TU Berlin

Software Engineering Group

Towards Type Safety of Aspect-Oriented Languages

by

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Outline

- **Introduction**
- Featherweight Java and formalization
- Formalization of aspects
- Formalization of weaving
- AO type soundness
- Future Work

Theorem provers

How do theorem provers work?

- Automatic or human-aided term-rewriting

What are the applications?

- Proofs over complex structures (like prog. languages)
- Extraction of verified programs

Theorem provers and type-safety

Project Bali: Verification of the Java specification

using the prover Isabelle.

Popular theorem provers

Isabelle

- Classical logic
- Extensive libraries
- User friendly

Coq

- Constructive logic
- Few libraries

PVS ACL 2 HOL 4 TWELF (...)

Why did we choose Coq?

Coq is a constructive theorem prover

Constructive proofs can be interpreted as algorithms (Curry-Howard Isomorphism)

-> Coq can extract code from proofs

-> We can extract a typechecker out of a proof for type safety

Definitions of type soundness

Natural language definition:

“Well Typed terms never get stuck.”

Formal definition: Progress & Preservation

Progress: Well-typed terms can be evaluated or they are values.

Preservation: The evaluation of a well-typed term leads to a another well-typed term.

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Featherweight Java

Java reduced to:

- Object creation
- Method invocation
- Field access
- Casting
- Variables

“Inside every large language is a small language struggling to get out.”

Properties of Featherweight Java

- Inheritance is part of the language
- Strictly formalized type system
- Very compact
- Quasi-functional language
- Nominal type system
- λ-calculus can be implemented in it

Featherweight Java example

```
class Pair extends Object {
  Object fst;
  Object snd;

  Pair(Object fst, Object snd) {
    super(); this.fst = fst; this.snd = snd; }

  Pair setfst(Object newfst) {
    return new Pair(newfst, this.snd); }
}
```

Coq-FJ-Formalization by Stephanie Weirich

- Nearly complete formalization of FJ in Coq
- Type soundness proofs were made
- Clear top-down structure

↓

Suitable foundation for extensions

Type-soundness in FJ

Coq-Code for progress and preservation

```
Lemma type_soundness :
  forall CT: classTable  e:expression e':expression,
     class_table_typing CT                    // All classes well typed
     -> multi_step CT e e'                     // Reduction from e to e' ex.
     -> ~(exists e'', reduction CT e' e'')     // No reduction from e' ex.
     -> (value e' \/ failed_cast CT e').       // e' is a value or a failed cast
```

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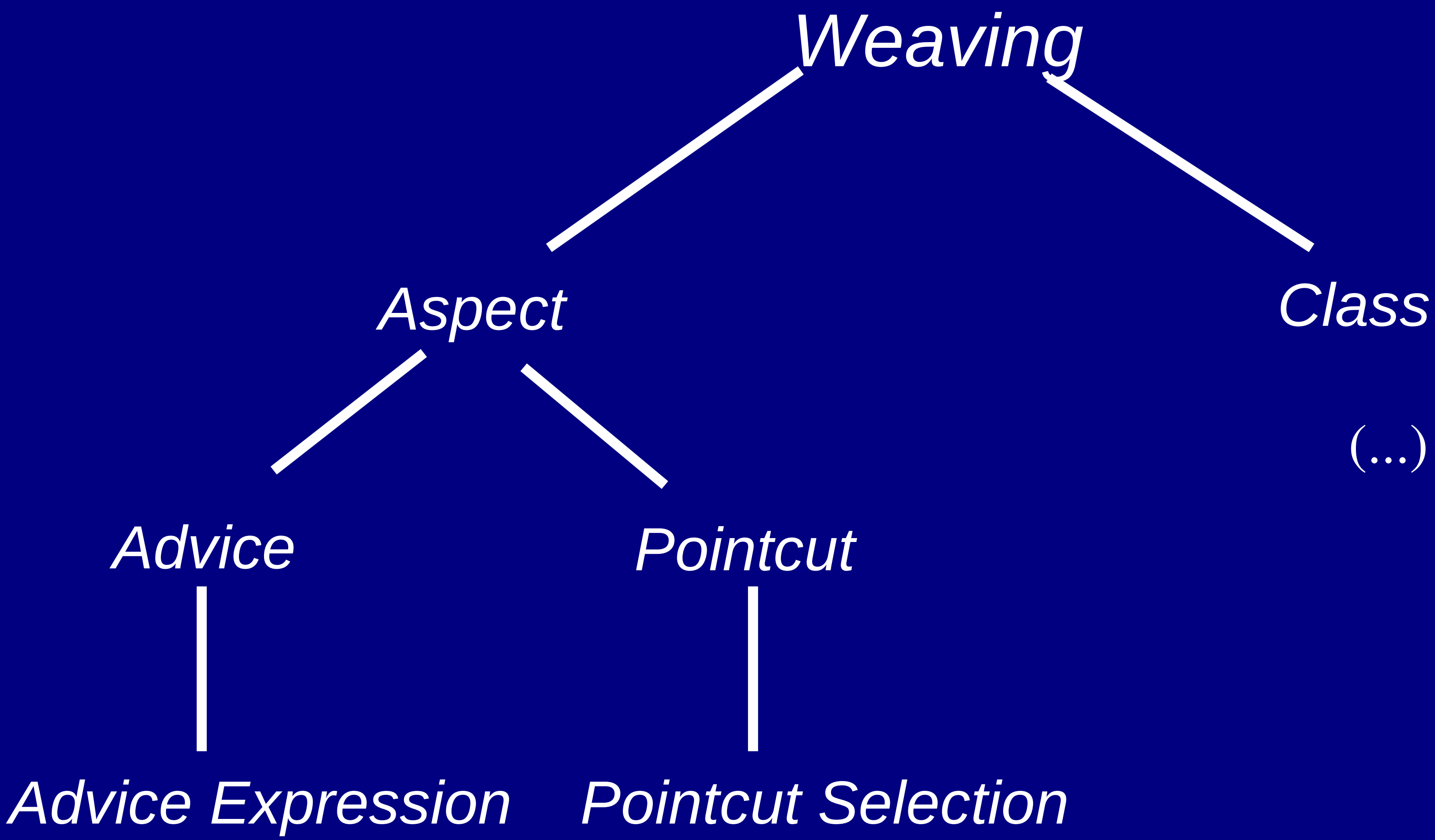
Formalization of AO



