Polyglot
An Extensible Compiler Framework for Java

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Language extension

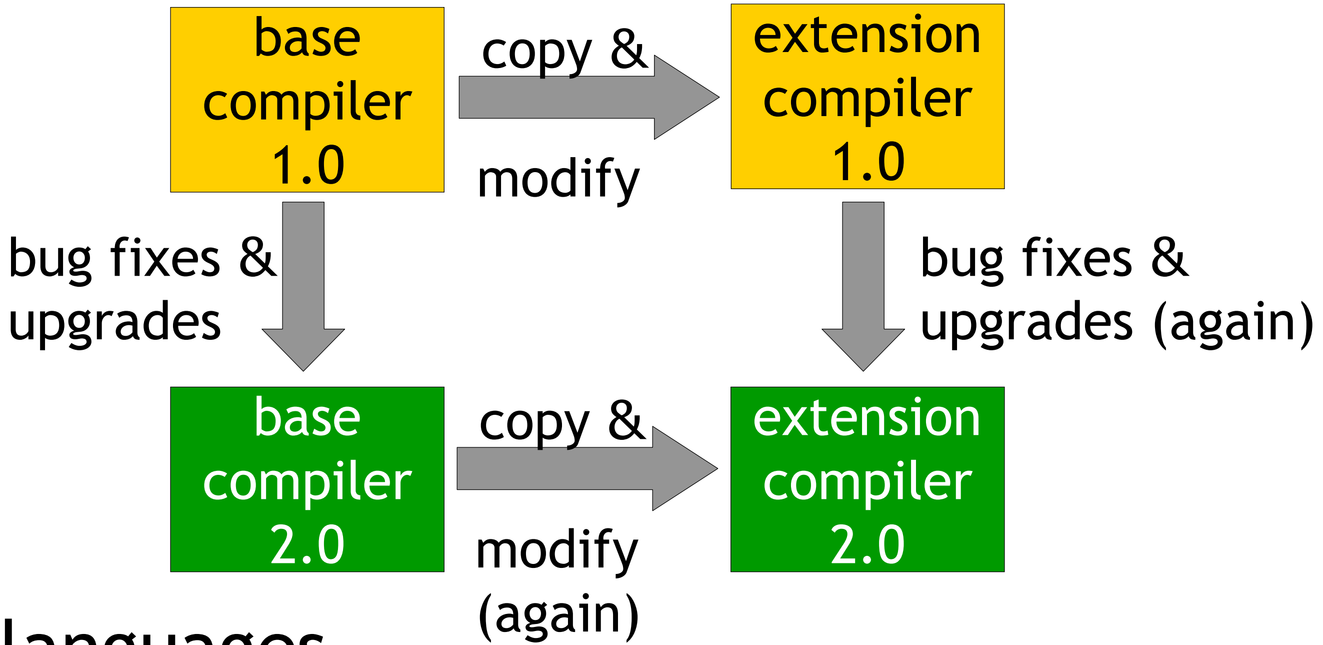
- Language designers often create extensions to existing languages
  - e.g., C++, PolyJ, GJ, Pizza, AspectJ, Jif, ArchJava, ESCJava, Polyphonic C#, ...
- Want to reuse existing compiler infrastructure as much as possible
- **Polyglot** is a framework for writing compiler extensions for Java

Requirements

- Language extension
  - Modify both syntax and semantics of the base language
  - Not necessarily backward compatible
- Goals:
  - Easy to build and maintain extensions
  - Extensibility should be **scalable**
    - No code duplication
  - Compilers for language extensions should be open to further extension

Rejected approaches

- In-place modification



- Macro languages
  - Limited to syntax extensions
  - Semantic checks *after* macro expansion

Polyglot

- Base compiler is a complete Java front end
- 25K lines of Java
  - Name resolution, inner class support, type checking, exception checking, uninitialized variable analysis, unreachable code analysis, …
- Can reuse and extend through inheritance

Scalable extensibility

Changes to the compiler should be proportional to changes in the language.

- Most compiler passes are **sparse**:

AST Nodes

Passes		+	**if**	x	*e*.f	=
	name resolution			🟦	🟦	
	type checking	🟦	🟦	🟦	🟦	🟦
	exception checking				🟦	
	constant folding	🟦				

