CPEG 421/621 - Fall 2010

Topics I
Fundamentals

Topic I: Outline

- Part I: Compiler Fundementals
  - An Overview on Compiler Design
  - Compiler Front-End and IR
  - Middle-End: Analysis and Optimizations
  - Back-End: Code Generation and Optimization

Foundations for Compiler Design

1. Processor architecture design flow
2. Compiler structure and design flow
3. Code generation design flow

Why Study Compilers?

- Influences on programming language design
- Influences on computer design
- Compiling techniques are useful for software development
  - Parsing techniques are often used
  - Learn practical data structures and algorithms
  - Basis for many tools such as text formatters, structure editors, silicon compilers, design verification tools,…

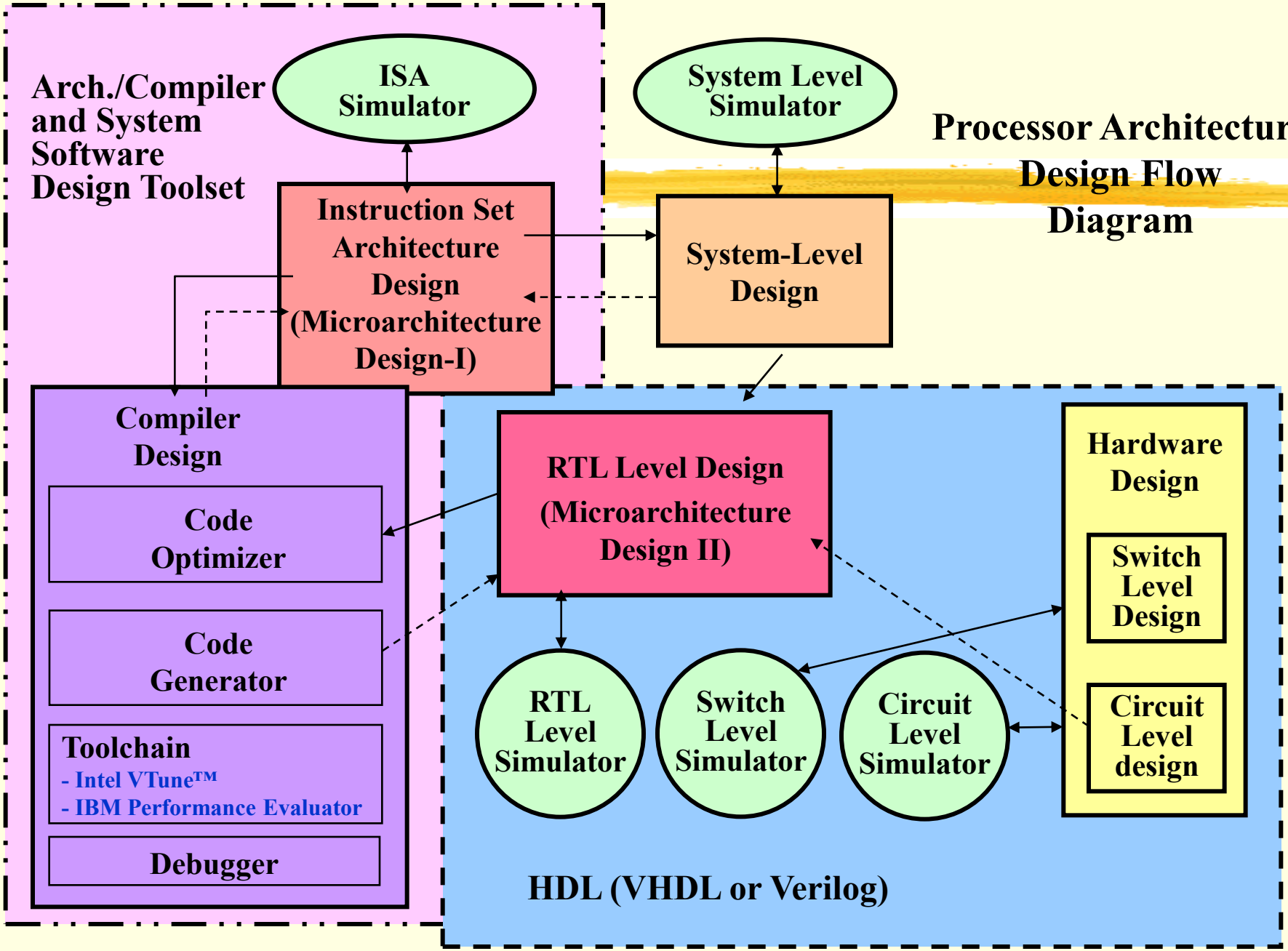
  Writing a compiler requires an understanding of almost all important CS subfields

