Mostly Modular Compilation of Crosscutting Concerns by Contextual Predicate Dispatch

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Aspect Oriented Programming

- … modularizes the un-modularizable.
- … breaks modularity.

10th AOSD

2011 March in Brazil

Object Oriented Programming

- Modular type checking
  and Separate compilation
  - Yes if super classes are given

- Modular reasoning
  - Fairly? but dynamic dispatch

~~Object Oriented~~ Programming

Aspect Oriented

- Modular type checking
  and Separate compilation
  - Yes if super classes are given

- Modular reasoning
  - Fairly? but dynamic dispatch

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GluonJ

- A simple AOP extension to Java
  - A subset of AOP functionality of AspectJ
  - An OOP-like mechanism
    - Enhanced method overriding and dispatching
    - For ease of comparison between AOP and OOP
    - Are type checking and compilation modular?

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AOP functionality (1)

- Destructive extension
  - An advice can obliviously modify a method.
    - Unlike subclass, mixin, traits, …

```
class AddExpr {
  Value eval() { … }
}
```

```
Value around(AddExpr ae):
    execution(Value AddExpr.eval())
    && this(ae) {
    if (…) proceed();
    else … ;
}
```

AOP functionality (2)

- Limited scope
  - An advice can modify a method call in a body
  - Breaking modularity?

```
class VarDecl {
  Value init() {
    v = right.eval();
} }

    class AddExpr {
      Value eval() { … }
    }
```

```
aspect Logging {
  before():
    call(void Expr.eval())
    && withincode(* VarDecl.init()) {
    ...
} }
```

GluonJ: A reviser

- Destructive extension
  - A reviser can add and override a method, and add a field to an existing class.
    - It cannot have an explicit constructor.

```
class AddExpr {
  Value eval() { … }
}
```

```
class FloatEx revises AddExpr {
  Value eval() {
    if (…) super.eval();
    else … ;
  }
}
```


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GluonJ: A within method

- Limited scope
  - A method may have a predicate.
  - Its method overriding is effective only when it is called from …

```
class VarDecl {
  Value init() {
    v = right.eval();
}}

    class AddExpr {
      Value eval() { … }
    }
```

```
class Log revises AddExpr {
  Value eval()
            within VarDecl.init() {
      …
}}
```

Contextual predicate dispatch

- GluonJ
  - Predicates refers to non-local contexts i.e. **within** who is a caller.
    - Currently only **within** is available.
  - to deal with crosscutting concerns

- Original predicate dispatch
  - Predicates refers to only local contexts such as arguments and receiver's fields
    - for unambiguity and exhaustiveness

GluonJ: requires

- Some revisers may modify the same.
  - Like mixin, they are linearized and applied one by one.
  - **requires** must be a total order

```
class FloatEx revises AddExpr {
  Value eval() { … }
}
```

```
class AddExpr {
  Value eval() { … }
}
```

```
class StringEx requires FloatEx
                          revises AddExpr {
  Value eval() {
    if (…) super.eval();
    else … ; }
}
```

GluonJ: using

- How to access revised methods/fields
  - Effects by a required reviser is visible.
  - A **using** declaration make them visible from classes.

```
class Printing revises AddExpr {
  void print() { … } }
```

```
class AddExpr {
  Value eval() { … }
}
```

```
using Printing;
class Printer {
  static void print(AddExpr e) {
      e.print();
  } }
```

Core Calculus of GluonJ

- An extension of Featherweight Java
  - to rigorously discuss modular compilation

- Syntax

```
CL ::= class C extends C using R { C f; M }
       | class R revises C using R { M }
L    ::= C | R
M    ::= C m(C ;x) { return e; } [ within L ]
e    ::= x | e.f | e.m(e) | new C(e) | e in L
v,w ::= new C(v)
```

S-REFL

$$\texttt{C} <: \texttt{C}$$

S-TRANS

$$\frac{\texttt{C} <: \texttt{D} \qquad \texttt{D} <: \texttt{E}}{\texttt{C} <: \texttt{E}}$$

S-EXTENDS

$$\frac{\texttt{C ext D}}{\texttt{C} <: \texttt{D}}$$

T-VAR

$$\texttt{L}; \Gamma \vdash \texttt{x} : \Gamma(\texttt{x})$$

T-FIELD

$$\frac{\texttt{L}; \Gamma \vdash \texttt{e}_0 : \texttt{C}_0 \qquad \mathit{fields}(\texttt{C}_0) = \bar{\texttt{C}}\ \bar{\texttt{f}}}{\texttt{L}; \Gamma \vdash \texttt{e}_0.\texttt{f}_i : \texttt{C}_i}$$

