The Java™ HotSpot™ Performance Engine - A Technical Tour

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The Java Programming Language

- platform-independent
- object-oriented
- multi-threaded
- dynamic class loading
- safe

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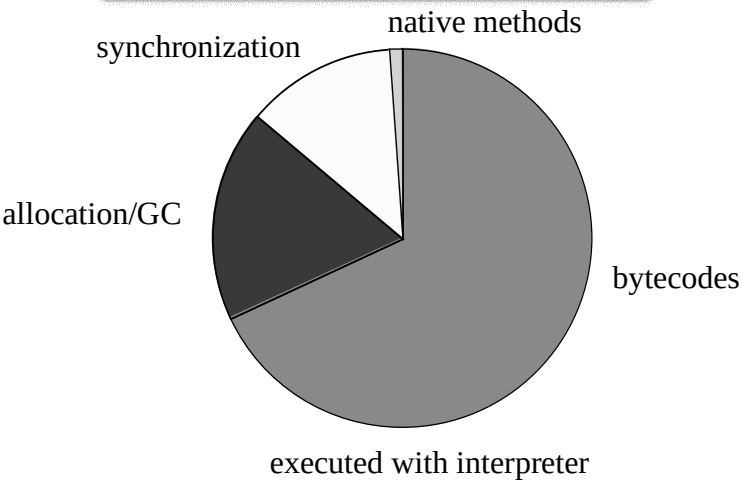
Example: javac



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Talk Overview

- dynamic code generation
- CHA & inline caches
- fast allocation/GC
- synchronization
- backpatching
- deoptimization

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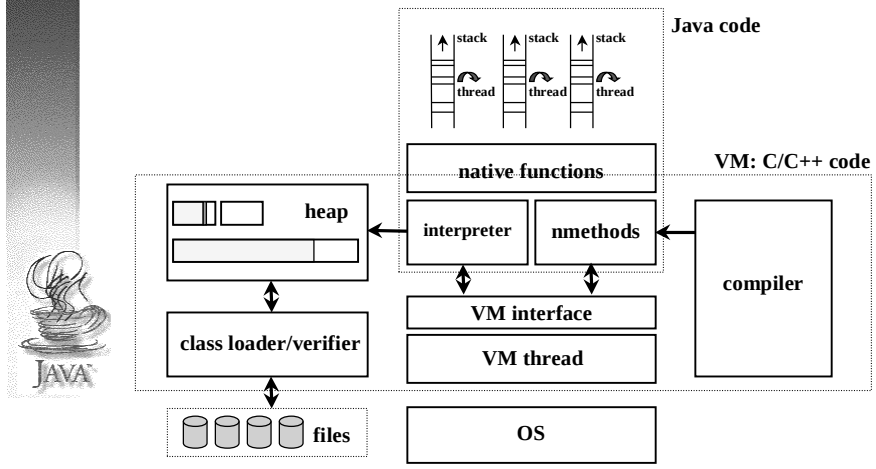
VM Overview



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Dynamic Code Generation

- overcome speed limitations of interpreters
- static compilation is not an option
  - dynamic class loading!
- more information available at run-time than statically

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Just-In-Time Compilers

- translate bytecodes to machine code
- happens at runtime
- standard JITs: compile method when first invoked
- proven technology

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The Trouble with JITs

- problem: consume execution time
- dilemma: either good code or fast compiler
- root of problem: compilation is too eager
  - balance compile & execution time
- can compilation cost be amortized?

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A Lazy Approach

- only compile/optimize the hotspots
- combine compiler with interpreter
- seamless transition between interpreted and compiled code
- predict the future by looking at the past

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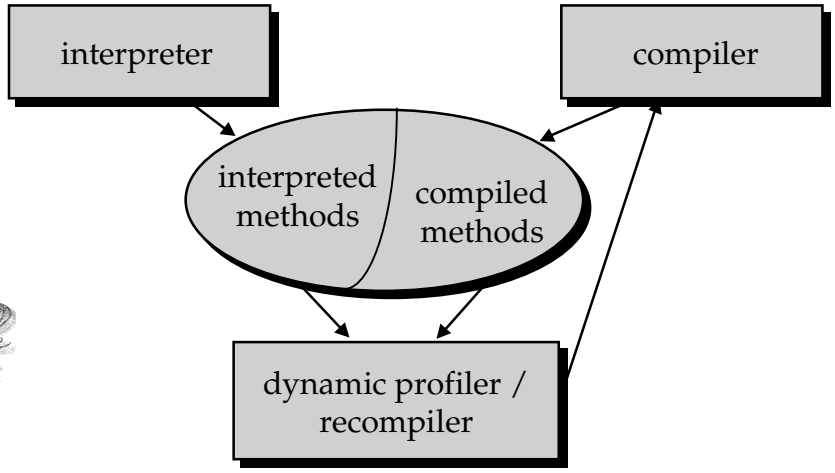
HotSpot Compilation Architecture



