Appendix A - An Optimization

The following set of pseudo-instructions suffixed by \texttt{\_quick} are variants of Java virtual machine instructions. They are used by the WebRunner/Java project to improve the execution of compiled code on our bytecode interpreter. They are not part of the virtual machine specification or instruction set, and are invisible outside of an Java virtual machine implementation. However, inside a virtual machine implementation they have proven to be an effective optimization.

A compiler from Java to the Java virtual machine instruction set emits only non-\texttt{\_quick} instructions. If the \texttt{\_quick} pseudo-instructions are used, each instance of a non-\texttt{\_quick} instruction with a \texttt{\_quick} variant is overwritten on execution by its \texttt{\_quick} variant. Subsequent execution of that instruction instance will be of the \texttt{\_quick} variant.

In all cases, if an instruction has an alternative version with the suffix \texttt{\_quick}, the instruction references the constant pool. If the \texttt{\_quick} optimization is used, each non-\texttt{\_quick} instruction with a \texttt{\_quick} variant performs the following:

- Resolves the specified item in the constant pool
- Signals an error if the item in the constant pool could not be resolved for some reason
- Turns itself into the \texttt{\_quick} version of the instruction. The instructions \texttt{putstatic}, \texttt{getstatic}, \texttt{putfield}, and \texttt{getfield} each have two \texttt{\_quick} versions.
- Performs its intended operation

This is identical to the action of the instruction without the \texttt{\_quick} optimization, except for the additional step in which the instruction overwrites itself with its \texttt{\_quick} variant.

The \texttt{\_quick} variant of an instruction assumes that the item in the constant pool has already been resolved, and that this resolution did not generate any errors. It simply performs the intended operation on the resolved item.

Pushing Constants onto the Stack (\texttt{\_quick} variants)

\texttt{ldc1\_quick}

Push item from constant pool onto stack

Syntax:

\begin{center}
\begin{tabular}{|c|}
\hline
\texttt{ldc1\_quick} = 199  \\
indexbyte1 \\
\hline
\end{tabular}
\end{center}

Stack: ... => ..., \texttt{item}

\texttt{indexbyte1} is used as an unsigned 8-bit index into the constant pool of the current class. The \texttt{item} at that index is pushed onto the stack.
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**ldc2_quick**
Push item from constant pool onto stack
Syntax:

<table>
<thead>
<tr>
<th>Syntax: ldc2_quick = 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>indexbyte1</td>
</tr>
<tr>
<td>indexbyte2</td>
</tr>
</tbody>
</table>

Stack: ... => ..., item

*indexbyte1* and *indexbyte2* are used to construct an index into the constant pool of the current class. The *constant* at that index is resolved and the *item* at that index is pushed onto the stack.

**ldc2w_quick**
Push long integer or double float from constant pool onto stack
Syntax:

<table>
<thead>
<tr>
<th>Syntax: ldc2w_quick = 201</th>
</tr>
</thead>
<tbody>
<tr>
<td>indexbyte1</td>
</tr>
<tr>
<td>indexbyte2</td>
</tr>
</tbody>
</table>

Stack: ... =>=== ..., constant-word1, constant-word2

*indexbyte1* and *indexbyte2* are used to construct an index into the constant pool of the current class. The *constant* at that index is pushed onto the stack.

**Managing Arrays (_quick variants)**

**anewarray_quick**
Allocate new array of objects
Syntax:

<table>
<thead>
<tr>
<th>Syntax: anewarray_quick = 216</th>
</tr>
</thead>
<tbody>
<tr>
<td>indexbyte1</td>
</tr>
<tr>
<td>indexbyte2</td>
</tr>
</tbody>
</table>

Stack: ..., size => result

*size* should be an integer. It represents the number of elements in the new array.

*indexbyte1* and *indexbyte2* are used to construct an index into the constant pool of the current class. The entry should be a class.

A new array of the indicated class type and capable of holding *size* elements is allocated. Allocation of an array large enough to contain *nelem* items of the given class type is attempted. All elements of the array are initialized to zero.

If *size* is less than zero, a NegativeArraySizeException is thrown. If there is not enough memory to allocate the array, an OutOfMemoryException is thrown.
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Manipulating Object Fields (_quick variants)

`putfield_quick`
Set field in object
Syntax:
```
putfield_quick = 203
offset
unused
```
Stack: ..., handle, value => ...