Architecture Models

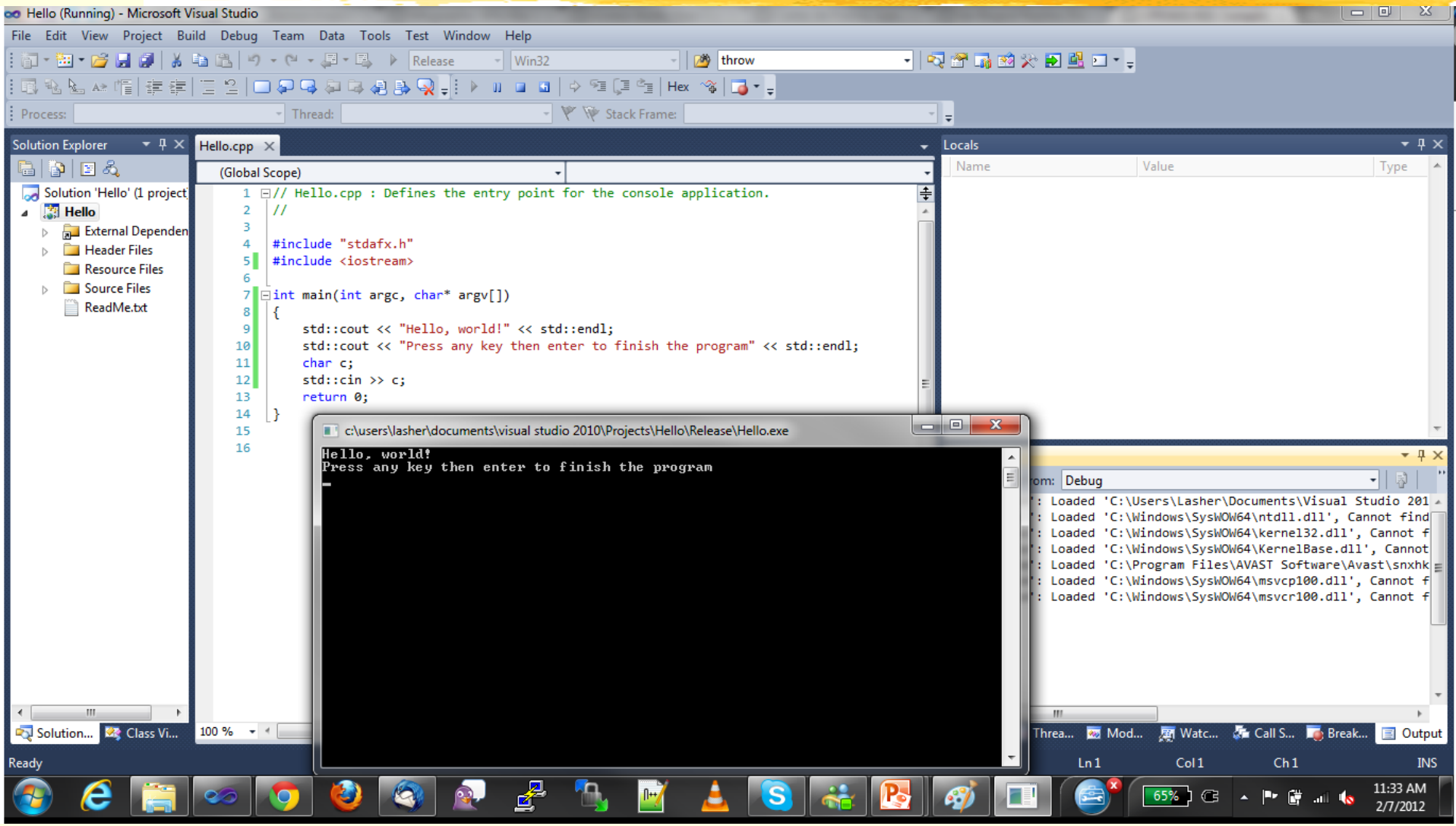
- Vector architctures, SIMD
- Instructional Level Parallelism (ILP)
  - superscalar
  - VLIW
- Multithreaded Architectures
- Chip multiprocessing (CMP, multi-core, many-core, etc.)
- GPGPUs
- Reconfiguratble Archtitectures

What is the impact of these ideas on compilers?

