A configurable binary instrumenter

making use of heuristics to select relevant instrumentation points

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JÜLICH FORSCHUNGSZENTRUM

Presentation outline

Introduction

Instrumentation

Configurable instrumenter

Heuristics to select relevant points

Architecture

Example

Introduction

Student at the RWTH Aachen, Germany

Helmholtz-University Young Investigators Group

“Performance Analysis of Parallel Programs”

Lead by Professor F. Wolf

Located at the “Jülich Supercomputing Center”

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scalasca

Integrated measurement & analysis toolset

- Runtime summarization (aka profiling)
- Automatic event trace analysis

Objective

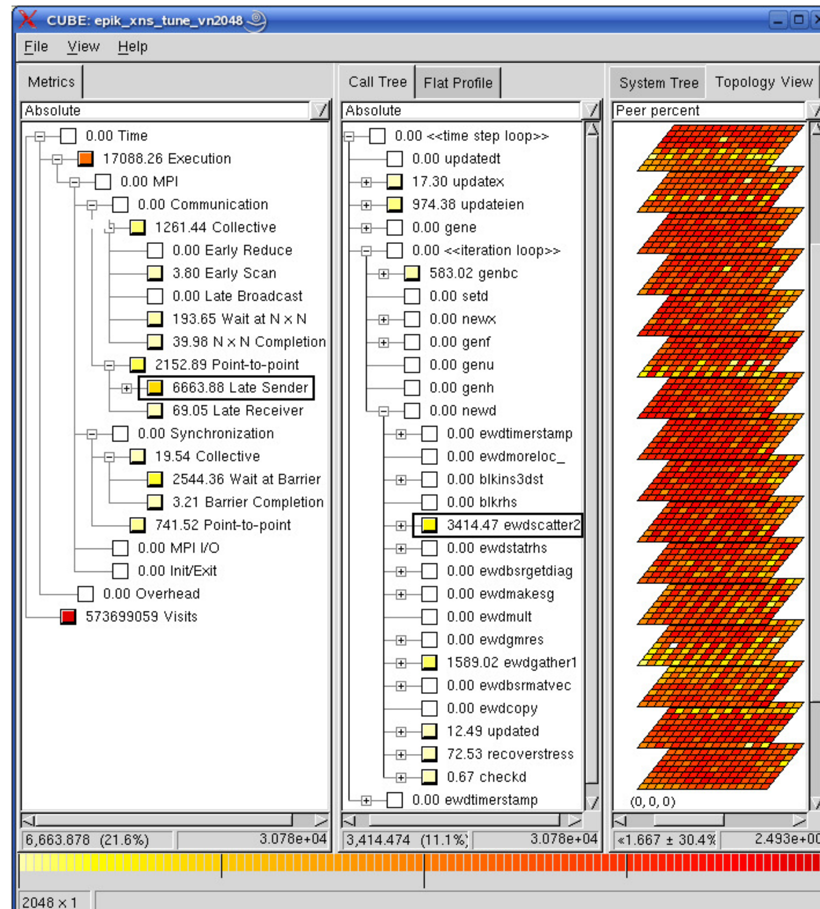
- Development of a **scalable** performance analysis toolset
- Specifically targeting **large-scale** applications

Supports various languages & parallel programming paradigms

- Fortran, C, C++
- MPI, OpenMP & hybrid MPI/OpenMP

More information at:

www.scalasca.org



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Instrumentation

Two ways to gather information

- By direct instrumentation
- By sampling, periodic measurement

Link between program and measurement system

- Trace events during program execution
- Profile to evaluate where time is spent

Possibilities of instrumentation

Source code transformation

- Manually added by user
- Automatically, e.g. TAU, OPARI

Compiler supported

- Wrapper functions
- Adding function calls

Library interposition

- MPI <-> PMPI

Binary instrumentation

- Static, e.g. TAU
- Dynamic, e.g. Paradyn

Static binary instrumentation

Advantages

- Language independent
- Instrumentation of optimized code
- Possible if no source available, e.g. libraries
- Templates are instantiated
- No need to recompile

Disadvantages

- Limited information available
- Not all platforms are supported

Information provided by Dyninst

Method identification

- E.g. Namespace::Class::Method in C++

List of called subroutines in given function

Control flow graph and loop tree

Possibility to access basic blocks

What information is available?

