Data Clustering for Anomaly Detection in Network Intrusion Detection

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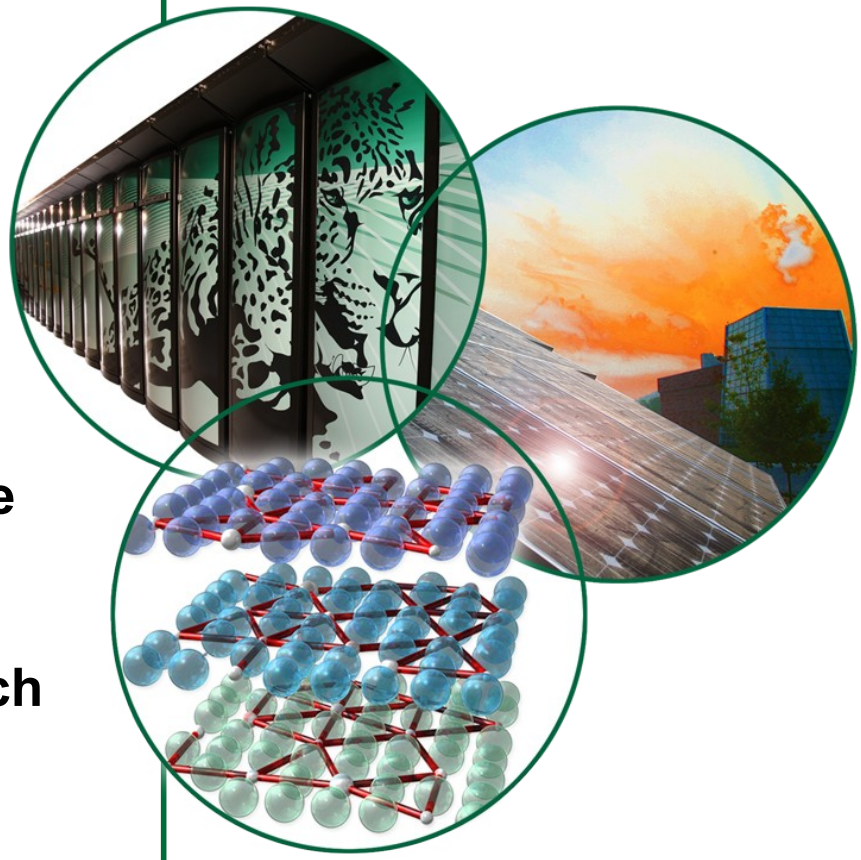

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Outline

- Introduction and motivation
- Background
  - Network intrusion detection
  - Anomaly detection
  - Data clustering
- Performance evaluation
- Summary

Introduction and motivation

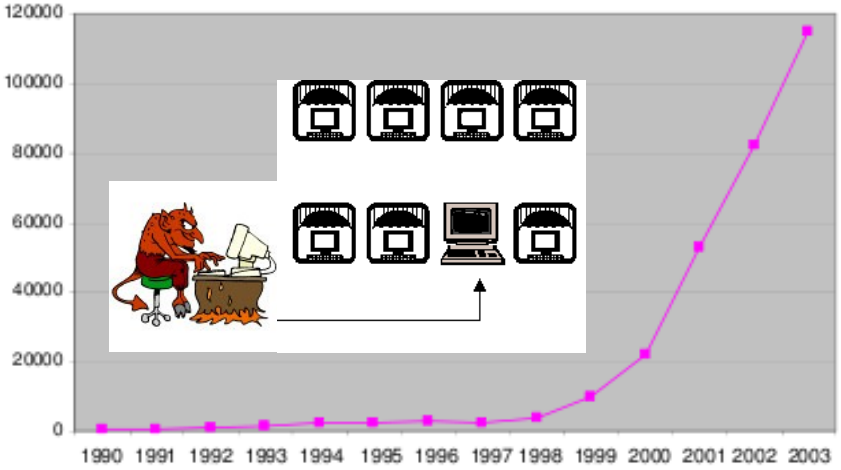


Figure 1. Computer incidents report (CERT/CC)