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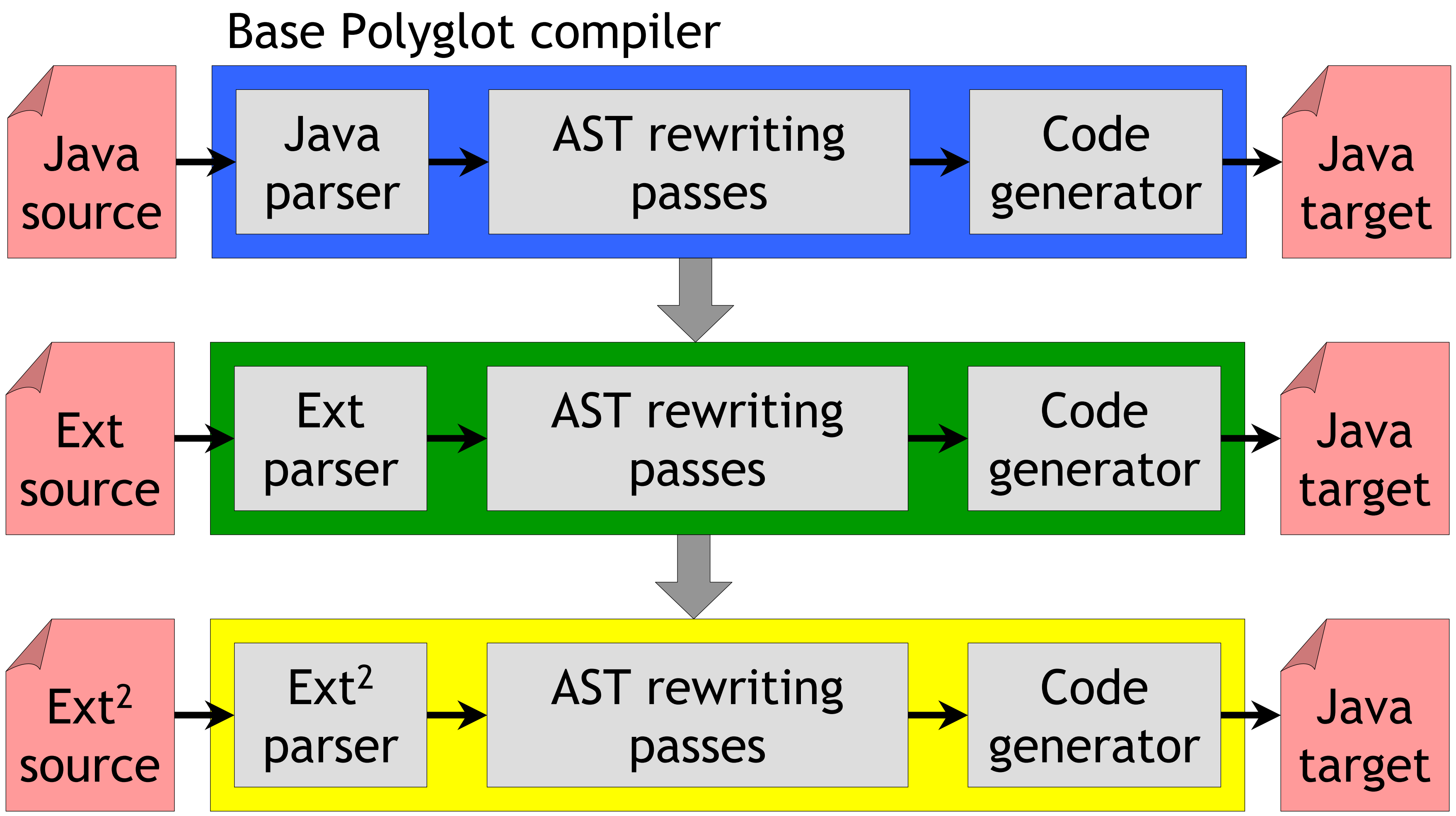
Non-scalable approaches

		Easy to add or modify	
		Passes	**AST nodes**
Using	**Visitors**	✓	✗
	pass as AST node method ("naive OO")	✗	✓
	Polyglot	✓	✓

Polyglot architecture



Architecture details

- Parser written using **PPG**
  - Adds grammar inheritance to Java CUP
- AST nodes constructed using a **node factory**
  - Decouples node types from implementation
- AST rewriting passes:
  - Each pass lazily creates a new AST
  - From naive OO: traverse AST invoking a method at each node
  - From visitors: AST traversal factored out

Example: PAO

- Primitive types as subclasses of Object
- Changes type system, relaxes Java syntax
- Implementation: insert boxing and unboxing code where needed

```
HashMap m;
m.put("two", 2);
int v = (int) m.get("two");
```

$\Rightarrow$

```
HashMap m;
m.put("two", new Integer(2));
int v = ((Integer) m.get("two")).intValue();
```

