Data Science for Cybersecurity
Hand-on Lab

September 25, 2024

InfoSec World 2024

#infosecworld

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DM24-1042

Devin Cortese
Data Scientist

Clarence Worrell, PhD, PE
Senior Data Scientist

Thomas Scanlon, PhD
Technical Manager

Software Engineering Institute
Carnegie Mellon University

Data Science Tools

Data Science Tools

- **No-code and low-code**
  - Excel (spreadsheets and macros)
  - Orange (drag-and-drop machine learning)

- **Code-based tools**
  - Python (general language, many data science libraries)
  - R (statistics)
  - MATLAB (engineering)

- ***Many*** **other options**

The BETH Dataset

BETH Dataset

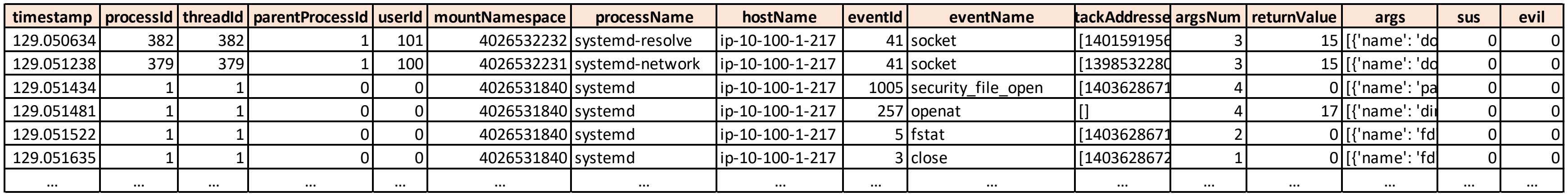
BETH* is a real cybersecurity dataset published in 2021 as a benchmark for anomaly detection researchers

- 8 million records, generated by 23 hosts, during 5 discontiguous hours
- Each host includes benign traffic as well as at most one single attack
- Each record is labeled as to whether it is “benign” or “malicious”

*Highnam, K., Arulkumaran, K., Hanif, Z., & Jennings, N. R. (2021). "BETH dataset: Real Cybersecurity Data for Anomaly Detection Research." ICML 2021 Workshop on Uncertainty and Robustness in Deep Learning. http://www.gatsby.ucl.ac.uk/~balaji/udl2021/accepted-papers/UDL2021-paper-033.pdf

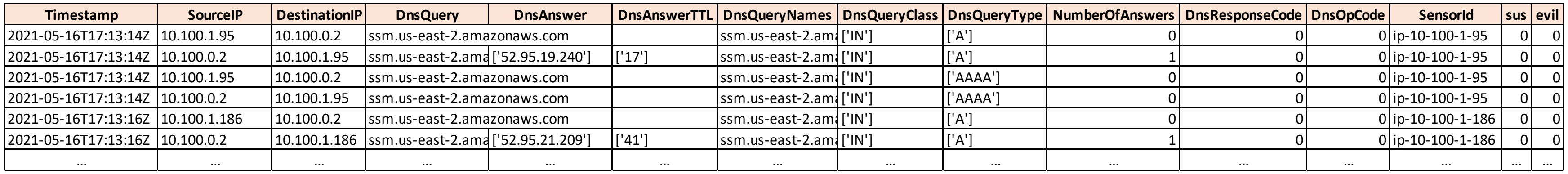
BETH Dataset (cont.)

