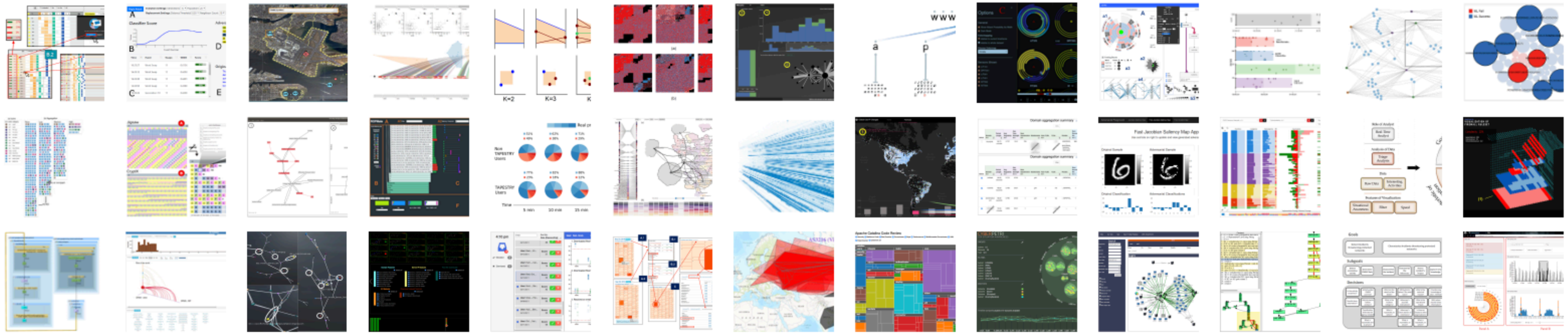
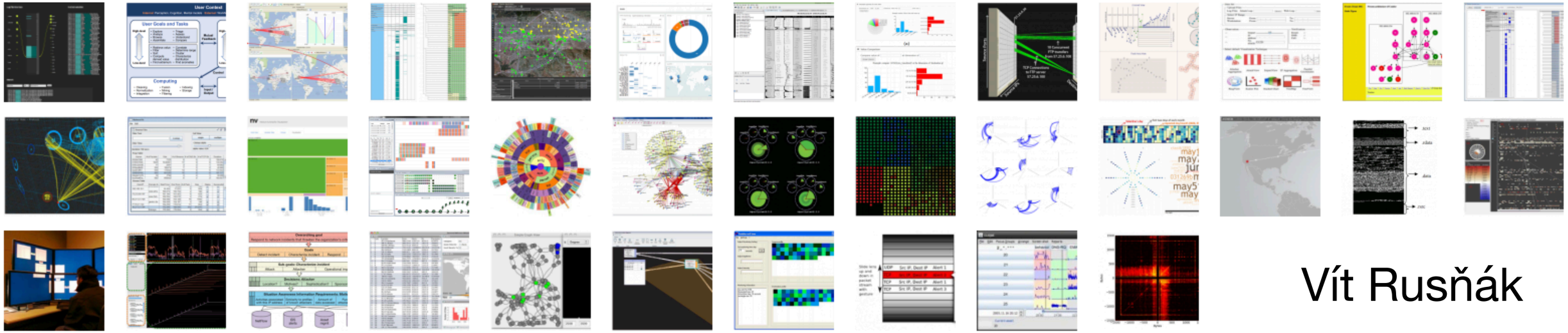


Visualizations for Cybersecurity

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

- Users and Data
- Visualization Categories
- Trends in Cybersecurity Visualization Research

Typical Users

Cybersecurity operations (L1)

- monitoring, countermeasures
- CSIRT, Incident handlers

Cybersecurity Analysts (L2)

- network, malware analysts

Management (both IT and non-IT background)

- Chief information security officer (CISO), policy makers, lawyers

Cybersecurity Researchers

- simulations, process automation, application of ML/AI

Data Sources

Applications

Network Services

Proxies

Operating System

Intrusion Detection Systems

Firewalls

Passive Network Analysis

Traffic Flows

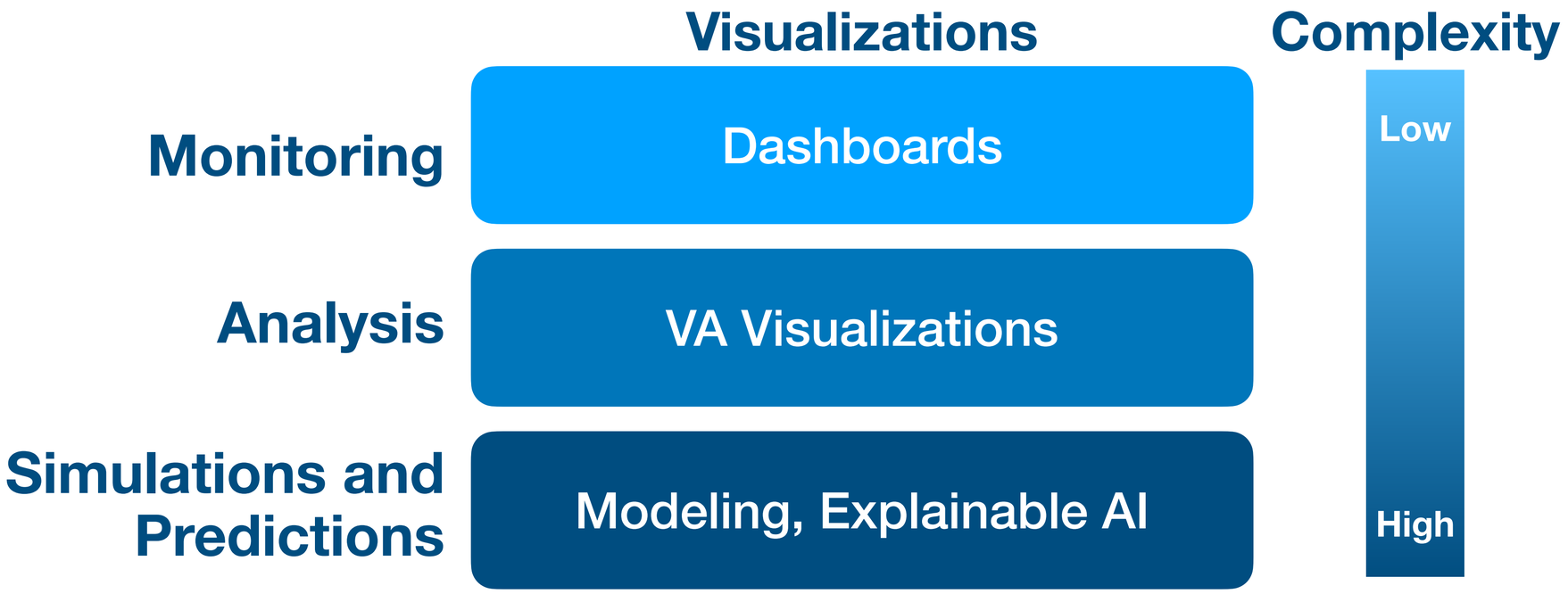
Packet Captures

Static data

Time-series

Adapted from [1].

Complexity of Visualizations



Monitoring

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

Characteristics

- **Dashboards are prevalent** (typically multiple panels)
- **Goal(s):** Easy to read, decode and understand
- **Used visualizations:** tables, sparklines (microvisualizations), basic 2D charts (bar charts, heatmaps), basic geovisualizations (choropleth, links)
- Interactive “shortcuts” to other (analytical) tools for drill-down

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

- current value of key measures (KPI, number of detected events, blocked IP addresses, …)
- comparison to target measures (difference, trend)
- a range of possible values of the measures with a qualitative association (semaphore, warnings)

Types

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

Examples: Commercial Tools

Dashboard | Reports | Notifications 0 | English | demo

Status | NetOps | SecOps | Inet Traffic | MySQL DB | QoS | ETA/TLS | DNS | Office 365 | Social Networks

Last 24 hours

Security sta... Last 24 hours (generic time span)

Critical priority events: 81

Security issues

Show details

2021-03-27 20:50 - 2021-03-28 21:50

Top 10 event types by priority and count Last 24 hours (generic time span)

	Event type	Name	Number of events
1	SMTPANOMALY	SMTP anomaly	26
2	DICTATTACK	Dictionary attacks	22
3	BLACKLIST	Communication with blacklisted hosts	11
4	RDPDICT	RDP attack	11
5	UPLOAD	Data upload anomaly	11
6	BPATTERNS	Flow-based behavior patterns	24
7	WEBSHARE	Web sharing traffic	13
8	TEAMVIEWER	TeamViewer traffic	13
9	SCANS	Port scanning	11
10	ICMPANOM	ICMP anomaly	22

