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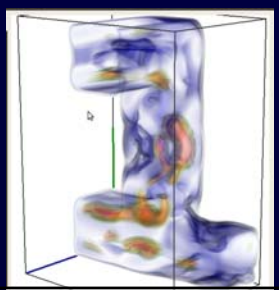
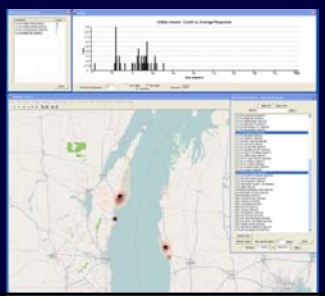
Visual Analytics for Command, Control, and Interoperability Environments
A U.S. Department of Homeland Security Center of Excellence

Visual Analytics Applications for Decision Making: From Research to End-User

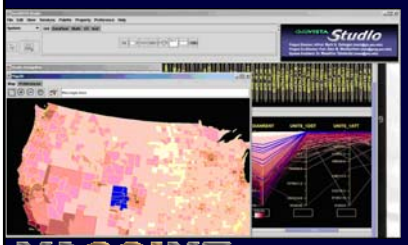
David S. Ebert





Motivation

To solve today's and tomorrow's problems requires exploring, analyzing, and reasoning with massive, multisource, multiscale, heterogeneous, streaming data



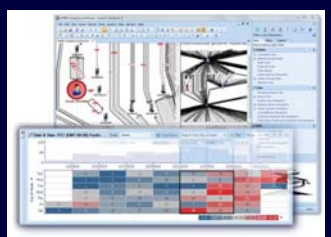
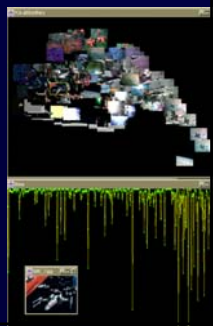


Image of Analyst's Notebook


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Research Motivation:

- Solving these real-world problems requires
  - Novel theories, techniques, approaches, and adaptations of algorithms
  - Integration of cross-disciplinary expertise
- Solving these real-world problems provides
  - Compelling, publicly understandable value for your research
  - Advances in CS and in other disciplines
  - New publication opportunities
  - Great collaboration partners and proponen
  - Opportunities for new adventures

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What's Needed for Solutions?

- Reliable and reproducible models and simulation
- Understanding of the data
  - Distribution and skewness, errors, appropriate analysis techniques
- Understanding of the sources and types of data
- Comparable or Correlative sources data
  - Appropriate transformations applies to enable meaningful comparison and correlation
- Understanding of the use and problem to be solved!

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Two Different Stories

- Short Story: Interactive computational flow and nanotechnology visual analytics
- Long and winding road (multi-year, multi-forked path):
  - Public health surveillance
  - Crime visual analytics
  - Public safety, resource allocation, and risk-based decision visual analytics

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Short Story: Interactive computational flow and nanotechnology visual analytics

- Question: Is there value in and is it possible to provide interactive visual analytics on HPC simulations?
  - Where will it have value?
- Two applications that are quite different:
  - Large computation with small data (computational nanotechnology)
  - Massive data with large computation (1meter resolution cloud and precipitation physics)