Weaving

Aspect

Class

(...)

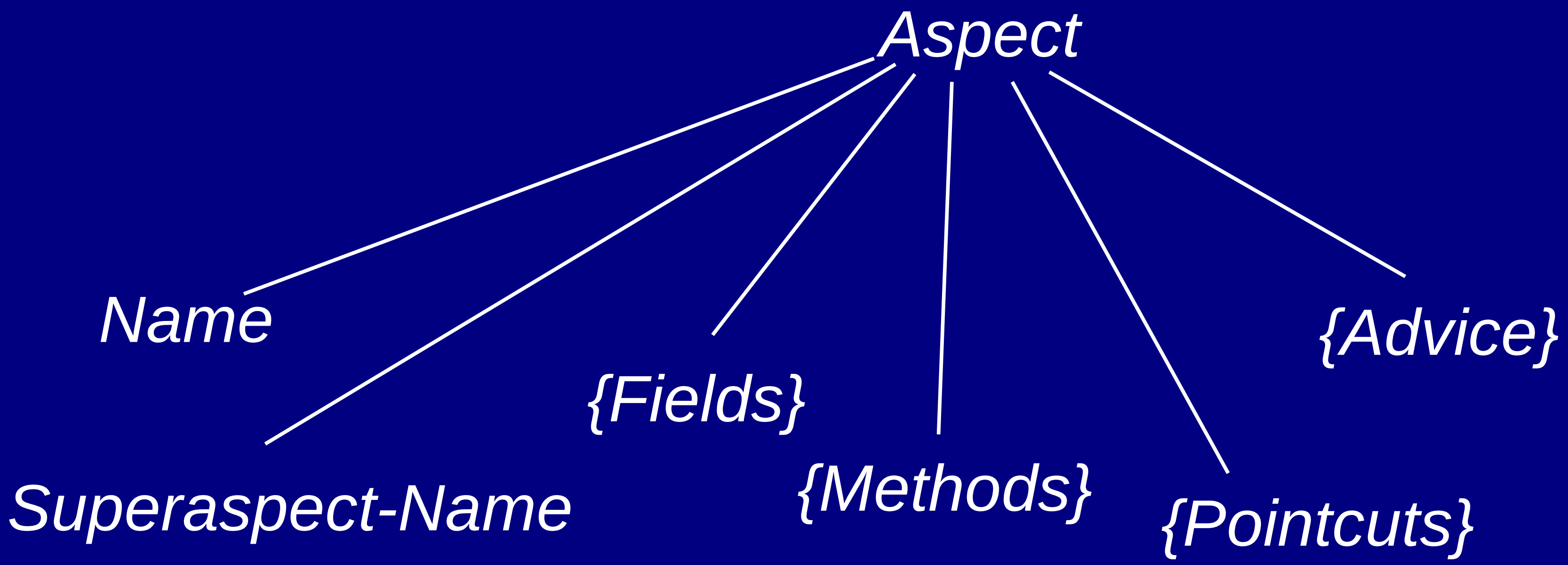
Advice

Pointcut

Advice Expression

Pointcut Selection

Aspects



Aspect

Name

Superaspect-Name

{Fields}

{Methods}

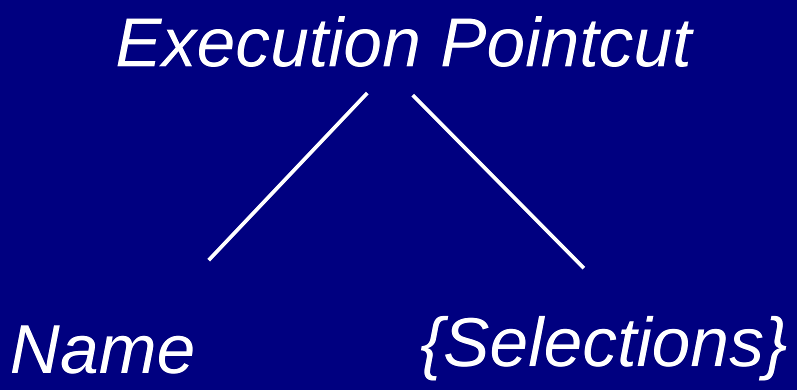
{Pointcuts}

{Advice}

Coq-Code:

```
Inductive aspectDef : Set :=
  | Aspect : aspectName -> aspectName -> list fieldDef  ->
methodTable ->pointcutTable -> adviceTable -> aspectDef.
```

Pointcuts



Execution Pointcut

