TDDB29 Compilers and Interpreters
TDDB44 Compiler Construction

Compiler Frameworks

A (non-exhaustive) survey

with a focus on open-source frameworks

Christoph Kessler, IDA,
Linköpings universitet, 2007.

LCC (Little C Compiler)

- Dragon-book style C compiler implementation in C
- Very small (20K Loc), well documented, well tested, widely used
- Open source: http://www.cs.princeton.edu/software/lcc
- Textbook *A retargetable C compiler* [Fraser, Hanson 1995] contains complete source code
- One-pass compiler, fast
- C frontend (hand-crafted scanner and recursive descent parser) with own C preprocessor
- Low-level IR
  - Basic-block graph containing DAGs of quadruples
  - No AST
- Interface to IBURG code generator generator
  - Example code generators for MIPS, SPARC, Alpha, x86 processors
  - Tree pattern matching + dynamic programming
- Few optimizations only
  - local common subexpr. elimination, constant folding
- Good choice for source-to-target compiling if a prototype is needed soon

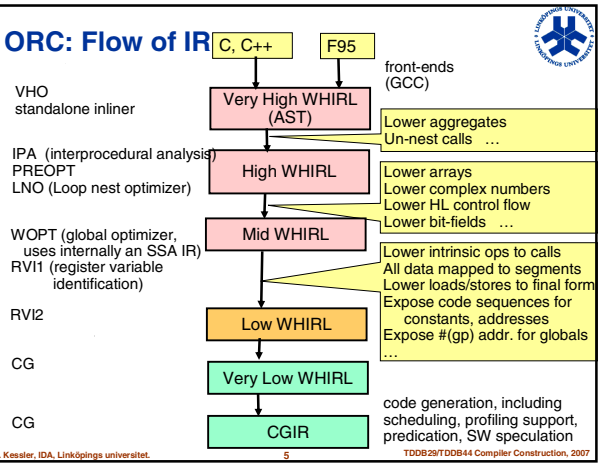
GCC 4.x

- Gnu Compiler Collection (earlier: Gnu C Compiler)
- Compilers for C, C++, Fortran, Java, Objective-C, Ada …
  - sometimes with own extensions, e.g. Gnu-C
- Open-source, developed since 1985
- Very large
- 3 IR formats (all language independent)
  - GENERIC: tree representation for whole function (also statements)
  - GIMPLE (simple version of GENERIC for optimizations) based on trees but expressions in quadruple form. High-level, low-level and SSA-low-level form.
  - RTL (Register Transfer Language, low-level, Lisp-like) (the traditional GCC-IR) only word-sized data types; stack explicit; statement scope
- Many optimizations
- Many target architectures
- Version 4.x (since ~2004) has strong support for retargetable code generation
  - Machine description in .md file
  - Reservation tables for instruction scheduler generation
- Good choice if one has the time to get into the framework

Open64 / ORC Open Research Compiler

- Based on SGI Pro-64 Compiler for MIPS processor, written in C++, went open source in 2000
- Several tracks of development (Open64, ORC, …)
- For Intel Itanium (IA-64) and x86 (IA-32) processors. Also retargeted to x86-64, Ceva DSP, Tensilica, XScale, ARM … "simple to retarget" (?)
- Languages: C, C++, Fortran95 (uses GCC as frontend), OpenMP and UPC (for parallel programming)
- Industrial strength, with contributions from Intel, Pathscale, …
- Open source: www.open64.net, ipf-orc.sourceforge.net
- 6-layer IR:
  - WHIRL (VH, H, M, L, VL) – 5 levels of abstraction
    - All levels semantically equivalent
    - Each level a lower level subset of the higher form
  - and target-specific very low-level CGIR

ORC: Flow of IR



Open64 / ORC Open Research Compiler

- Multi-level IR
  - translation by lowering
  - ☺ Analysis / Optimization engines can work on the most appropriate level of abstraction
  - ☺ Clean separation of compiler phases
  - ☹ Framework gets larger and slower
- Many optimizations, many third-party contributed components

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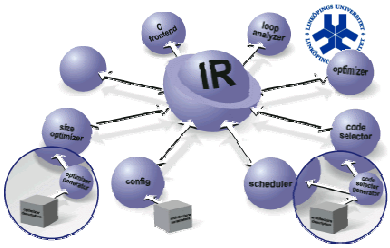
CoSy



A commercial compiler framework

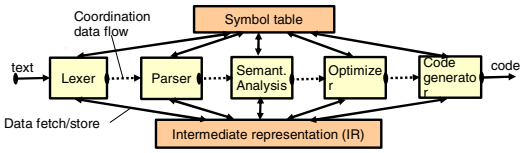
www.ace.nl

Christoph Kessler, IDA,
Linköpings universitet, 2007.

