System Security Modeling of Feature Selection and Behavior Analysis for Efficient Malware Detection

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2016 Verizon Data Breach Investigations Report*

Trends and Numbers

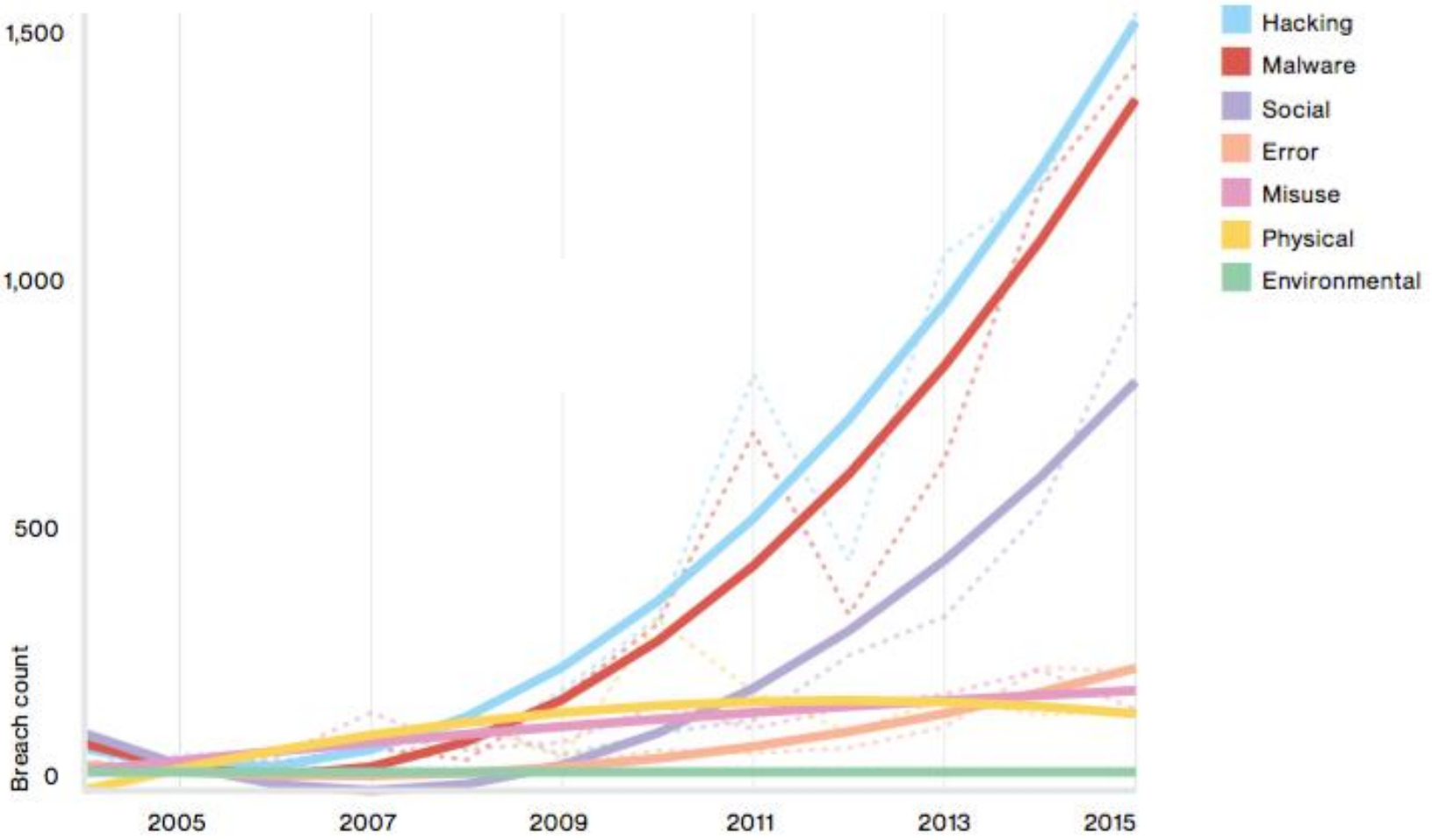

Figure 1: Growing number of breaches over time

*Source: www.verizonenterprise.com/resources/reports/rp_DBIR_2016_Report_en_xg.pdf

2016 Verizon Data Breach Investigations Report*

Trends and Numbers

Figure 2: Percentage of phishing emails resulting in "clicks"

