PNNL-SA-65448

*AAAI 2009 Spring Symposium Series*
*Technosocial Predictive Analytics*

# Managing Complex Network Operation with Predictive Analytics

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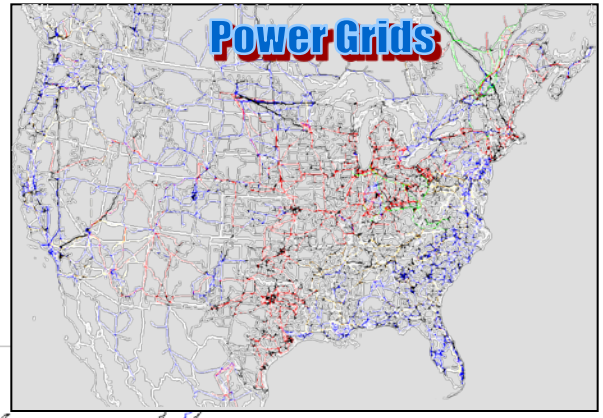
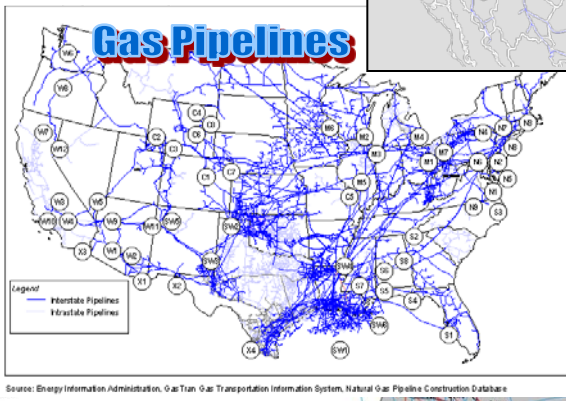
# Presentation Outline

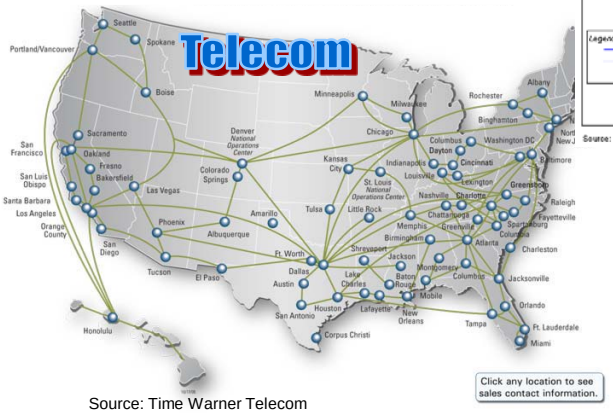
- Background on Complex Networks and Complex Network Operation
- Predictive Analytics for Decision Support
  - Visual Analytics for Risk Assessment
  - Visual Trending Analysis
  - Clustering Analysis
- Conclusion and Future Work

# Background – Complex Networks

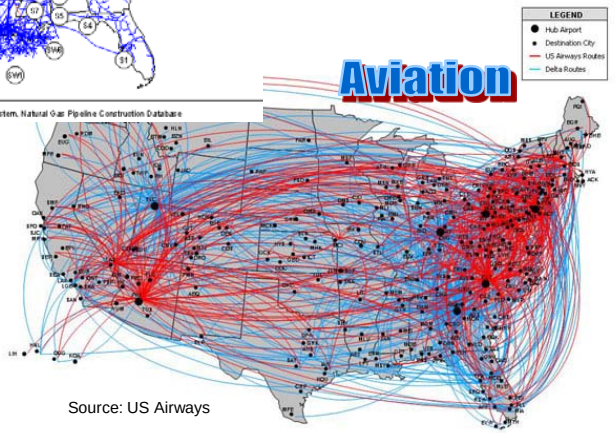
- General Features
  - Complex structure
  - Wide geographical coverage
  - Large volume of data
  - Complex data/IT support systems
  - Critical role of human operators




Source: Time Warner Telecom

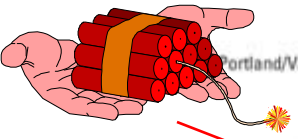



Source: US Airways

# Background – Complexity of Network Operations

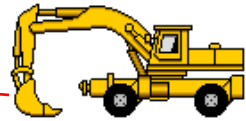
Human Errors

Physical Attacks



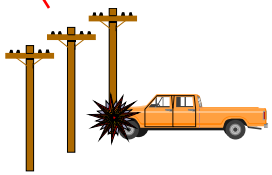
Ice & Lightening Storms

Cyber Attacks



Dig-Ins

Map Source: Time Warner Telecom



Vehicular Collisions

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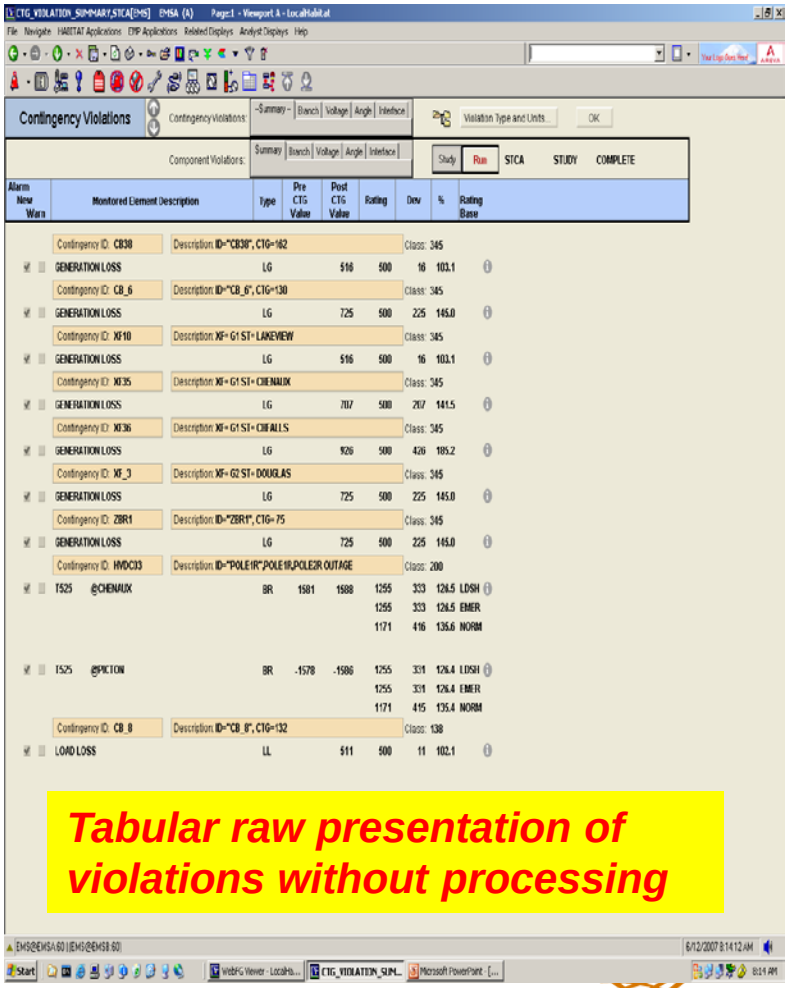
# Background – Inadequacy in Network Operations