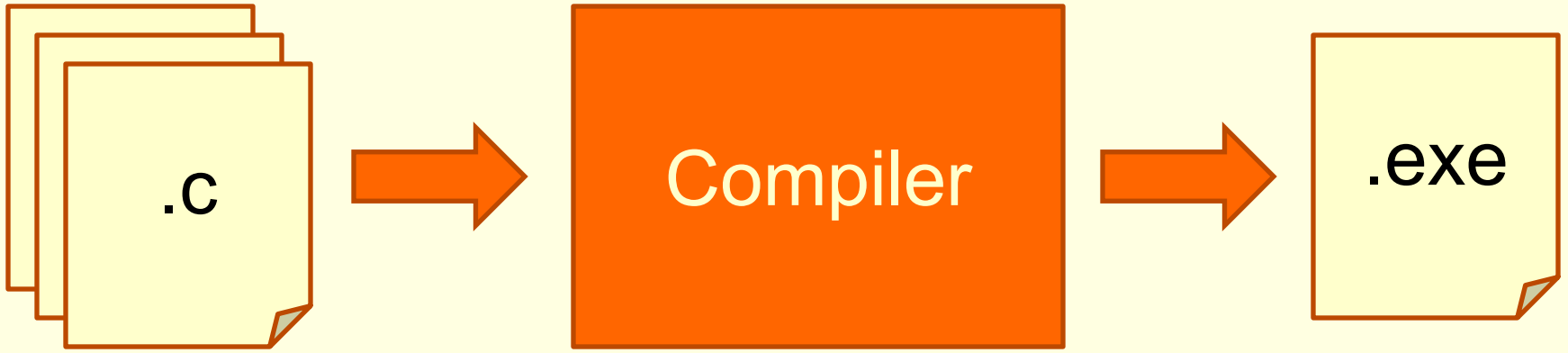
Processor Architecture Design Flow Diagram



What does a Compiler do Anyway?



What does a Compiler do Anyway? (Cont'd)



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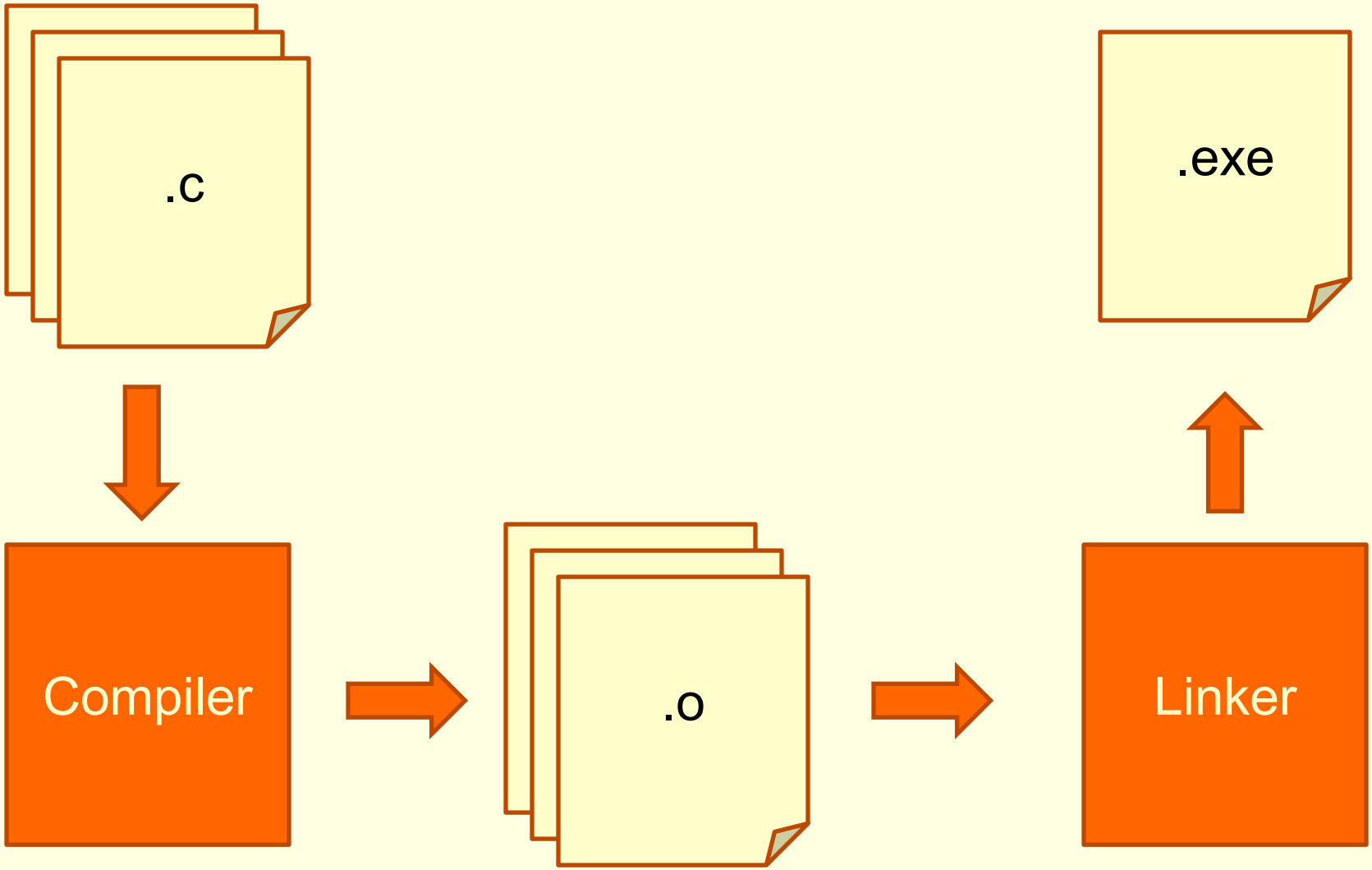

