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JÜLICH FORSCHUNGSZENTRUM

Configurable instrumentation components and their use by Scalasca

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Source-code instrumentation

- Generic source-code analysis frameworks
  - Program Database Toolkit (PDT)
  - ROSE
- Special-purpose source-code instrumenters
  - OPARI (OpenMP)
  - TAU instrumentor

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No configurable source-code instrumenter available.

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Conclusion I

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Conclusion II

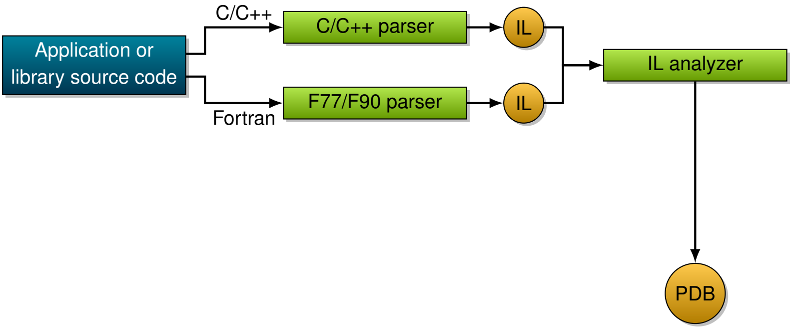
Take the initiative and create one!

- Based on the TAU instrumentor
- Developed in collaboration with UOregon

TAU source-code instrumentor

- Based on Program Database Toolkit (PDT)
  - Uses commercial-grade compiler frontends
  - Creates a database of source-code entities
  - Provides a C++ library to access this data
- Pros
  - Robust, well tested
  - Works for C, C++, Fortran
  - Able to instrument routines, methods, and loops
  - Provides extensive filtering capabilities
- Cons
  - Only inserts instrumentation code for the TAU Performance System

TAU instrumentor workflow



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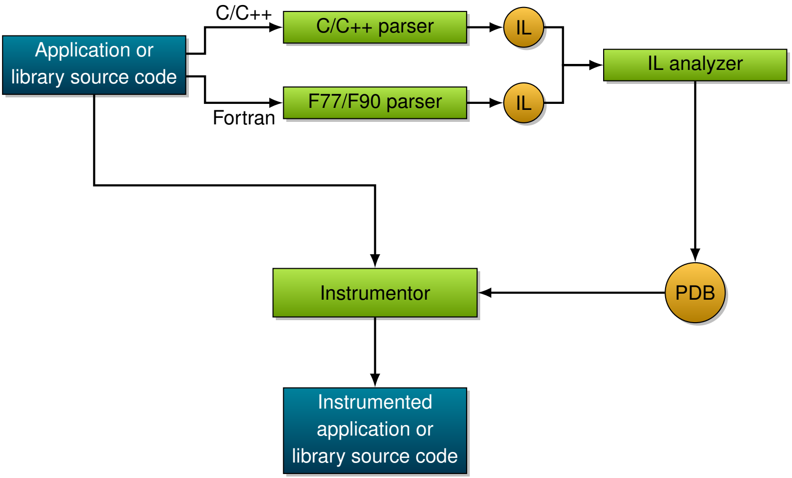

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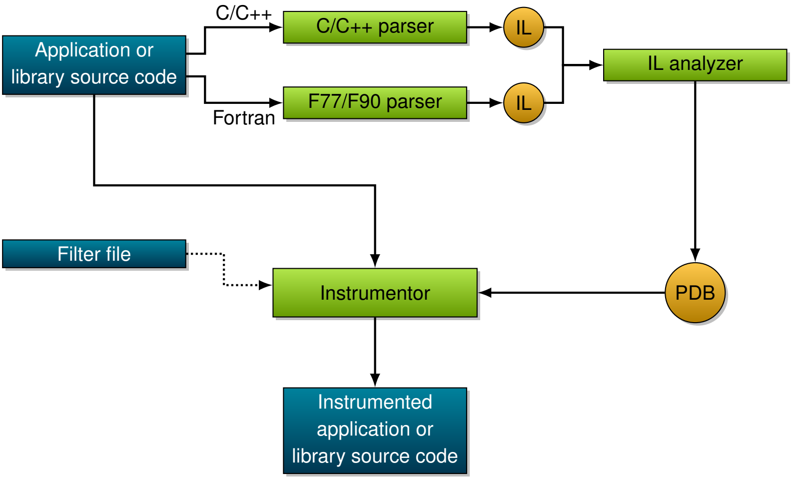

