

Polyglot

An Extensible Compiler Framework for Java

Nathaniel Nystrom

Michael R. Clarkson

Andrew C. Myers

Cornell University

Language extension

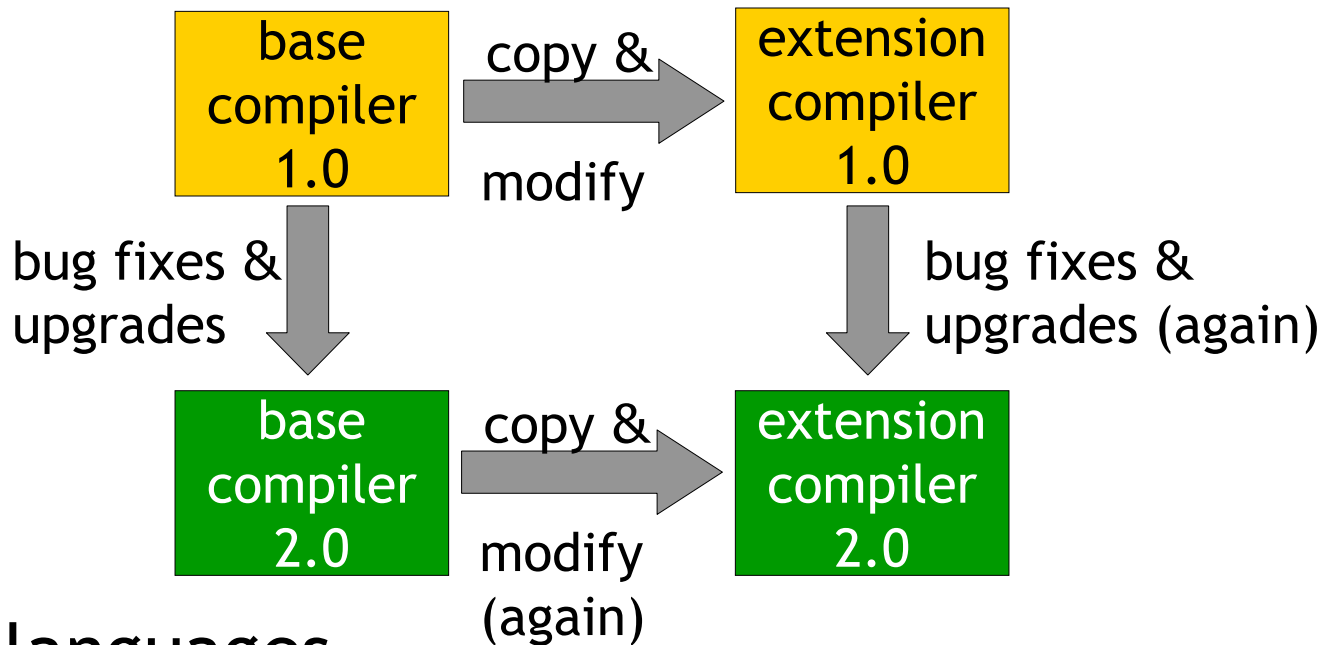
- Language designers often create extensions to existing languages
 - e.g., C++, PolyJ, GJ, Pizza, AspectJ, Jif, ArchJava, ESCJava, Polyphonic C#, ...
- Want to reuse existing compiler infrastructure as much as possible
- **Polyglot** is a framework for writing compiler extensions for Java

