Course introduction

Advanced Compiler Construction

Michel Schinz – 2022–02–24

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:

- excellent 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

The grade will be based on three aspects:

1. several group projects, to be completed in groups of at most two people,
2. an individual oral exam.

Note: 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 11 weeks, which contribute to 80% of the grade,
- the final exam, which contributes to 20% of the grade.

Resources

Lecturer:

Michel Schinz

Assistant:

Carlo Refice

Web page:

`https://cs420.epfl.ch`

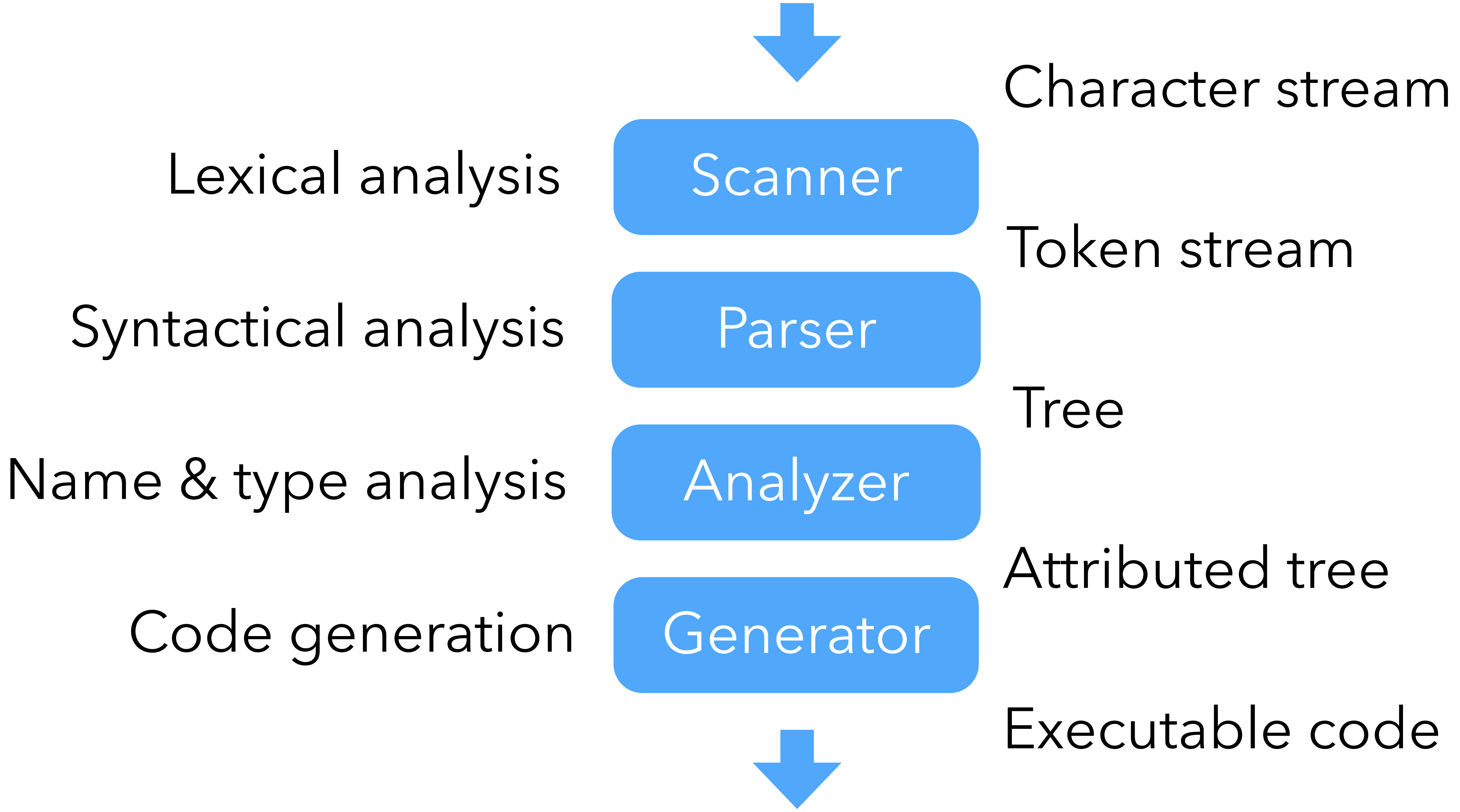
Forum:

