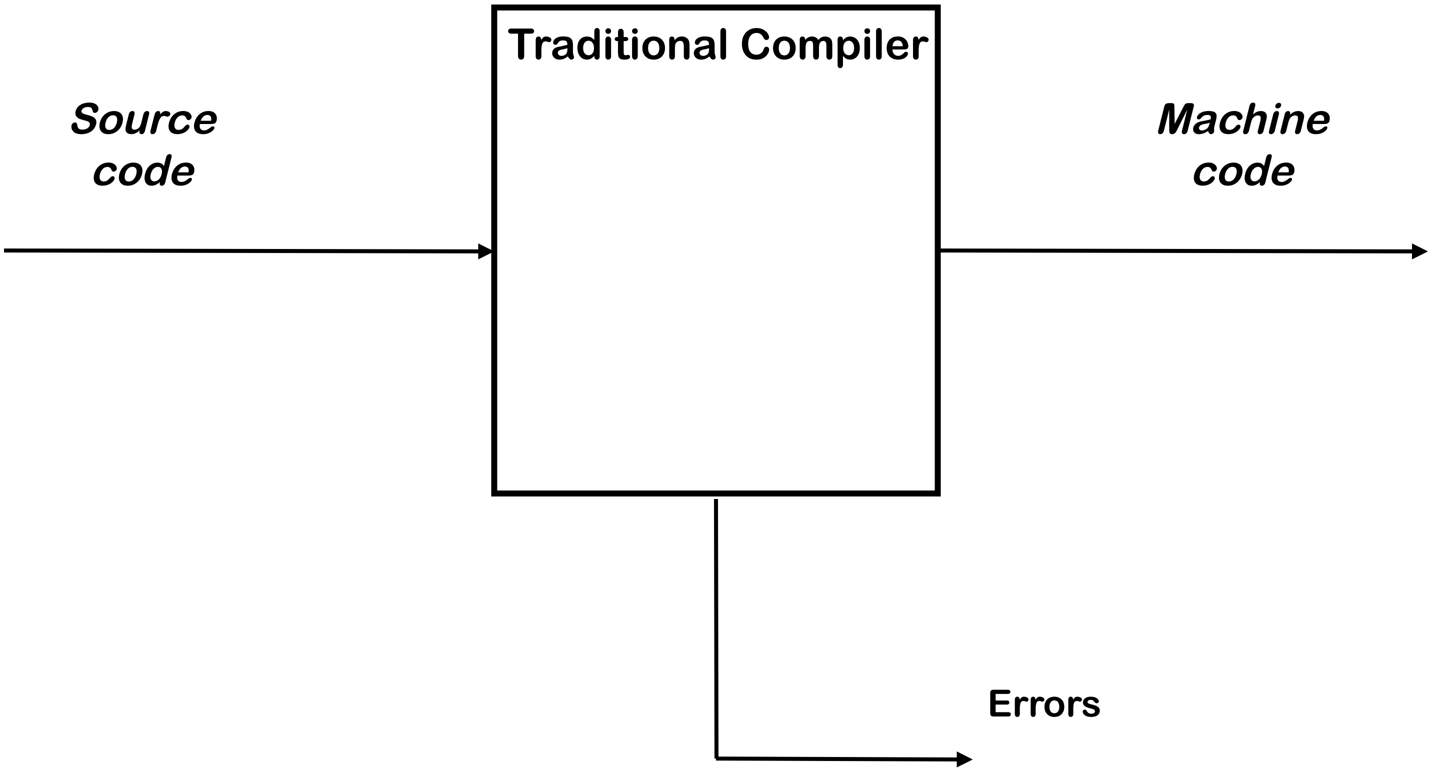
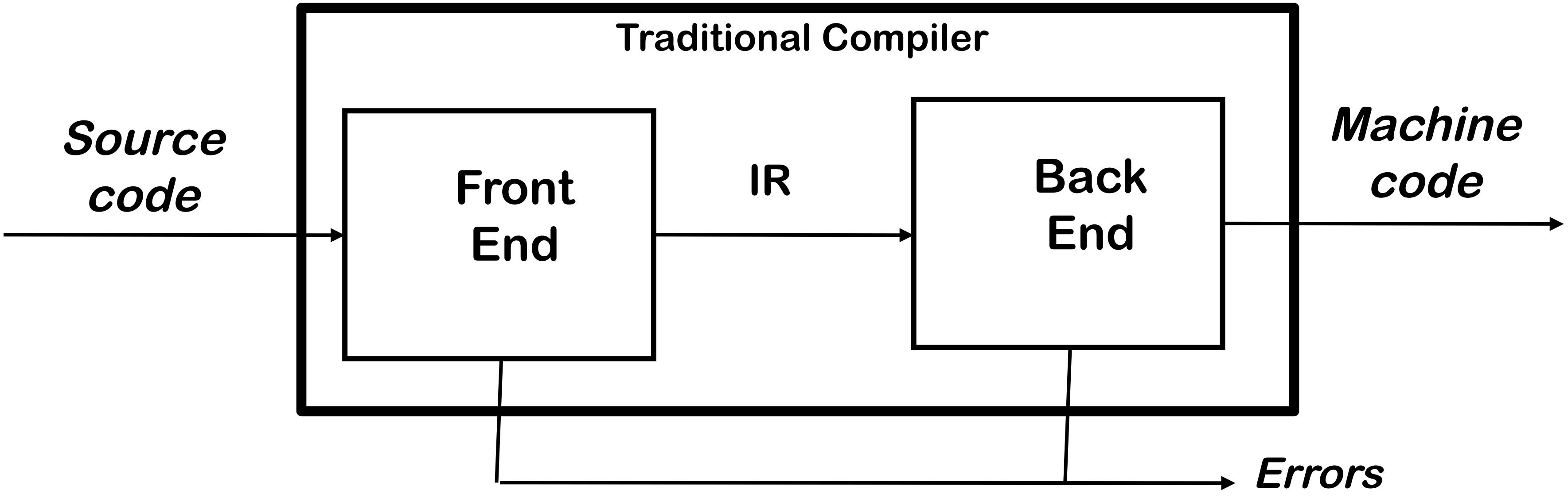
The View from 35,000 Feet