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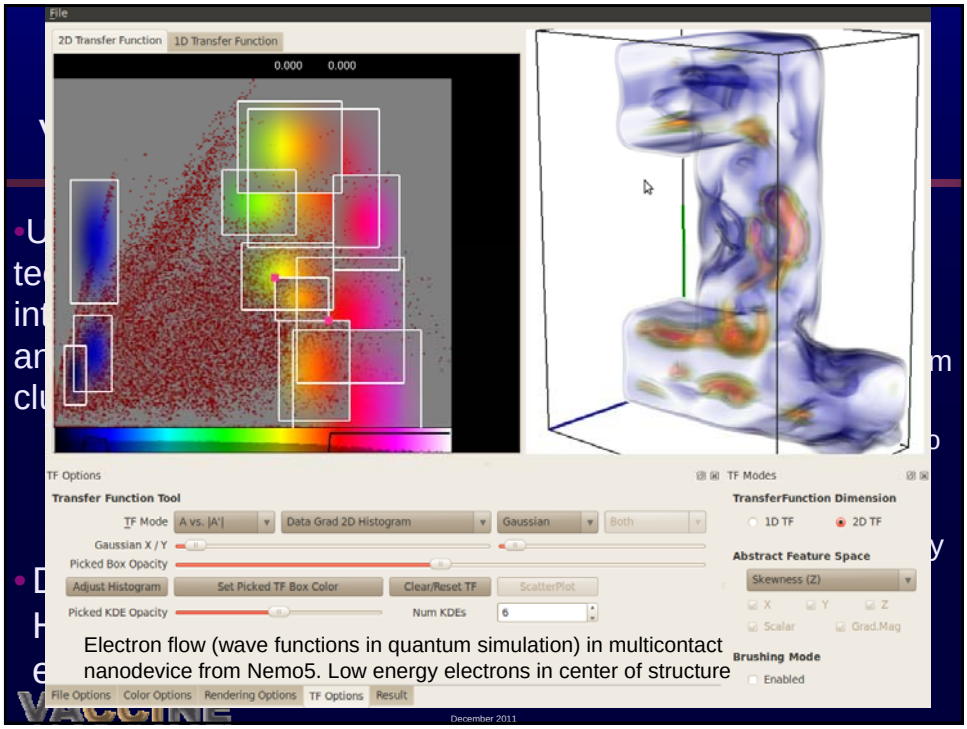

Electron flow (wave functions in quantum simulation) in multicontact nanodevice from Nemo5. Low energy electrons in center of structure

The Long and Winding Road

- Public health surveillance
  - Fusing apparently similar data that isn't (health data)
  - Dual domain decision making and real-world visualization and analysis for disease spread and interdiction
- Spatial and temporal visual analytics for law enforcement
- Search and rescue and risk based visual analysis

"The long and winding road
That leads to your door
Will never disappear" – P. McCartney

Improving Syndromic Surveillance

Interactive visual analytic environment for effective syndromic surveillance and response

- System designed based on collaboration and feedback with state epidemiologists
- Integrated temporal, geospatial, multi-source, multi-scale analytic capability
- Density estimation for data exploration
- Syndromic control charts for temporal alerts
- Demographic filter controls for advanced analysis

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Improving Syndromic Surveillance

Benefits/ impact

- Enhanced hypothesis testing capabilities
- Linked views allow quicker cross validation of hypothesis
- Less time investigating false positives
- Systemic biological pandemic, syndromic, chem/bio/nuclear surveillance, management, and response

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Data, Analysis, and VA Issues

- Data management
  - Data Preparation
  - Privacy-Preserving Data Sharing
- Statistical analysis
  - Data transformation, normalization
  - Aberration detection for sparse, dependent data
  - Seasonal trend decomposition
- Visual analytics
  - Interactive, direct access to database
  - Statistical displays
  - Factor specification and filtering

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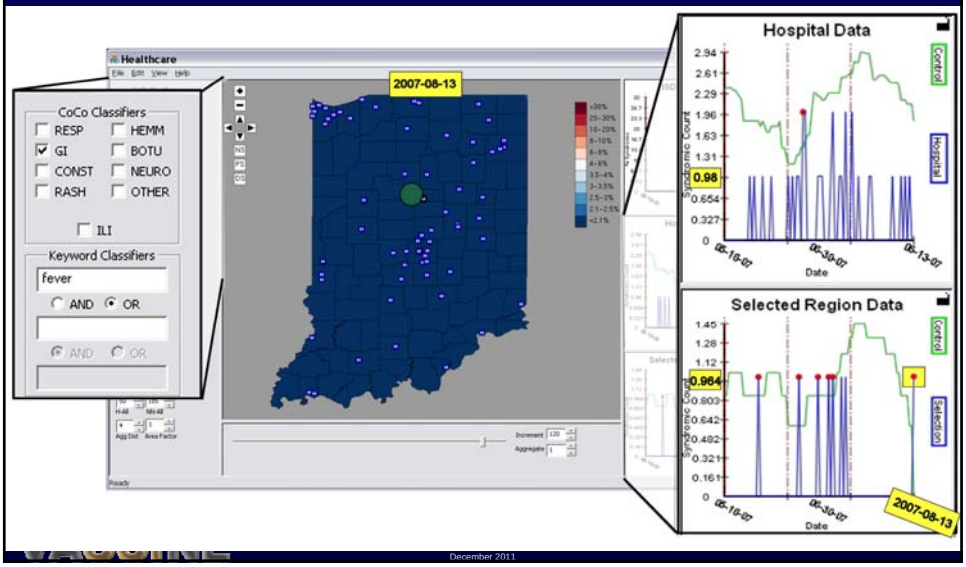
Spatiotemporal Hypothesis Generation and Visual Analysis



