# MethodHandle implemention tips and tricks

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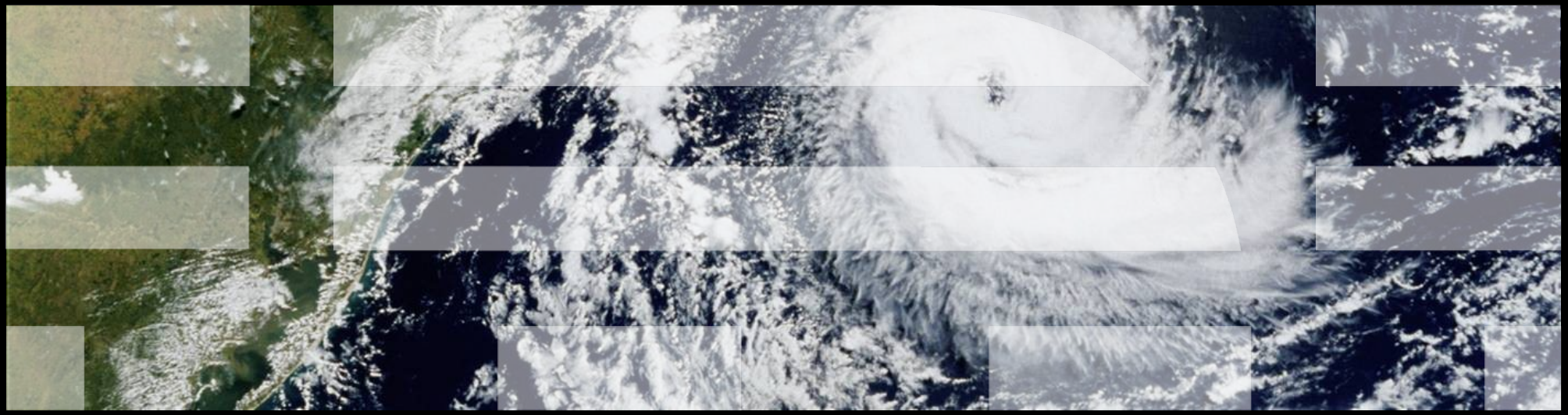

# MethodHandles: a 30 sec introduction

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- typed – strongly typed function pointer. Type is carried by an instance of MethodType.
- **directly executable** – 3 execution modes:
  - invokeExact – invoking signature must exactly match the handle's type
  - invoke – (formally invokeGeneric) – is equivalent to handle.asType(invokingSignature).invokeExact()
  - invokeWithArguments – allows "reflection-style" invocation using arguments collected into arrays

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- method, constructor, field, or similar low-level operation – emulates existing java bytecode set: invoke*, put/getField, put/getStatic
- **transformations** - argument insertion and deletion, argument and return filtering, catching and throwing exceptions, collecting and spreading, permuting, casting, decision trees, etc.

# Talk Purpose

- Let you peek behind the curtain and see how MethodHandles have been implemented
  - It's a major change to the JVM
- Provide you with a solid initial performance model for MethodHandle related code
  - Guidance on what is fast
  - How to write your own fast code

# Design of a JSR 292 implementation

- How do you add something like this to the JVM?
  - Implement it in Java as much as possible and let the JIT do what it does best
  - Find the smallest set of things that need to be done primitively
  - Use these as building blocks to make the rest of the system work
  - Rebalance the line between primitive and Java as required

- Add interpreter support to determine if the feature is feasible, useful, etc.
  - Usually easy to prototype by hacking the interpreter
  - Sufficient to validate if the design will work and to find corner cases