PAO implementation

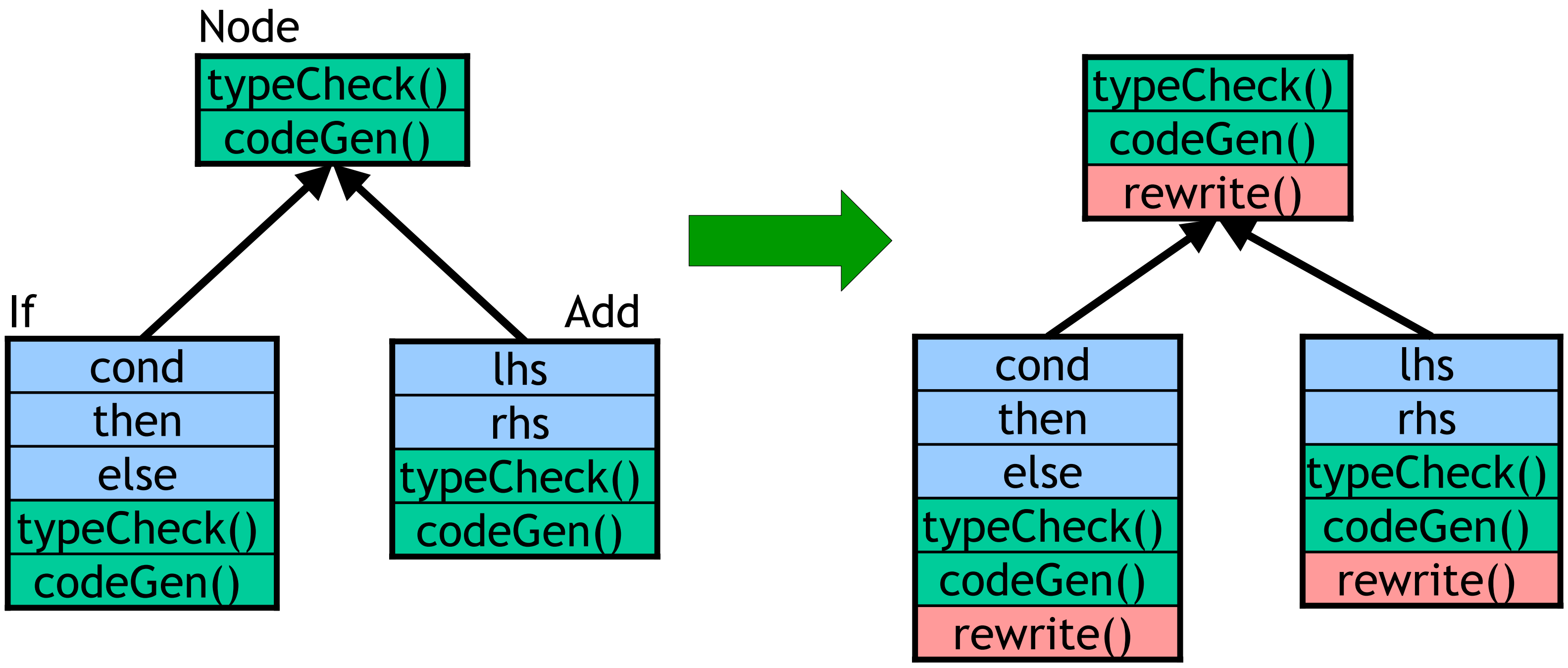
- Modify parser and type-checking pass to permit e instanceof int
    - Parser changes with PPG:

```
include "java.cup"
drop { rel_expr ::= rel_expr INSTANCEOF ref_type }
extend rel_expr ::= rel_expr:a INSTANCEOF type:b
  {: RESULT = node_factory.Instanceof(a, b); :}
```