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

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

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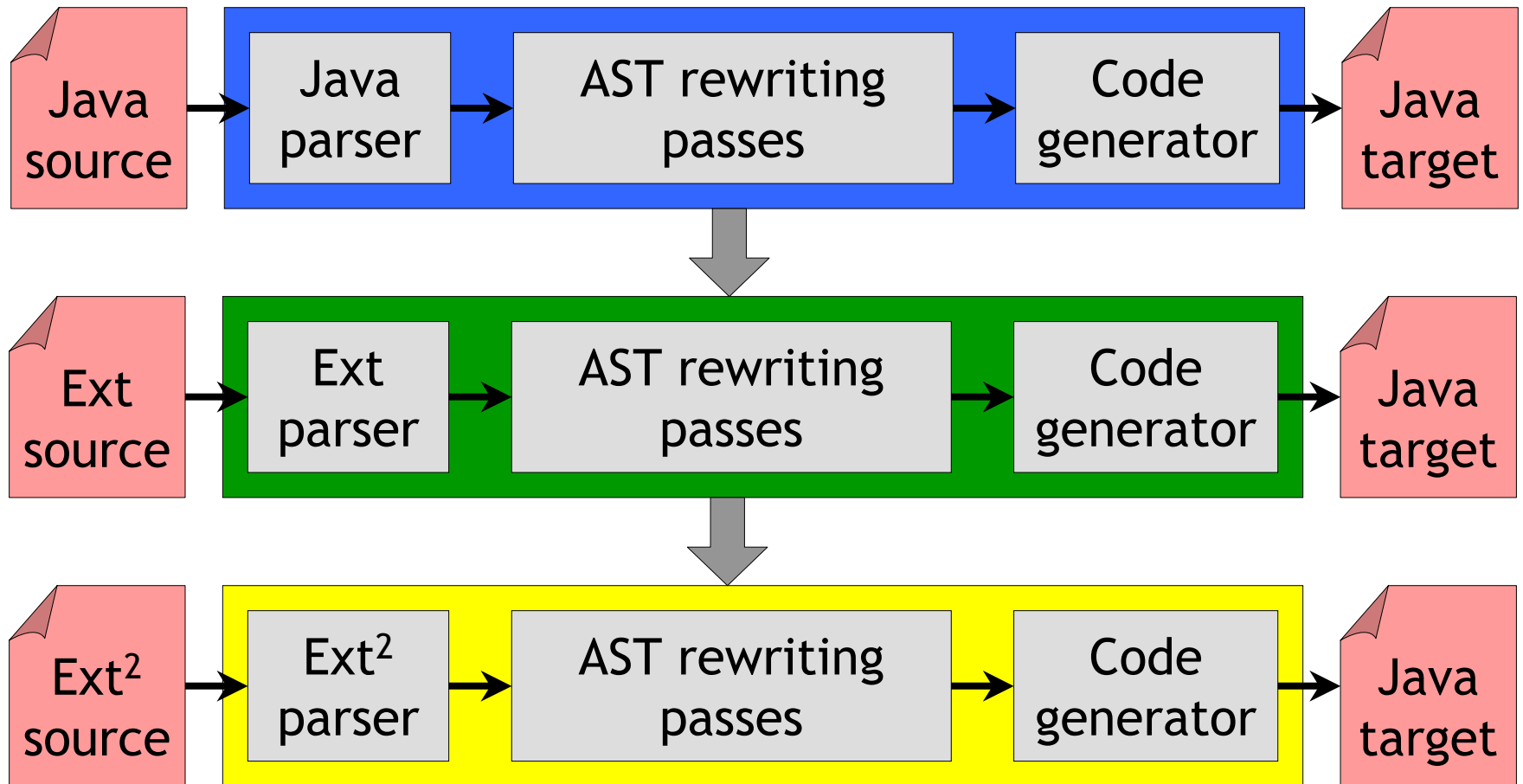
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Non-scalable approaches

