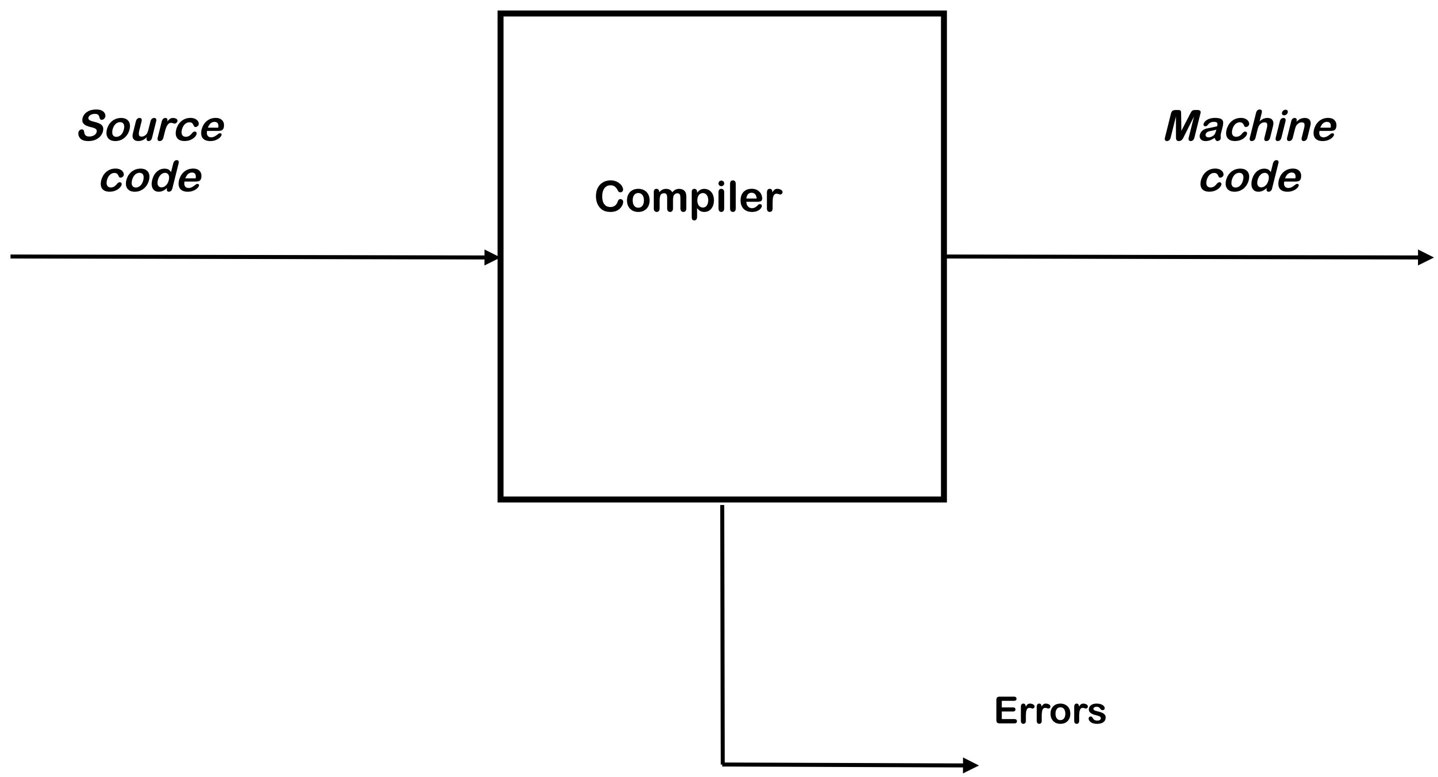
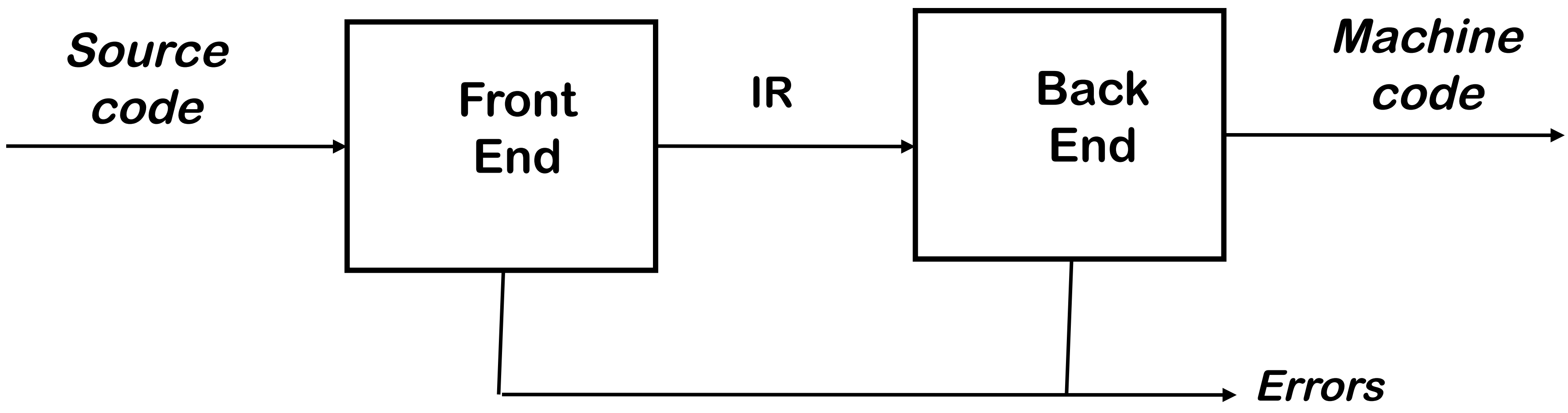
# The View from 35,000 Feet

