The pivot – a brief overview

Bjarne Stroustrup
Gabriel Dos Reis
Texas A&M University
http://www.research.att.com/~bs

Overview

- The Pivot
  - Context
  - Aims
  - Organization
  - Basic representations
- High-level program representation for HPC
  - Concept-based checking and transformation

Bell Labs proverbs

- Library design is language design
- Language design is library design

But the devil is in the details

Context for the Pivot

- Semantically Enhanced Library (Language)
  - Enhanced notation through libraries
  - Restrict semantics through tools
    - And take advantage of that semantics
- Provide the advantages of specialized languages
  - Without introducing new “special purpose” languages
  - Without supporting special-purpose language tool chains
  - Avoiding the 99.?% language death rate
- Provide general support for the SELL idea
  - Not just a specialized tool per application/library
  - The Pivot fits here

Example SELL: Safe C++

- Add
  - Range-checked std::vector
    - iterators
  - Resource handles
  - Any (if needed) (a typesafe union type)
- Subtract
  - Arrays
  - Pointers
  - New/delete
  - Unions
  - Excessively complex/obscure code
    - Uses of undefined construct not caught by compilers (e.g. a[++i] = i)
- Transforms
  - Pointers into iterators and resource handles (if porting)
  - New/delete into resource handle uses

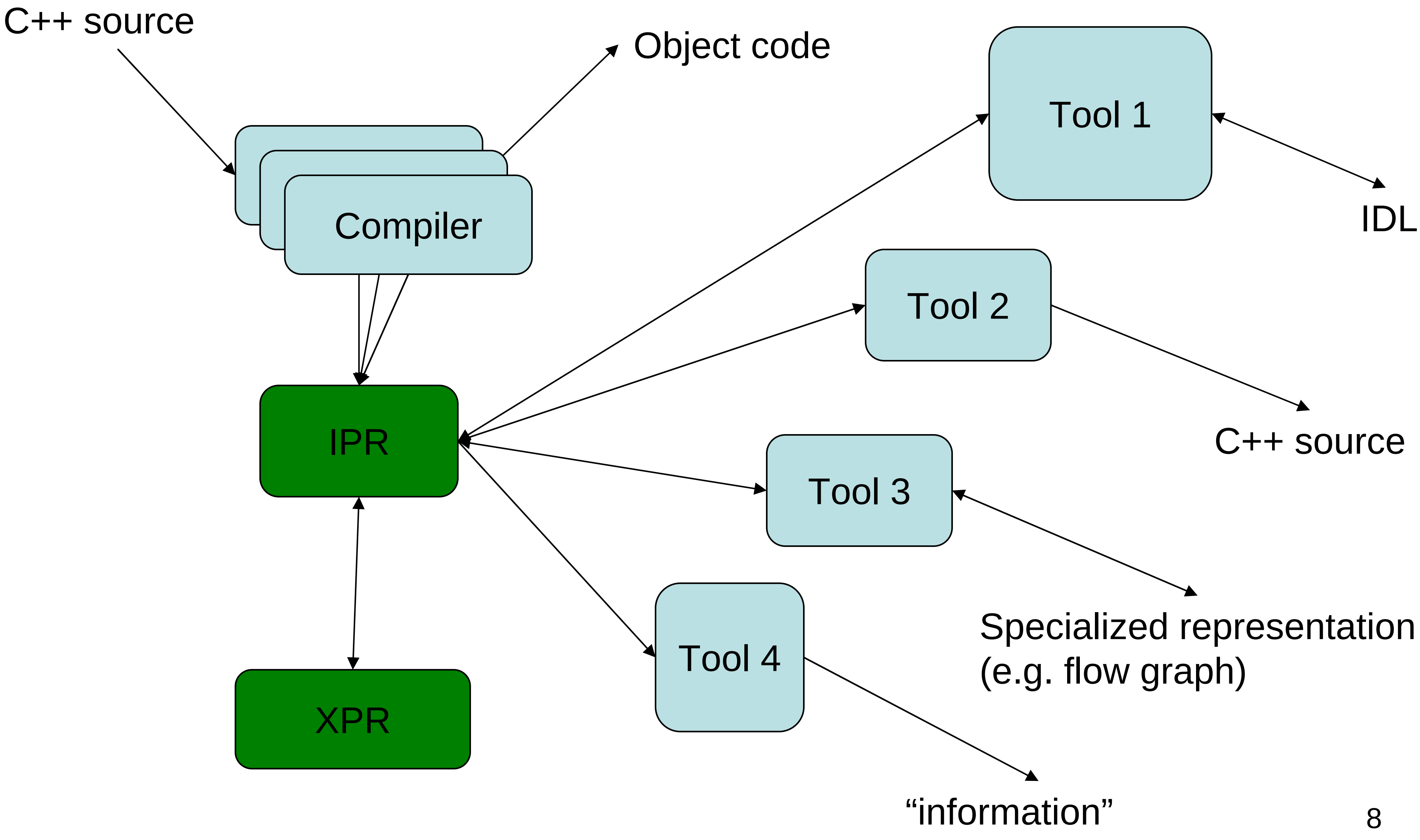
Aims

- To allow fully general analysis of C++ source code
  - "What a human can do"
  - Foci
    - Templates (e.g. specialization)
    - C++0x features (e.g. concepts, generalized initializers)
    - Distributed programming
    - Embedded systems
  - Limitation: we work after macro expansion
- To allow transformation of C++ code
  - i.e. production of new code from old source
- Non-aim: handling other languages
  - e.g. Fortran, Java
  - but C and C++ dialects are relatively easy