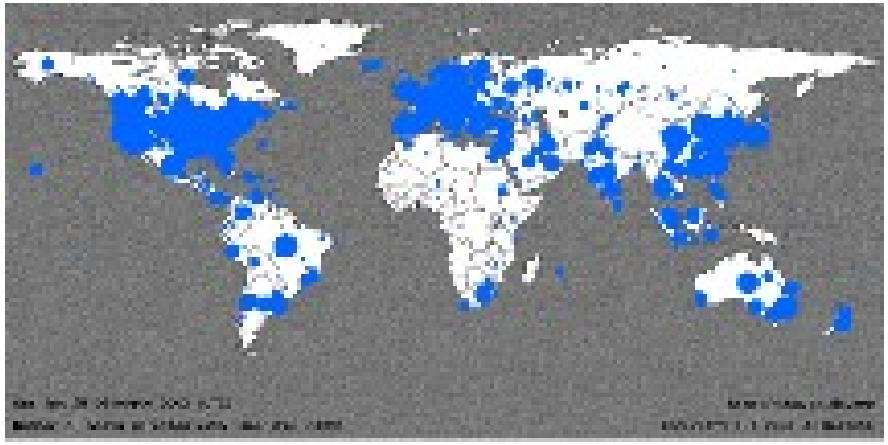


Figure 2. Worm spread after 30 min www.caida.org

- **Network intrusions pose a high security risk**
- **NIDS aim to identify intrusions**
- **NIDS capable of detecting new emerging threats**
- **Main goal**
  - **Present different methods for network intrusion detection**
  - **Select one method and evaluate its performance**

Network intrusion detection methods

- Signature-based
  - Based on signatures of known attacks
  - Signature database has to be manually updated
  - Expensive and time consuming
  - Cannot detect new emerging threats
- Misuse detection
  - Models built from labeled data sets
  - Samples labeled as 'normal' or 'attack'
  - Expensive and time consuming
  - Can not detect new threats
- Anomaly detection
  - Identify anomalies, deviations from 'normal' behavior
  - Can detect new emerging threats
  - Potential false alarm rate

Anomaly detection

- Supervised methods
  - Models built from 'normal' labeled samples
  - Expensive and time consuming
- Unsupervised method (data clustering)
  - Group unlabeled patterns into clusters based on similarities
  - Do not required labeled samples
  - Anomalies are deviation from 'normal' clusters

