SAND2015-2557R

LDRD Highlight: Pattern ANalytics To Support High-performance Exploitation and Reasoning (PANTHER) researchers are developing *analytic techniques that efficiently detect patterns in high-volume, noisy, remote sensing and other geospatial data,* improving an analysts' ability to detect possibly off-normal events in complex homeland security, nuclear weapons, and emerging threat environments. ***Background:*** High-consequence, national security decisions rely on timely, comprehensive answers to complex questions, yet critical gaps in our approach to these questions remain. PANTHER addresses these gaps through fundamental research on: geospatial-temporal feature extraction via image segmentation and classification; geospatial-temporal graph algorithms and computational geometry; and domain-relevant models of human perception and cognition informing the design of analytic systems. PANTHER's cross-disciplinary R&D approach uses fundamental science and mathematics to understand how to maximize decision systems through rethinking key aspects of geospatial data analysis. New methods in motion and trajectory analysis support both rapid search for known trajectories as well as rapid clustering and anomaly detection. Thus, the perceptual and visual load on users is reduced by providing pattern analytics with elegant visual cues to spatial and temporal characteristics. ***Approach and Accomplishments*****:** The team chose a novel approach based on the notion of a *feature vector*, an n-dimensional vector of real numbers describing aspects of a trajectory. Given remote sensing position and time, questions arise like: What are the moving objects? What are they doing now? Have we seen this behavior before? What *might* they do? When will we be able to tell? To answer these questions and more, algorithms to index, cluster and search trajectories were developed according to shape. Simple scalar measures associated with each trajectory (such as time, total distance, etc.), were combined with geometric scalar quantities that describe the relevant geometric characteristics of the trajectory. This provides a feature vector associated with each trajectory that can be used to store information about, and do comparisons between, different trajectories. Once feature vectors are determined, clustering, search, indexing, comparison and machine learning algorithms can be applied to quickly make sense of large bodies of trajectories. The PANTHER team developed *Tracktable*, a code base, to easily visualize large and complex sets of trajectory data. One particularly important class of features involve *intra-trajectory distances* (distance geometry). While the other descriptors are very important in finding flights with specific characteristics, the distance geometry features describe different trajectory shapes without having to *a priori* know what sort of shapes one is expecting. ***LDRD Impact*****:** PANTHER has made advances in the visualization of geospatial patterns that will simplify the analysts' ability to query large volumes of geospatial data. Success will be demonstrated via creation of metrics and subsequent measurements of *human* performance improvement by PANTHER technology vs. current state-of-the-art, deploying of practical technology to national stakeholders and intellectual property dissemination via publications, patents and copyrights. Several recent examples of recognition and IP dissemination include: a) *Tracktable* software was used to create an image that was one of three finalists for the International Data Visualization Contest (see Figure 1), b) several algorithms are in the patent process and c) a manuscript entitled "Trajectory Analysis via a Geometric Feature Space Approach" has been accepted for publication in Statistical Analysis and Data Mining. Follow-on funding may ensue for further development and potential application to mission problems. In a related task, a CRADA recently executed between Sandia and EYETRACKING, Inc. will produce new algorithms, software, interfaces, and user workflow models for eye tracking studies that incorporate dynamic visual stimuli. Activities under this CRADA will advance the collection and analysis of human visual perception and cognition with dynamic content. These projects span a number of NNSA and other mission areas, including cybersecurity analysis research, development and training (e.g., TracerFire workshops), nuclear weapons component analysis, DHS transportation and security capabilities, and imagery analysis activities related to Sandia programs in airborne and space-based remote sensing.

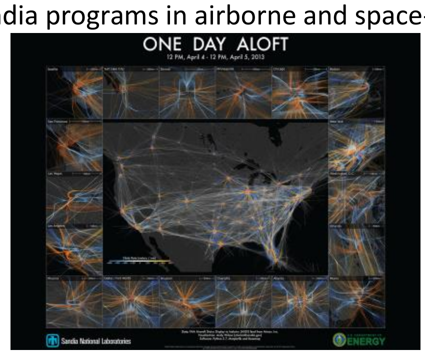


Figure 1. A poster created with *Tracktable* won runner-up at visualization art contest.

