Toba: Java for Applications

A Way-Ahead-of-Time Compiler

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Overview

The Java language is gaining prominence
Java is designed for interpretation
Toba precompiles Java programs
to cut execution time by 2/3
Toba trades flexibility for speed

Toba: An Independent Project

Compatible with Java language spec
Different implementation internals
Different C interface

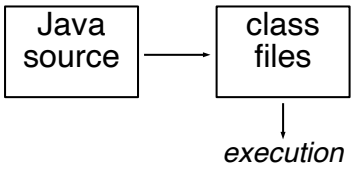
Full Language Support

Java specifies (among other things):
- array bounds checking
- thread support
- garbage collection
- exception handling

These feature affect performance
- some compilers omit them

Original Java Model

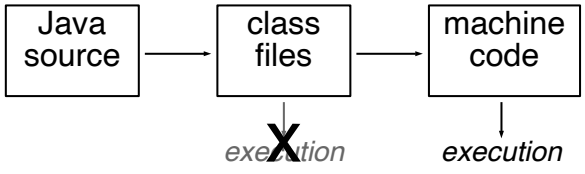
Compile for abstract Java Virtual Machine



Interpretation
Just-in-time (JIT) compilation

Toba: WAT Compilation

Compile JVM code to machine code



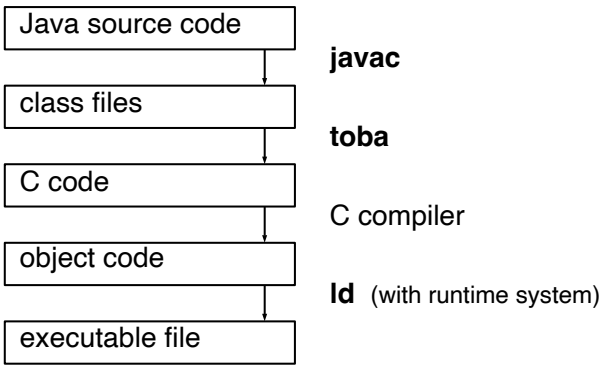
Quick startup – no JIT compilation
Fast execution – better optimization

Applicability of Toba

Not for applets
- not architecture-independent
- machine code can't be trusted

For stand-alone applications
- Java compiler
- "server side" programs
- many other possibilities

Using Toba



The Translator

A 5000-line Java program
Reads class files
Writes (mostly) ANSI C code
- data structure definitions
- static initialization
- executable method code

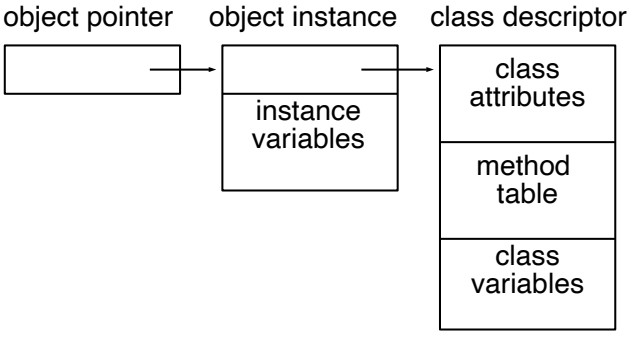
Uses **long long** for 64-bit ints

Runtime Datatypes

Primitive Java types map to C types
- e.g.: **char** –> **unsigned short**

Reference types map to **void** *
- the pointer addresses an allocated object
- Toba does not use handles

Java Objects



Runtime Class Descriptor

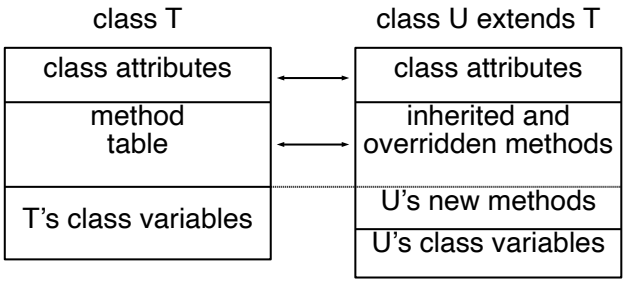
Common attributes
- name, flags, superclass, etc.

