Malware Category Detection

Karan Sunil
Nancy Vuong
Kevin Elkin



85% market share

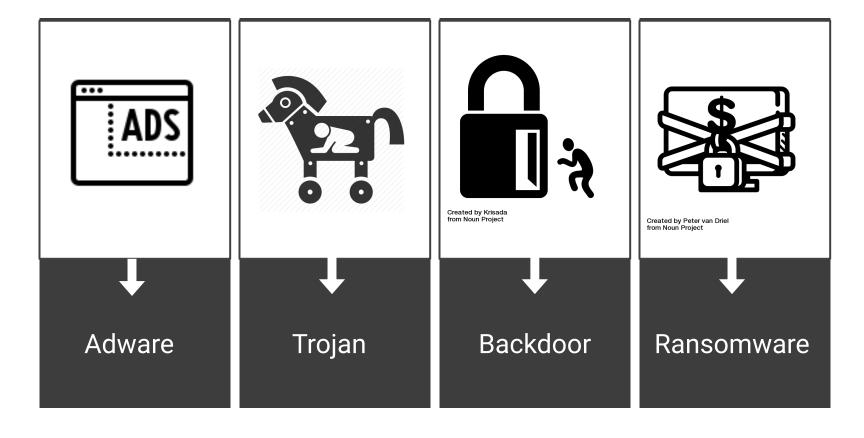
20%

Apps on the Google play store are malicious.

Performed static code analysis to detect the category of malware an app belonged to.

Performed model explainability to understand the strengths and shortcomings of our model.

Categories and Types of Malware

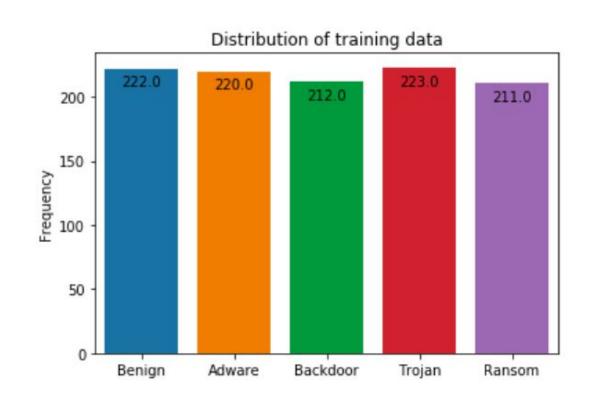


Dataset

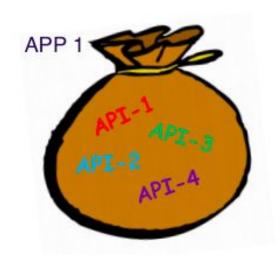
Downloaded 300 apps for each category and performed a 75-25 train-test split.

Benign apps were sourced from apkpure.com

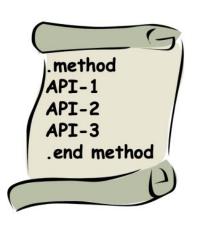
Malware apps were sourced from amd.arguslab.org

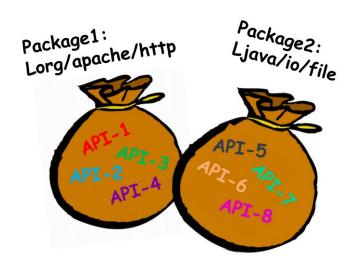


Hindroid Explanation





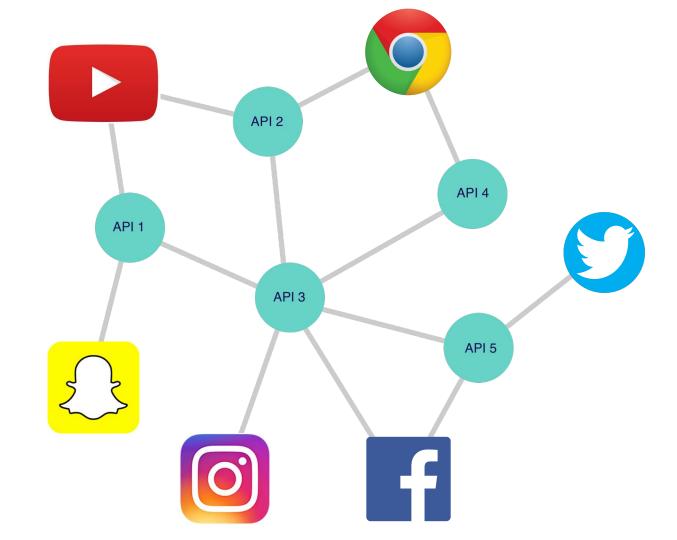




A matrix

B matrix

P matrix



Ensemble Model

We trained 3 separate multi class classifiers using the following kernels - AA^T, ABA^T, APA^T.