`piazza.com/epfl.ch/spring2022/cs420`

Course overview

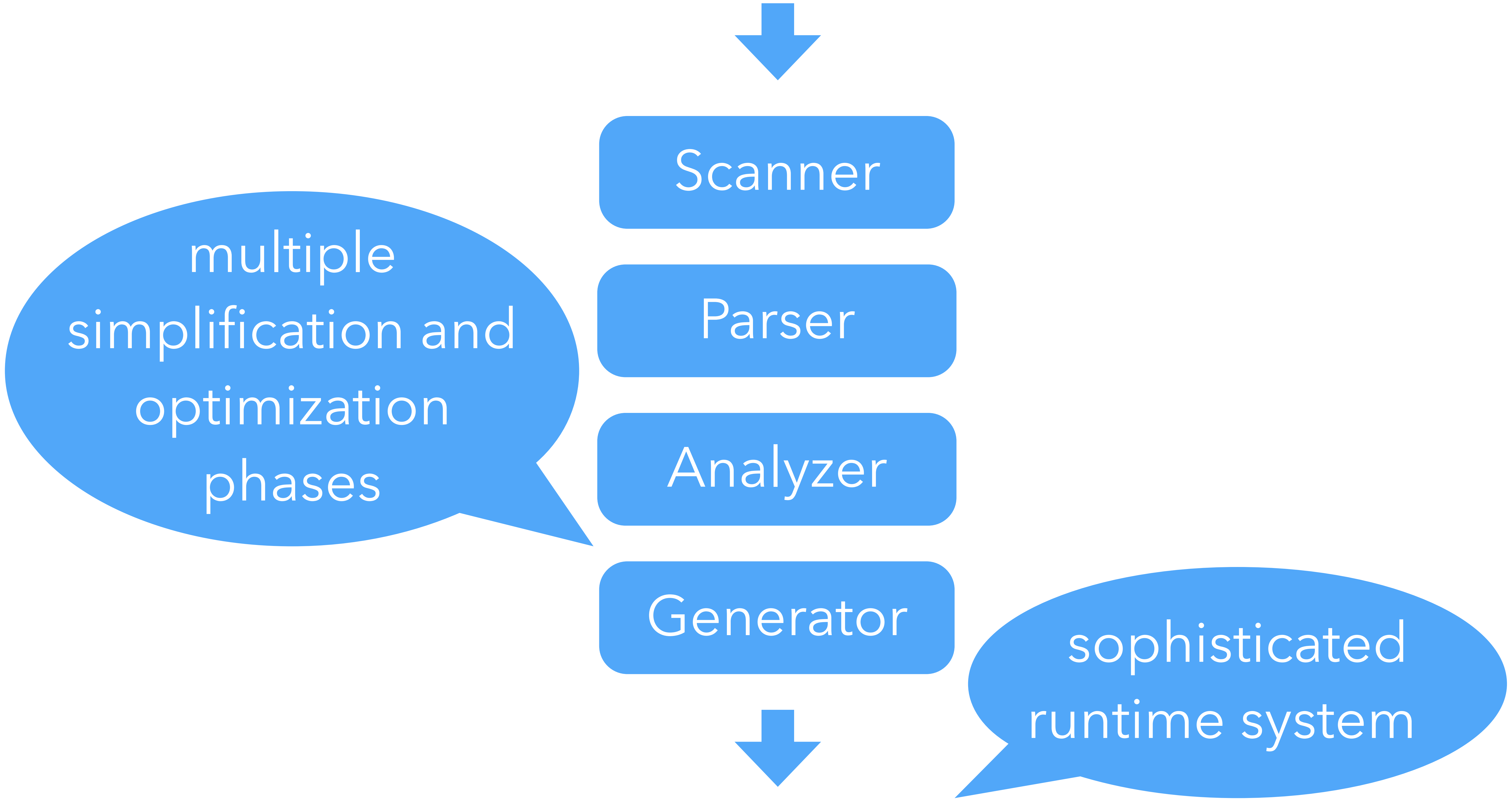
What is a compiler?

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 (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;
  }
}
```

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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.