When should one inline recursive functions?

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Abstract

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Contents

1 Introduction

Describe layout of paper. What does each section in turn discuss?

1.1 Problemsetting

Re-state the assignment: Inlining -¿ Easy, what is it, benefits/drawbacks.
"This paper details the problems and benefits of inlining"
Introduce Jive in a few sentences, say that it's further introduced in section 2.

Inlining is a simple and straight-forward technique used in code compilation, where one replaces the call of a function with the body of said function. Its benefits include removal of function call overhead and unveiling of additional potential optimizations in the code. The drawbacks are potentially increased code size as well as longer execution times for the compilation of the program.

The contribution of this paper is an inliner for the Jive compiler, and detailing the problems and benefits of inlining wrt. the Jive compiler. Jive is a new backend compiler which works on intermediate representation (IR) code, and optimizes it with a new type of graph; the regionalized value-state dependency graph (RVSDG[1]).

insert reference

Further details of this assignment can be found in Appendix A.

2 Background

2.1 The Jive Compiler

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2.2 The Regionalized Value-State Dependency Graph

The RVSDG is a directed acyclic graph (DAG), upon which the Jive compiler bases its operations on. Jive converts the control flow graph (CFG) representing the control flow of a program in IR code into an RVSDG graph.

The RVSDG, fulfilling the properties required by a DAG, have different types of nodes. These nodes are (among others) the γ, θ, λ, apply, and ϕ nodes. Each type of node represents a different typical part of a program, like loops, functions, and if-statements.

Bahmann et. al detail algorithms for how almost any CFG can be converted into an RVSDG, and any RVSDG back again into a CFG, with the consequence that almost any program can be represented as a RVSDG.

Cite HiPEAC paper

Check up on the veracity of this

- γ nodes in the RVSDG represent conditional statements. Each γ node has two sets of inputs: the predicate, and the variables the predicate depend upon. The outputs are X, representing the dataflow of the RVSDG.

This term is wrong, check up on this.

same as previous todo.

- θ nodes(/regions) represent loops in the program. They are structured as do-while-loops, with a γ node in front of the loop if it's representing a

[1] Detailed in Section 2.1.

for-loop. The γ node at the end of the node/region has a directed edge back to the top of the node (containing the representation of the body of the loop), or onwards out of the node/region onto the next one in the control flow of the program.

- λ nodes(/regions) represent functions. Their input edges represent all data worked upon by the function, as well as the function's input parameter variables. The RVSDG forces all λ nodes to represent strict functions.

- *Apply* nodes are "call nodes", nodes which represent places where a function is called. When scanning the program represented by the RVSDG, it is these nodes that are looked upon as potential places upon which to perform inlining.

- ϕ regions are nodes representing parts of the program's control flow where either a functions behave recursively either by calling themselves (mutually recursive), or each two or more calling each other in turn.

  A ϕ region needs to have at least one λ node and one γ node. It may have apply nodes instead of λ nodes, as long as these λ nodes exist somewhere else in the graph. A mutually recursive function will then have an output edge from the γ node going back "up" to the λ node supplying the input for said γ node.

  In functional languages such as Haskell, there can be several mutually recursive functions calling each other, "mutually recursive binding groups" [4]. This is represented in the RVSDG as several λ nodes where the trailing γ nodes have one or more output edges going to one or more λ nodes. It must have at least one edge going to a different λ node for the RVSDG to represent a mutually recursive binding group.

3 Scheme

4 Methodology

5 Results

6 Discussion

7 Related Work

In this section (...)

To do...

7.1 Inlining

W. Davidson and M. Holler [2] examine the proposition that the increased code-size of inlined code affects the execution time performance on demand-paged virtual memory machines. Using equations developed to the describe an inlined programs' execution time, they test this propositing through the use of a source-to-source subprogram inliner.

Cavazos and F.P. O'Boyle [1] use a genetic algorithm in their auto-tuning heuristics to show how conjunctive normalform (CNF) can easily be used to decide if and when to inline a specific call site. They report between 17% and 37% execution time improvements without an explosion of the resulting code size.