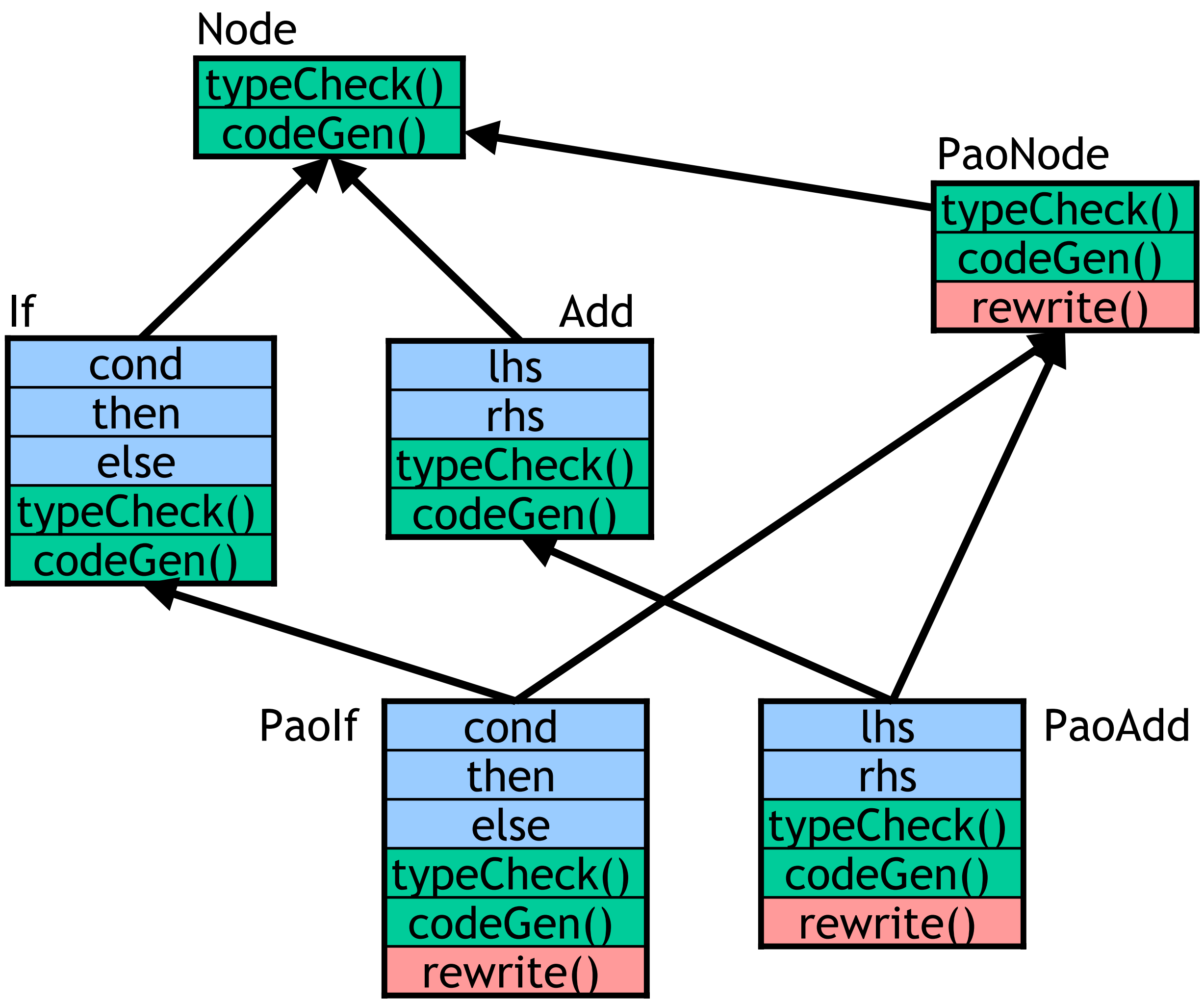
- Add one new pass to insert boxing and unboxing code

Implementing a new pass

- Want to extend Node interface with rewrite() method
  - Default implementation: identity translation
  - Specialized implementations: boxing and unboxing
- **Mixin extensibility**: extensions to a base class should be inherited by subclasses