`handle` should be a handle to an object. `value` should be a value of a type appropriate for the specified field. `offset` is the offset for the field in that object. `value` is written at `offset` into the object referenced by `handle`. Both `handle` and `value` are popped from the stack.

If `handle` is null, a `NullPointerException` exception is generated.

`putfield2_quick`
Set long integer or double float field in object
Syntax:
```
putfield2_quick = 205
offset
unused
```
Stack: ..., handle, value-word1, value-word2 => ...

`handle` should be a handle to an object. `value` should be a value of a type appropriate for the specified field. `offset` is the offset for the field in that object. `value` is written at `offset` into the object referenced by `handle`. Both `handle` and `value` are popped from the stack.

If `handle` is null, a `NullPointerException` exception is generated.

`getfield_quick`
Fetch field from object
Syntax:
```
getfield_quick = 202
offset
unused
```
Stack: ..., handle => ..., value

`handle` should be a handle to an object. The value at `offset` into the object referenced by `handle` replaces `handle` on the top of the stack.

If `handle` is null, a `NullPointerException` exception is generated.
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**getfield2_quick**

Fetch field from object

Syntax:

```
getfield2_quick = 204

offset

unused
```

Stack: ... handle => ... value-word1, value-word2

*handle* should be a handle to an object. The value at *offset* into the object referenced by *handle* replaces *handle* on the top of the stack.

If *handle* is null, a NullPointerException exception is generated.

**putstatic_quick**

Set static field in class

Syntax:

```
putstatic_quick = 207

indexbyte1

indexbyte2
```

Stack: ... value => ...

*indexbyte1* and *indexbyte2* are used to construct an index into the constant pool of the current class. The constant pool item will be a field reference to a static field of a class. *value* should be the type appropriate to that field. That field will be set to have the value *value*.

**putstatic2_quick**

Set static field in class

Syntax:

```
putstatic2_quick = 209

indexbyte1

indexbyte2
```

Stack: ... value-word1, value-word2 => ...

*indexbyte1* and *indexbyte2* are used to construct an index into the constant pool of the current class. The constant pool item will be a field reference to a static field of a class. That field should either be a long integer or a double precision floating point number. *value* should be the type appropriate to that field. That field will be set to have the value *value*.

**getstatic_quick**

Get static field from class

Syntax:

```
getstatic_quick = 206

indexbyte1

indexbyte2
```

Stack: ... => ... value

*indexbyte1* and *indexbyte2* are used to construct an index into the constant pool of the current class. The constant pool item will be a field reference to a static field of a class. The value of that field will replace *handle* on the stack.
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getstatic2_quick
Get static field from class
Syntax:

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>getstatic2_quick = 208</td>
<td></td>
</tr>
<tr>
<td>indexbyte1</td>
<td></td>
</tr>
<tr>
<td>indexbyte2</td>
<td></td>
</tr>
</tbody>
</table>

Stack: ..., => ..., value-word1, value-word2

indexbyte1 and indexbyte2 are used to construct an index into the constant pool of the current class. The constant pool item will be a field reference to a static field of a class. The field should be a long integer or a double precision floating point number. The value of that field will replace handle on the stack.

Method Invocation (_quick variants)

invokevirtual_quick
Invoke class method
Syntax:

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>invokevirtual_quick = 210</td>
<td></td>
</tr>
<tr>
<td>offset</td>
<td></td>
</tr>
<tr>
<td>nargs</td>
<td></td>
</tr>
</tbody>
</table>

Stack: ..., handle, [arg1, [arg2 ...]] => ...

The operand stack is assumed to contain a handle to an object and nargs arguments. The method block at offset in the object’s method table is retrieved. The method block indicates the type of method (native, synchronized, etc.) and the number of arguments (nargs) expected on the operand stack.

If the method is marked synchronized the monitor associated with handle is entered. The exact behavior of monitors and their interactions with threads is a runtime issue.

The base of the local variables array for the new Java stack frame is set to point to handle on the stack, making handle and the supplied arguments (arg1, arg2, ...) the first nargs local variables of the new frame. The total number of local variables used by the method is determined, and the execution environment of the new frame is pushed after leaving sufficient room for the locals. The base of the operand stack for this method invocation is set to the first word after the execution environment. Finally, execution continues with the first instruction of the matched method.

