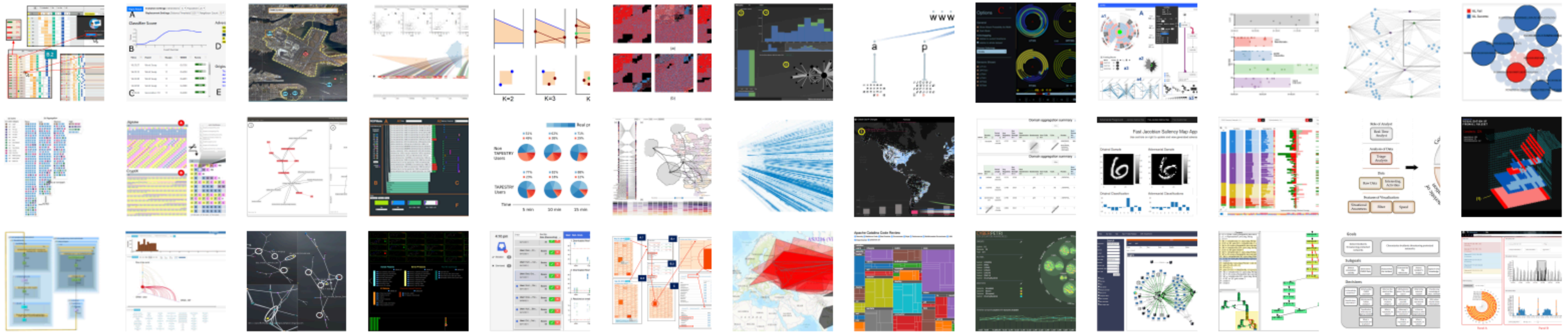
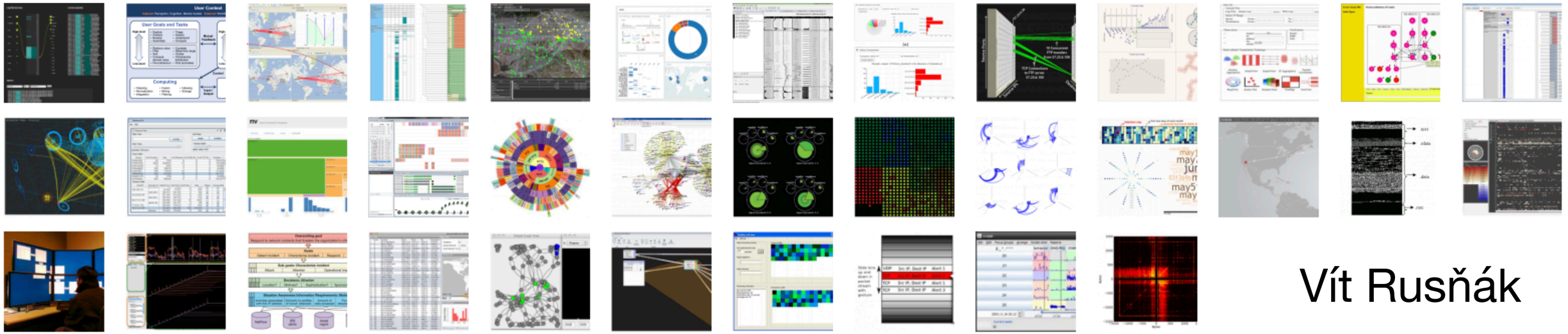


Visualizations for Cybersecurity

PA214 — Visualization II



Vít Rusňák


CYBERTHREAT REAL-TIME MAP
EN
Protect Yourself
MAP
STATISTICS
DATA SOURCES
BUZZ
WIDGET
Share
DEMO ON
https://cybermap.kaspersky.com

Talk Overview

- **Taxonomy** of Cybersecurity Visualizations
  - Data sources, data types, and tasks
- **Application Scenarios**
  - Monitoring, SIEM Dashboards, Analysis (threat hunting, forensics, malware)
- **Research Trends** in Cybersecurity Visualization

Typical Users

Cybersecurity operations (L1)

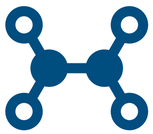
- monitoring, countermeasures
- CSIRT, Incident handlers

Cybersecurity Analysts (L2-L3)

- network traffic anomalies, malware analysts

Management (both IT and non-IT background)

- Chief information security officer (CISO), policy makers



Cybersecurity Researchers

- simulations, application of ML/AI

Data Sources

Applications

Network Services

Users

Operating System

Intrusion Detection Systems

Firewalls

Passive Network Analysis

Traffic Flows

Packet Captures

Logs

Time-series

Adapted from [1]

Data Types

- Network traffic
- Log files and events
- User behavior
- Alerts and incidents
- Malware analysis data

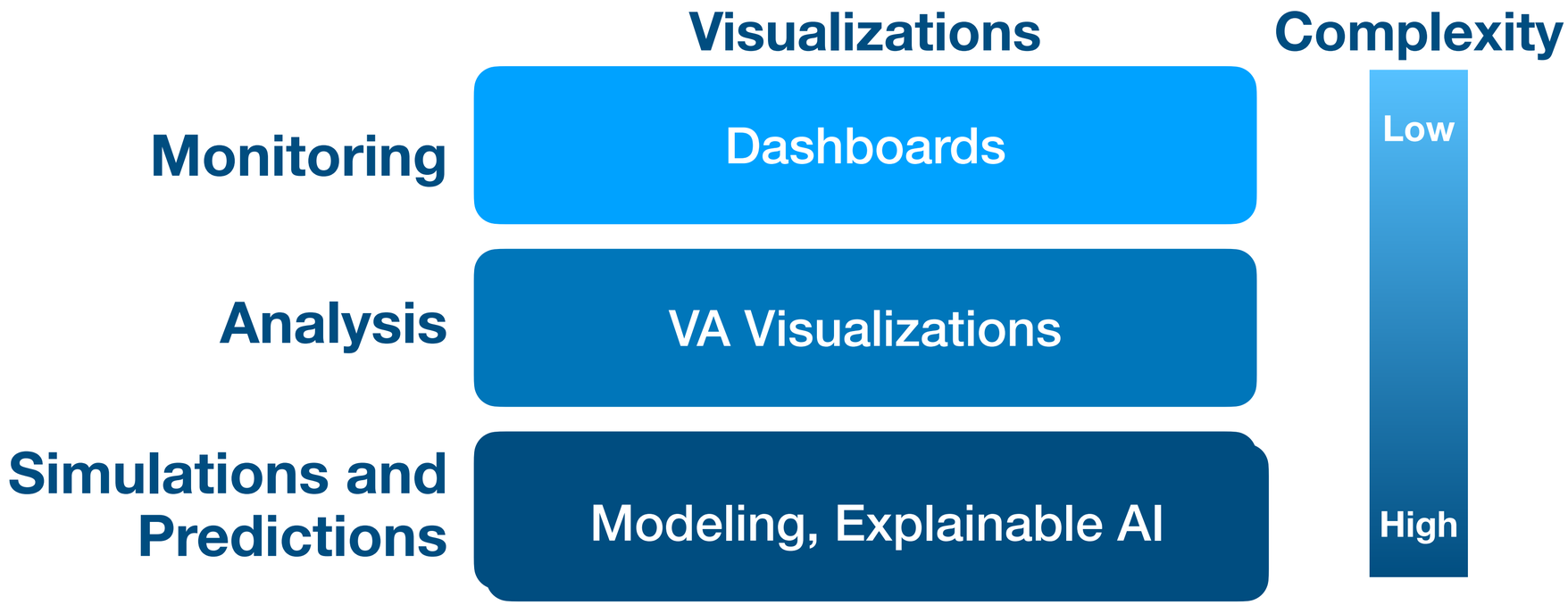
Goals and Tasks

Monitoring	▶ Network traffic, log files, events, alerts
Anomaly detection	▶ Alerts, events
Incident investigation	▶ User behavior data, network traffic, log files, events
Situational awareness	▶ Network traffic, log files, user behavior data
Atrribution and forensics	▶ Network traffic, alerts, events, user behavior data, malware analysis data