Inheritance is inadequate



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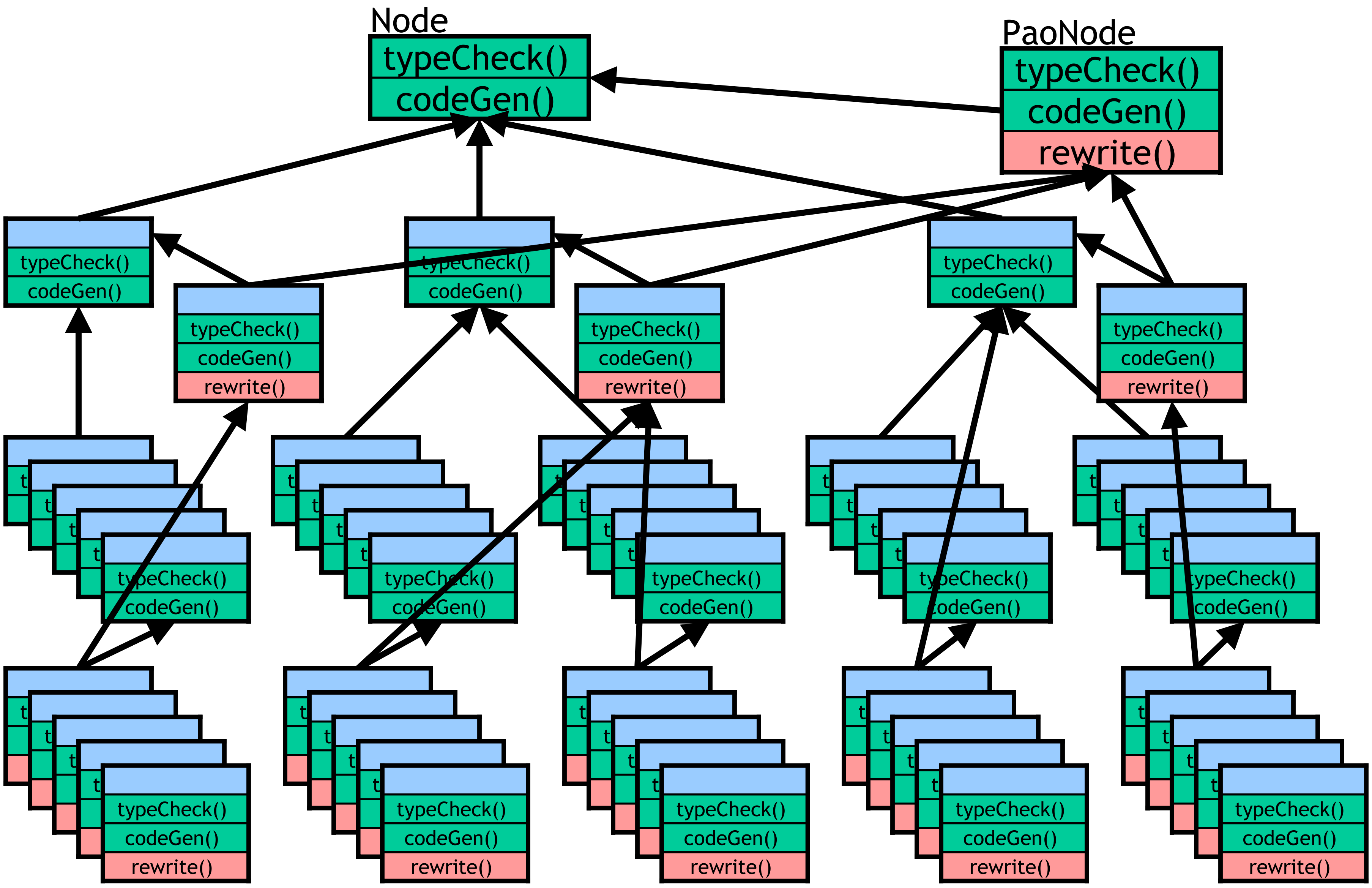
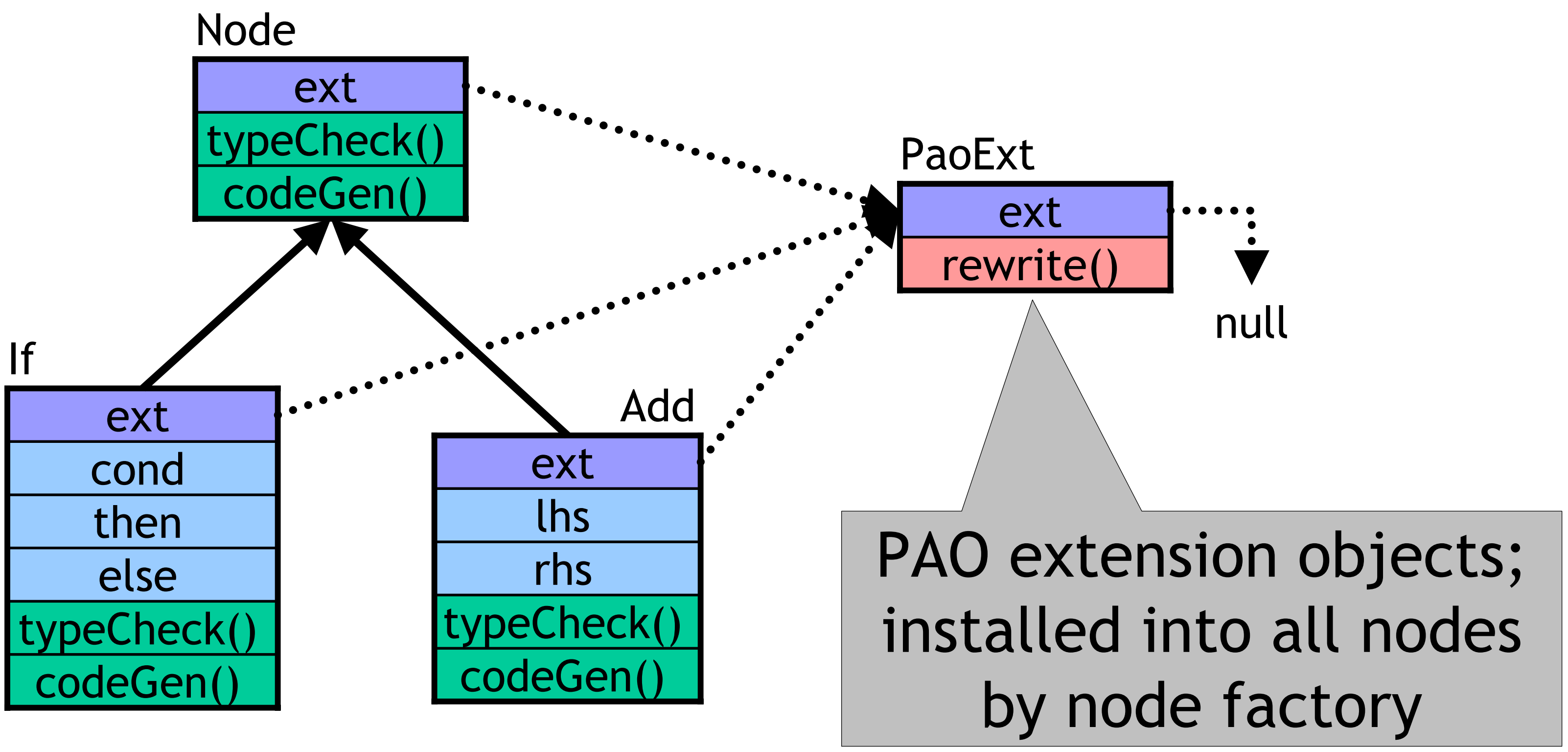


