vmgen - A Generator of Efficient Virtual Machine Interpreters

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Summary

- vmgen generates fast interpreters from instruction descriptions
- also generates parts of associated tools
    - profiler
    - debugger
    - disassembler
    - code generator

Motivation

- writing/modifying an interpreter toolset is tedious and error-prone
    - many parts can be automated
- can generated interpreters compete with those hand-written in assembly?

Motivation

- C compiler does most of the complicated things
- vmgen makes modifying an instruction set easier than rewriting *anything* in assembly

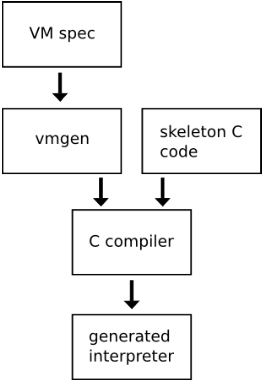
Process

- inputs: description of instruction set
- outputs: C code
    - interpreter
    - profiler
    - debugger
    - VM code disassembly
    - VM code generation

Process

- producing a working interpreter requires a bit more work
    - C code for interpreter skeleton
    - C code from vmgen
    - C compiler

Process


VM spec

vmgen

skeleton C code

C compiler

generated interpreter

Figure: vmgen process

Vmgen input example

- input format:

```
iadd:

iadd  ( i1 i2 -- i )

i = i1 + i2;
```

  - name
  - stack effect, input and output types
  - C implementation code

Output example

```
I_iadd:{
  int i1, i2, i;
  NEXT_P0;
  i1 = vm_Cell2i(sp[1]);
  i2 = vm_Cell2i(sp[0]);
  sp += 1;
  {
    i = i1 + i2;
  }
  NEXT_P1;
  sp[0] = vm_i2Cell(i);
  NEXT_P2;
}
```

Architecture

- designed and optimized for stack-based VMs
    - but register-based VMs are possible
- generated interpreter uses direct threading
    - but indirect threading is possible
- flexible!

Optimizations

- vmgen interpreters are designed for optimization
- built-ins
  - TOS caching, software pipelining, efficient stack usage
- tail duplication for branch prediction
- superinstructions

Existing optimizations

- TOS caching
- software pipelining/scheduled dispatch
    - interleave instruction execution with instruction fetch
- superinstructions

Superinstructions

- not superoperators
  - superoperators are tree operators
  - superinstructions are DAG operators, work on stack-based interpreters
- arbitrary combination of previously-defined instructions

Superinstructions

- consequences
  - C compiler ideally generates more efficient code
  - VM code generator generates fewer instructions
  - interpreter interprets fewer instructions
  - profiler can recommend superinstructions

Novel optimizations

- store elimination
  - example:

    ```
    dup ( i -- i i )
    ```

  - avoid creating a temporary variable and pushing it twice
  - doesn't work with superinstructions
- tail duplication for branch prediction

Performance

- two interpreters built with vmgen
    - Gforth: Forth interpreter
    - Cacao int: JVM interpreter, with threaded code instead of byte code

Performance

- Gforth is faster than Win32Forth
  - Win32Forth is written in assembly, but uses indirect threading and PIC
- Gforth is slower than BigForth
  - BigForth compiles Forth to native code

Performance

- Cacao int is faster than the DEC JVM native JIT compiler for some benchmarks
- Cacao int is slower than Cacao native, but only by a factor of two for most benchmarks
  - Cacao int and Cacao native share synchronization and garbage collection mechanisms, and Cacao int spends 30% of its time in these routines

Performance

- optimizations were generally beneficial
- but architecture-dependent
    - example: TOS caching improved performance on PPC by 20%, but net effect on a particular Alpha machine was 5%
- and benchmark-dependent

Discussion

- quality of resulting interpreter depends on quality of compiler used to build interpreter
- authors claim GCC does a good job, but did not verify all compiled code
- authors manually allocated registers in Gforth because GCC inappropriately spilled important interpreter registers