Method table
- function pointers and hash values

Class (static) variables

Subclass Descriptor

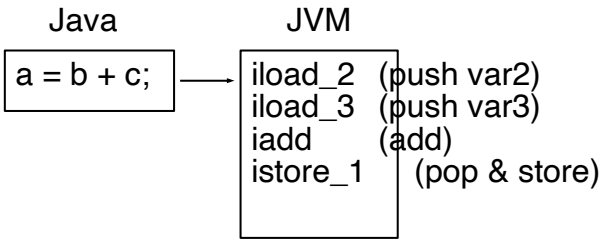
Duplicates and extends superclass layout



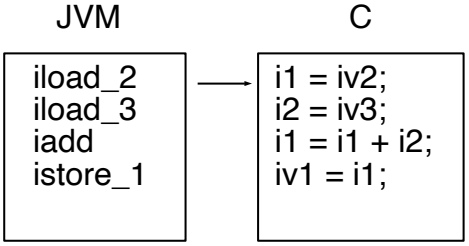
Code Generation

One **.c** / **.h** pair for each class
One function per method
Each method is translated independently
- a key difference from Harissa

JVM is Stack-Based



C Code Models Stack



i1, **i2** are first two integer stack positions
iv1, **iv2**, **iv3** are Java local variables

Naive But Effective

The generated code is simpleminded
C compilers produce efficient code

Control Flow

Use C **goto** statements when possible
- conditional and unconditional jumps

Use **switch** when target is not fixed
- JVM **ret** instruction is an indirect jump

Three Kinds of Method Calls

- Static method
  - direct call to C function
- Instance method
  - indirect call through method table
- Interface method
  - search for matching name and signature
  - use hashcode for quicker searching

Java Exceptions

- Java programs can throw and catch exceptions across method boundaries
- Exceptions are thrown by
  - explicit code
  - execution errors
- Toba uses **setjmp** / **longjmp**

Exception Setup

- A method that catches exceptions
  - calls **setjmp** on entry
  - maintains a PC variable
- No overhead if no **catch**

Exception Dispatching

- **throw** executes a **longjmp** to the innermost **setjmp** point
- Dispatching is based on exception class and PC
- Unselected exceptions are rethrown

The Runtime System

- Java library (API) from Sun
- Toba runtime system (C code)
  - 3000 lines of API support
  - 3000 lines of language support
- Boehm-Demers-Weiser conservative garbage collector
- BISS AWT (window toolkit)
- Thread package

Garbage Collection

- Use Boehm-Demers-Weiser collector
- A free conservative collector
- Originally needed minor changes for Java finalization
- Now used off-the-shelf

Threads and Synchronization

- Thread layer interfaces to system
- Solaris threads supported now
- Others in works
- Thread support impacts performance even when not used

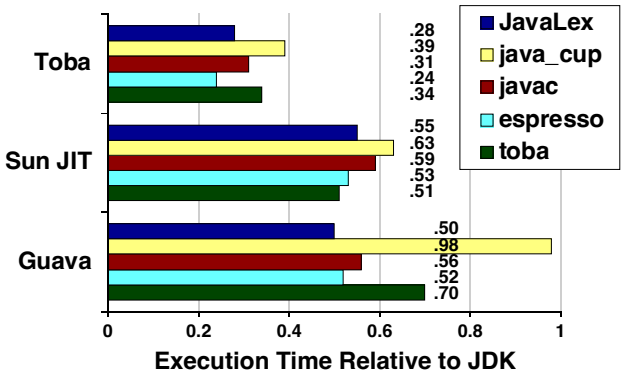
Performance Measurements

- Benchmarks use software tools found on the net
- Toba is compared with three other full implementations:
  - **JDK**: the original Sun interpreter
  - **Sun JIT**: a Sun just-in-time compiler
  - **Guava**: an independent JIT compiler

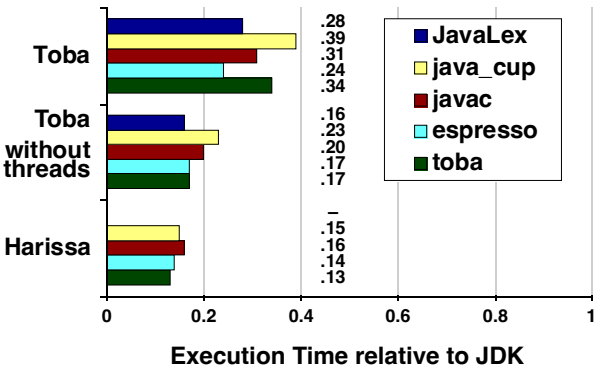
Micro-Benchmarks

- UCSD microbenchmarks isolate specific language features
- Toba is generally faster than others
  - Guava interface calls 16% faster
  - A few others <10% faster
  - Toba wins most comparisons

Application Performance



The Effect of Thread Support



Toba and Harissa

- Toba has thread support
- Harissa does class hierarchy analysis, inlining, and optimization
- Different exception handling approach
- Different null-pointer checking

Current Status

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Full implementation for Solaris
SGI has ported to Irix with pthreads
Partial implementation for Linux, NT
(no threads, no AWT)
Source code is on the Web

Future Work

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JIT compiler
JDK version 1.1
More full ports, using POSIX threads

Software Distribution

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Source code and documentation:

http: // www.cs.arizona.edu /
sumatra / toba /

* Toba is a large lake on Sumatra,
the island just west of Java.