Using the 3 predictions, we would pick the most common prediction.

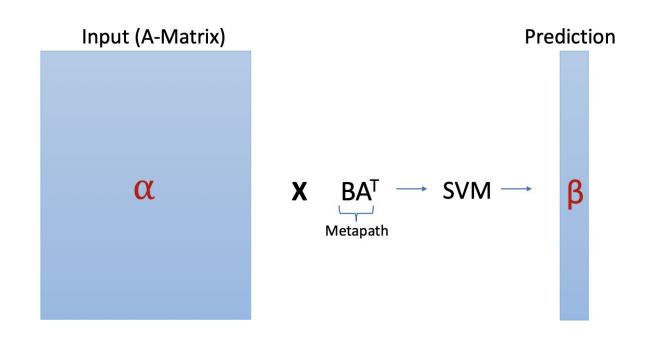
Helps eliminate weaknesses of certain kernels.

Ex - Backdoor performs bad on APA^T. Balanced by other kernels.

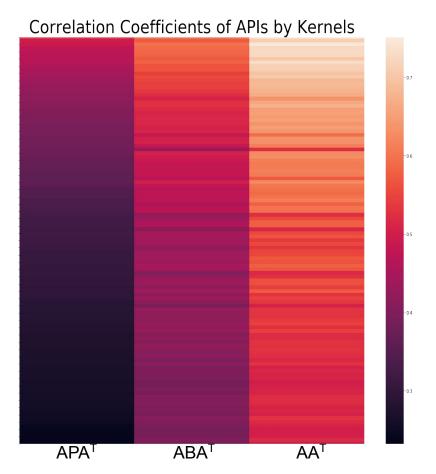
	True Negatives	False Positives	False negatives	True positives	F1
Benign	295	4	5	73	0.94
Adware	295	6	4	72	0.94
Trojan	295	7	6	69	0.91
Backdoor	298	2	8	69	0.93
Ransom	301	5	1	70	0.96

Correlation Coefficient





Correlation Coefficient



Corelation Coefficient for a Direct Relationship	Corelation Coefficient for an Indirect Relationship	Relative Strength of the Variables
0.0	0.0	None/trivial
0.1	- 0.1	Weak/small
0.3	- 0.3	Moderate/medium
0.5	- 0.5	Strong/large
1.0	- 1.0	Perfect