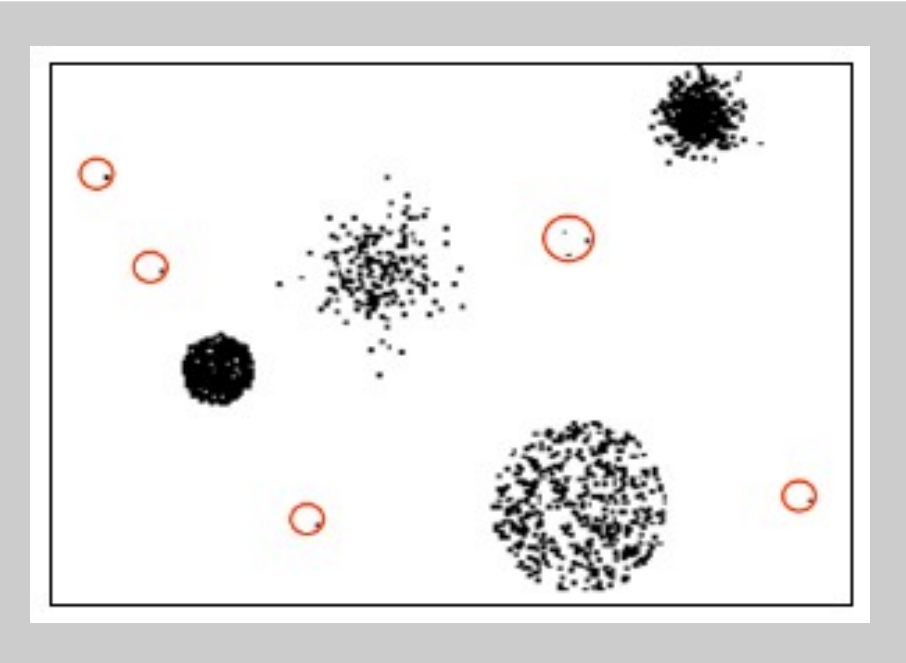


Figure 3. Clustering for anomaly detection

Basic steps for data clustering

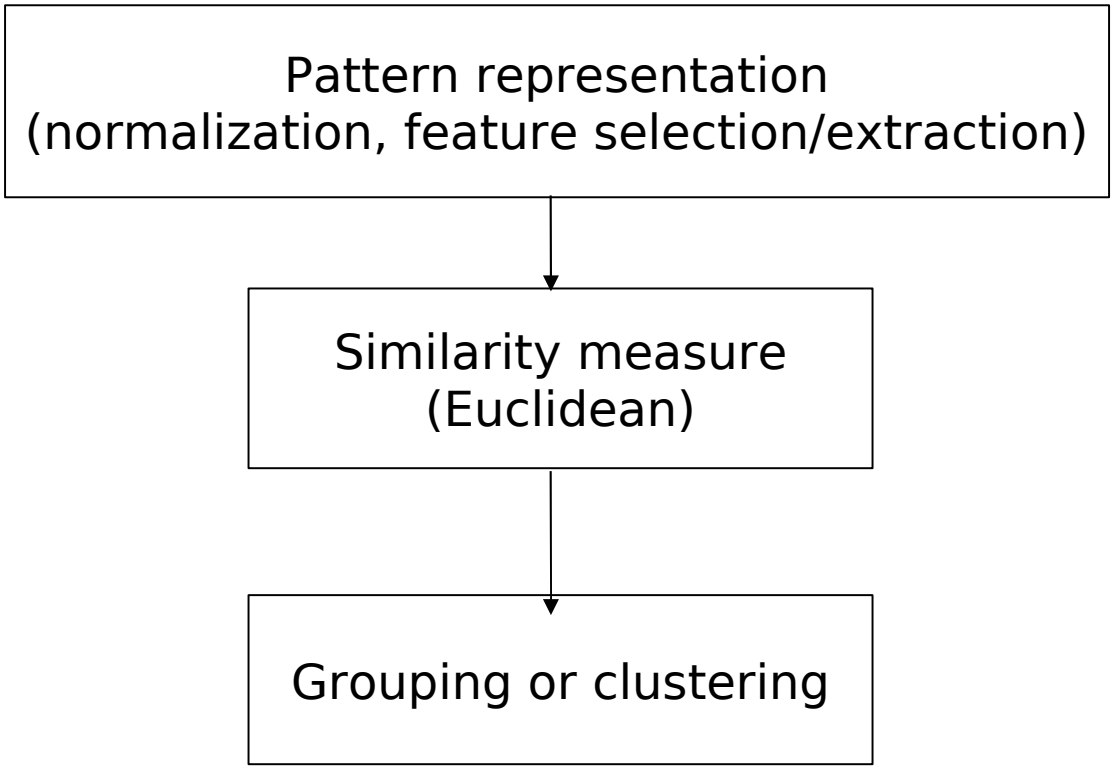


Figure 4. Data clustering steps

Algorithm

- Kmeans
  - Choose number of clusters
  - Initialize centroids or clusters centers
  - Assign each sample to nearest cluster centroid
  - Calculate means to be new centroid of each cluster