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

Polyglot architecture

Base Polyglot compiler



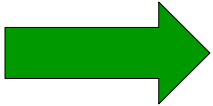
Architecture details

- 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");
```



```
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 }
```

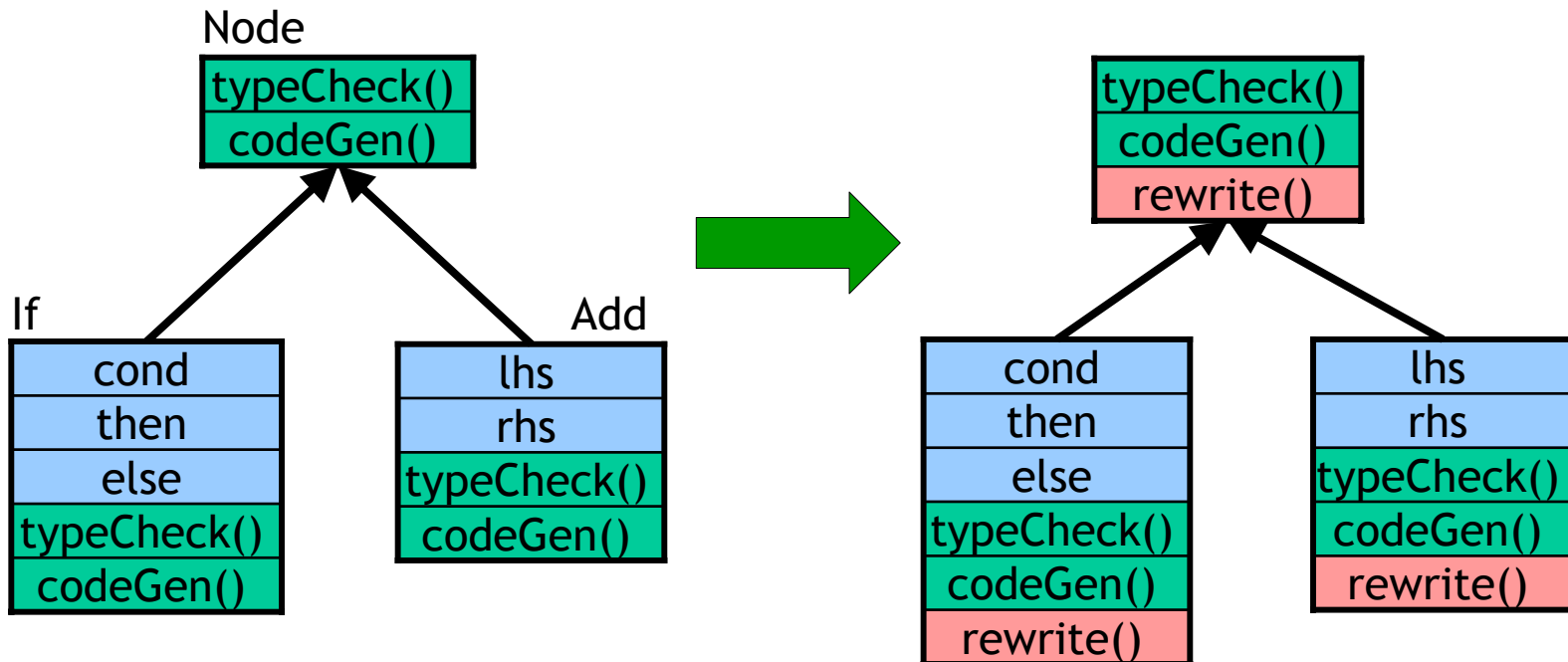
```
extend rel_expr ::= rel_expr:a INSTANCEOF type:b
```