T-NEW

$$\frac{\mathit{fields}(\texttt{C}) = \bar{\texttt{D}}\ \bar{\texttt{f}} \quad \texttt{L}; \Gamma \vdash \bar{\texttt{e}} : \bar{\texttt{C}} \qquad \bar{\texttt{C}} <: \bar{\texttt{D}}}{\texttt{L}; \Gamma \vdash \texttt{new C}(\bar{\texttt{e}}) : \texttt{C}}$$

T-IN

$$\frac{\texttt{L}'; \Gamma \vdash \texttt{e} : \texttt{C}}{\texttt{L}; \Gamma \vdash \texttt{e in L}' : \texttt{C}}$$

T-INVK

$$\frac{\texttt{L using } \bar{\texttt{R}} \qquad \begin{array}{c}\texttt{L}; \Gamma \vdash \texttt{e}_0 : \texttt{C}_0 \qquad \texttt{L}; \Gamma \vdash \bar{\texttt{e}} : \bar{\texttt{C}} \\ \mathit{mtype}(\texttt{m}, \mathit{lowest}(\texttt{C}_0, \bar{\texttt{R}}), \bar{\texttt{R}}, \texttt{L}) = \bar{\texttt{D}} \rightarrow \texttt{C}\end{array} \qquad \bar{\texttt{C}} <: \bar{\texttt{D}}}{\texttt{L}; \Gamma \vdash \texttt{e}_0.\texttt{m}(\bar{\texttt{e}}) : \texttt{C}}$$

T-METHOD

$$\frac{\begin{array}{c}\texttt{C}; \bar{\texttt{x}} : \bar{\texttt{C}}, \texttt{this} : \texttt{C} \vdash \texttt{e}_0 : \texttt{E}_0 \qquad \texttt{E}_0 <: \texttt{C}_0 \\ \text{for any } \texttt{L}, \text{ if } \mathit{mtype}(\texttt{m}, \mathit{super}(\texttt{C}), \mathit{dom}(RT), \texttt{L}) = \bar{\texttt{D}} \rightarrow \texttt{D}_0, \text{ then } \bar{\texttt{C}} = \bar{\texttt{D}} \text{ and } \texttt{C}_0 = \texttt{D}_0\end{array}}{\texttt{C}_0\ \texttt{m}(\bar{\texttt{C}}\ \bar{\texttt{x}})\{\ \texttt{return e}_0;\ \}\ \texttt{OK IN C}}$$

T-METHODR

$$\frac{\begin{array}{c}\texttt{R rev D} \qquad \texttt{R}; \bar{\texttt{x}} : \bar{\texttt{C}}, \texttt{this} : \texttt{D} \vdash \texttt{e}_0 : \texttt{E}_0 \qquad \texttt{E}_0 <: \texttt{C}_0 \\ \text{for any } \texttt{L}, \text{ if } \mathit{mtype}(\texttt{m}, \mathit{super}(\texttt{R}), \mathit{dom}(RT), \texttt{L}) = \bar{\texttt{D}} \rightarrow \texttt{D}_0, \text{ then } \bar{\texttt{C}} = \bar{\texttt{D}} \text{ and } \texttt{C}_0 = \texttt{D}_0\end{array}}{\texttt{C}_0\ \texttt{m}(\bar{\texttt{C}}\ \bar{\texttt{x}})\{\ \texttt{return e}_0;\ \}\ [\texttt{within L}']\ \texttt{OK IN R}}$$

T-CLASS

$$\frac{\bar{\texttt{M}}\ \texttt{OK IN C}}{\texttt{class C extends D using } \bar{\texttt{R}}\ \{\ \bar{\texttt{C}}\ \bar{\texttt{f}};\ \bar{\texttt{M}}\ \}\ \texttt{OK}}$$

T-RCLASS

$$\frac{\bar{\texttt{M}}\ \texttt{OK IN R}}{\texttt{class R revises D using } \bar{\texttt{R}}\ \{\ \bar{\texttt{M}}\ \}\ \texttt{OK}}$$