- Today's Network Operation Tools
  - Mainly experience-based
  - Raw/Tabular presentation dominates
  - Overwhelmed operators
  - No support for real-time situational awareness and decision making
- Technical gap between data and actionable information

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# Need for Predictive Analytics for Decision Support

- Decision Support with Predictive Analytics for Command and Control of Complex Networks
  - Is the network becoming compromised?
    – Recognize developing problems
  - What would the problem cause to the network?
    – Predict consequences of failures
  - How effective would our response be to the problem?
    – Evaluate potential remedial actions

***"Enabling predictive complex network operations"***

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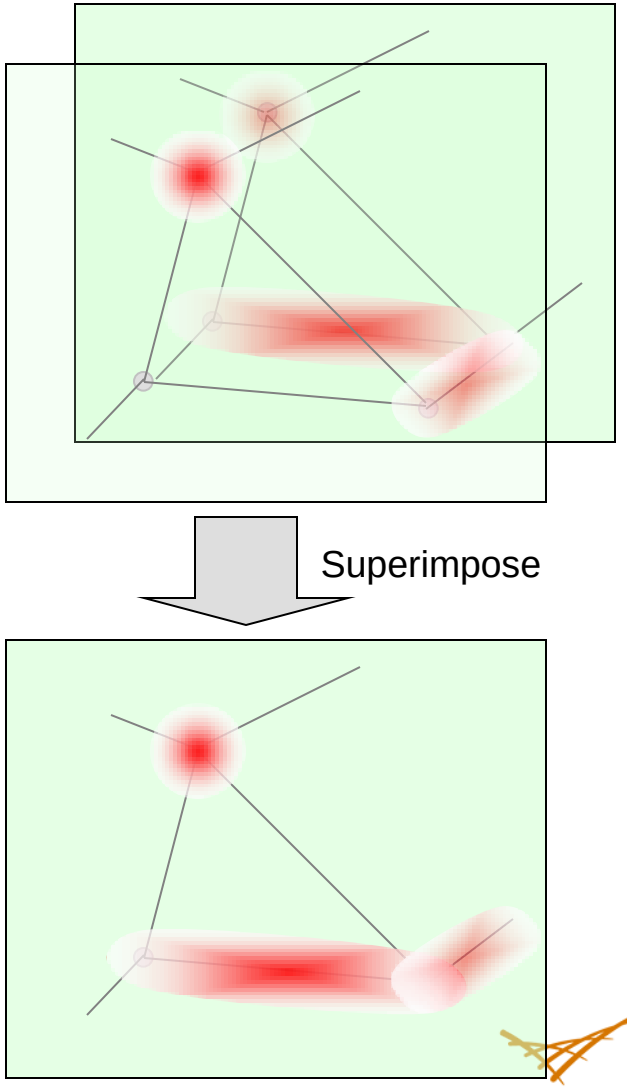
# 1. Visual Analytics for Risk Assessment (1)

- Risk Index Based on Network Stress
  - Node index

    *R% = node stress level*
  - Link index

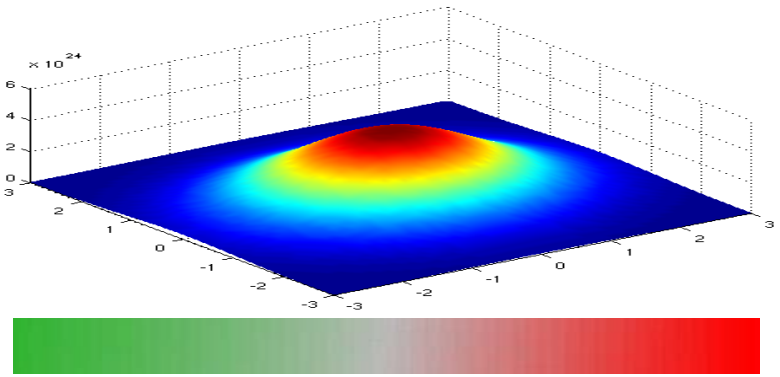
    *R% = link stress level*
- Multi-Layer Risk Index
  - Superimpose risk indices for multiple possible configurations

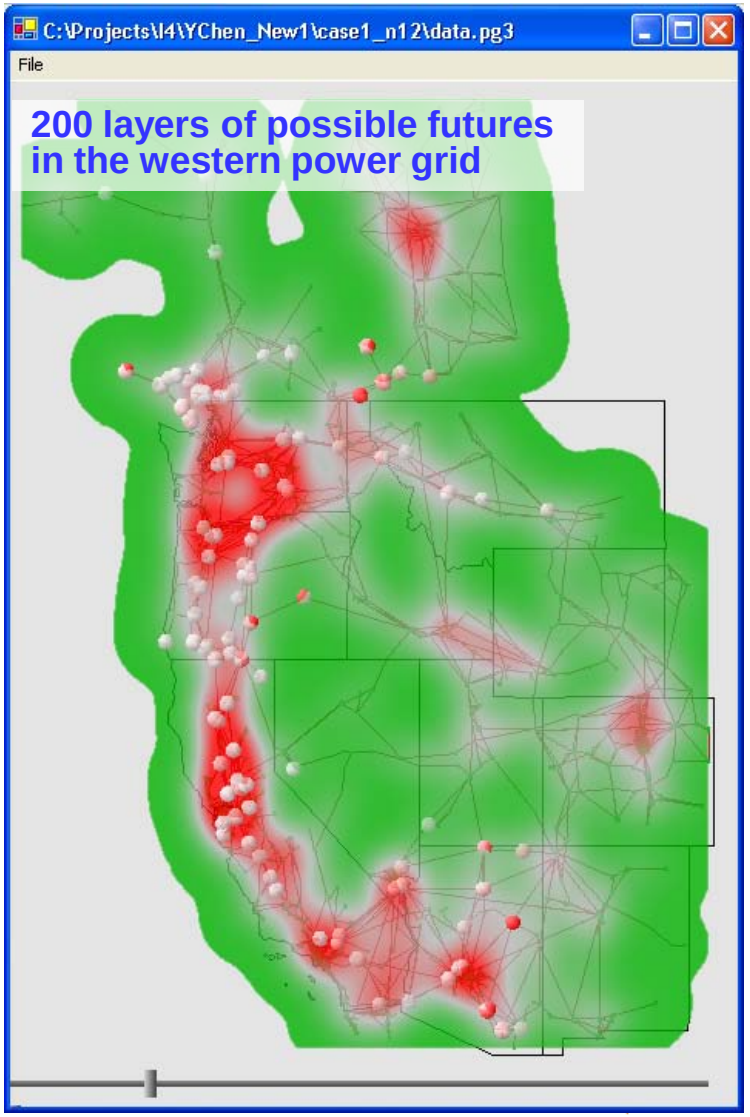
    *R% = max($R\%_i$)*



# 1. Visual Analytics for Risk Assessment (2)

- Visual Representation of Risk Indices
  - Based on HaveGreen in C#, using Managed DirectX
  - Gaussian color mapping with green/gray/red scale

