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Truffle@DSLDI Summer School

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What to expect

- Overview over Truffle APIs
- How to speculate using Truffle
- Hands-on Demos!

Truffle API

```
class ANode extends Node {

    public int execute() {
        return 21 + 21;
    }

}
```

```
class ARootNode extends RootNode {
    @Child ANode childNode = new ANode();
    @Override
    public Object execute(VirtualFrame arg0) {
        return childNode.execute();
    }
}
```

```
public static void main(String[] args) {
    CallTarget target = Truffle.getRuntime().createCallTarget(new ARootNode());
    target.call();
}
```

Truffle API

```
public interface TruffleRuntime {

    CallTarget createCallTarget(RootNode rootNode);

    DirectCallNode createDirectCallNode(CallTarget target);

    IndirectCallNode createIndirectCallNode();

    Assumption createAssumption();

    <T> T iterateFrames(FrameInstanceVisitor<T> visitor);
    ...
}
```

Truffle API

```
public class CompilerDirectives {

    public static void transferToInterpreter() {...}

    public static void transferToInterpreterAndInvalidate() {...}

    public @interface CompilationFinal {}

    public @interface ValueType {}

    public @interface TruffleBoundary {}

    ...
}
```

Truffle API

Used in the next examples

```
public abstract class Node {
    ...
}


public final class CompilerDirectives {

    public static void transferToInterpreterAndInvalidate() {...}

    public @interface CompilationFinal {}
    ...

}
```

Truffle API Example

```java
class NegateNode extends Node {

    @CompilationFinal boolean minValueVisited;

    public int execute(int operand) {
        if (operand == Integer.MIN_VALUE) {
            if (!minValueVisited) {
                transferToInterpreterAndInvalidate();
                minValueVisited = true;
            }
            return Integer.MAX_VALUE;
        }
        return -operand;
    }
}
```

minValueVisited = true

```java
if (operand == Integer.MIN_VALUE) {
    return Integer.MAX_VALUE;
}
return -operand;
```

minValueVisited = false

```java
if (operand == Integer.MIN_VALUE) {
    transferToInterpreterAndInvalidate();
}
return -operand;
```

Branch Profiles

```
class NegateNode extends Node {

    final BranchProfile minValueProfile = BranchProfile.create();

    public int execute(int operand) {
        if (operand == Integer.MIN_VALUE) {
            minValueProfile.enter();
            return Integer.MAX_VALUE;
        }
        return -operand;
    }
}
```

Condition Profiling

```
class AbsNode extends Node {

    final ConditionProfile smallerZero = ConditionProfile.createBinaryProfile();

    public int execute(int operand) {
        if (smallerZero.profile(operand < 0)) {
            return -operand;
        } else {
            return operand;
        }
    }
}
```

Identity Profiling

```java
public class IdentityValueProfile extends ValueProfile {
    private static final Object UNINITIALIZED = new Object();
    private static final Object GENERIC = new Object();

    @CompilationFinal private Object cachedValue = UNINITIALIZED;

    public <T> T profile(T value) {
        if (cachedValue != GENERIC) {
            if (cachedValue == value) {
                return (T) cachedValue;
            } else {
                transferToInterpreterAndInvalidate();
                if (cachedValue == UNINITIALIZED) {
                    cachedValue = value;
                } else {
                    cachedValue = GENERIC;
                }
            }
        }
        return value;
    }
```

Type Profiling

```
public class ExactClassValueProfile extends ValueProfile {

    @CompilationFinal protected Class<?> cachedClass;
    @Override
    public <T> T profile(T value) {
        if (cachedClass != Object.class) {
            if (cachedClass != null && cachedClass.isInstance(value)) {
                return (T) cachedClass.cast(value);
            } else {
                CompilerDirectives.transferToInterpreterAndInvalidate();
                if (cachedClass == null) {
                    cachedClass = value.getClass();
                } else {
                    cachedClass = Object.class;
                }
            }
        }
        return value;
    }
}
```

Profiles: Summary

- BranchProfiles to speculate on unlikely branches
- ConditionProfile to speculate on binary conditions
- Identity Profiles to speculate on constant values
- Type Profiles to speculate on constant type
- ...