Visualizations

- Time-series (e.g., stacked graphs, horizon graphs)
- Graph-based (e.g., node-link diagrams)
- Spatial/geo (e.g., attack maps)
- Matrix-based (e.g., heatmaps, adjacency matrices)
- Hybrid/multiview systems

Complexity of Visualizations



Monitoring

Image source: https://www.logpoint.com/en/

Characteristics

- **Dashboards are prevalent**
  - Typically easy to read, decode and understand, multiple views (panels)
- **Goal(s):** situational awareness, trends, outliers and anomalies (e.g., peaks)
- **Typical visualizations:** tables, line/area charts, sparklines (microvisualizations), basic 2D charts (bar charts, heatmaps), basic geovisualizations (choropleth, links)
- **Shortcuts** and **click-throughs** allowing **drill-down** in analytical tools

Dashboards

> *“A dashboard is a visual display of the most important information needed to achieve one or more objectives that has been consolidated in a single computer screen so it can be monitored at a glance.”*
>
> — **Stephen Few**, Information Dashboard Design

Provide

- a snapshot of the current state (number of detected events, blocked IP addresses, …)
- comparison to target measures (KPIs, warnings, trends)

Types

- **Operational** (monitoring, single source of information)
- **Tactical** (planning, communication)
- Strategic (management, decision)

Dashboards

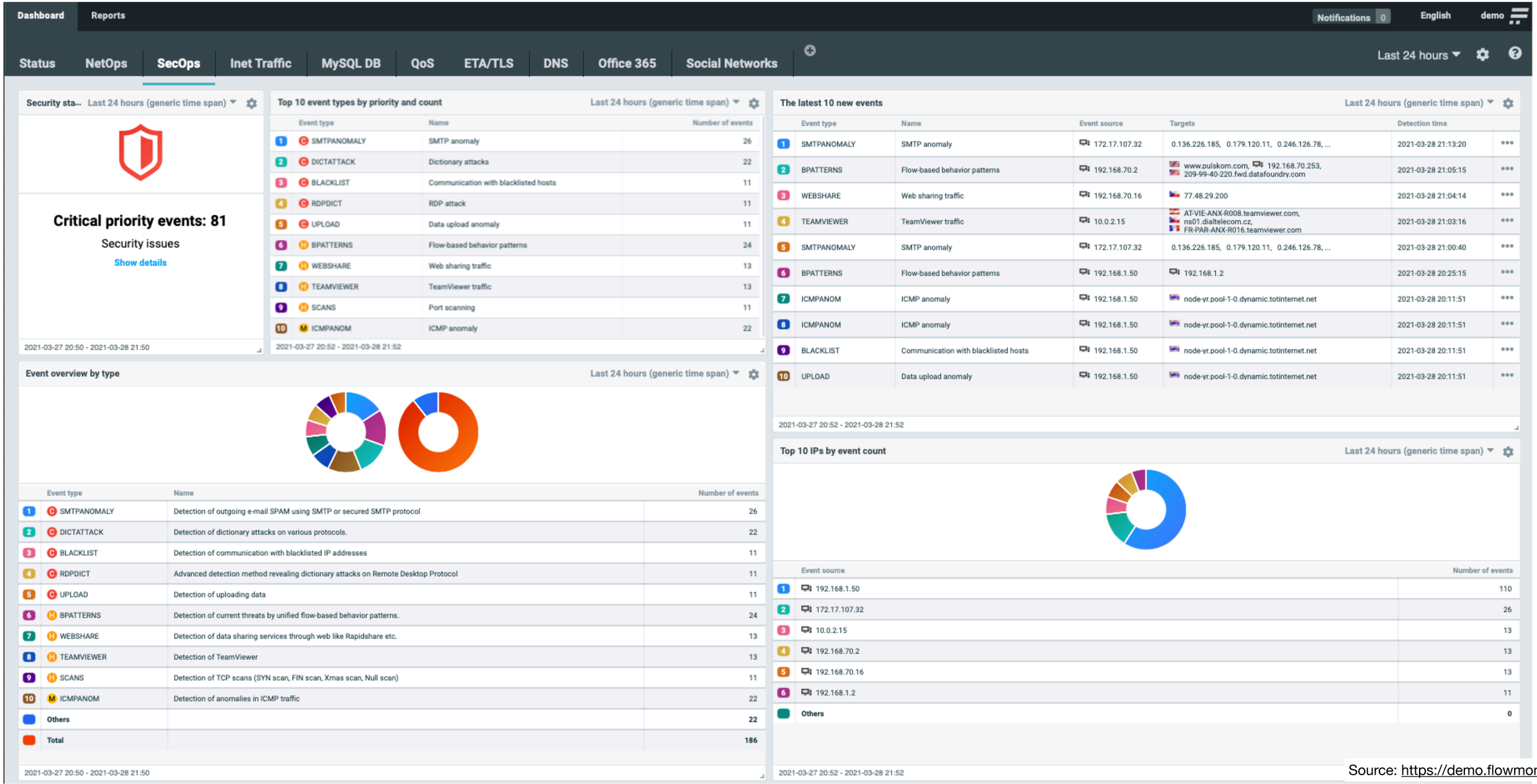
Design principles

- Contextual awareness
- Prioritization and alerting
- Configurability vs. cognitive overload

Common pitfalls

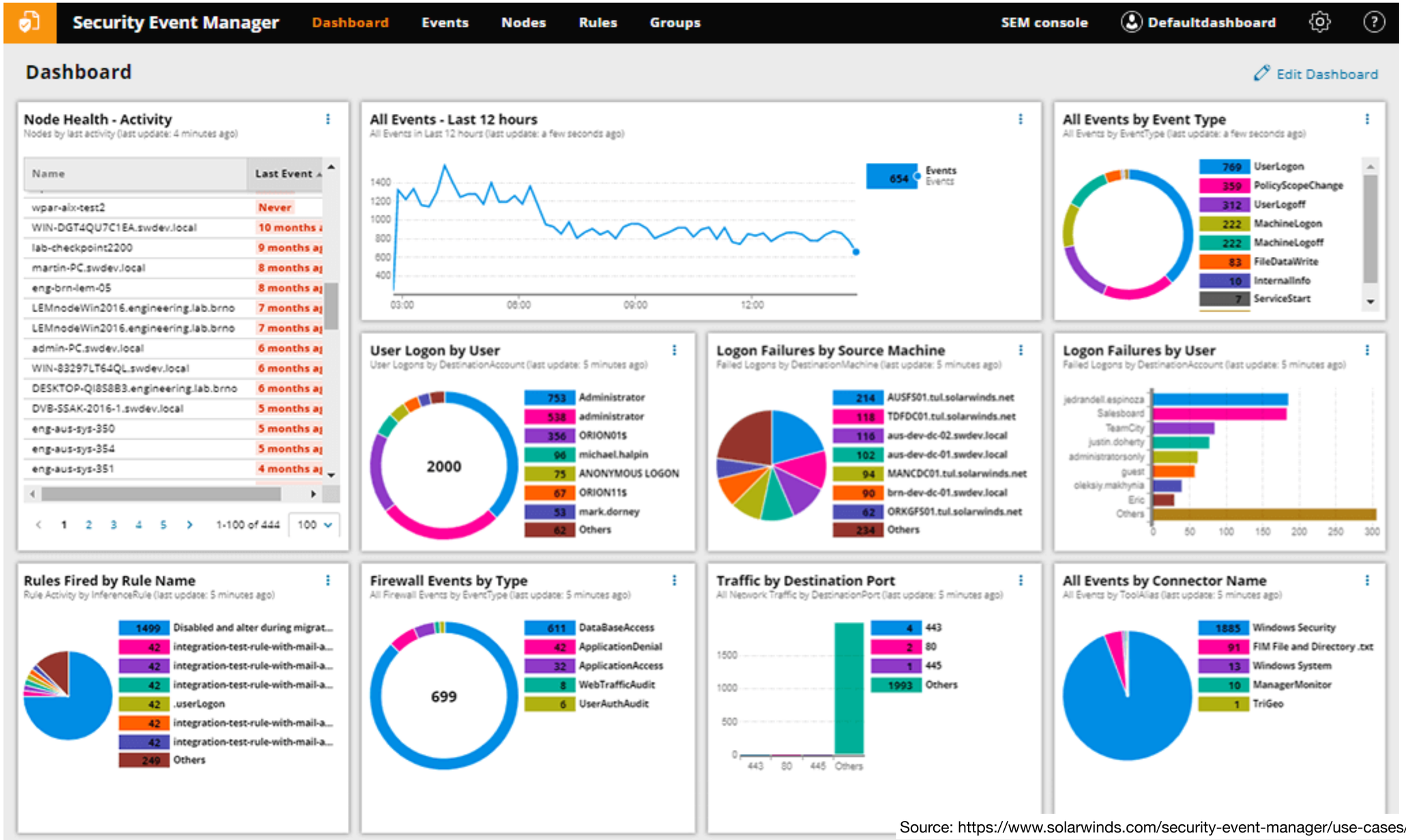
- Over-reliance on static views
- Poor encoding choices
- Lack of drill-down capabilities

