ROSE Compiler Infrastructure
Source-to-Source Analysis and Optimization

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Overview

- **ROSE Compiler Infrastructure**
- **Research Objectives**
  - General Optimization of existing applications
  - Optimization of High-Level Abstractions
    - Telescoping Language
    - Plus/Minus Languages
    - Many other names for this
  - Empirical Optimization
- Targets non-compiler audience
- Emphasis on whole program capabilities
- Open Source (EDG part as binary)
- Conclusions
Motivation for Compiler Based Tools

- Current Status:
  - DOE generates huge amounts of software
  - ROSE provides a mechanism to automatically read, analyze, and fully rewrite ASC scale software in C, C++ (and eventually F90 as part of collaboration with Rice, we hope).

- ROSE Project focus IS on *optimization*

But a lot of tools could be built …,

Simple tools can only discover superficial things about software, to really know what is going on in an application you need a compiler infrastructure.
ROSE Source-to-Source Approach

- **ROSE Translator acts just like the vendor compiler**
- **Replaces compiler in application’s Makefile**
ROSE Project

- Software analysis and optimization for scientific applications
- Tool for building source-to-source translators
- Support for C and C++
- F90 in development
- Loop optimizations
- Lab and academic use
- Software engineering
- Performance analysis
- Domain-specific analysis
- Development of new optimization approaches
- Optimization of object-oriented abstractions
Program Analysis and Optimization

- Program Analysis (most are from Qing + contributions from students)
  - Call graph
    - Resolution of function pointers
    - Resolution of Virtual functions
    - Resolution of pointers to virtual functions
  - Dependence (procedural)
  - Control Flow (working on inter-procedural case)
  - Slicing (inter-procedural)
  - Partial Redundancy Elimination (PRE)
  - Connection to Open Analysis (work with ANL)

- Optimizations
  - Loop Optimization (Qing Yi)
    - Loop fusion, fission, blocking, unrolling, array copy, etc.
    - inlining and outlining
  - Annotation Based Optimizations
  - Custom optimizations
    - Define your own optimization (high level or low level)
Automated Recognition
(Library Abstractions and other things)

int main() {
  Range I(1,98,1), J(1,98,1);
  doubleArray A(100,100);
  doubleArray B(100,100);

  A(I,J) = B(I+1,J) + B(I-1,J) + B(I,J+1) + B(I,J-1);
  return 0;
}

Even performance information is in the AST (HPC Toolkit, RICE)
ROSE Whole Application Analysis

Three Separate source files (ASTs)

Supports Whole Program Analysis (Alternative to SQLite Interface)

• Shares AST nodes
• Preserves simplicity
• Preserves all analysis info
• Simple tools work on whole ASC applications
• Supports hundreds of source files
• Supports million line applications

Merged ASTs save space and permit whole ASC scale application analysis
Large-Scale Application Support

- Call Graph Analysis
- Scaling up existing analysis
Automated Generation of Symbolic Equations for building Application Models

// Count-controlled loop complexity:
// 19+13*loop_expression0x8217f78+4*loop_expression0x8217f78^2+
// 19*loop_expression0x8217fa0+10*loop_expression0x8217fa0^2
int foobar( int bound1, int bound2 )
{
  for (int i = 0; i < bound1; i++)
  {
    array[i] = 0;
    for (int j = 0; j < bound1; j++)
    {
      x = 0;
    }
  }
  for (int i = 0; i < bound2; i++)
  {
    array[i] = array[i -1] + array[i+1];
    for (int j = 0; j < bound2; j++)
    {
      x = 0;
    }
  }
  return x;
}

// Count-controlled loop complexity:
// 8+13*loop_expression0x8217 f78^3+4*loop_expression0x8217f78^4+
int main()
{
  for (int i = 0; i < bound; i++)
  {
    array[i] = 0;
    for (int j = 0; j < bound; j++)
    {
      x = foobar( bound,bound );
    }
  }
  return 0;
}
Unparsed Example

Preserves formatting, comments, and preprocessor control structure
Interactions with Others

• DOE Laboratories:
  • LLNL (A-Div (Kull), B-Div (IRS), Mark Graff, TSTT, Overture, Babel)
  • ANL (Paul Hovland)
  • ORNL

• DOE Research Programs:
  • PERC (SLAC, TSTT, C/C++ Optimization, UT, ANL, Dyninst Binary Rewriting)

• Collaborations:
  • IBM Haifa (Shmuel Ur)
  • Texas A&M (Lawrence Rauchwerger, Bjarne Stroustrup)
  • Rice University (Ken Kennedy, John Mellnor-Crummey)
  • Vienna University of Technology (Markus Schordan)
  • University of Tennessee (Jack Dongarra’s group)
  • Cornell University (Sally McKee, Brian White)
  • Indiana University (Andrew Lumsdaine, Jeremiah Willcock)
  • University of California at Berkeley (UPC, Kathy Yelick)
  • University of Oslo (Hans, Andreas, Are)
  • University of Maryland (Jeff Hollingsworth, Chadd Williams)
  • Friedrich-Alexander-University Erlangen-Nuremberg (Markus Kowarschik, Nils Thurey)
  • University of Texas at Austin (Calvin Lin)
  • USCD (Scott Baden)
  • London Imperial College (Olav Beckman, Paul Kelly)
  • UC Davis (Su, Bishop)