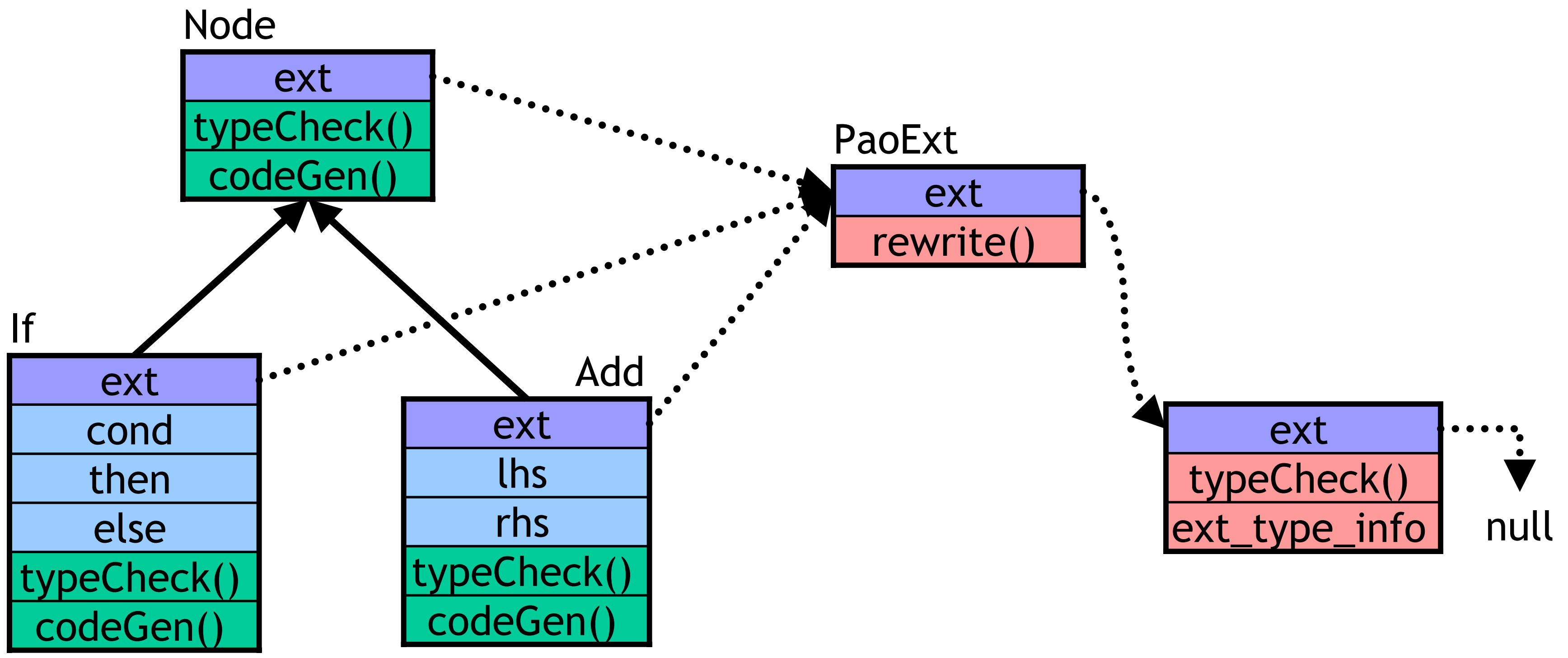
Extension objects

Use composition to mixin methods and fields into AST node classes



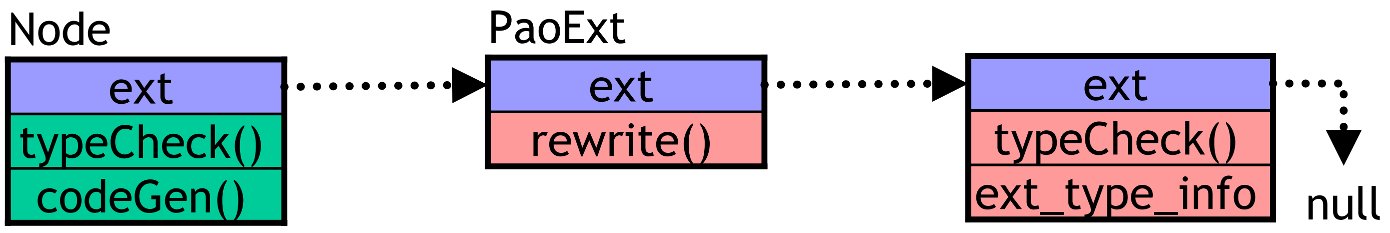
Extension objects

Extension objects have their own ext field to leave extension open



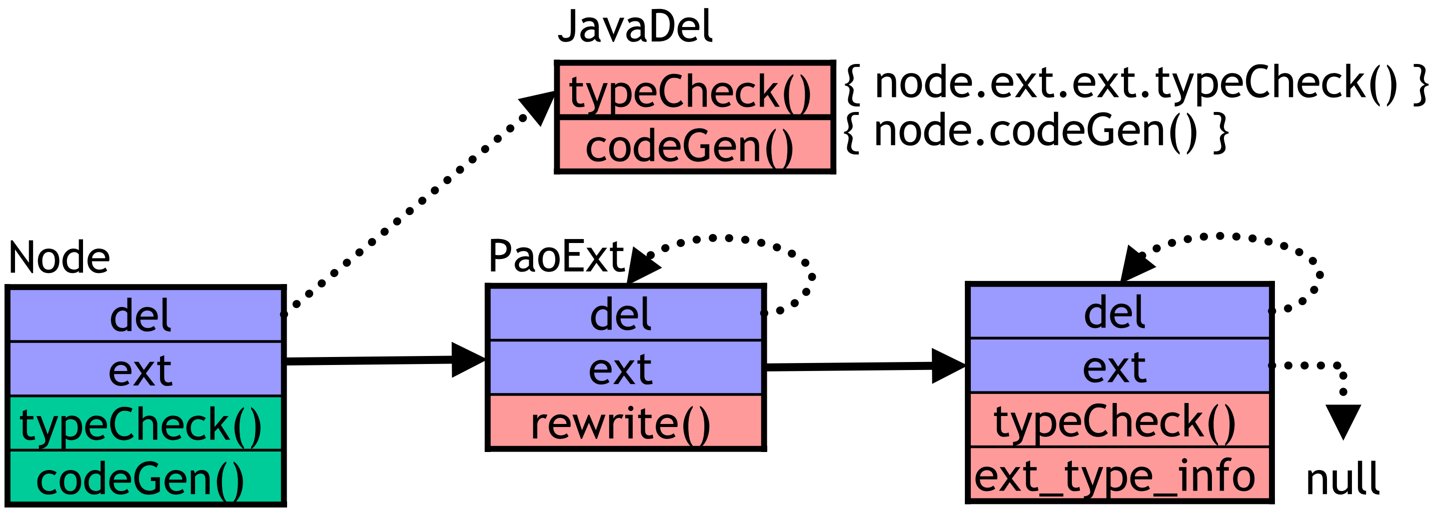
Method invocation

- A method may be implemented in the node or in any one of several extension objects.
- Extension should call `node.ext.ext.typeCheck()`
- Base compiler should call: `node.typeCheck()`
- Cannot hardcode the calls