2021-03-27 20:52 - 2021-03-28 21:52

The latest 10 new events Last 24 hours (generic time span)

	Event type	Name	Event source	Targets	Detection time
1	SMTPANOMALY	SMTP anomaly	172.17.107.32	0.136.226.185, 0.179.120.11, 0.246.126.78, ...	2021-03-28 21:13:20
2	BPATTERNS	Flow-based behavior patterns	192.168.70.2	www.pulskom.com, 192.168.70.253, 209-99-40-220.fwd.datafoundry.com	2021-03-28 21:05:15
3	WEBSHARE	Web sharing traffic	192.168.70.16	77.48.29.200	2021-03-28 21:04:14
4	TEAMVIEWER	TeamViewer traffic	10.0.2.15	AT-VIE-ANX-R008.teamviewer.com, ns01.dialtelecom.cz, FR-PAR-ANX-R016.teamviewer.com	2021-03-28 21:03:16
5	SMTPANOMALY	SMTP anomaly	172.17.107.32	0.136.226.185, 0.179.120.11, 0.246.126.78, ...	2021-03-28 21:00:40
6	BPATTERNS	Flow-based behavior patterns	192.168.1.50	192.168.1.2	2021-03-28 20:25:15
7	ICMPANOM	ICMP anomaly	192.168.1.50	node-yr.pool-1-0.dynamic.totinternet.net	2021-03-28 20:11:51
8	ICMPANOM	ICMP anomaly	192.168.1.50	node-yr.pool-1-0.dynamic.totinternet.net	2021-03-28 20:11:51
9	BLACKLIST	Communication with blacklisted hosts	192.168.1.50	node-yr.pool-1-0.dynamic.totinternet.net	2021-03-28 20:11:51
10	UPLOAD	Data upload anomaly	192.168.1.50	node-yr.pool-1-0.dynamic.totinternet.net	2021-03-28 20:11:51

2021-03-27 20:52 - 2021-03-28 21:52

Event overview by type Last 24 hours (generic time span)

	Event type	Name	Number of events
1	SMTPANOMALY	Detection of outgoing e-mail SPAM using SMTP or secured SMTP protocol	26
2	DICTATTACK	Detection of dictionary attacks on various protocols.	22
3	BLACKLIST	Detection of communication with blacklisted IP addresses	11
4	RDPDICT	Advanced detection method revealing dictionary attacks on Remote Desktop Protocol	11
5	UPLOAD	Detection of uploading data	11
6	BPATTERNS	Detection of current threats by unified flow-based behavior patterns.	24
7	WEBSHARE	Detection of data sharing services through web like Rapidshare etc.	13
8	TEAMVIEWER	Detection of TeamViewer	13
9	SCANS	Detection of TCP scans (SYN scan, FIN scan, Xmas scan, Null scan)	11
10	ICMPANOM	Detection of anomalies in ICMP traffic	22
	Others		22
	Total		186

2021-03-27 20:50 - 2021-03-28 21:50

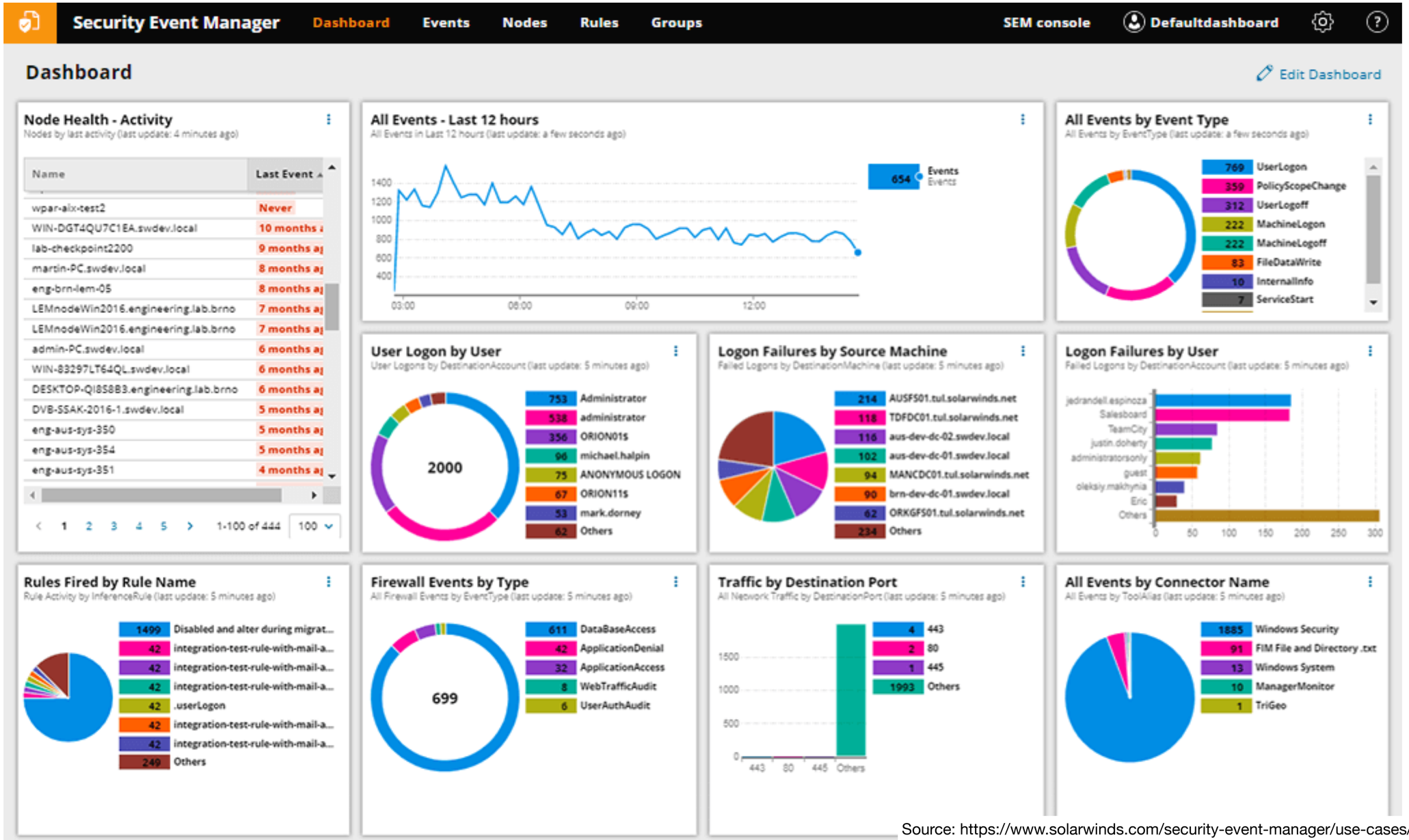
Top 10 IPs by event count Last 24 hours (generic time span)

	Event source	Number of events
1	192.168.1.50	110
2	172.17.107.32	26
3	10.0.2.15	13
4	192.168.70.2	13
5	192.168.70.16	13
6	192.168.1.2	11
	Others	0