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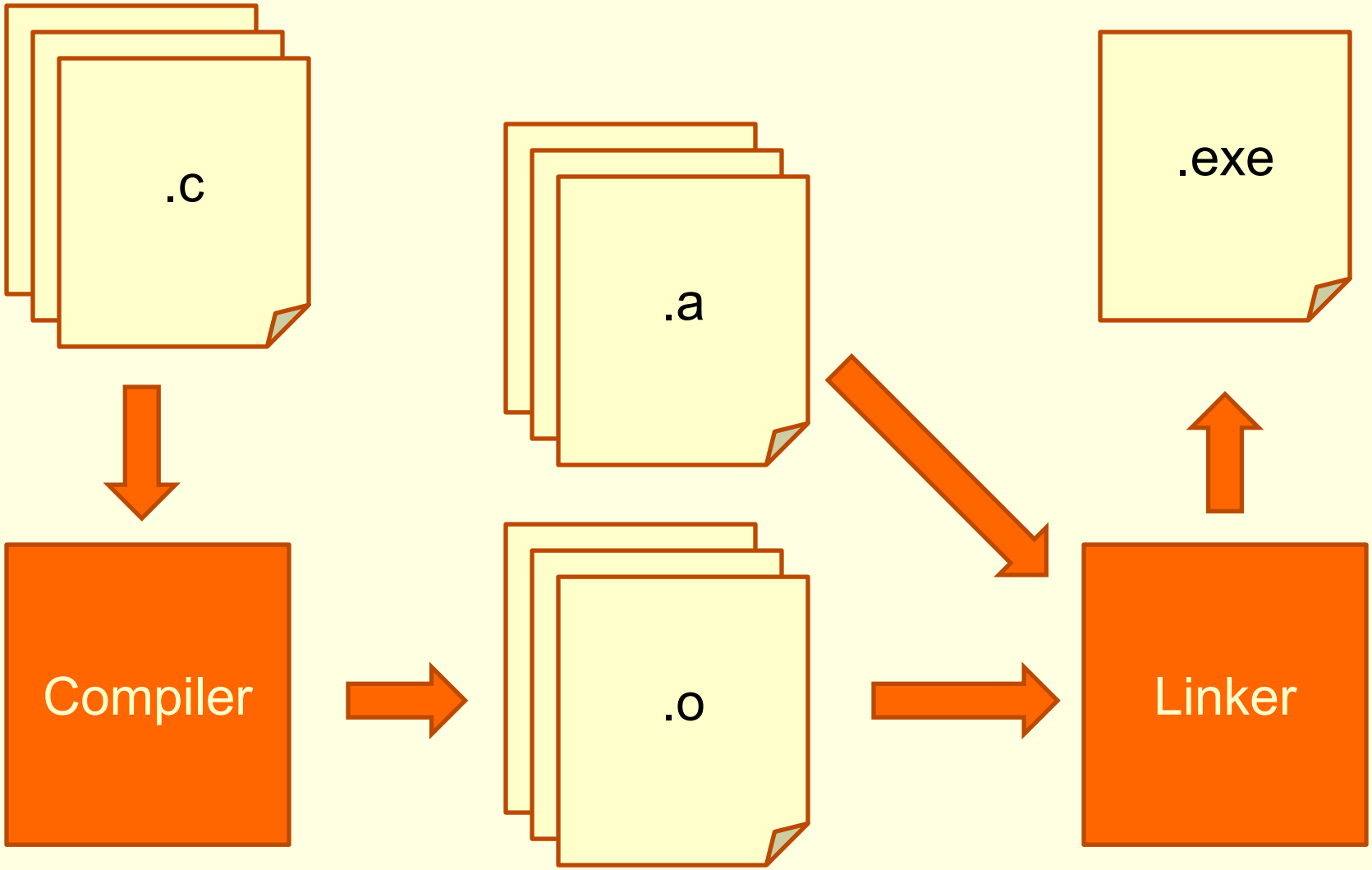