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# 1. Visual Analytics for Risk Assessment (3)

- Statistical Analysis for Deriving Network Risk Indices
  - System Risk Index
  - Regional Risk Index

Arithmetic Average Risk Index

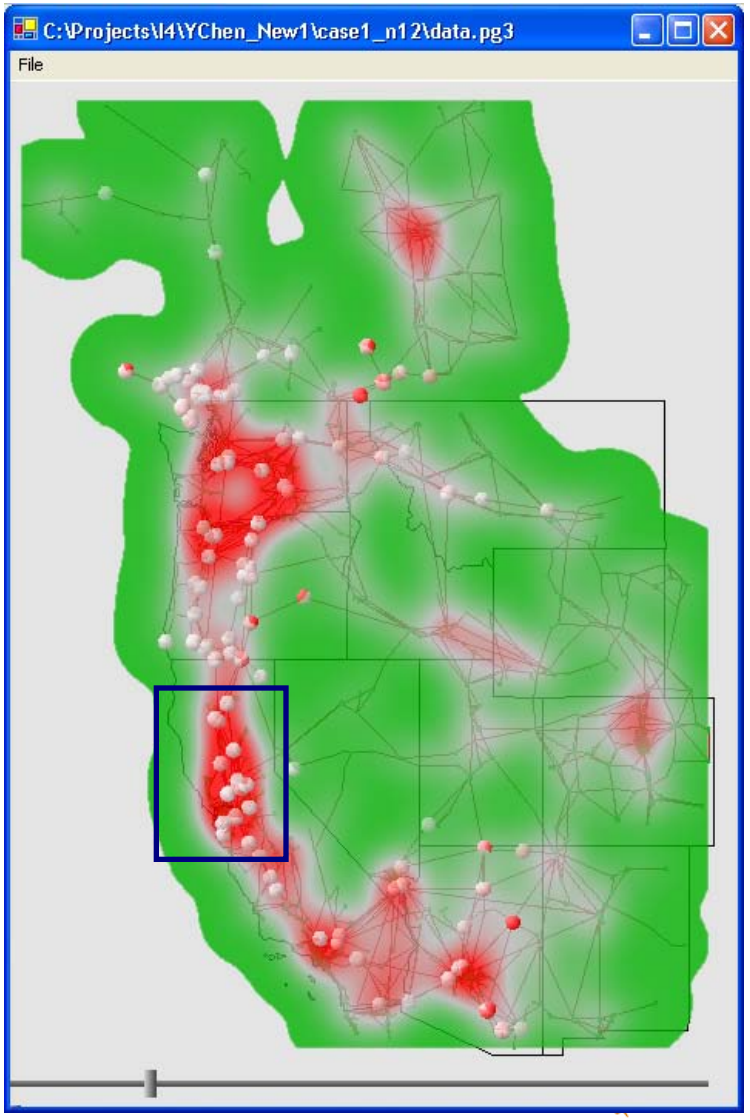
$$\eta = \frac{\sum_i R\%_i \, n_i}{\sum_i n_i}$$

Geometric Average Risk Index

$$\gamma = \left[\prod_i \left(R\%_i^{\,n_i}\right)\right]^{\frac{1}{\sum_i n_i}}$$

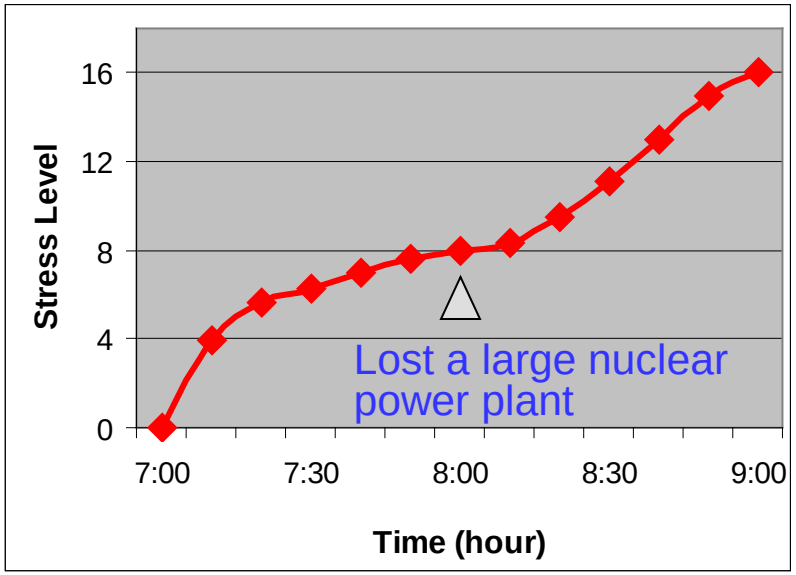
Risk Index:

