Homework 3: Profile Guided Optimization
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CSE 501

How To Run:

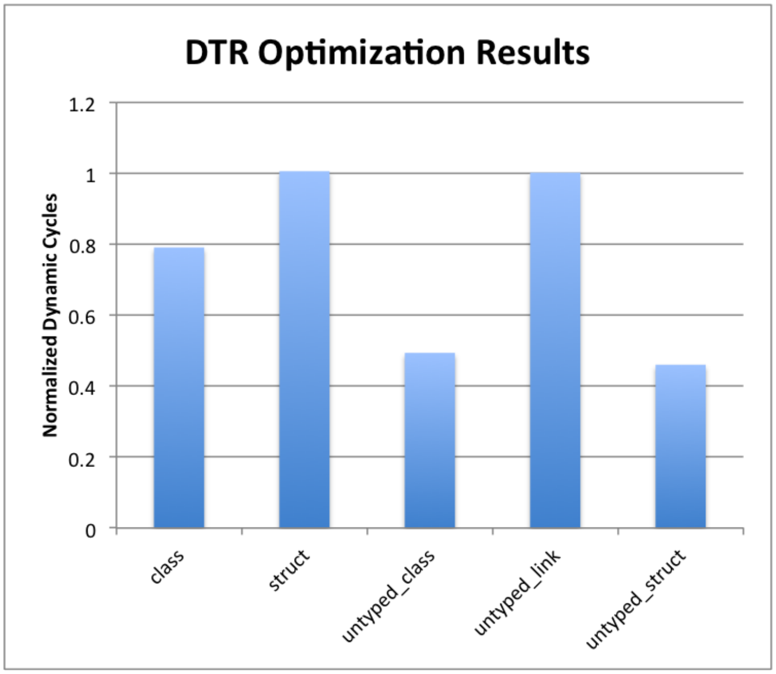
Compile: (Scala Compiler Version 2.10.1)
In code directory: scalac *.scala

Run:
In test or untyped directory: run.sh [-opt=OPTIONS] filename
OPTIONS: ssa, cse, scp, cbr, dtr, mem
cse, cbr, and scp will not run without also specifying ssa

Optimizations

Dynamic Type Refinement

The purpose of the Dynamic Type Refinement (DTR) optimization is to attempt to eliminate dynamic loads and stores via profile-based optimization. Dynamic loads and stores can make up a significant amount (up to 50% in the example programs) of the run-time of a program, so reducing them is a potentially high-value target for optimization. The profiling is conducted by inserting a counter before each dynamic load and store instruction to track which type the object is that is used in the dynamic instruction. These counts are gathered and any count showing that only a single type is ever used at a certain position is marked for optimization. Since the type of the object being operated on is known, the exact offset (and type of the value loaded, if it is a dynamic load) can be determined. To optimize a dynamic load, the lddynamic instruction is converted into a load preceded by an add to create the proper address from the object address and offset. Additionally, if the type of the expected return value is a primitive then the subsequent unboxing instructions are deleted since the load instruction will automatically unbox the primitive. To optimize a dynamic store is simpler; this only requires replacing the stdynamic instruction with an add and store to the proper address offset. The results of this optimization are impressive for the programs it works on: class, untyped_class, and untyped_struct all show significant improvements, with untyped_class and untyped_struct runtimes being more than cut in half.



Code Layout

This optimization is enabled with the option "cbr". It will not work if "ssa" is not also specified.

Here, we aim to improve the layout of basic blocks in memory by counting how many times branches are taken in the code. First, we instrument all unconditional branches with a counter, and instrument each conditional branch with two counters. We do this while the code is in SSA form, which is also the point in our code where all transitions between basic blocks are explicit, i.e. there are no points where we simply fall off the end of a basic block into the next basic block. These counters are then used as the priorities of the basic blocks when they are layed out in each function. Previously, blocks were layed out in an arbitrary topological sort, now they are layed out in a priority topological sort. The only difference is, instead of a worklist, a priority queue is used to keep the blocks currently being processed, and thus higher priority blocks (those on the hot code path) are all layed out close to each other.

This has surprisingly little effect on runtime, in most cases leaving the optimized program with the exact same dynamic cycle count as its non-optimized version. In the cases where the runtime is not the same, the optimized code ends up running slightly slower. We are not entirely sure what causes this. These results confirmed our hypothesis that code layout was not an especially large factor in program runtime, and that the original order a program is written in is in fact not that bad as a basic block layout.

Output Memoization

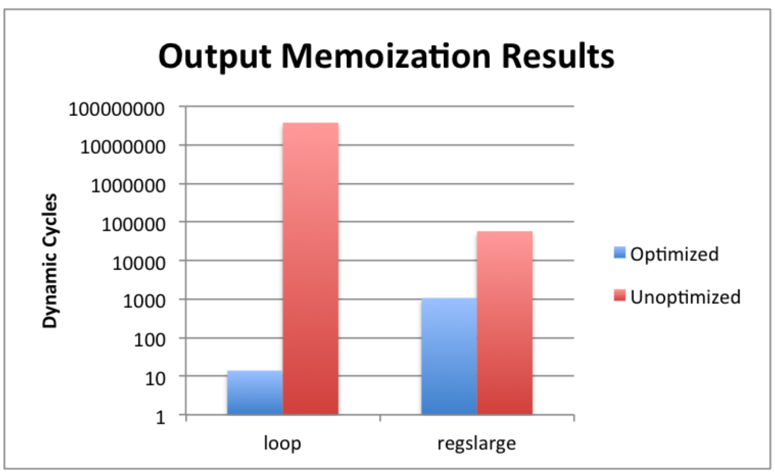
This optimization is enabled by the "mem" option.

This optimization runs the program, and grabs all output the program produces. It then constructs a program that is a series of instructions that writes the same output, and produces that as its optimized program.

This optimization is provably optimal, if we consider program equivalence as only an I/O equivalence, i.e. two programs are equivalent if and only if they produce the same output. We noticed the key point that Start has no capacity for input (other than constants hard coded into the program text), and has only the capacity to write integers and newline characters to the screen. Thus, if we have some input program that produces some output when run, there is an infinite set of programs that produce the same output when run. However, one of these programs is optimal, in that it does no other computational work other than that required to produce the output. As there is only one way for a Start program to produce a specific output, the program that produces this output and computes nothing is thus optimal, in that it will run in a shorter amount of time than any other equivalent program in this set.

This does not work if the program does not halt. However, for us to apply a profile guided optimization, we are already making the assumption that the program halts, and none of our profile guided optimizations work if this assumption breaks.

In practice this optimization garners a massive speedup on any program that isn't a series of print statements. This is still of limited use in any useful setting, as most languages that exist in the wild have the capacity for input to their programs.



Code Statistics

Our final implementation is 2443 lines of Scala in 12 files. When compiled, they generate 612 distinct Java class files.