- Depends in part on available symbol table
- Improves when debug information are present
  - Sourcefile and sourceline become available

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Configurable binary instrumenter

Configurable by both the tool provider and user

Tool provider focuses on adapter specification

- Define code for initialization
- Define code for instrumentation
- Includes filter for the measurement system

User starts with provided filter

- Refines the filter to his or her needs

Possible instrumentation points

Functions

- Function enter and exit

Loops

- Before and after the loop
- Loop body enter and exit

Callsites

- Before the function call
- After the return

Filter requirements

Selective binary instrumentation

- Provide a usable default filter
- Allow the user to refine which parts to instrument

Configurable set of instrumentation points

- Filter by function, class and module names
- Filter by properties
- Ability to combine filters

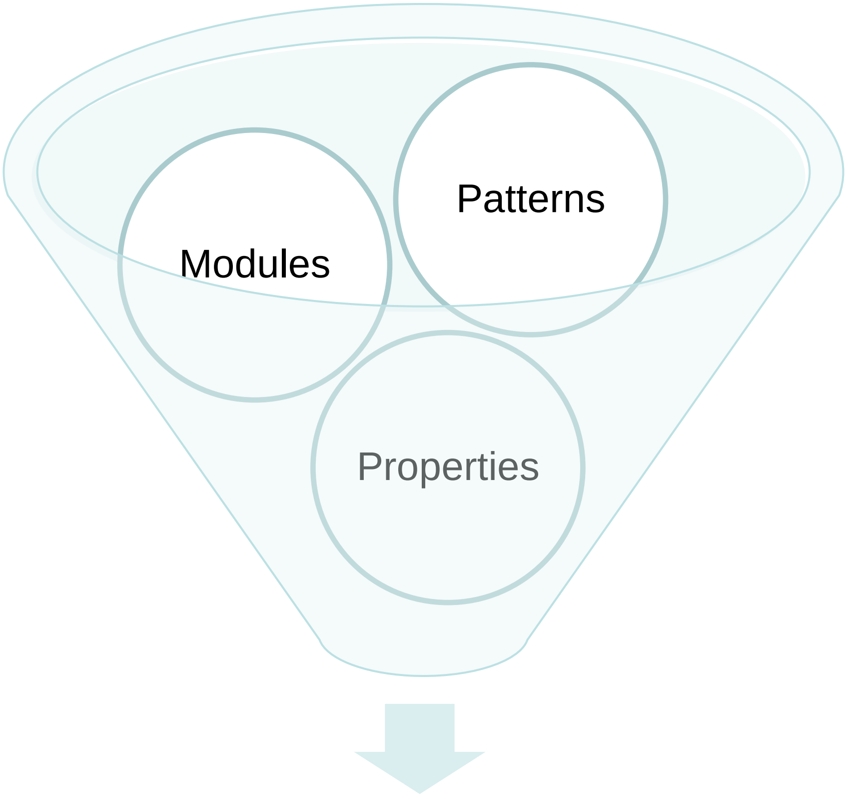
Filter

Start with set of functions

- All
- None

Filter set further using

- String patterns for
  - *Filename (module)*
  - *Namespace, classname*
- Properties
  - *E.g. callgraph, depth*



What to instrument?

Filter specifcation

A single XML document

- Patternlists as plain text for elements taking lists

Filter

- Include or exclude elements containing
  - *„and", „or", „not" and „true" or „false"*
  - *Functions, classes, namespaces, modules*
  - *Property*
- Callsite filter for restricting instrumentation

Filter specification example

```
<filter name="pathtest" instrument="functions=handletest" start="all">
<exclude>
        <or>
                <not>
                        <property name="path">
                                <functionnames match="simple">
                                        MPI*
                                </functionnames>
                        </property>
                </not>
                <functionnames>main</functionnames>
        </or>
</exclude>
</filter>
```

Inserted code

The instrumenter has to support

Additional dependencies (measurement system)

Variable declarations (e.g. region handles)

Code for initialization (run once at startup)