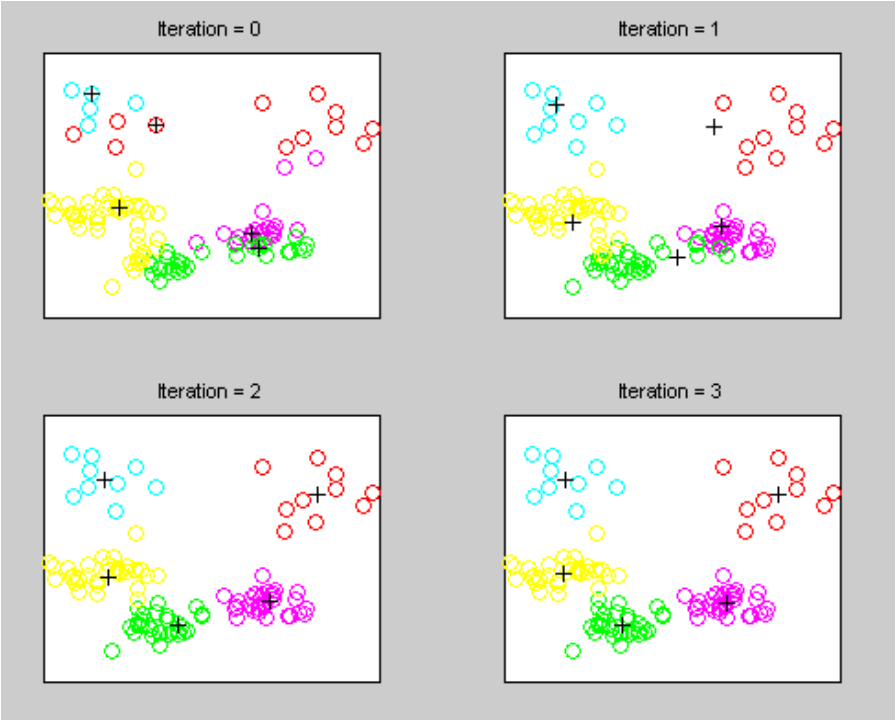
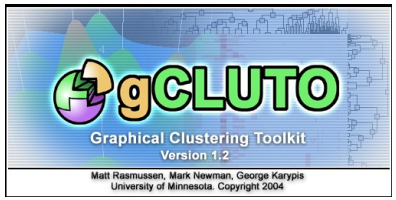
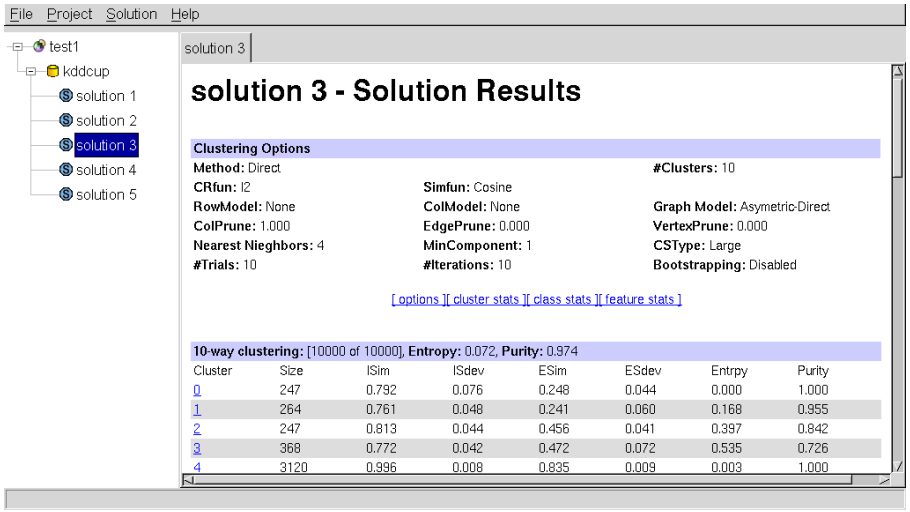


Figure 5. Kmeans clustering algorithm

Software

- **Cluto (University of Minnesota)**
  - **Clustering toolkit**
  - **Simple interface**
  - **3-D cluster output visualization**