High-level View of a Compiler



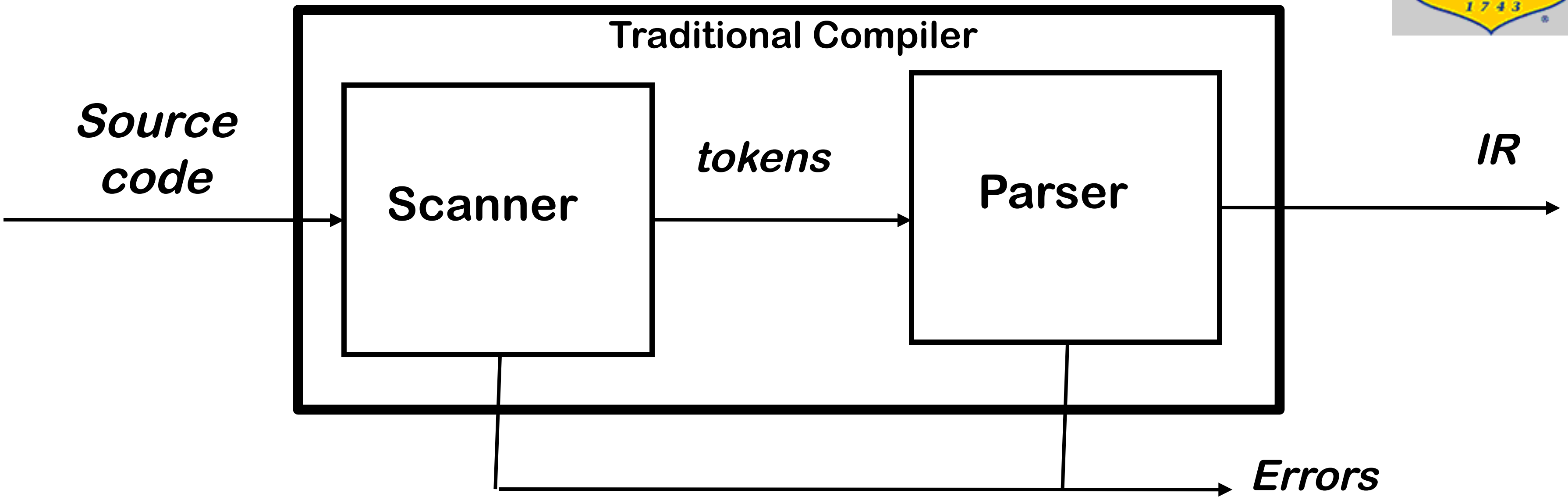
Traditional Two-pass Compiler



Responsibilities

- Front end produces intermediate representation (IR)
- Back end produces machine code

