Bump-Pointer Method Caching for Embedded Java Processors

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Itinerary

- Introduction
- Method Cache Design
- Evaluation
- Discussion
- (Multithreading)
Introduction

Cache hierarchy
- mandatory to span the performance gap between core and memory.
- accelerates the common case.
- complicates the WCET analysis.

Java method caches
- feasible as Java methods tend to be small.
- tie predictable costs to method invocations and returns.
- avoid intra-procedural jitter caused by misses.
Blocked Method Cache

- TagCode = \text{NB}
- Request
- Base Addr
- Hit
- 1-Hot-to-Binary

<table>
<thead>
<tr>
<th>Base Addr</th>
<th>Code</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x000</td>
<td>\text{Code}_0</td>
<td>\text{f1()}</td>
</tr>
<tr>
<td>0x100</td>
<td>\text{Code}_1</td>
<td>\text{f2()}</td>
</tr>
<tr>
<td>0x200</td>
<td>\text{Code}_2</td>
<td>--</td>
</tr>
<tr>
<td>0x300</td>
<td>\text{Code}_3</td>
<td>--</td>
</tr>
</tbody>
</table>
Traditional vs. Stack-Based

- Traditional cache *often* performs better as thrashing of multiple methods in a loop is avoided:

```c
void a() {
    for(;;) {
        b();
        c();
    }
}
```

- Stack-based cache is more predictable as hits only depend on *local* call hierarchy.

- Stack-based cache can be implemented to populate available memory densely through bump-pointer allocation.
Method Data Layout

Ring Buffer with Method Entries:

![Diagram of a ring buffer with method entries including base pointer and additional state]

Additional State:
- PB, CB, NB – registered copies of previous, current and next method base pointer
- PT, CT, NT – corresponding registered tags
- VP – valid pointer: start of memory area not overridden by farthest extend of call hierarchy

Hits can be distinguished into:
- returning one stack frame is unwound
- recursive re-invocation of calling method
- invoking re-invocation of previously invoked method
Valid Pointer

- is increased on method load beyond it encountering order CB, VP, NB rather than CB, NB, VP:

\[ VP - CB \leq NB - CB \]

- used to validate returning hits by checking the order VP, PB, CB \( \equiv \) CB, VP, PB:

\[ VP - CB \leq PB - CB \]

Distance calculation ignores overflows in subtractions. Re-use of same circuit with single input multiplexer.
Empirical Evaluation

Overall Caffeine Benchmark (without FloatTest):

![Graph showing empirical evaluation results](image-url)
Discussion

- Hit rates of about 90% comparable to a blocked cache with 4 blocks.
- Sliding window view on cache space is acceptable.
- Larger cache memory is only utilized by multi-slice implementation:
  - Slice size according to average call hierarchy.
  - Slices reduce thrashing in loops.
  - Number of comparators grows with slice number.
  - Slicing and coloring of slices may benefit multithreaded analysis.
Anomalies with Multithreading

StringTest regularly ran faster when forked into extra Thread.
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Normal layout of method cache content (looped):

```
StringAtom.execute() ->
   StringBuffer.append() ->
      String.length() |
      String.getChars() -> System.arraycopy()
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  String.getChars() -> System.arraycopy()
```

Cache layout after destructive interruption of forking Thread yielding:

```
System.arraycopy() ->
  String.getChars() ->
    StringBuffer.append() ->
      StringAtom.execute() |
    String.length()
```

Mutual replacement now limited to small methods.
Thank you!