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Advantages Over Standard JIT

- less to compile
  - faster startup
  - smaller code space
  - more time left for optimizations
- better code quality
  - use dynamic run-time information
- more flexibility
  - speed/space tradeoffs

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Why Have an Interpreter?

- space
- startup time
- “source-level” debugging
- portability
- compiler can be simpler
  - deoptimization

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More Opportunities for Dynamic Code Generation

- interpreter
  - fine-tuning on machine code level for better performance
  - generated at startup time for flexibility and robustness
- runtime interface stubs
- dynamic stub-routines

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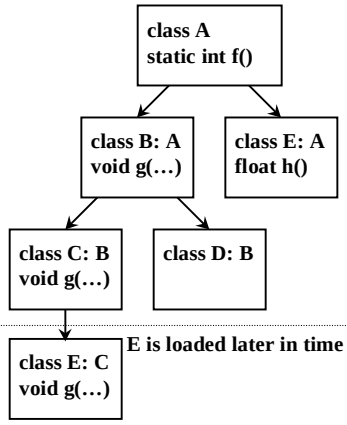
Class Hierarchy Analysis



- f can be statically bound or inlined
- g must be dynamically dispatched for recv of **static type B**
- g can be statically bound or inlined for recv of **static type C or D**
- h can be statically bound or inlined

Note: these observations may not be true anymore after class loading!

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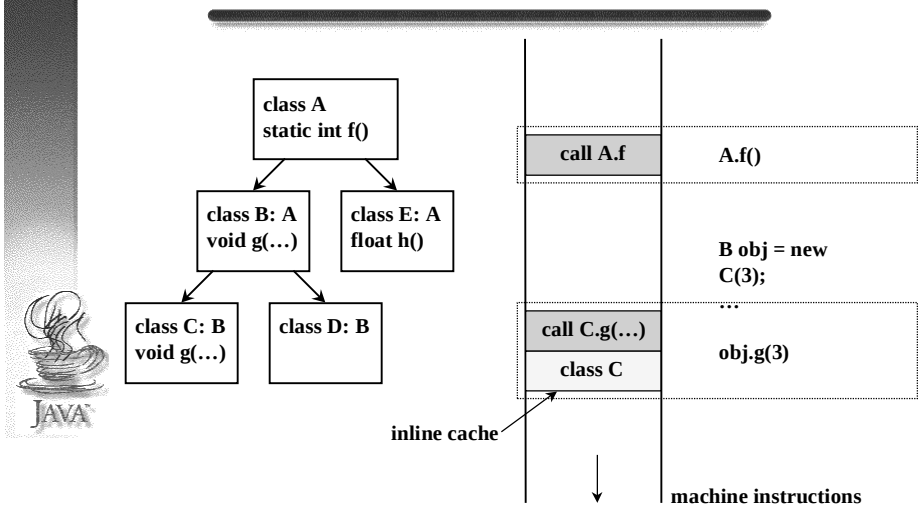
Inline Caches: Caller