Related work

- Lots
  - 20+ tools for analyzing C++
- But
  - Most are specialized
    - E.g. alias analysis, flow analysis, numeric optimizations
  - Most are attached to a single compiler/parser
  - None handles all of C++
    - E.g. C + classes, C++ but not standard libraries
    - Hardly two tools handle the same subset
  - Some are proprietary
  - No serious interoperability

The Pivot



C++ source
Object code
Tool 1
IDL
Compiler
Tool 2
IPR
C++ source
Tool 3
Specialized representation
(e.g. flow graph)
Tool 4
XPR
"information"

The Original Project

- Communication with remote mobile device
  - Calling interface
    - CORBA, DCOM, Java RMI, …, homebrew interface
  - Transport
    - TCP/IP, XML, …, homebrew protocol
- Big, Ugly, Slow, Proprietary, …
  - Why can’t I just write ISO Standard C++?

The original Project
Distributed programs in ISO C++

```
// use local object:


X x; // remote at "my host"
A a;
std::string s("abc");
// …
x.f(a, s); // a function call
```

```
// use remote object :
proxy<X> x;
x.connect("my_host");
A a;
std::string s("abc");
// …
x.f(a, s); // a message send
```

- "as similar as possible to non-distributed programming, but no more similar"

IPR high-level principles

- Complete: Direct representation of C++
  - Built-in types, classes, templates, expressions, statements, translation units …
  - Can represent erroneous and incomplete C++ programs
- Regular
  - The structure contains all of C++ but doesn't mimic irregularities
- Programming effort proportional to complexity of task
  - IPR is not just a data structure
- Extensible
  - Node types
  - Information associated with a node
  - Operations
- No integration with compilers

IPR design choices

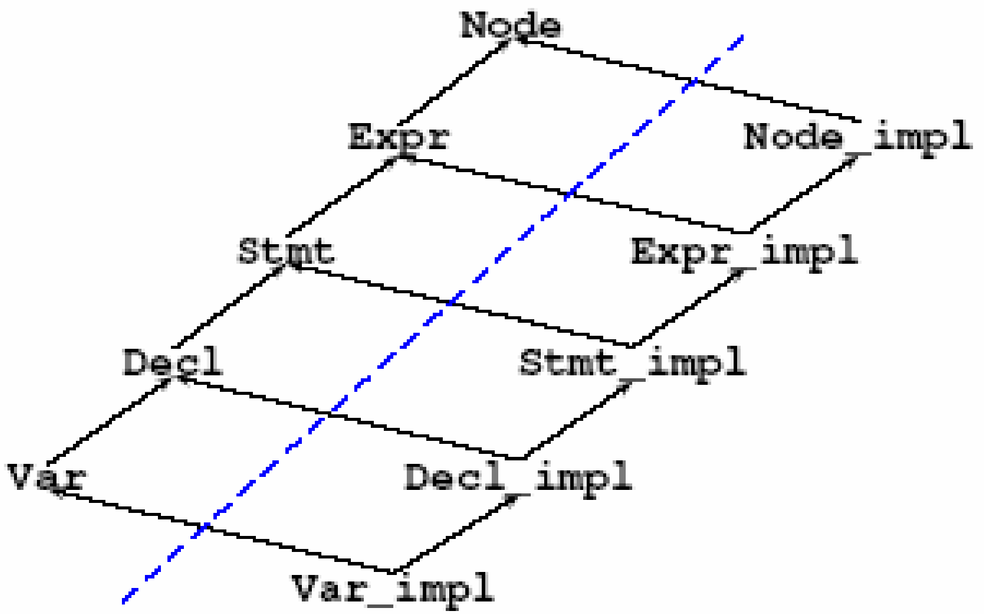
- Type safe
- IPR (not its users) handles memory management
- Minimal (run-time and space)
  - Minimal number of nodes (unification)
  - Minimal number of checked indirections (usually, virtual function calls)
- Expression-based regular superset of C++
  - E.g. statements, declarations are expressions too
  - C++0x features (most important: concepts – types have types)
- Interfaces:
  - Purely .functional., abstract classes, for most users
    - No mutation operation on abstract classes
    - Users don't get pointers directly
  - Mutating (operates on .concrete. classes)
    - Users get to use pointers for in-place transformation
  - Traversals (and queries)
    - Several, most not in “the Pivot core”

