PNNL-SA-65448

AAAI 2009 Spring Symposium Series Technosocial Predictive Analytics

Managing Complex Network Operation with Predictive Analytics

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Pacific Northwest National Laboratory

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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



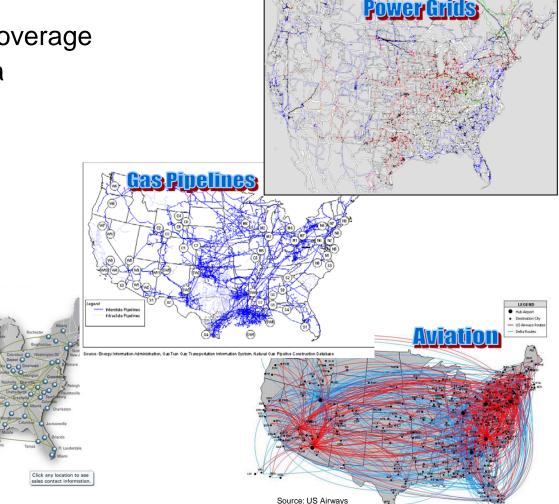
Background – Complex Networks

General Features

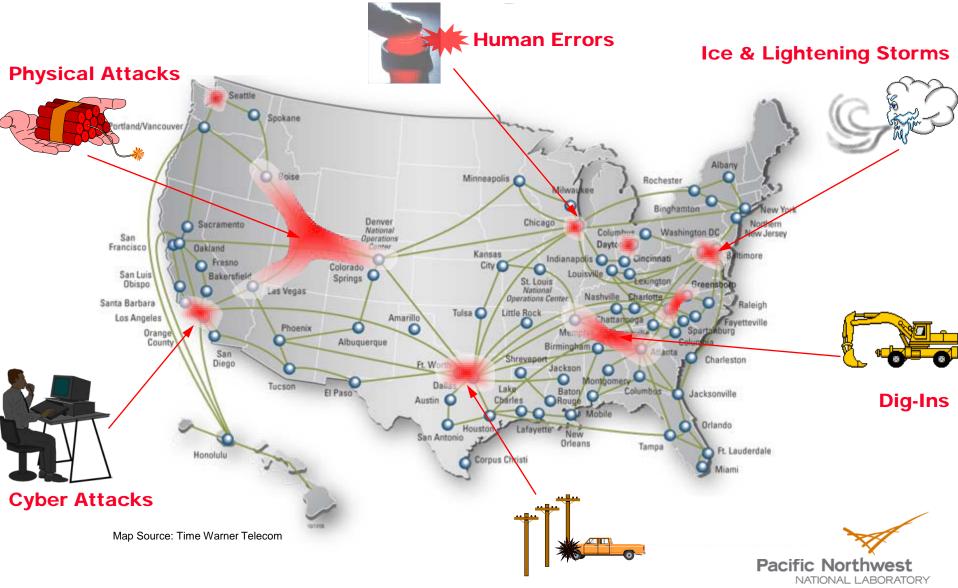
- Complex structure
- Wide geographical coverage

Source: Time Warner Telecom

- Large volume of data
- Complex data/IT support systems
- Critical role of human operators



Background – Complexity of Network Operations



Vehicular Collisions

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"



1. Visual Analytics for Risk Assessment (1)

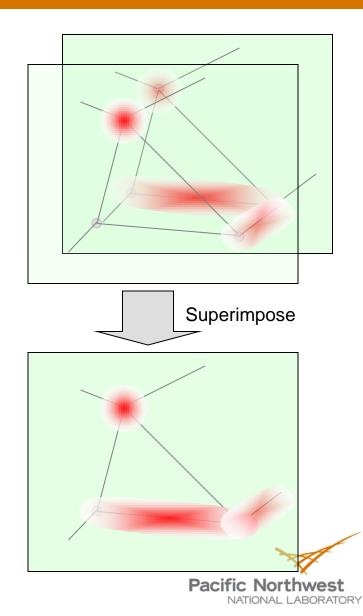
- Risk Index Based on Network Stress
 - Node index