Examples: Commercial Tools



Source: https://demo.flowmon.com

Examples: Commercial Tools



Source: https://www.solarwinds.com/security-event-manager/use-cases/event-log-analyzer-tool

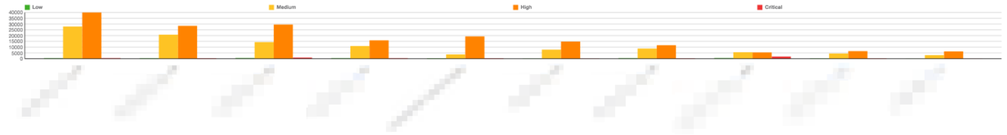
Examples: Commercial Tools

tenable.sc Dashboard Analysis Scans Reporting Assets Workflow Users

Understanding Risk

Switch Dashboard Options

Understanding Risk - Vulnerability Severity Summary



Last Updated: 18 minutes ago

Understanding Risk - Details by Severity

	Total	Exploitable	Vuln Publ >90d	Patch Avail >30d	Hosts
All Severities	1204157	2%	3%	6%	1356
Critical	7025	32%	31%	91%	765
High	198029	8%	10%	17%	962
Medium	118985	6%	7%	20%	1008
Low	4957	7%	35%	47%	974
Info	875161	0%	0%	0%	1352

Last Updated: 5 hours ago

Understanding Risk - Details by Vulnerability Grouping

	Total	Exploitable	Vuln Publ >90d	Patch Avail >30d	Hosts
Default Cred.	10199	1%	0%	0%	495
OS	39974	48%	52%	94%	573
Web Tech.	2434	47%	88%	91%	233
Web Browser	6162	73%	93%	93%	210
Office Suite	809	73%	83%	83%	162

Last Updated: 5 hours ago

Understanding Risk - CVSS Scores by Severity

	Total	CVSS 10.0	CVSS 7.0 - 9.9	CVSS 4.0 - 6.9	CVSS 0.0 - 3.9
Critical	7025	100%	0%	0%	0%
High	198029	0%	16%	0%	0%
Medium	118985	0%	0%	24%	0%
Low	4957	0%	0%	0%	87%
Info	875161	0%	0%	0%	0%

Last Updated: 5 hours ago

Understanding Risk - Remediation Opportunities

Solution	Risk Reduction	Host Total
Apply MS16-106: Security Update for Microsoft Graphics Component (3185848)	3.36%	185
Apply MS16-111: Security Update for Windows Kernel (3186973)	3.16%	187
Apply MS16-097: Security Update for Microsoft Graphics Component (3177393)	3.13%	179

Last Updated: 5 hours ago

Understanding Risk - Most Severe

Plugin ID	Name	Severity	Host Total
9309	OpenSSH < 7.0 Multiple Vulnerabilities	Critical	393
91786	CentOS 6 / 7 : libxml2 (CESA-2016:1292)	Critical	144
91605	MS16-077: Security Update for WPAD (3165191)	Critical	131
89059	CentOS 6 / 7 : openssl (CESA-2016:0301) (DROWN)	Critical	98

Last Updated: 5 hours ago

Understanding Risk - Most Prevalent

Plugin ID	Name	Severity	Host Total
51192	SSL Certificate Cannot Be Trusted	Medium	468
9312	OpenSSH < 7.2p2 X11Forwarding xauth Command Injection	Medium	406
7200	TLS Certificate Signed Using Weak Hashing Algorithm - SHA-1	Low	401