- System log files



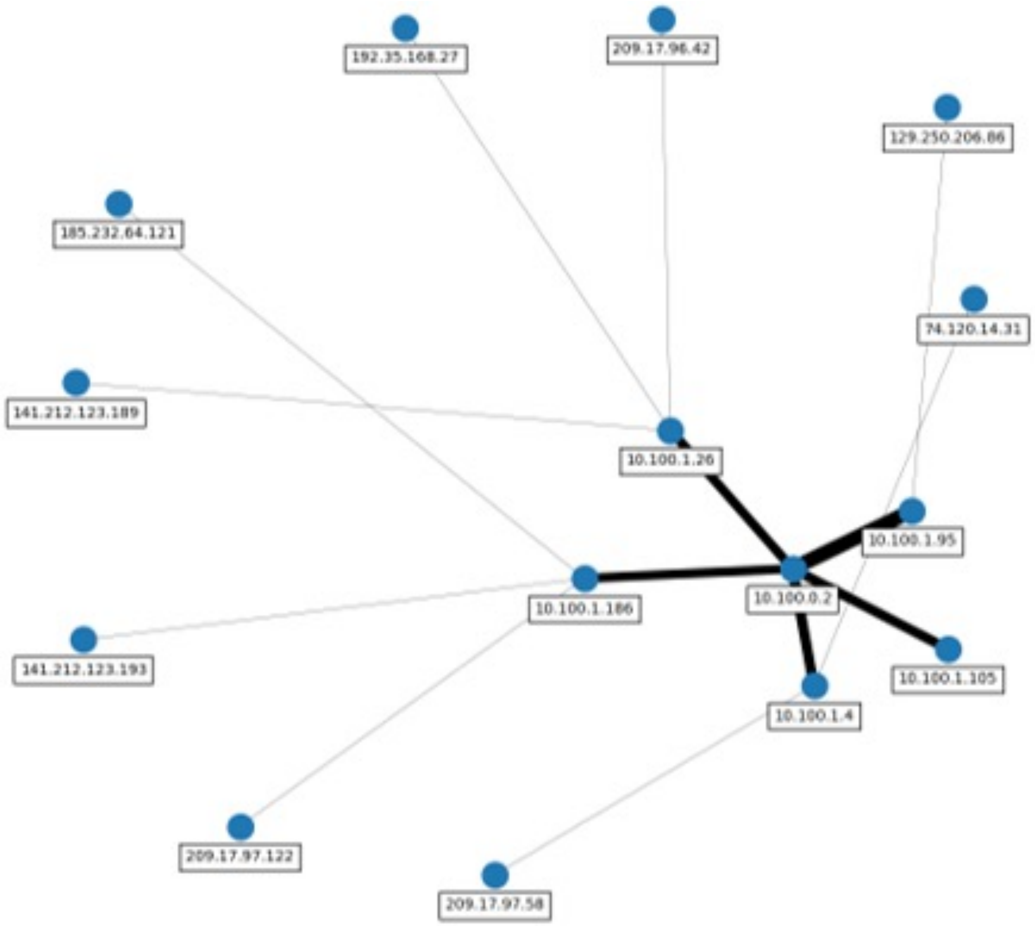
timestamp	processId	threadId	parentProcessId	userId	mountNamespace	processName	hostName	eventId	eventName	tackAddresse	argsNum	returnValue	args	sus	evil
129.050634	382	382	1	101	4026532232	systemd-resolve	ip-10-100-1-217	41	socket	[1401591956	3	15	[{'name': 'do	0	0
129.051238	379	379	1	100	4026532231	systemd-network	ip-10-100-1-217	41	socket	[1398532280	3	15	[{'name': 'do	0	0
129.051434	1	1	0	0	4026531840	systemd	ip-10-100-1-217	1005	security_file_open	[1403628671	4	0	[{'name': 'pa	0	0
129.051481	1	1	0	0	4026531840	systemd	ip-10-100-1-217	257	openat	[]	4	17	[{'name': 'di	0	0
129.051522	1	1	0	0	4026531840	systemd	ip-10-100-1-217	5	fstat	[1403628671	2	0	[{'name': 'fd	0	0
129.051635	1	1	0	0	4026531840	systemd	ip-10-100-1-217	3	close	[1403628672	1	0	[{'name': 'fd	0	0
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