R% = node stress level

Link index

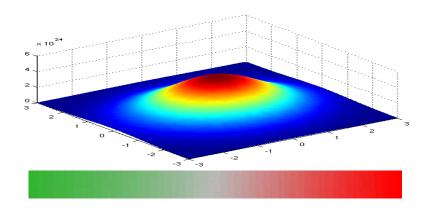
R% = link stress level

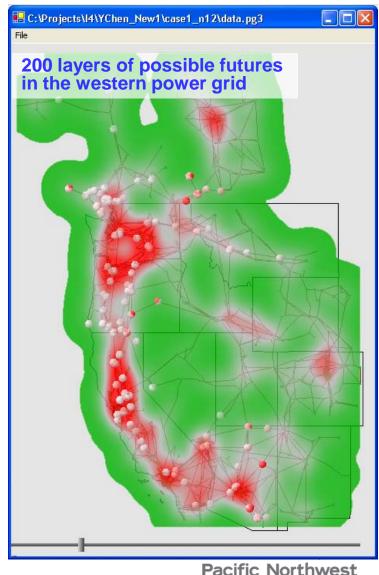
- Multi-Layer Risk Index
 - Superimpose risk indices for multiple possible configurations
 R% = max(R%_i)



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

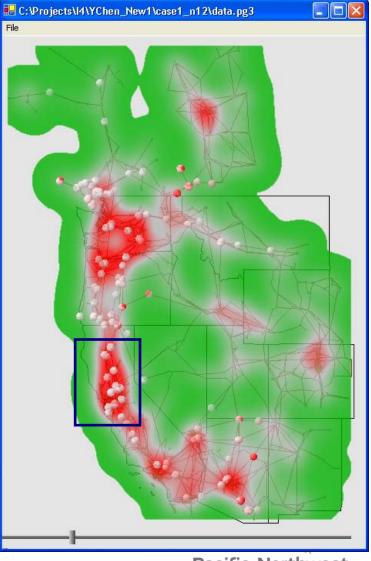
$$\eta = \frac{\sum_{i} R\%_{i} n_{i}}{\sum_{i} n_{i}}$$

Geometric Average Risk Index

$$\gamma = \left[\prod_{i} \left(R\%_{i}^{n_{i}} \right) \right]^{\frac{1}{\sum_{i} n_{i}}}$$

Risk Index:

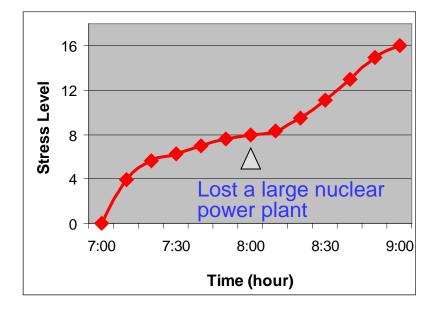
$$R\% = a_1\eta + a_2\gamma$$

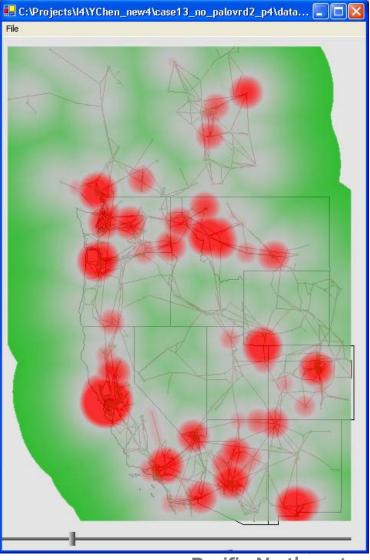


1. Visual Analytics for Risk Assessment (4)

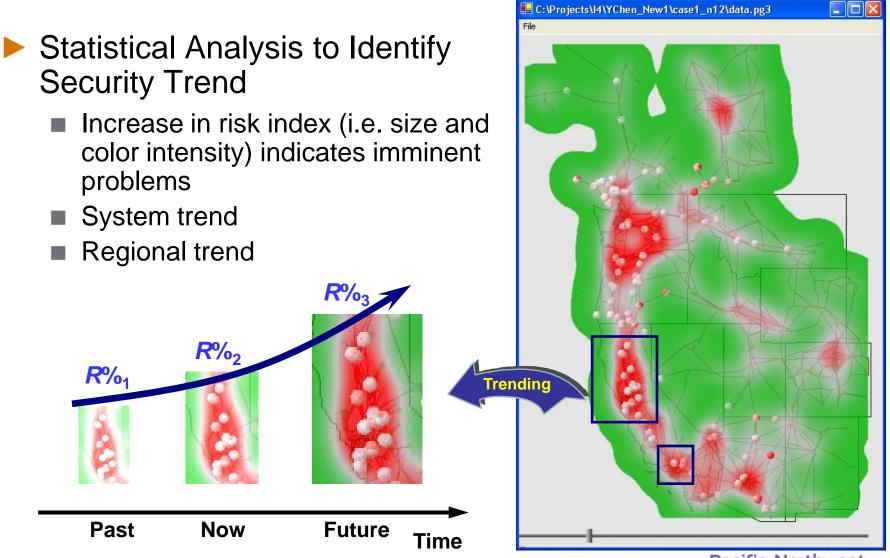
Time Series Analysis

 Scenario: western power grid with increasing stress and lost element



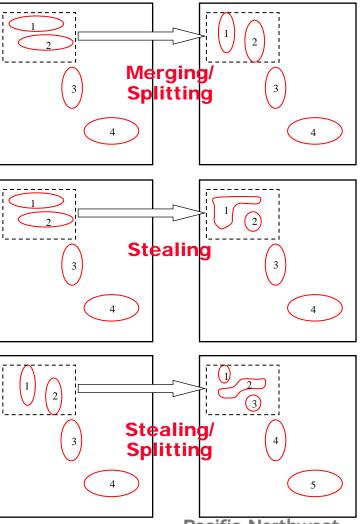


2. Visual Trending Analysis (1)

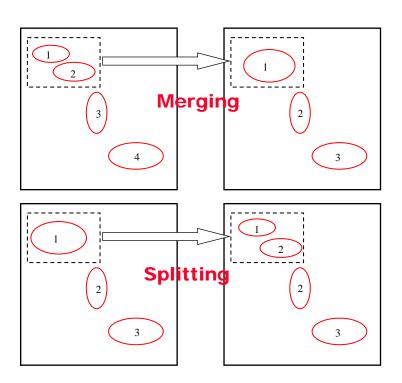


2. Visual Trending Analysis (2)

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

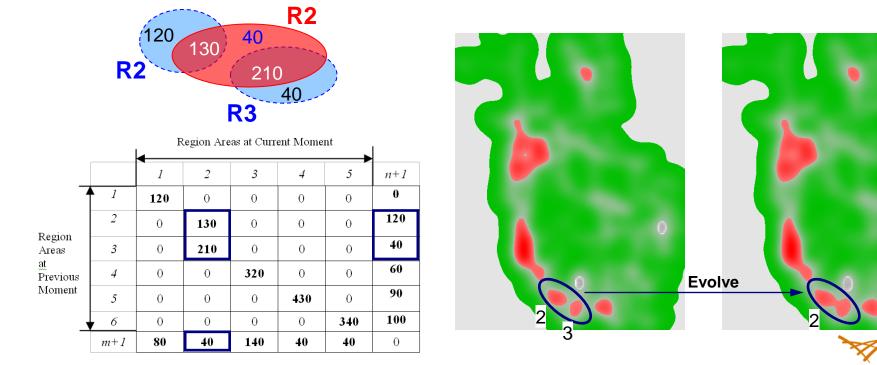


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2. Visual Trending Analysis (3)

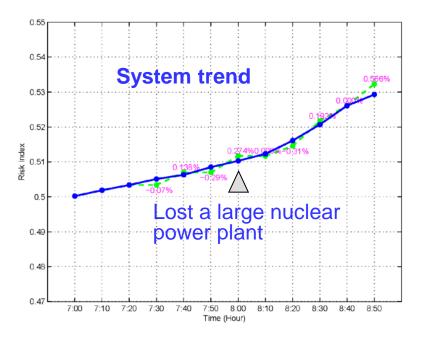
- Combination of Structural Analysis and Statistical Analysis via Relation Matrix
 - Statistical analysis for risk indices of individual regions
 - Structural analysis to identify evolving patterns

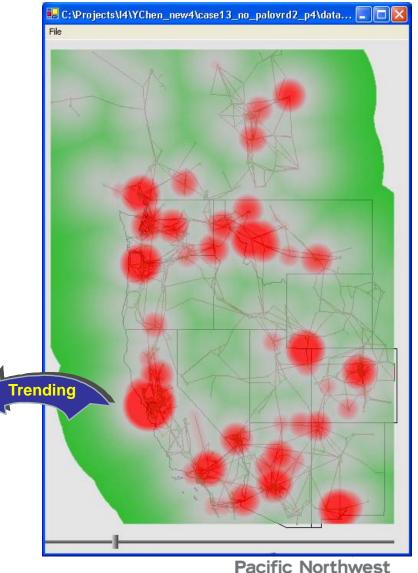


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2. Visual Trending Analysis (4)