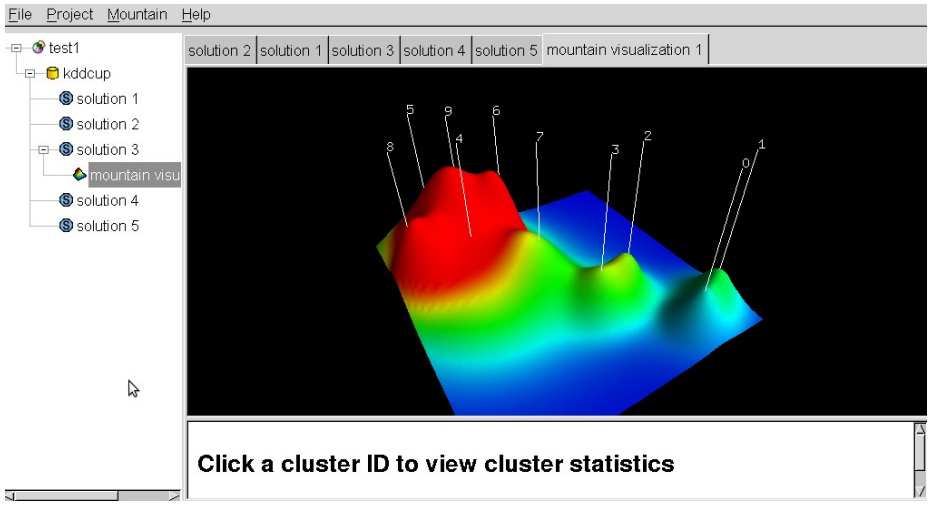


Figure 6. Cluto software for data clustering

Data set

Kddcup 1999

Based on the Darpa 1998 data set from MIT Lincoln Lab

- Original data set
  - Total samples = 400,000
  - Total features = 41 (categorical and continuous values)
  - Types of attacks: DoS, Probe, U2R, R2L
- Data set used
  - Total samples = 9,200
  - Categorical features encoded to binary values
  - Total features = 80 (continuous and binary values)
  - Attacks 2% of samples

Performance metrics

- **Detection rate:** detected attacks / total attacks
- **False alarm rate:** normal classify as attacks / total normal

Performance evaluation

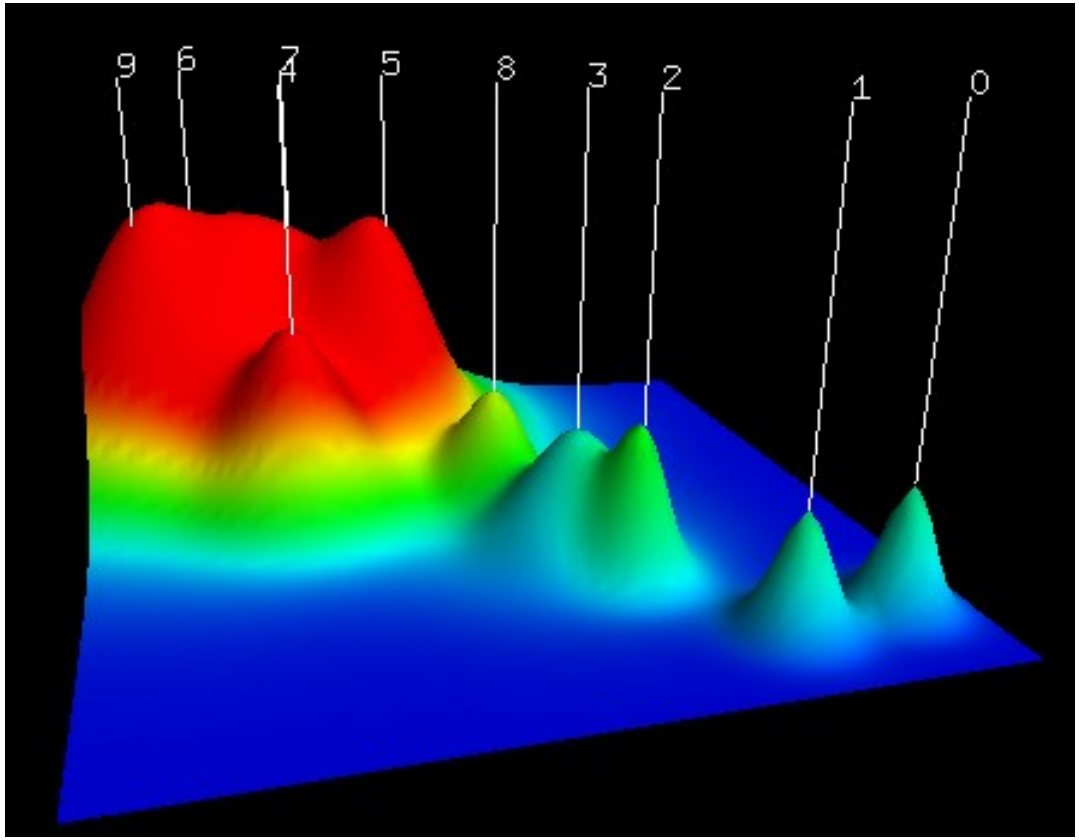


Figure 7. Clustering visualization for K = 10 using Cluto

- **Smaller clusters labeled as 'attacks'**
- **Big clusters labeled as 'normal'**

Performance evaluation

K = 10
(7 sec)

K = 20
(11 sec)

K = 30
(14 sec)