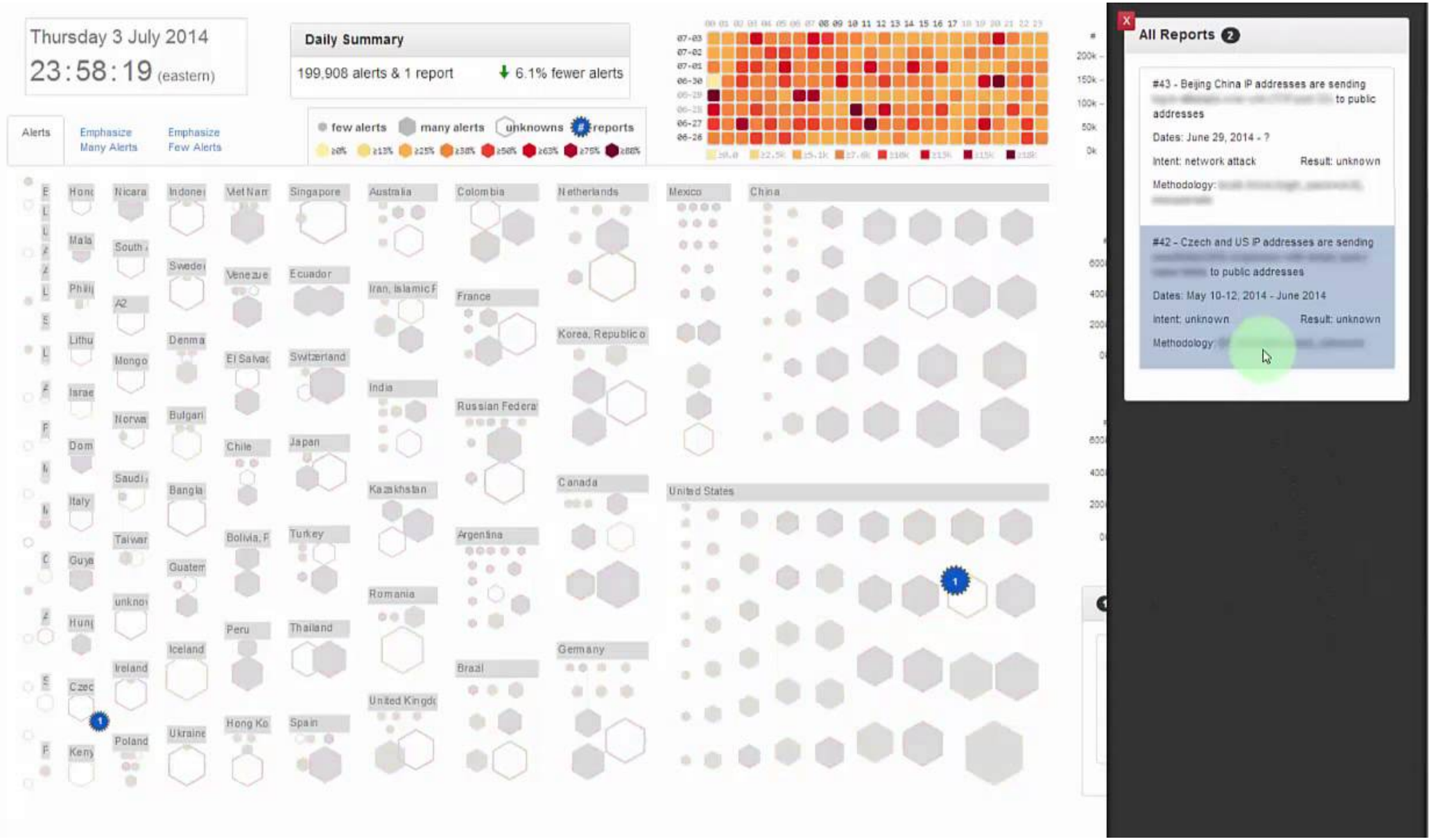
Last Updated: 5 hours ago

Understanding Risk - By Asset Group

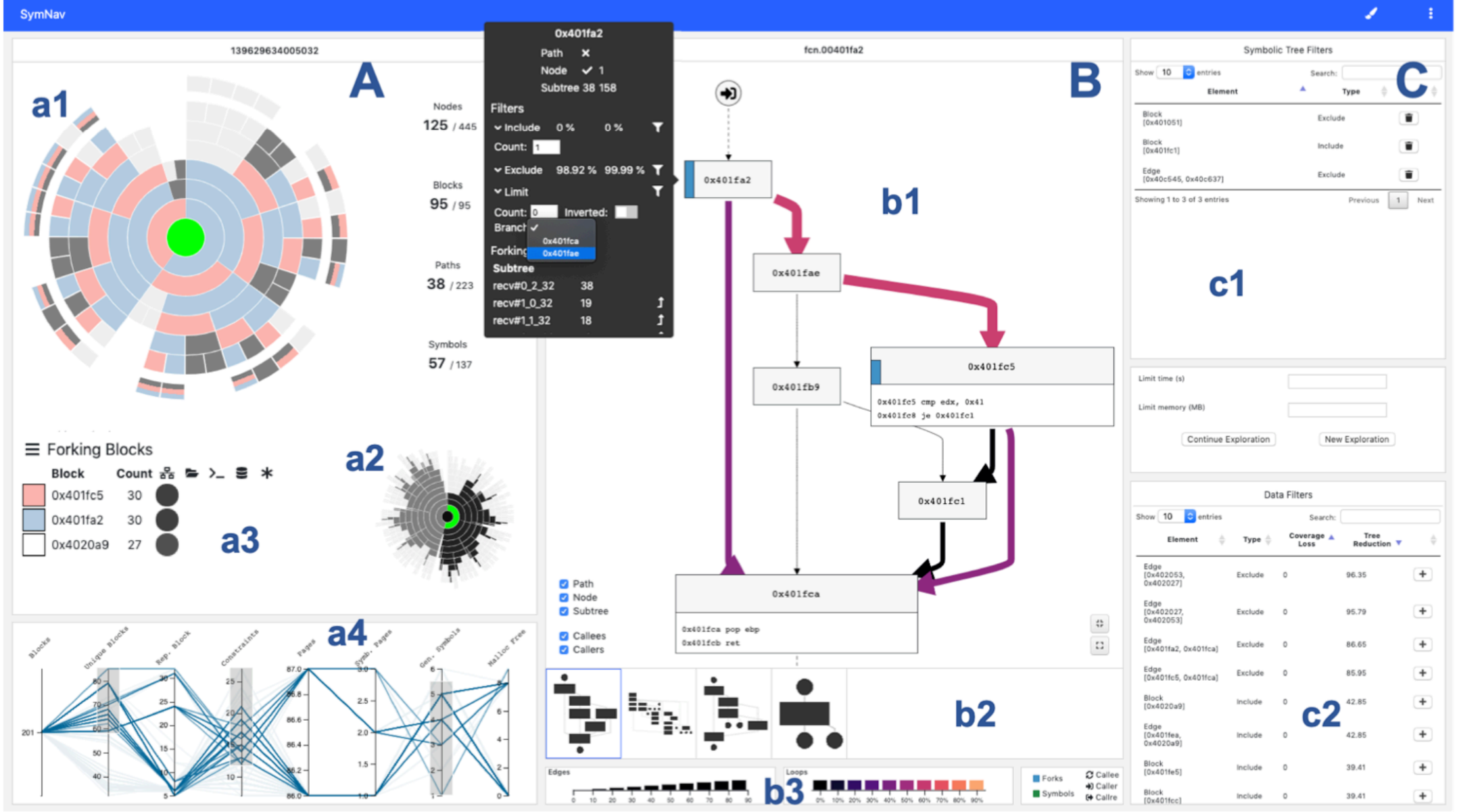
Asset	Total	Vulnerabilities
Exploitable (Generic)	319161	191640 116012
Exploited by Malware	303460	182596 111359

Source: https://www.tenable.com/sc-dashboards/cyber-essentials-scheme-dashboard

Examples: Research



Source [4], video from https://www.youtube.com/watch?v=7-RkJOdqHvI



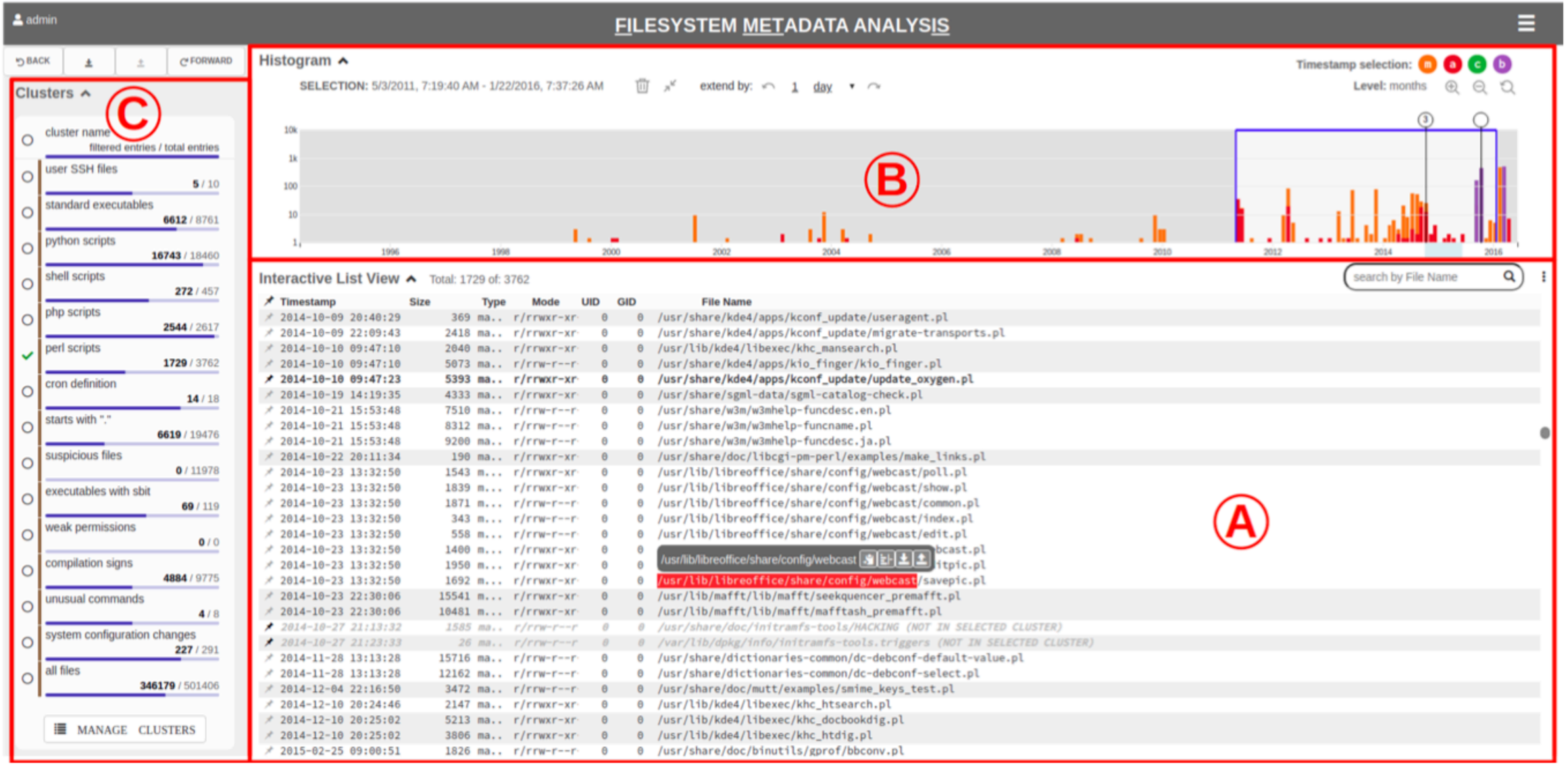
Analysis

Source: [5]