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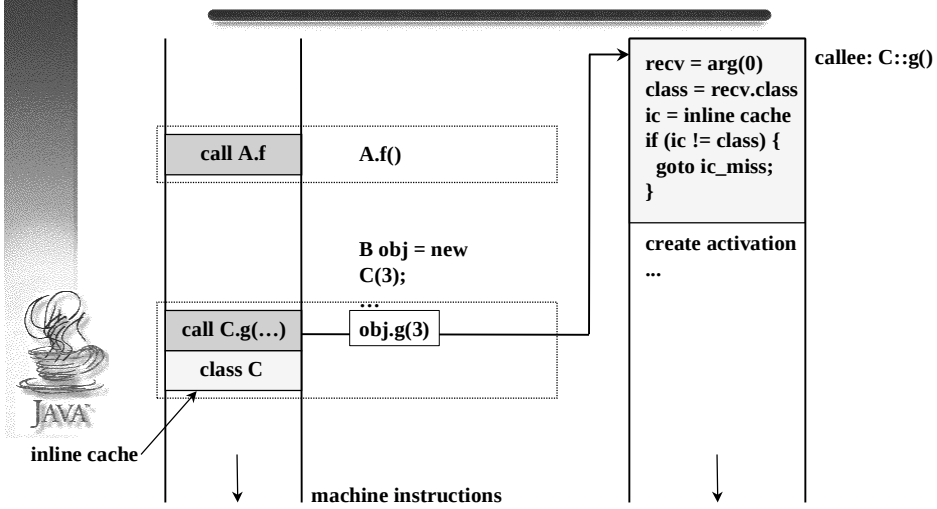
Inline Caches: Callee



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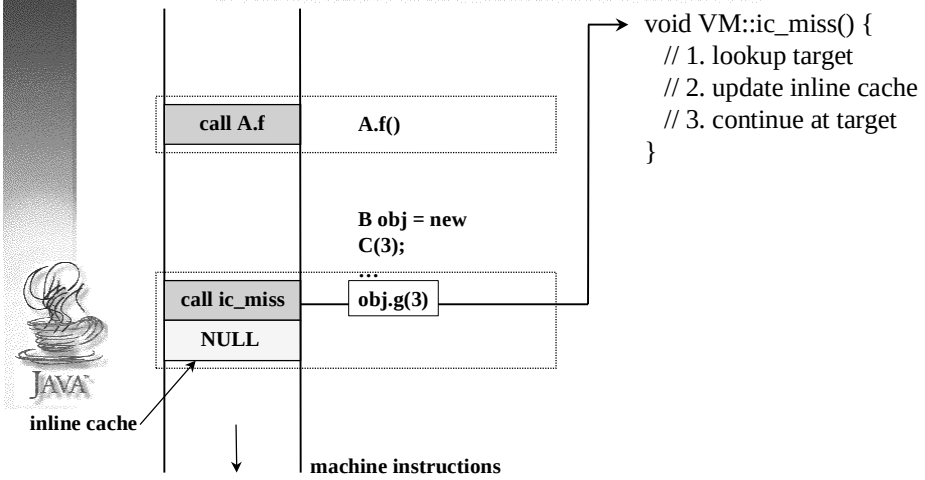
Inline Caches: First Time



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Fast Allocation

- smallest object is 2 words
- no handles in Java code
- accurate GC
  - compaction possible & required for fast allocation
- allocation = increment 1 pointer
- allocation code inlined

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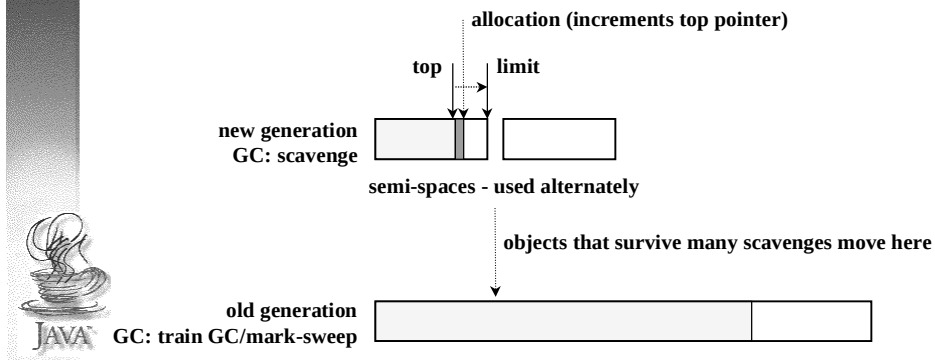
Heap: The Big Picture



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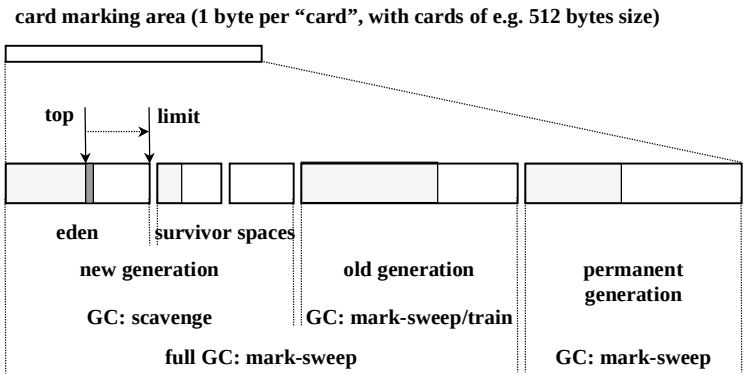
Heap: (Almost) the Real Story



