TECHNISCHE UNIVERSITÄT DRESDEN

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Enabling Constant-Time Interface Method Dispatch in Embedded Java Processors

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Vienna, JTRES'07

Itinerary

- Method Dispatch Overview
- Interface Type Coercion
- Employment Issues
- SHAP Integration
- Discussion

Method Dispatch – Foundations

Method Dispatch

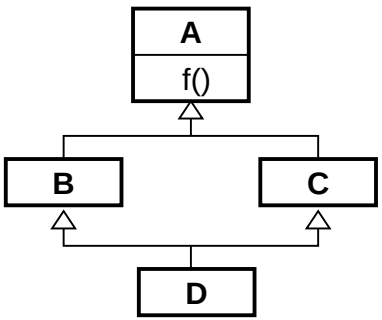
- is the *dynamic* binding of method implementations to invocations.
- incurs overhead over a static compiler-resolved call.

Specification

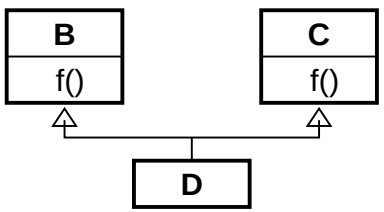
Search for first matching method from *runtime* type up the type hierarchy:

→ Most specific implementation is invoked.

→ Search order is relevant for multiple inheritance:



Diamond Problem: Which `A`?



Which `f()`?

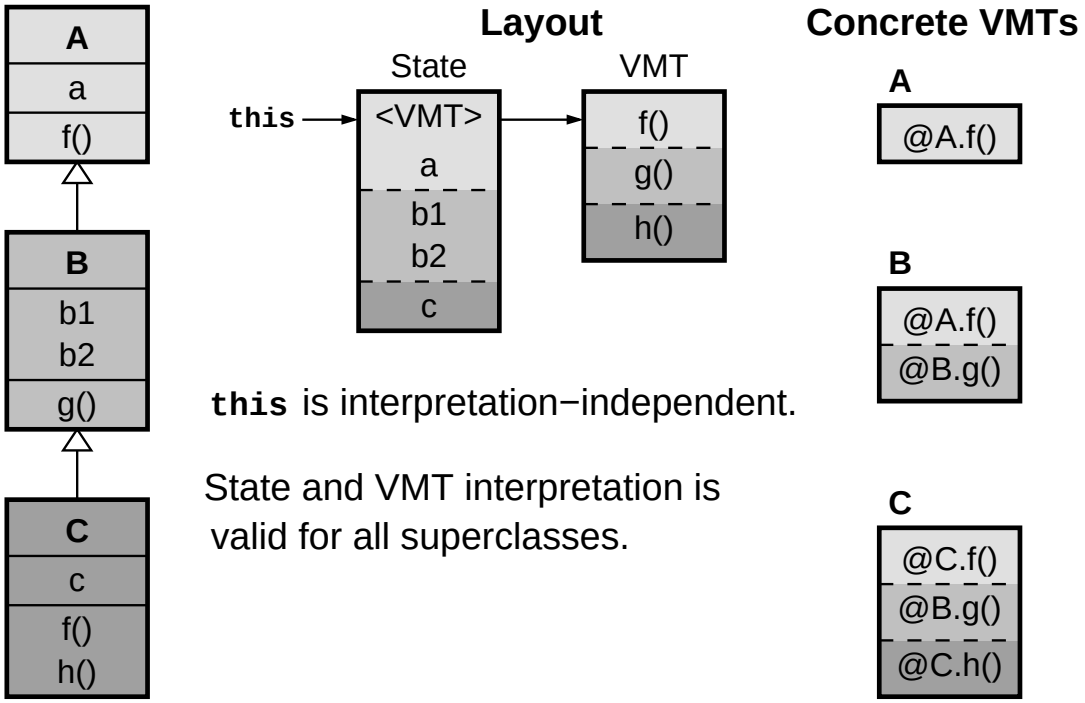
Method Dispatch – Java Specifics

- *Statically verifiable* type system.
  vs. *dynamic* typing à la Perl, Python, JavaScript (duck typing)
- *Single* dispatch based solely on the type of `this` argument.
  vs. *Multiple* dispatch à la Common Lisp
- *Single* inheritance of method implementations.
  vs. *Multiple* inheritance à la Eiffel, C++, Python, Perl
- *Multiple* inheritance of interfaces.

Concept also found in Objective-C (*protocols*) and C#.