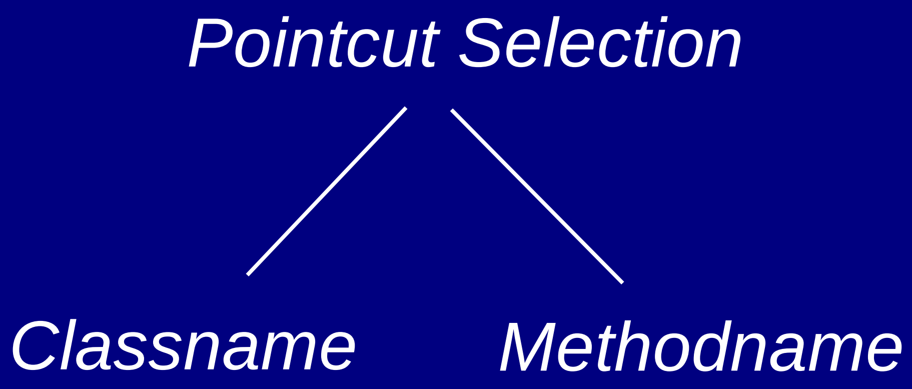
Name

{Selections}

Coq-Code:

```
Inductive pointcutDef: Set :=
  | Execution : pointcutName -> pointcutSelectionList
                      -> pointcutDef.
```

Pointcut Selections



Pointcut Selection

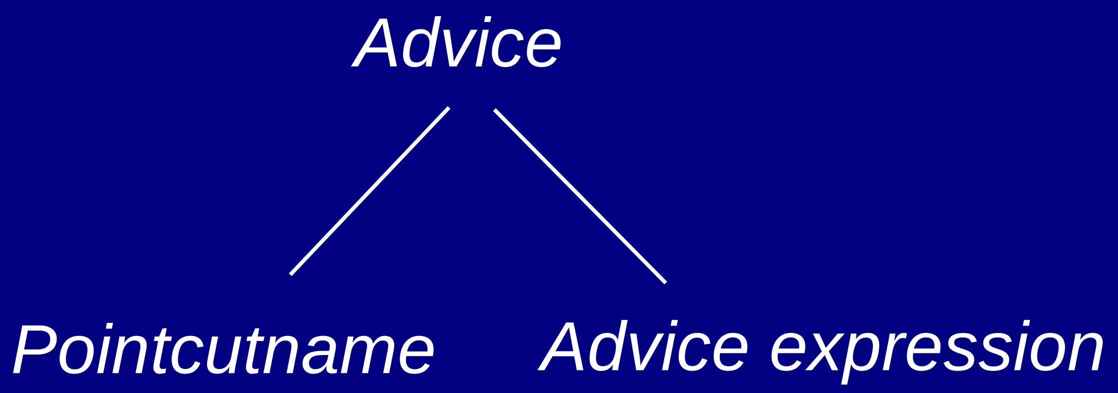
Classname

Methodname

Coq-Code:

```
Inductive pointcutSelection : Set :=
   | methodSel: className -> methodName ->
                           pointcutSelection.
```