Characteristics

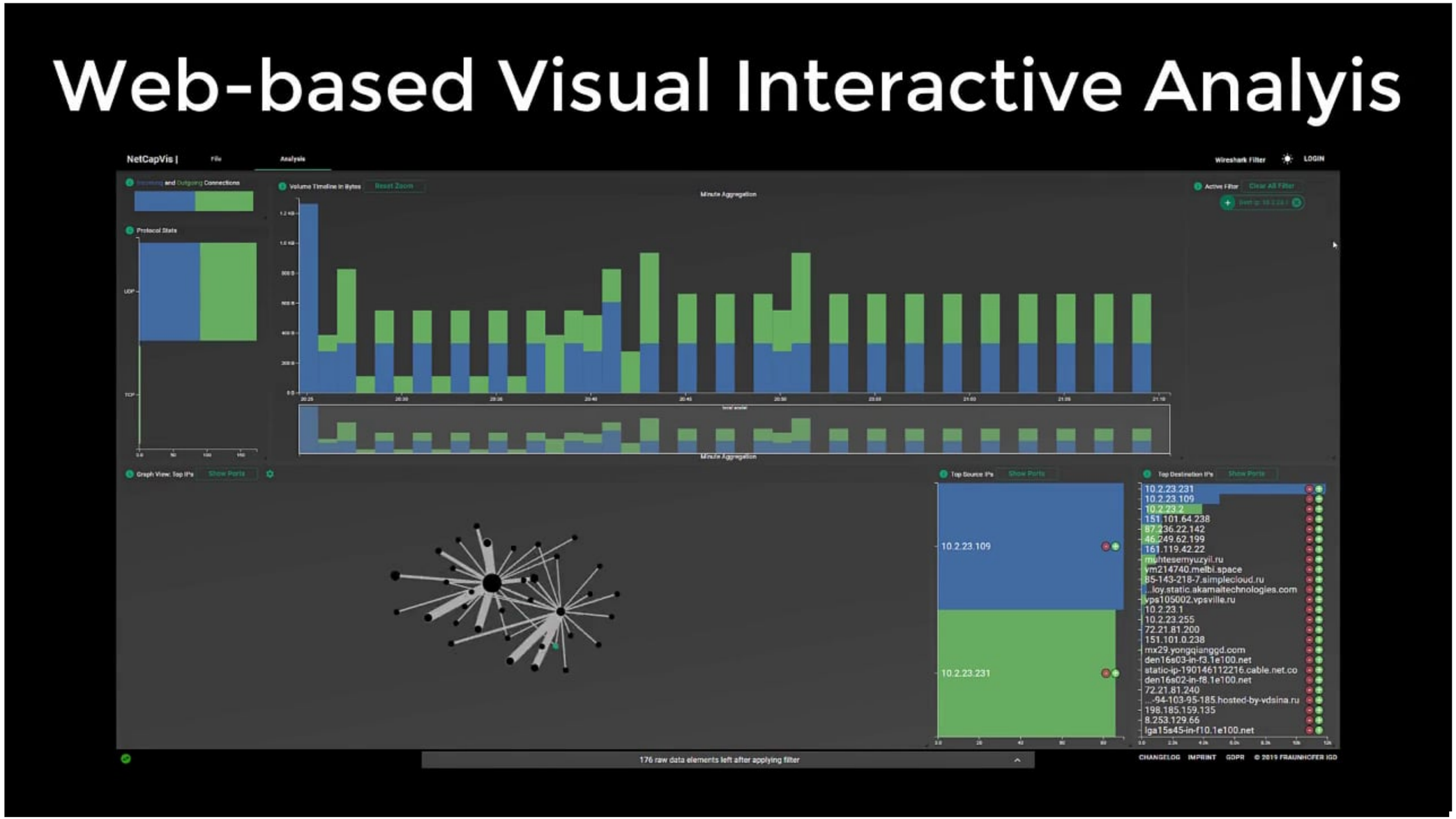
- Drill-down **Visual Analytics Tools**
  - Usually designed for particular use-case (e.g., malware vs. network analysis)
- **Goal(s):** Reduce “time-to-insight”, automate repetitive tasks, help to identify anomalies in data
- **Typical visualizations:** linked views, basic but also novel visualization types
- Extend command line interface, use of APIs
  - Supported in existing systems (e.g, Splunk, Flowmon ADS) vs. custom-made tools
- Computational notebooks (e.g., Jupyter) are also in this category