Profiles: Limitations

- Polymorphism:
  - profiles only work with monomorphic situations
  - requires the use of inline caches
- For local speculation only:
  - *`transferToInterpreterAndInvalidate()`* just invalidates the current compilation unit.
  - requires the use of non-local assumptions

Non-local assumptions

```
public interface Assumption {

    boolean isValid();

    void invalidate();
}

Assumption a = Truffle.getRuntime().createAssumption();
```

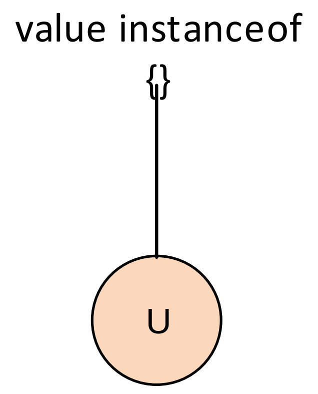
Non-local assumptions

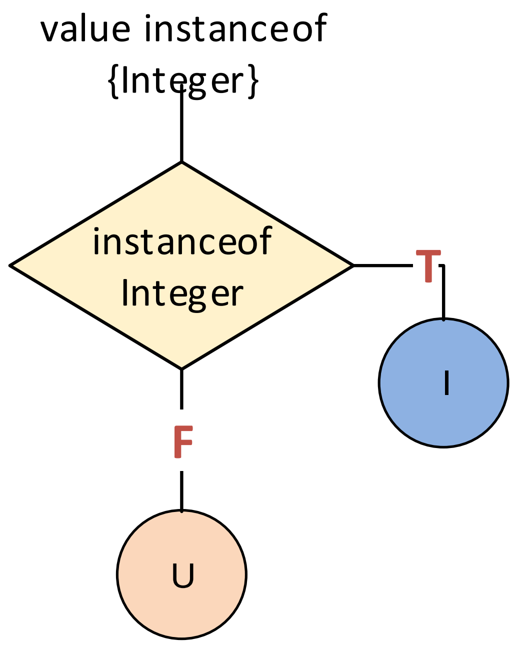
```
public class ANode extends Node {

    private final Assumption assumption = getInstrumentationDisabled();

    public void execute() {
        if (assumption.isValid()) {
            // do nothing
        } else {
            // do instrument
        }
    }
}
```

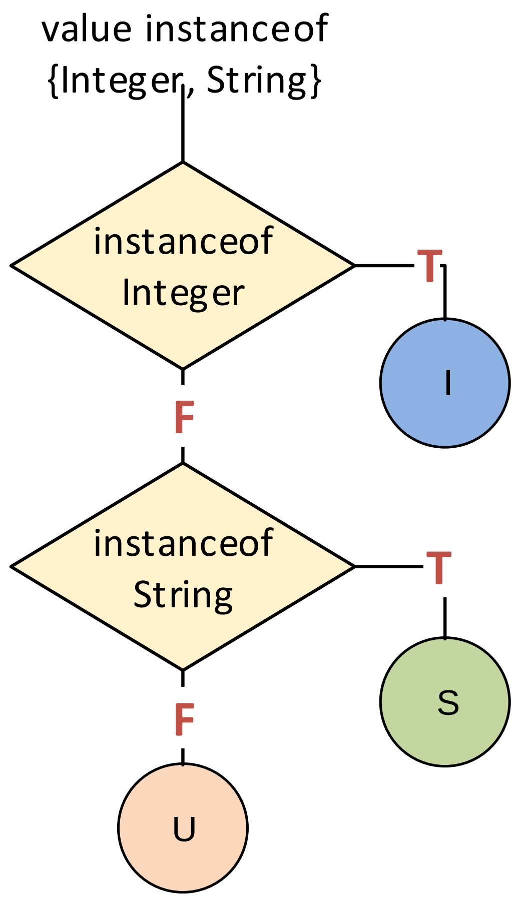
Use-cases for non-local assumptions

- Function redefinition
- Assumed global values
- Tracing / Debugging / Instrumentation
- …