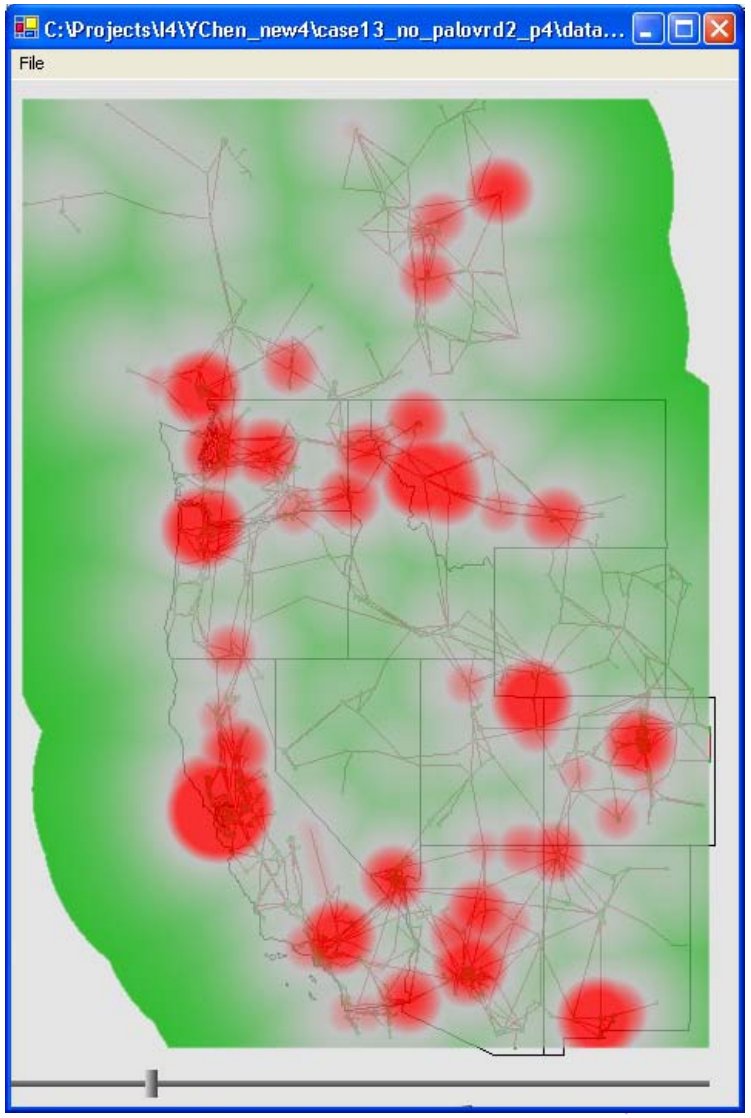
$$R\% = a_1\eta + a_2\gamma$$



# 1. Visual Analytics for Risk Assessment (4)

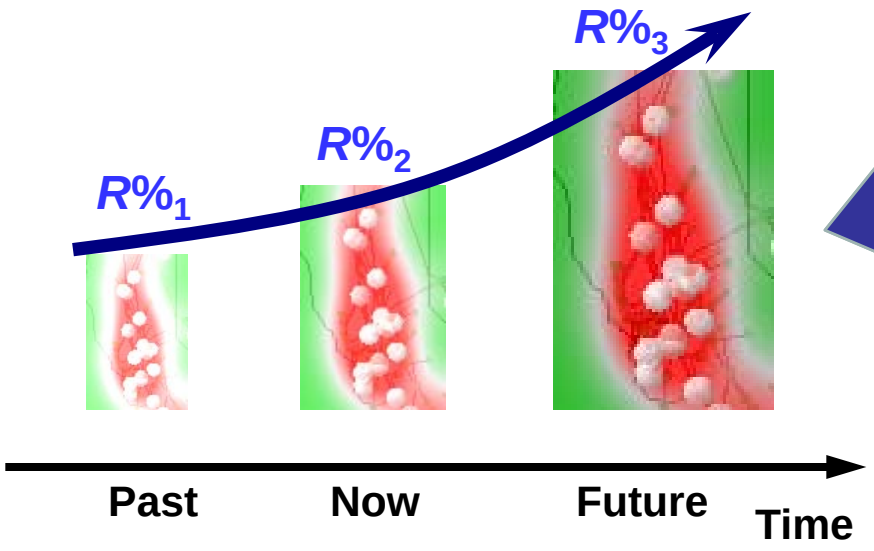
- Time Series Analysis
  - Scenario: western power grid with increasing stress and lost element

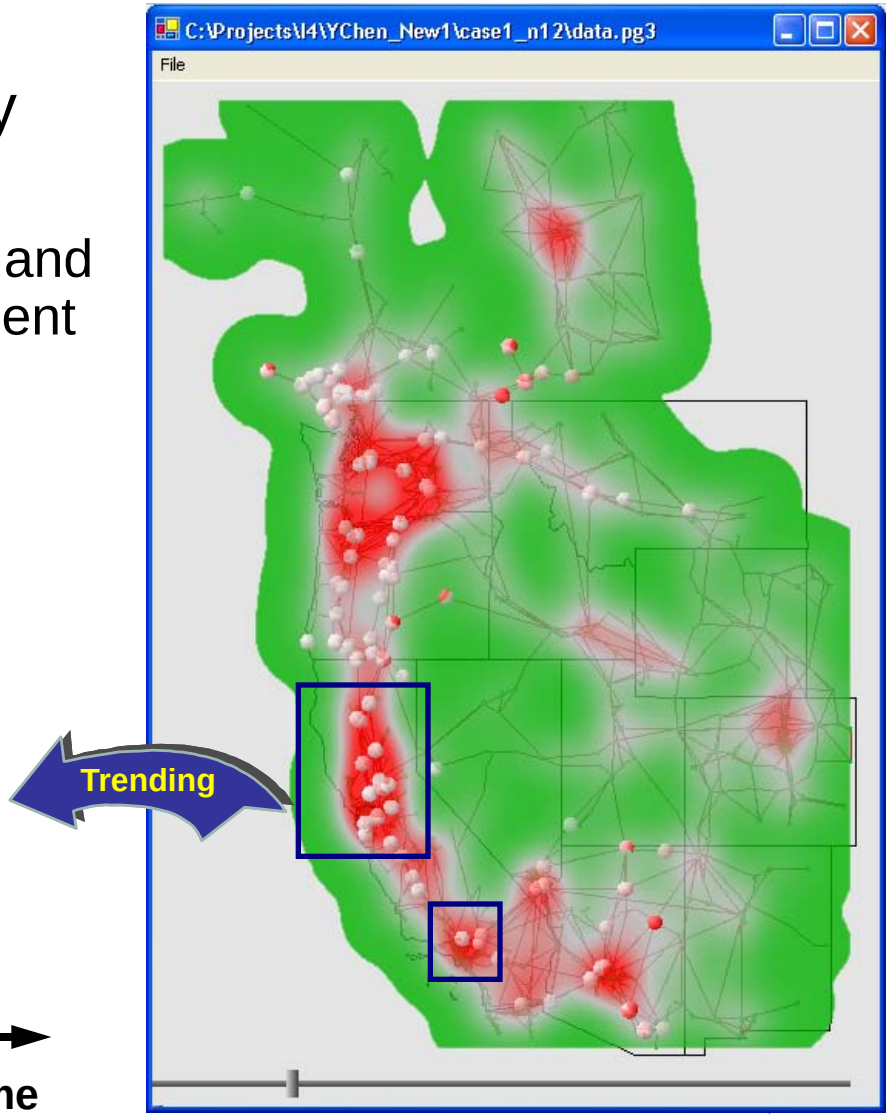


# 2. Visual Trending Analysis (1)

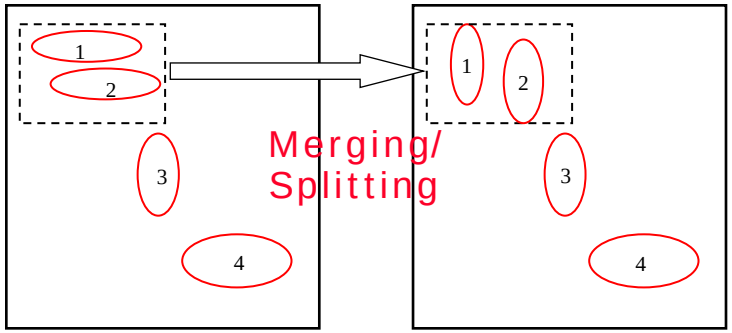
- Statistical Analysis to Identify Security Trend
  - Increase in risk index (i.e. size and color intensity) indicates imminent problems
  - System trend
  - Regional trend