*Source: www.verizonenterprise.com/resources/reports/rp_DBIR_2016_Report_en_xg.pdf

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Trends and Numbers

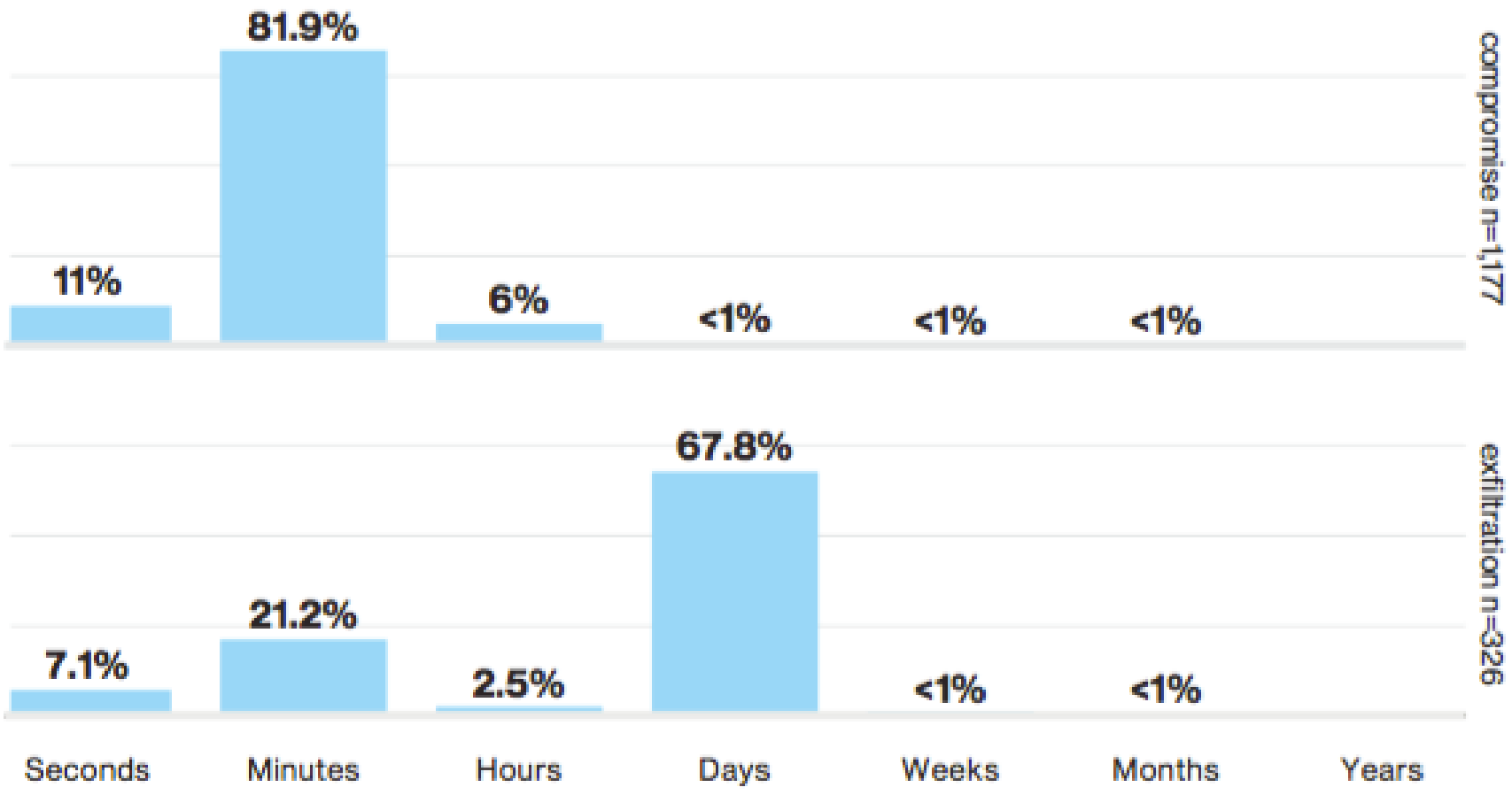

Figure 3: Average compromise and exfiltration times

*Source: www.verizonenterprise.com/resources/reports/rp_DBIR_2016_Report_en_xg.pdf