# High-level View of a Compiler



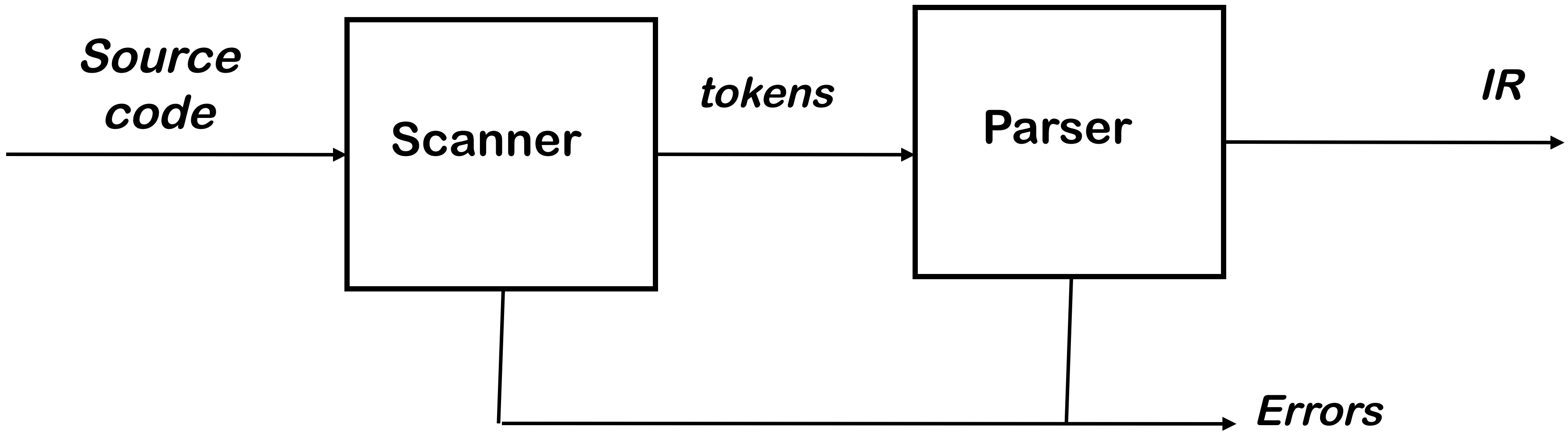
# Traditional Two-pass Compiler




Responsibilities

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

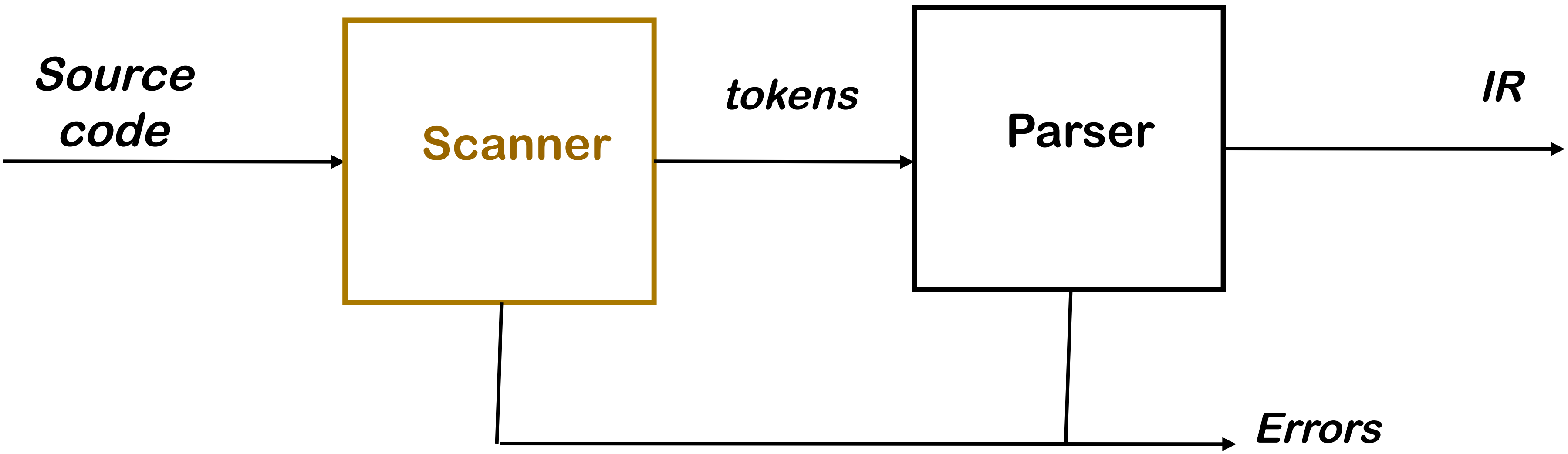
# The Front End




Responsibilities

- Recognize legal (and illegal) programs
- Produces IR

