Course introduction

Advanced Compiler Construction
Michel Schinz – 2010-02-26

General information

Course goal

The goal of this course is to teach you:

1. how to compile high-level functional and object-oriented programming languages,
2. how to optimize the generated code, and
3. how to support code execution at run time.

To achieve these goals, the course is roughly split in three parts of unequal length:

1. a part covering the compilation of high-level concepts (closures, continuations, etc.),
2. a part covering intermediate languages and optimizations,
3. a part covering virtual machines and garbage collection.

Evaluation

The grade will be based on three aspects:

- several group projects, to be completed in groups of at most two people
- one individual project, to be completed alone,
- an individual oral exam.

Warning: the course is evaluated during the semester, which has two important consequences:

- there is no retake exam,
- the oral exam will take place during the last week of the semester, not during the official exam period.

Grading scheme

The final grade will be based on your results in:

- the various project parts, spread over 10 weeks, which contribute to 80% of the grade – 8% per week,
- the final exam, which contributes to 20% of the grade.

Resources

Lecturer:
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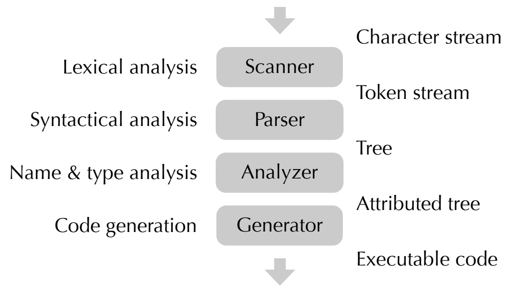
Web page:
  `http://tinyurl.com/acc2010`
Moodle site:
  `http://tinyurl.com/acc2010m`
  (enrolment key: `ACC`)

Course overview

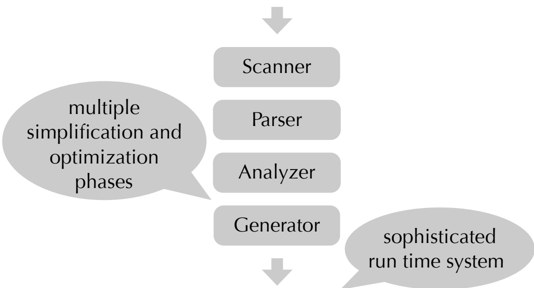
What is a compiler?

Your current view of a compiler must be something like this:



What is a compiler, really?

Real compilers are often more complicated…



Additional phases

Simplification phases transform the program so that complex concepts of the language – pattern matching, anonymous functions, etc. – are translated using simpler ones.

Optimization phases transform the program so that it hopefully makes better use of some resource – e.g. CPU cycles, memory, etc.

Of course, all these phases must preserve the meaning of the original program!

Simplification phases

Example of a simplification phase: Java compilers have a phase that transforms nested classes to top-level ones.

```
class Out {
  void f1() { }
  class In {
    void f2() {
      f1();
    }
  }
}
```

```
class Out {
  void f1() { }
}
class Out$In {
  final Out this$0;
  Out$In(Out o) {
    this$0 = o;
  }
  void f2() {
    this$0.f1();
  }
}
```


Optimization phases

Example of an optimization phase: Java compilers optimize expressions involving constant values. That includes removing **dead code**, i.e. code that can never be executed.

```
class C {
  public final static boolean debug = !true;
  int f() {
    if (debug) {
      System.out.println("C.f() called");
    }
    return 10;
  }
}
```

dead code, removed during compilation

Intermediate representations

To manipulate the program, simplification and optimization phases must represent it in some way.

One possibility is to use the representation produced by the parser – the abstract syntax tree (AST).

The AST is perfectly suited to certain tasks, but other **intermediate representations** (**IR**) exist and are more appropriate in some situations.

Intermediate representations

Many intermediate representations have been used in compilers. They can be differentiated according to several criteria:

- imperative (i.e. with a notion of mutable variables) or functional,
- typed or untyped,
- structured as a control-flow graph (CFG), or as an abstract syntax tree,
- lazy or strict,
- etc.

We will look at several popular example in the course.

Run time system

Implementing a high-level programming language usually means more than just writing a compiler!

A complete **run time system** (**RTS**) must be written, to assist the execution of compiled programs by providing various services like memory management, threads, etc.

For example, the Java Virtual Machine is the run time system for Java, Scala, Groovy and many other programming languages. It handles (lazy) class loading, byte-code verification and interpretation, just-in-time compilation, threading, garbage collection, etc. and provides a debugging interface.

A good Java Virtual Machine is actually more complex than a Java compiler!

Memory management

Most modern programming languages offer **automatic memory management**: the programmer allocates memory explicitly, but deallocation is performed automatically.

The deallocation of memory is usually performed by a part of the run time system called the **garbage collector** (**GC**).

A garbage collector periodically frees all memory that has been allocated by the program but is not reachable anymore.

Virtual machines

Instead of targeting a real processor, a compiler can target a virtual one, usually called a **virtual machine** (**VM**). The produced code is then interpreted by a program emulating the virtual machine.

Virtual machines have many advantages:

- the compiler can target a single, usually high-level architecture,
- the program can easily be monitored during execution, e.g. to prevent malicious behavior, or provide debugging facilities,
- the distribution of compiled code is easier.

The main (only?) disadvantage of virtual machines is their speed: it is always slower to interpret a program in software than to execute it directly in hardware.

Dynamic (JIT) compilation

To make virtual machines faster, **dynamic**, or **just-in-time** (**JIT**) compilation was invented.

The idea is simple: Instead of interpreting a piece of code, the virtual machine translates it to machine code, and hands that code to the processor for execution.

This is usually faster than interpretation.

Summary

Compilers for high-level languages are more complex than the ones you've studied, since:

- they must translate high-level concepts like pattern-matching, anonymous functions, etc. to lower-level equivalents,
- they must be accompanied by a sophisticated run time system, and
- they should produced optimized code.

This course will be focused on these aspects of compilers and run time systems.