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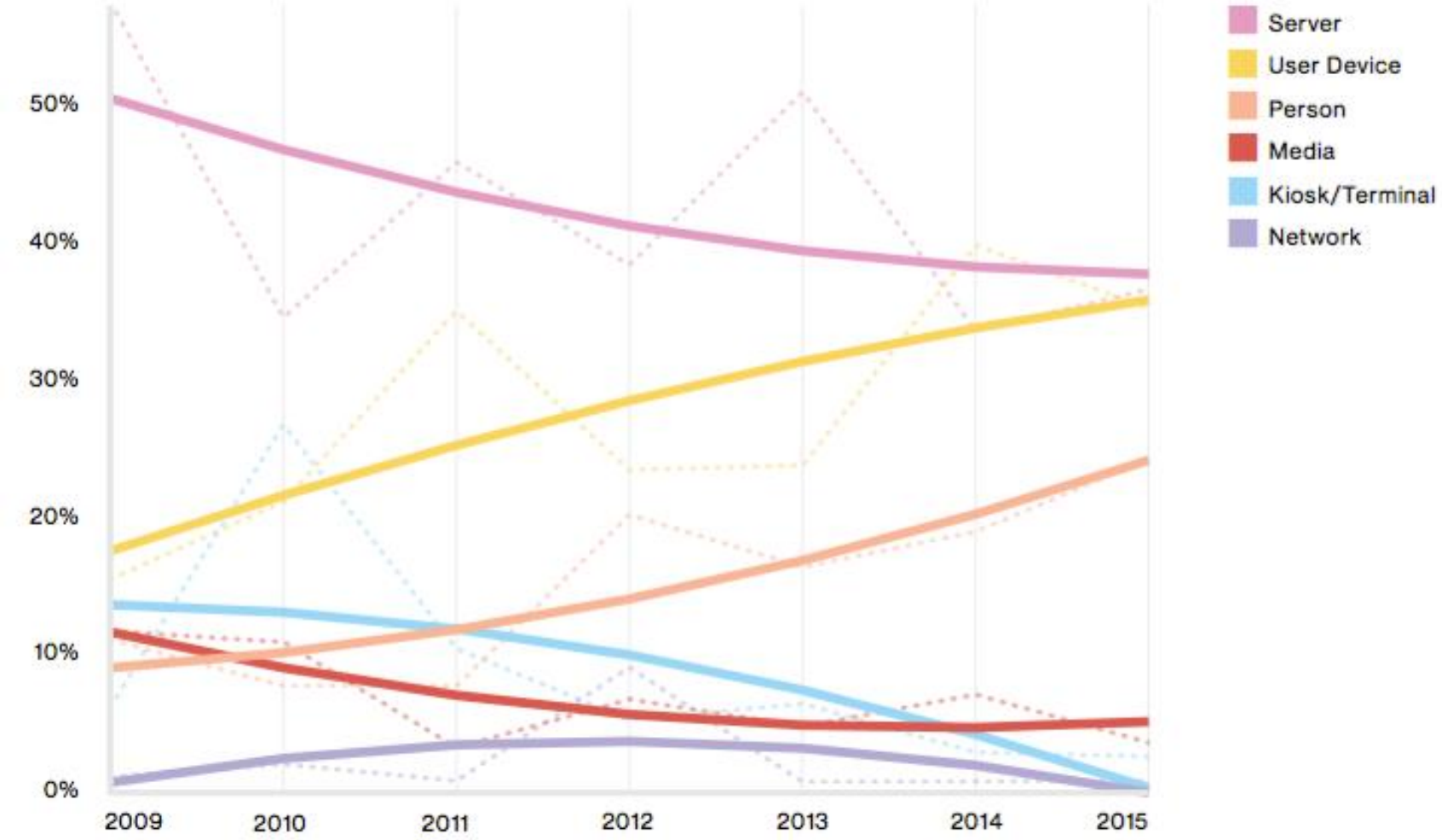