2021-03-27 20:52 - 2021-03-28 21:52

Source: https://demo.flowmon.com

Examples: Commercial Tools



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

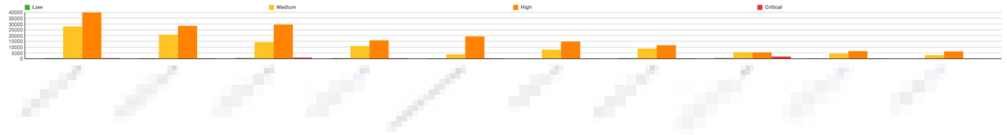
Examples: Commercial Tools

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

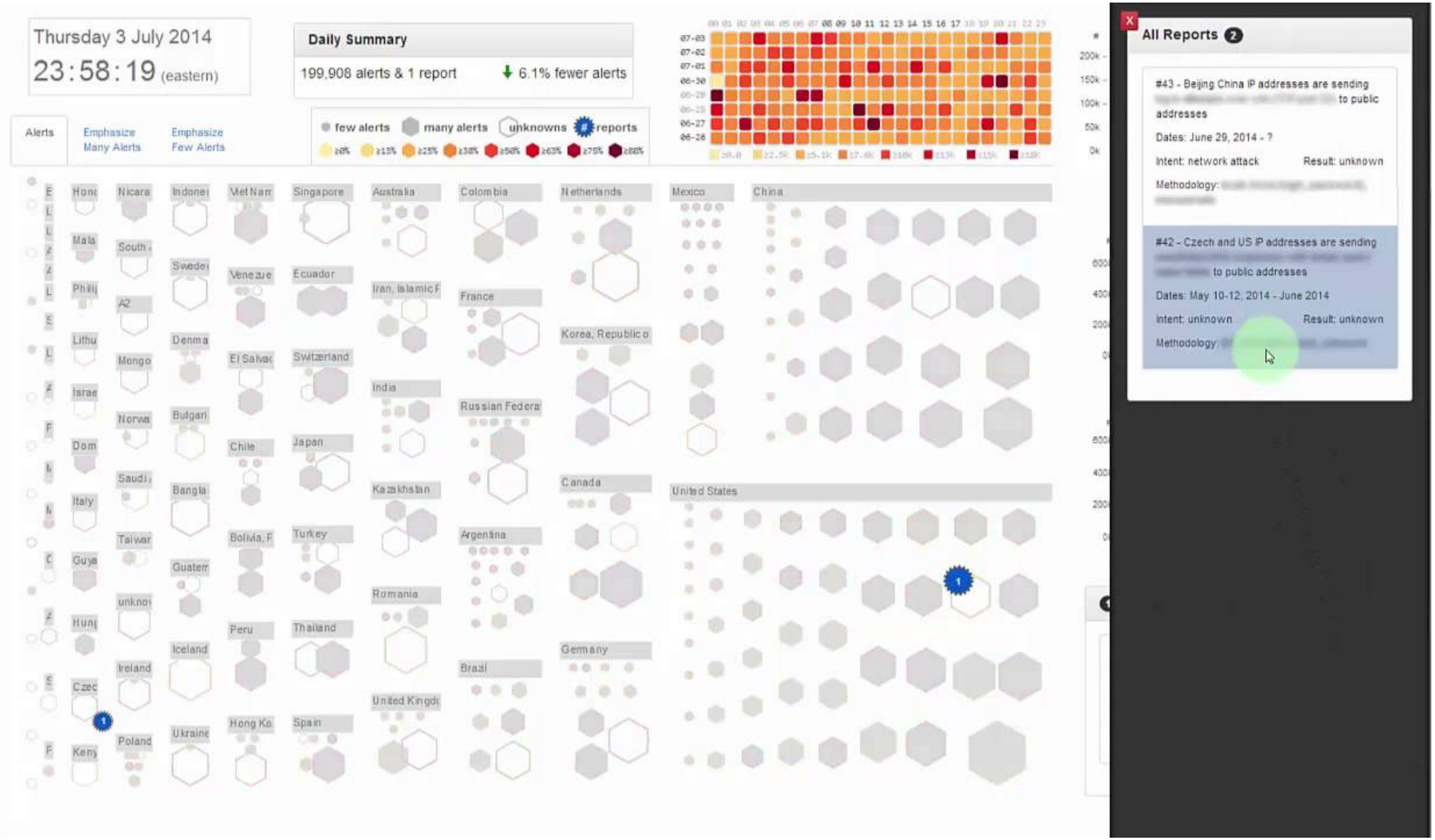
Last Updated: 5 hours ago

Understanding Risk - By Asset Group

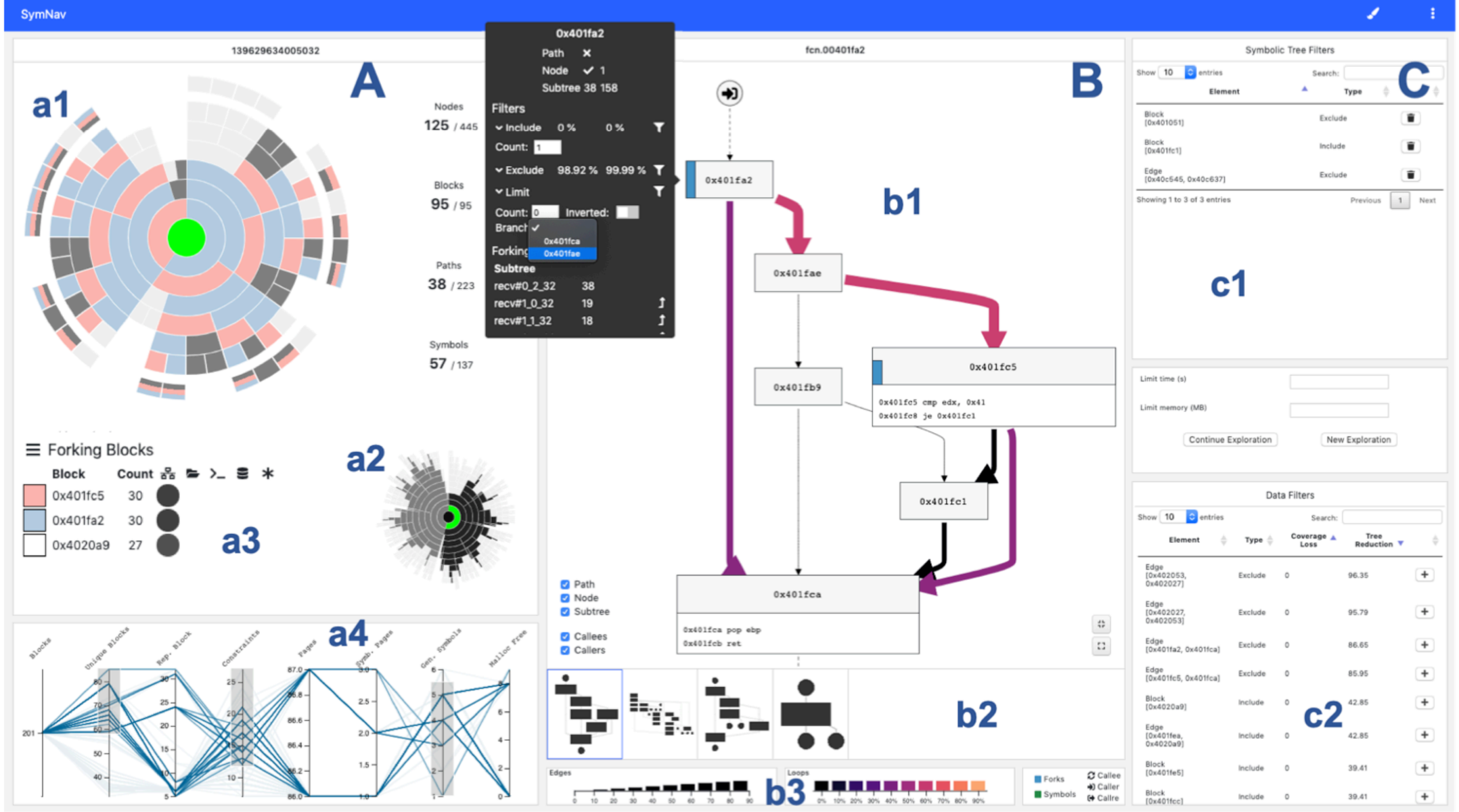
Asset	Total	Vulnerabilities
Exploitable (Generic)	319161	101640 / 116012
Exploited by Malware	303460	182596 / 111359

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**, for particular use-case
- **Goal(s):** Reduce “time-to-insight”, automate repetitive tasks, help to identify anomalies in data
- **Used visualizations:** linked views, basic visualizations, specific (also novel) visualizations
- Extend command line tools, 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

admin

FILESYSTEM METADATA ANALYSIS

BACK | FORWARD

Clusters (C)

cluster name	filtered entries / total entries
user SSH files	5 / 10
standard executables	6612 / 8761
python scripts	16743 / 18460
shell scripts	272 / 457
php scripts	2544 / 2617
perl scripts	1729 / 3762
cron definition	14 / 18
starts with "."	6619 / 19476
suspicious files	0 / 11978
executables with sbit	69 / 119
weak permissions	0 / 0
compilation signs	4884 / 9775
unusual commands	4 / 8
system configuration changes	227 / 291
all files	346179 / 501406

MANAGE CLUSTERS

Histogram

SELECTION: 5/3/2011, 7:19:40 AM - 1/22/2016, 7:37:26 AM

extend by: 1 day

Timestamp selection: m a c b

Level: months

(B)

