# Practical Mostly-Static Information Flow Control

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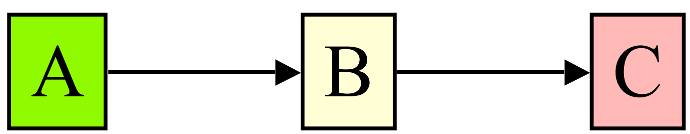
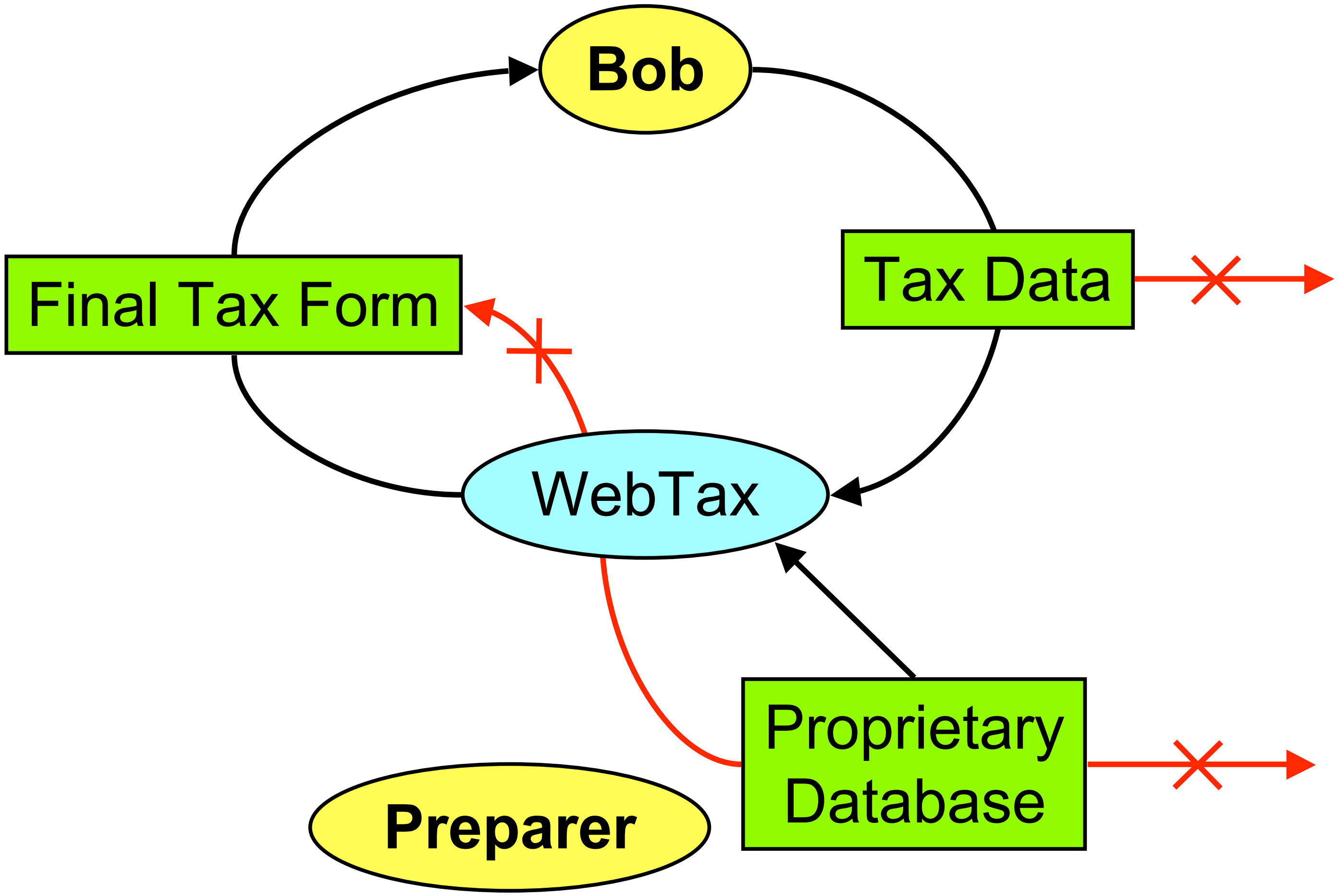
# Privacy

- Old problem (secrecy, confidentiality) : prevent programs from leaking data
- Untrusted, downloaded code: more important
- Standard security mechanisms not effective (*e.g.*, access control)

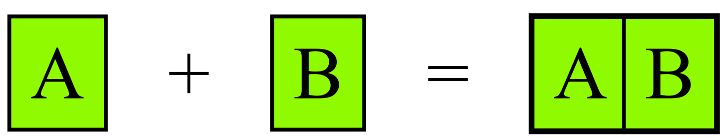


# Privacy with Mutual Distrust



# Static Information Flow

- Denning & Denning ’77
- Programs must follow rules
- Annotations added for tractability
- Static analysis = type checking
- Security property composes