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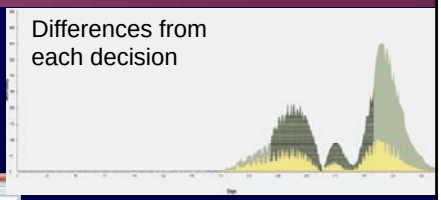
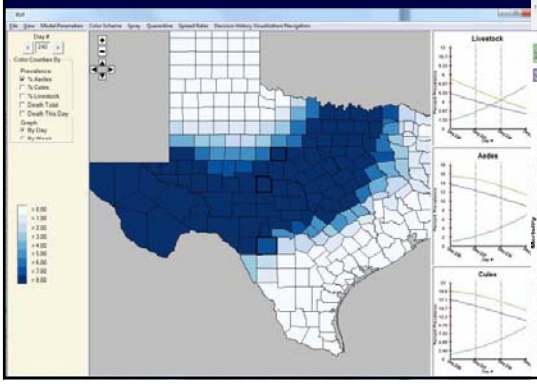
Example Decision Analysis Linked Displays – Example with 3 Decisions

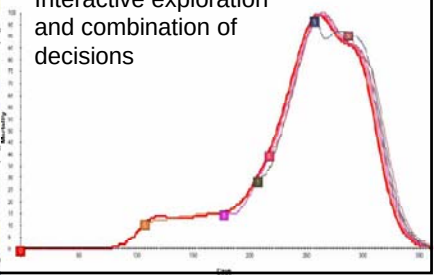
Partnership with FAZD

Differences from each decision



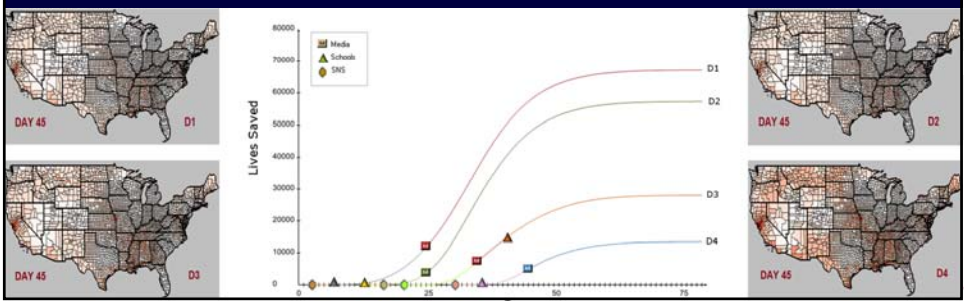


Interactive exploration and combination of decisions



Integrated Interactive Simulations and Analysis

- Analysis and simulation must be interactive for integration into interactive environment
- Need novel computational & statistical models
- Goal: enable improved discovery, decision making, analysis, and evaluation



Situational Surveillance and Predictive Visual Analytics

- **Focus is on categorical spatiotemporal event data**
- **Utilizing time series and density estimations we want to create an interactive environment for predicting future event magnitudes and locations**
- **We utilize seasonal trend decomposition with Loess smoothing**
- **3D Kerenel density estimation for spatiotemporal probability distributions**