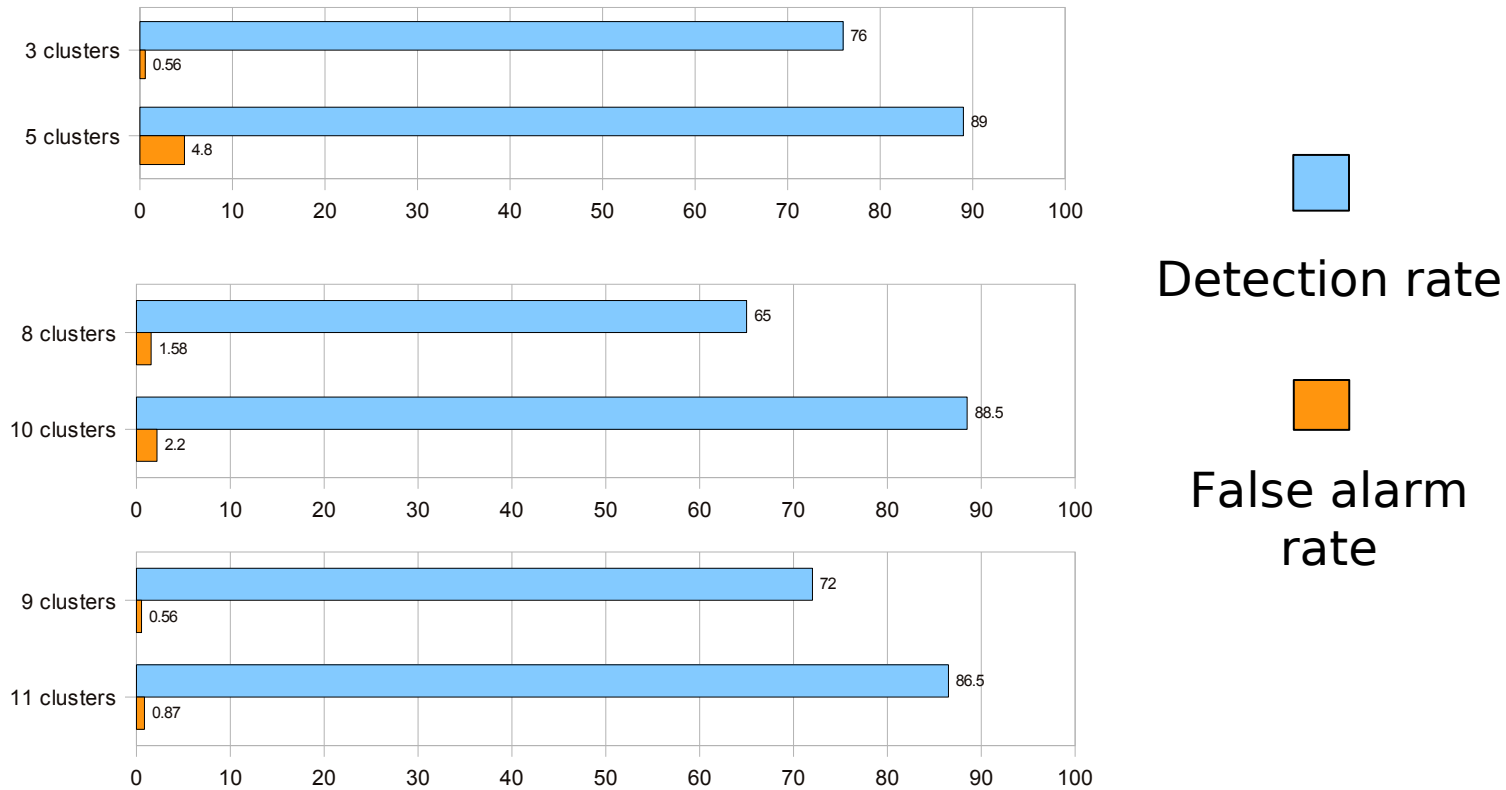


Figure 8. Bar plots of detection and false alarm rate

Clusters	Purity (0 → 1)
K=10	0.989
K=20	0.995
K=30	0.997

Summary

- Network intrusion detection
  - Methods
  - Advantages and disadvantages
- Method used
  - Data clustering for anomaly detection
  - Advantages
- Evalutation results
  - Increasing number of 'attacks' clusters affect the detection rate and false alarm rate
  - High detection rate can be achieved with a low false alarm rate

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Acknowledgements

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Thanks!!

Questions?