Introduction

Sebastian Hack

http://compilers.cs.uni-saarland.de

Compiler Construction Core Course 2017
Saarland University

Why take a compiler course?

- Compilers are everywhere!

  web browsers, graphics drivers, databases, phones, etc.
- Compilers are interesting!

  We'll use concepts from automata, graph theory and algorithms, linear programming, lattice theory, etc.
- Learn the foundations of Syntax Analysis

  Helpful when you design your own language
- Learn the foundations of Program Analysis

  Helpful beyond compilers (security, verification, PL)
- Improve your software engineering skills

  Compilers are sophisticated artifacts that are hard to test and debug
- Very good job market for compiler experts!
- Get some easy 9 CP ;)

Compilers

- Compilers translate a program from language S to language T and thereby implement S in T.
- Typically, S is some "higher" programming language and T some "low-level" language, like assembly.
- Programming languages provide abstractions to make the life of the programmer easier
- Their straight-forward implementation in T typically incurs some overhead (in space and time)
- It is the purpose of the compiler to reduce (remove) this overhead
- More convenient languages need more powerful compilers

Abstractions

High level	Low level
Control flow (for, while, functions)	Instruction pointer, jumps
Variable	Memory address, register name
Objects[1]	Memory, registers
Lifetimes	Garbage collection, memory management stack frames
Basic data types (int, float)	Different instruction sets
Compound data types (structs, arrays, etc.)	Addresses, index arithmetic
Parallelism (task, data)	Threads, SIMD instructions

[1] C Standard terminology: means a container that holds a value

Example

sort.c

Challenges

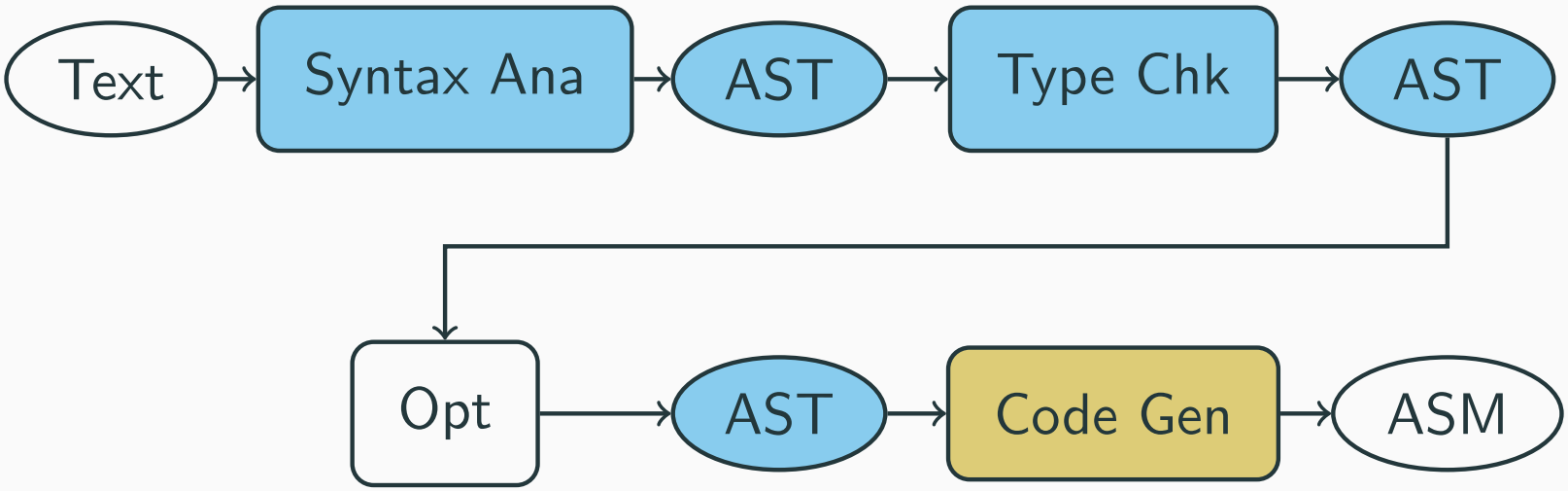
- Compile-time has to be sub-quadratic for the common case
- Most relevant code generation problems are at least NP-hard
- Mainly because target machines have resource constraints
  (finite amount of memory, registers, parallelism, etc.)