AA^T

- 111 API's with Correlation Coefficients greater than 0.5

ABA^{T}

- 29 API's with Correlation Coefficients greater than 0.5

APA^{T}

 1 API's with a Correlation Coefficient greater than 0.5

0 API's with Correlation Coefficients less than-0.5 across all kernels

Landroid/content/pm/PackageManager;->getPackagesForUid()[Ljava/lang/String; -	0.84	0.07	0.08	0	0.01	
Landroid/widget/ImageView;->onMeasure()V -	0.82	0.01	0.07	0	0.01	
Landroid/net/UriBuilder; -> authority() Landroid/net/UriBuilder() Landroid	0.87	0.15	0.14	0	0.01	
Landroid/view/View;->getLocationInWindow()V -	0.83	0.11	0.08	0	0.01	
Landroid/net/UriBuilder; - > scheme()Landroid/net/UriBuilder; -	0.89	0.15	0.17	0.01	0.01	
Landroid/widget/ViewFlipper;->setInAnimation()V -	0.01	0.63	0.02	0.11	0	
Landroid/widget/ViewFlipper;->setOutAnimation()V -	0.01	0.63	0.02	0.11	0	
Landroid/webkit/WebSettings;->setCacheMode()V -	0.23	0.74	0.16	0.21	0.15	
Landroid/location/Criteria;->setAccuracy()V -	0.06	0.71	0.16	0.21	0	
Lorg/apache/http/conn/ClientConnectionManager;->shutdown()V -	0.15	0.79	0.29	0.27	0	
Ljava/io/DataInputStream;->close()V -	0.11	0.13	0.59	0.17	0.04	
Landroid/os/Process;->killProcess()V -	0.18	0.23	0.51	0.21	0.2	
Lorg/meteoroid/plugin/device/MIDPDevice;->getWidth()I -	0	0	0.28	0	0	
Lorg/meteoroid/plugin/device/MIDPDevice;->getHeight()I -	0	0	0.28	0	0	
Lorg/meteoroid/core/MeteoroidActivity;->getWindow()Landroid/view/Window; -	0	0	0.28	0	0	
Landroid/telephony/TelephonyManager;->getSimSerialNumber()Ljava/lang/String; -	0.02	0.21	0.29	0.75	0	
Ljava/io/LineNumberReader;->close()V -	0	0	0	0.39	0	
Ljava/io/LineNumberReader;->readLine()Ljava/lang/String; -	0.01	0.03	0	0.39	0	
Ljava/net/MalformedURLException; -> printStackTrace()V-	0.21	0.3	0.26	0.63	0	
Landroid/content/ComponentName;->getShortClassName()Ljava/lang/String; -	0.08	0.05	0.08	0.4	0	
Landroid/app/admin/DeviceAdminReceiver;->onDisabled()V -	0	0	0.06	0.03	0.5	
Ljavax/crypto/CipherInputStream;->close()V -	0.01	0	0	0	0.43	
Ljavax/crypto/CipherOutputStream;->flush()V -	0	0	0.02	0	0.43	
Landroid/app/admin/DeviceAdminReceiver;->onEnabled()V -	0	0	0.07	0.03	0.46	
Ljavax/crypto/CipherOutputStream;->close()V -	0.02	0	0.03	0.03	0.43	
·	Benign	Adware	Trojan	Backdoor	Ransom	

- 0.75

Landroid/content/pm/PackageMan	ager;->getPackagesForUid()[Ljava/lang/String; -	0.84	0.07	0.08	0	0.01	
	Landroid/widget/ImageView;->onMeasure()V -	0.82	0.01	0.07	0	0.01	
Landroid/net/UriBuilder; - > authority()Landroid/net/UriBuilder; -			0.15	0.14	0	0.01	
	Landroid/view/View;->getLocationInWindow()V -	0.83	0.11	0.08	0	0.01	- 0.75
Landroid/net/Ur	iBuilder; – > scheme()Landroid/net/UriBuilder; -	0.89	0.15	0.17	0.01	0.01	-0.75
Lar	ndroid/widget/ViewFlipper;->setInAnimation()V -	0.01	0.63	0.02	0.11	0	
Land	froid/widget/ViewFlipper;->setOutAnimation()V -	0.01	0.63	0.02	0.11	0	
Lan	ndroid/webkit/WebSettings;->setCacheMode()V -	0.23	0.74	0.16	0.21	0.15	
	Landroid/location/Criteria;->setAccuracy()V -	0.06	0.71	0.16	0.21	0	- 0.60
Lorg/apache/http/	conn/ClientConnectionManager;->shutdown()V -	0.15	0.79	0.29	0.27	0	
	Ljava/io/DataInputStream;->close()V -	0.11	0.13	0.59	0.17	0.04	
	Landroid/os/Process;->killProcess()V -	0.18	0.23	0.51	0.21	0.2	
Lorg/mete	eoroid/plugin/device/MIDPDevice;->getWidth()I -	0	0	0.28	0	0	- 0.45
Lorg/mete	oroid/plugin/device/MIDPDevice;->getHeight()I -	0	0	0.28	0	0	
Lorg/meteoroid/core/Meteoroid	Activity;->getWindow()Landroid/view/Window; -	0	0	0.28	0	0	
Landroid/telephony/TelephonyMana	ager;->getSimSerialNumber()Ljava/lang/String; -	0.02	0.21	0.29	0.75	0	
	Ljava/io/LineNumberReader;->close()V -	0	0	0	0.39	0	- 0.30
Ljava/io/Line	eNumberReader;->readLine()Ljava/lang/String; -	0.01	0.03	0	0.39	0	
Ljava/net	/MalformedURLException;->printStackTrace()V -	0.21	0.3	0.26	0.63	0	
Landroid/content/ComponentN	Name;->getShortClassName()Ljava/lang/String; -	0.08	0.05	0.08	0.4	0	
Landroid/app	/admin/DeviceAdminReceiver;->onDisabled()V -	0	0	0.06	0.03	0.5	- 0.15
	Ljavax/crypto/CipherInputStream;->close()V -	0.01	0	0	0	0.43	
	Ljavax/crypto/CipherOutputStream;->flush()V -	0	0	0.02	0	0.43	
Landroid/app	p/admin/DeviceAdminReceiver;->onEnabled()V -	0	0	0.07	0.03	0.46	
	Ljavax/crypto/CipherOutputStream;->close()V -	0.02	0	0.03	0.03	0.43	-0.00
		Benign	Adware	Trojan	Backdoor	Ransom	