Interactive List View Total: 1729 of: 3762

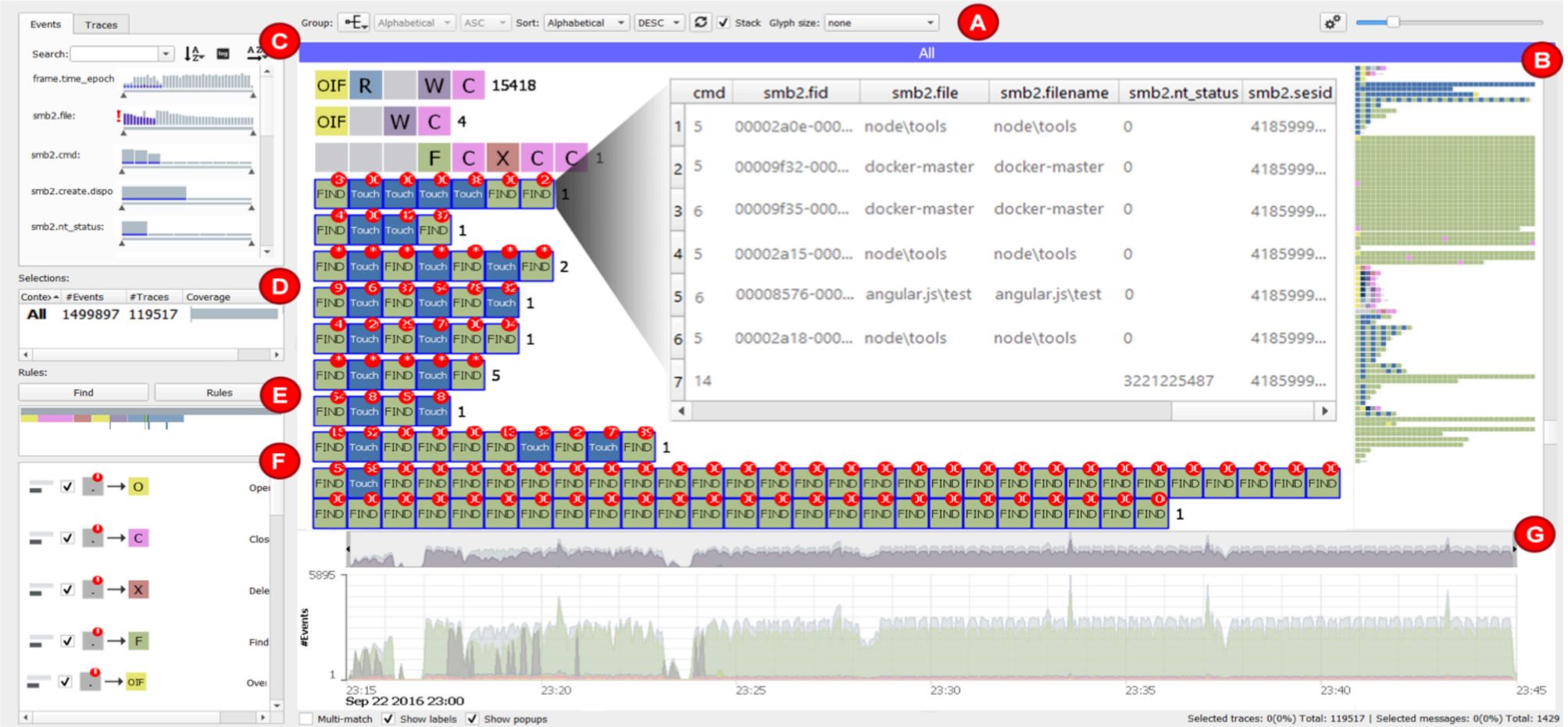
search by File Name

Timestamp	Size	Type	Mode	UID	GID	File Name
2014-10-09 20:40:29	369	ma..	r/rrwxr-xr	0	0	/usr/share/kde4/apps/kconf_update/useragent.pl
2014-10-09 22:09:43	2418	ma..	r/rrwxr-xr	0	0	/usr/share/kde4/apps/kconf_update/migrate-transports.pl
2014-10-10 09:47:10	2040	ma..	r/rrwxr-xr	0	0	/usr/lib/kde4/libexec/khc_mansearch.pl
2014-10-10 09:47:10	5073	ma..	r/rrw-r--r	0	0	/usr/share/kde4/apps/kio_finger/kio_finger.pl
2014-10-10 09:47:23	**5393**	**ma..**	**r/rrwxr-xr**	**0**	**0**	**/usr/share/kde4/apps/kconf_update/update_oxygen.pl**
2014-10-19 14:19:35	4333	ma..	r/rrwxr-xr	0	0	/usr/share/sgml-data/sgml-catalog-check.pl
2014-10-21 15:53:48	7510	ma..	r/rrw-r--r	0	0	/usr/share/w3m/w3mhelp-funcdesc.en.pl
2014-10-21 15:53:48	8312	ma..	r/rrw-r--r	0	0	/usr/share/w3m/w3mhelp-funcname.pl
2014-10-21 15:53:48	9200	ma..	r/rrw-r--r	0	0	/usr/share/w3m/w3mhelp-funcdesc.ja.pl
2014-10-22 20:11:34	190	ma..	r/rrwxr-xr	0	0	/usr/share/doc/libcgi-pm-perl/examples/make_links.pl
2014-10-23 13:32:50	1543	m...	r/rrwxr-xr	0	0	/usr/lib/libreoffice/share/config/webcast/poll.pl
2014-10-23 13:32:50	1839	m...	r/rrwxr-xr	0	0	/usr/lib/libreoffice/share/config/webcast/show.pl
2014-10-23 13:32:50	1871	m...	r/rrw-r--r	0	0	/usr/lib/libreoffice/share/config/webcast/common.pl
2014-10-23 13:32:50	343	m...	r/rrw-r--r	0	0	/usr/lib/libreoffice/share/config/webcast/index.pl
2014-10-23 13:32:50	558	m...	r/rrw-r--r	0	0	/usr/lib/libreoffice/share/config/webcast/edit.pl
2014-10-23 13:32:50	1400	m...	r/rrwxr-xr	0	0	bcast.pl
2014-10-23 13:32:50	1950	m...	r/rrwxr-xr	0	0	itpic.pl
2014-10-23 13:32:50	1692	m...	r/rrwxr-xr	0	0	/usr/lib/libreoffice/share/config/webcast/savepic.pl
2014-10-23 22:30:06	15541	m...	r/rrwxr-xr	0	0	/usr/lib/mafft/lib/mafft/seekquencer_premafft.pl
2014-10-23 22:30:06	10481	m...	r/rrwxr-xr	0	0	/usr/lib/mafft/lib/mafft/mafftash_premafft.pl
2014-10-27 21:13:32	*1585*	*ma..*	*r/rrw-r--r*	*0*	*0*	*/usr/share/doc/initramfs-tools/HACKING (NOT IN SELECTED CLUSTER)*
2014-10-27 21:23:33	*26*	*ma..*	*r/rrw-r--r*	*0*	*0*	*/var/lib/dpkg/info/initramfs-tools.triggers (NOT IN SELECTED CLUSTER)*
2014-11-28 13:13:28	15716	ma..	r/rrw-r--r	0	0	/usr/share/dictionaries-common/dc-debconf-default-value.pl
2014-11-28 13:13:28	12162	ma..	r/rrw-r--r	0	0	/usr/share/dictionaries-common/dc-debconf-select.pl
2014-12-04 22:16:50	3472	ma..	r/rrw-r--r	0	0	/usr/share/doc/mutt/examples/smime_keys_test.pl
2014-12-10 20:24:46	2147	ma..	r/rrwxr-xr	0	0	/usr/lib/kde4/libexec/khc_htsearch.pl
2014-12-10 20:25:02	5213	ma..	r/rrwxr-xr	0	0	/usr/lib/kde4/libexec/khc_docbookdig.pl
2014-12-10 20:25:02	3806	ma..	r/rrwxr-xr	0	0	/usr/lib/kde4/libexec/khc_htdig.pl
2015-02-25 09:00:51	1826	ma..	r/rrw-r--r	0	0	/usr/share/doc/binutils/gprof/bbconv.pl

(A)

