model to transition through its various states supplying a time varying variable that will be used to adequately assess the impact of network security, wireless sensors, agent technology, and distributed energy resources on the communications infrastructure.

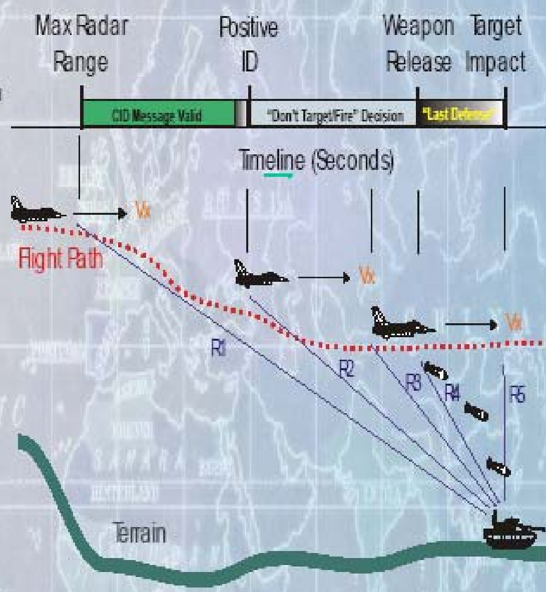
Objective

To provide a communication modeling and simulation tool to support combat identification trade studies as they relate to reduction of fratricide and combat efficiency.

Methods/Software Used

MATLAB 7.0

- **MATLAB** is a high-performance language for technical computing. It integrates computation, visualization, in an easy-to-use environment where problems and solutions are and programming expressed in familiar mathematical notation.
- **Typical Uses**
  Math and computation
  Algorithm development
  Modeling, simulation, and prototyping
  Application development, including graphical user interface building
- **Markov Model Process**
  With MATLAB I constructed a function to calculate the total probability of a five state Markov model. This function was integrated into a Markov model, which allows the model to transition through its various states.



Fighter Attack Geometry (F15 Platform)

Conclusion

A model was developed which will be implemented into a tool that is under development and will be used to address both security and performance issues for the current energy communication infrastructure as well as proposed future infrastructure.

Future Plans

The results of this research will be integrated into a Combat I.D. Systems of Systems Application and will be used to access information flow and integrity verifying network simulation.

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