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Type judgment for methods

- T-MethodR

$$\frac{\begin{array}{c}\texttt{R rev D} \qquad \texttt{R}; \overline{\texttt{x}} : \overline{\texttt{C}}, \texttt{this} : \texttt{D} \vdash \texttt{e}_0 : \texttt{E}_0 \qquad \texttt{E}_0 \;\texttt{<:}\; \texttt{C}_0 \\ \text{for any } \texttt{L}, \text{if } \mathit{mtype}(\texttt{m}, \mathit{next}(\texttt{R}), \mathit{dom(RT)}, \texttt{L}) = \overline{\texttt{D}} \rightarrow \texttt{D}_0, \\ \text{then } \overline{\texttt{C}} = \overline{\texttt{D}} \text{ and } \texttt{C}_0 = \texttt{D}_0\end{array}}{\texttt{C}_0\ \texttt{m}(\overline{\texttt{C}}\ \overline{\texttt{x}})\{\ \texttt{return e}_0;\ \}\ [\texttt{within L}']\ \texttt{OK IN R}} \quad \text{(T-MethodR)}$$

```
class BinExpr {}
```

```
class StringEx revises BinExpr {
  String eval() { … } }
```

```
class AddExpr ex. BinExpr {}
```

```
class FloatEx revises AddExpr {
  float eval() { … } }
```

Discussion

inherent in crosscutting concerns?

- Mostly modular type checking because of this global analysis:
  - TMETHODR requires all the revisers are known at compile time.
  - **requires** must be a total order on every target class.

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Implementation (1)

- 1st stage: translation
  - source code to Java bytecode
  - a reviser becomes a Java class.
  - Inserting type casts

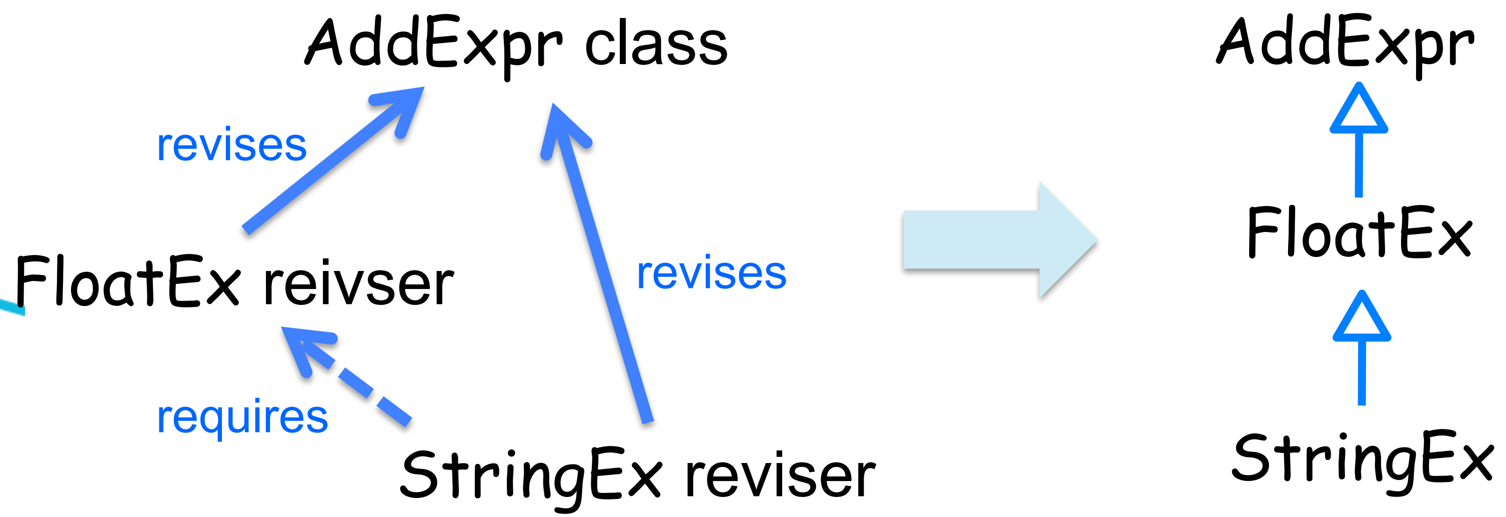
```
using Printing;
class Printer {
  static void print(AddExpr e) {
      e.print();
  } }
```

```
((Printing)e).print();
```

Implementation (2)

- 2nd stage: linking
  - Final type checking
  - A reviser inherits from its target class
    - Revisers targeting the same class are linearized.
    - Object creation is modified.

new AddExpr() → new StringEx()