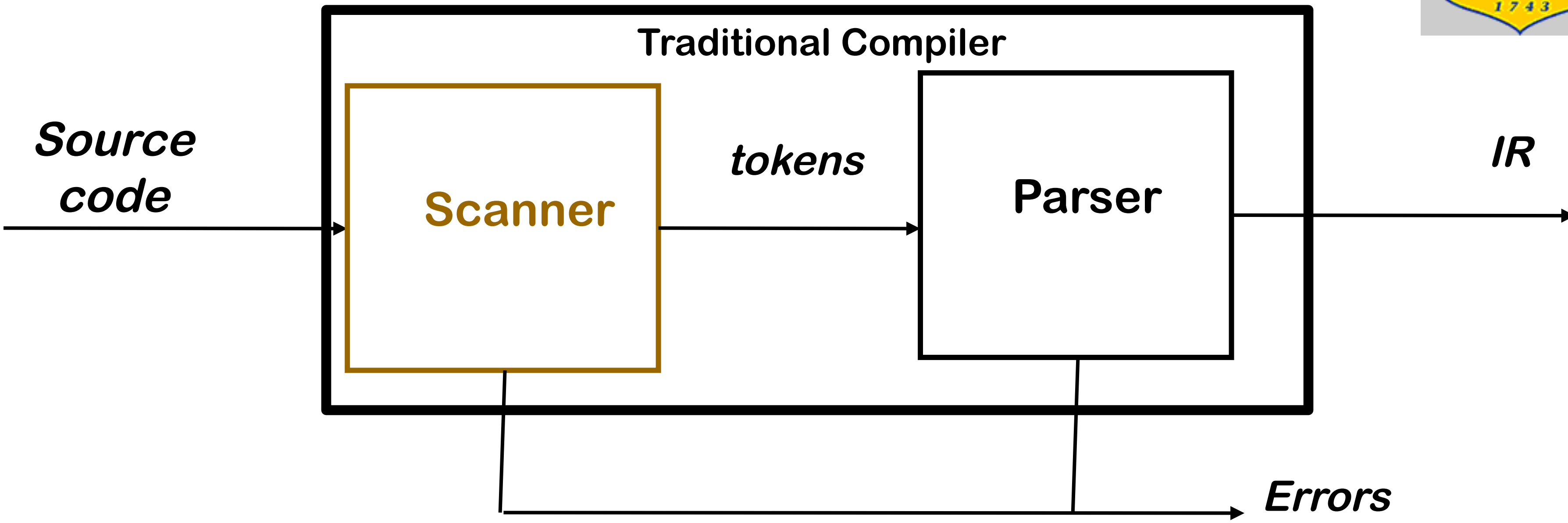
The Front End



Responsibilities

- Recognize legal (and illegal) programs
- Produces IR

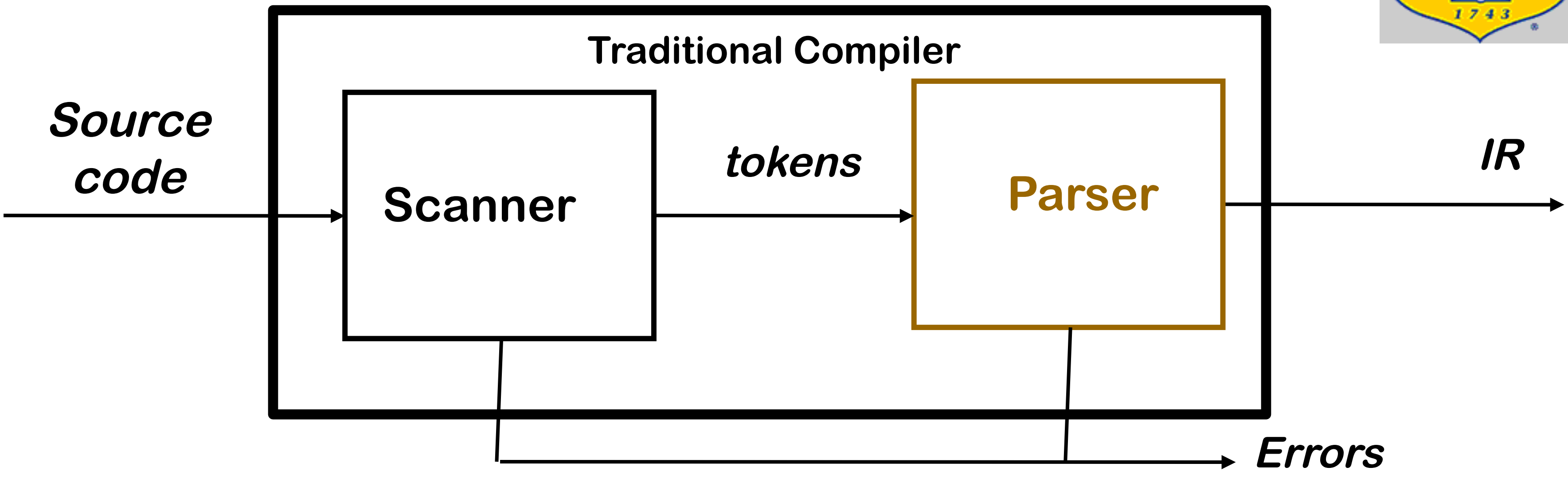
The Front End



Scanner

- Maps character stream into words
  - the basic unit of syntax
- Produces pairs — a word & its part of speech

The Front End



Parser

- Recognizes syntax (context-free) and reports errors
- Builds IR for source program

The Front End

Context-free syntax is specified with a grammar

$$\mathit{SheepNoise} \rightarrow \underline{\text{baa}}\ \mathit{SheepNoise}$$
$$|\quad \underline{\text{baa}}$$

This grammar defines the set of noises that a sheep makes under normal circumstances

It is written in a variant of Backus–Naur Form (BNF)

The Front End

Backus-Naur Form (BNF)

Formally, a grammar $G = (S,N,T,P)$