- DNS query log files

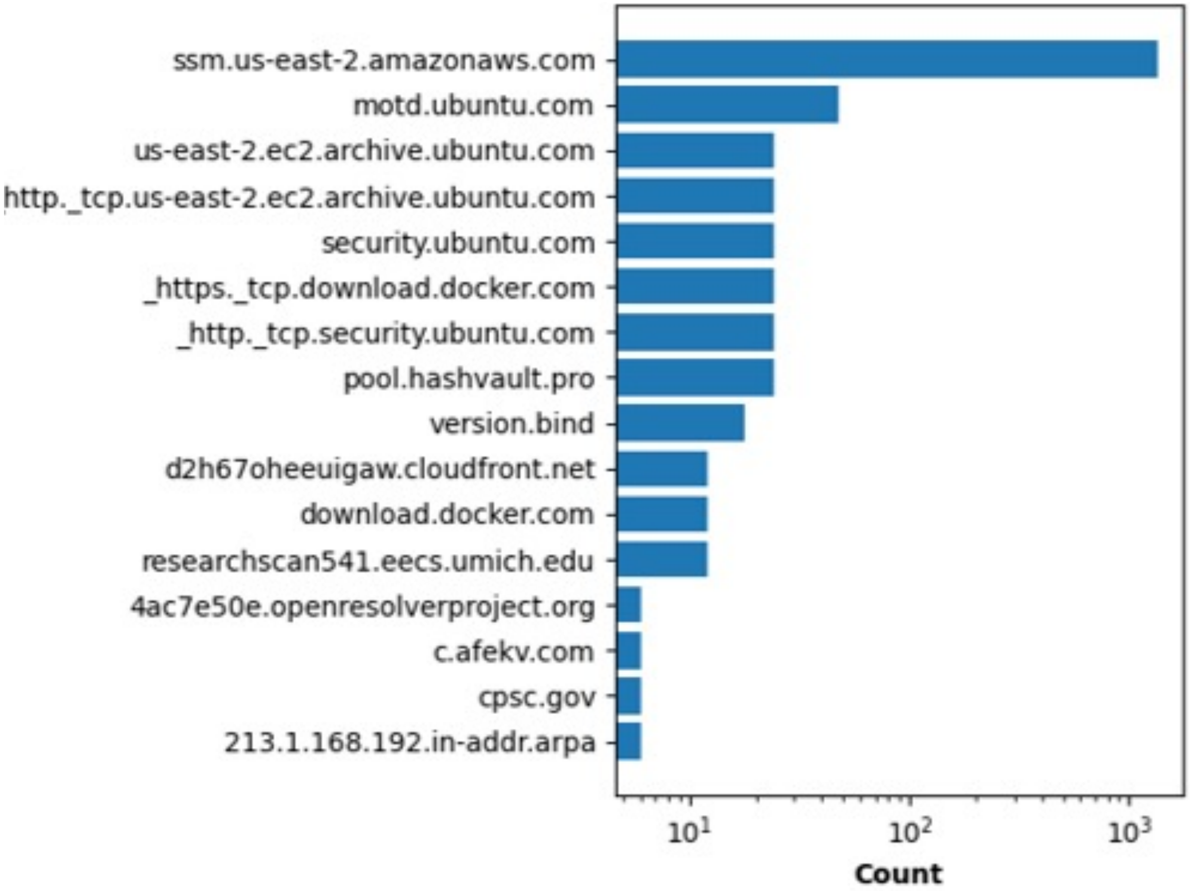


Timestamp	SourceIP	DestinationIP	DnsQuery	DnsAnswer	DnsAnswerTTL	DnsQueryNames	DnsQueryClass	DnsQueryType	NumberOfAnswers	DnsResponseCode	DnsOpCode	SensorId	sus	evil
2021-05-16T17:13:14Z	10.100.1.95	10.100.0.2	ssm.us-east-2.amazonaws.com			ssm.us-east-2.ama	['IN']	['A']	0	0	0	ip-10-100-1-95	0	0
2021-05-16T17:13:14Z	10.100.0.2	10.100.1.95	ssm.us-east-2.ama	['52.95.19.240']	['17']	ssm.us-east-2.ama	['IN']	['A']	1	0	0	ip-10-100-1-95	0	0
2021-05-16T17:13:14Z	10.100.1.95	10.100.0.2	ssm.us-east-2.amazonaws.com			ssm.us-east-2.ama	['IN']	['AAAA']	0	0	0	ip-10-100-1-95	0	0
2021-05-16T17:13:14Z	10.100.0.2	10.100.1.95	ssm.us-east-2.amazonaws.com			ssm.us-east-2.ama	['IN']	['AAAA']	0	0	0	ip-10-100-1-95	0	0
2021-05-16T17:13:16Z	10.100.1.186	10.100.0.2	ssm.us-east-2.amazonaws.com			ssm.us-east-2.ama	['IN']	['A']	0	0	0	ip-10-100-1-186	0	0
2021-05-16T17:13:16Z	10.100.0.2	10.100.1.186	ssm.us-east-2.ama	['52.95.21.209']	['41']	ssm.us-east-2.ama	['IN']	['A']	1	0	0	ip-10-100-1-186	0	0
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