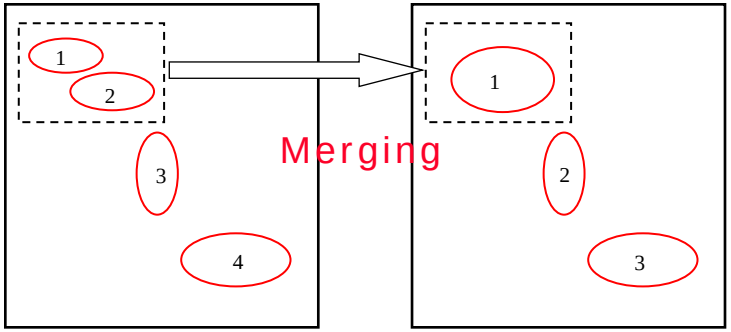


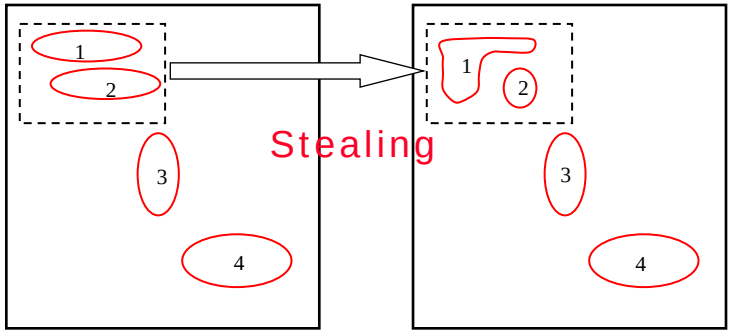



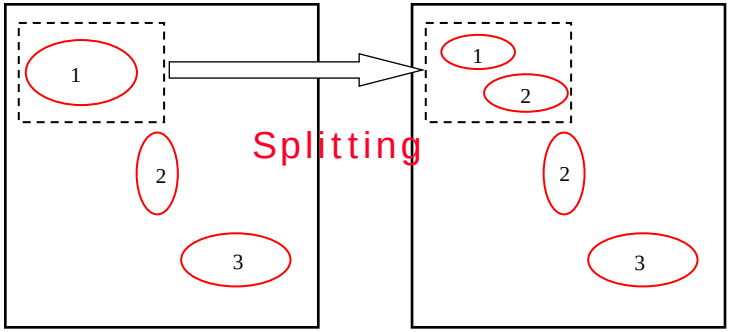
# 2. Visual Trending Analysis (2)

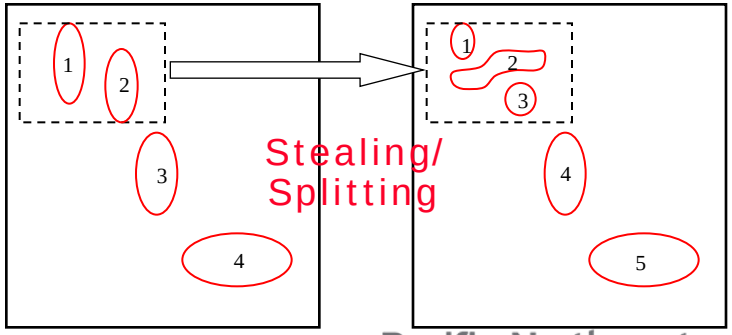
- Automatic Recognition of Merging and Separation of Security Regions
  - Complex trend evolving patterns



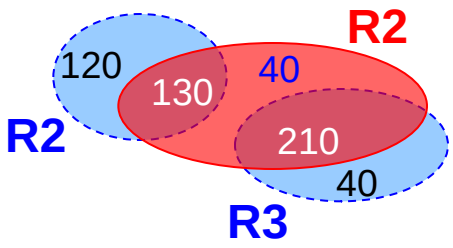



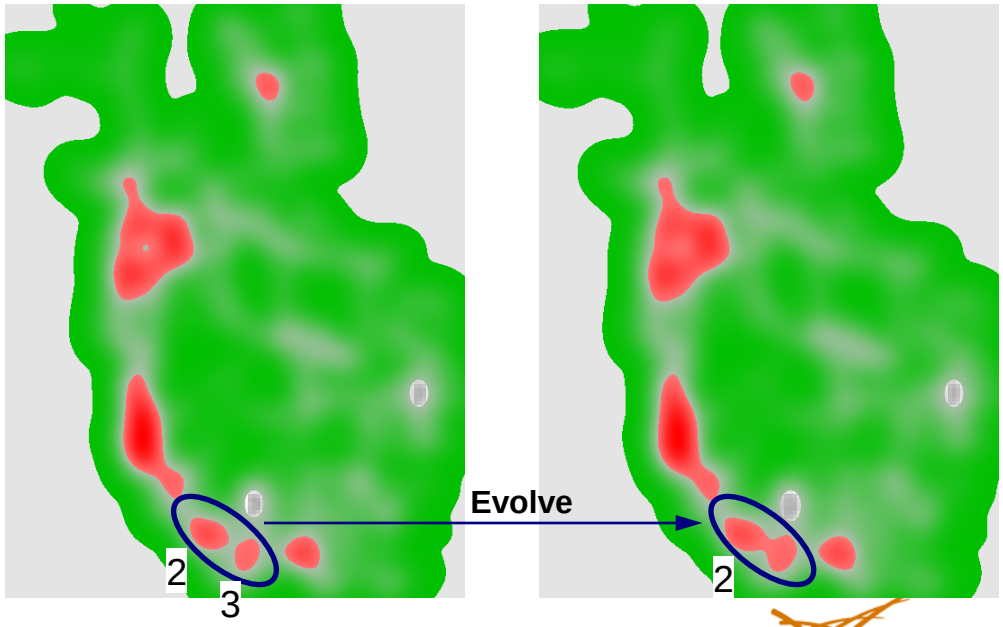
# 2. Visual Trending Analysis (3)

- Combination of Structural Analysis and Statistical Analysis via Relation Matrix
  - Statistical analysis for risk indices of individual regions
  - Structural analysis to identify evolving patterns




Region Areas at Current Moment

| Region Areas at Previous Moment | 1 | 2 | 3 | 4 | 5 | n+1 |
|---|---|---|---|---|---|---|
| 1 | **120** | 0 | 0 | 0 | 0 | **0** |
| 2 | 0 | **130** | 0 | 0 | 0 | **120** |
| 3 | 0 | **210** | 0 | 0 | 0 | **40** |
| 4 | 0 | 0 | **320** | 0 | 0 | **60** |
| 5 | 0 | 0 | 0 | **430** | 0 | **90** |
| 6 | 0 | 0 | 0 | 0 | **340** | **100** |
| m+1 | **80** | **40** | **140** | **40** | **40** | 0 |