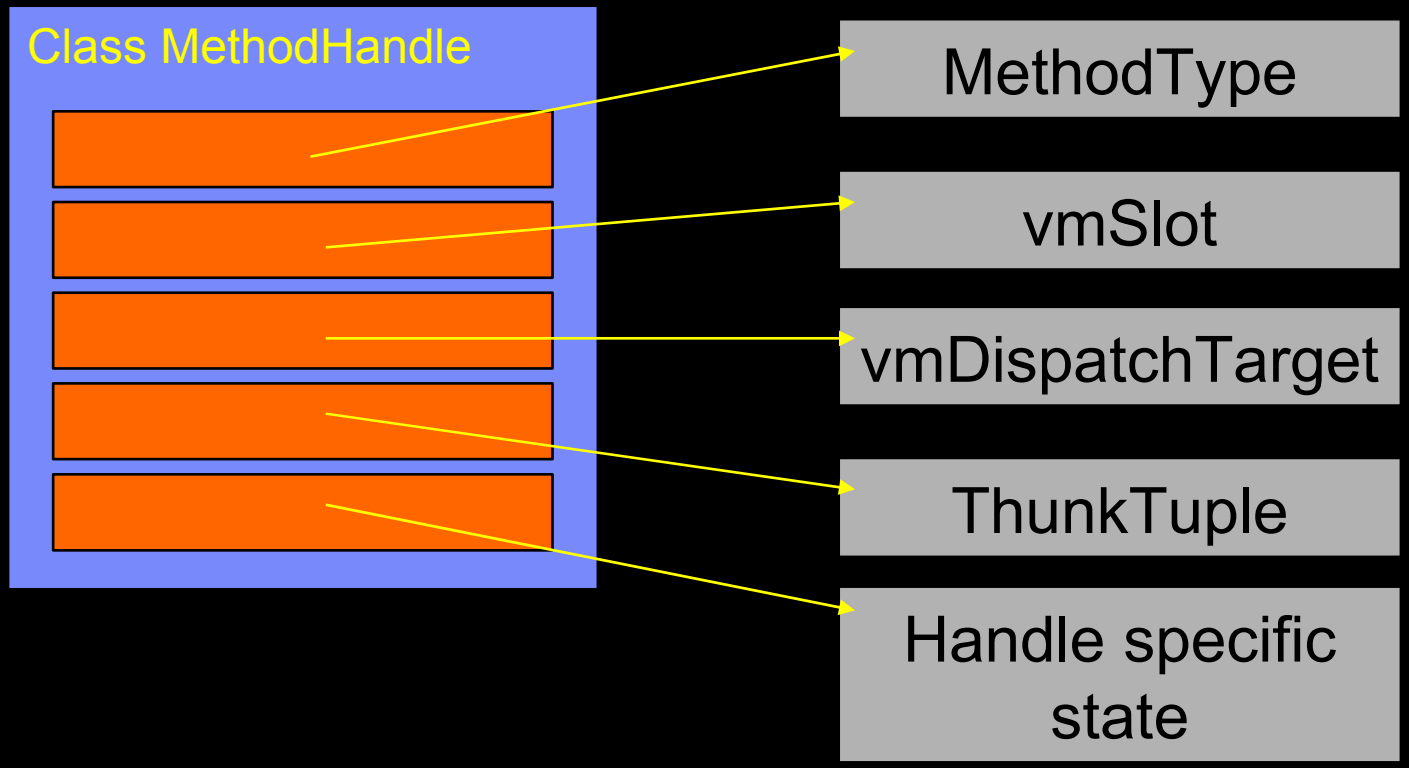
- Add JIT support to make it fast
  - JIT design is informed by the lessons learned doing the interpreter support
  - Modifies the interpreter support as required to aid the JIT design

# Primitive vs. “Java” MethodHandles

Primitive handles require VM support
- Invoking methods
- Getting and setting fields
- Constructors
- Collecting arguments
- Type conversion
- Return filtering
- Bound parameters
- DynamicInvokers
- Special MethodHandle.{invokeExact, invoke} handles

- Everything else can be built on top of this:
  - Primitive handles on helper methods. Mostly API in the MethodHandles factory class:
    arrayElement{Getter,Setter}, identity, constant, throwException
  - Primitive handles bound to helper classes.
    - These helper classes hold the necessary state for the handle's operation