Landroid/content/pm/PackageManager;->getPackagesForUid()[Ljava/lang/String; -	0.84	0.07	0.08	0	0.01
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Landroid/widget/ViewFlipper;->setInAnimation()V -	0.01	0.63	0.02	0.11	0
Landroid/widget/ViewFlipper;->setOutAnimation()V -	0.01	0.63	0.02	0.11	0
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Lorg/apache/http/conn/ClientConnectionManager;->shutdown()V -	0.15	0.79	0.29	0.27	0
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Lorg/meteoroid/plugin/device/MIDPDevice;->getWidth()I -	0	0	0.28	0	0
Lorg/meteoroid/plugin/device/MIDPDevice;->getHeight()I -	0	0	0.28	0	0
Lorg/meteoroid/core/MeteoroidActivity;->getWindow()Landroid/view/Window; -	0	0	0.28	0	0
Landroid/telephony/TelephonyManager;->getSimSerialNumber()Ljava/lang/String; -	0.02	0.21	0.29	0.75	0
Ljava/io/LineNumberReader;->close()V -	0	0	0	0.39	0
Ljava/io/LineNumberReader;->readLine()Ljava/lang/String; -	0.01	0.03	0	0.39	0
$linear_$	0.21	0.3	0.26	0.63	0
Landroid/content/ComponentName;->getShortClassName()Ljava/lang/String; -	0.08	0.05	0.08	0.4	0
Landroid/app/admin/DeviceAdminReceiver;->onDisabled()V -	0	0	0.06	0.03	0.5
Ljavax/crypto/CipherInputStream;->close()V -	0.01	0	0	0	0.43
Ljavax/crypto/CipherOutputStream;->flush()V -	0	0	0.02	0	0.43
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Lorg/meteoroid/plugin/device/MIDPDevice;->getWidth()I -	0	0	0.28	0	0
Lorg/meteoroid/plugin/device/MIDPDevice;->getHeight()I -	0	0	0.28	0	0
Lorg/meteoroid/core/MeteoroidActivity;->getWindow()Landroid/view/Window; -	0	0	0.28	0	0
Landroid/telephony/TelephonyManager;->getSimSerialNumber()Ljava/lang/String; -	0.02	0.21	0.29	0.75	0
Ljava/io/LineNumberReader;->close()V -	0	0	0	0.39	0
Ljava/io/LineNumberReader;->readLine()Ljava/lang/String; -	0.01	0.03	0	0.39	0
Ljava/net/MalformedURLException;->printStackTrace()V -	0.21	0.3	0.26	0.63	0
Landroid/content/ComponentName;->getShortClassName()Ljava/lang/String; -	0.08	0.05	0.08	0.4	0
Landroid/app/admin/DeviceAdminReceiver;->onDisabled()V -	0	0	0.06	0.03	0.5
Ljavax/crypto/CipherInputStream;->close()V -	0.01	0	0	0	0.43
Ljavax/crypto/CipherOutputStream;->flush()V -	0	0	0.02	0	0.43
Landroid/app/admin/DeviceAdminReceiver;->onEnabled()V -	0	0	0.07	0.03	0.46
Ljavax/crypto/CipherOutputStream;->close()V -	0.02	0	0.03	0.03	0.43
	Benign	Adware	Trojan	Backdoor	Ransom

-0.75

- 0.60

- 0.45

- 0.30

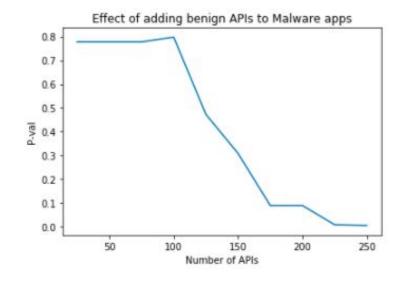
-0.15

Hypothesis Testing

We infused the APIs that we knew were most Benign into malware apps.

