Graph Convolutional Network for Classifying Binaries with Control Flow Graph Data

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***Abstract*—The ability to precisely identify the threats that unknown binaries propose to an environment is an ongoing issue within cyber security. Malware analysis is typically performed through two general methods, static analysis and dynamic analysis. Through static analysis control flow graphs can be generated to represent the flow of a program between different code blocks. Data can be further generated to represent individual instructions as VEX commands. By organizing this data into StellarGraph objects, we can use GraphSAGE models to generate low-dimensional embeddings for familial attribution with greater resistance to unseen samples causing overfitting.**

I. Introduction

As current intrusion detection systems (IDSs) and intrusion prevention systems (IPSs) rely on static, signature-based solutions, the most minute changes to code can cause the same signatures to be targeted or misclassify malicious binaries as otherwise benign. Malware analysis is typically performed through two general methods, static analysis and dynamic analysis. Static analysis is conducted without running the binary and the same methods can be performed against source code as well. Whereas dynamic analysis requires running the binary and then inspecting different elements about the binary itself, it's memory or the environment it is running [1].

Where this research diverges from traditional methods is the type of static features extracted, their represented format, and the algorithms used to assess familial inferences. In doing so we hope to reduce the number of false positives produced by misfit models classifying unknown binaries; in short, reducing the number of networks or environments compromised by emerging malware or advanced persistent threats (APTs).

II. Inductive Representation Learning on Large Graphs

Executables can have thousands of functions or code-blocks represented within a control flow graph. Because of this, it is important to determine whether there are any valid ways to efficiently generate embeddings and inferences from the nodes within those graphs. In [2], the authors presented Graph Sample and Aggregate (GraphSAGE) from the StellarGraph library [3], an inductive framework that leverages node attribute information to generate embeddings via forward propagation for previously undigested data.

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III. Metamorphic Malware Detection using Control Flow Graph Mining

There are different ways that executables can be represented, but the three most common are: source code, disassembly, and control flow graphs. For instance, with source code we know exactly what the code originally looked like before the executable was compiled. We can see the libraries that were imported, the functions called from those libraries, as well as the structure of any methods or data types.

We can disassemble an executable and use the raw assembly or opcodes produced from that disassembler to count opcode frequency, instruction count, or to even track references to addresses within memory. Similarly, we can use that same disassembly to create decompilations which are a form of pseudo-source code meant to improve the understanding of a program. Depending on the language an executable was written in, decompilation will produce wildly different results. For instance, the difference between the decompiler used by dnSpy for .NET code versus the results produced by IDA with Hex-Rays and any C or C++ programs [5]. In [4], the authors discussed how to use the third representation type, control flow graphs (CFG), to gather further data as features for our datasets.

Control flow is indicated by instructions using an unconditional jump *jmp*, a conditional jump *jcc*, a function call *call*, or a function return *ret* operator. Using this intuition, we can build CFGs defined by the entrypoint address of a function to where any of the previously indicated instructions are made. This will produce CFGs consisting of multiple interconnected blocks.

IV. Proposed Solution

The phases for this proposal are as defined by Fig. 1. Under the Data Generation Phase, malicious portable executable (PE32) samples will be gathered from the shown sources: *VirusShare*, *HybridAnalysis*, *VirusTotal*, and Microsoft Windows images; popular online platforms for computer virus checking. Samples are ingested with *angr* then, as described under Section IV-B, their respective VEX features are extracted. Based on our experimental data, the exact distribution for this sampling is 991 malicious and 991 benign samples. During employment at the Idaho National Laboratory, access to Annotated Translated Disassembled Code [8] was provided to create embeddings for this ML analysis.