Advice



Advice

Pointcutname *Advice expression*

Coq-Code:

```
Inductive adviceDef: Set :=
  | aroundAdvice: pointcutName -> adviceExp -> adviceDef.
```

Advice Expression

They are method expressions including a proceed statement

Coq-Code:

```
Inductive adviceExp : Set :=
  | proceed: adviceExp
  | adVar : varName -> adviceExp
  | adFieldProj : adviceExp -> fieldName -> adviceExp
  | adMethodInvk : adviceExp -> methodName ->
                list adviceExp -> adviceExp
  | adNew   : className -> list adviceExp -> adviceExp
  | adCast : className -> adviceExp -> adviceExp.
```

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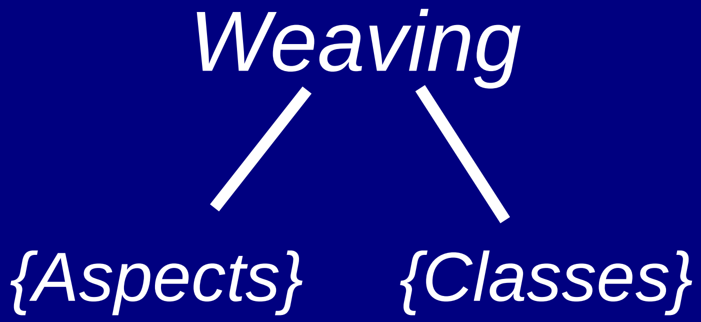
Weaving, top-level

An aspect-Table is weaved into a class-Table

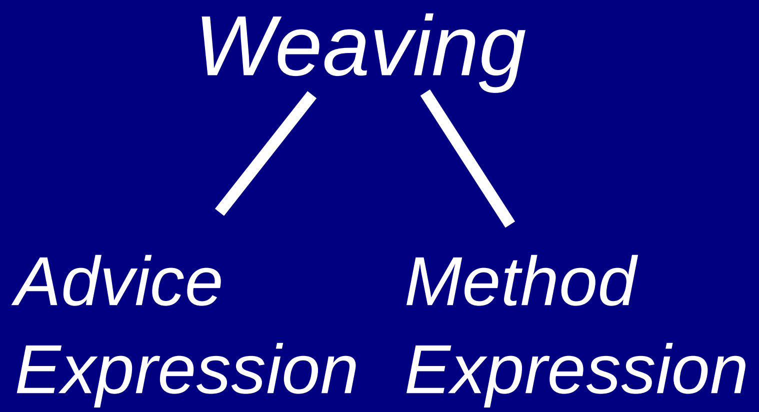


Coq-Code:

```
Definition wv_AT_CT (CT: classTable) (AT: aspectTable) :
classTable :=
   MapCollect _ _ (fun _ asp => wv_asp_CT CT asp) AT.
```

Weaving, bottom level

An advice expression is weaved into a method expression



Weaving

Advice Expression

Method Expression

Coq-Code:

```
Fixpoint merge_expr (mExpr: exp) (aExpr: adviceExp) {struct aExpr}: exp :=
    match aExpr with
         proceed                              => mExpr
       | adVar        v                       => Var v
       | adFieldProj  aExpr2 fieldN  => FieldProj (merge_expr mExpr aExpr2) fieldN
       (...)
    end.
```

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Type soundness (1)

Is an aspect table well typed?

```
Parameter asp_table_typing: aspectTable -> Prop.
```

A well typed aspect table weaves a well typed class table

```
Axiom type_soundness_woven:
forall (AT:aspectTable) (CT:classTable),
        class_table_typing CT
    -> asp_table_typing AT
    -> class_table_typing (wv_AT_CT CT AT).
```

Type soundness (2)

Progress and Preservation with AO:

```
Lemma weave_type_soundness:
forall (CT0 CT: classTable)(e e': exp)(AT: aspectTable),
     CT = wv_AT_CT CT0 AT
  -> class_table_typing CT0
  -> asp_table_typing AT
  ->  multi_step CT e e'
  -> ~(exists e'', reduction CT e' e'')
  -> (value e' \/ failed_cast CT e').
```

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Future work

There is a lot to do

- Completion of the formalization
- Proof type soundness, confinement etc.
- Investigate the runtime weaving problem

Thanks for listening!