A Brief History of Just-In-Time

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Introduction

• What is JIT compilation?
  • Any translation performed dynamically
  • After a program has started execution
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- What is JIT compilation?
  - Any translation performed dynamically
  - After a program has started execution
- Why do we care?
  - May offer advantages over static compilation and translation
  - Has received much attention in recent years
  - Many concepts have been reinvented
Advantages

• Advantages over compiled programs
  • Typically smaller in size
  • More portable
  • Access to run-time information
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  - Typically smaller in size
  - More portable
  - Access to run-time information
- Advantages over interpreted programs
  - Faster execution
History

- **1960-1969**
  - Earliest published work
- **1970-1979**
  - Prioritize space optimizations
  - Optimization of “hot spots”
- **1980-1989**
  - JIT similar to memory management
  - Aggressive JIT customization
- **1990-2000**
  - Spreading out compilation time
  - Slim binaries
  - Staged compilation
History

• 2000-today
  • Huge investment of time and money into JIT
  • Concurrent development of many approaches
  • Reinvention of many concepts
Space optimizations

- Mixed code
  - Compile “hot spots” only
  - Fine grained mixture implied
Space optimizations

- **Mixed code**
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- **Caveats**
  - Both a compiler and interpreter need to be in memory
  - Both a compiler and interpreter need to be maintained
Space optimizations

- Throw-away code
  - Compile a block
  - Execute it
  - Discard the code
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  - Keep a fixed-size cache of program code
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  - Compile a block
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- Alternatively
  - Keep a fixed-size cache of program code
- Deferred compilation of uncommon cases
  - Some cases may never be compiled during typical execution
Dynamic and adaptive optimization

- Collect run-time information
  - Utilize runtime type information
  - Maintain execution counters
  - Perform optimizations in order of increasing complexity
  - Concentrate effort on hot-spots
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- Considerations
  - “What” to optimize is more important than “when”
  - The code that should be optimized may not be the one that triggered the optimization
  - Inlining may be the answer to frequently called short methods
  - Cache coherency issues may arise
  - Implicit or explicit invocation of JIT compiler (Erlang)
Dynamic and adaptive optimization

- Alternatively
  - Start by profiling
  - Amortize profiling cost over program execution
Continuous run-time optimization

- Input may vary over time
  - Similar in spirit to cache strategies
  - Optimize based on the most recent input patterns
  - Dynamically reorder code
Continuous run-time optimization

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  - Similar in spirit to cache strategies
  - Optimize based on the most recent input patterns
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- Possible extensions
  - Dynamically optimize based on available resources
  - The resources available may change
  - Resource utilization may change due to contention
Customization

- Customize frequently executed methods
  - Many classical compiler techniques apply
  - Constant propagation/folding
  - Dead code elimination
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- Specialize interpreter’s instructions
  - Reduce the overhead of instruction dispatch
  - Yield opportunities for macro opcode optimization
  - The speedup obtained is significant
  - Does not compete with compilation
  - May not be as fruitful as other approaches
Improving the user experience

- Avoid large compilation spikes
  - Large periods of unresponsiveness degrade user experience
  - Favor response time over total execution time
  - Perform optimizations in stages

- Spread out compilation time
  - Two or more closely followed compilation pauses can appear as one large pause

- Deferred compilation of uncommon cases
  - Compile only the current execution path
  - Set up stubs for non-compiled cases

- Responsiveness can improve significantly for large case blocks
  - Fast code generation
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Machine independent code representation

- Slim binary, Java, etc.
- Same executable vs heterogeneous substrate computing environment
- Slim binary: a high-level, machine independent program module
- Generate executable on-the-fly when loaded
- Generate module at once is superior to method-at-a-time
Simulators

- Running executable code for one architecture on another
  - Highly specialized with respect to source and target
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- Categories
  - Interpreters: First generation
  - Dynamically translated *instructions*: Second generation
  - Dynamically translated *blocks*: Third generation
    - Block-at-a-time or page-at-a-time
  - Dynamically translated *paths*: Fourth generation
Fourth generation

• Predominant in recent literature
Fourth generation

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- Common techniques
  - Profiled execution
  - Hot path detection: counter, code structure, sample PC
  - Code generation, optimization and verification
  - “Bail-out” mechanism
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- Recurring themes
  - Binary to binary translation
  - Legacy to VLIW code translation
  - Target architecture provide extra resource
  - Can these scale?
Classification of JIT systems

- Invocation
  - Implicit: transparent to the user
  - Explicit: Allows for better control
  - Currently implicit invocation systems dominate
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- Executability
  - Monoexecutable
  - Polyexecutable
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- Concurrency
  - Concurrent execution and compilation
  - Execution stalls in order to compile
  - Concurrent systems are becoming more important
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- Hard real time systems
  - Little research in this area
  - Usually developed using worst case analysis
  - Implicit compiler invocation incompatible
Issues faced by JIT tools

- Binary code generation
  - Rife with opportunities for error
  - Lots of bookkeeping tasks
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- Execution
  - Restrictions on where executable code can reside
  - Restrictions on which parts of memory can be edited
Java

- Static compilation to bytecode
- JIT compilation from bytecode to machine code
- Originally only interpreted
  - Surprisingly slow
- Different implementations have surfaced
  - Stack based, register based
  - Some skip the bytecode phase altogether
- Was the driving force for much research in JIT
- Other languages are now targeting the JVM
Java

- Other JIT compilation approaches
  - Compile-only strategy
  - Translate byte code into Self code to leverage existing optimization
  - Code annotation to facilitate code optimization prior to run-time
  - Continuous compilation for Java
Conclusion

- JIT compilation is an old technique
- It has received much attention in recent years
- It can result in smaller footprint than compiled code
- It has the potential to achieve
  - Better performance than interpreted code
  - Or even compiled code
- It can provide platform independence
Thank you for your attention

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- Questions?