# Primitive MethodHandle layout



# Primitive MethodHandle interpreter implementation

- **MH.type**: The strongly typed signature descriptor for this MethodHandle.
  - Describes the arguments for this handle instance
- **MH.vmSlot**: Stores vm-specific references used by the dispatchTarget
  - Virtual function table indexes
  - Field offsets
  - Method addresses
- **MH.vmDispatchTarget**: interpreter entry point for the handle
  - Performs the necessary stack operations for this handle
- Primitive handles avoid building frames in the interpreter where possible
  - MethodHandle.{invoke, invokeExact} don't get frames
  - Modifes the stack and jumps to the next primitive handle in the chain
  - Frames for eventual target methods do get created

# Primitive MethodHandle JIT implementation

- **MH.thunkTuple**: a shared object that holds the JIT entrypoint for a handle instance
  - Shared between multiple handles when possible to conserve code cache
  - Without sharing, 5 million handle stress test --> code cache filled with duplicate code

- ThunkArchetypes
  - Templates implemented in Java that describe the operation of a handle subclass
  - JIT specializes the template for the MethodType
  - Specialized thunkArchetype JIT entry point is stored in the ThunkTuple
  - Jump from archetype to archetype as appropriate
- ThunkTable: holds the thunkTuples and manages the sharing
  - Sharing is done on a per-MethodHandle subclass basis
  - Criteria for sharing is very different between different handle subclasses
    - Signature only (e.g. FieldHandle)
    - Signature + data (e.g. AsTypeHandle)

- Don't affect Security-related stack walks and can't be seen in stack traces

# FilterReturnHandle and continuation based JVMs

- J9's interpreter is continuation based
  - Each bytecode dispatches directly to the next one
  - Requires a very different mindset than “call-return” semantics

- MethodHandles.filterReturnValue() creates a handle that modifies the return value
  - Need to get the value returned by the previous handle invocation
  - Usual technique: call back into the interpreter
    - Expensive!  Interpreter state needs to be preserved
    - FilterReturn will be very common

# FilterReturnHandle and continuation based JVMs

- Solution: placeholder frames
  - Insert an “extra” frame on the stack
    - Arguments are described for the GC using a normal Java method
    - The bytecodes for the frame are NOT from the method
    - impdep1: a reserved bytecode provides the “next continuation”

- impdep1
  - Remove the placeholder frame
  - Redispatch as required

```
Exception in thread "main" java.lang.RuntimeException
        at Example.<init>(Example.java:8)
        at MethodHandle.constructorPlaceHolder()
        at MethodHandle.returnFilterPlaceHolder()
        at Example.main(Example.java:14)
```

# FilterReturnHandle JIT implementation

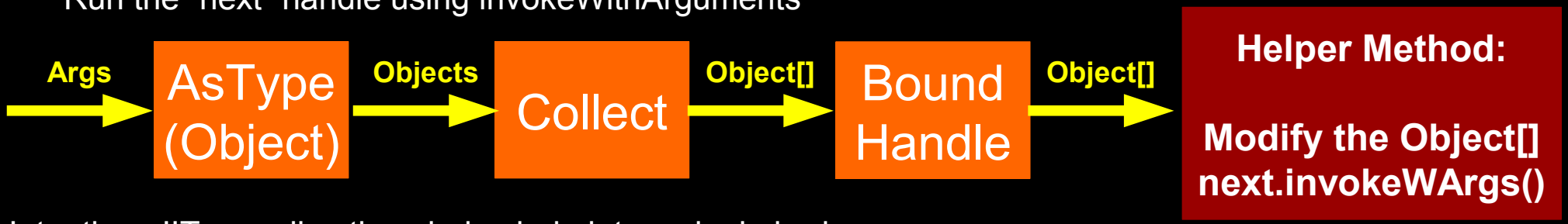
- This is easy for the JIT
  - No placeholder frames required
  - It's just regular Java code
- None of the natives in the thunkArchetype have real implementations
  - Can't be invoked by the interpreter
  - Recognized by the JIT and converted to the appropriate code

```
private final int
invokeExact_thunkArchetype_I(int argPlaceholder) throws Throwable
{
    return ILGenMacros.invokeExact_I(
            filter,
            fixReturnType(
                    ILGenMacros.invokeExact_I(
                            next,
                            argPlaceholder)
                    )
            );
}
```