Delegate objects

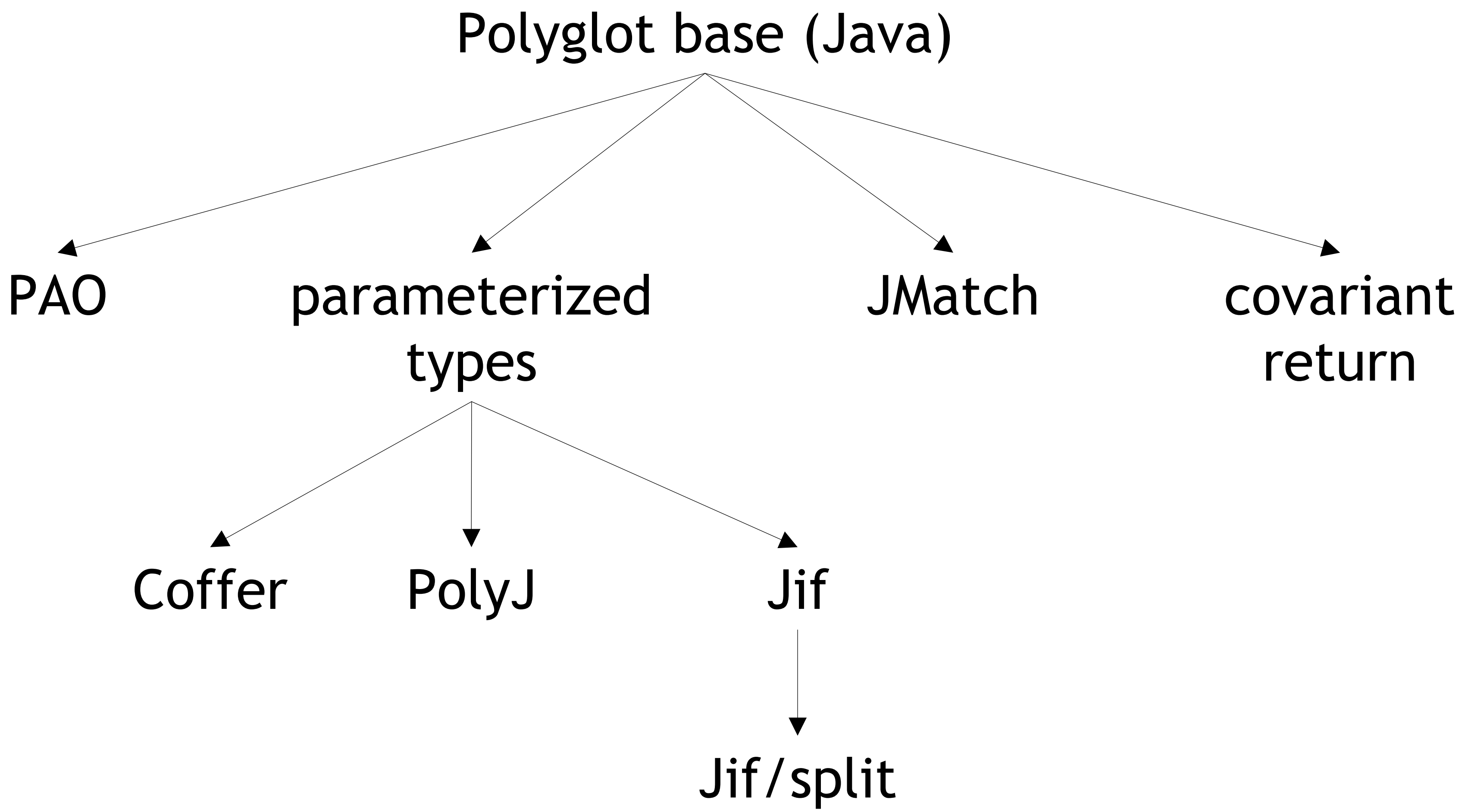
- Each node & extension object has a del field
- **Delegate object** implements same interface as node or ext
- Directs call to appropriate method implementation
  - Ex: node.del.typeCheck()
  - Ex: node.ext.del.rewrite()
- Run-time overhead < 2%



Scalable extensibility

- To add a new pass:
  - Use an extension object to mixin default implementation of the pass for the `Node` base class
  - Use extension objects to mixin specialized implementations as needed
- To change the implementation of an existing pass
  - Use delegate object to redirect to method providing new implementation
- To create an AST node type:
  - Create a new subclass of `Node`
  - Or, mixin new fields to existing node using an extension object

Polyglot family tree



Results

- Can build small extensions in hours or days
- 10% of base code is interfaces and factories

Extension	# Tokens	% of Base
Polyglot base (Java)	166K	100
Jif	129K	78
JMatch	108K	65
Jif/split	99K	60
PolyJ	79K	48
Coffer	24K	14
PAO	6.1K	3.6
parameterized types	3.2K	2
covariant return	1.6K	1
javac 1.1	132K	80

Related work

- Other extensible compilers
  - e.g., CoSy, SUIF
  - e.g., JastAdd, JaCo
- Macros
  - e.g., EPP, Java Syntax Extender, Jakarta
  - e.g., Maya
- Visitors
  - e.g., staggered visitors, extensible visitors

Conclusions

- Several Java extensions have been implemented with Polyglot
- Programmer effort scales well with size of difference with Java
- Extension objects and delegate objects provide **scalable extensibility**
- Download from:

  http://www.cs.cornell.edu/projects/polyglot

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Lantian Zheng	Jif, Jif/split

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Questions?