# Smalltalk Implementation:

# Optimization Techniques

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# Optimization Ideas

- Just-In-Time (JIT) compiling

  When a method is first invoked, compile it into native code.

- Caching the Method Dictionary

  Method Look-up will be speeded up.

- Inline Method Sending

  Will turn many SENDs into native CALL instructions

- Use the hardware calling stack

  ***MethodContexts*** → activation records allocated on a stack

- Code the VM directly in Smalltalk

  Automatic translation into “C”

# Misc Points

## Porting the Smalltalk Interpreter

The virtual machine is implemented in Smalltalk!
Using a subset of Smalltalk, called "*Slang*"

The image also includes a translator / compiler
Slang→ "C"

Steps to porting:
- Produce automatically generated interpreter in "C"
- Hand-code the machine-dependent parts in "C"
- Compile
- Use any existing image

# Misc Points

## Porting Images

Each VM executes the same bytecodes.
*Any* image can be executed on by *any* VM.

**EXAMPLE: An image produced on *MAC OS X* can be executed on *Windows*.**

## Porting Code Fragments

# Misc Points

## Porting Images

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## Porting Code Fragments

**Also, code fragments can be** ***filed out***
**… and** ***filed in*** **to another image**

***Will it work?***

**The Smalltalk language is uniform.**
**What pre-existing classes does the code use?**

# Misc Points

## Hash Values

**Some classes rely on "hash values".**

***Dictionary*, *Set*, etc.**

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*Need special VM support for hash values!*

- Each object contains a hash value.
- 12 bits
- Stored in it header
- Initialized when the object is created

# Optimizations to the Interpreter

## Virtual Machine

Does not match underlying hardware well

*Examples:*

OOP/SmallInteger Tagging

Registers versus Stacks in Context objects

## Bytecodes vs. Machine Instructions

The bytecodes are interpreted

Fetch-decode-execute done at two levels.

Difficult to optimize bytecodes

Bytecodes are complex operations

Corresponding to several machine level instructions

# “Just in Time” Compiling

***Translate bytecodes into native machine language***

**… and execute them directly**

**Do it “on the fly”**

**… on individual methods**

**Source → bytecodes → machine instructions**

***When the method is first invoked…***

- Call the JIT compiler
- Translate bytecodes to native instructions
- Save the native code for next time.

# "Just in Time" Compiling

## Benefits:

- Optional
  Compatible with existing system
- Still have bytecodes
  (for the debugging tools)
- Can perform many optimizations at the native code level
- Can do it just to frequently invoked methods
- Running out of memory?
  Throw away some of the compiled methods

# "Just in Time" Compiling

## Problem:

Activation records are user-visible

***MethodContexts***, ***BlockContexts***

Activation record contains a pointer to the current bytecode

"instructionPointer" = "Program Counter (PC)"

*Used by the debugging tools!*

## Solution:

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## Problem:

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## Solution:

Whenever an activation record becomes user-visible…

Map the native code PC back into a bytecode PC

# Allocating Contexts on the Hardware Stack

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Smalltalk VM…

linked list of ***Context*** objects

Want to use the hardware stack

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Contexts are usually allocated in LIFO (stack) order.

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Asks for a pointer to the current context

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## The Idea:

**Store stack frames on hardware stack, not as objects.**

**When a pointer is generated to the current context…**

**Convert the stack frame into a real object.**

# Details

Converting a stack frame into a real object…

Allocate a new ***Context*** object and fill in its fields

Convert the program counter (PC)

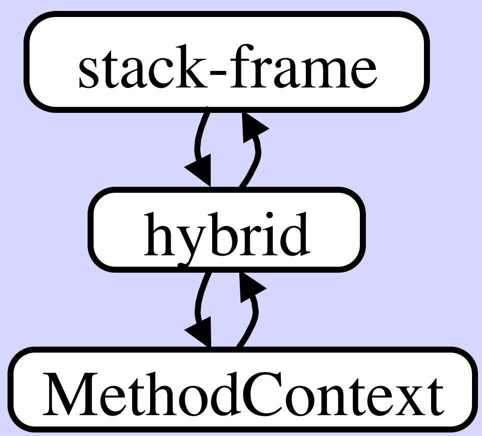
absolute address → byte offset into a ***CompiledMethod*** object

***Context***s point to other ***Context***s

But other ***Context***s are still on hardware stack

Convert all frames into Objects…? No!