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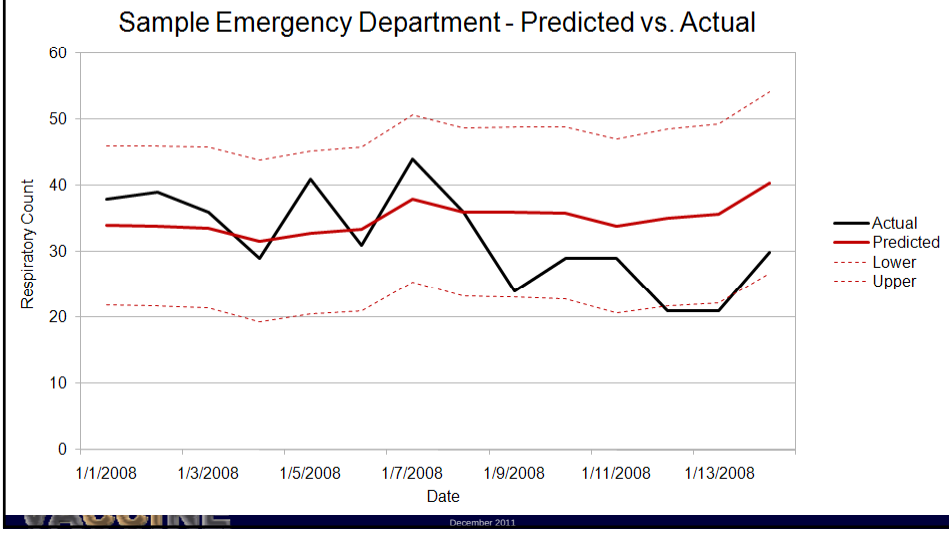
Predictive Visual Analytics



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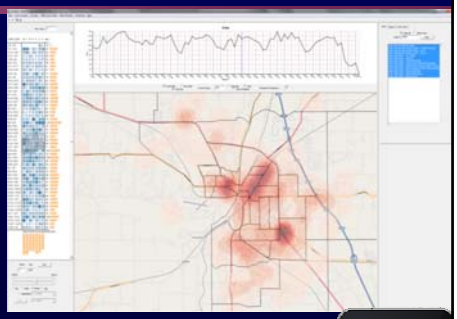
Visual Analytics Law Enforcement Toolkit (VALET, iVALET)

Ebert, Maciejewski, Collins
Collaborating Institution(s): Purdue University
End-User(s): Indiana Public Safety Consortium (Lafayette, WL Police, Indiana Fusion Center), Ohio Fusion Center (in negotiation)

Impacts:

- In use to analyze crime patterns in Lafayette, Indiana and connect strings of activities
- Mobile version being released to public (November 2011) for community-based policing
- Investigating correlation of bus routes and crime, street lights and crime
- Analyzing time of day problems and improving accuracy of police record management system
- Novel statistical predictive model incorporated for planning



VALET delivered:
- Spring 2011: WL, Lafayette Police

iVALET delivered:
- October 2011: Purdue, WL Police

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iVALET

VALET Issues and Techniques

- Fuse data from a variety of sources
  - Law enforcement records management
  - Weather and phases of the moon
  - Street light locations, bus routes
  - Tracking release data of offenders
  - Civil court data
  - Social Media
  - Local event calendar

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VALET Issues and Challenges

- Reliable predictive models
- Understandability and trust of predictions
- Main Question: What helps officers, detectives, chief do their variety of jobs?