DNS Query Traffic between IP Addresses



DNS Query Volume by Domain



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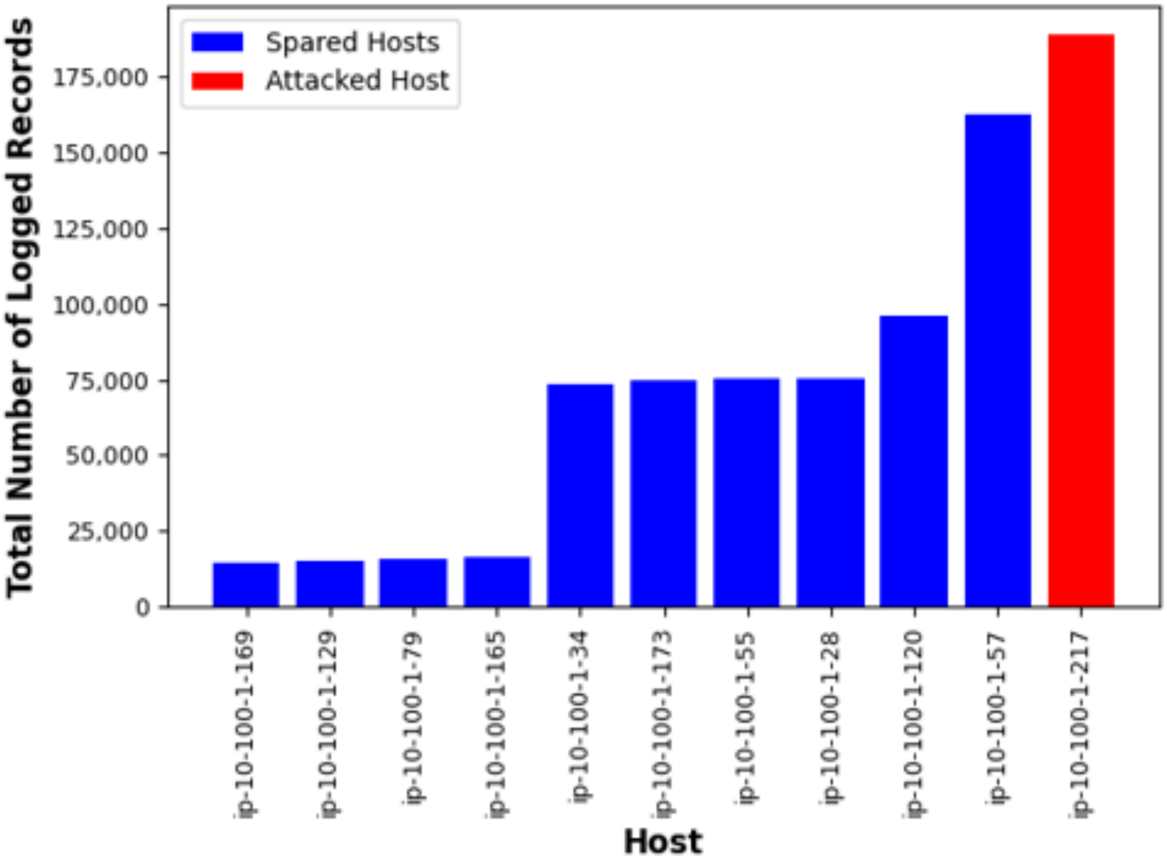
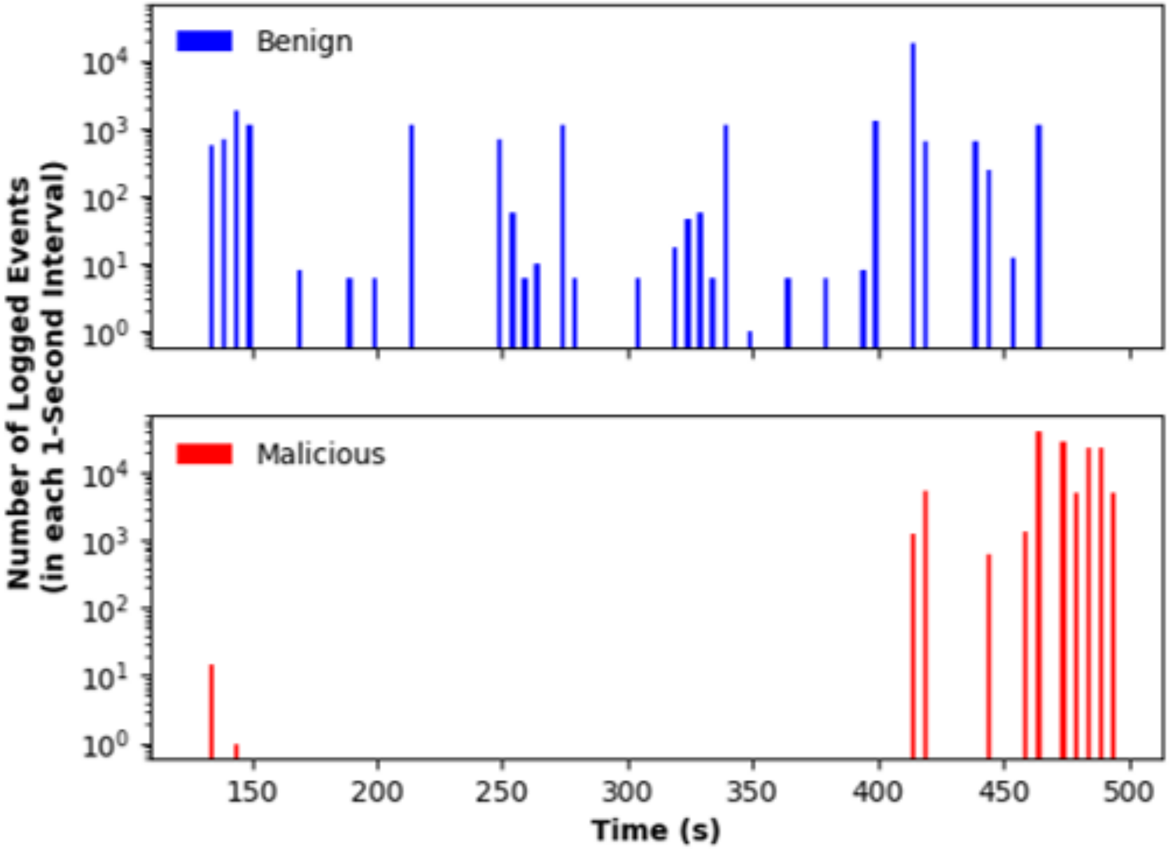
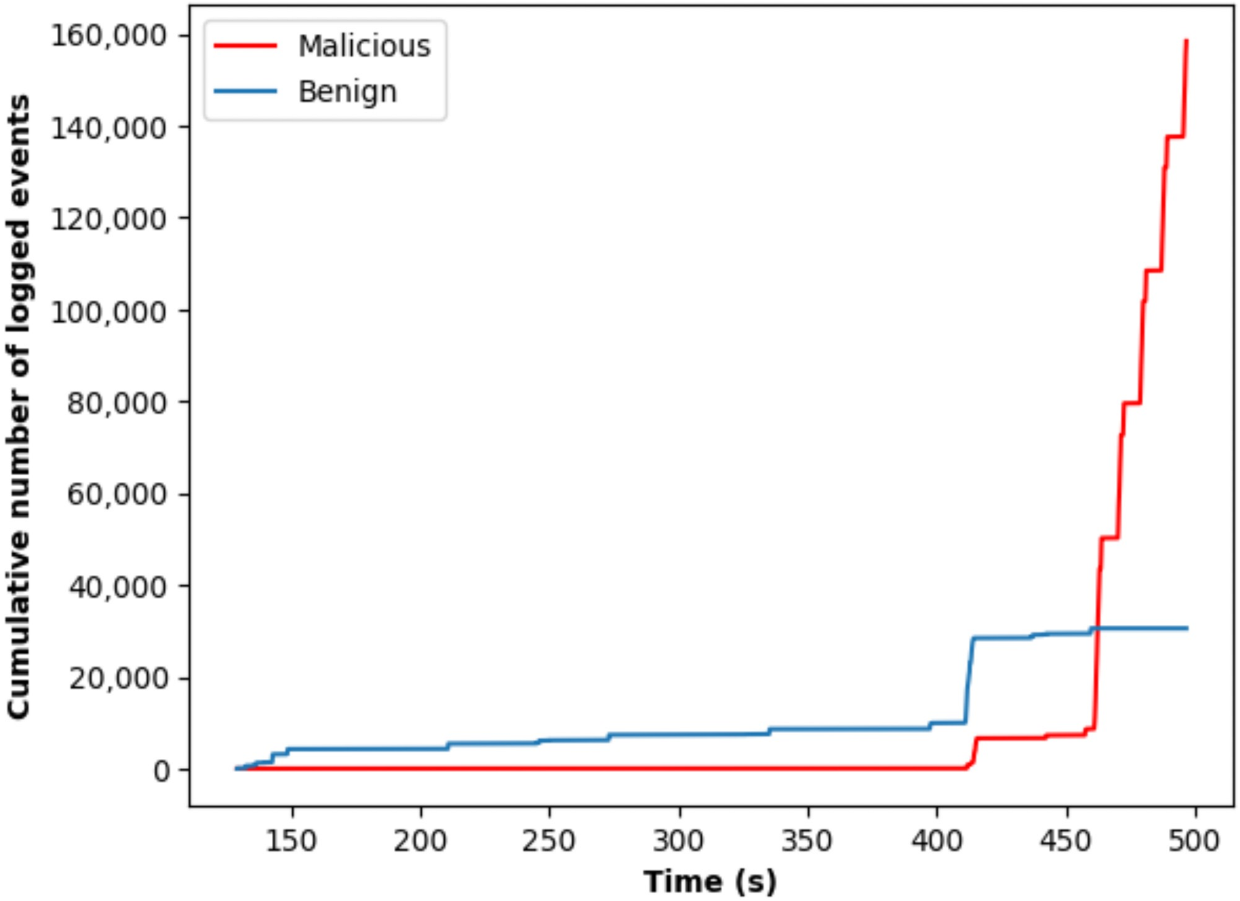
Logged Events by Host