- S is the *start symbol*
- N is a set of *non-terminal symbols*
- T is a set of *terminal symbols* or *words*
- P is a set of *productions* or *rewrite rules*

The Front End

1. *goal* → *expr*
2. *expr* → *expr op term*
3. | *term*
4. *term* → number
5. | id
6. *op* → +
7. | -

S = *goal*

T = { number, id, +, - }

N = { *goal*, *expr*, *term*, *op* }

P = { 1, 2, 3, 4, 5, 6, 7}

Context-free syntax can be put to better use

- This grammar defines simple expressions with addition & subtraction over "number" and "id"

The Front End

Given a CFG, we can *derive* sentences by repeated substitution

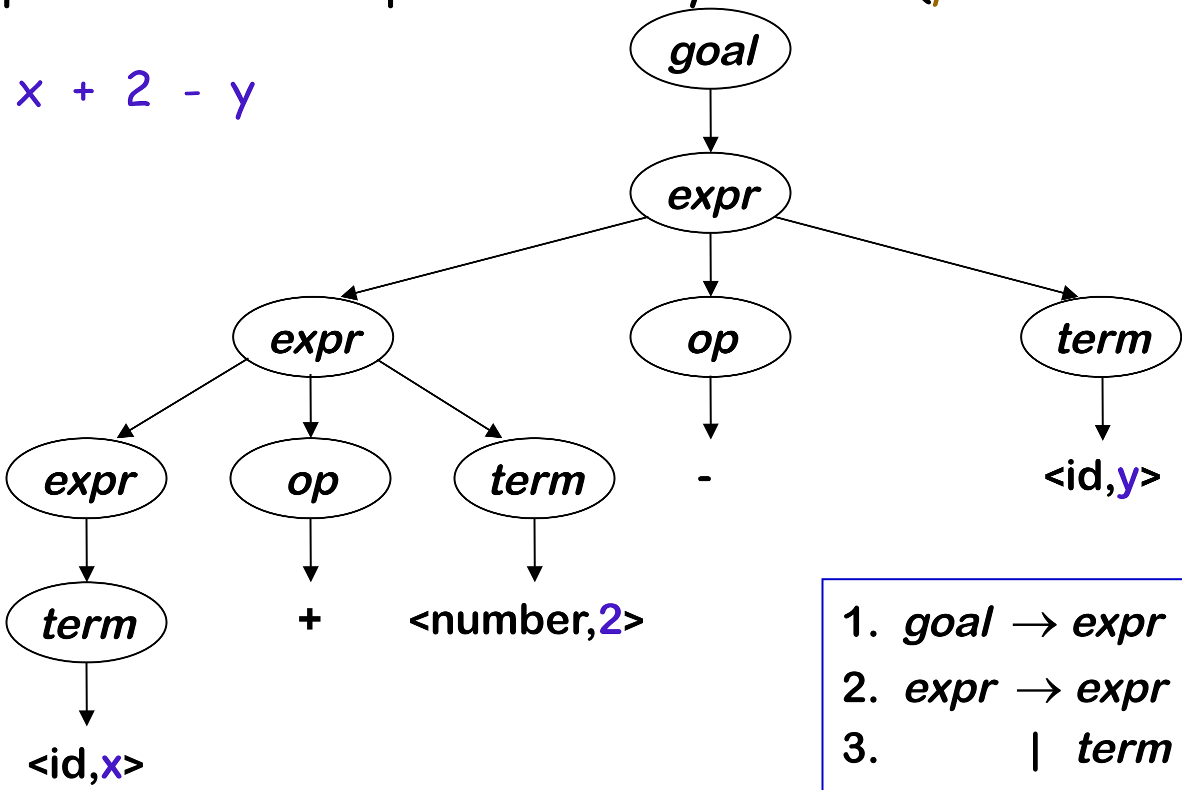
Production	Result
	goal
1	*expr*
2	*expr op term*
5	*expr op* y
7	*expr* - y
2	*expr op term* - y
4	*expr op* 2 - y
6	*expr* + 2 - y
3	*term* + 2 - y
5	x + 2 - y