- Case Studies western US power grid
 - System trending

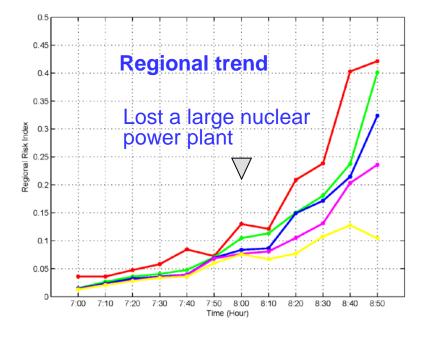


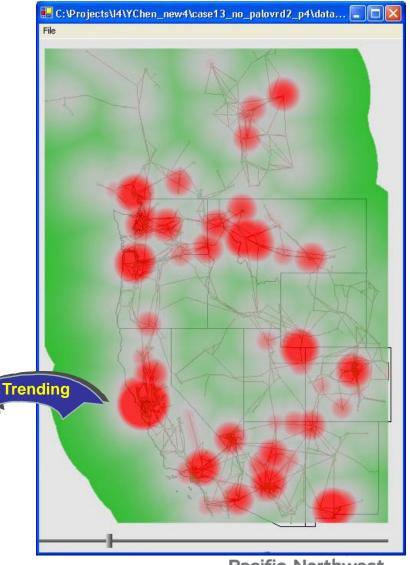


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2. Visual Trending Analysis (5)