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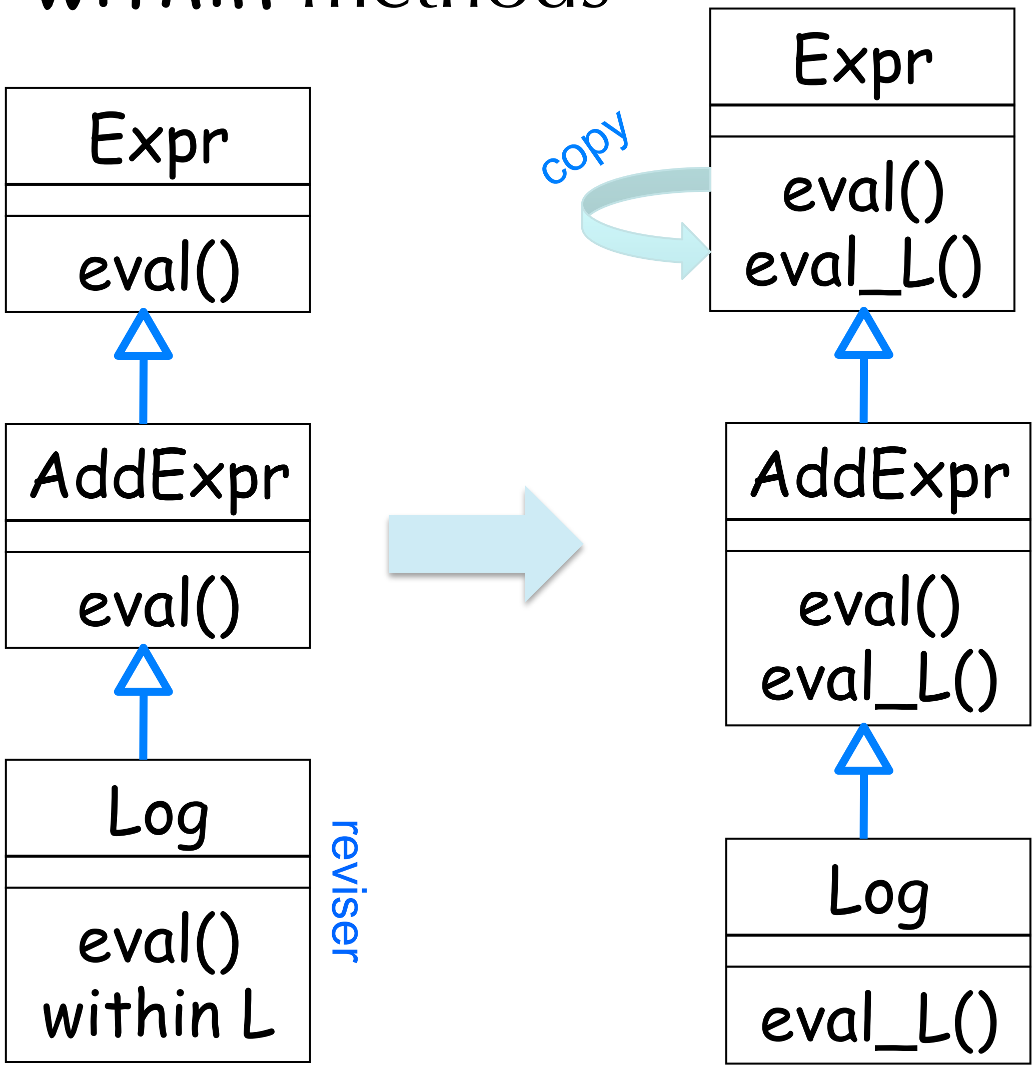
Implementation (3)

- within methods




```
class L { …
      v = right.eval();
 … }
```

```
v = right.eval_L();
```

Related work

- Predicate dispatch and AOP
  - D. Orleans pointed out in 2001
  - C. Bockisch [SPLAT'06], M. Haupt [ECOOP'07]
- Destructive extension
  - MixJuice, FOP, JavaGI, …
  - Open classes, expanders, …
- Limited scope
  - Classbox/J, COP, …

Not discussed AOP functionalities

- Pattern matching
  - A single advice may modify multiple methods matching a given pattern.
- dynamic pointcuts like `cflow`

Summary

- GluonJ
  - A simple AOP language with OOP-like constructs
    - Revisers and within methods
    - mostly modular   inherent in AOP?
- More in the paper
  - The type system is sound.
  - A formal model for compilation
    - GluonFJ to FJ translation
    - It preserves typing.
  - Benchmarking
    - Execution overheads are negligible.
  - http://www.javassist.org

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