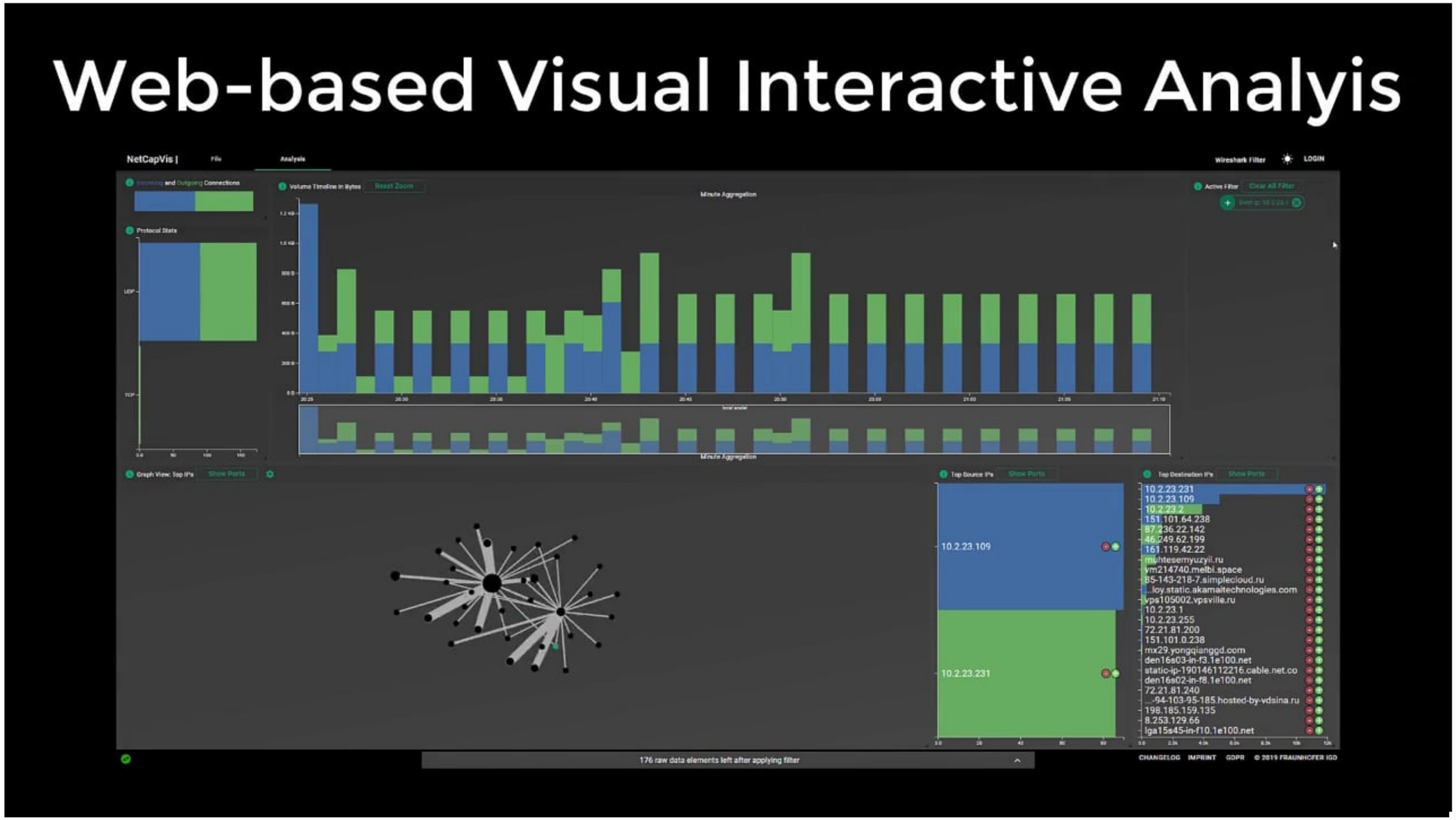
Source: [6]

Example: Malware Analysis

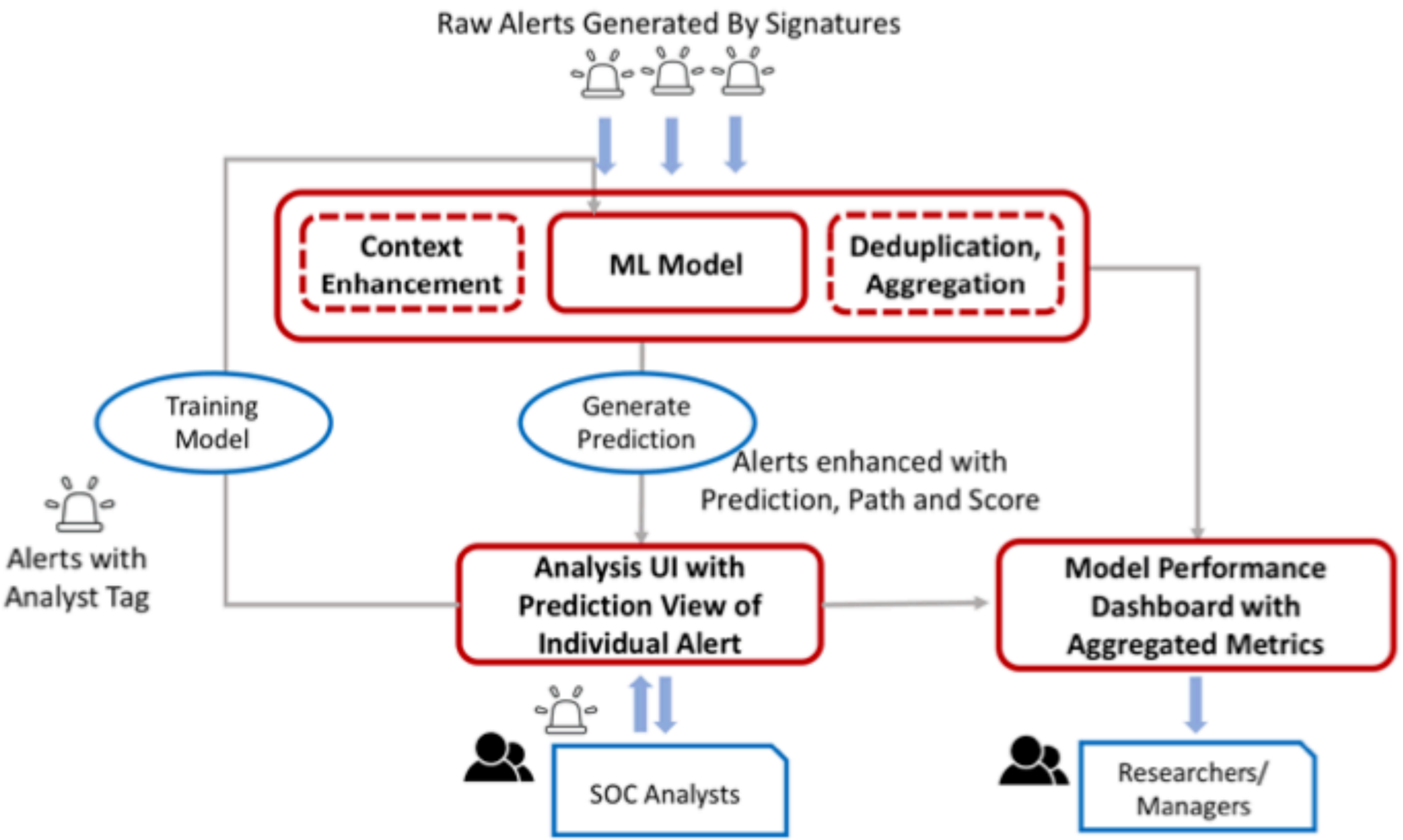


Source: [7]

Example: Network Analysis



Source: [8]



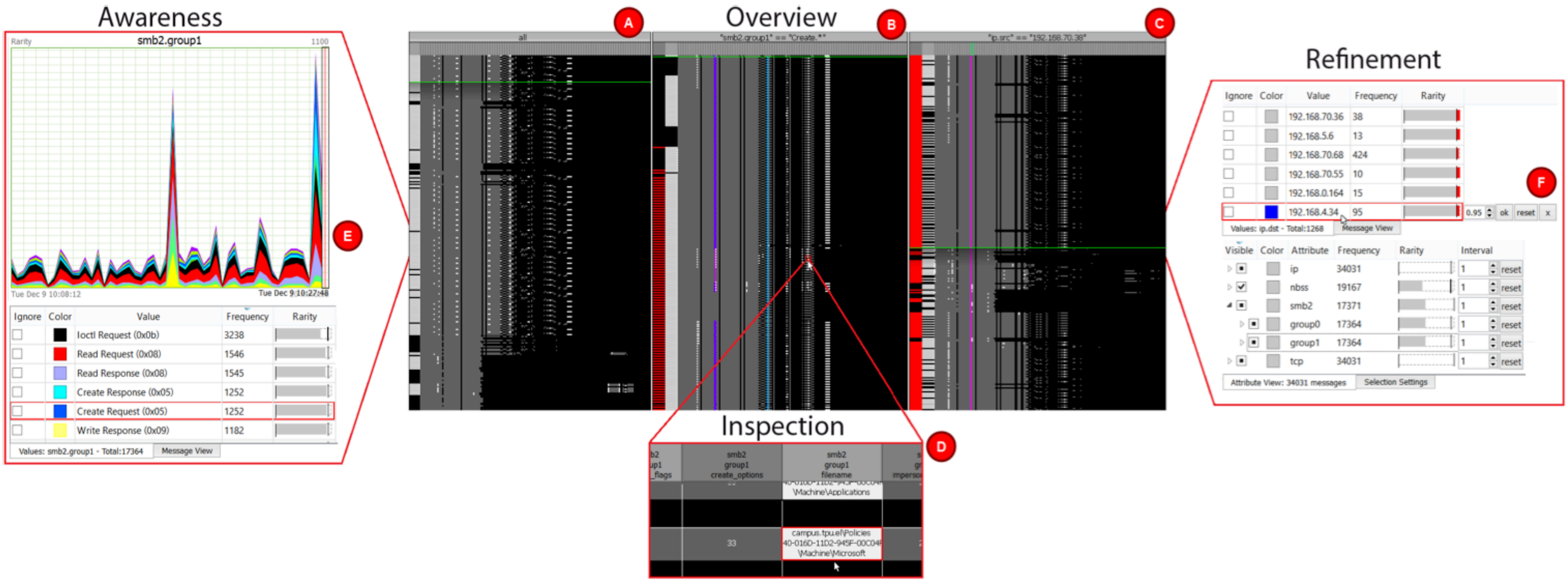
Simulations and Predictions

Source: [9]