If the object handle on the operand stack is null, a NullPointerException is thrown. If during the method invocation a stack overflow is detected, a StackOverflowException is thrown.

invokevirtualobject_quick
Invoke class method
Syntax:

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>invokevirtualobject_quick = 214</td>
<td></td>
</tr>
<tr>
<td>offset</td>
<td></td>
</tr>
<tr>
<td>nargs</td>
<td></td>
</tr>
</tbody>
</table>

Stack: ..., handle, [arg1, [arg2 ...]] => ...

The operand stack is assumed to contain a handle to an object or to an array and nargs arguments. The method block at offset in the object’s method table is retrieved. The method block indicates the type of
method (native, synchronized, etc.) and the number of arguments \((nargs)\) expected on the operand stack.

If the method is marked \textit{synchronized} the monitor associated with \textit{handle} is entered. The exact behavior of monitors and their interactions with threads is a runtime issue.

The base of the local variables array for the new Java stack frame is set to point to \textit{handle} on the stack, making \textit{handle} and the supplied arguments \((\text{arg1, arg2, ...})\) the first \(nargs\) local variables of the new frame. The total number of local variables used by the method is determined, and the execution environment of the new frame is pushed after leaving sufficient room for the locals. The base of the operand stack for this method invocation is set to the first word after the execution environment.

Finally, execution continues with the first instruction of the matched method.

If the object handle on the operand stack is null, a \texttt{NullPointerException} is thrown. If during the method invocation a stack overflow is detected, a \texttt{StackOverflowException} is thrown.

\textbf{invokenonvirtual\textunderscore quick}

Invoke superclass method

Syntax:

\begin{verbatim}
invokenonvirtual_quick = 211
indexbyte1
indexbyte2
\end{verbatim}

Stack: \(..., \text{handle, [arg1, [arg2 ...]]} => ...

The operand stack is assumed to contain a \textit{handle} to an object and some number of arguments. \texttt{indexbyte1} and \texttt{indexbyte2} are used to construct an index into the constant pool of the current class. The item at that index in the constant pool contains a method slot index and a pointer to a class. The method block at the method slot index in the indicated class is retrieved. The method block indicates the type of method (native, synchronized, etc.) and the number of arguments \((nargs)\) expected on the operand stack.

If the method is marked \textit{synchronized} the monitor associated with \textit{handle} is entered. The exact behavior of monitors and their interactions with threads is a runtime issue.

The base of the local variables array for the new Java stack frame is set to point to \textit{handle} on the stack, making \textit{handle} and the supplied arguments \((\text{arg1, arg2, ...})\) the first \(nargs\) local variables of the new frame. The total number of local variables used by the method is determined, and the execution environment of the new frame is pushed after leaving sufficient room for the locals. The base of the operand stack for this method invocation is set to the first word after the execution environment.

Finally, execution continues with the first instruction of the matched method.

If the object handle on the operand stack is null, a \texttt{NullPointerException} is thrown. If during the method invocation a stack overflow is detected, a \texttt{StackOverflowException} is thrown.

\textbf{invokestatic\textunderscore quick}

Invoke a static method

Syntax:

\begin{verbatim}
invokestatic_quick = 212
indexbyte1
indexbyte2
\end{verbatim}

Stack: \(..., \text{[arg1, [arg2 ...]]} => ...

The operand stack is assumed to contain some number of arguments. \texttt{indexbyte1} and \texttt{indexbyte2} are used to construct an index into the constant pool of the current class. The item at that index in the constant pool contains a method slot index and a pointer to a class. The method block at the method
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Slot index in the indicated class is retrieved. The method block indicates the type of method (native, synchronized, etc.) and the number of arguments (nargs) expected on the operand stack.

If the method is marked synchronized the monitor associated with the method’s class is entered. The exact behavior of monitors and their interactions with threads is a runtime issue.

The base of the local variables array for the new Java stack frame is set to point to the first argument on the stack, making the supplied arguments (arg1, arg2, ...) the first nargs local variables of the new frame. The total number of local variables used by the method is determined, and the execution environment of the new frame is pushed after leaving sufficient room for the locals. The base of the operand stack for this method invocation is set to the first word after the execution environment. Finally, execution continues with the first instruction of the matched method.