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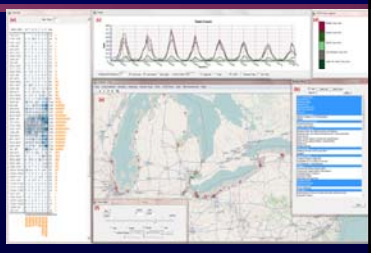
U.S. Coast Guard Search and Rescue VA (cgSARVA)

PI: Ebert, Maciejewski
Collaborating Institution(s): USCG LANT 7 (Operational Analysis)
End-User(s): USCG D9, USCG D5, USCG LANT

Delivered: Summer 2010: USCG LANT 7, USCG D9

IMPACTS:

- Analyzed impact of CG auxiliary stations on search and rescue mission in Great Lakes
- Used for resource allocation for SAR
- Provided evidence of temporal and spatial patterns used in planning – new insights to SAR mission
- Hurricane Irene resource allocation decision based on cgSARva analysis and visualization
  - Highest SAR workload that weekend for D9



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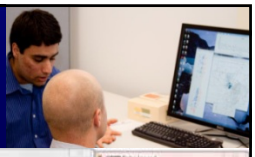
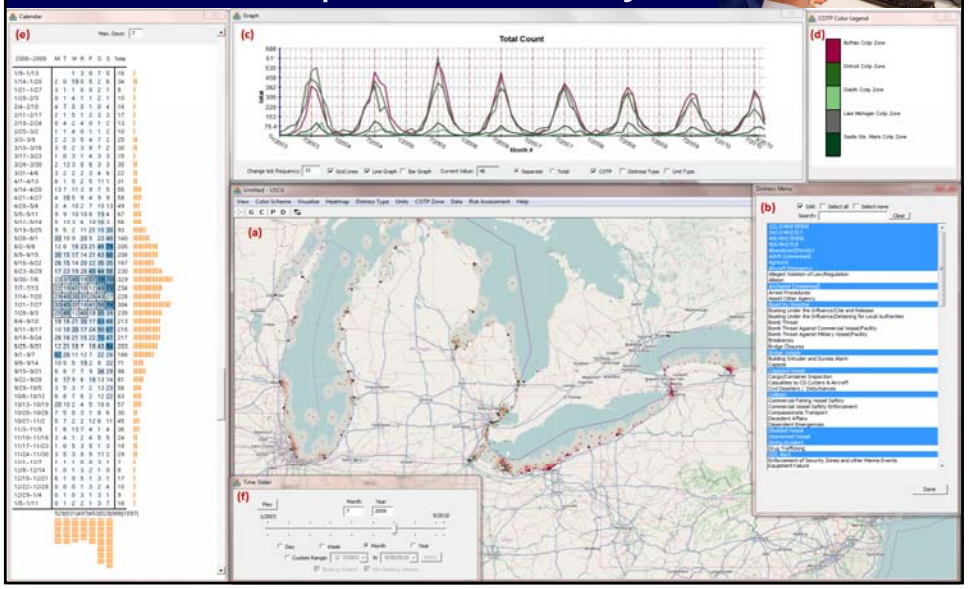
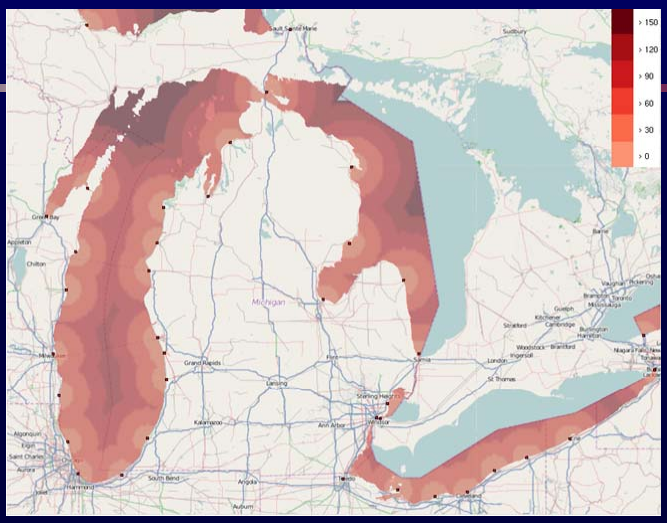
Example: USCG D9 Search And Rescue Operational Analysis





System Features: SAR Risk Profile



Time taken by CG stations to deploy an asset to the Great Lakes to respond to a SAR incident.