- Case Studies western US power grid
 - Regional trending





2. Visual Trending Analysis (6)

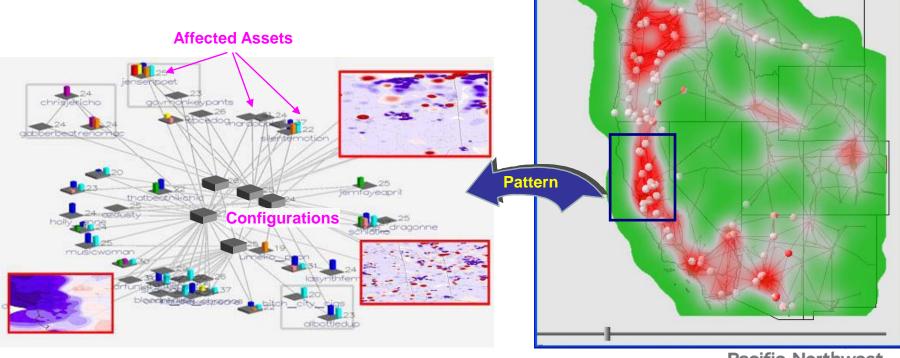
Case Studies – western US power grid

Regional evolving patterns

	7:00	7:10	7:20	7:30	7:40	7:50	8:00	8:10	8:20	8:30	8:40	8:50	
	25 Regions	32 Regions	30 Regions	30 Regions	28 Regions	27 Regions	28 Regions	26 Regions	24 Regions	28 Regions	19 Regions	17 Regions	
	0.0078	5.0083-			-0.0305	<u>_0.0599</u> _	<u>0.1047</u>		-0.0696	0.0018-	0.2034	<u>_1.3231</u>	1
2	<u>0.0143</u>	0.0160	-0.0202-	-0.0240-	-0.0273	~0.0390—	<u>_0.1300</u> _	-0.0473-	<u>_0.1493</u>	0.1716	0.0841	0.2360	2
3	0.0078	0.0078-	-0.0078	<u>0.0580</u>	0.0844	<u>0.0726</u>	<u>0.0836</u>	<u>0.1212</u>	0.1503	0.0774	0.2147	0.0417	3
4	0.0105	0.0079—	0.0475	0.0078	0.0259-	0.0683	0.0608	8080.0	0.0101	0.1804	0.0201	0.0485	4
5	0.0066	0.0151	-0.0189-	0.0231	0.0025-	0.0169	0.0170	0.0134	0.0296		0.0441	0.4214	5
6	0.0078		-0.0029-	0.0025	0.0198	0.0229	0.0359	0.0002	0.0554	0.0364	0.4029	0.0078	6
1 '	0.0076	0.0264	0.0137-		/	0.0176		0.0239		0.0144	0.1277		8
8	0.0078		0.0126	0.0141	0.0257	0.0359	0.0283	0.0369	0.0078	0.1076	0.0078	0.0652	9
10	0.0070	0.0089	0.0112-	0.014 P	0.0394	-0.0293	.0.0078	0.0401	0.0078	5.0023	0.0078	0.0993	10
11	0.0078	0.0003	0.0134	0.0176	0.0233	0.0234	0.007.0	0.0078	0.0394	0.0078	0.0397	0.0203	11
12	0.0125	0.0089	0.0134	0.01/8	0.0255	0.0078		0.0070	0.0314		0.0037	0.0075	12
13	0.0036	0.0008	20.0176-	-0.0207	.0.0078	0.0070	0.0010		0.0314	0.0468	/D.0223	0.0302	13
14	0.0078	0.0148	0.0212-	0.0237	0.007.0	0.0010	0.0220	0.0307	0.1051	0.0488	//0.0838	0.0973	14
15	0.0070	0.0185	0.0078-		0.0204	0.0209	0.0244	0.0255	2.0028	0.0383		0.0201	15
16	0.0097	0.0078	0.0123-	-0.0170	0.0477-	0.0705	0.0239	0.0115//	0.0153	0.0307///	M.D.0901	0.0302	16
17	0.0092	0.0010	0.0115-	-0.0151	0.0144	0.0191	0.0138	0.0865	0.0396	0.1309	10.0141	0.0865	17
18	0.0078	0.0086	0.0113-	-0.0124	.0.0151-	0.0201	0.0522	0.0153	0.0209	0.0131	///0.0239		18
19	0.0153	0.007	0.0324	0.0406	0.0387	0.0049	0.0153	0.0305	0.0769	0.0153	///0.0786		19
20	0.0001	0.0103	.0.0105-	-0.0131	0.0233	0.0694	-0.0176	0.0170	0.0314	0.0502	V///		20
21	0.0004	0.0234	0.0278	-0.0337	0.0153-	0.0153	0.0223	0.0671	1.0.0525	0.0052///	W//		21
22	0.0028	0.0078	0.0153	_0.0197	0.0205	_0.0223	_0.0123	0.0036	0.0608	0.0880///	W/		22
23	0.0084	0.0211	0.0151	0.0153	0.0197	0.0134	0.0767	0.0428	/ 10.0485		V		23
24	0.0137	0.0153	0.0138-	-0.0176	0.0134	0.0579	0.0071	0.0086//	0.0018	0.0502////			24
25	0.0086	0.0105	0.0118-	-0.0162	0.0194	_0.0339—	-0.0413	0.0467//	[0.0750///			25
26		0.0097	0.0097-	-0.0118	0.0237	0.0337	0.0116	0.0392		0.0028//			26
27		0.0076	0.0118-	-0.0155	0.0316	0.0303	0.0408	/		0.0121			27
28		\\ \0.0078/	0.0150-	-0.0197	0.0226		0.0320			\0.0623/			28
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30		0.0105	0.0144—	-0.0183									30
31		0.0152	r i										31
32		0.0102											32 🏅

3. Clustering Analysis

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



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Conclusion and Future Work (1)

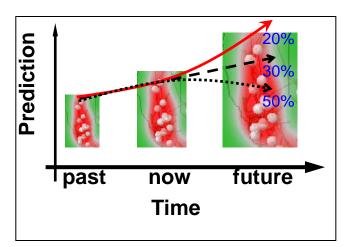
- Predictive analytics can play a key role in complex network operations
 - Color contoured map representation of large amount of operation data for improved situational awareness
 - Predictive capability by analyzing the trend of the visual representation
 - Converting large amounts of operation data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

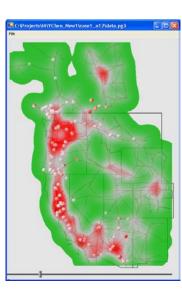


Conclusion and Future Work (2)

Future Work

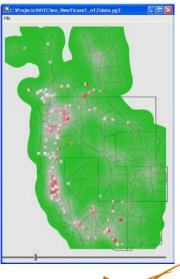
- Probability Analysis for Multiple Predictions
 - Enable the management of multiple possible futures
- Interactive Evaluation of Remedial Actions
 - Provide guidance for preventing and mitigating failures





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







Questions?