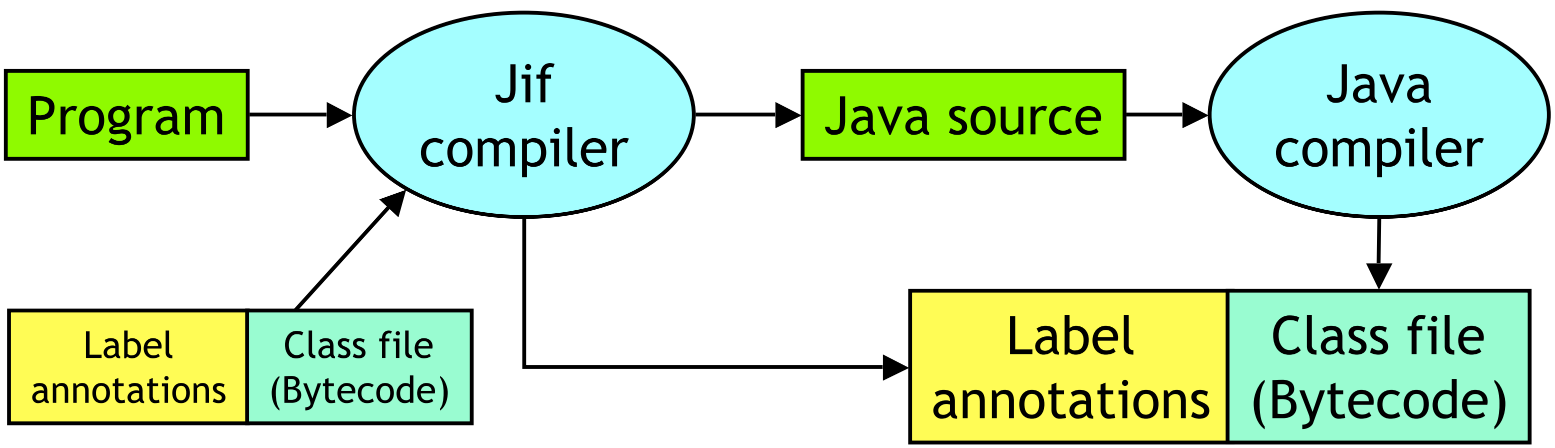


# Jif Language

- Jif = Java + information flow annotations (Java Information Flow)
- More practical than previous work
  - Real language: supports Java features
  - Convenience: automatic label inference
  - Genericity: label polymorphism
  - Decentralized declassification mechanism
  - Run-time label checking

# Architecture

- Source to source translator (mostly erasure)
- Modification to the **PolyJ** compiler (Java + parametric polymorphism)



# Jif Features

- Labeled types
- Convenience: automatic label inference
- Genericity: label polymorphism
- Static, decentralized declassification
- Safe run-time label checking (first-class labels)
- First-class principals
- Object-oriented features
  - Subtyping rules
  - Inheritance
  - Constructors
  - Method constraints
- Exceptions
- Arrays
- Described by formal inference rules

# Labeled Types

- Variables, expressions have *labeled type* $T\{L\}$
- Labels express privacy constraints
- $L_2$ is at least as restrictive as $L_1$: $L_1 \sqsubseteq L_2$
- Assignment rule (simplified)

$$\frac{v : T\{L_v\} \in A \quad A \vdash E : L_e \quad L_e \sqsubseteq L_v}{A \vdash v = E : L_e}$$

# Decentralized Label Model

- Label is a set of policies
- Each policy is owner : $\text{reader}_1$, $\text{reader}_2$, ...
  - owner (principal)
  - set of readers (principals)

{ Bob : Bob, Preparer ; Preparer : Preparer }

- Every owner's policy is obeyed
- Relation $\sqsubseteq$ is pre-order w/lattice properties [ML98]

# Implicit Label Polymorphism

- Method signatures contain labeled types

```
float {Bob: Bob} cos (float {Bob: Bob} x) {
   float {Bob: Bob} y = x – 2*PI*(int)(x/(2*PI));
   return 1 - y*y/2 + ...;
}
```

- Omitted argument labels: *implicit label polymorphism*

```
float{x} cos (float x) {
   float y = x – 2*PI*(int)(x/(2*PI));
   return 1 - y*y/2 + ...;
}
```