If the object handle on the operand stack is null, a NullPointerException is thrown. If during the method invocation a stack overflow is detected, a StackOverflowException is thrown.

**invokeinterface_quick**

Invoke interface method

Syntax:

```
invokeinterface_quick = 213

idbyte1
idbyte2
nargs
guess
```

Stack: ..., handle, [arg1, [arg2 ...]] => ...

The operand stack is assumed to contain a handle to an object and nargs-1 arguments. idbyte1 and idbyte2 are used to construct an index into the constant pool of the current class. The item at that index in the constant pool contains the complete method signature. A pointer to the object’s method table is retrieved from the object handle.

The method signature is searched for in the object’s method table. As a short-cut, the method signature at slot guess is searched first. If that fails, a complete search of the method table is performed. The method signature is guaranteed to exactly match one of the method signatures in the table.

The result of the lookup is a method block. The method block indicates the type of method (native, synchronized, etc.) but unlike invokemethod and invokesuper, the number of available arguments (nargs) is taken from the bytecode.

If the method is marked synchronized the monitor associated with handle is entered. The exact behavior of monitors and their interactions with threads is a runtime issue.

The base of the local variables array for the new Java stack frame is set to point to handle on the stack, making handle and the supplied arguments (arg1, arg2, ...) the first nargs local variables of the new frame. The total number of local variables used by the method is determined, and the execution environment of the new frame is pushed after leaving sufficient room for the locals. The base of the operand stack for this method invocation is set to the first word after the execution environment. Finally, execution continues with the first instruction of the matched method.

If the object handle on the operand stack is null, a NullPointerException is thrown. If during the method invocation a stack overflow is detected, a StackOverflowException is thrown.

guess is the last guess. Each time through, guess is set to the method offset that was used.
Miscellaneous Object Operations (_quick variants)

new_quick
Create new object
Syntax:

| new_quick | indexbyte1 | indexbyte2 |

Stack: ... => ..., handle

indexbyte1 and indexbyte2 are used to construct an index into the constant pool of the current class. The item at that index should be a class. A new instance of that class is then created and a handle for it pushed on the stack.

checkcast_quick
Make sure object is of given type
Syntax:

| checkcast_quick | indexbyte1 | indexbyte2 |

Stack: ..., handle => ..., handle

handle should be a handle to an object. indexbyte1 and indexbyte2 are used to construct an index into the constant pool of the current class. The object at that index of the constant pool should have already been resolved.

cast then determines whether handle can be cast to an object of class class. A null handle can be cast to any class, and otherwise the superclasses of handle are searched for class. If class is determined to be a superclass of handle, or if handle is null, object can be cast to class and execution proceeds at the next instruction, and the handle for handle remains on the stack.

If handle cannot be cast to class, a ClassCastException is thrown.

instanceof_quick
Determine if object is of given type
Syntax:

| instanceof_quick | indexbyte1 | indexbyte2 |

Stack: ..., handle => ..., result

handle should be a handle to an object. indexbyte1 and indexbyte2 are used to construct an index into the constant pool of the current class. The item of class class at that index of the constant pool is assumed to have already been resolved.

instanceof determines whether handle can be cast to an object of the class class. A null handle can be cast to any class, and otherwise the superclasses of handle are searched for class. If class is determined to be a superclass of handle, or if handle is null, handle is overwritten by 1. Otherwise, handle is overwritten by 0.
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Constant Pool Resolution

When the class is read in, an array `constant_pool[]` of size `nconstants` is created and assigned to a field in the class. `constant_pool[0]` is set to point to a malloc-ed array which indicates which fields in the `constant_pool` have already been resolved. `constant_pool[1]` through `constant_pool[nconstants - 1]` are set to point at the "type" field that corresponds to this constant item.

When an instruction is executed that references the constant pool, an index is generated, and `constant_pool[0]` is checked to see if the index has already been resolved. If so, the value of `constant_pool[index]` is returned. If not, the value of `constant_pool[index]` is resolved to be the actual pointer or data, and overwrites whatever value was already in `constant_pool[index]`. 
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