To recognize a valid sentence in some CFG, we reverse this process and build up a *parse*

The Front End

A parse can be represented by a tree (*parse tree* or *syntax tree*)

x + 2 - y

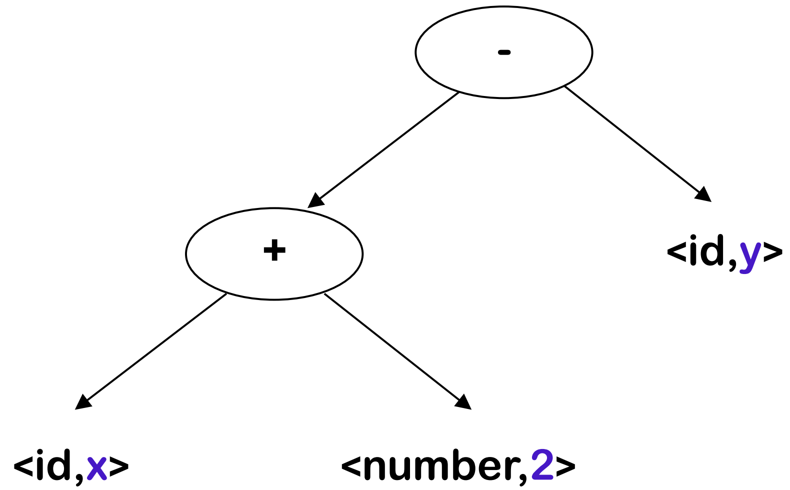


This contains a lot of unneeded information.

1. *goal* → *expr*
2. *expr* → *expr op term*
3. | *term*
4. *term* → number
5. | id
6. *op* → +
7. | -

The Front End

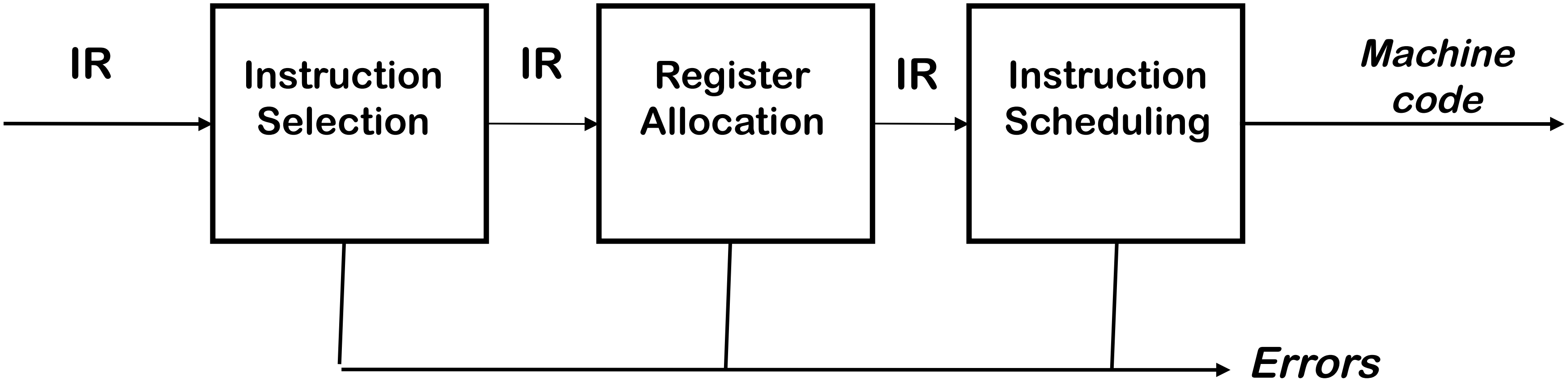
Compilers often use an *abstract syntax tree*