Example: File System Analysis

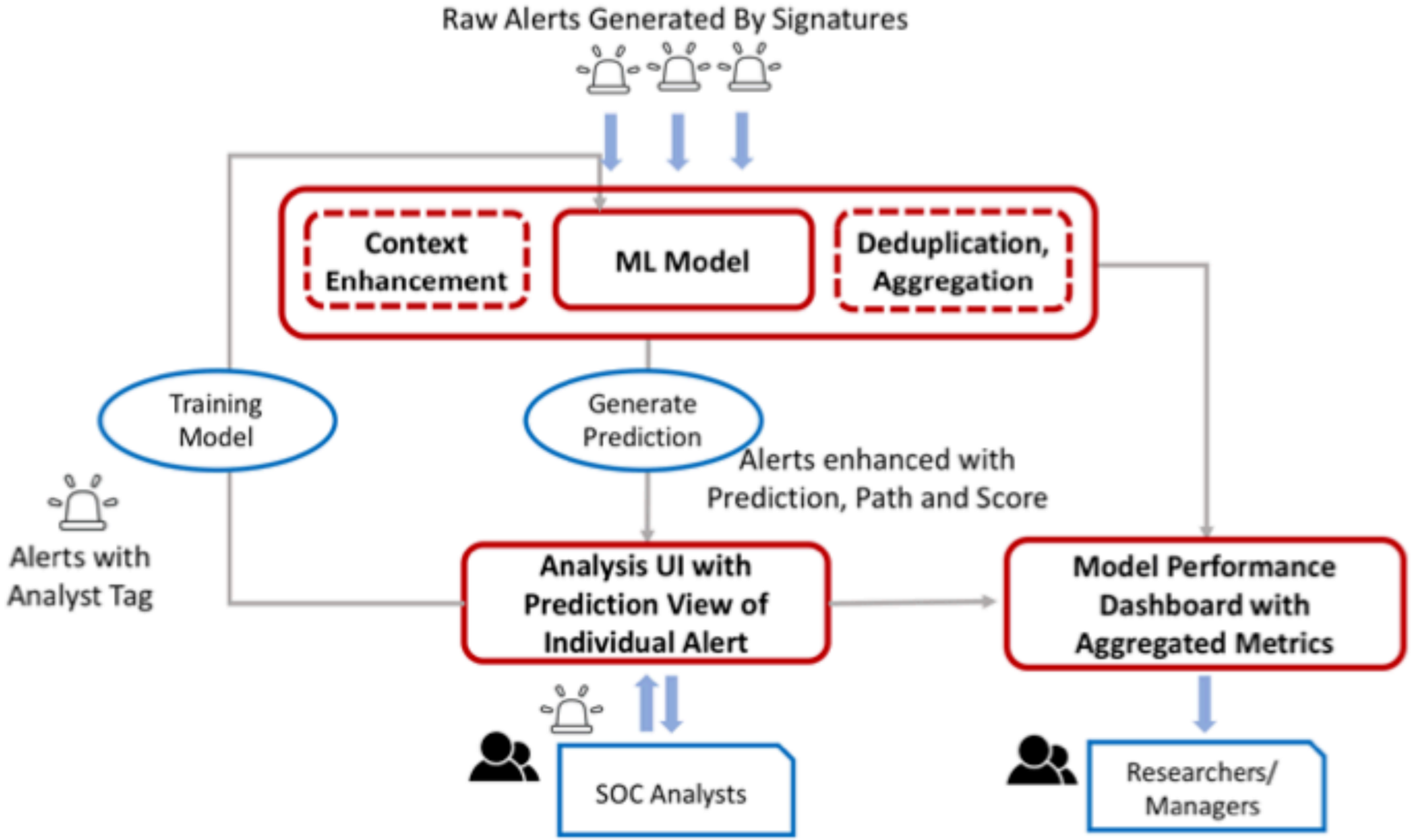


Source: [6]

Example: Traffic Analysis



Source: [8]



Predictions and Simulations

Source: [9]

Characteristics

- Visual support for understanding **ML/AI** techniques, visualizations for explainability (**XAI = eXplainable AI**)
- **Goal(s):** understanding ML/AI techniques, behavior explanation, trust building
- **Typical visualizations:** clustering visualizations (for dimensionality reduction methods), linked views, basic visualizations
- Rise on popularity correlates with growing application of ML/AI in cybersecurity.
- Explainability approaches are transferable between different domains

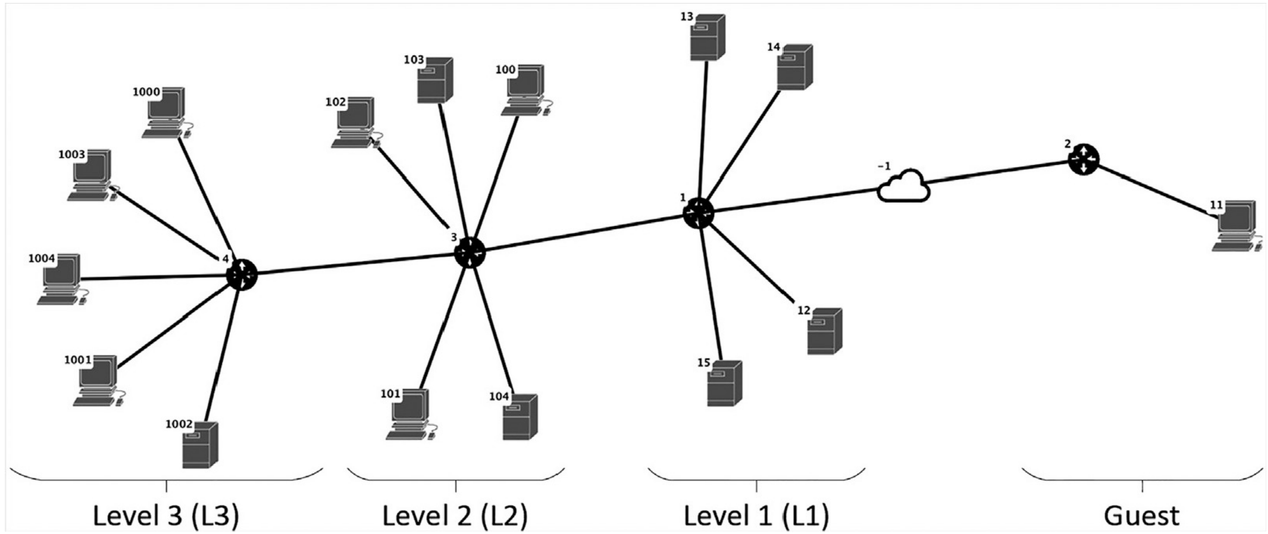
AI in Cybersecurity

- Application of AI in cybersecurity is substantially difficult comparing to domains such as image recognition

- Three main areas:
  - **Insights Generation:** analyze the data to discover hidden patterns which can be used by decision-makers in order to react to anomalies.
  - **Recommendations:** the model discovers patterns in the data and provides recommendations on what should be best to do to a security specialist.
  - **Autonomous mitigation:** the model discovers patterns and tries to automatically solve problems without needing user input (e.g., approvals).

Simulations

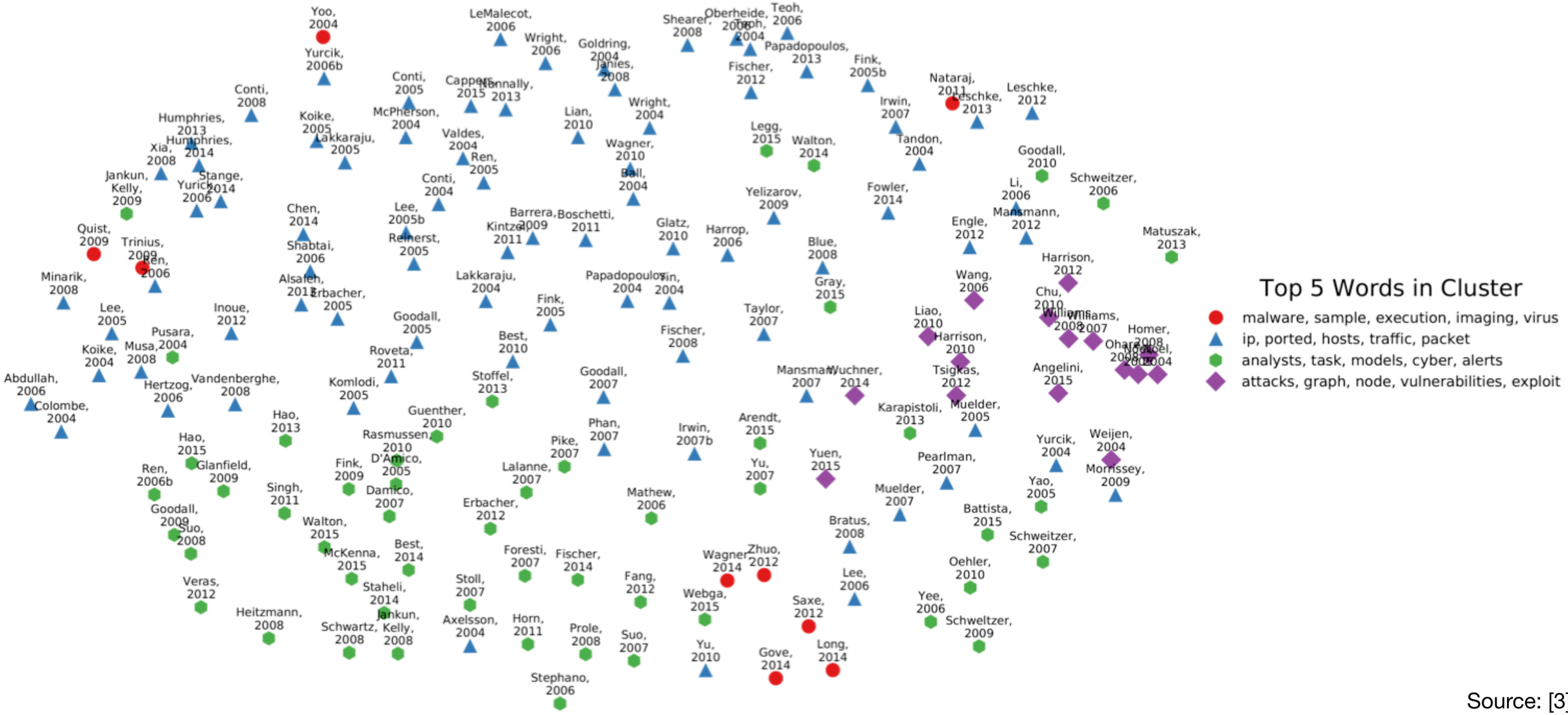
- Largely unexplored
- Areas:
  - Attack surface and attack vectors
  - Scenario modelling tool
  - Autonomous agents (attackres) behavior
  - Comparison and explanation of their decisions



