Source-to-source transformations

Supporting tools and infrastructure

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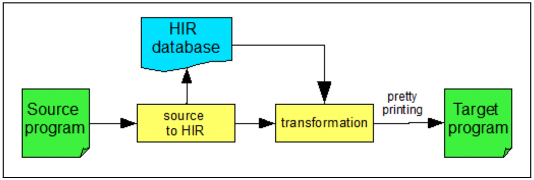
Source-to-source transformation (1)

- By the term “source-to-source transformation” we refer to any mechanism that when applied to a SOURCE program, a functionally equivalent TARGET program is produced
- Basic assumptions
  - SOURCE and TARGET programs submit to the same programming language semantics
  - A “database” of the source program is generated by translating to a form of high-level intermediate representation (HIR)
  - The target program is produced by pretty-printing the HIR view of the source program
- Secondary assumptions
  - Structural information (e.g. program layout, line numbers) may not be preserved when translating to the HIR form

Source-to-source transformation (2)

- Potential uses of source-to-source (also termed as "source-level") transformations
  - Algebraic and other simplifications (e.g. matrix flattening)
  - Data access improvements for enhancing data locality
  - Enforcing the use of a data memory hierarchy (data reuse transformations)
  - Conversion to a standard (canonicalized) form
  - Enabling the application of lower level transformations (closer to the underlying machine model)
- High-level view of the source-to-source translation process



Pragmatics of a source-to-source transformation framework

- Useful software facilities for implementing a source-to-source transformation framework
  - AST builder and walker
  - AST/HIR query engine
  - Semantics checker and/or HIR validator
  - AST2HIR and HIR2AST modules
  - ☞ In general, comprehensive frontend facilities would be extremely useful to build upon

An overview of tools and infrastructure

- Existing software systems
  - The C-to-C source code translator (ftp://theory.lcs.mit.edu/pub/c2c/), now defunct
  - Memphis tree builder and walker tool (http://memphis.compilertools.net/index.html)
  - EDG C/C++ frontend (http://www.edg.com)
  - TXL (http://www.txl.ca)
  - The Cetus project (http://cetus.ecn.purdue.edu/)
  - ROSE compiler infrastructure (http://www.rosecompiler.org)
- ...or "Roll Your Own" system/infrastructure
  - Based on extensible text transformation technology: XML + XSLT (http://www.w3.org/2001/XMLSchema)
  - Adapt to exactly fit your needs

The C-to-C MIT source code translation tool

- Features
  - AST building and type checking from ANSI C
  - Data flow analysis on the AST
  - MIT license
- Cons
  - Relatively few built-in transformations
  - Further development has ceased
  - Distribution site now defunct (as of late 2005)
- Suggestions
  - Lack of features and support prevent C2C from being a reliable infrastructure

Memphis

- Characteristics and features
  - Intended audience are compiler writers
  - Provides basic mechanisms for rule-based tree transformations
  - Works well with Lex and Yacc
  - Memphis personal license + GPL
- Cons
  - Lack of a ready-to-use C grammar
  - No real world examples
  - Largely unknown to the community
  - Development site ceased (`http://www.combo.org`)
- Suggestions
  - Infrastructure is only minimal and not really useful for any practical use

EDG C/C++ frontend

- Features
  - Mature and complete C/C++ frontend
  - Covers the entire C99 and latest C++ standards
  - AST construction and a rich set of related data structures
  - Extensive documentation ($\sim$ 600 pages)
  - Actively supported by a company (Edison Design Group)
  - Proprietary open-source license; free for academic research
- Cons
  - Developing user tools requires a significant time investment
  - No API (which would simplify the development of extensions and plugins)
- Suggestions
  - Viable choice in case infrastructure development time is more or less irrelevant

TXL

- Features
  - TXL is a functional programming language mainly used for domain-specific language development
  - Language primitives for specifying tree rewriting rules
  - Comes with many frontends (C, C++, Java, Modula-2/3, etc)
  - Has been used in production environments (source code transformations for eliminating patterns of code arising Y2K problems)
- Cons
  - Development seems to be steered by a single person; no real community being able to contribute
  - TXL is a narrow-scope language
  - No previous experience with TXL
- Suggestions
  - Viable choice only if the source transformations involved could be easily specified by bare bones term rewriting

Cetus

- Features
  - Source-to-source C compiler written in Java
  - Extensive set of compiler passes working on a high-level IR
  - Supports parallelization techniques
  - Analyses and transformations
    - Data dependence analysis
    - Loop parallelizer
    - Source program canonicalization
    - Loop outlining (procedural abstraction of loops)
- Modified Artistic License
- Cons
  - Depending on external tools (Java libraries, ANTLR)
  - Very small (nonexistent?) community outside Purdue Univ.
- Suggestions
  - The scope of this infrastructure seems appropriate
  - Focuses on parallelism extraction for OpenMP and not loop restructuring transformations suitable for other purposes

ROSE

- Features
  - A C++ tool for building source-to-source translators
  - Support for C, C99, UPC, C++, Fortran 77-90/95-2003
  - Builds upon the EDG frontend (included)
  - Under active development
  - Analyses and transformations
    - AST construction, traversal and querying, CFG construction, data flow analyses
    - Predefined loop optimizations: loop interchange, loop fusion, loop fission, loop splitting, loop unrolling
  - Revised BSD license
- Cons
  - External dependencies (Java, compiled version of Boost)
  - It is unclear whether there is an active community yet
- Suggestions
  - Scope and purpose of this infrastructure seem appropriate
  - Heavy work for an EDG-based ecosystem already done

Custom text transformation engine based on XML

- Features
  - XML is a well-established and mature technology
  - Provides the means for specifying your own text manipulation and transformation primitives
  - Vast community of developers and users
- Cons
  - Development of the infrastructure: constructors, traversals, querying mechanisms, pretty-printers, dumping to debugging formats, fundamental analyses and transformations
  - Development effort cannot be easily estimated
- Suggestions
  - XML is a tool for serious work given that the development project is closely managed in respect to timeframes and human resources

Conclusion

- There exist viable solutions for creating a source-to-source translation tool fitting our needs
  - EDG: roll your own analyses and transformations
  - XML: roll your own and customize to your specific needs
  - ROSE: open and extensible infrastructure based on the EDG frontend
- The choice of one of these solutions requires taking into account subjective factors such as:
  - Communication of ideas, concepts and results to and from other parties involved
  - Extensibility of the infrastructure
  - Preexisting knowledge
  - Personal preference

References I

- TXL homepage. http://www.txl.ca
- Memphis tree builder and walker.
  http://memphis.compilertools.net/index.html
- The C-to-C source code translator.
  ftp://theory.lcs.mit.edu/pub/c2c/
- The EDG C/C++ frontend. http://www.edg.com
- The Cetus project. http://cetus.ecn.purdue.edu
- ROSE: A tool for building source-to-source translators.
  http://www.rosecompiler.org

Revision history

v0.1 (30/03/2009): Initial version