Method Dispatch – Single Inheritance

Straightforward memory layout of instance state and VMT:



Method Dispatch – Multiple Inheritance

Approaches:

- Reflective Search
- Sparse Method Tables
- Hashed Lookup with Conflict Resolution

On statically-typed platforms:

- class-specific data structures
- problem size reduction by indirection through `itable`
  set of interface methods → set of interfaces

JVM Implementations:

Jalapeño (Jikes RVM)	hashed lookup in fixed-size IMTs
CACAO	sparse arrays of `itable` references
JOP / SableVM	sparse interface method tables
SHAP	`itable` attachment through type coercion

Interface Type Coercion

Coloring of *reference values* to identify class-specific `itable` for desired interface.
Goals:

- Automatic coercion by compiler or classfile loader.
- Allow use of standard / legacy classfiles.
- Coloring must be transparent to all but interface-related operations.

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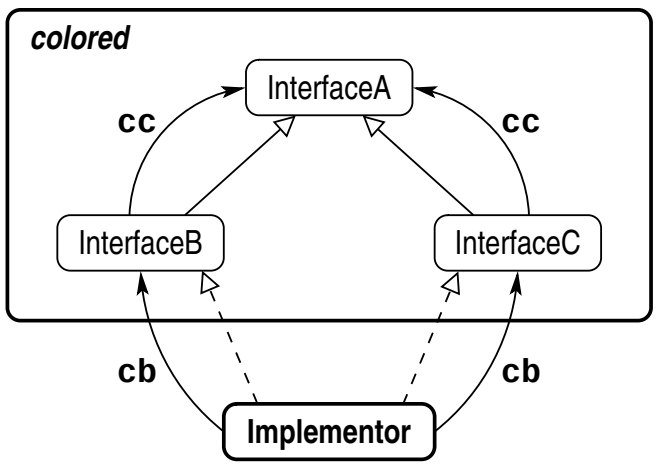
Enabled by:

- DFA based on type meta-data found in classfiles using ASM.
- Injection of constant-time coercion bytecodes.
- Reference value representation as (Object, Color) tuple.



Data Flow Analysis

Construction of data flow graph by abstract interpretation.

Source Verteces

- method arguments
- values returned by a method call
- successful `checkcast`s
- caught exceptions

Inner Verteces

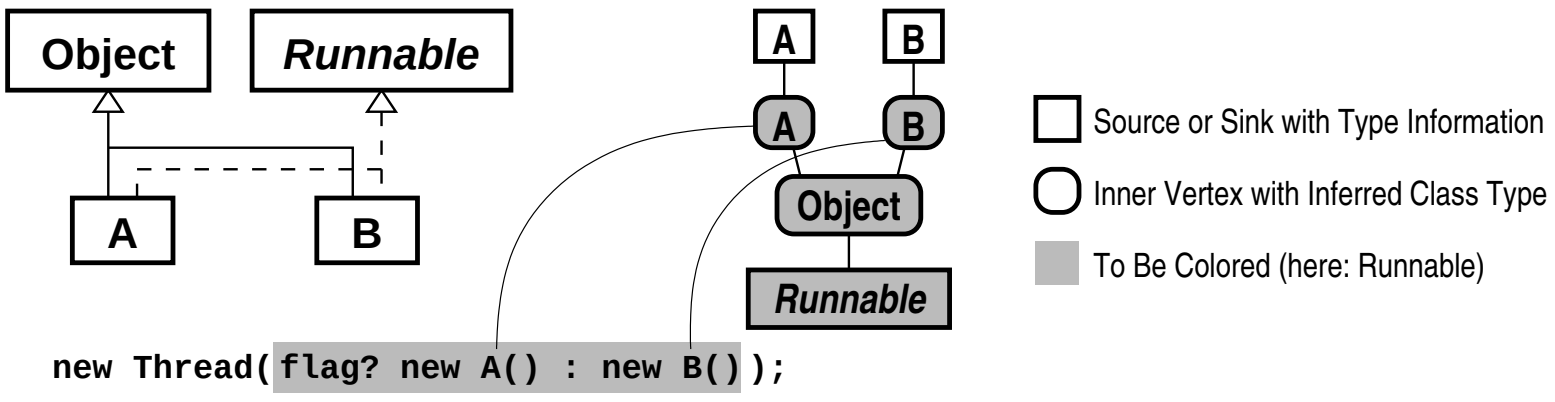
- stack values
- values in local variables (including arguments)

Sink Verteces

- arguments passed to a method
- values stored into an array

Edges reflect data movement.
Interest limited to connected components with interface type sinks!

