Course introduction

Advanced Compiler Construction
Michel Schinz – 2025–02–20

General information

Course goals

The goal of this course is to teach you:

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

To achieve this, the course is split in three parts:

1. compilation of high-level concepts (e.g. closures),
2. intermediate languages and optimizations,
3. virtual machines and garbage collection.

Prerequisite skills

To complete the project successfully, you need:

- good knowledge of functional programming, ideally in Scala,
- good knowledge of (relatively) low-level programming in C.

Beware: acquiring these skills during the course can be challenging.

Evaluation

Element	Points
P1: conversion to CPS	80
P2: values representation	40
P3: closure conversion	80
P4: optimization	100
P5: garbage collector	100
Oral exam	100
Total	500

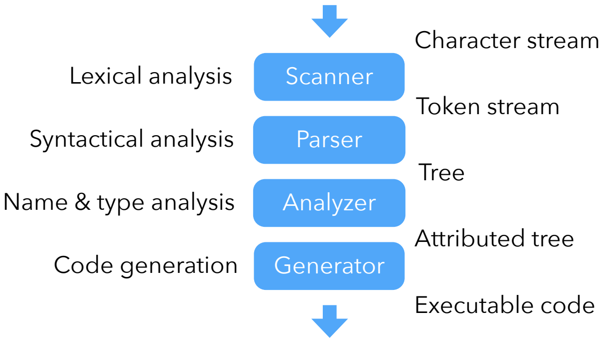
Resources

Lecturer:
Michel Schinz
Assistants:
Alexandre Pinazza, Marcin Wojnarowski
Web page:
`https://cs420.epfl.ch`
Forum:
`https://edstem.org/eu/courses/1949/discussion`

Course overview

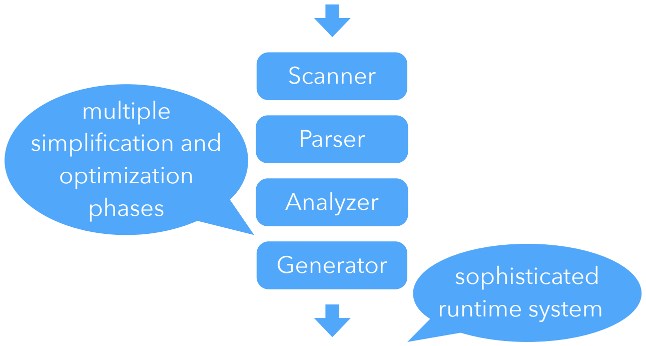
What is a compiler?

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



What is a compiler, really?

Real compilers are often more complicated…


Scanner
Parser
Analyzer
Generator
multiple simplification and optimization phases
sophisticated runtime system

Additional phases

Simplification (or **lowering**) **phases**
translate complex concepts of the language (e.g. pattern matching) into simpler ones.

Optimization phases
try to improve the program's usage of some resource (e.g. CPU time, memory).

Simplification phases

Example of a simplification phase in Java compilers: transformation of nested classes into 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 in Java compilers: removal of **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. Options:

- use the abstract syntax tree (AST),
- use another **intermediate representation** (**IR**).

Sophisticated compilers usually use several different IRs.

Run time system

Apart from the compiler, a complete **run time system** (**RTS**) must be written, to provide various services to executing programs, like:

- code loading and linking,
- code interpretation, compilation and optimization,
- memory management (garbage collection),
- concurrency,
- etc.

That's a lot, and Java RTSs, for example, are often more complex than Java compilers!

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 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 produce optimized code.

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