Figure 4: Compromises by Category

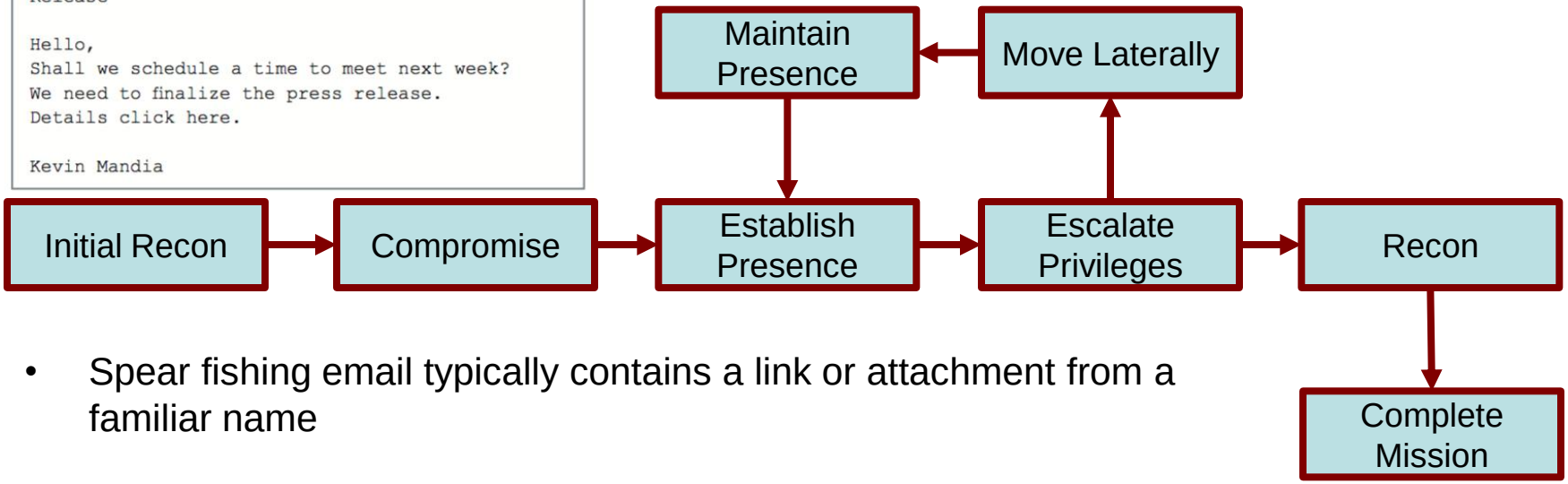
*Source: www.verizonenterprise.com/resources/reports/rp_DBIR_2016_Report_en_xg.pdf

Attack Methodology

```
Date: Wed, 18 Apr 2012 06:31:41 -0700
From: Kevin Mandia <kevin.mandia@rocketmail.com>
Subject: Internal Discussion on the Press
Release

Hello,
Shall we schedule a time to meet next week?
We need to finalize the press release.
Details click here.

Kevin Mandia
```



- Spear fishing email typically contains a link or attachment from a familiar name
- Victim will inadvertently open a backdoor for adversary
- Adversary will collect information about network and attempt to escalate privileges and move laterally from system to system
- Extremely difficult to detect an adversary that uses legitimate credentials
- When adversary finds target data, they will export the data to C2 servers

Source: https://www.fireeye.com/content/dam/fireeye-www/services/pdfs/mandiant-apt1-report.pdf

Model Features

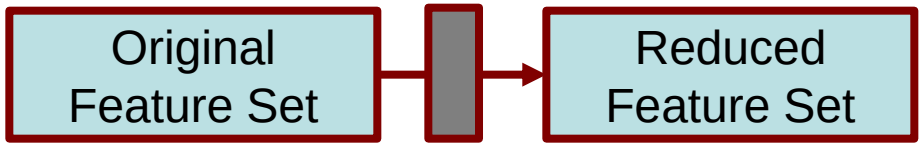
- A data set is comprised of features that represent the different characteristics of a sample
- Feature selection is a pre-processing step to classification in which important features are identified and the original feature set is reduced in order to improve classifier performance [Identify Relevance, Remove Redundancy]
- Constructed features can be created from the original feature set