Source: [11]

CyberSecVis Research

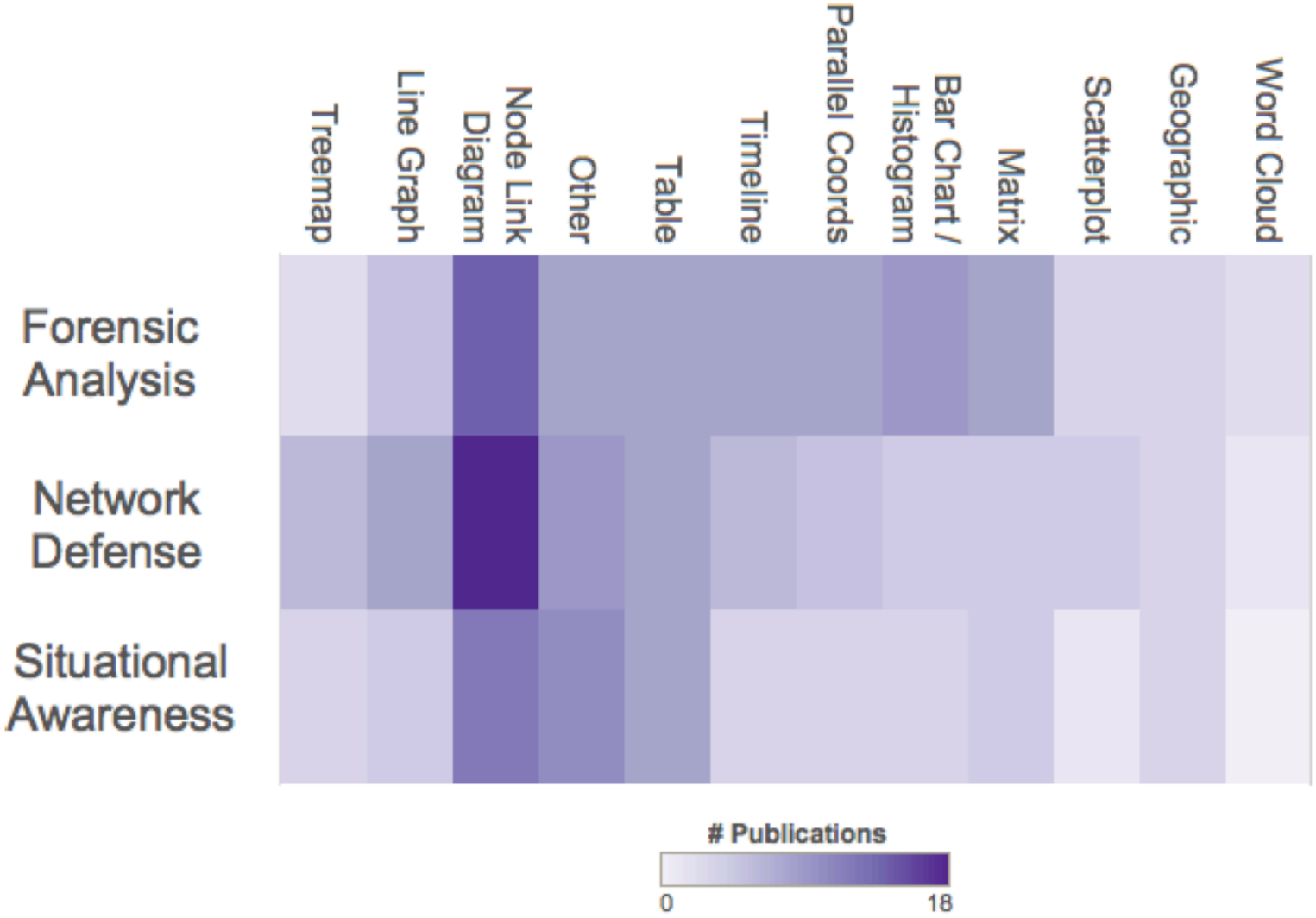
VizSec papers 2004—2015



Source: [3]

Utilization of Visualizations

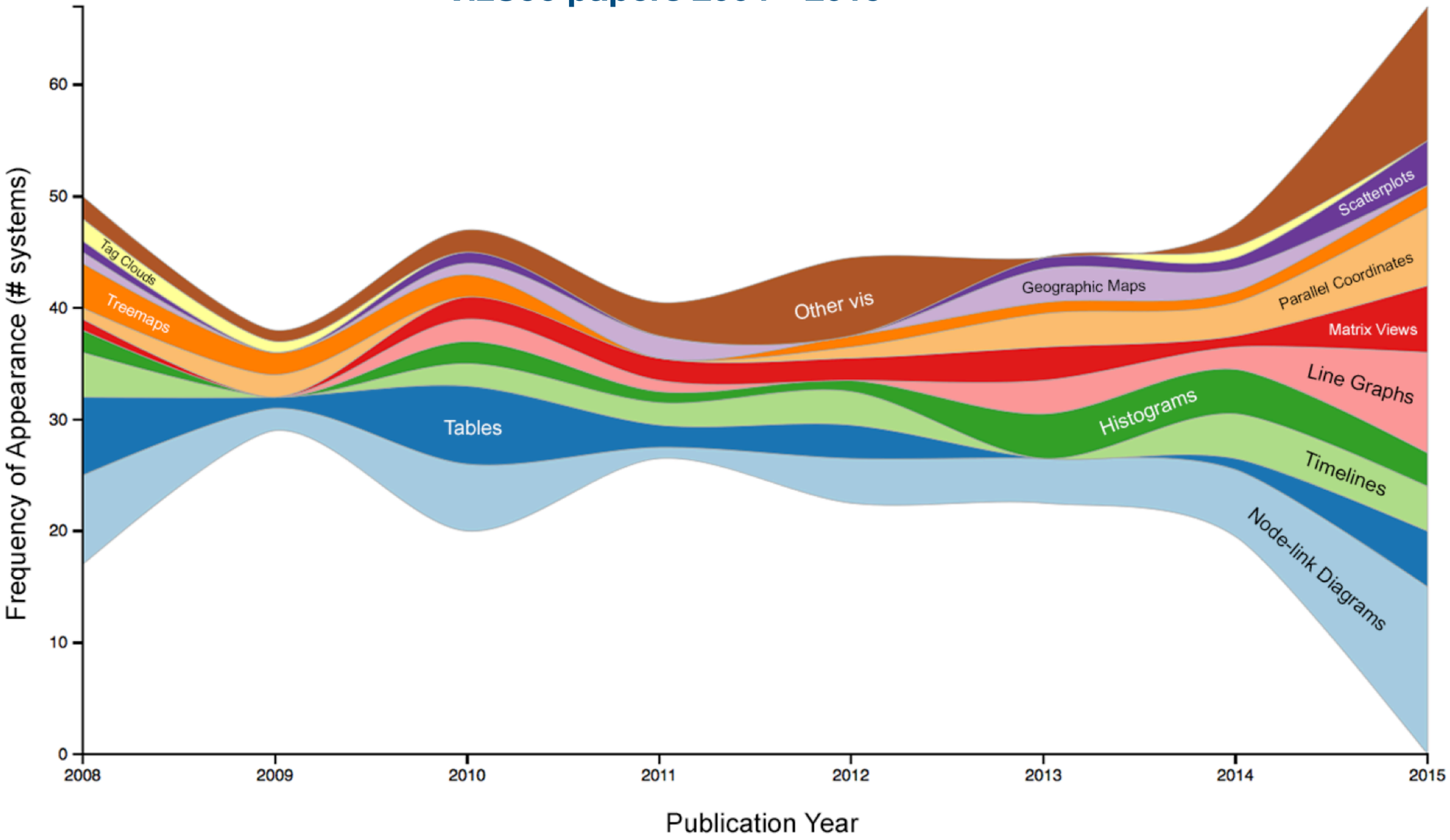
VizSec papers 2004—2015



Source: [3]