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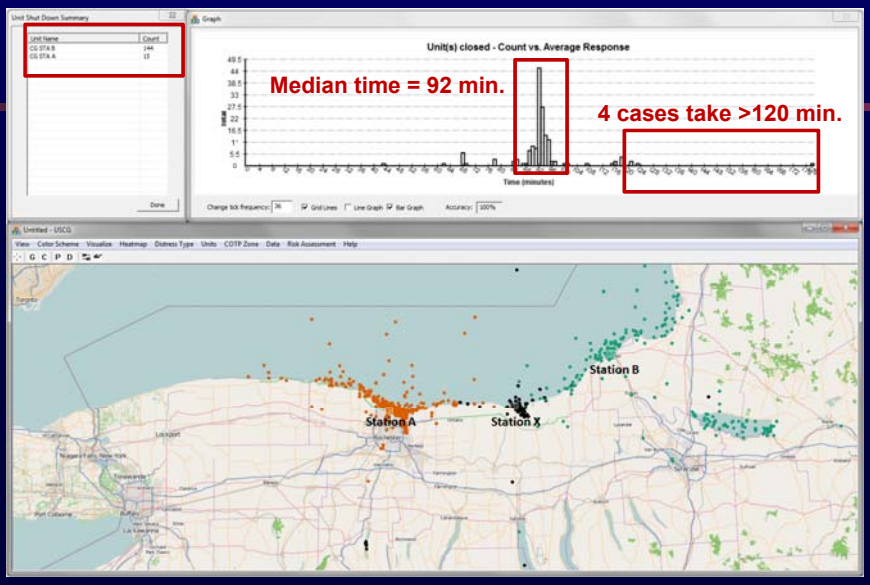
Risk Assessment Scenario – contd.



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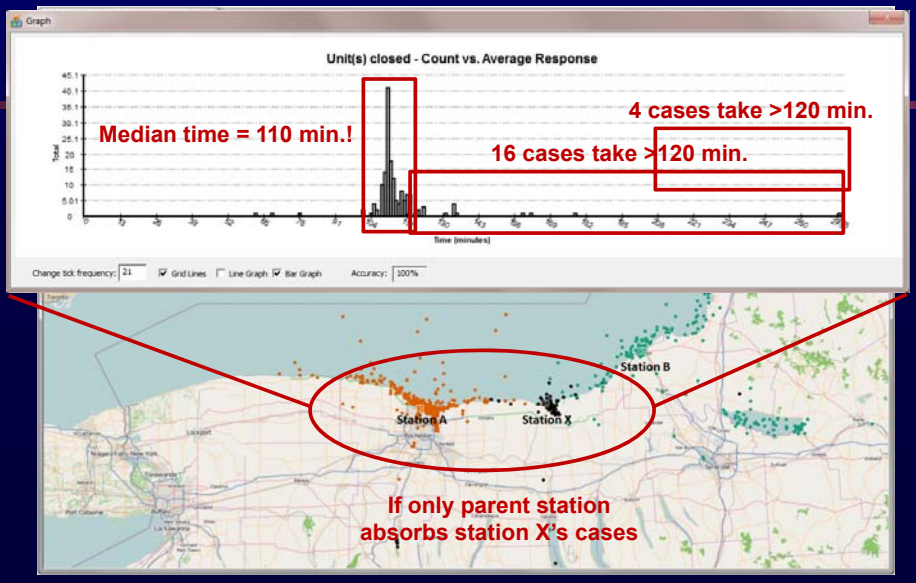
Risk Assessment Scenario – contd.



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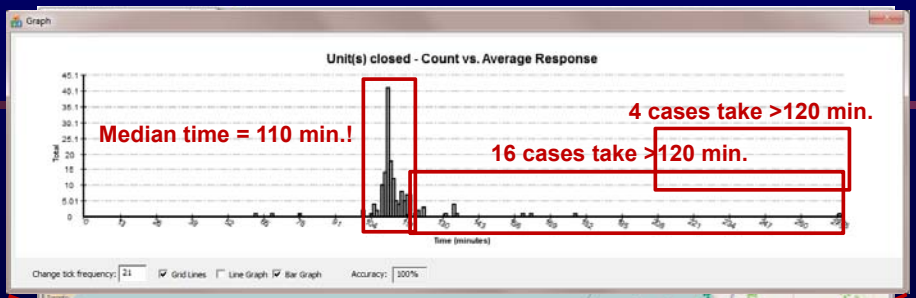
Risk Assessment Scenario – contd.



