Basic C Interpreter

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Abstract

My project was initially to interact with the Amazon Alexa (software development kit) SDK, however, I made a change to implement a basic C interpreter due to its relevance to programming languages. Through my research I hoped to gain a better understanding of the underpinning of the C languages formal and operational semantics. Also, to understand how to appropriately implement a subset of the different expressions, declarations, and scope of the language. This is not a replacement for compilers such as GCC, however just an abstract interpreter implementation to understand the foundation of how the C language is interpreted.

1 Introduction

Motivation for this project was to submerge in a profound understanding of new concepts learned in the programming languages course. Concepts of the operational semantics of a language, and the formation of abstract syntax trees when parsing a language. Assignments in the course introduced the idea of interpreters, however, implementation was only applied to the WHILE language. A language not widely used in the realm of computer science. Therefore, I wanted to gather a deeper understanding of programming languages topics as to how they relate to a popular general-purpose programming language such as C. And in doing so I would add to my formal reasoning about C programs, a valuable tool in software development when using C in practice. There has been much development of the C language since its inception in the Bell Labs by Dennis Ritchie between 1972 and 1973.

From first being developed in order to make utilities running on Unix, to becoming a widely used programming language standardized by the ANSI since 1989, I believe there is much to learn on the progressive development of C. Related material for C has been closer to compiler development rather than interpreters. Even through interpreters and compilers are similar in structure, they have some key differences. Interpreters directly execute the instructions in the source programming language such as C, while a compiler translates the instructions into efficient machine code. Portability is highly kept in mind for the C language. Therefore there has been extensive work on compilers for C in order to be utilized in a wide variety of computer platforms and operating systems while only introducing minor changes to the source code.

2 Related Work

C is a general purpose procedural language that is capable of supporting paradigms such as lexical variable scope and recursion. During the 1980's C slowly gained popularity and became one of the most widely used programming language. It is due to this sole development that has made C studied language. Resulting in informal semantics of ANSI C defined in standard [4]. A source of ambiguity in interpretation, but an excellent source in determining my subset of defined syntax. It is these ambiguities within the C language that has influenced the development of formal semantics of C. Ellison and Rosu's recent work describes an executable semantics of C that has been tested against the GCC torture test suite, passing 99.2% test programs. This is the most complete and thoroughly tested formal definition of C [2]. This formal semantics of C, shows capability of automatically finding program errors both statically and at runtime.

3 Abstract Syntax

Initially, I was to implement both the parsing and interpreting of the C language, with my development being in Python. Through trial I quickly started realizing the difficulty in creation of a Lexer and Parser for a basic subset of the C language. In hopes to finish the interpreter, I then turned to utilizing the Python library PyCParser.

Though I started utilizing PyCParser to parse C code into an abstract syntax tree (AST), I still spend extended periods of time on implementation and design of the syntax my interpreter would evaluate. I started focusing on the complexity in formation of the C language. This had me develop different structures for the syntax of the C language. Initially starting with declarations, I needed to define the different type of declaration for my basic C interpreter. As I progressed on what my interpreter would support, I resulted in capability of declaring functions and type declarations, where a type declaration is the declaration of a variable to a value or nothing (e.g., int x = 9;).

```
Declaration ::= TypeDeclaration | FunctionDeclaration
```

Next, was determining the different types to support. With C having a vast type set, (e.g., signed char, unsigned char, short int, long int, double, long double, etc) I chose to prune the amount of interpretable types chars, floats and integers.

```
type-specifier ::= char | int | float
```

The abstract syntax supported for the different type of statements are also a trimmed down set of standard C. Statements such as if, while for and return are included as evaluable. The abstract syntax for statements are:

```
Statement ::= expression
    | if (expression) Statement
    | if (expression) Statement else Statement
    | while (expression) statement
    | for (expression; expression; expression) Statement
    | Var = expression
  | return expression;
  | [Statement]
```

3.1 Memory

The majority of difficulty in my implementation was through the introduction of functions and function calls. With functions being included in the semantics and syntax, this introduced the concept of scope. Scope is a region of the program, and the scope of variables refers to the area of the program where these variables can be accessed once they are declared. Therefore I needed to implement different levels of scope. The first was the global scope (e.g., File scope), this is the top level scope where all declarations of functions in a file (e.g., test.c) are visible.

Functions introduced Function Scope as well, where every declaration is valid only for that block. Where the containing block is within a function. Therefore this results in scope to be a part of a function. A scope that ends once a function returns. In the case of the C language, scope of the function is created when called, and destroyed at return. C does provide static local variables, where the lifetime of the variable lives on throughout the entire life of the program, however, I decided to not include this ability into the syntax of my simple C interpreter. For implementation of scope and memory, I needed to further my understandings of the C language stack and frames.

To keep track of different scopes of a C file being interpreted I created A memory class that within itself had an implementation of a stack. This call stack is then composed of stack frames, where each stack frame is a call to a subroutine which has not yet terminated with a return. For example, a C program with only a 'main' function would add a stack frame to the stack to keep the main function block in scope, while the code within the main function continues executing. This is so all variables declared within the main function are accessible, throughout main function execution.

4 Model Checking

5 Conclusion

6 References

6.1 Literature

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6.2 Code and Online References

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