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Fast Locking

- lock usage is “method” structured
  - locks can be stack-allocated
- software only
- virtually no per-object space overhead
  - 2 bits per object
- supports native threads, SMP

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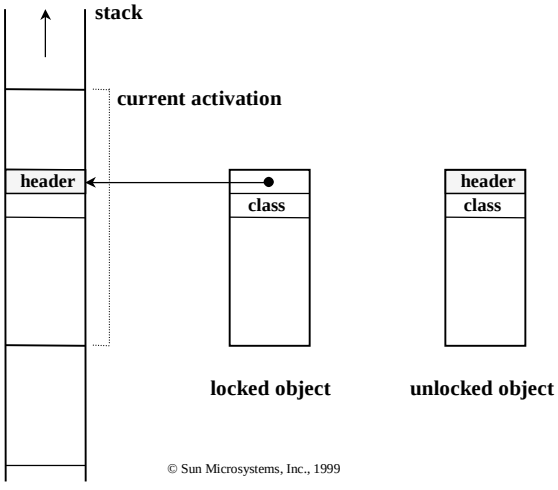
Fast Locking



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Backpatching

- code changed during execution
  - used by interpreter (“quickening”)
  - used by compiler (e.g., inline caches)
- can avoid repeated checks
- must be very careful with MT/MP
- “undo” possible

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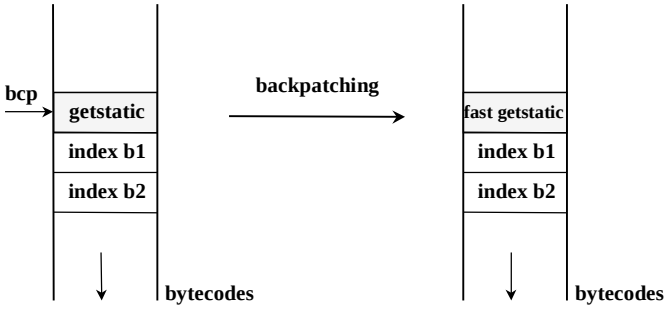
Backpatching in the Interpreter



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Deoptimization

- optimizations may need to be undone
- reflective information in compiled code
- deoptimization: compiled activations => interpreter activations
- required to do optimistic optimizations
- inverse: on-stack replacement

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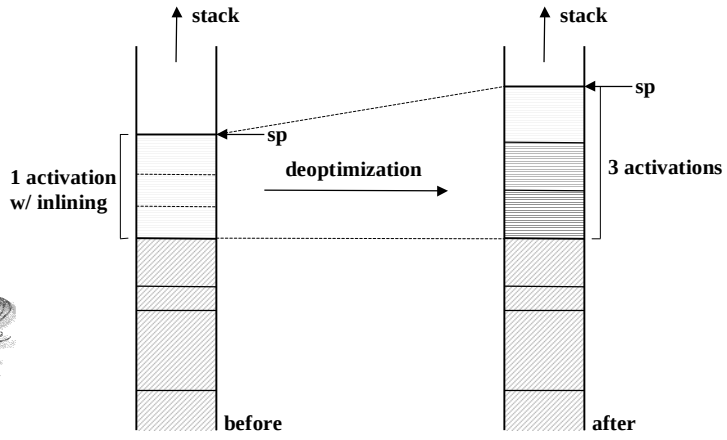
Deoptimization of a Stack Frame



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Observations

- there is no silver bullet
  - must optimize many parts of a system
- careful balance of optimizations
  - optimizing A may slow down B
- complexity requires rigorous programming style

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Conclusions

- HotSpot Technology is a reality & solves Java's challenges
- dynamic code generation has become standard technology
- Java performance has improved dramatically

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References

- The Java™ HotSpot™ Performance Engine
  - http://java.sun.com/products/hotspot/
  - JavaOne talks and White Paper
- The Self project
  - http://self.sunlabs.com/
  - links to many Self-related papers

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