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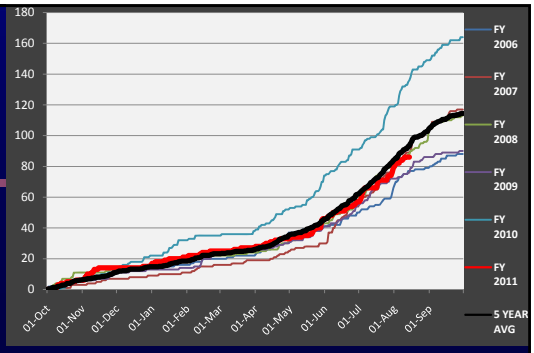
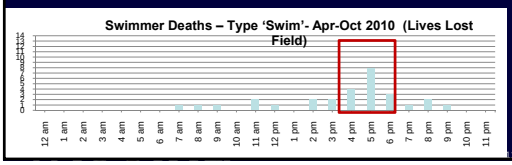
U.S. Coast Guard Swimmer Death Analysis

PI: Ebert, Maciejewski
End-User(s): USCG District 9
Delivered: May 2010



Impact:

- Analyzed spatial and temporal patterns of shore-based and boat-based swimmer deaths to understand death dramatic increase in D9 in Summer 2010
- Provided information and visualizations used for public information campaign 2011 and for patrols 2011
- Significant decrease in deaths in 2011



Findings:

- Swimmer deaths
  - August highest frequency
  - Late afternoon highest frequency
  - Lake Michigan (south and west shore) have high concentration
- Boating deaths
  - Fri, Sat, Sun account for almost all deaths
  - Mid July to Mid August have highest frequency (only 1 week significantly high)
- 2009-2010 from MISLE Data
  - Large increase on Mon, Thu, Fri, Sun
  - Early and late season increase

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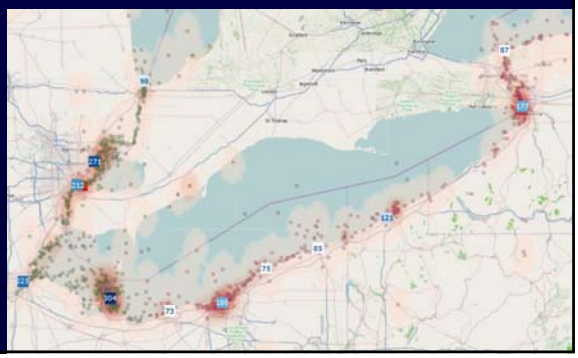
Comparative Visual Analysis of SAR Cases vs. SAR Boat Hours

- Explore less intrusive way to visualize Boat Hours while enabling effective comparison
- Spatio-temporal analysis and exploration at varying granularities and areas of interest



Boat Hours for 2009 and SAR Risk.