Utilization of Visual Metaphors

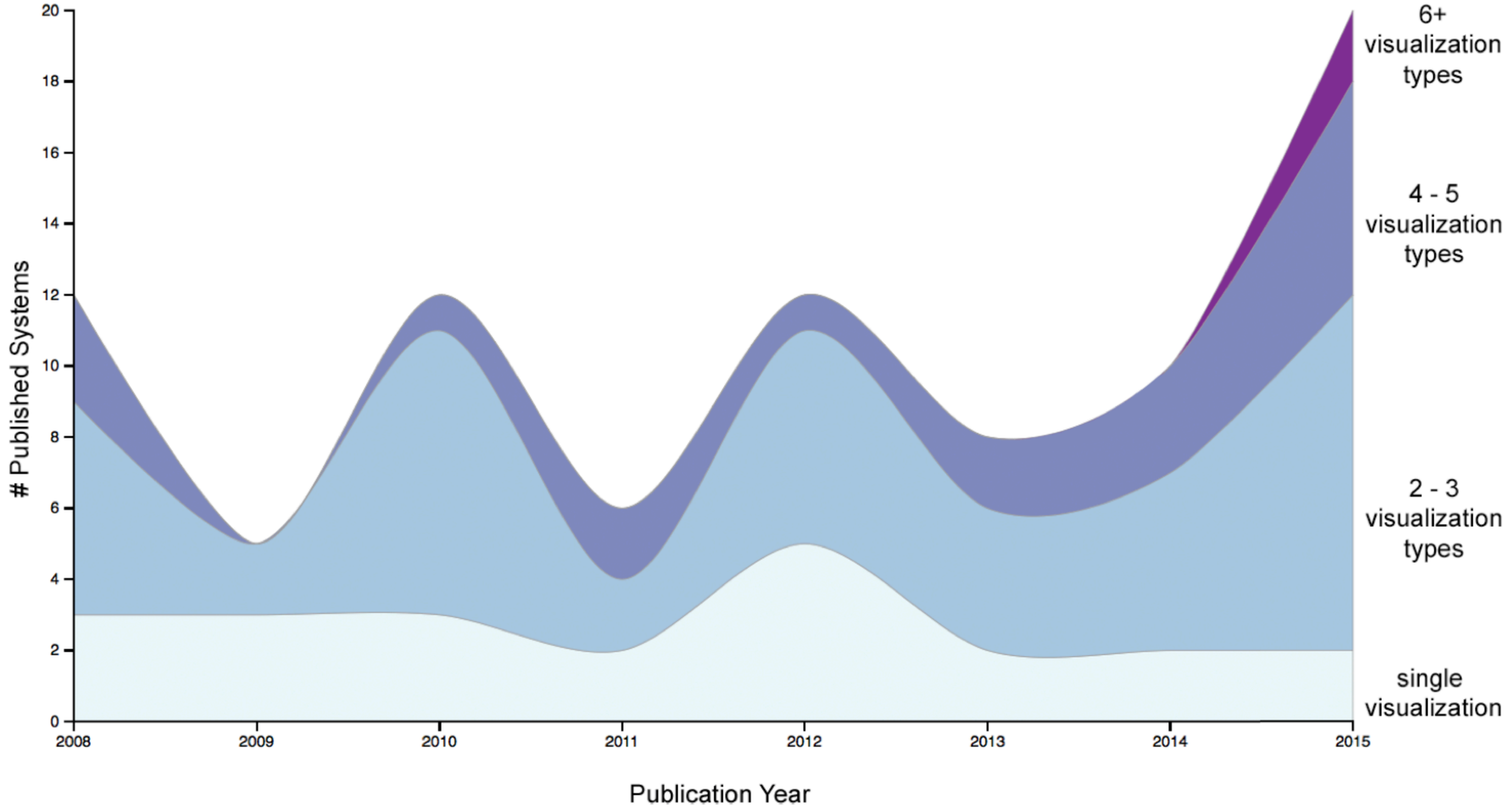
VizSec papers 2004—2015



Source: [3]

Interface Complexity

VizSec papers 2004—2015



Source: [3]

Take-aways

- What makes cybersecurity data challenging?
  - volume, velocity, heterogenity, context
- Why visualization matters?
  - cognitive amplification, anomaly detection, decision making
- The commercial tools use only common charts and visualizations …

  … → lot of space for improvements

Resources

- [1] Raffael Marty. 2008. Applied Security Visualization (1st. ed.). Addison-Wesley Professional.
- [2] Jay Jacobs, Bob Rudis. 2014. Data-Driven Security: Analysis, Visualization and Dashboards.
- [3] R. J. Crouser, E. Fukuda and S. Sridhar, "Retrospective on a decade of research in visualization for cybersecurity," *2017 IEEE International Symposium on Technologies for Homeland Security (HST)*, Waltham, MA, USA, 2017, pp. 1-5, doi: 10.1109/THS.2017.7943494.
- [4] S. Mckenna, D. Staheli and M. Meyer, "Unlocking user-centered design methods for building cyber security visualizations," *2015 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Chicago, IL, USA, 2015, pp. 1-8, doi: 10.1109/VIZSEC.2015.7312771.
- [5] M. Angelini *et al*., "SymNav: Visually Assisting Symbolic Execution," *2019 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Vancouver, BC, Canada, 2019, pp. 1-11, doi: 10.1109/VizSec48167.2019.9161524.
- [6] M. Beran, F. Hrdina, D. Kouřil, R. Ošlejšek and K. Zákopčanová, "Exploratory Analysis of File System Metadata for Rapid Investigation of Security Incidents," *2020 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Salt Lake City, UT, USA, 2020, pp. 11-20, doi: 10.1109/VizSec51108.2020.00008.
- [7] B. C. M. Cappers, P. N. Meessen, S. Etalle and J. J. van Wijk, "Eventpad: Rapid Malware Analysis and Reverse Engineering using Visual Analytics," *2018 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Berlin, Germany, 2018, pp. 1-8, doi: 10.1109/VIZSEC.2018.8709230.
- [8] A. Ulmer, D. Sessler and J. Kohlhammer, "NetCapVis: Web-based Progressive Visual Analytics for Network Packet Captures," *2019 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Vancouver, BC, Canada, 2019, pp. 1-10, doi: 10.1109/VizSec48167.2019.9161633.
- [9] A. Sopan, M. Berninger, M. Mulakaluri and R. Katakam, "Building a Machine Learning Model for the SOC, by the Input from the SOC, and Analyzing it for the SOC," *2018 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Berlin, Germany, 2018, pp. 1-8, doi: 10.1109/VIZSEC.2018.8709231.
- [10] B. C. M. Cappers and J. J. van Wijk, "SNAPS: Semantic network traffic analysis through projection and selection," *2015 IEEE Symposium on Visualization for Cyber Security (VizSec)*, Chicago, IL, USA, 2015, pp. 1-8, doi: 10.1109/VIZSEC.2015.7312768.
- [11] Moskal S, Yang SJ, Kuhl ME. Cyber threat assessment via attack scenario simulation using an integrated adversary and network modeling approach. *The Journal of Defense Modeling and Simulation*. 2018;15(1):13-29. doi:10.1177/1548512917725408

Other

- IEEE Symposium on Visualization for Cyber Security https://vizsec.org and its database of published papers: https://vizsec.dbvis.de
- Shixia Liu, Xiting Wang, Mengchen Liu, Jun Zhu, Towards better analysis of machine learning models: A visual analytics perspective, Visual Informatics, Volume 1, Issue 1, 2017, Pages 48-56, ISSN 2468-502X