Characteristics

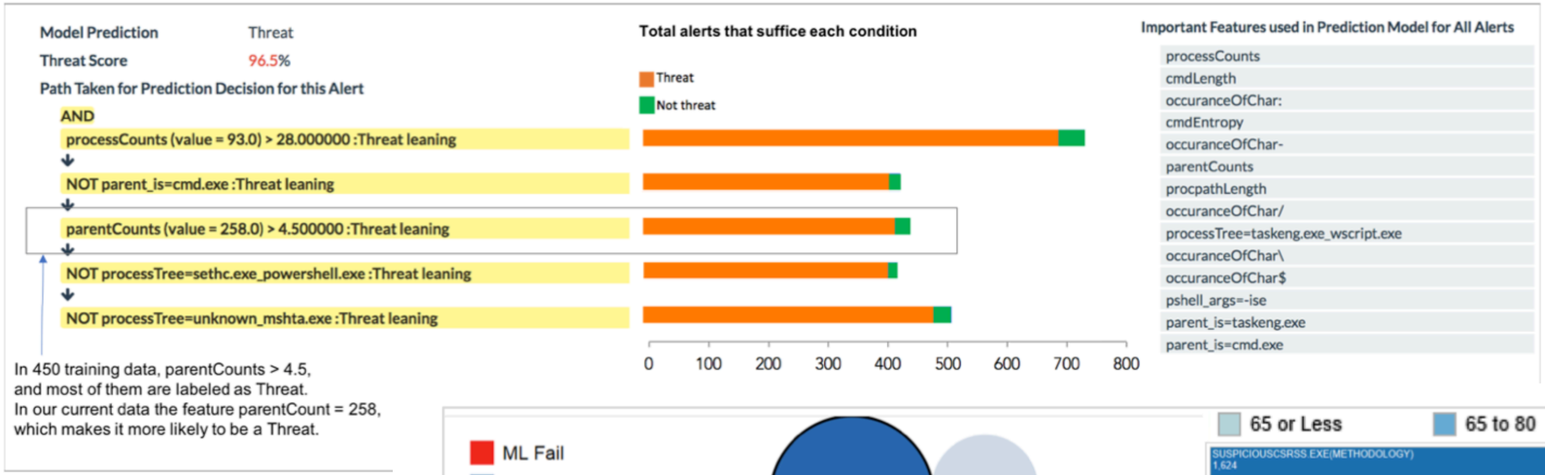
- Visual support for understanding **ML/AI** techniques, visualizations for **explainable AI**
- **Goal(s):** Understanding ML/AI techniques, explain their behavior, gain trust in them
- **Used visualizations:** linked views, basic visualizations, clustering visualizations (for dimensionality reduction methods)
- Rise on popularity correlates with growing application of ML/AI in cybersecurity

Example: Traffic Analysis



Source: [10]

Example: Alert Predictions



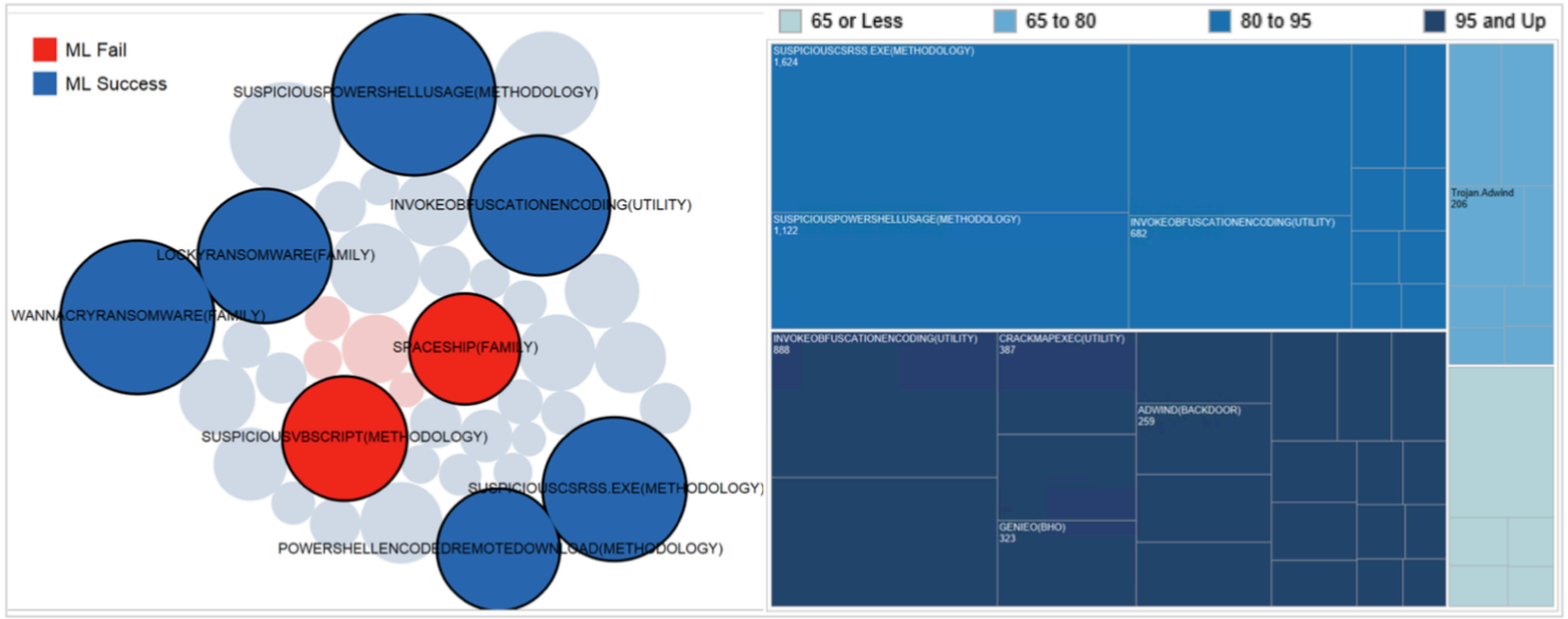
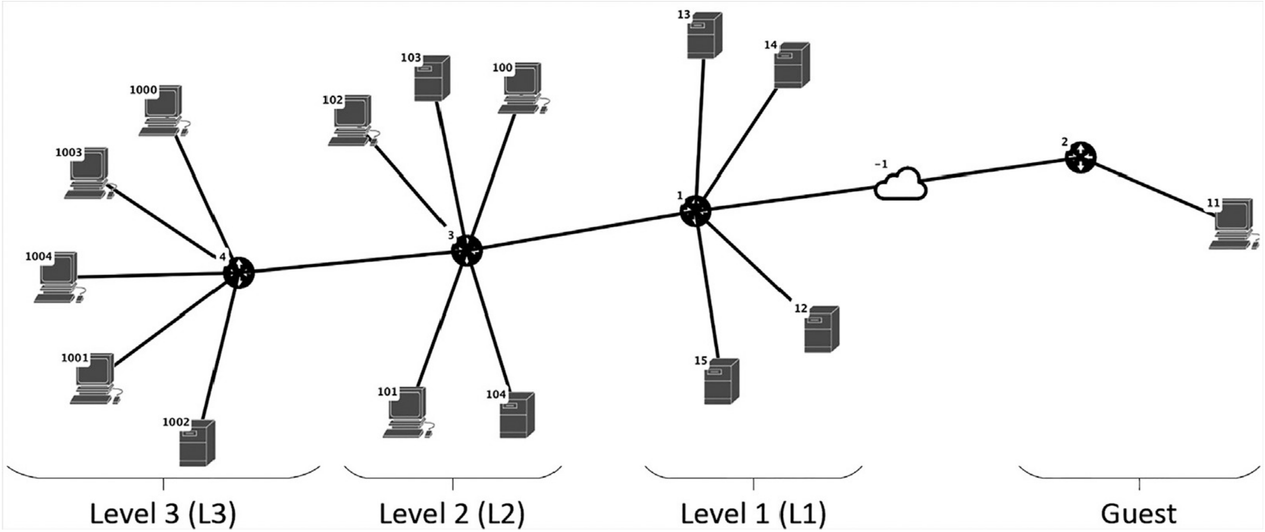


Figure 7: Left: Circle pack visualization showing alerts by signatures. Each circle represents alerts from a particular signature. Circles are sized by the total alerts of that signature and color coded by the ML Model success of ML failure. Right: A Treemap visualization showing only alerts that are correctly labeled by the model, grouped by signatures. Color coded by prediction Score range, sized by total number of alerts in that signature group. It shows which signatures are more common and how the model is performing to classify alerts triggered by those signatures.