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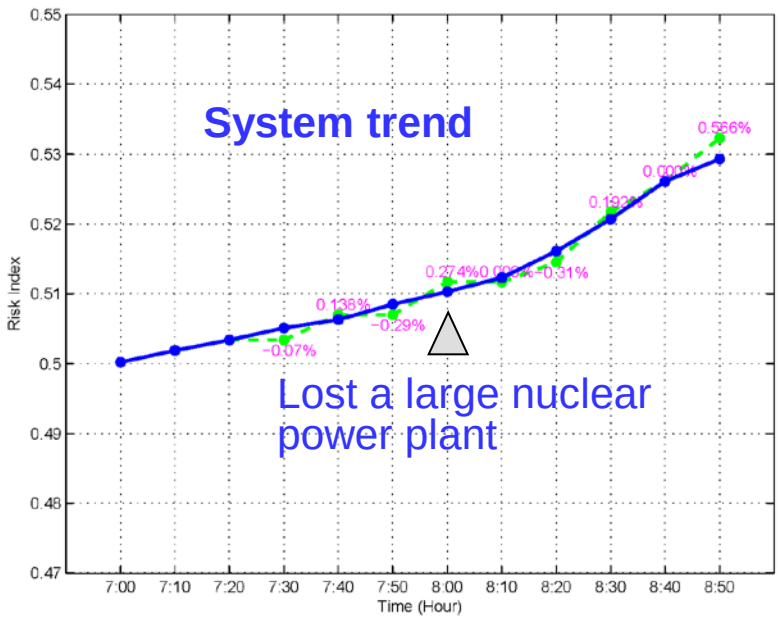
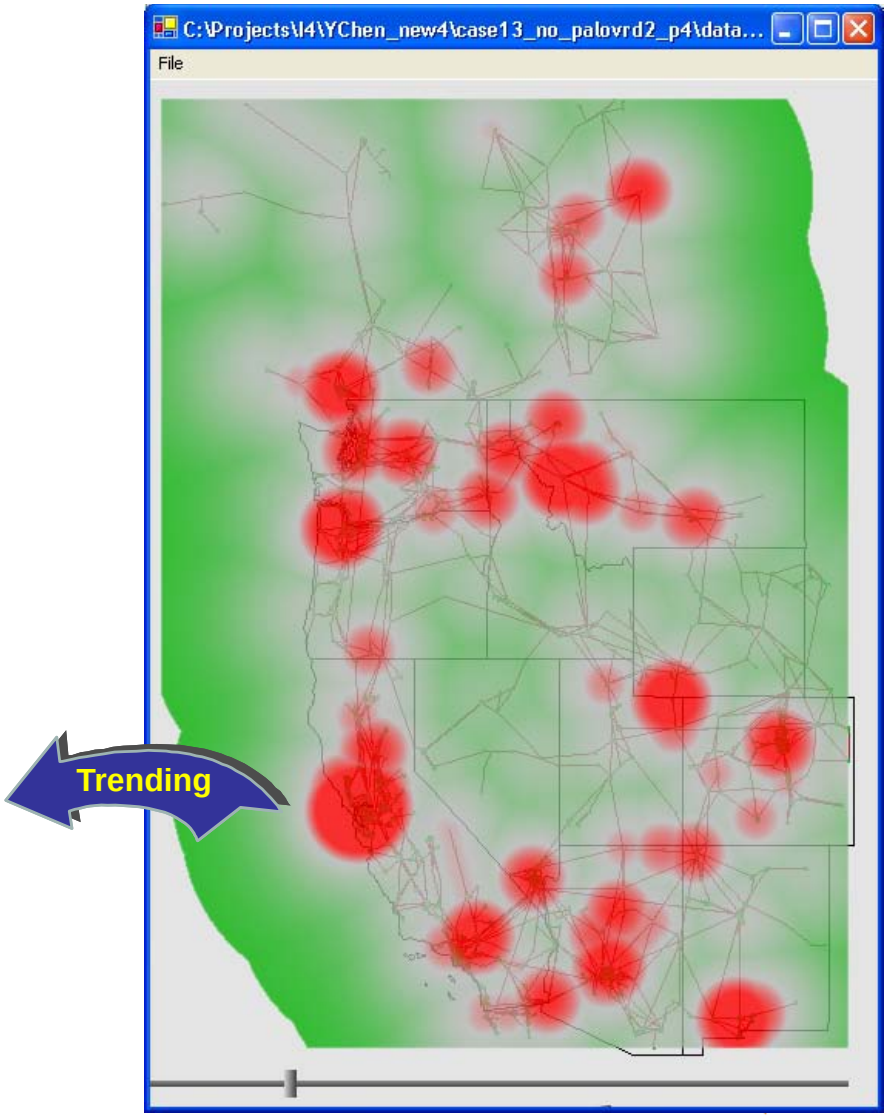
# 2. Visual Trending Analysis (4)

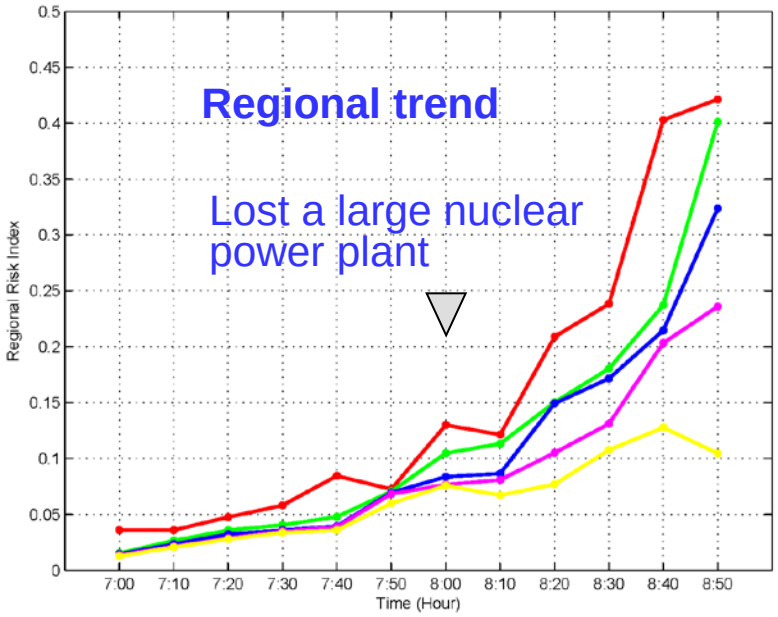
- Case Studies – western US power grid
  - System trending