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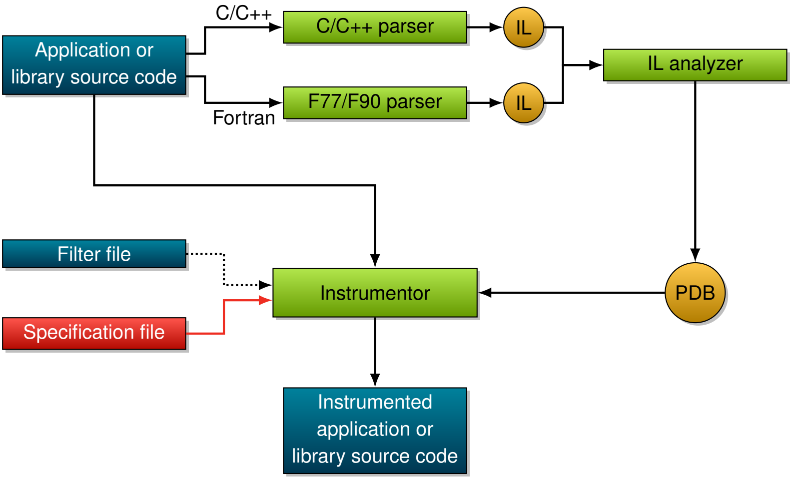

“Building blocks” for user-defined instrumentation

- Entering a routine

```
entry file="..." routine="..." code="..."
```

- Leaving a routine

```
exit file="..." routine="..." code="..."
```

- Insert arbitrary code (e.g., to include header files)

```
file="..." line=...  code="..."
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file="..." line=...  code="..."
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- Declaration of local variables

```
decl file="..." routine="..." code="..."
```

- Aborting the application

```
abort file="..." routine="..." code="..."
```

- Initialization

```
init file="..." code="..."
```

Wildcards

- Files and routines can be specified using wildcards
  - '?' matches a single character
  - '*' matches multiple characters in file names
  - '#' matches multiple characters in routine names
    - Avoids escaping '*' characters in pointer types of arguments and return values
- If `file` and/or `routine` clause is omitted, '*' or '#' is implicitly assumed

Code clauses

- Code clauses support C-style escaping of characters
  - `\"` Quotation mark
  - `\n` Newline character
  - `\t` Horizontal tab
  - ...
- Instrumentor knowledge can be referenced through keyword substitution

Keyword substitution

Keyword	Substitution
All constructs:	
@FILE@	File name
@LINE@	Source line of insertion
@COL@	Column of insertion
decl, init, entry, exit, abort only:	
@ROUTINE@	Routine name
@BEGIN_LINE@	Begin line of routine body
@BEGIN_COL@	Begin column of routine body
@END_LINE@	End line of routine body
@END_COL@	End column of routine body
decl, entry, exit, abort only (C++):	
@RTTI@	Dynamic routine name (class/member function templates)
init only (C/C++):	
@ARGC@	Name of first paramater to main()
@ARGV@	Name of second parameter to main()

Example

- Print a message at each routine entry stating
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  - how often it has been called so far
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Specification