This is much more concise

An AST is just one of several *intermediate representations (IR) that can be used in a compiler*

The Back End

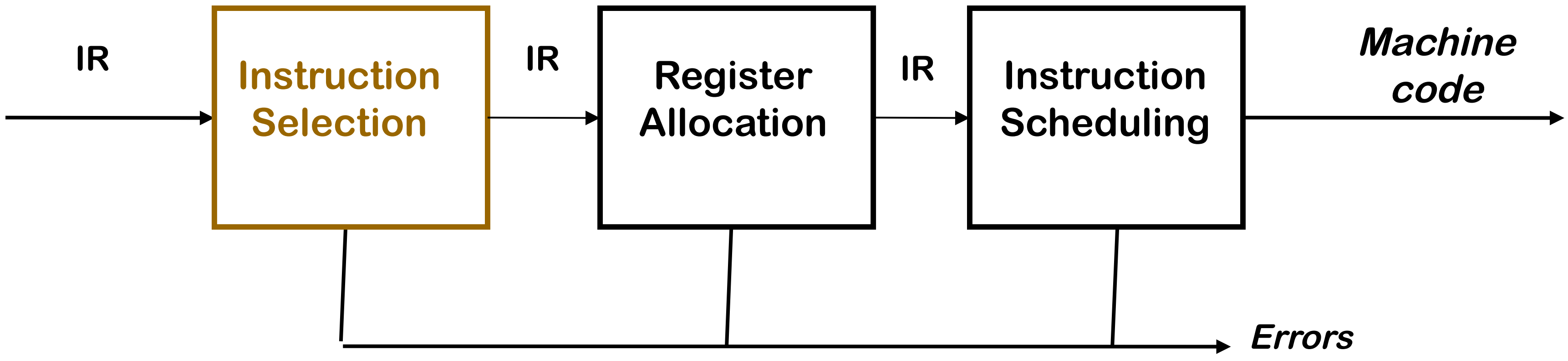


Responsibilities

- Translate IR into target machine code
- Choose instructions to implement each IR operation
- Decide which values to keep in registers