```
{: RESULT = node_factory.Instanceof(a, b); :}
```

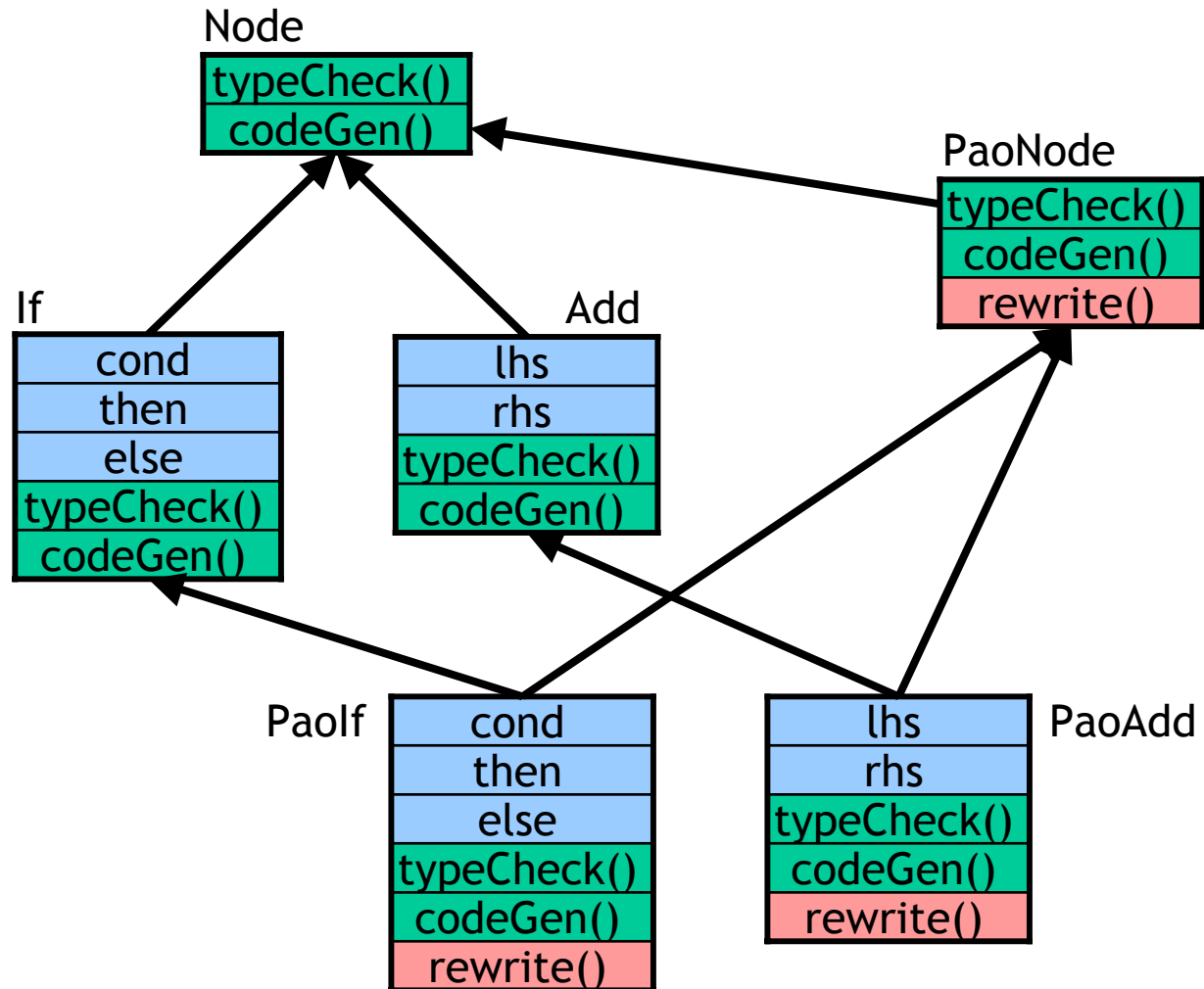
- Add one new pass to insert boxing and unboxing code

Implementing a new pass

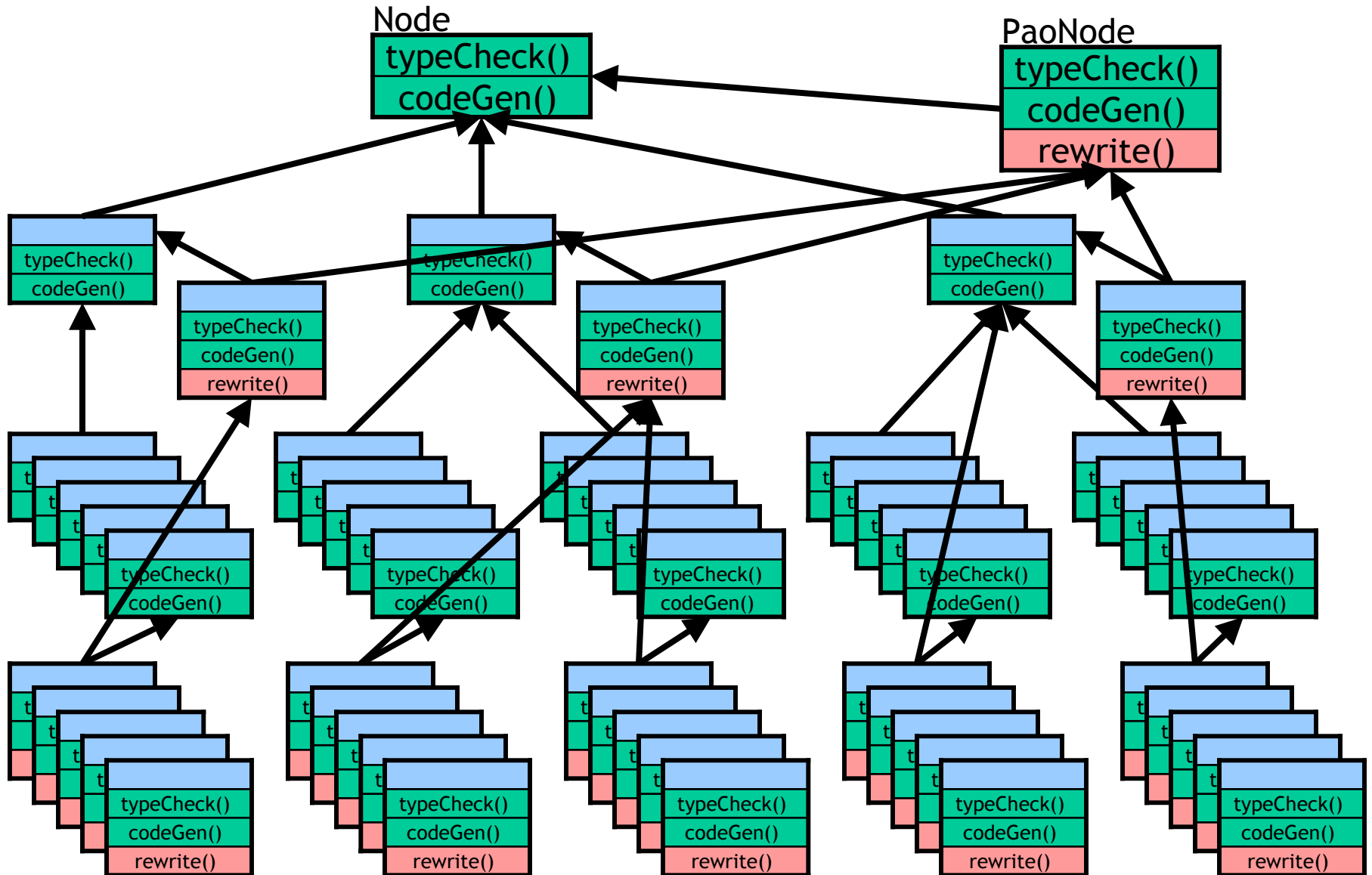
- Want to extend `Node` interface with `rewrite()` method