Inline Caching

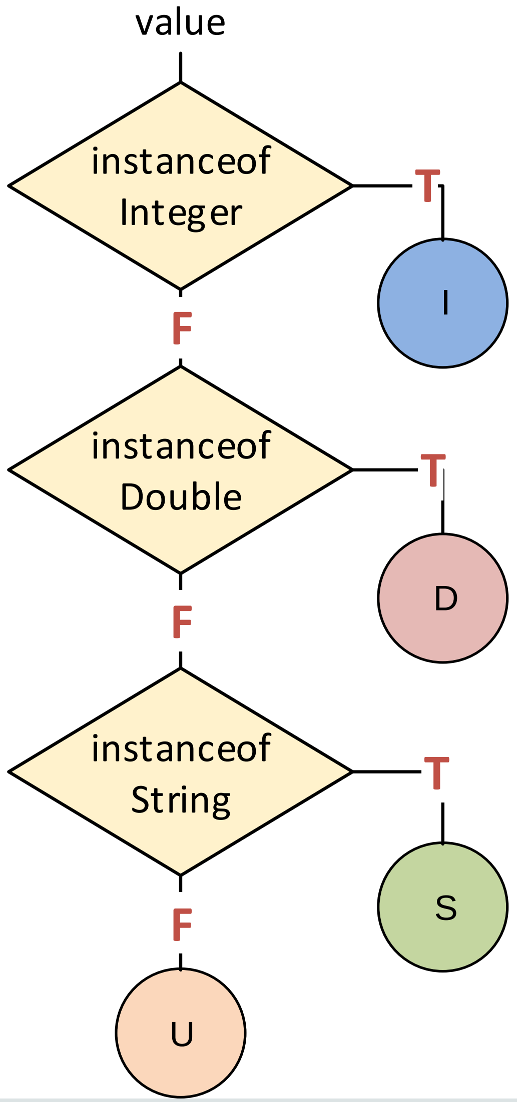






Inline Caching using Truffle DSL

```
class OperationNode extends Node {

    @Specialization
    int doInt(int value) {
        // int implementation
    }

    @Specialization
    double doDouble(double value) {
        // double implementation
    }

    @Specialization
    String doString(String value) {
        // String implementation
    }
}
```



Identity Inline Caching

```
public abstract class ANode extends Node {

    public abstract Object execute(Object operand);

    @Specialization(guards = "operand == cachedOperand", limit = "3")
    protected Object doCached(AType operand,
                    @Cached("operand") AType cachedOperand) {
        // implementation
        return cachedOperand;
    }

    @Specialization(contains = "doCached")
    protected Object doGeneric(AType operand) {
        // implementation
        return operand;
    }
}
```

Type Inline Caching

```
public abstract class ANode extends Node {

    public abstract Object execute(Object operand);

    @Specialization(guards = "operand.getClass() == cachedClass", limit = "3")
    protected Object doCached(AType operand,
                    @Cached("operand.getClass()") Class<? extends AType> cachedClass) {
        AType operand = cachedClass.cast(operand);
        // implementation
        return operand2;
    }

    @Specialization(contains = "doCached")
    protected Object doGeneric(AType operand) {
        // implementation
        return operand;
    }
}
```

Truffle Speculations

Profile, Inline Cache or Assumption?

- Use Profiles where monomorphic speculation is sufficient
- Use Inline Caches for speculations where polymorphism is required
- Use Assumptions for non-local, global speculation

Next up: Simple Language Demos

- SimpleLanguage:
  - Demonstration language for Truffle features (well documented)
- Division speculation
- Zero-overhead tracing

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Engineered to Work Together

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