- Target machines become less “standard” (aka heterogeneous)
  Think of GPUs, accelerators or even FPGAs
- Target machines become more complex
  Memory hierarchy, out-of-order execution, speculation, etc.
- Hence it is often impossible to give a precise notion of
  “optimality” with respect to the quality of the code.
- End of Dennard Scaling:
  Performance $\cong$ Performance / Watt

Example

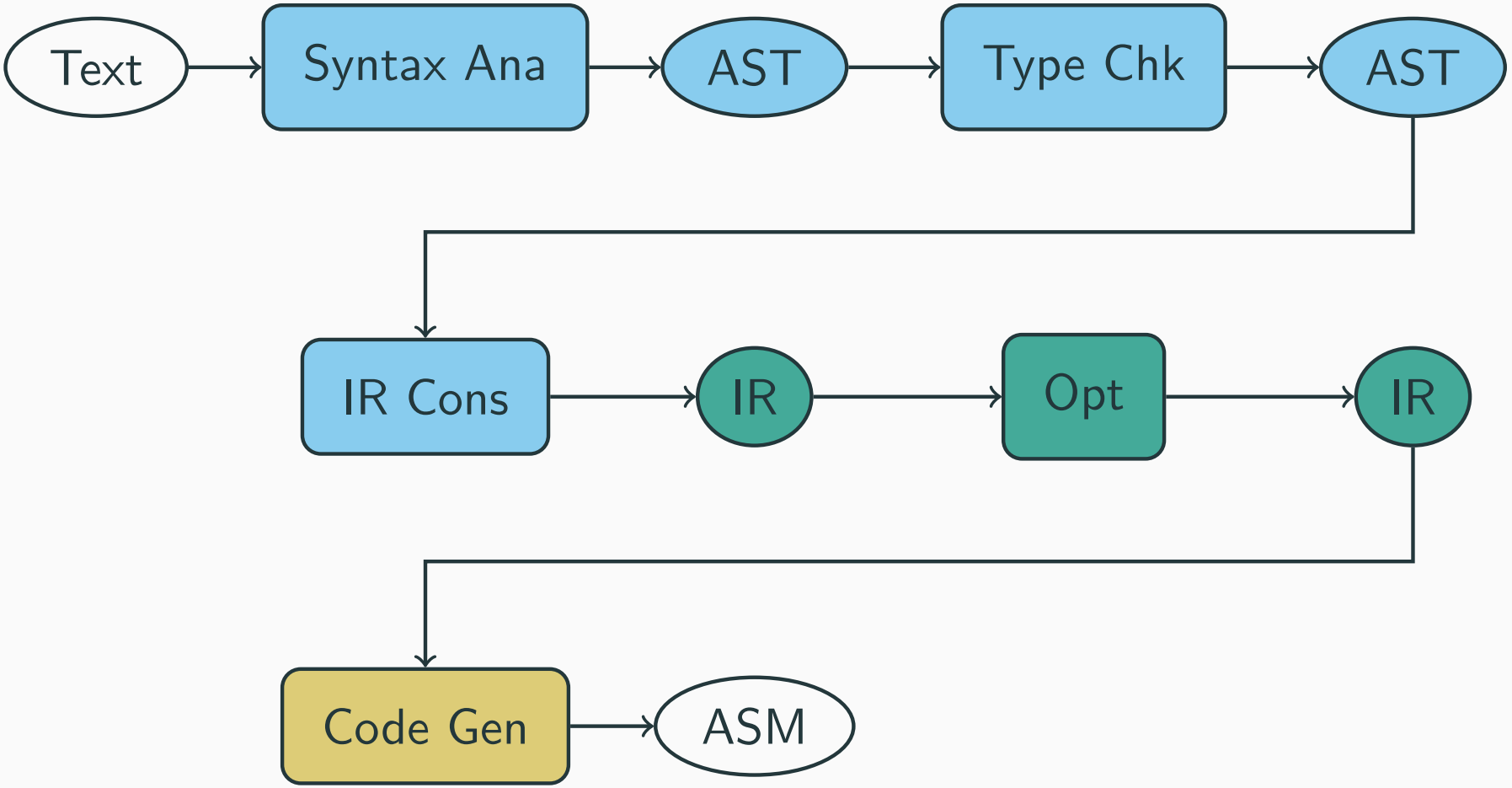
matmul.c

Compiler Structure: Back in the day



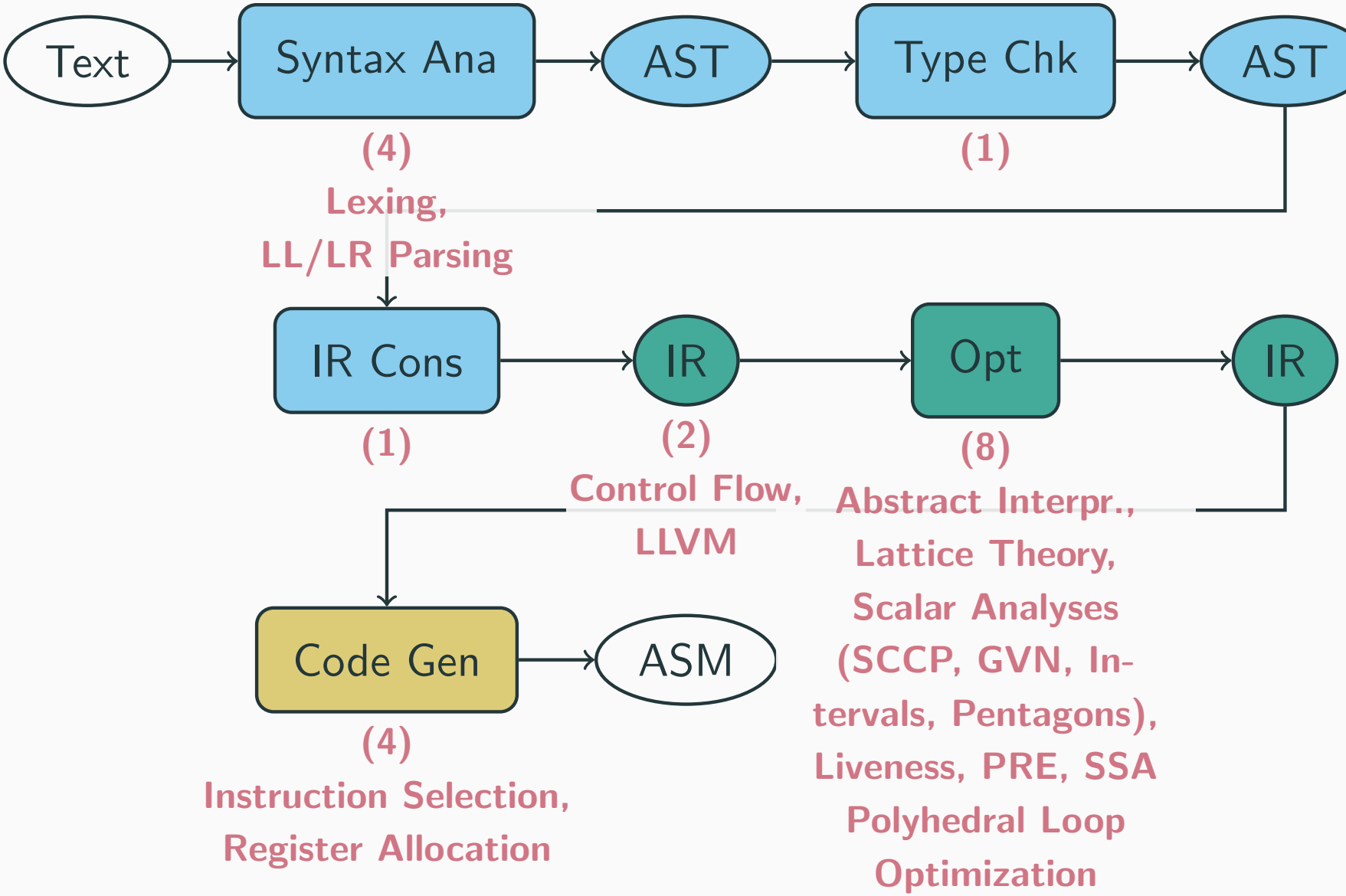
- AST = abstract syntax tree
- **Frontend**: Dependent on input language
- **Backend**: Dependent on target language

Compiler Structure: Nowadays



- intermediate representation (IR) decouples language-specific AST from code generation

Course Structure



(n) Number of lectures

Course Organization

- Course website (all materials, dates, etc.):
  `http://compilers.cs.uni-saarland.de/teaching/cc/2017`
- Online discussion forum at:
  `https://discourse.cdl.uni-saarland.de`
- Please register for the forum until 18 Oct 2017 18:00
- Read and follow the First Steps post
- Tutorials Fri 10–12 (location: tba). First session: 27 Oct 2017
- (voluntary) exercise sheets
- Exam and Re-exam (20 Feb 2018, 20 Mar 2018)
- Grade: 50% exam, 50% project (have to pass both)

Project

- Programming project done in groups of 2–3 students
  (present to us end of February 2018 the latest)
- Compiler for a subset of C using LLVM
- Own frontend, own optimizations,
  use LLVM as IR and code generator
- Project is organized in milestones
  Assignments handed out periodically
- You can test your compiler against our test suite by pushing to your repo (tests run once a day)
- You can track the progress of all groups on the course web site
- Competition: There will be a prize for the fastest compiler and for the compiler that produces the fastest code.
  Precondition: Pass all tests.


LLVM
COMPILER
INFRASTRUCTURE
E2