Automation has been *less* successful in the back end

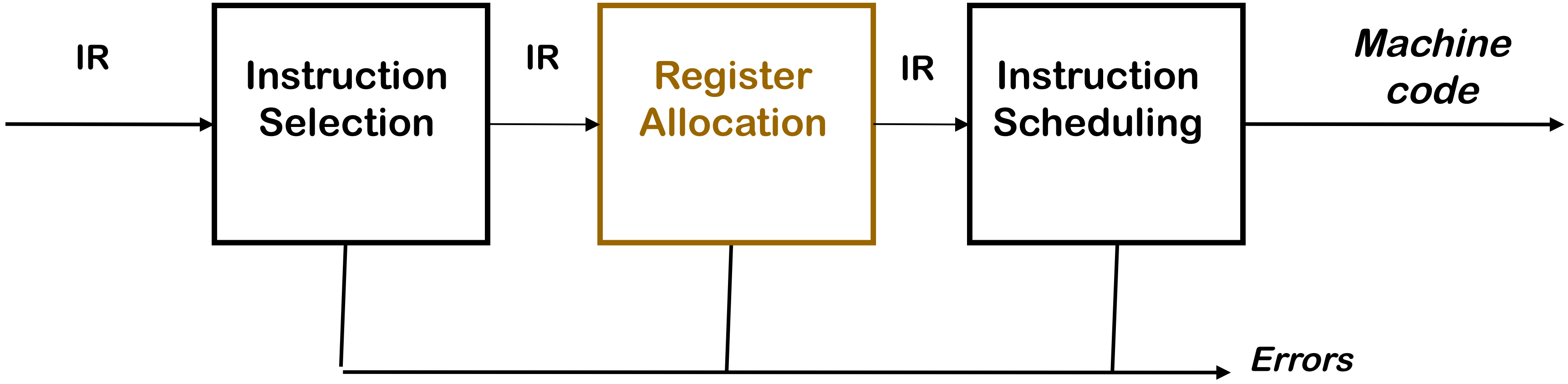
The Back End



Instruction Selection

- Produce fast, compact code
- Take advantage of target machine features
- Usually viewed as a pattern matching problem
  - → *ad hoc* methods, pattern matching, dynamic programming

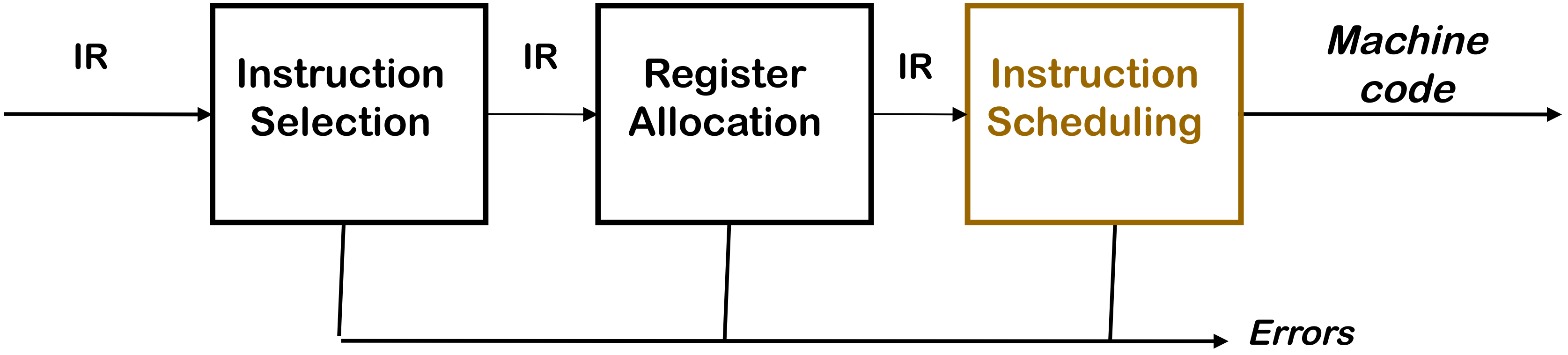
The Back End



Register Allocation

- Allocating variables (i.e., values) into registers
- Manage a limited set of registers
  - Often more variables than registers available
- Optimal allocation is NP-Complete

