"Learning Highly Recursive Input Grammars": A Replication Study

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Abstract

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Contents

Chapter 1

INTRODUCTION

In the field of software testing, generating test inputs for a program (fuzzing) is a well-known and popular technique. To improve the effectiveness of fuzzers, recent research has focused on recovering input grammars from existing programs, as incorporating knowledge about the input language and grammar of the program under test drastically improves the effectiveness of fuzzers [1].

Learning Highly Recursive Input Grammars, authored by Lemieux C., Sen K., and Kulkarni N., and published in 2021 at UCB [2], presents an algorithm called ARVADA, developed for this purpose. ARVADA attempts to learn context-free grammars (CFGs) of a specified program given a set of valid inputs and a boolean-value black-box oracle $\mathcal{O}$. Along with presenting the algorithm, the paper evaluates it by comparing ARVADA to GLADE [3], a previously developed state-of-the-art algorithm for the same task in a similar setting. During the evaluation, it was observed that the F1 scores of GLADE were much lower than those reported in the official GLADE paper [3]. This led to a replication study of the original GLADE paper, conducted by Gopinath R., Bachir B., and Zeller A., and published as "Synthesizing Input Grammars: A Replication Study" [4] at CISPA, which investigated the accuracy of the results in the original paper. Similarly, as done by the researchers at CISPA, this thesis aims to replicate ARVADA to reproduce and investigate the results presented in the original paper [2].

This thesis is an attempt to reproduce ARVADA in a clean-room environment, meaning with no reference to or knowledge of the original implementation, but only the abstraction and explanations provided in the paper [2]. The implementation language of choice is C.

First, this paper will introduce general concepts of grammar and parsing, the importance of learning input grammars, a deeper explanation of ARVADA, and the motivation for conducting a replication study. This is followed by a brief explanation of ARVADA and how it works according to the original paper [2], then a more in-depth explanation of the algorithm and how it was reproduced in C with reference to the code. Afterward, an evaluation compares the results of the reproduced implementation with those from the original paper [2]. Finally, a discussion highlights and comments on the original algorithm, the reproduced results, and the overall process of conducting the replication study, followed by a brief conclusion.

• All code and implementation are open source and can be found here: `https://github.com/Stainima/ARVADA`

Chapter 2

GENERAL REVIEW OF LITERATURE

2.0.1 What is ARVADA?

Introcution

ARVADA is an algorithm, published in "Learning Highly Recursive Input Grammars" [2] at the University of California, Berkeley in 2021. It is an algorithm designed to learn context-free grammars from a set of positive examples and a Boolean-valued oracle $\mathcal{O}$. Starting from an initially flat parse trees, ARVADA repeatedly utilizes two specialised operations, **bubbling** and **merging**, to add structure to these trees. Which is used to extract the smallest set of context-free grammar possible that accommodates for all the given examples. The algorithm aim to generalise the language as much as possible, while not over generalising the language accepted by the $\mathcal{O}$.

ARVADA, similar to GLADE [3], works assuming a black-box oracle $\mathcal{O}$. Meaning ARVADA has no access or knowledge about how the oracle works, but only can see the Boolean value return from the $\mathcal{O}$.

Walktrough

2.0.2 What are Grammars?

Grammars both in the natural and artifical language can be defined as a set of rules by which valid sentences in a language are constructed [5]. Beginning with a start symbol, which is a single non-termial, production rules are applied sequentially adding alphabet from the grammar to generate a string which is valid in the grammar.

2.0.3 Further Quesitons

What are parsers?

What are context free grammar?

Why do a replication study?

2.0.4 Why C?

In the original study [2], the ARVADA algorithm was implemented in Python. When compared to GLADE [3], which was implemented in Java, ARVADA exhibited a slower average runtime across all benchmarks. As stated in the study, this could be attributed to the natural runtime disadvantage of Python compared to Java.

In a comparative study, "A Pragmatic Comparison of Four Different Programming Languages" [6], it was found that if speed and efficiency were important in an implementation, C was a better options compared to Python. C, being a mid-level, statically typed, structured language that runs under a compiler, will always be faster than a dynamic language run under an interpreter such as Python [7]. Along with being a structured language, C also comes with only essential features. These limited features contribute to its efficiency but also introduce a higher level of complexity compared to Python [6][7].

Hence, with the aim of replicating and improving upon the runtime bottleneck presented by Python—while acknowledging the rise in complexity C introduces compared to Python—C was chosen as the language of implementation.

Why ARVADA / Problem Statement?

Why is learning highly input grammar important?

What is GLADE?

What are other Similar works done?

What is the work done in this field after ARVADA?

Chapter 3

ALGOTRITHM & METHODOLGIES

Methodolgies: ARVADA walkthrough

How you did it, and point out any differences?

Listing 3.1: Struct used in code to store all *trees*

```
1 typedef struct nodes{
2     int capacity;
3     int count;
4     struct node **nodes;
5 } Nodes;
```

Listing 3.2: Struct used in *trees*

```
1 typedef struct node{
2     int capacity;
3     char character;
4     struct node *parent;
5     int t;
6     int num_child;
7     int pos;
8     struct node **children;
9 } Node;
```

Chapter 4

EVALUATION

Chapter 5

DISCUSSION

Chapter 6

CONCLUSION

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