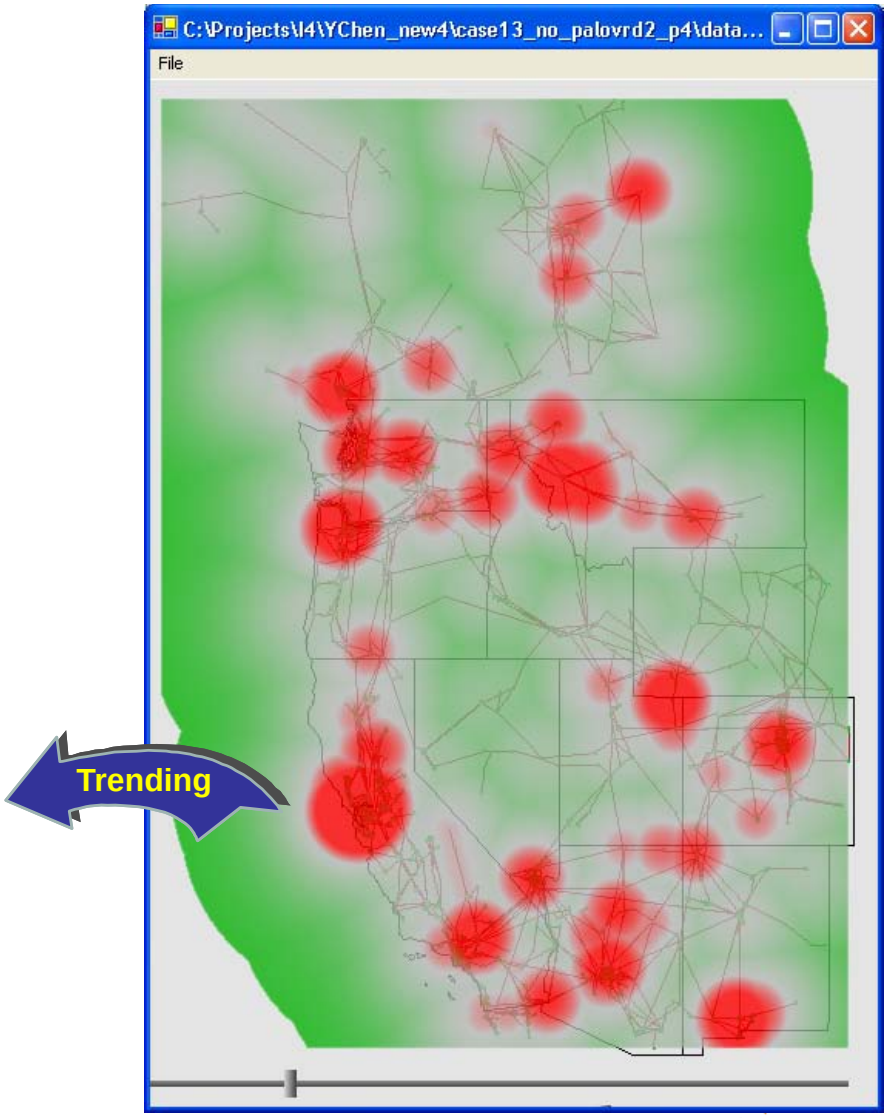


# 2. Visual Trending Analysis (5)

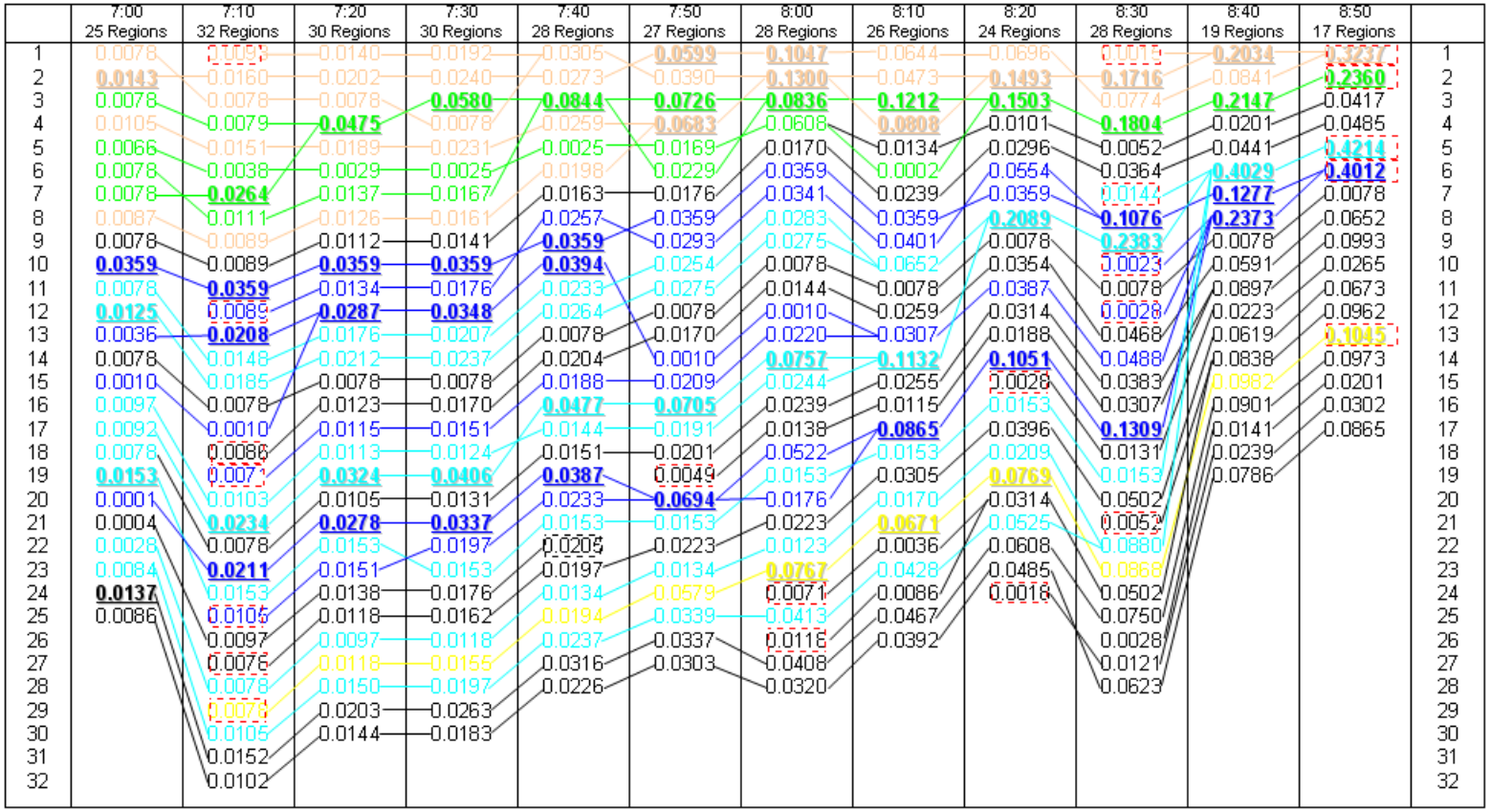
- Case Studies – western US power grid
  - Regional trending