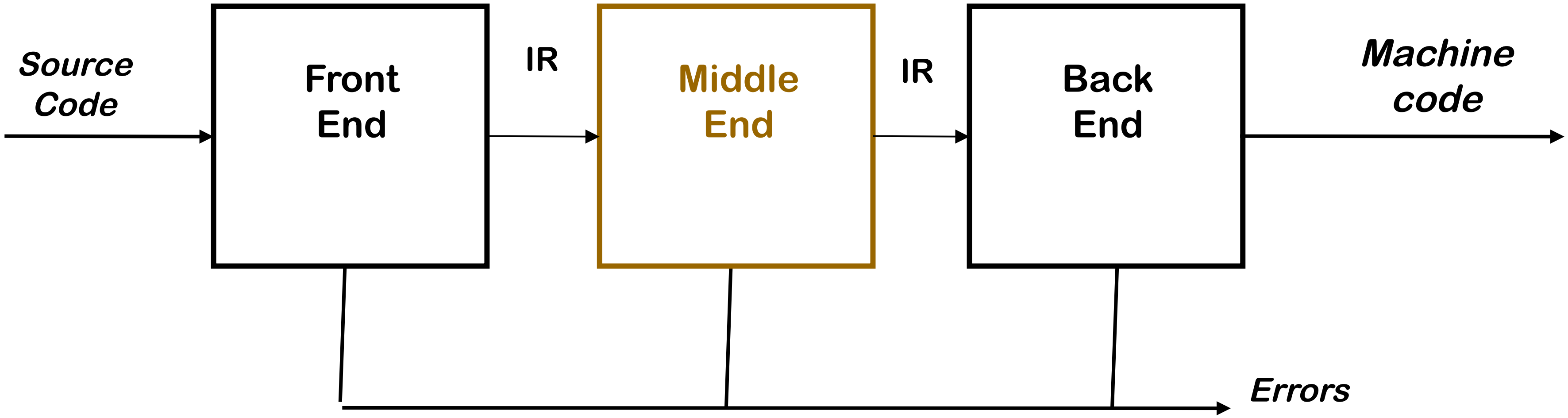
The Back End



Instruction Scheduling

- Tries to find a better ordering of the assembly instructions
- Architecture dependent
- Finding optimal ordering (schedule) is NP-complete

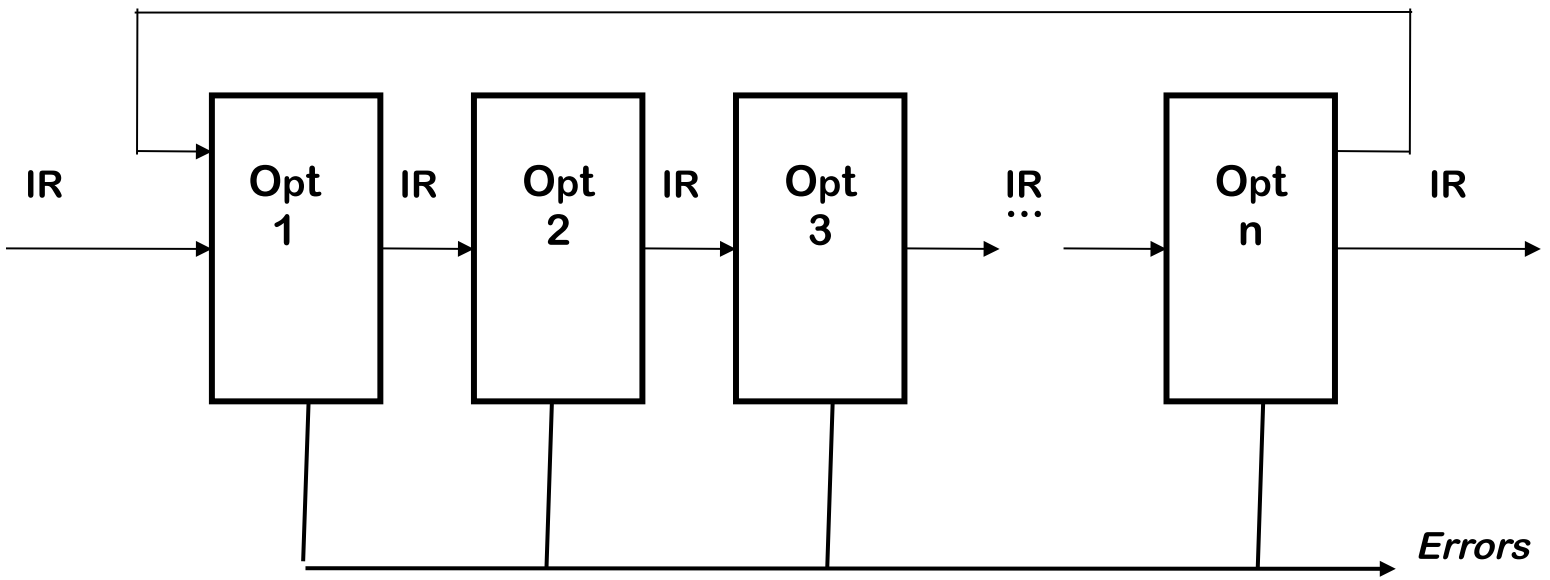
Traditional Three-pass Compiler



Code Improvement (or *Optimization*)

- Analyzes IR and rewrites (or *transforms*) IR
- Primary goal is to reduce running time of the compiled code
  - → May also improve space, power consumption, …
- Must preserve "meaning" of the code
  - → Measured by values of named variables

The Optimizer (or Middle End)



Modern optimizers are structured as a series of passes

Typical Transformations

- Discover and propagate some constant value
- Move a computation to a less frequently executed place

Next Week

- Introduction to Scanning (aka Lexical Analysis)
- Material is in Chapter 2

- Phase 2 available next Monday (2/12)