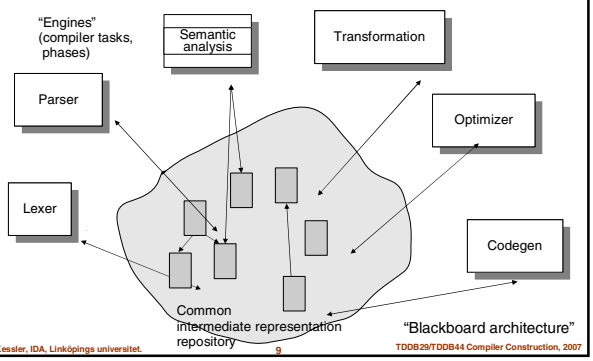
Traditional Compiler Structure

- Traditional compiler model: sequential process

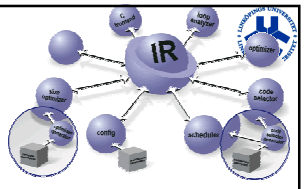
- Improvement: Pipelining
  (by files/modules, classes, functions)
- More modern compiler model with shared symbol table and IR:



A CoSy Compiler with Repository-Architecture



Engine



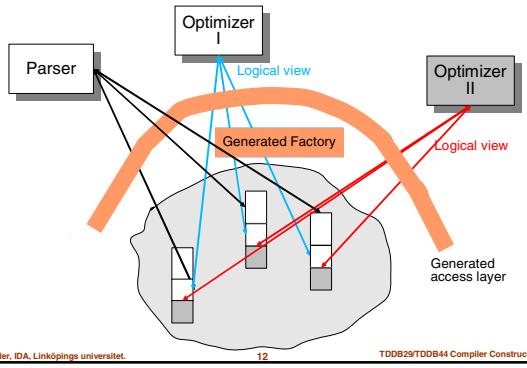
- Modular compiler building block
- Performs a well-defined task
- Focus on algorithms, not compiler configuration
- Parameters are handles on the underlying common IR repository
- Execution may be in a separate process or as subroutine call -
  the engine writer does not know!
- View of an engine class:
  the part of the common IR repository that it can access
  (scope set by access rights: read, write, create)
- Examples: Analyzers, Lowerers, Optimizers, Translators, Support

Composite Engines in CoSy

- Built from simple engines or from other composite engines
  by combining engines in interaction schemes
  (Loop, Pipeline, Fork, Parallel, Speculative, ...)
- Described in EDL (Engine Description Language)
- View defined by the joint effect of constituent engines
- A compiler is nothing more than a large composite engine

```
ENGINE CLASS compiler (IN u: mirUNIT) {
   PIPELINE
      frontend (u)
      optimizer (u)
      backend (u)
}
```


A CoSy Compiler



Example for CoSy EDL (Engine Description Language)

- Component classes (engine class)
- Component instances (engines)
- Basic components are implemented in C
- Interaction schemes (cf. skeletons) form complex connectors
  - SEQUENTIAL
  - PIPELINE
  - DATAPARALLEL
  - SPECULATIVE
- EDL can embed automatically
  - Single-call-components into pipes
  - p<> means a stream of p-items
  - EDL can map their protocols to each other (p vs p<>)

```
ENGINE CLASS optimizer ( procedure p )
{
    ControlFlowAnalyser cfa;
    CommonSubExprEliminator cse;
    LoopVariableSimplifier lvs;
    PIPELINE cfa(p); cse(p); lvs(p);
}

ENGINE CLASS compiler ( file f )
{   ....
    Token token;
    Module m;
    PIPELINE  // lexer takes file, delivers token stream:
              lexer( IN f, OUT token<> );
              // Parser delivers a module
              parser( IN token<>, OUT m );
              sema( m );
              decompose( m, p<> );
              // here comes a stream of procedures
              // from the module
              optimizer( p<> );
              backend( p<> );
}
```


Evaluation of CoSy

- The outer call layers of the compiler are generated from view description specifications
  - Adapter, coordination, communication, encapsulation
  - Sequential and parallel implementation can be exchanged
  - There is also a non-commercial prototype [Martin Alt: *On Parallel Compilation.* PhD thesis, 1997, Univ. Saarbrücken]
- Access layer to the repository must be efficient (solved by generation of macros)
- Because of views, a CoSy-compiler is very simply extensible
  - That's why it is expensive
  - Reconfiguration of a compiler within an hour

More frameworks…

- **LLVM** (Univ. of Illinois at Urbana Champaign)
  - llvm.org
  - ”Low-level virtual machine”, IR
  - compiles to several target platforms: x86, Itanium, ARM, Alpha, SPARC
  - Open source
- **Cetus**
  - http://cobweb.ecn.purdue.edu/ParaMount/Cetus/
  - C/C++ source-to-source compiler written in Java.
  - Open source
- **Tools and generators**
  - TXL source-to-source transformation system
  - ANTLR frontend generator

More frameworks…

- **Some influential frameworks of the 1990s:**
  - **SUIF** Stanford university intermediate format, suif.stanford.edu
  - **Trimaran** (for instruction-level parallel processors) www.trimaran.org
  - **Polaris** (Fortran) UIUC
  - GMD Toolbox / Cocolab **Cocktail**™ compiler generation tool suite
  - and many others …
- And many more for the embedded domain …

The End (?)

”Now this is not the end.
It is not even the beginning of the end.
But it is, perhaps, the end of the beginning.”
- *W. Churchill*

- Do you like compiler technology? Learn more?
  - TDDC86 Compiler optimizations and code generation 6hp
  - TDDC18 Component-based software 4.5hp
  - Thesis project at PELAB, 30 hp