Code to be executed at points

- Enter / exit
- Before / after

Provide access to context information

- @linenumber@, @functionname@,…

Instrumentation specification

Independent XML document

- Include adapter filter

Dependencies

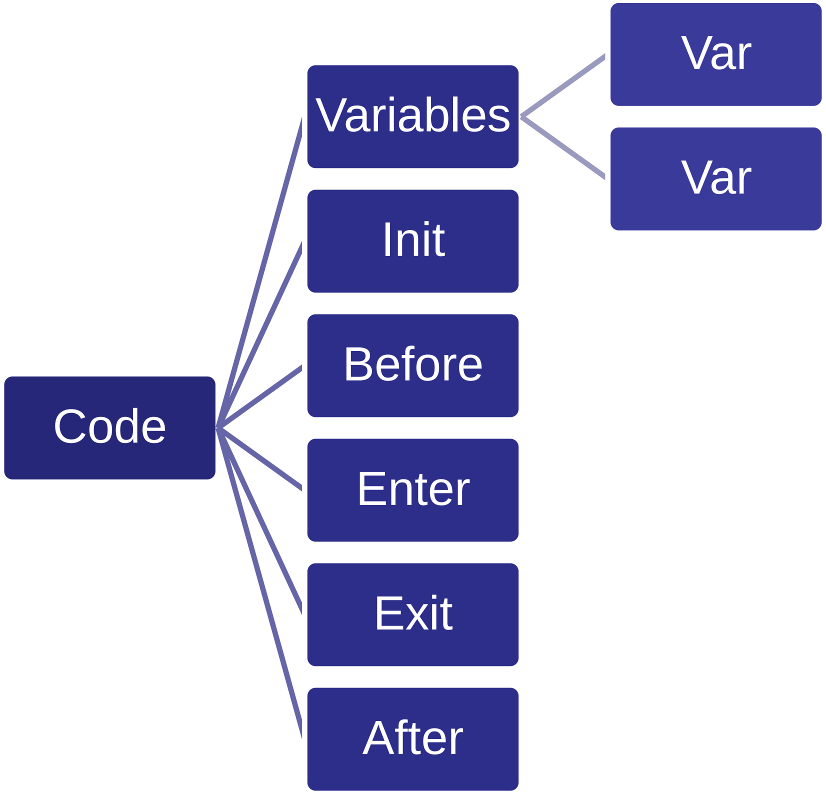
- Add dynamic libraries

Variable element

- Type information
- Memory to allocate

Code in plain text

- C-like syntax



Example specification

```
<code name="handletest">
        <variables>
                <var name="handle" type="void*" size="4" />
        </variables>
        <init>
                initNotify(@functionname@,@linenumber@,@filename@);
                handle = createHandle(@functionname@);
        </init>
        <enter>enterHandle(handle);</enter>
        <exit>exitHandle(handle); </exit>
</code>
```

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Goal

Automatic selection of relevant instrumentation points

How to select instrumentation points

What makes a point relevant?

- Granularity of trace to locate possible problems
- Ability to profile where time is spent

- Communication
- I/O

Is decision possible with available information?

Heuristics using binary code

Aim here: do not instrument short functions

- Instrumentation costs exceed function costs

Complexity of function

- Contains „if" and „loop" statements
- Amount of instructions
- Subroutine calls

Cyclomatic Complexity

- Complexity M = E(dges) – N(odes) + 1

Heuristics using debug information

Lines of code

- May be obscured by comments and code style

Method name hints

- Exclude e.g., helper functions „get*“, „set*“
- Include „do*“ ,“process*“, „calculate*“, or „solve*“

Classname and namespace

Heuristics using callpath

Callpath of functions

- Leads to I/O functions?
- Leads to MPI functions?
- Leads to functions using OpenMP?

Depth of function in call graph

- Instrument only to specified depth

Problem for static callpath construction

- Virtual functions, function pointers

Unevaluated results

CP2K Fortran code with Intel 10 compiler

- 12652 functions (50MB binary)
- Using MPI path reduced to 5194
- Using adapter filter and mpi path 767 remain

GENE Fortran code

- 7095 functions (13MB binary)
- Using adapter filter and MPI path reduced to 3144
- Remove nodes on direct path, leaves 2510 function

BT (NAS Parallel Benchmark)