Logged Events in Time on the Attacked Host



Logged Events in Time on the Attacked Host



Lab Environment Setup

Environment Options

- **Option 1: Google Colab (recommended)**
  - Write and execute code in a browser
  - No installation required
  - Requires gmail account
  - https://colab.research.google.com

- **Option 2: Student-preferred python environment**

Tour of Google Colab Functionality

- Add and execute code cells
- Add formatted text cells
- Import data

Download Lab Files from GitHub

https://github.com/CDS-Team/InfoSecWorld24

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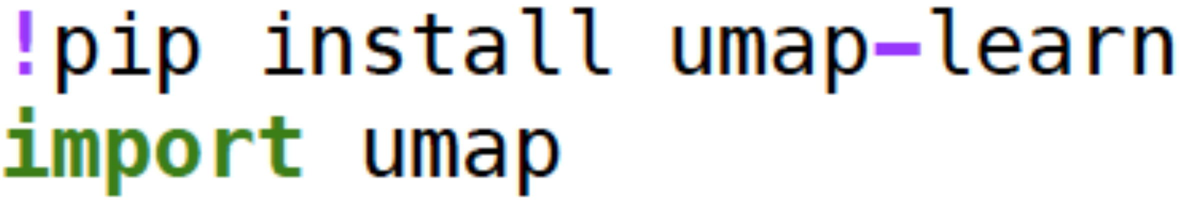
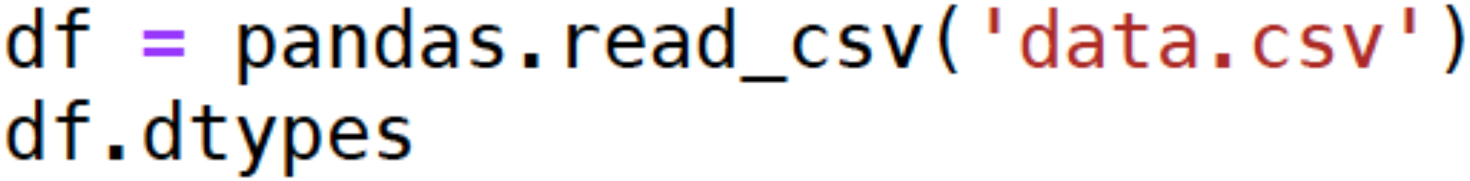
Hands-on Exercise

Install and Import Libraries



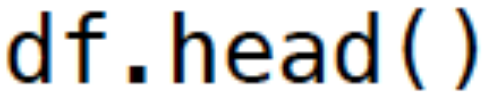
```
!pip install umap-learn
import umap
```

Read .csv into Pandas Dataframe



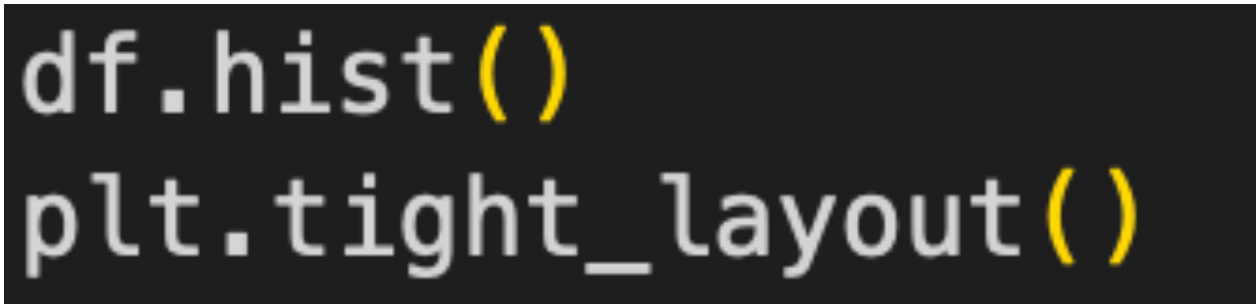
```
df = pandas.read_csv('data.csv')
df.dtypes
```