*The Technique:*



# Caching the Method Dictionary

***Method Lookup:***

**Given:** • the receiver's class

• the message selector

**Find:**

• the right ***CompiledMethod***

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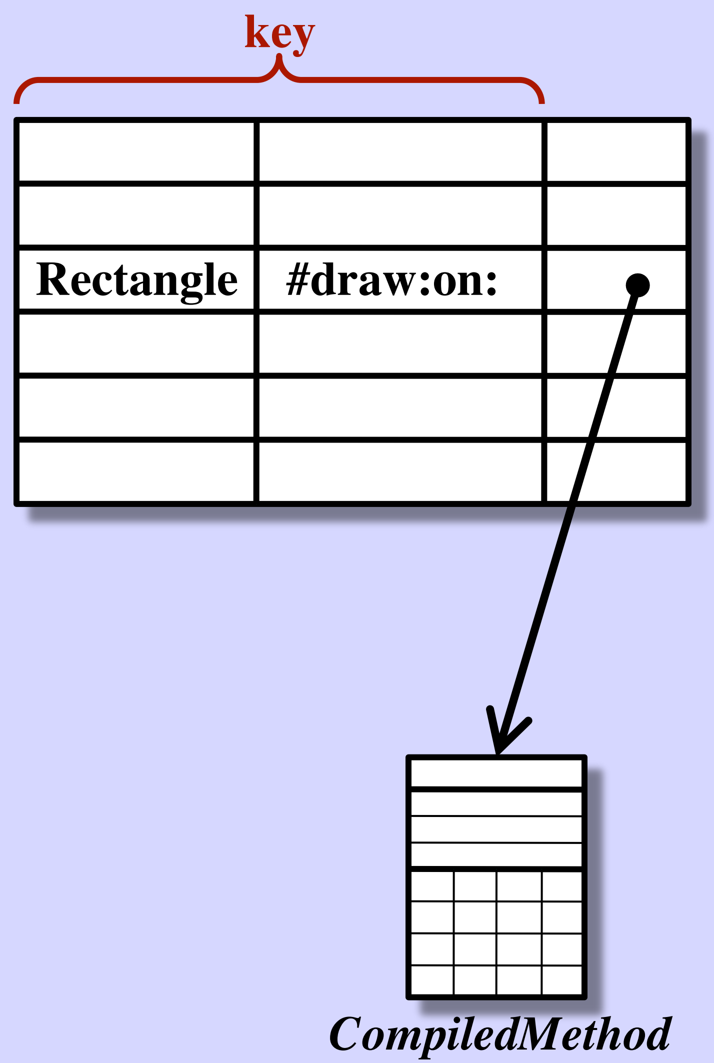


***The Idea:***

Use a Hash Table
Maintained by the VM
(it is not an object)
Not in the hash table?
• Do a full method lookup
• Add an entry to the hash table

# Inline Method Caching

Assume methods are compiled into native code.

***Code to send a message:***

```
< code to push receiver >
< code to push args >
CALL MessageSend (arg = selector)
```

A machine-language CALL instruction

A routine that searches for the proper method/routine and then calls it.

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***Code to send a message:***

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< code to push receiver >
< code to push args >
CALL MessageSend (arg = selector)
```

## The Idea:

- Upon locating the correct routine…
  Replace the CALL to the "MessageSend" routine
  … with a CALL straight to the native code routine!
- Next time we execute the above code,
  we CALL the right routine immediately.
- Gradually all message sends are replaced with
  native code CALL instructions.

# Inline Method Caching

## Problem:

*Dynamic Look-Up*

The receiver's class determines which method to invoke.
Different class? → Different method!

## Assumption:

## Approach:

# Inline Method Caching

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***Dynamic Look-Up***

The receiver's class determines which method to invoke.
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## Assumption:

*Any particular SEND will invoke the same method*
*… almost always!*

## Approach:

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## Problem:

***Dynamic Look-Up***

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*Any particular SEND will invoke the same method*
*… almost always!*

## Approach:

At the beginning of each method:

- Check the class of the receiver
- If it is what this method expects
  … continue with this method.
- If the receiver has the wrong class…
  - Perform a full method lookup.
  - Overwrite the CALL (to jump to the correct method next time)
  - Jump to the correct method.

# Effectiveness of Optimizations

| | space | time |
|---|---|---|
| Straight interpreter | 1.0 | 1.0 |
| Compiler | 2.3 | .69 |
| Compiler w/ inline caching | 3.4 | .62 |
| Compiler w/ peephole optimizer | 5.0 | .56 |
| Compiler w/ inline caching w/ optimizer | 5.0 | .51 |