Machine-Learning Based Malware Classification

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Abstract

Modern day anti-virus software can quickly detect *known* malicious programs that exist in databases containing hundreds of millions of malware signatures. Today's malware can alter its signature to avoid detection. In this project, we seek to develop a ***machine-learning*** model that accurately detects previously unseen malware based on the program's x86 instruction sequence

Noise Reduction Strategy

- To reduce the amount of noise in our data, we compute the `term-frequency (tf) * inverse-document-frequency (idf)` score for each instruction in each file in our dataset
- We then use the `tf*idf` score as input to a Random Forest Classifier (RFC)
- Using the output of the RFC, we can find and remove non-informative instructions from the instruction sequences [1], before passing them as input to a Recurrent Neural Network [2]

Feature Selection and Preprocessing

Parse	*Extract sequences of opcodes from x86 assembly files*
Count	*Use frequency statistics to quantify rarity of opcode with respect to the entire dataset*
Filter	*Use opcode `tf*idf` scores as input to a Random Forest Classifier (RFC)*
Reduce	*Parse through opcode sequences, keeping only the most informative opcodes based on the RFC output*
Vectorize	*Convert opcode sequences into vector sequences, to ease use as input for a Recurrent Neural Network*
Train Test	*Fit and train the Recurrent Neural Network*

Opcode Extraction, Noise Reduction, and Vectorization

```
long arith
(long x, long y, long z)
{
  long t1 = x+y;
  long t2 = z+t1;
  long t3 = x+4;
  long t4 = y * 48;
  long t5 = t3 + t4;
  long rval = t2 * t5;
  return rval;
}
```

Original C / C++ code

`(x,y,z) -> (%rdi,%rsi,%rdx)`

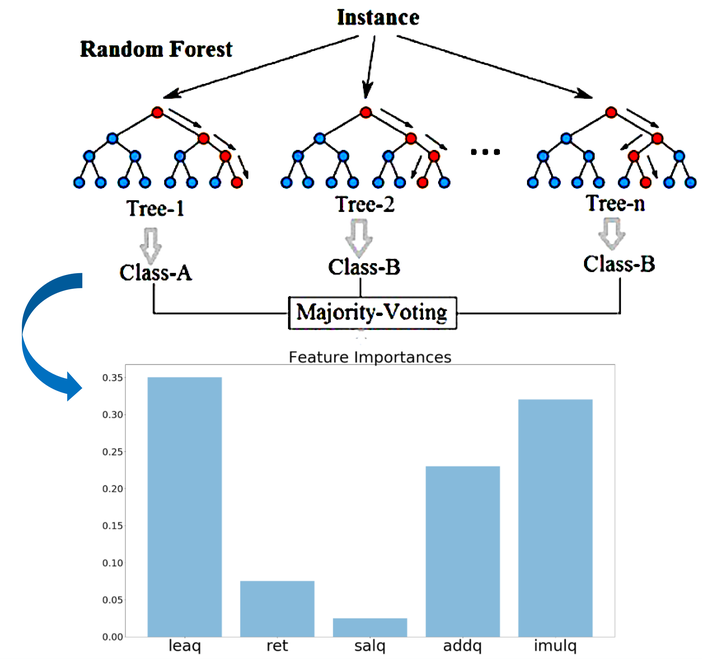
```
arith:
  leaq   (%rdi,%rsi), %rax
  addq   %rdx, %rax
  leaq   (%rsi,%rsi,2), %rdx
  salq   $4, %rdx
  leaq   4(%rdi,%rdx), %rcx
  imulq  %rcx, %rax
  ret
```

Intel x86 Assembly Instructions

['leaq', 'addq', 'leaq', 'salq', 'leaq, 'imulq', 'ret']