View First 5 Records



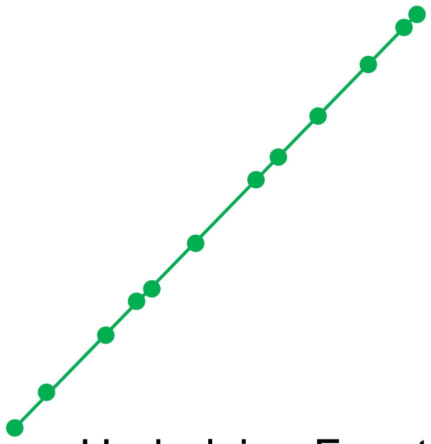
```
df.head()
```

Histograms of the Raw Data

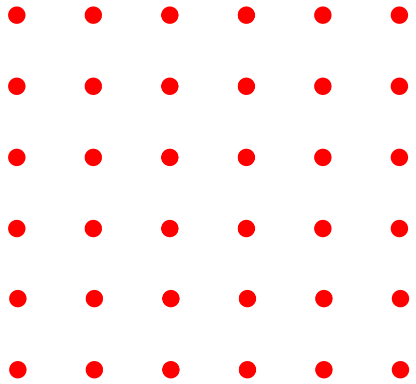


```
df.hist()
plt.tight_layout()
```

Cyber-Specific Challenges (cont.)



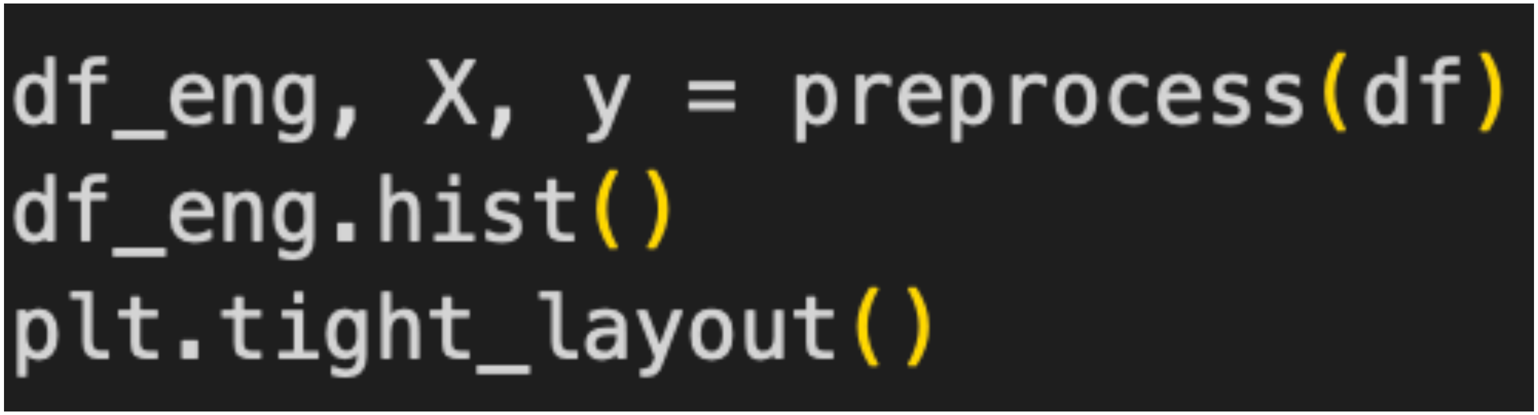
Underlying Function



Underlying Function?

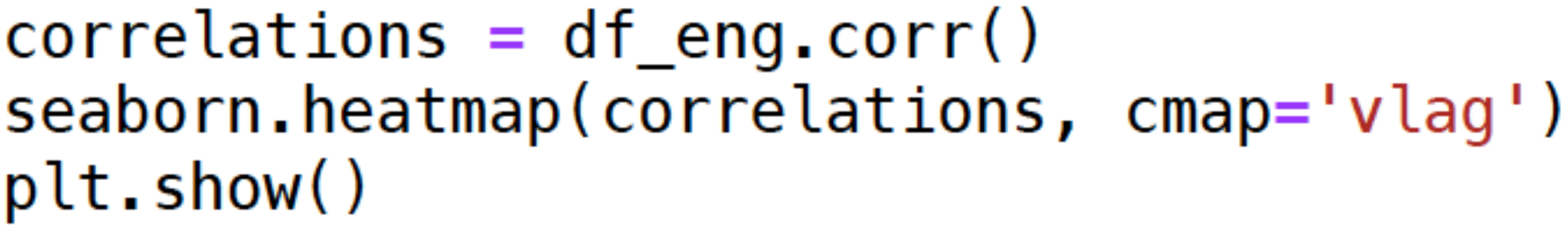
Cyber data often limit us to basic statistics and challenge the modeling of relationships

Histograms of the Engineered Features



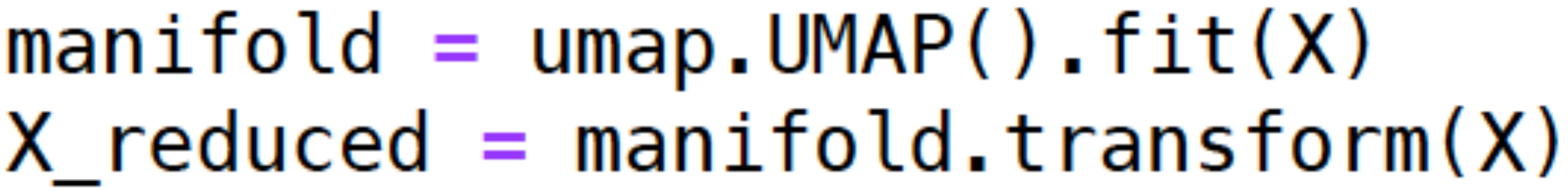
```
df_eng, X, y = preprocess(df)
df_eng.hist()
plt.tight_layout()
```