IPR is minimal

- Necessary for dealing with real-world code
  - Multi-million line programs are not uncommon
- Given the constraint of completeness
  - C++ is complex
    - especially when we use the advanced template features essential for high-performance work
- Unified representation
  - E.g., there is only one **int** and only one **1**
  - Type comparison becomes pointer comparison
- Indirections are minimized
  - An indirection (only) when there is a choice of different types of information

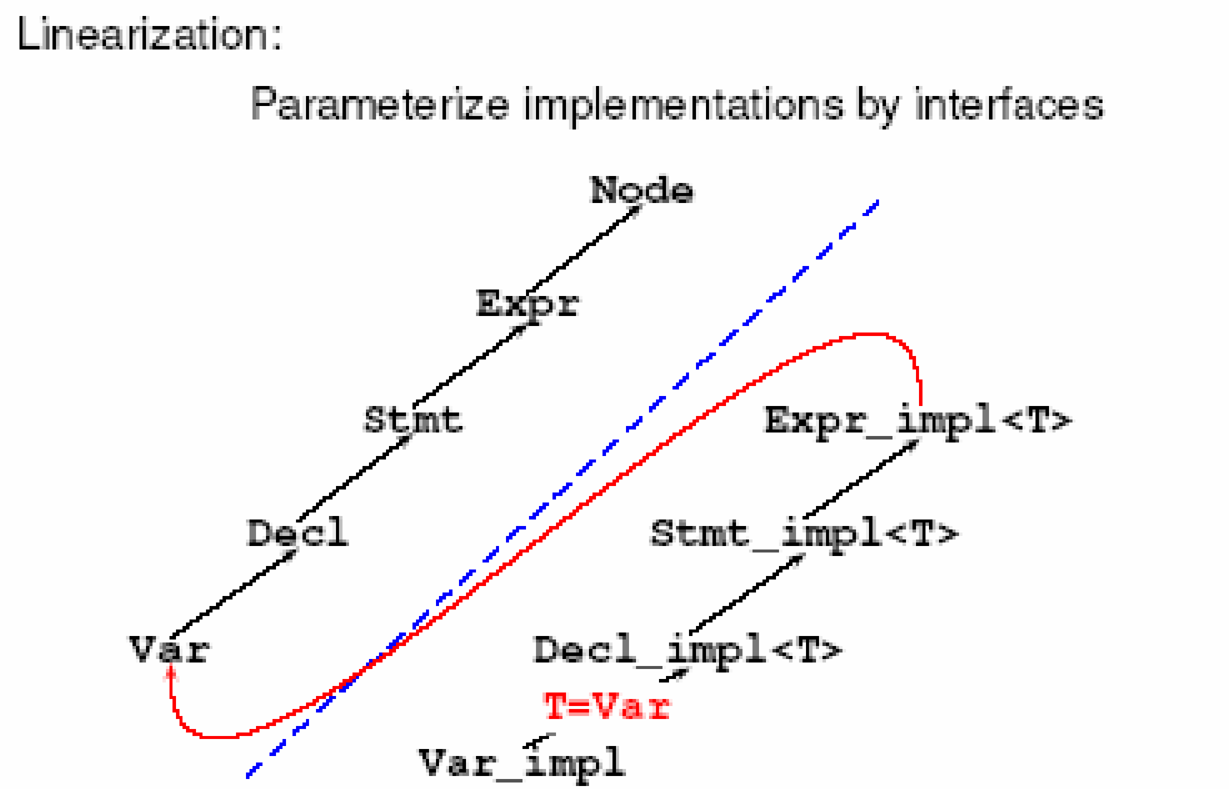
Original idea (XTI)

Every interface class **Xyz** should have a corresponding implementation class **Xyz_impl**.



- Too large, too slow

Current hierarchy (IPR)



- Compact
- minimal call overhead

XPR (eXternal Program Representation)

- Can be thought of as a specialized portable object database
  - Easy/fast to parse
  - Easy/fast to write
- Compact
  - About as compact as C++ source code
- Robust
  - Read/write without using a symbol table
- LR(1), strictly prefix declaration syntax
- Human readable
- Human writeable
- Can represent almost all of C++ directly
  - No preprocessor directives
  - No multiple declarators in a declaration
  - No <, >, >>, or << in template arguments, except in parentheses

XPR

```
i : int                                  // int i;
C : class {                              // class C {
    m : const int                        //     const int m;
    mm : *const int                      //     const int* mm;
    f : (:int,:*char) double             //     double f(int,char*);
    f : (z:complex) C                    //     C f(complex z);
}                                        // };
vector : <T> class {                     // template<class T> class vector {
    p : *T                               //     T* p;
    sz : int                             //     int sz;
}                                        // };
```

Current and future work

- Complete infrastructure
  - Complete EDG and GCC interfaces
  - Represent headers (modularity) directly
  - Complete type representation in XPR
- Initial applications
  - Style analysis
    - including type safety and security
  - Analysis and transformation of STAPL programs

- Build alliances