 - Default implementation: identity translation
 - Specialized implementations: boxing and unboxing
- **Mixin extensibility**: extensions to a base class should be inherited by subclasses



Inheritance is inadequate

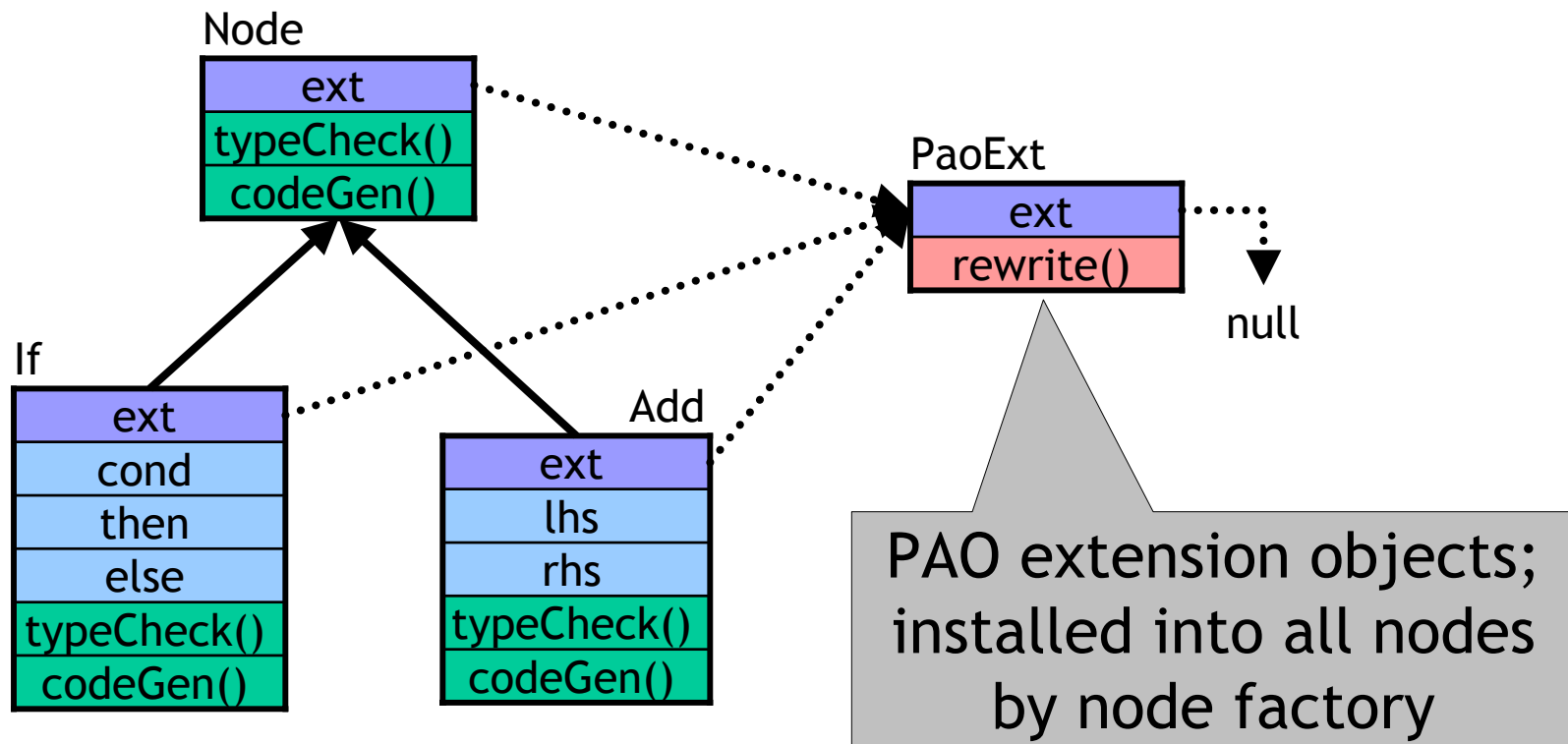


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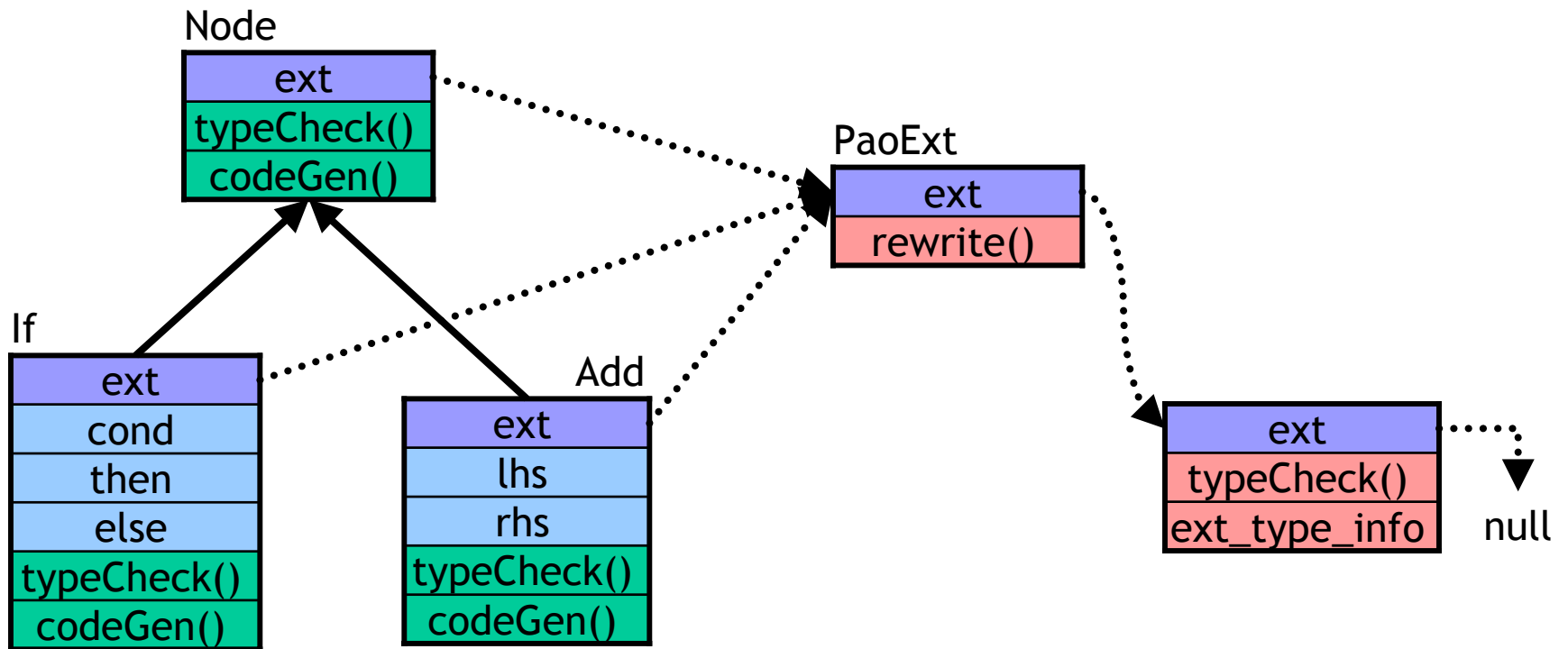
