A configurable binary instrumenter

making use of heuristics to select relevant instrumentation points

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Presentation outline

Introduction
Instrumentation
Configurable instrumenter
Heuristics to select relevant points
Architecture
Example
Introduction

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Helmholtz-University Young Investigators Group
“Performance Analysis of Parallel Programs”
Lead by Professor F. Wolf

Located at the “Jülich Supercomputing Center”
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
Presentation outline

Introduction

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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 specification

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=handlestest" 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 $M = E(\text{edges}) - N(\text{nodes}) + 1$
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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Mutatee
  - Layer between Dyninst and filter component

Filter
  - Responsible for reading filter
  - Evaluate filter

CodeGenGenerator
  - 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

```text
skin = scalasca -instrument -comp=none -user
scan = scalasca -analyze mpirun -n 4 ./mutated
```