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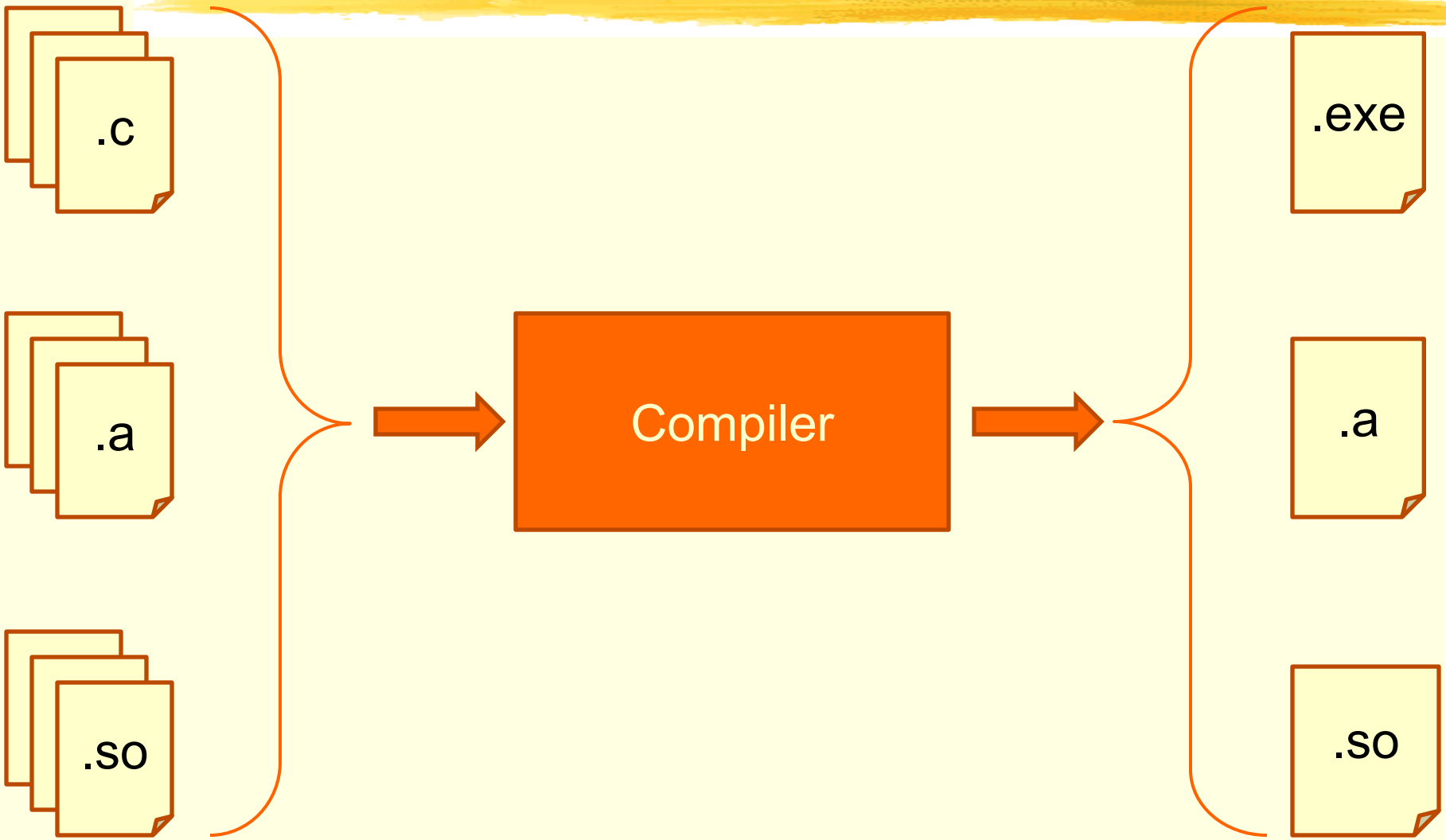
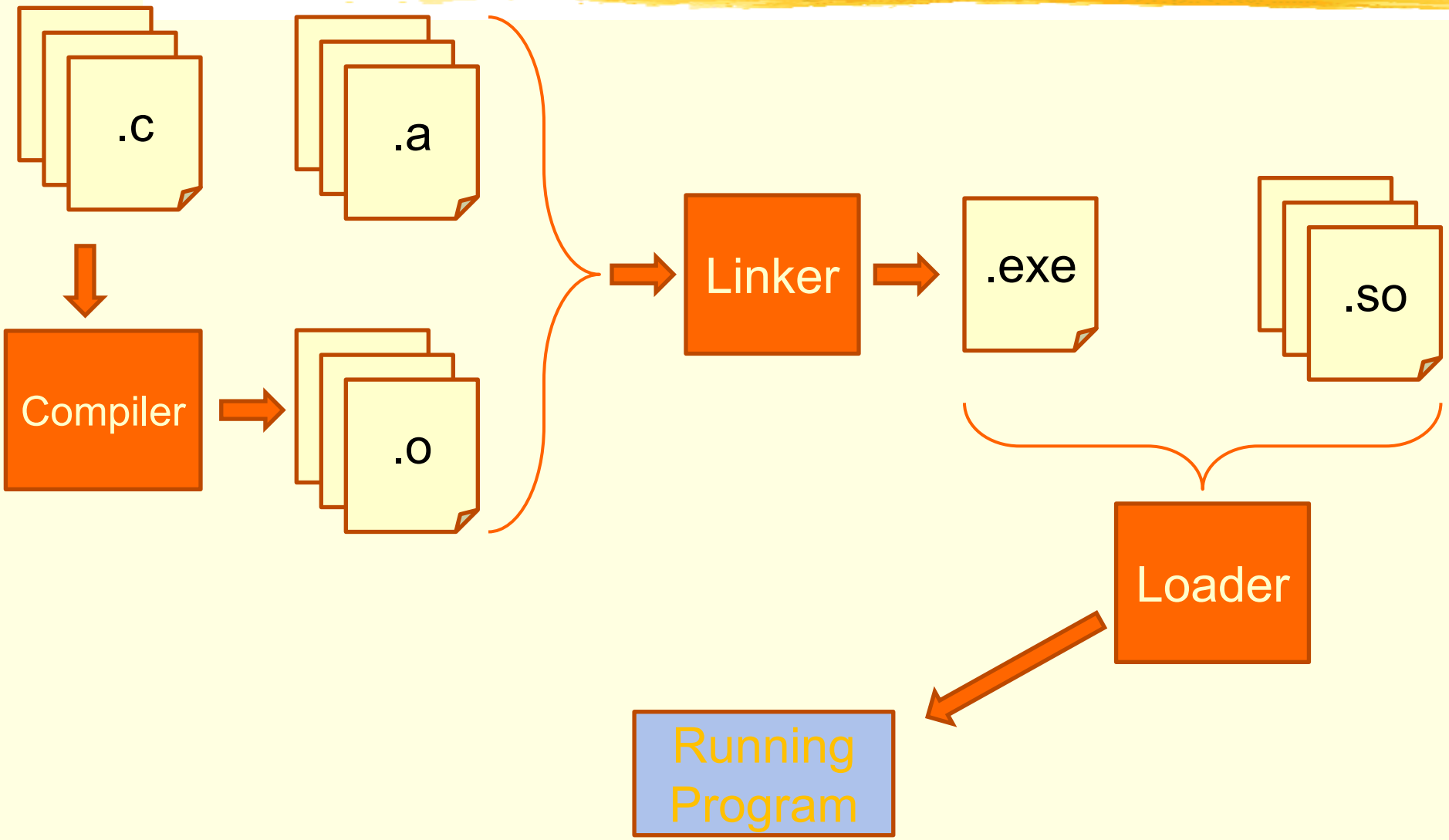