Extension objects

Use composition to mixin methods and fields into
AST node classes



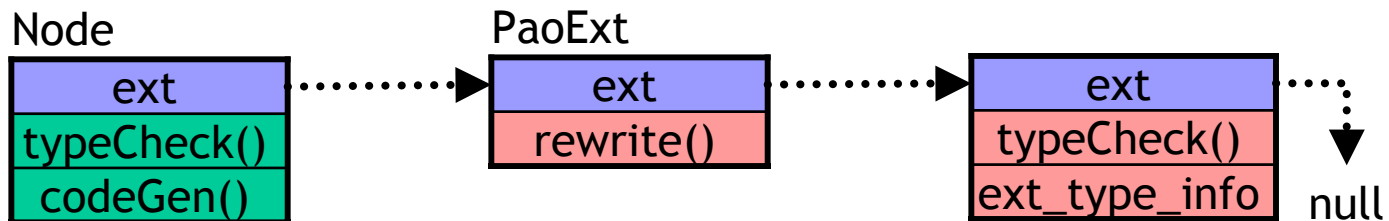
Extension objects

Extension objects have their own `ext` field to leave extension open



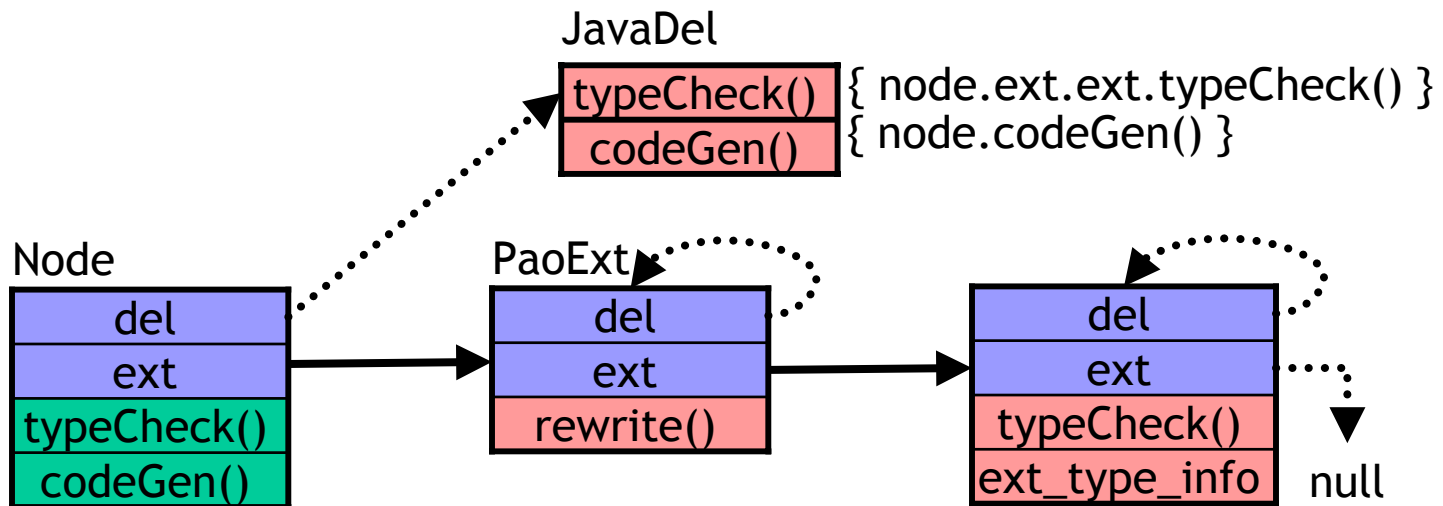