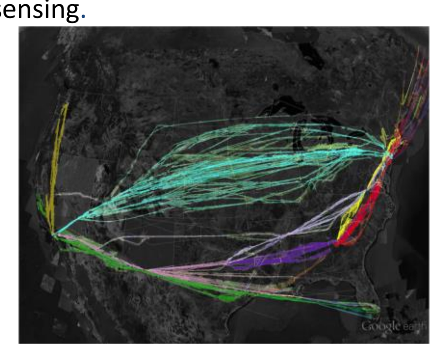
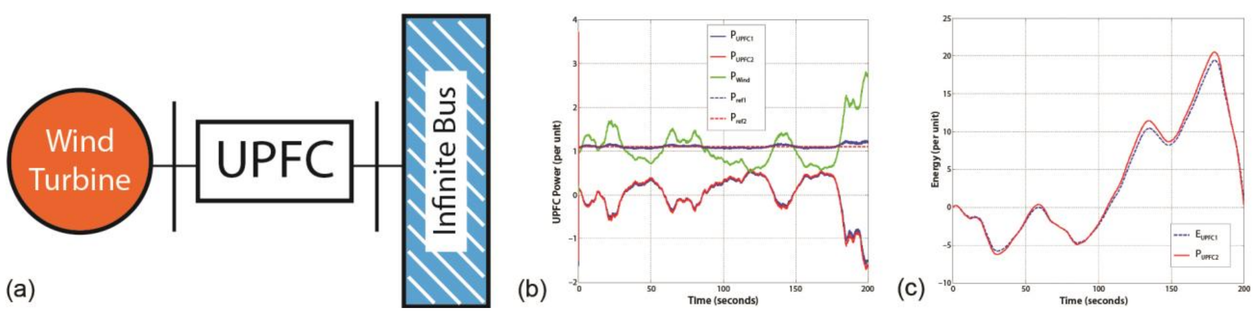


Figure 2. *Tracktable* code used to find "portals" that segment nationwide traffic patterns.

LDRD Highlight: Enabling Secure, Scalable Microgrids with High Penetration Renewables – LDRD-originating technologies are being developed to address challenges inherent to highly stochastic energy sources and loads, to conceivably satisfy electrical energy needs of national/international power systems. ***Background:*** The Enabling Secure, Scalable Microgrids with High Penetration Renewables Grand Challenge LDRD (FY11-FY13) aimed to develop a novel intelligent grid architecture, Secure Scalable Microgrid (SSM), based on closed loop controls and an agent-based architecture supporting intelligent power flow control. The approach was to enable self-healing, self-adapting, self-organizing architectures and allow a trade-off between storage in the grid versus information flow to control generation sources, power distribution, and where necessary, loads. ***LDRD Impact:*** The SSM GC LDRD resulted in a SSM research capability engaged in developing technologies to solve many complex challenges in satisfying electrical energy needs. Initial focus has been on enabling resilient and reliable performance when incorporating high penetration levels of stochastic renewable energy sources in power systems. Theories and concepts from multiple fields were integrated to advance solutions, including Hamiltonian Surface Shaping and Power Flow Control (HSSPFC)™ based nonlinear distributed control theory, informatics/agent based algorithms, communication theory, and power electronic system theory. With the advancement of Microgrid power systems that include high levels of renewable energy penetration comes the need to determine energy storage requirements. Because of the stochastic nature of the sources, energy storage is an important design component in Microgrids with high penetration renewables to maintain the system stability. Storage devices can be distributed close to the source and/or at the Microgrid bus (centralized). Selected solutions to these challenges have recently been published in the online journal Electrical Power and Energy Systems, "*Energy storage requirements of dc microgrids with high penetration renewables under droop control*", W. Weaver, et.al. This paper highlights a novel design and analysis approach of energy storage devices in a DC Microgrid system with high penetration renewable energy sources that have high variability. The focus of the study is the effects and trade-offs in placing energy storage close to the sources, or at a centralized bus storage device. In addition, due to the novel nature of the energy storage Unified Power Flow Control (UPFC) architectures, a patent was recently awarded. A simple wind integration with the electric power grid demonstrates this capability and performance (Wilson and Robinett, IEEE MSC 2011). Figure (a) shows a One Machine Infinite Bus (OMIB) model with a UPFC and wind turbine generator. The power and energy storage requirements are given in Figures (b) and (c), where the wind variability is compensated with the UPFC device to prove a constant power output.



Upcoming LDRD Events

- March 2 – April 9: LDRD Idea Reviews
- April 14 – May 21: New and Continuation Standard and Grand Challenge proposals submission

LDRD Projected Budget and Status

- FY15 Q2 - $146M, 363 projects funded at $137.2M

Awards and Recognition for LDRD Participants:

- Jon Madison was recently named the winner of a Black Engineer of the Year Award (BEYA) for Most Promising Scientist. BEYA is a program of the national Career Communications Group, an advocate for corporate diversity, and is part of its STEM achievement program. Madison received his award at the 29th BEYA conference in Washington, D.C.
- Margot Hutchins was selected by the Society of Manufacturing Engineers as one of 11 Outstanding Young Manufacturing Engineers for her career achievements. This year's awardees, age 35 or younger, from industry and academia, were selected based on their R&D efforts in emerging manufacturing applications, published works, design ingenuity, entrepreneurship and leadership.