Typical Malware Features

- N-grams, Metadata, Entropy, Opcode counts, Register Values, API calls

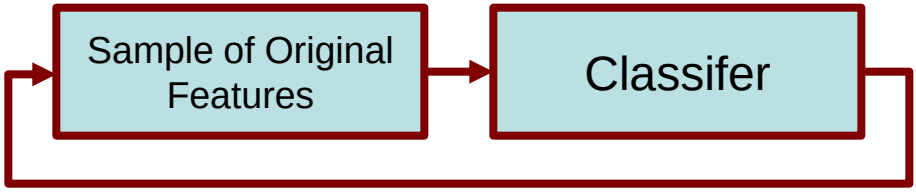
Filter Method

- Based on specific filter metrics



Wrapper Method

- Based on a feedback loop between classifier and feature selection algorithm



Classification

- Classifiers are trained with a training set of data
- Classifier accuracy is validated with cross-fold validation or a test data set
- The “Kernel Trick” can be applied to high dimensional data

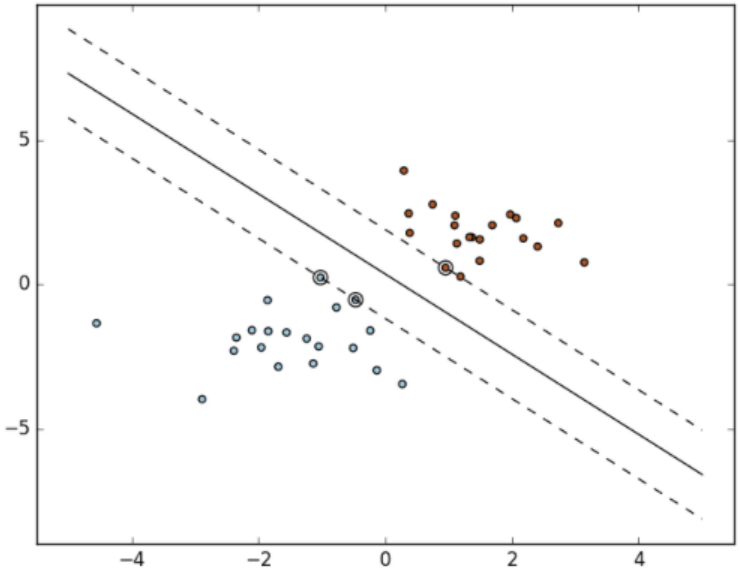
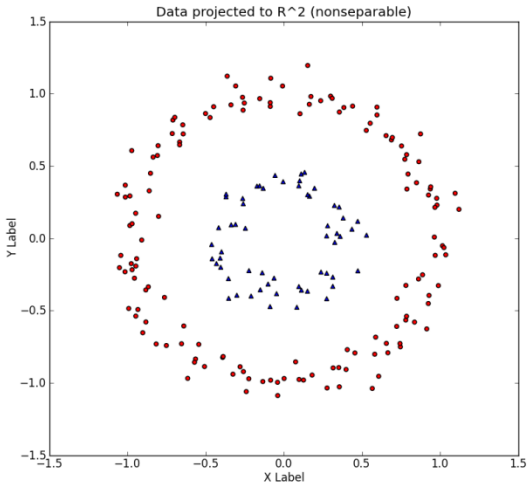


Figure 5: Support Vector Machine*



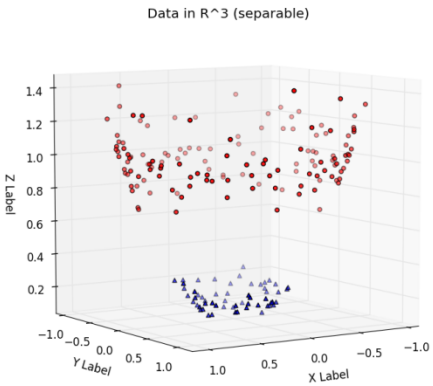


Figure 6: Kernel Trick Visualized**

Malware Accuracy Measures:

- True Positive
- True Negative
- False Positive
- False Negative

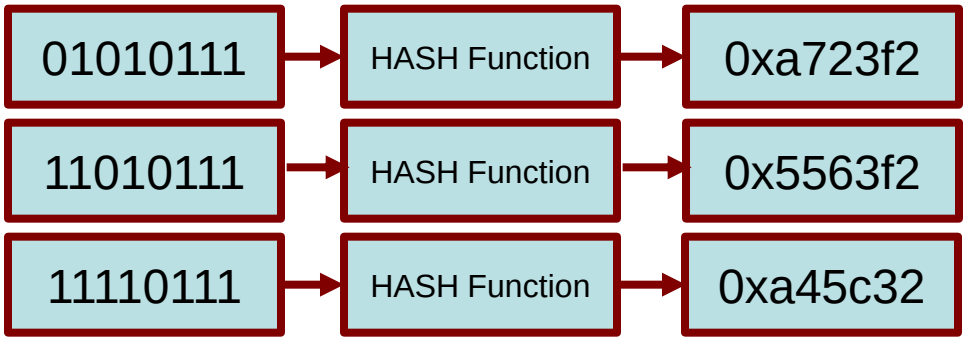
- Kernel = Mapping of inputs to feature space
- Multiple Kernel Learning approaches involve combining kernels