Correlations Plot



```
correlations = df_eng.corr()
seaborn.heatmap(correlations, cmap='vlag')
plt.show()
```

UMAP Dimensionality Reduction



```
manifold = umap.UMAP().fit(X)
X_reduced = manifold.transform(X)
```

Outlier Detection in Cybersecurity

- Consider a busy SOC analyst
- Recently installed NDR/EDR anomaly detection
- System promises to identify novel zero-day threats through the power of ML…

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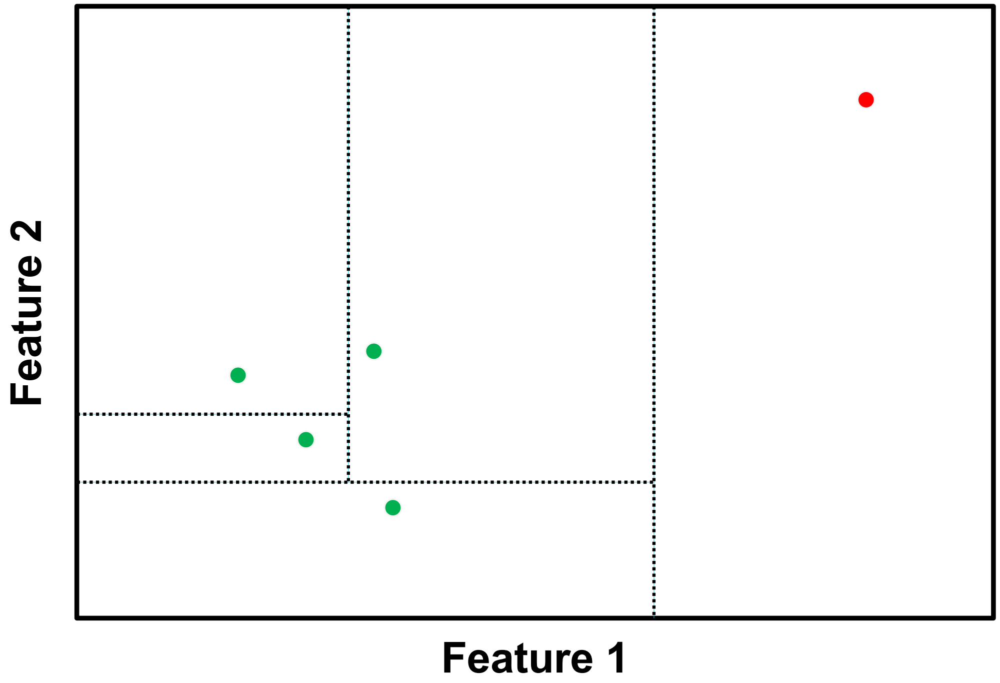
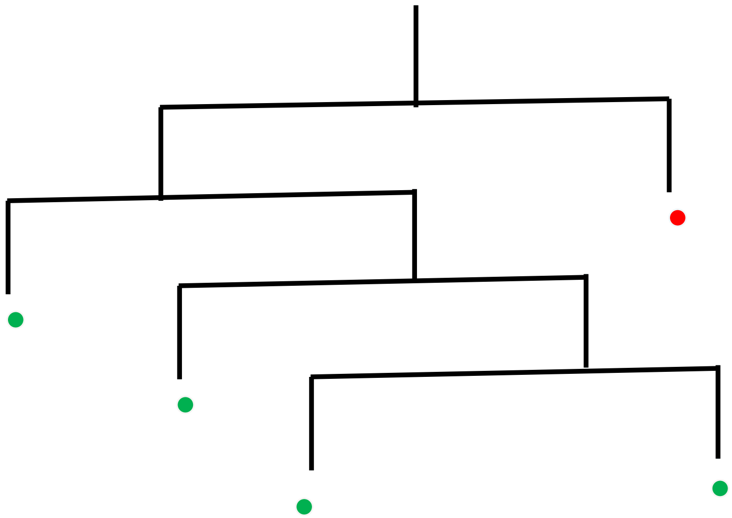
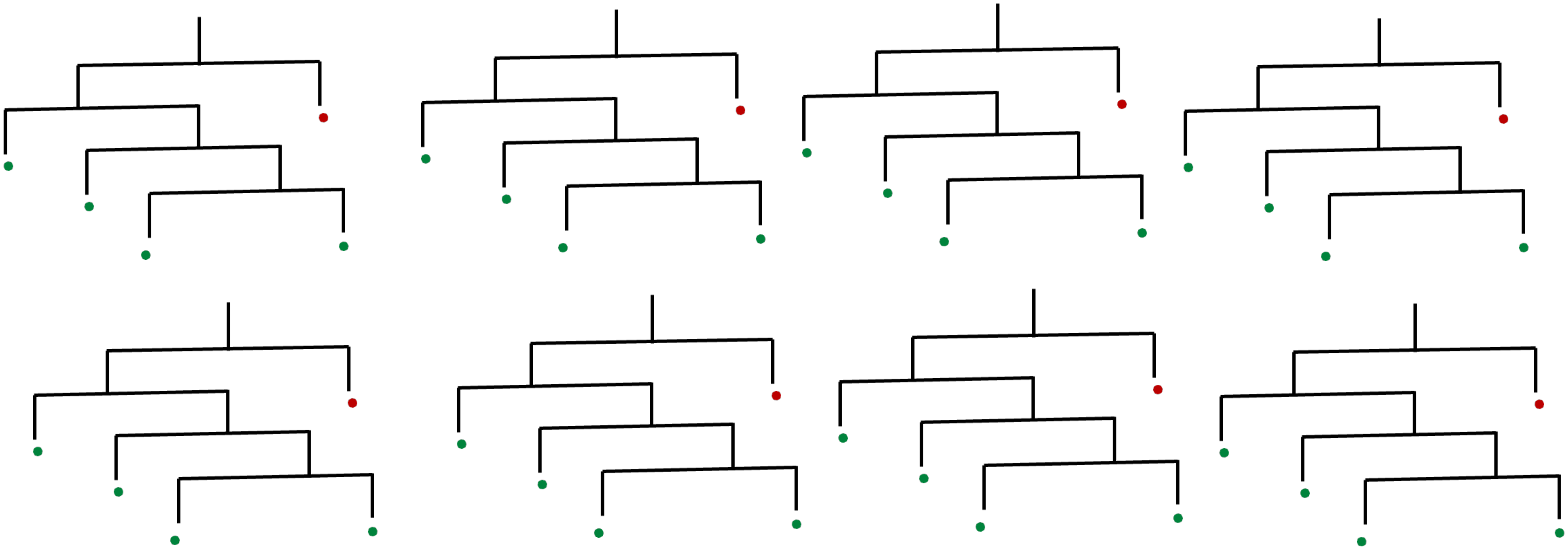
Isolation Forest