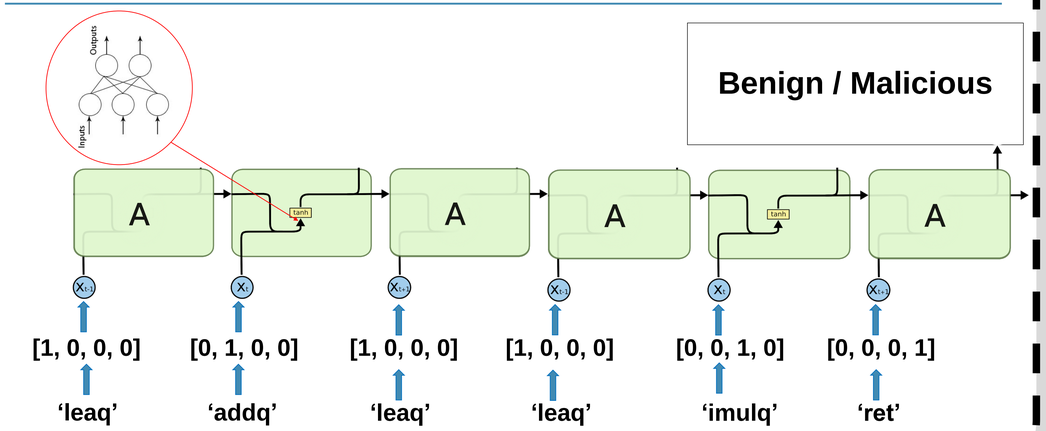
TF * IDF

Opcode	leaq	addq	salq	imulq	ret
TF * IDF score	0.43	0.14	0.14	0.14	0.14

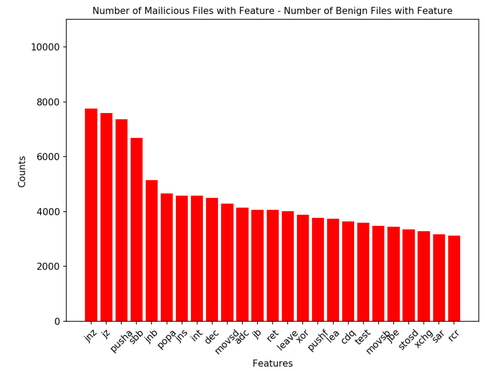


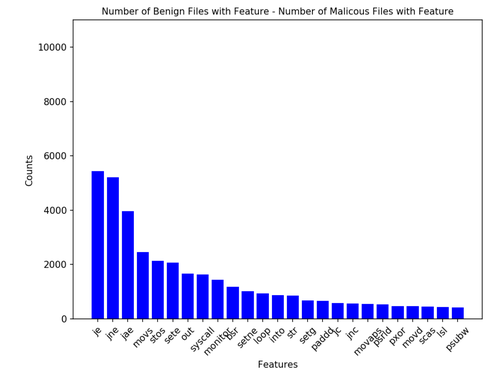
['leaq', 'addq', 'leaq', 'salq', 'leaq, 'imulq', 'ret']

['leaq', 'addq', 'leaq', ~~'salq'~~, 'leaq', 'imulq', 'ret']

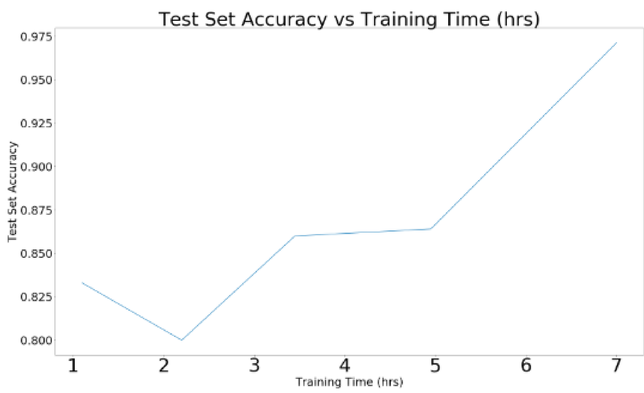


Benign / Malicious





Results



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References

[1] Jinpei Yan, Yong Qi, and Qifan Rao, "Detecting Malware with an Ensemble Method Based on Deep Neural Network," Security and Communication Networks, vol. 2018, Article ID 7247095, 16 pages, 2018

[2] S. Hochreiter and J. Schmidhuber, "Long short-term memory," Neural Computation, vol. 9, no. 8, pp. 1735–1780, 1997