As we add more apps our results are significantly worse.

Adware's F1 score actually improves by 0.01



	True Negatives	False Positives	False negatives	True positives	F1
Benign	256	43	4	74	0.76
Adware	299	2	6	70	0.95
Trojan	297	5	12	63	0.88
Backdoor	299	1	18	59	0.86
Ransom	303	3	14	57	0.87

SVM Weights

Multi Class SVM Weights

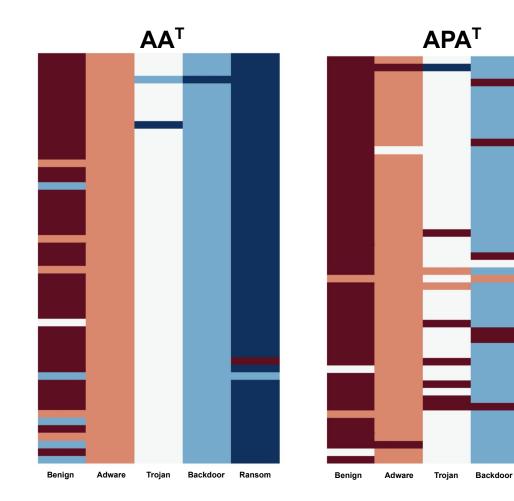
1 vs. The Rest

- Positive Weights correspond to 1 class (i.e. Benign)
- Negative Weights correspond to incorrect classes (i.e. All malware classes)

Figures shown have the top 5% of their positive weights in order from greatest (top) to least (bottom)

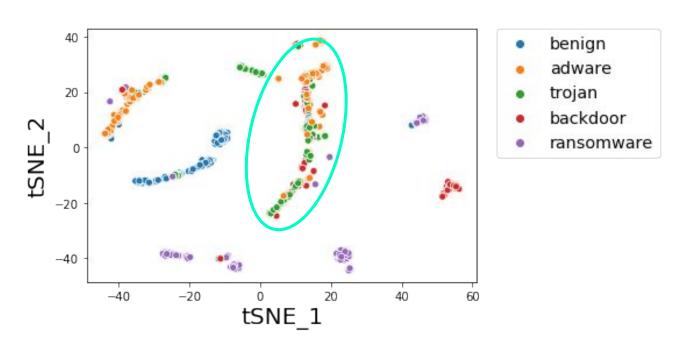
Weights on the top have more say in the classification as they are larger

Top 5% of positive weights account for ~ 30-45% of "decision" on the positive side



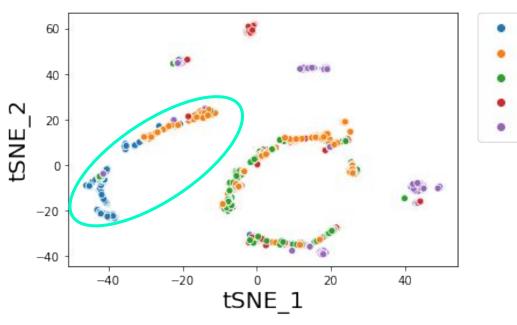
tSNE





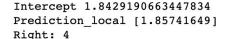
tSNE

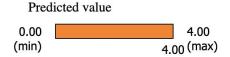
APA^T

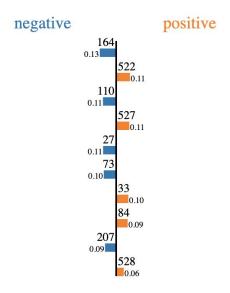


- benign
- adware
- trojan
- backdoor
- ransomware

Local Interpretable Model-agnostic Explanations (LIME)







LIME allows us to understand why and how our model made a decision based on its features

Trojan was the most difficult category to classify; we investigated why certain Trojan apps may have been misclassified.

We identified a subset of 4 apps that would heavily influence the classification of Trojan in a negative way.

These 4 apps were all Benign. The subcategories of these apps were Beauty and Productivity.

Conclusion and Future Work

Summary

- High Frequency in 1 Category + Low
 - Frequency in Others -> Strong
 - Classification Influence
- Multi-kernel learning performs better
- Kernels have weaknesses

Future Considerations

- Include more kernels
- Improve classification of trojans
- Use ranking algorithm to screen new apps before they get
 - published

Work cited

http://yes-lab.org/files/HinDroid KDD2017 Slides Ye.pdf