*Source: http://scikit-learn.org/stable/modules/svm.html

**Source: http://www.eric-kim.net/eric-kim-net/posts/1/kernel_trick.html

Malware Detection Approaches: Signature/Anomaly

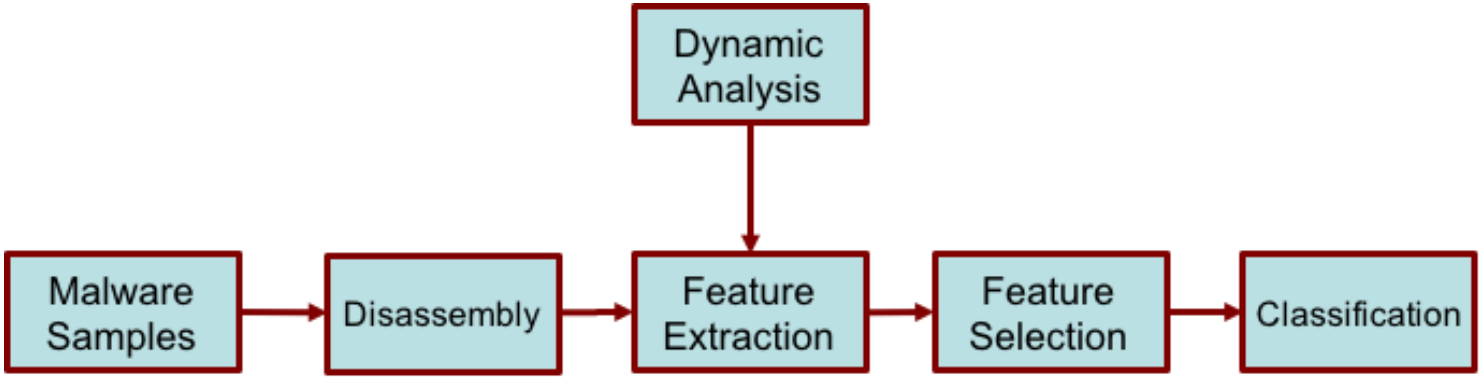
- **Signature based detection methods are well suited for known threats**



Code Obfuscation can easily overcome signature based methods!

- **Anomaly methods (Static/Dynamic Analysis) are required to prevent zero-day attacks**

Standard Anomaly-based Malware Classification System



Dynamic System Analysis Modeling of Malware*

- Paper discusses an approach for the detection and characterization of malware based on the properties of kernel data structures
- Kernel object mapping system identifies dynamic kernel objects at runtime using virtualization software
- An object map of memory allocation events is created
- This approach takes into account “data hiding” which is a malware technique to hide kernel objects by removing memory references
- A profile/signature is created that describes the malware’s unique data access behavior