Serrano [5] implements an inliner in the Scheme programming language. He details an algorithm for which functions to inline, as well as an algorithm for how to inline reccursive functions and non-recursive functions.

Waterman's Ph.D. thesis [6] examines the use of techniques to adaptively decide which functions to inline. The thesis shows the use of CNF for deciding which functions to inline.

E. Hank, W. Hwu, and R. Rau [3] introduces a new technique called *Region-Based Compilation*. And examines the benefits an aggressive compiler can gain from inlining.

P. Jones and Marlow [4] explore a inlining approach for the Glasgow Haskell Compiler (GHC). The paper introduces a novel approach for deciding which mutually recursive functions can be (if any) safely inlined for optimization purposes.

7.2 Regionalized Value-State Dependency Graph

Insert reference/summary of HiPEAC paper when published

8 Conclusion

8.1 Further Work

9 References

[1] John Cavazos and Michael F. P. O'Boyle. Automatic tuning of inlining heuristics. In *Proceedings of the 2005 ACM/IEEE Conference on Supercomputing*, SC '05, pages 14–, Washington, DC, USA, 2005. IEEE Computer Society.

[2] J.W. Davidson and A.M. Holler. Subprogram inlining: a study of its effects on program execution time. *Software Engineering, IEEE Transactions on*, 18(2):89–102, Feb 1992.

[3] Richard E. Hank, Wen-Mei W. Hwu, and B. Ramakrishna Rau. Region-based compilation: An introduction and motivation. In *Proceedings of the 28th Annual International Symposium on Microarchitecture*, MICRO 28, pages 158–168, Los Alamitos, CA, USA, 1995. IEEE Computer Society Press.

[4] Simon Peyton Jones and Simon Marlow. Secrets of the glasgow haskell compiler inliner. *J. Funct. Program.*, 12(5):393–434, July 2002.

[5] Manuel Serrano. Inline expansion: When and how? In *Proceedings of the9th International Symposium on Programming Languages: Implementations, Logics, and Programs: Including a Special Trach on Declarative Programming Languages in Education*, PLILP '97, pages 143–157, London, UK, UK, 1997. Springer-Verlag.

[6] Todd Waterman. *Adaptive Compilation and Inlining.* PhD thesis, Houston, TX, USA, 2006. AAI3216796.

A Project Description

(On next page)

Project Description: An Inliner for the Jive compiler

Nico Reissmann

December 12, 2014

Compilers have become an essential part of every modern computer system since their rise along with the emergence of machine-independent languages at the end of the 1950s. From the start, they not only had to translate between a high-level language and a specific architecture, but had to incorporate optimizations in order to improve code quality and be a par with human-produced assembly code. One such optimization performed by virtually every modern compiler is *inlining*. In principle, inlining is very simple: just replace a call to a function by an instance of its body. However, in practice careless inlining can easily result in extensive *work* and *code duplication*. An inliner must therefore decide carefully when and where to inline a function in order to achieve good performance without unnecessary code bloat.

The overall goal of this project is to implement and evaluate an inliner for the Jive compiler back-end. The project is split in a practical and an optional theoretical part. The practical part includes the following:

- Implementation of an inliner for the Jive compiler back-end. The inliner must be able to handle recursive functions and allow for the configuration of different heuristics to permit rapid exploration of the parameter space.
- An evaluation of the implemented inliner. A particular emphasis is given to different heuristics and their consequences for the resulting code in terms of work and code duplication.

The Jive compiler back-end uses a novel intermediate representation (IR) called the Regionalized Value State Dependence Graph (RVSDG). If time permits, the theoretical part of the project is going to clarify the consequences of using the RVSDG along with an inliner. It tries to answer the following research questions:

- What impact does the RVSDG have on the design of an inliner and the process of inlining?
- Does the RVSDG simplify/complicate the implementation of an inliner and the process of inlining compared to other commonly used IRs?

The outcome of this project is threefold:

1. A working implementation of an inliner in the Jive compiler back-end fulfilling the aforementioned criteria.
2. An evaluation of the implemented inliner.
3. A project report following the structure of a research paper.