Anomaly score based on path length

Isolation Forest (cont.)



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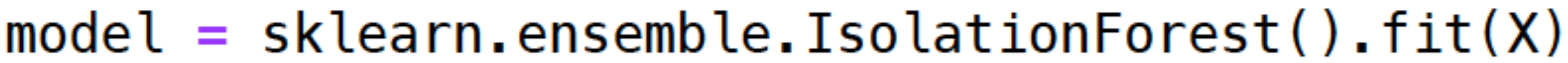
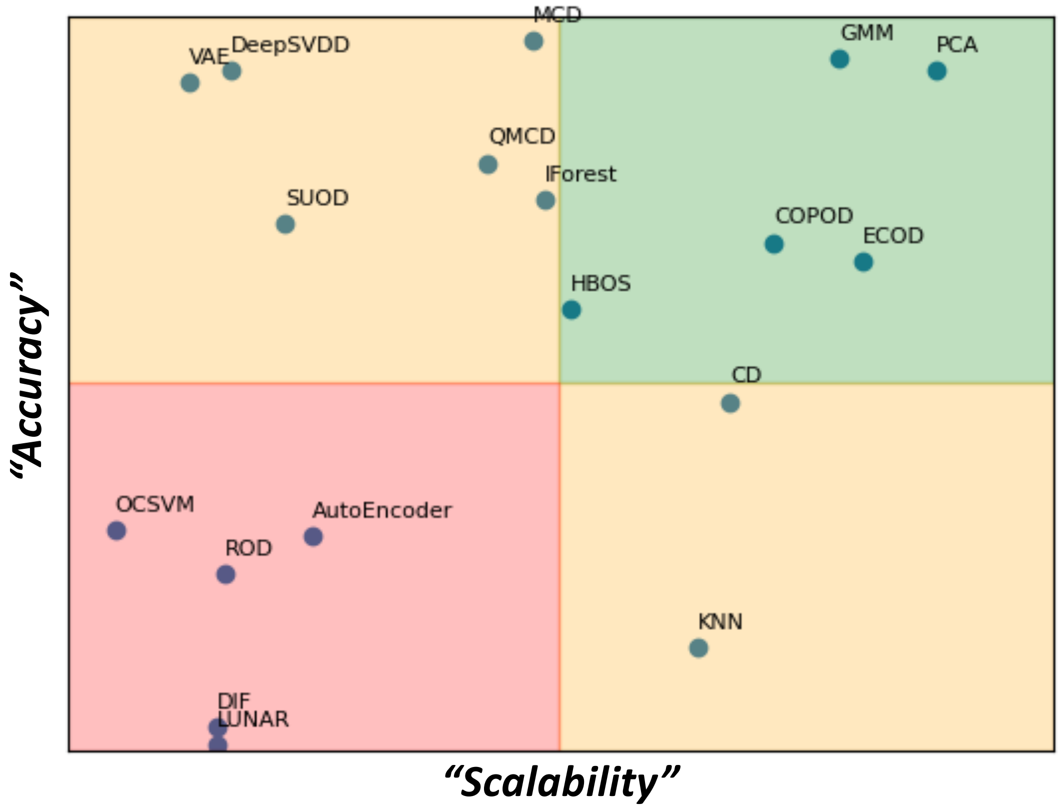
Fit Anomaly Detection Model



```
model = sklearn.ensemble.IsolationForest().fit(X)
```

Algorithm Performance



- Accuracy-scalability tradeoff
- We tested 18 algorithms on a cybersecurity dataset
- However, these results do not generalize
- ***Algorithm performance is application-specific***

THANK YOU!