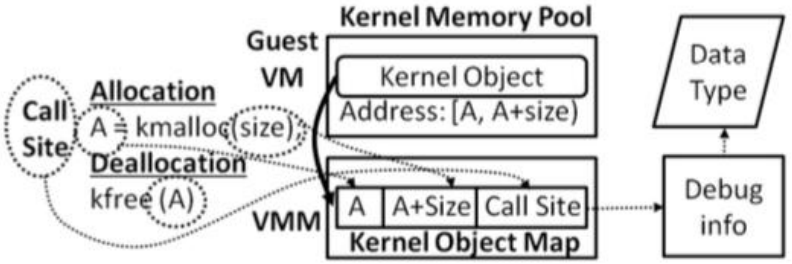


Figure 7: Memory Allocation Structure

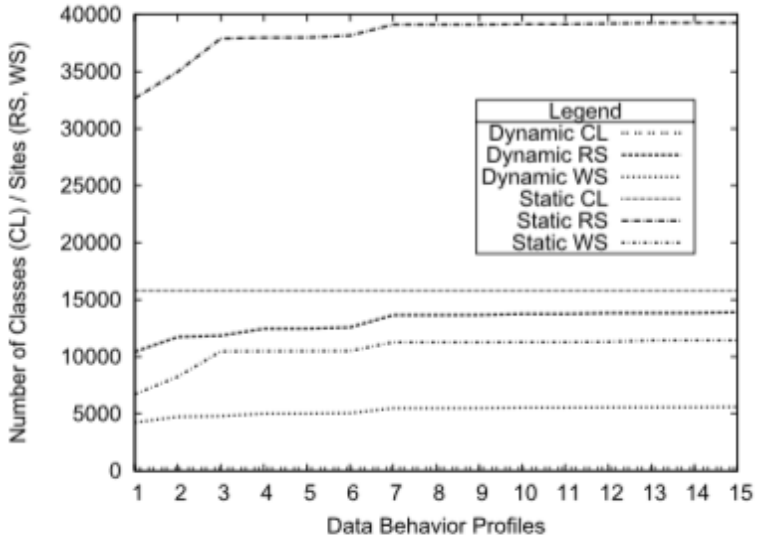


Figure 8: Unique Signature

*Source: Rhee, Junghwan (01/2014). Data-Centric OS Kernel Malware Characterization. *IEEE transactions on information forensics and security.* , 9 (1), p. 72 - 87. (ISSN: 1556-6013)

Machine Learning: Genetic Programming

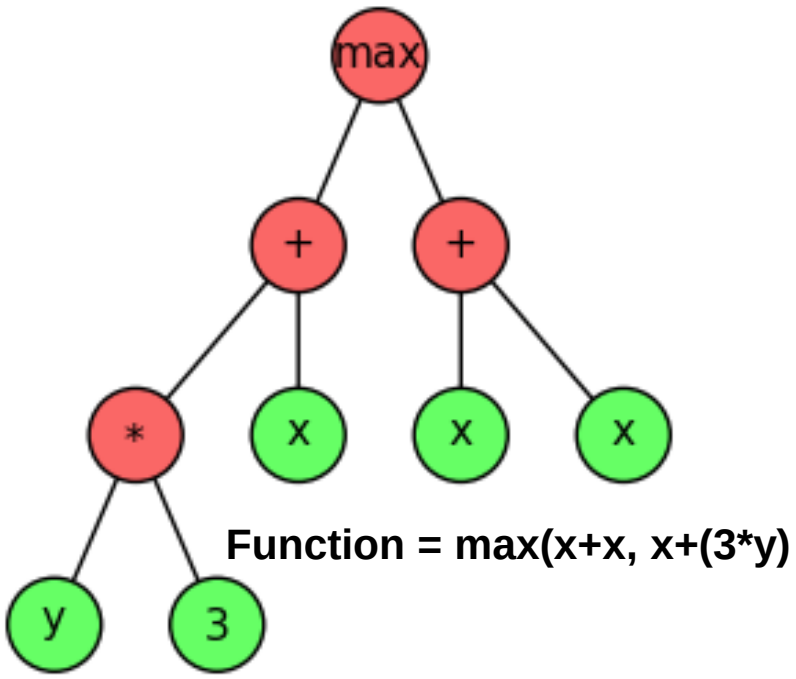


Figure 9: Example of Genetic Programming Function*

- Genetic Programming (GP) models are evolutionary algorithms to produce the “most fit” individual
- For classification applications, fitness is typically representative of classifier accuracy
- Model Parameters: Population Size, Generations, Probability of crossover/mutation, max depth
- A population of individuals is initially created
- Individual fitness is calculated
- Individuals in each generation undergo crossover and mutation
- The “fittest individuals” survive