Method invocation

- 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

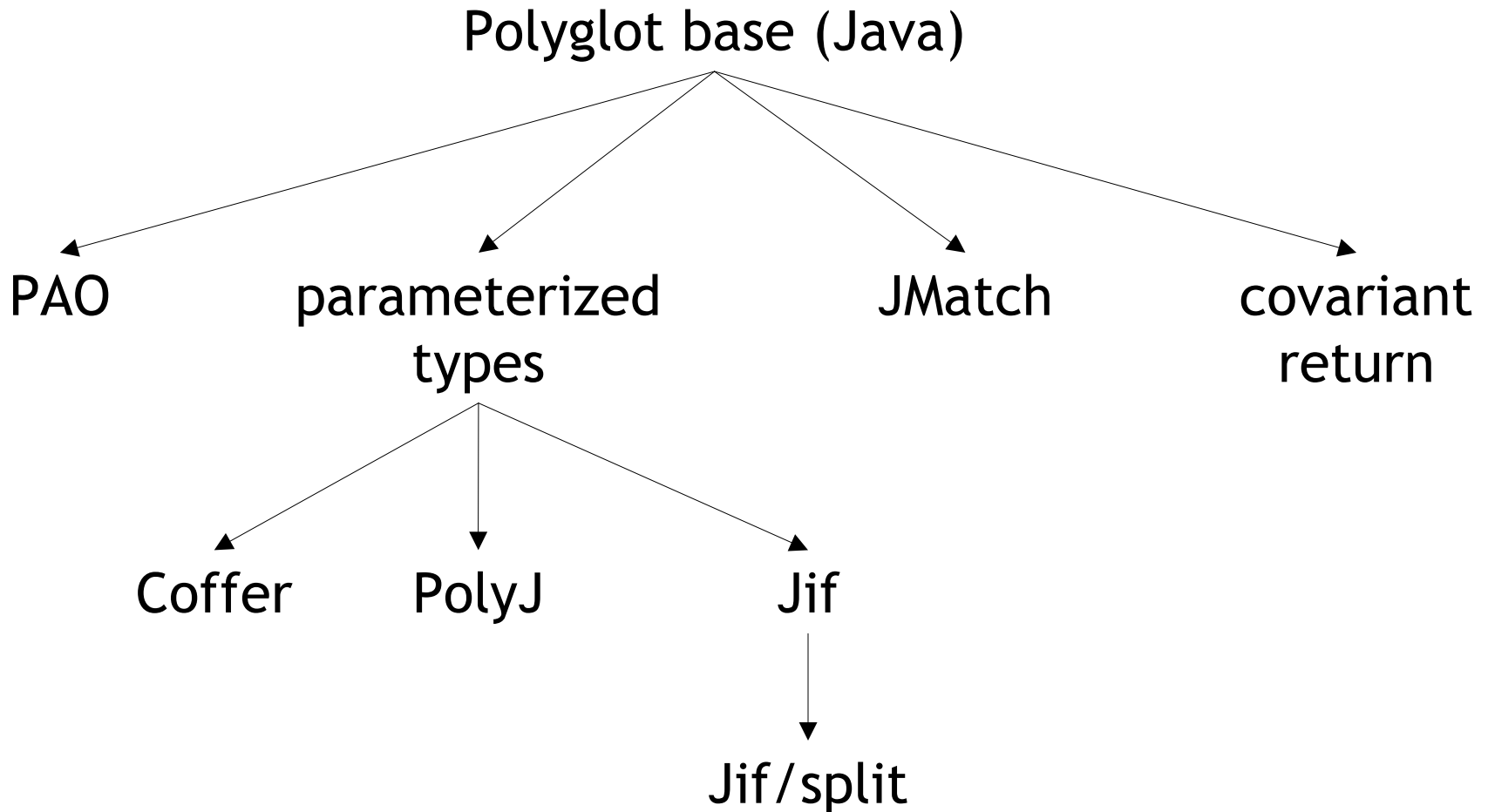
- Each node & extension object has a **del** field
- **Delegate object** implements same interface as node or **ext**
- Directs call to appropriate method implementation
 - Ex: `node.del.typeCheck()`
 - Ex: `node.ext.del.rewrite()`
- Run-time overhead < 2%



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>

Acknowledgments

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Lantian Zheng	Jif, Jif/split

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Questions?