Source: [9]

Simulations

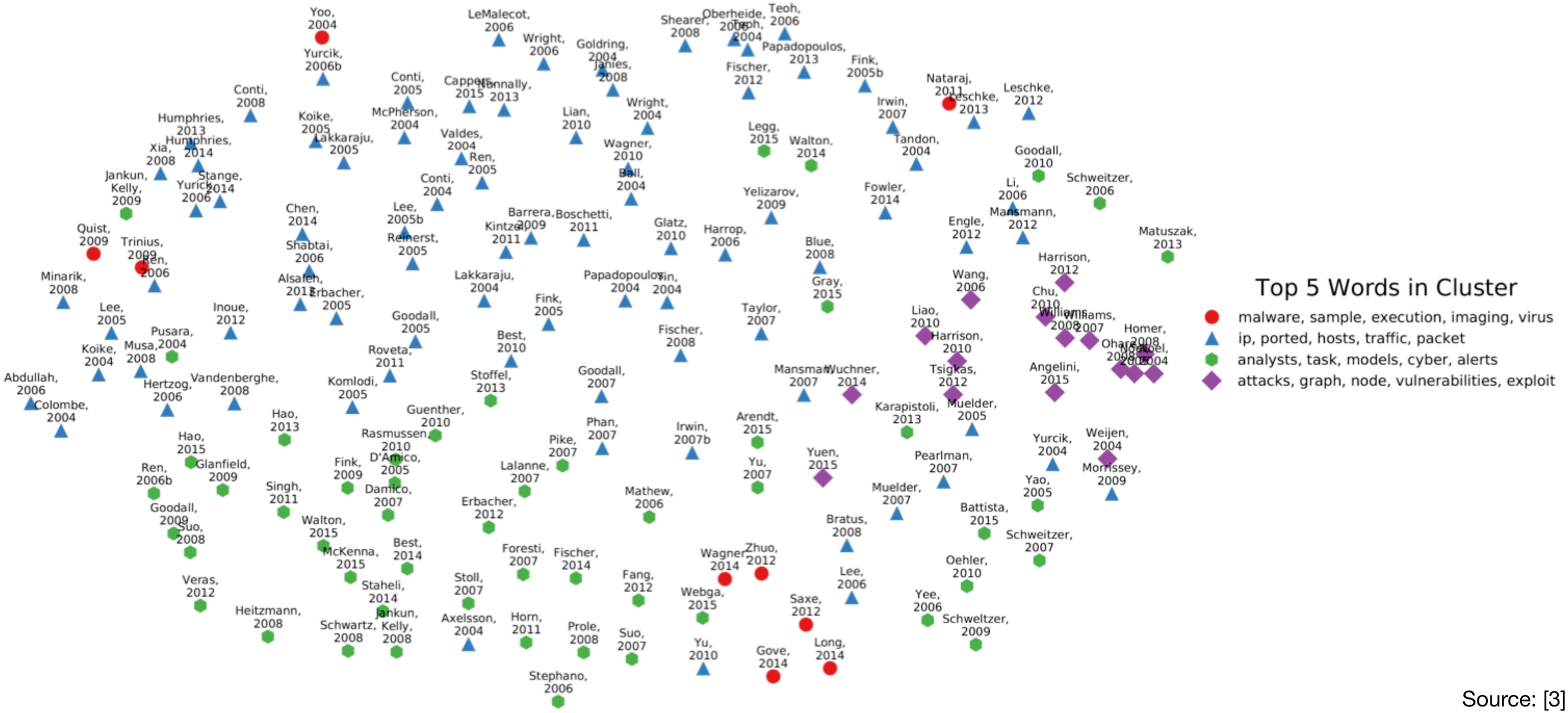
- Largely unexplored
- Areas:
  - Attack surface and attack vectors
  - Scenario modelling tool
  - Autonomous agents (attackres) behavior
  - Comparison and explanation of their decisions



Source: [11]

CyberSecVis Research

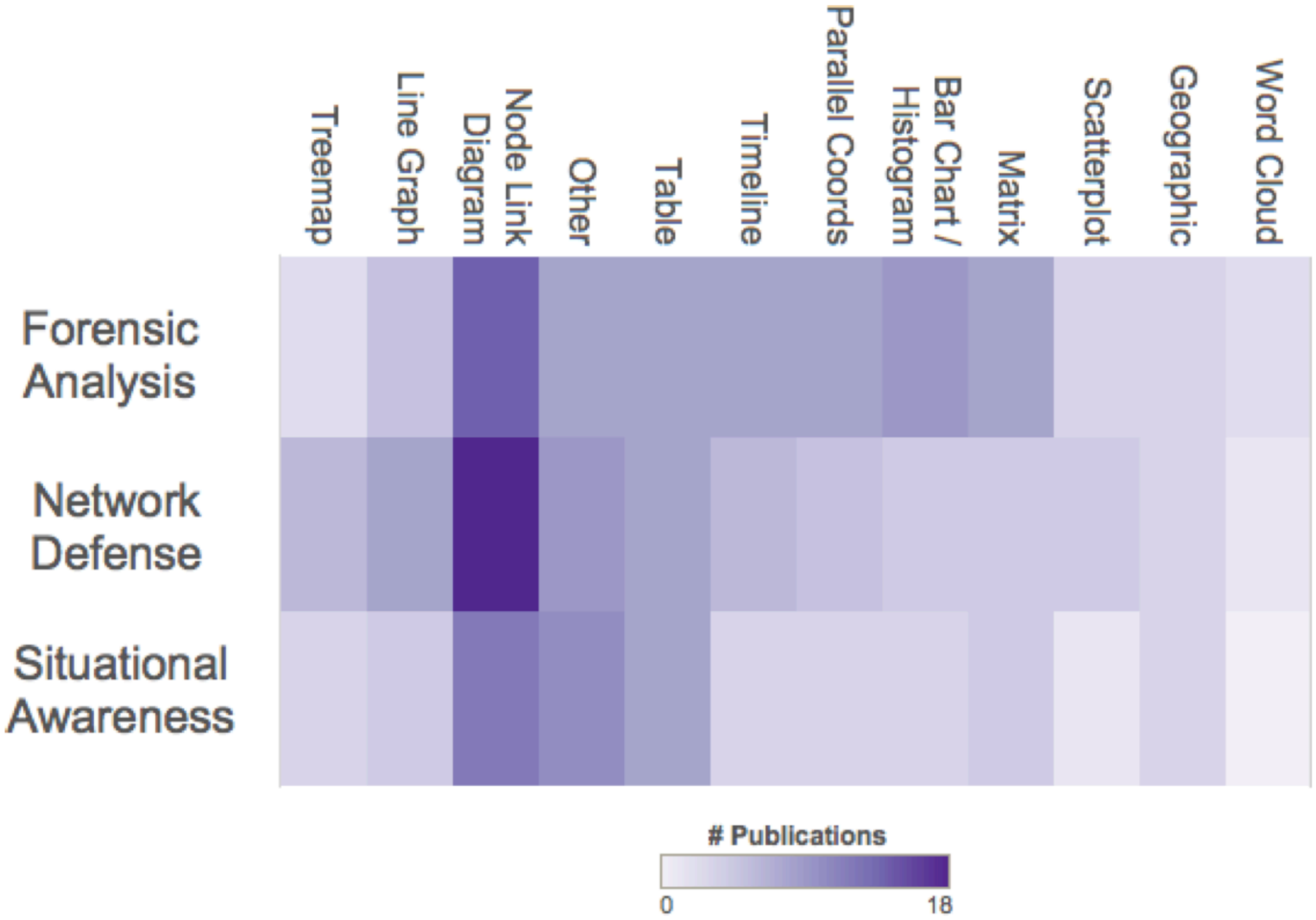
VizSec papers 2004—2015



Source: [3]

