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Title: Detecting Code Injection Attacks in Internet Explorer

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Detecting Code Injection Attacks in Internet Explorer

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Abstract

Code injection vulnerabilities are a major threat to Internet security. The ability for a malicious website to install malware on a host using these vulnerabilities without its knowledge is particularly menacing. In this paper, we approach this problem from a new perspective by constructing a Markov chain graph from the system calls Internet Explorer executes and then modeling this graph over time. We apply a Gaussian process change-point algorithm to detect code injection attacks. To show the efficacy of this approach, we collect a novel dataset of system call traces of 6 code injection attacks using 3 distinct exploits against the Internet Explorer browser. Our algorithm was able to detect all of the code injection attacks with a limited number of false positives.

Detecting Code Injection Attacks in Internet Explorer

Blake Anderson, Daniel Quist, Terran Lane

Introduction

- **The Internet is a dangerous place**
- **Malicious downloads, Drive-by downloads**
- **Collect system call traces of Internet Explorer**
- **Use change-point detection algorithms to find changes in the application's behavior over time**
- **Real-world example of concept drift (with ground truth)**

Code Injection Attacks

- **Just visiting a website can lead to infection**
- **Javascript is used to host the shellcode**
- **Exploits typically use vulnerabilities in Internet Explorer's associated plug-ins**
- **The plug-ins are called within javascript, and the exploit is initiated**

Exploits

- **Aurora**
  - Uses an invalid pointer reference within Internet Explorer
  - Creates a backdoor connection to a command and control server
- **Dllloader**
  - IE calls DLLs with relative paths
  - Icon is presented to the user, user downloads dll, IE then calls the dll
- **Unsafe Scripting**
  - Takes advantage of a buffer overflow exploit in the ActiveX controls of IE

Data Collection

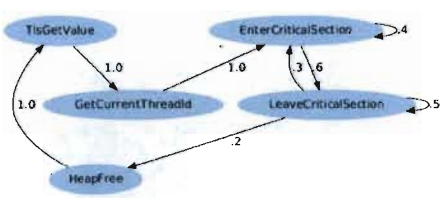
- **Xen Virtual Machine**
  - Provides a safe environment to perform exploits
- **Metasploit**
  - Many exploits are already written
  - Easy to use interface
- **StraceNT**
  - Collects the system calls made by the process

Data Collection: Part II

- **Collect normal IE usage for 10 or 15 minutes**
- **Initiate exploits, then let IE run for 5 or 10 minutes (20 minutes total)**
- **This process results in files with ~1-1.4 million system calls**
- **Each time bin consists of 10,000 system calls**

Data Representation

- **Markov chain**
  - Vertices are the system calls performed by the process
  - Transition probabilities (edges) are estimated by the traces



Change-Point Detection Algorithm

- **Goal: find** $p(r_t|x_{1:t})$

$$p(r_t|x_{1:t}) = \frac{p(r_t, x_{1:t})}{\sum_{r_t} p(r_t, x_{1:t})}$$

- **Use recursive message passing scheme to find** $p(r_t, x_{1:t})$

$$p(r_t, x_{1:t}) = \sum_{r_{t-1}} p(x_t|x_{t-1})\, p(r_{t-1}, x_{1:t-1})$$

- $p(x_t|x_{t-1})$ **Is given by a Gaussian process time-series model**

Change-Point Detection Algorithm: Part II

- $p(x_t | x_{t-1}) = N(m_t, v_t)$ where

$$m_t = K_s^T (K + \sigma^2 I)^{-1} \mathbf{x}$$

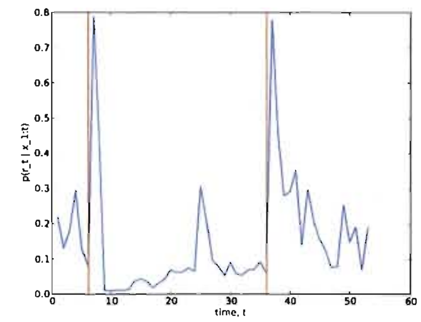
$$v_t = K_{ss} - K_s^T (K + \sigma^2 I)^{-1} K_s$$

- We use the Gaussian kernel

$$K(\mathbf{x}, \mathbf{y}) = \sigma^2 e^{-\frac{1}{2\lambda^2} \sum_{i,j} (x_{ij} - y_{ij})^2}$$

Synthetic Results

- Benign and malicious instruction traces
- 5,000 instructions per bin
- Inserted malicious instruction bins in two places within the benign trace



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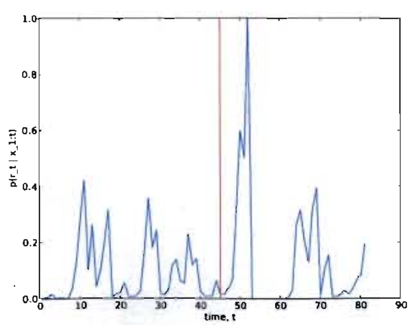
Real-World Results: Aurora

- Bins of 10,000 system calls
- Ran for 10 minutes, exploit, ran another 10 minutes



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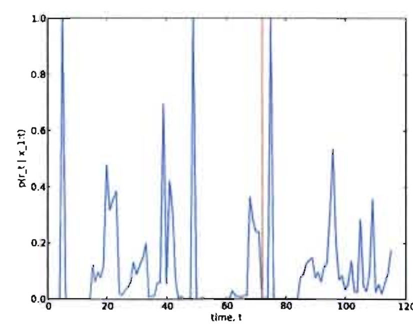
Real-World Results: dllloader

- Bins of 10,000 system calls
- Ran for 15 minutes, exploit, ran another 5 minutes



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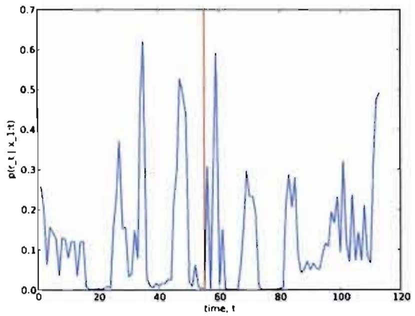
Real-World Results: unsafescripting

- **Bins of 10,000 system calls**
- **Ran for 10 minutes, exploit, ran another 10 minutes**



Conclusions

- **We are able to detect when attacks happen**
- **The number of false positives will be prohibitive in a production setting**
- **Ideas to lower false positive rate:**
  - Use instruction traces instead of system call traces
  - More advanced kernels in the GPTS model
  - Using a simpler change-point model