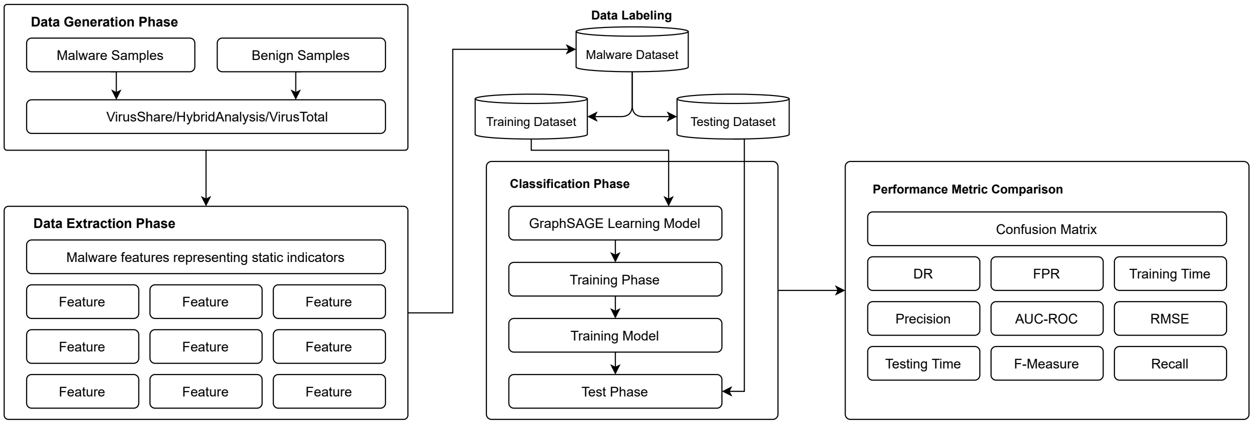

Fig. 1: Four Main Phases of the Proposed Solution

A. Data Extraction

The CFG data will be extracted from the samples using *angr*, a multi-architecture binary analysis toolkit, with the ability to perform dynamic symbolic execution, and various static analyses on binaries. For the purpose of this proposed solution, we will use a static CFG (CFGFast) to generate a CFG for each sample. The analytical data for these CFGs are stored using the VEX IR, an architecture-neutral intermediate representation, of each node or block within Neo4j [6].

B. Data Labeling

Through the use of *angr*, the VEX commands chosen to identify code blocks within a given sample are the following:

TABLE I: Extracted *angr* Features

libname	iex_vecret	ist_storeg
funcaddr	iex_abihint	ist_wrtmp
iex_binop	ist_dirty	ico_u1
iex_ccall	ist_exit	ico_u8
iex_const	ist_imark	ico_u16
iex_get	ist_llsc	ico_u32
iex_geti	ist_loadg	ico_u64
iex_gsptr	ist_mbe	ico_f32
iex_load	ist_cas	ico_f64
iex_qop	iex_ite	ico_f64i
iex_rdtmp	ist_noop	ico_v128
iex_triop	ist_putist_puti	ico_v256
iex_unop	ist_store	

These 38 features represent the different nodes features for each block within Stellargraph. Brief descriptions of what each feature represents can be found at [7].

C. Classification

The GraphSAGE framework from Stellargraph is currently the preferred method for supervised learning and node classification of the CFGs and their node features generated by *angr*. Using this framework will allow typical splits of 70% training and 30% testing dataset. After several runs of training the models with a mix of benign and malicious PE32 binaries, the model will be used to predict the family and class of the binaries. The output of the classification phase is a confusion matrix and other details not limited to training/testing time.

D. Performance Metric Computation

The performance metric computation phase will calculate the necessary performance metrics as indicated in Fig. 1. The matrix will be used to calculate False Positive Rate (FPR), Precision, Accuracy, Root Means Square Error (RMSE), F-Measure, and AUC-ROC. Finally, a table of the performance metrics will be created containing the values from the proposed metrics.

V. Conclusion and Future Work

In this paper, we discussed the limits of current detection methods and potential for current machine learning models to identify familial relations within malware samples. We proposed a solution with control flow graph data gathered using *angr* and generative convolutional networks to attribute the malware samples. Future contributions aim to refine the proposed implementation by increasing overall detection rate and time to train through dimensionality reduction; a form of exploratory data analysis not considered at the time of testing.

References

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