Utilization of Visualizations

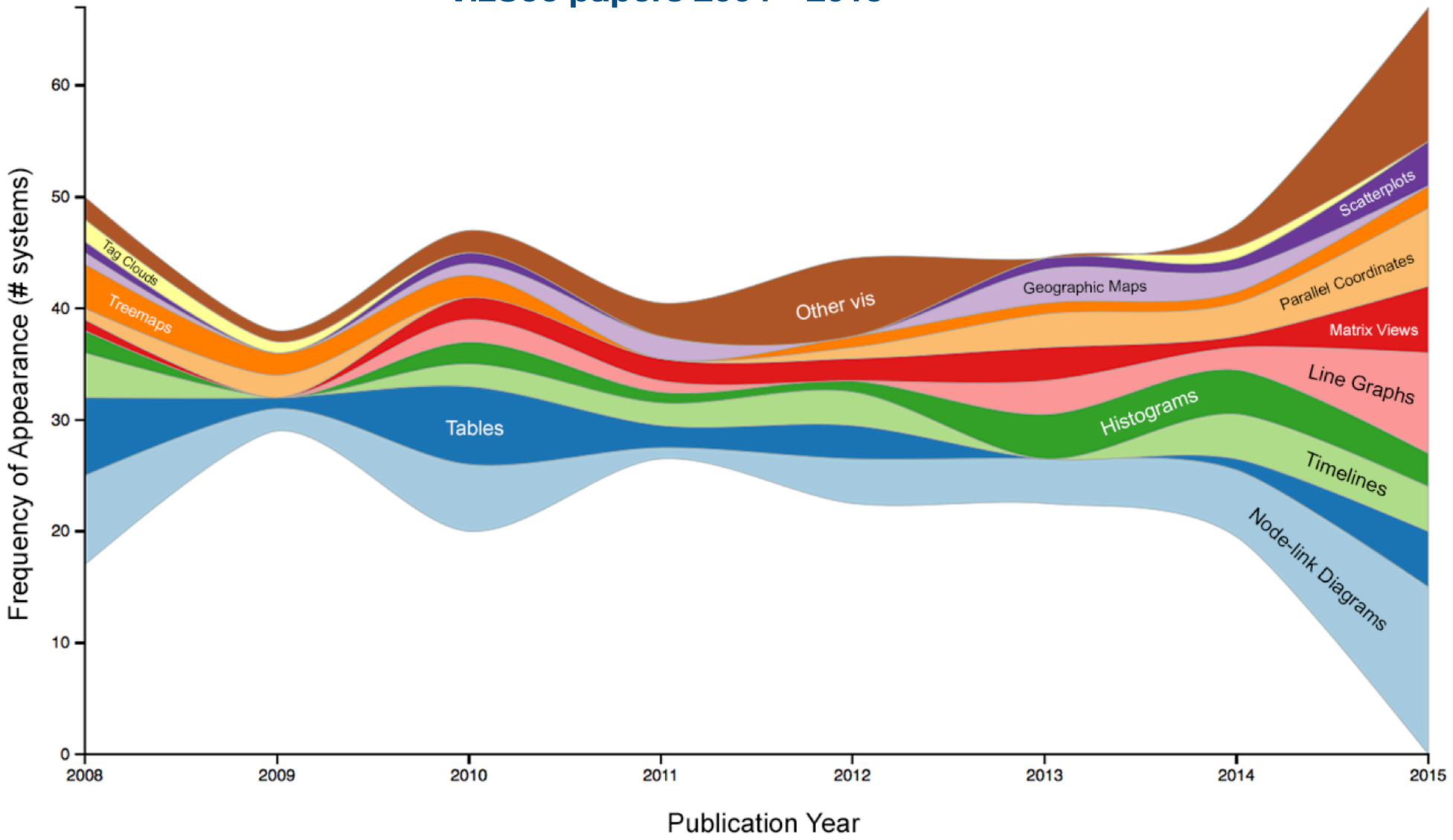
VizSec papers 2004—2015



Source: [3]

Utilization of Visual Metaphors

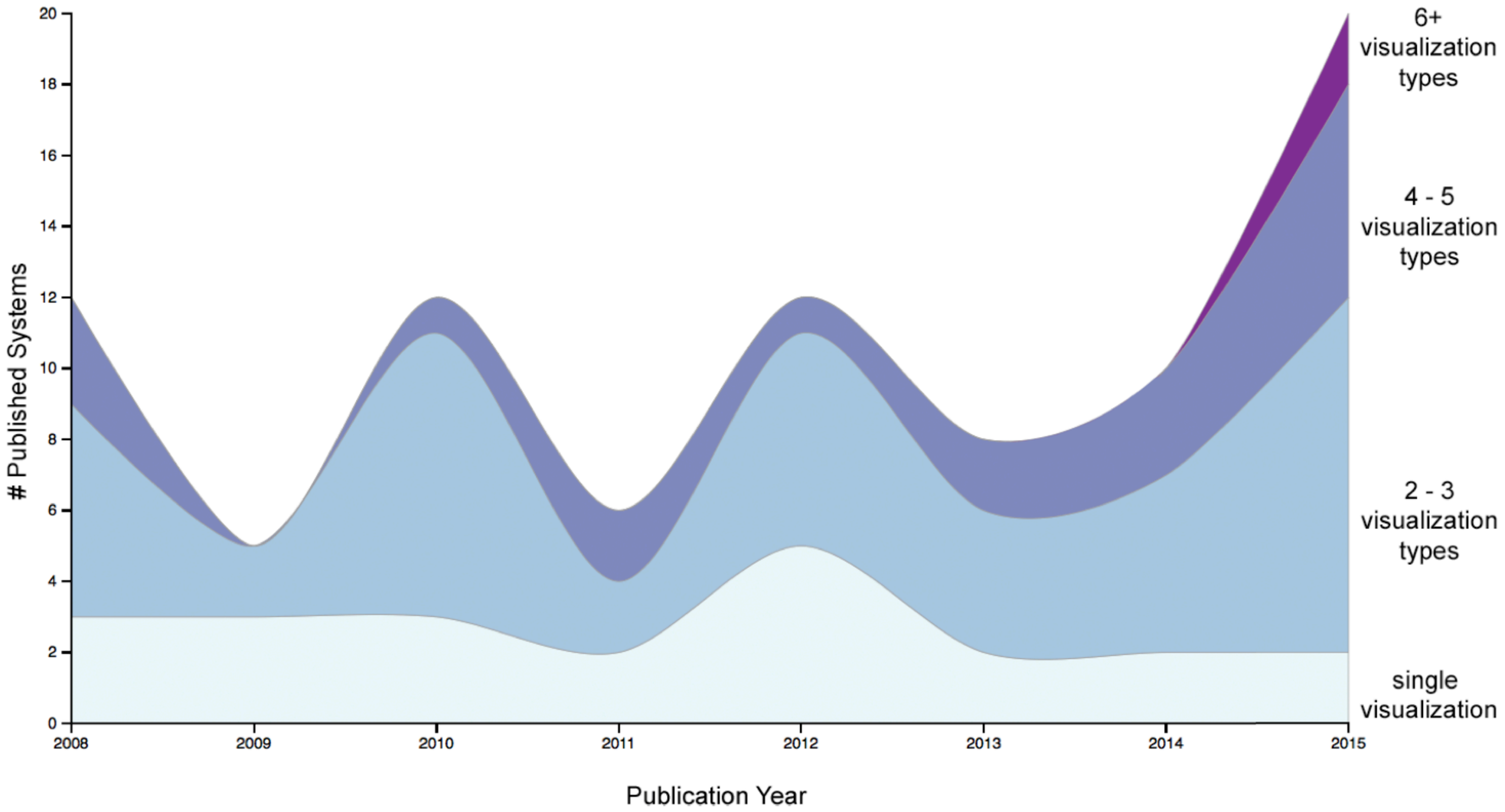
VizSec papers 2004—2015



Source: [3]

Interface Complexity

VizSec papers 2004—2015



Source: [3]

Take-aways

- Cybersecurity visualizations (as any others) span multiple subcategories
- Common 2D charts are predominant, complex visualizations are mostly research prototypes only
- The commercial tools use only basic visualizations …
- … which still need improvements
- Research prototypes

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