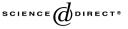


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Static insertion of safe and effective memory reuse commands into ML-like programs[☆]

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Abstract

We present a static analysis that estimates reusable memory cells and a source-level transformation that adds explicit memory reuse commands into the program text. For benchmark ML programs, our analysis and transformation system achieves a memory reuse ratio from 5.2% to 91.3% and reduces the memory peak from 0.0% to 71.9%. The small-ratio cases are for programs that have a number of data structures that are shared. For other cases, our experimental results are encouraging in terms of accuracy and cost. Major features of our analysis and transformation are: (1) polyvariant analysis of functions by parameterization for the argument heap cells; (2) use of multiset formulas in expressing the sharings and partitionings of heap cells; (3) deallocations conditioned by dynamic flags that are passed as extra arguments to functions; (4) individual heap cells as the granularity of explicit memory reuse. Our analysis and transformation system is fully automatic. © 2005 Elsevier B.V. All rights reserved.

Keywords: Program analysis; Program transformation; Type system; Compile-time garbage collection

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1. Overview

Our goal is to automatically insert explicit memory reuse commands into ML-like programs so that they do not blindly request memory when constructing data. We present a static analysis and a source-level transformation system that automatically adds explicit memory reuse commands into the program text. The explicit memory reuse is accomplished by inserting explicit memory-free commands right before data-construction expressions. Because the unit for deallocation and allocation is an individual cell, such deallocation and allocation sequences can be implemented as memory reuses.¹

Example 1. Function call "insert i 1" returns a new list where integer i is inserted into its position in the sorted list 1.

fun insert i l =	
case l of [] => i::[]	(1)
h::t => if i <h i::1<="" td="" then=""><td>(2)</td></h>	(2)
else h::(insert i t)	(3)

Let us assume that the argument list 1 is not used after a call to insert. If we program in C, we can destructively add one node for i into 1 so that the insert procedure should consume only one cons-cell. Meanwhile, the ML program's line (3) will allocate as many new cons-cells as that of the recursive calls. Knowing that list 1 is not used any longer, we can reuse the cons-cells from 1:

In line (4), "free 1" will deallocate the single cons-cell pointed to by 1. The very next expression's data construction "::" will reuse the freed cons-cell. \Box

1.1. Related works

The type systems [25,24,2] based on linear logic fail to achieve the Example 1 case because variable 1 is used twice. Kobayashi [10], and Aspinall and Hofmann [1] overcome this shortcoming by using more fine-grained usage aspects, but their systems still reject Example 1 because variables 1 and t are aliased at line (2)-(3). They cannot properly handle aliasing: for "let x=y in e" where y points to a list, this list cannot in general be reused at *e* in their systems. Moreover, Aspinall and Hofmann did not consider an automatic transformation for reuse. Kobayashi provides an automatic transformation, but he requires the memory system to manage a reference counter for every heap cell.

Deductive systems like separation logic [9,16,17] and the alias-type system [18,26] are powerful enough to reason about shared mutable data structures, but they cannot be used

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¹ The drawback of this approach might be that the memory reuse "bandwidth" is limited by the dataconstruction expressions in the program text. But our experimental results show that such a drawback is imaginary.

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