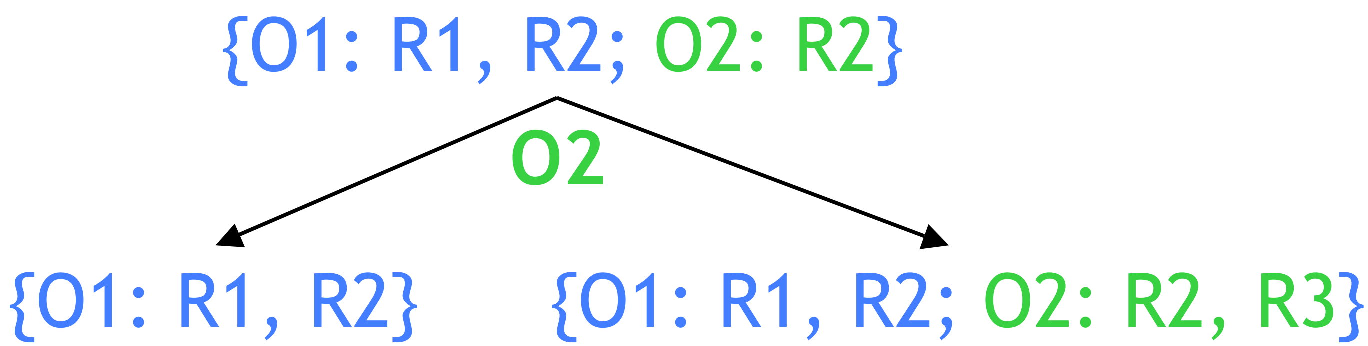
# Explicit Parameterization

```
class Cell[label L] {
   private Object{L} y;
   public void store{L} ( Object{L} x ) { y = x; }
   public Object{L} fetch ( ) { return y; }
}
                    Cell[{Bob: Amy}]
```

- Straightforward analogy with type parameterization
- Allows generic collection classes
- Parameters not represented at run time

# Declassification

- A principal can rewrite its part of the label




- Other owners' policies still respected
- Must know authority of running process
- Potentially dangerous: explicit operation

declassify($E$, $L$)

# Static Authority

- Authority of code is tracked statically

```
class C authority(root) {
      ...
}
```

- Authority propagated dynamically:

```
void m(principal p, int {root:} x) where caller(p) {
      actsFor(p, root) {
            int{} y = declassify(x, {}) // checked statically
      } else {
            // can't declassify x here
      }
}
```

# Implicit Flows and Exceptions

- Implicit flow: information transferred through control structure
- Static program counter label (pc) that expression label always includes
- Fine-grained exception handling: pc transfers via exceptions, break, continue

$\{b\} \sqsubseteq \{x\}$

```
x = b;
```

```
x = false;
if (b) {
   x = true;
}
```

```
x = false;
try {
   if (b) throw new Foo ();
} catch (Foo f) {
   x = true;
}
```

# Methods and Implicit Flows

begin-label = pc

```
class Cell[label L] {
        private Object{L} y;
        public void store{L} ( Object{L} x ) { y = x; }
        public Object{L} fetch ( ) { return y; }
}
```

implicit begin-label

- Begin-label constrains calling pc : pc ⊑{L}
- Prevents implicit flow into method
- Omitted begin-label: implicit parameter, prevents mutation

# Run-time Labels

- Labels may be first-class values, label other values:

```
final label a = ...;
int{*a} b;
```

- Run-time label treated statically like label parameter: unknown fixed label
- Exists at run time (`Jif.lang.Label`)
- `int{*a}` is dependent type

# Run-time Label Discrimination

- switch label statement tests a run-time label dynamically:

```
final label a = ... ;
int{*a} b;
int { C: D } x;
switch label(b) {
  case ( int { C: D } b2 )  x = b2;
  else throw new BadLabelCast();
}
```

tests a ⊑ { C : D } at run time

# Run-time Labels and Implicit Flows

```
final label{b} a = b ? new label {L1} : new label {L2};
int{*a} dummy;
switch label(dummy) {
  case ({L1}) : x = true;
  case ({L2}) : x = false;
}
```

≡

```
x = b;
```

- Proper check is {b} ⊑ {x}
- In `case` clause, pc augmented with label *of* label `a` (which is {b})
- Therefore: `x = true` results in proper check

# Implementation

- Translates to efficient Java, mostly by erasure
  - Labeled types become unlabeled types
  - Label parameters erased
- First-class label, principal values remain
- `switch label`, `actsFor` translated simply

# Is it Practical yet?

- Addresses limitations of earlier approaches to checking information flow statically
  - allows run-time checking
  - infers annotations
  - limited declassification mechanism
  - genericity: implicit & explicit polymorphism
- Greater expressiveness and convenience
- Only small programs so far
- Can reuse existing Java code
- Only sequential programs, no timing channels

# Related Work

Denning, Denning. CACM 1977

Palsberg, Ørbæk. ISSA 1995

Volpano, Smith, Irvine. JCS 1996

Myers, Liskov. SOSP 1997, IEEE S&P 1998

Heintze, Riecke. POPL 1998

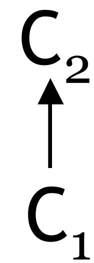
Smith, Volpano. POPL 1998

Abadi, Banerjee, Heintze, Riecke. POPL 1999

# Conclusions

- Most practical language yet for static enforcement of privacy
- Promising; more experience needed to understand limitations
- Why not 20 years ago?

# Inheritance/Subtyping




- Subclass signature (1) constrained by superclass signature (2)
- Argument, begin-label a : $\{ a_2 \} \sqsubseteq \{ a_1 \}$
- Return value, exception r : $\{ r_1 \} \sqsubseteq \{ r_2 \}$
- Class authority (set of principals) can only increase with inheritance : $A_1 \supseteq A_2$