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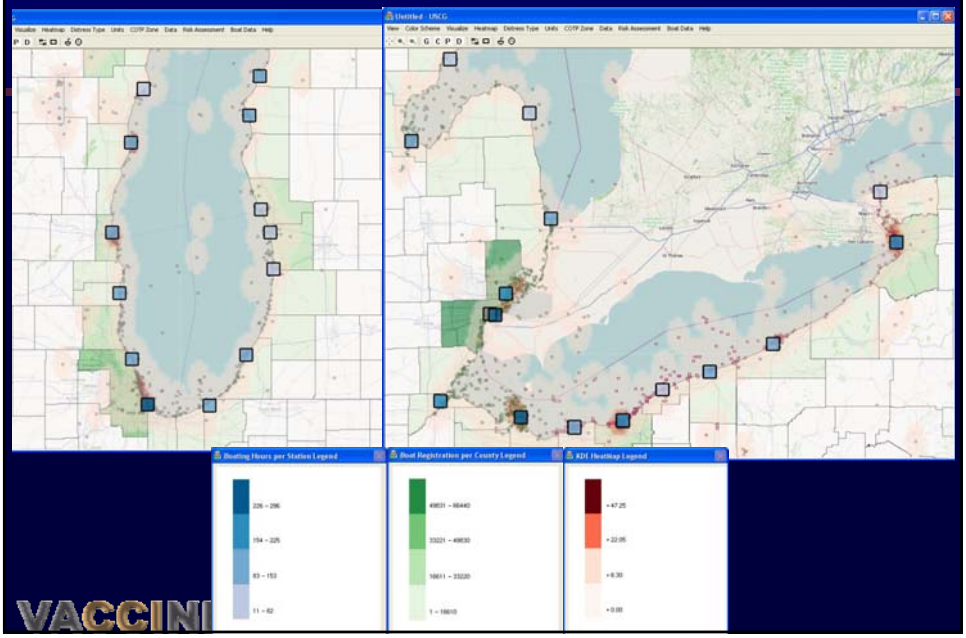
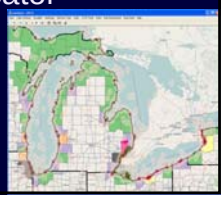
2010: Total SAR Risk vs. Boat Hours



Uncertain Information for Decision Making

- What numbers make sense?
- Counts vs. rates?
  - How many boats are in an AOR over a year?
    - No reliable data source
    - Registered boats by county not accurate
    - Marina slips not a reliable indicator
    - Marina fuels sales probably not reliable indicator



Visual Analytics

- We need to be cognizant of parameters for visual representations
- Appropriate analysis can guide users to interesting features in the data
- Refined analysis through user interaction and their domain knowledge can help discover hidden problems
- There is no single catch-all visual representation or analysis

Keys for Success

- User and problem driven
- Balance human cognition and automated analysis and modeling
  - Often applied on-the-fly for specific components identified by the user
- Interactivity and easy interaction
  - Utilizing HPC and novel analysis approaches
- Understandability of why predicted value is what it is
- Intuitive visual cognition
- Not overloaded with features

Technologies in the Transition Cycle

- **VALET -** Visual Analytics Law Enforcement Toolkit
  - Deployed for Test & Evaluation Feedback - 2010
  - Lafayette PD, W. Lafayette PD, Purdue PD, Tippecanoe County Sheriff
- **GARI -** Gang Graffiti Automatic Recognition and Interpretation
  - Initial Prototype Deployment Scheduled July 2011
  - Indianapolis Gang Task Force, Lafayette PD, Purdue PD
- **CGSaRVA -** Coast Guard Search and Rescue Visual Analytics
  - Deployed for Operational Use – USCG LANT - 2010
- **MERGE -** Mobile Emergency Response Guide
  - Initial Prototype Deployment June 2011
  - Indianapolis Fire, Lafayette Fire
- **Ulearning (Captico)-** Training portal for S&T and COE Technologies
  - Deployed for Test & Evaluation Feedback - March 2011

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Technologies in the Transition Cycle

- **JigSaw –** VA for Exploring and Understanding Document Collections (Georgia Tech)
  - Deployed for Test & Evaluation Feedback Dec - 2010
  - Indianapolis PD, Lafayette PD, West Lafayette PD
- **PROTECT** - Port Resilience Operational / Tactical Enforcement to Combat Terrorism
  - Collaboration with CREATE
  - Prototype deployed in Boston April, 2011 extending to NYC Fall 2011
- **COE Explorer –** Exploring the Centers of Excellence (Purdue, SFU)
  - Collaboration with CCICADA
- **CrimeViz -** Sensemaking about criminal activity in space and time (Penn St)
  - Testing in progress with Harrisburg PD
  - Prototype deployment Q2 2011 Harrisburg PD, JIBC
- **ISIS -** Infovis System for Investigating Intrusions (Stanford)
  - Awaiting deployment to US CERT

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For Further Information

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