Data Flow Graph – Example Component



Legacy Issue: Multitype

```
    ifxxx @0                          – Branch
    new A                             – Create Instance of A
    dup
    invokespecial A.<init>()V
    goto @1
@0:
    new B                             – Create Instance of B
    dup
    invokespecial B.<init>()V
@1:                                   – Merging Control Flows
    dup
    invokeinterface I1.f()V           – Invoke Interface Method of I1
    invokeinterface I2.g()V           – Invoke Interface Method of I2
```

Legacy Issue: Late Runtime Verification

```
    ifxxx @0                          – Branch
    new A                             – Create Instance of A
    dup
    invokespecial A.<init>()V
    goto @1
@0:
    new Object                        – Create Instance of Object
    dup
    invokespecial Object.<init>()V
@1:                                   – Merge Control Flows
    invokeinterface I1.f()V           – Invoke Interface Method
```

Disarming Runtime Casts

Runtime casts to interface types require expensive `itable` search.
Fast interface method dispatch is rendered absurd if preceded by a cast.

Measures

- Never uncolor references.
- Simply check the color before performing a searching cast (fast!).
- Defensive coloring for pre-Tiger legacy code (after SableVM evaluation).

Result

References stored in generic data structures will already have the correct color if:

- having been passed as typed method argument such as through `addActionListener(ActionListener)`, or
- having been stored in a appropriately parametrized generic collection such as `ArrayList<ActionListener>`.

SHAP Integration

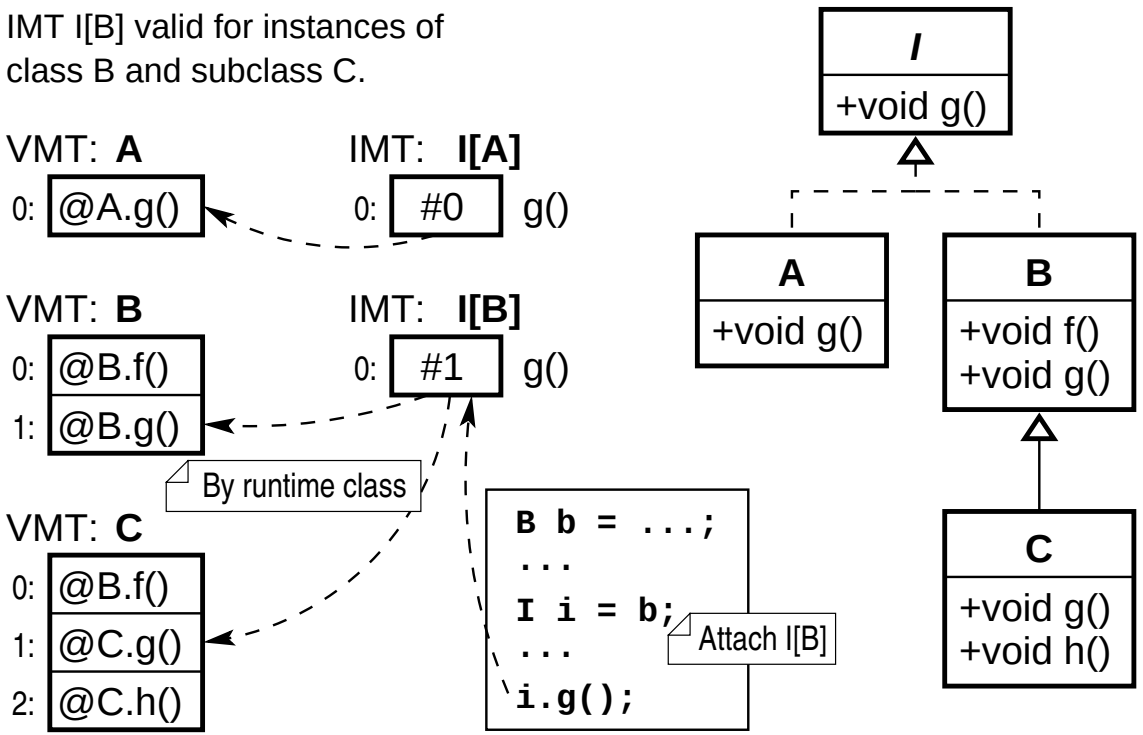
Embedded JVM with restricted runtime type information:

- CLDC 1.0 runtime implementation
- no support of reflection, and
- no `itable` searching interface typecasts (hit or fail).

Use of indirect `itable`s:

- `cb` uses statically resolved `itable` references.
- Indirection through VMT at invocation rather than at coloring time.
- `itable` can be reused for all subclasses once created.
- `cc` resolved through `itable`.

Indirect `itables`



Discussion

- Coercion impact on code size highly dependable on application.
- Well below 0.1 % for all the Embedded Caffeine benchmarks.
- Optimizing compilers supplying tight `StackMapTable`s would be favorable for:
  - virtualization of interface method calls,
  - devirtualization of virtual method calls, and
  - abandoning defensive coloring.
- Tupled interface objects hinders great adoption on standard JVMs.

Thank you!