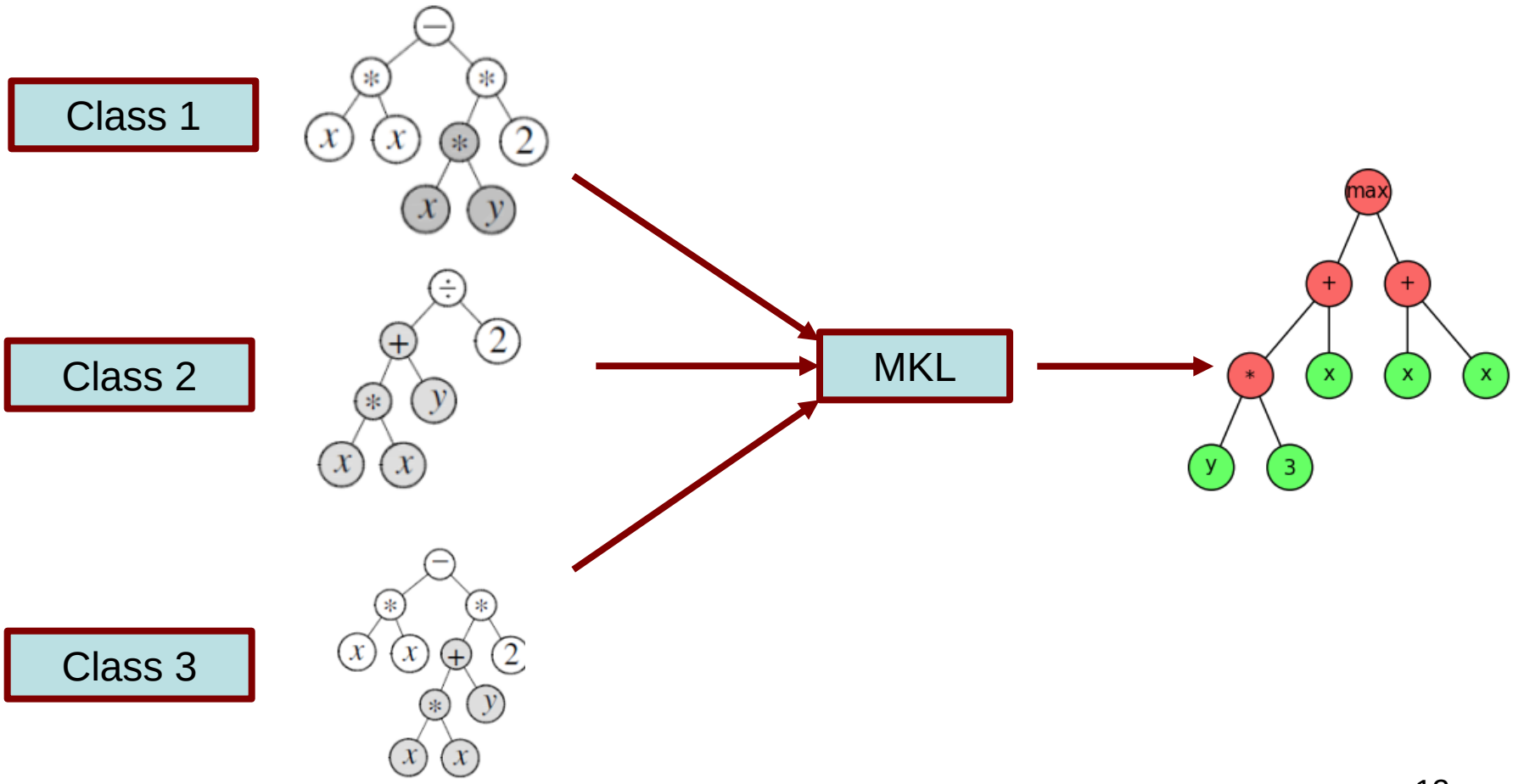
Genetic Programming for Malware Classification

- Prior research has successfully applied GP to malware classification and feature selection
- My Ph.D. research is focused on improving existing GP methods for malware classification
  - Preliminary results are promising

*Source: http://deap.readthedocs.io/en/master/tutorials/advanced/gp.html

Genetic Programming for Multi-Class Classification

- X-sized populations of discriminant functions for each class are developed
- Second phase is based on exploring the best combination of individuals with an emphasis on reducing conflicting situations between classes



Source: Soltani, Abolfazl (01/2016). Designing efficient discriminant functions for multi-category classification using evolutionary methods. *Neurocomputing (Amsterdam).* , 173 p. 1885 - 1897. (ISSN: 0925-2312)

Final Thoughts

- Increasing threat space = More focus on feature reduction and feature importance to build accurate classifiers
- Feature construction appears to be a promising method to capture multiple data characteristics into a single element
- A combination of system behavior analysis and source code disassembly are needed to build complete models
- New methods needed to account for the human factor in system security
- Manual malware analysis is time consuming
- Future work: Models needed to account for increasing system complexity and interaction

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