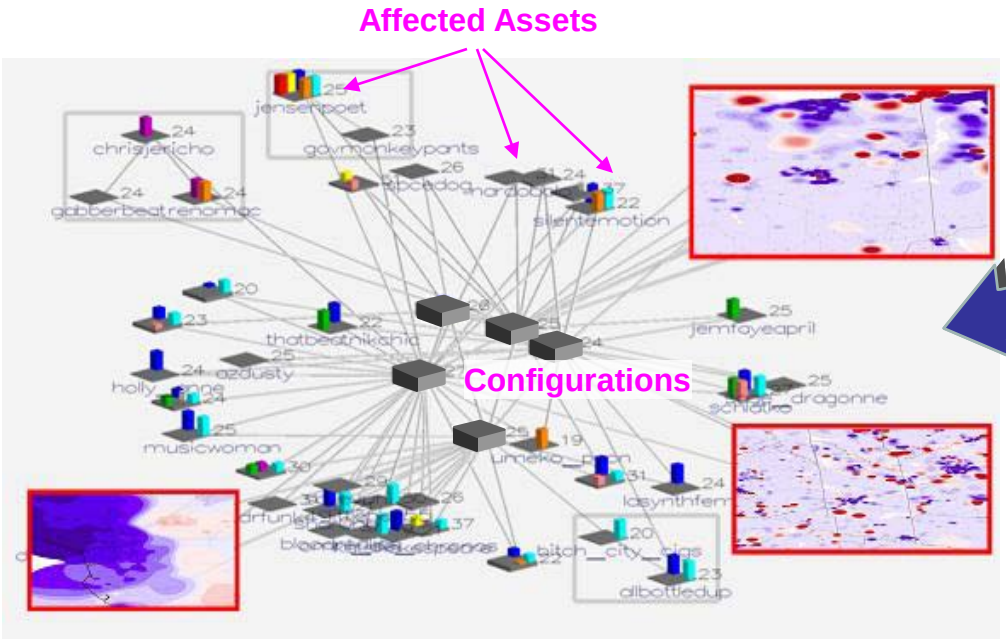
# 2. Visual Trending Analysis (6)

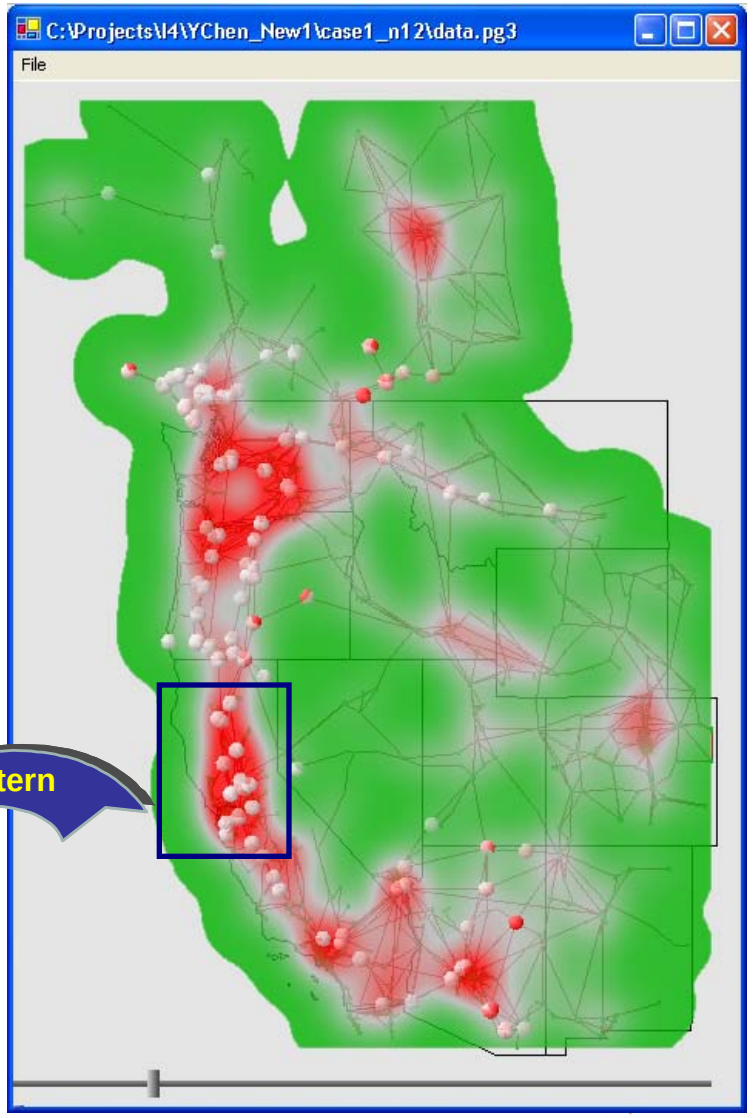
- Case Studies – western US power grid
  - Regional evolving patterns



# 3. Clustering Analysis

- Identify relationship between configurations and affected assets
- Enable operators to focus on important information



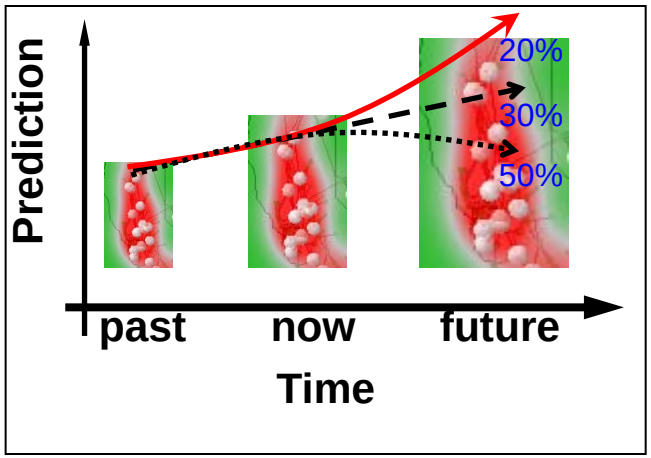



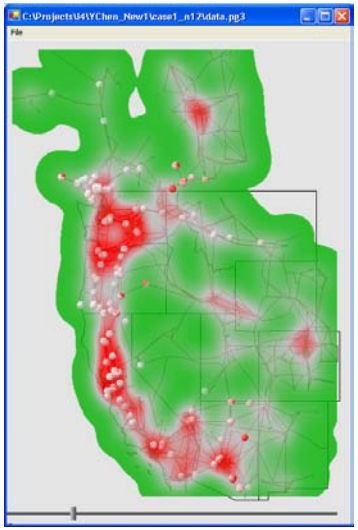
# Conclusion and Future Work (1)

- Predictive analytics can play a key role in complex network operations
  - Color contoured map representation of large amount of operation data for improved situational awareness
  - Predictive capability by analyzing the trend of the visual representation
  - Converting large amounts of operation data into actionable information
- Actual models and data of the western North American power grid demonstrate the validity of the predictive analytics.

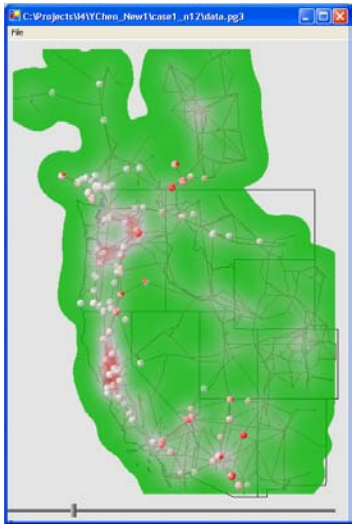
# Conclusion and Future Work (2)

- Future Work
  - Probability Analysis for Multiple Predictions
    - Enable the management of multiple possible futures
  - Interactive Evaluation of Remedial Actions
    - Provide guidance for preventing and mitigating failures



**Operator Actions:**
reconfiguration,
re-dispatch,
load shedding,
…



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# Questions?

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