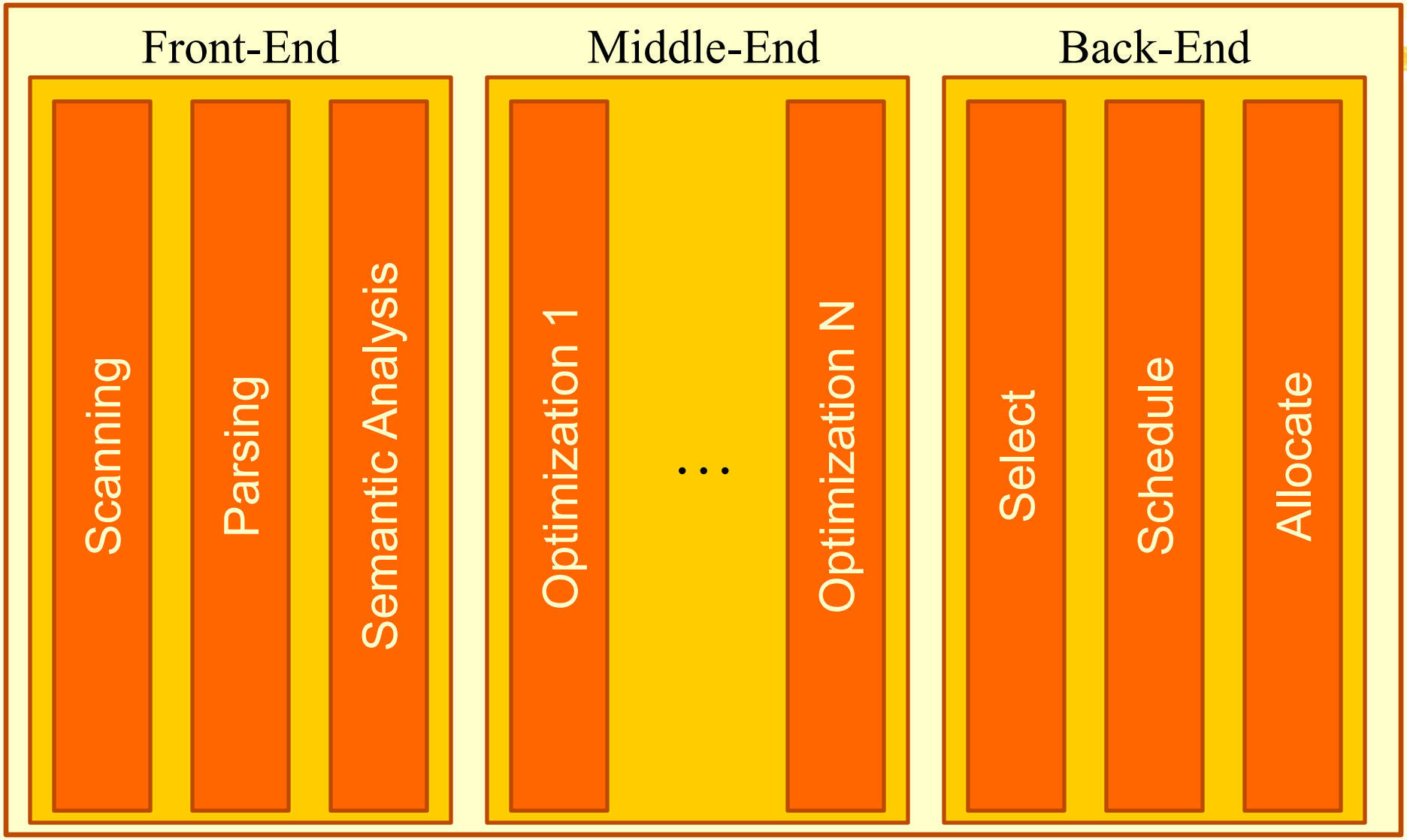