```
decl  file="foo_*" code="static int count=0;"
entry file="foo_*"
      code="printf(\"@ROUTINE@ called %d times\\n\",
            ++count);"
```

Language issues

- Rules often need to be restricted to a particular language
  - All rules accept an optional `lang="..."` clause
  - Argument: comma-separated list of language names (“`c`”, “`c++`”, “`fortran`”)

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- Fortran issues
  - Line-length limit
  - Different line continuation syntax for free-/fixed-form
- C++ issues
  - Template support
    - Solvable for member function templates through RTTI
    - Information returned is implementation-dependent
    - For non-members, only generic template prototype available
  - Exception support
    - Needs to be (partially) handled by the user’s code

Evaluation

Usability evaluated using three different performance-analysis toolsets

- Scalasca
  - Documented user API uses macros and __FILE__/__LINE__
  - Lower-level API needs to be used
  - Requires `line`, `decl`, `entry` and `exit` constructs

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- VampirTrace
  - API very similar to Scalasca
  - Only minor modifications required

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- VampirTrace
  - API very similar to Scalasca
  - Only minor modifications required
- TAU
  - Far more challenging
  - Use of all provided constructs required
  - Two minor differences remaining
    - Default function grouping for C/C++
    - Slightly different semantics for C++ templates

Current status

- Instrumentor available as part of the PDT distribution
- Supported by Scalasca as optional component on most platforms
  - Configure Scalasca using

    ```
    --with-pdt=<DIR>
    ```
  - Instrument your code using

    ```
    scalasca -instrument -comp=none -pdt <compile_cmd>
    ```
  - Optionally provide filter using

    ```
    -optTauSelectFile=<filter_file>
    ```
- Language-specific issues still work in progress

Lessons learned

- Writing a configurable instrumenter is possible!
  - Can leverage existing technologies
  - Keyword substitution provides enough information for existing instrumentation APIs
    - New keywords can be added if needed
- Usage by existing tool compiler wrappers is no big deal either

Lessons learned

- Writing a configurable instrumenter is possible!
  - Can leverage existing technologies
  - Keyword substitution provides enough information for existing instrumentation APIs
    - New keywords can be added if needed
- Usage by existing tool compiler wrappers is no big deal either
- However...
  - Combining code specification and definition of what to instrument does not always work
  - Example: loops
    - User: “Instrument loop 2 in routine ‘foo’ ”
    - Tool developer: “Use code snippet ‘...’ to instrument loops”

Binary instrumentation

- Dynamic instrumentation frameworks
  - PIN
  - Dyninst
    - Better portability
    - Also allows static binary rewriting (though x86/x86_64 only)
- Special-purpose binary instrumenters
  - P^nMPI
  - tau_pin / tau_run

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Conclusion I

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Conclusion II

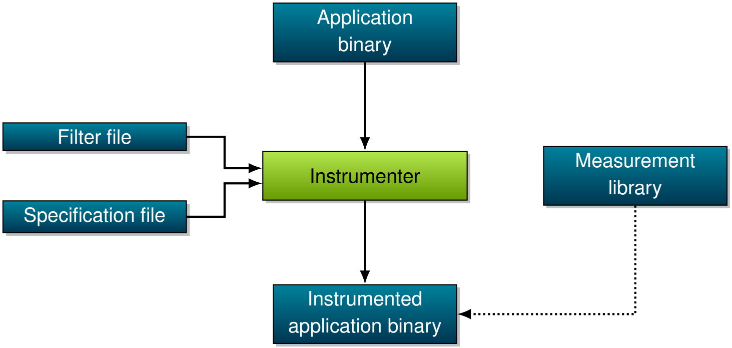
Take the initiative and create one!

- Based on Dyninst with support from UW Madison

Design decisions

- Focus on static binary rewriting
- Prototype new specification language
  - XML-based
  - Fully separate code and filter specifications
- Experiment with property-based filters
  - Number of instructions
  - Lines of Code
  - Cyclomatic complexity
  - Callpaths to MPI/OpenMP only
  - ...

Binary instrumenter workflow



Filter file

- Specifies what to instrument
  - Functions
  - Callsites
  - Loops (as a whole / loop body)
- Allows filtering by
  - Function names
  - Class names
  - Namespaces / Fortran modules
  - Properties
- Supports black- and whitelisting
- Supports boolean operations

Example

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- Use code snippet “func_inst” provided by specification file

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Specification

```
<?xml version="1.0" encoding="UTF-8"?>
<filter name="foo_funcs"
        instrument="functions=func_inst"
        start="none">
  <include>
    <modulenames match="prefix">foo_</modulenames>
  </include>
</filter>
```

Specification file (adapter)

- Provides named code snippets referenced from filter file
  - This is the tool specific part!
  - Uses a C-like syntax
- Allows specification of additional library dependencies
- Can contain special adapter filter to exclude, e.g., functions of a measurement library
- Supports keyword substitution

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Specification

```
<?xml version="1.0" encoding="UTF-8"?>
<instrumentation>
  <dependencies>
    <library name="libc.so" />
  </dependencies>

<!-- continued on next slide -->
```

Example (cont.)

Specification

```
<!-- continued from previous slide -->

  <code name="func_inst">
    <variables>
      <var name="count" type="int" size="4" />
    </variables>
    <init>
      count = 0;
    </init>
    <enter>
      count = count + 1;
      printf(@functionname@);
      printf("called %d times\n", count);
    </enter>
  </code>
</instrumentation>
```

Current status

- Work in progress
  - Any feedback is welcome!
- Evaluation mostly using Scalasca
  - DROPS (C++)
  - Cactus benchmarks PUGH / Carpet (C++)
  - Gadget (C)
- Small proof-of-concept experiments using TAU
- Full integration into Scalasca pending
- Release as a component is planned

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