# “Java” MethodHandles

- Primarily to implement the complicated methods in the MethodHandles factory
  - Argument modification: spread, permute, drop, insert, filter, & fold
  - CatchException & guardWithTest

- Employ a simple pattern:
  - Convert the arguments to Object
  - Collect the Objects into an array
  - Modify the array as required
  - Run the “next” handle using invokeWithArguments




- Intention: JIT compiles the whole chain into a single body
  - Without boxing/unboxing
  - Without collecting
  - Minimal conversions

- All the standard optimizations will kick in

# Custom LoopHandle example

```
class LoopHandle {
    final MethodHandle loopStarter;

    LoopHandle(MethodHandle starter) {
        loopStarter = starter;
    }

    final Object helper(Object[] args) throws Throwable {
        MethodHandle target = (MethodHandle) loopStarter.invokeWithArguments(args);
        while(target != null) {
            target = (MethodHandle) target.invokeWithArguments(args);
        }
        return null;
    }

    public static MethodHandle createLoopHandle(MethodHandle starter,
            MethodType loopType) throws Throwable {

        MethodType helperType = MethodType.methodType(Object.class, Object[].class);
        return lookup()
                .bind(new LoopHandle(starter), "helper", helperType)
                .asCollector(Object[].class, loopType.parameterCount())
                .asType(loopType);
    }
}
```

# LoopHandle example

```
public class Summit {
    int i = 0;
    MethodHandle next;

    public static void main(String[] args) throws Throwable {
        Summit s = new Summit();
        MethodType handleType = methodType(MethodHandle.class, Object[].class);
        MethodHandle handle = lookup().bind(s, "printArg", handleType);
        s.next = handle;

        MethodHandle looper =
            LoopHandle.createLoopHandle(handle, genericMethodType(4));
        looper.invoke("Hello", "JVM", "Lang", "Summit");
    }

    public MethodHandle printArg(Object... args) {
        System.out.println(i + ": " + args[i]);
        if (++i == args.length) {
            return null;
        }
        return next;
    }
}
```

```
--- Example Output ---
C:\intrels>java Summit
0: Hello
1: JVM
2: Lang
3: Summit
```

# LoopHandle example implications

- Custom “user” handles are possible
  - Simple pattern that's easy to implement
  - Performance characteristics will be similar to standard java.lang.invoke API handles

- Security stack  walks
  - Many methods walk the stack to determine the caller for security purposes
  - Beware: the helper class will be visible to the stack walks

- Best practice:
  - Lean on handles provided by the standard API
    - They will receive the most attention from JSR 292 implementors
  - Don't feel handcuffed by the standard API
    - If necessary, use this pattern to create the custom behaviour you need

# Performance hints

- Caveat: These are true today.  They may not be true tomorrow.

- Use invokeExact where possible
  - Provides the fastest path to run a handle
  - invoke is as fast when MethodTypes exactly match
    - Otherwise it needs to do expensive validation

- Put asType() operations in out-of-line paths to ensure that the main-line can use invokeExact
  - Only worth the effort if the asType() actually ends up only on the infrequent path
  - mh.asType(type).invokeExact() is equivalent to mh.invoke()

- invokedynamic is a lazily resolved invokeExact
  - ConstantCallSite is “free”
  - Mutable and Volatile both incur an additional dynamicInvoker() handle invocation

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