The Whole Compilation Chain



Inside a Compiler



A Quick Look at the Front-End: The Lexer

- Makes sure that every single “word” in the programming language is well-formed
- Outputs tokens which describe to what category each word in a given program belongs to
- Think of it as a “spell checker”

A Quick Look at the Front-End: The Parser

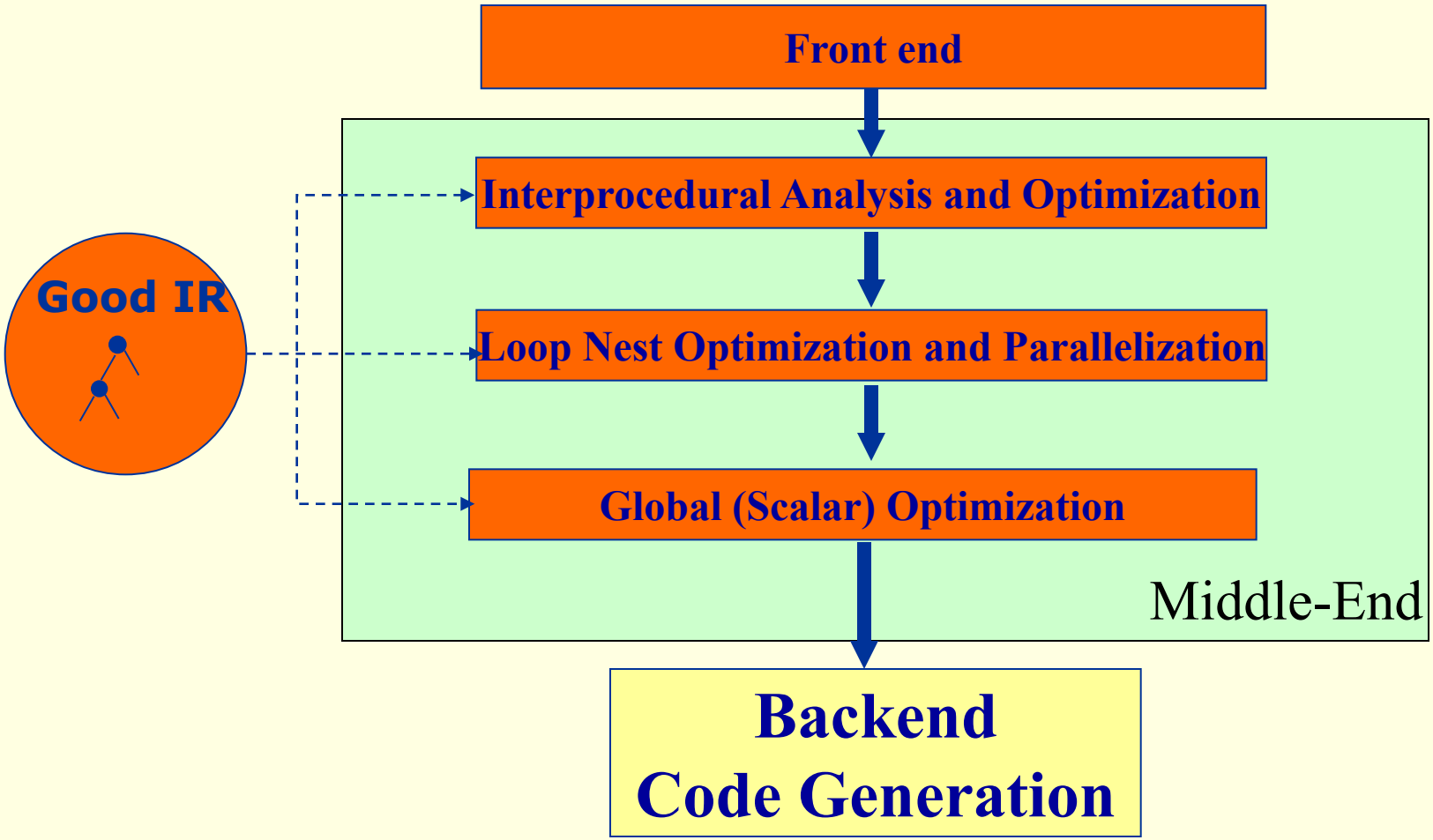
- Takes tokens as input
- Makes sure the tokens are inserted in a valid sequence
- Think of it as a “grammatical checker”

The lexer and the parser make sure there the input program is correct with respect to the formal semantics of the language used by the programmer

A Quick Look at the Front-End: The Semantic Analyser

- Context-sensitive analysis (or semantic analysis) checks that the output of the lexer and parser has *meaning*.
  - E.g. “This house is very clever” vs “This student is very clever” → both are grammatically correct, only one has meaning
- It is useful at several levels:
  - Correctness can be further ensured
  - Can ensure safety through type-checking
  - Can provide the middle-end and back-end with useful information w.r.t. certain expressions

A Good Compiler Infrastructure Needed – A modern View



Middle-End Optimization

- Flow Analysis
  - Control flow analysis
  - Dataflow analysis
- Global scalar optimization
- Loop nest optimization
- Advanced topics:
  - Static Single Assignment form (SSA)
  - Application of SSA to scalar optimization

Backend Optimization (I)

- Instruction selection
- Instruction scheduling
- Register allocation
- Others

Backend Optimization (II)

- Loop optimization and scheduling
- Software pipelining