- Reduced to 27 functions with MPI callpath filter
- More in the example later

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Architecture

Mutatee

- Layer between Dyninst and filter component

Filter

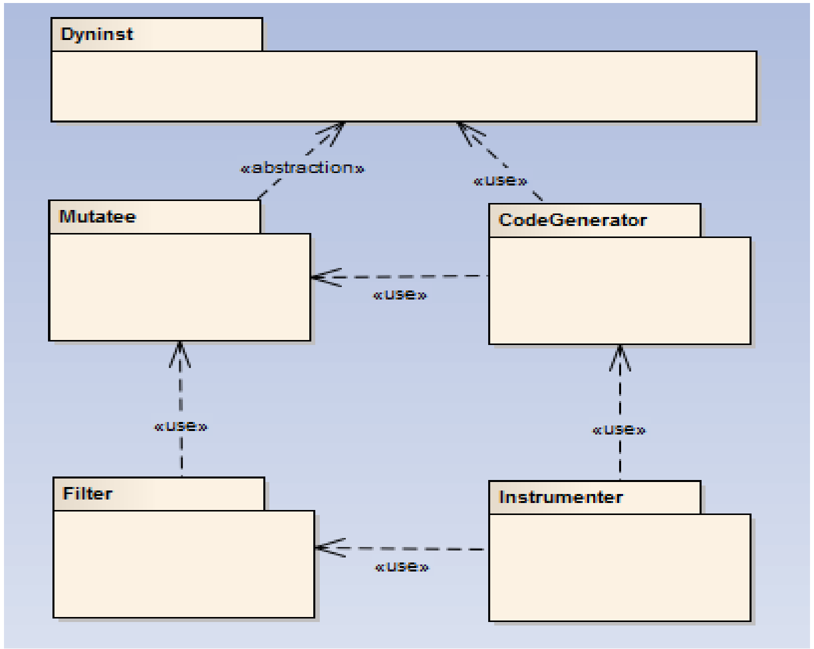
- Responsible for reading filter
- Evaluate filter

CodeGenerator

- Parses code specification
- Generates Dyninst snippets

Instrumenter

- Instruments the filtered set with generated code



Dependencies

Dyninst

Boost

- Spirit – Parser for adapter code
- Regex – Regular expressions in filter
- Tokenizer

Apache Xerces

- XML DOM parser for the adapter and filter files

Open issues

Binaries contain a lot of functions

Compiler-specific functions added

Scalasca does not provide dynamic library

- Need to preinstrument with “skin –comp=none –user”

Future work

Adding more properties

- sourceLines, hasControlStructure, calledInLoop

Evaluate reduction in instrumented functions

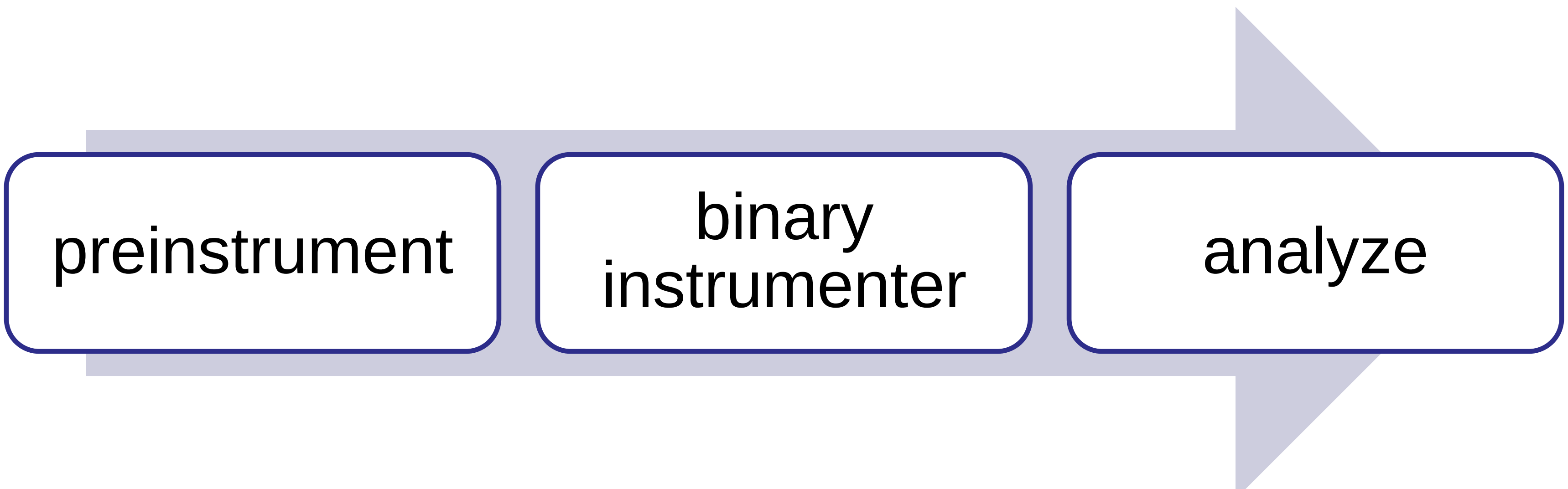
- Instrument benchmarks
- Instrument sample application

Evaluate advantage over filtering at runtime

Evaluate advantage of instrumenting optimized code

Example

Instrumenting NAS Parallel Benchmark BT



skin = scalasca –instrument –comp=none –user
scan = scalasca –analyze mpirun –n 4 ./mutated