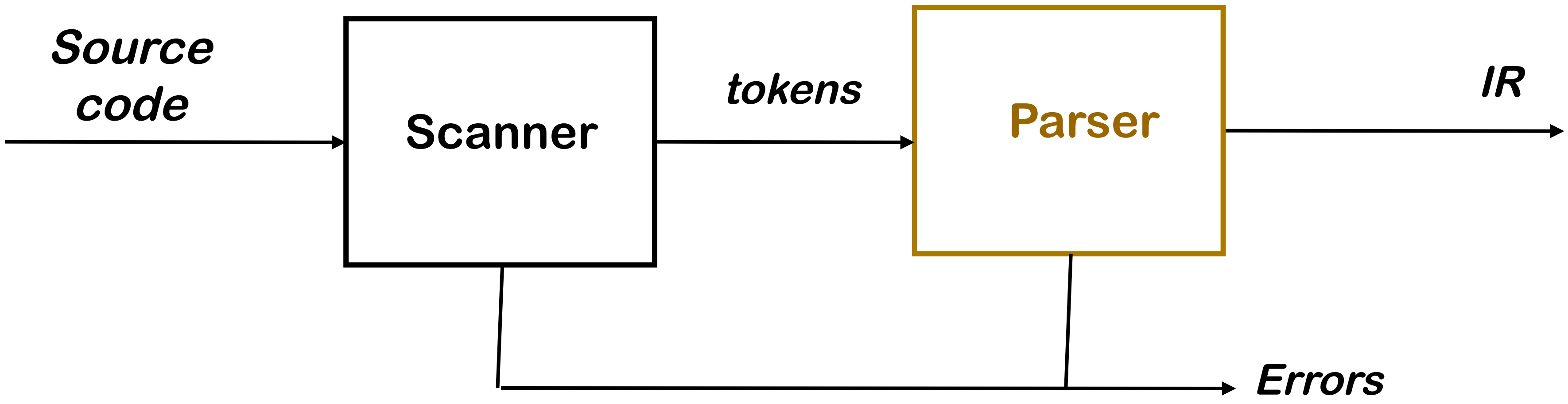
# The Front End




## 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

$$\begin{array}{rcl} \textit{SheepNoise} & \rightarrow & \underline{\text{baa}}\ \textit{SheepNoise} \\ & | & \underline{\text{baa}} \end{array}$$

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

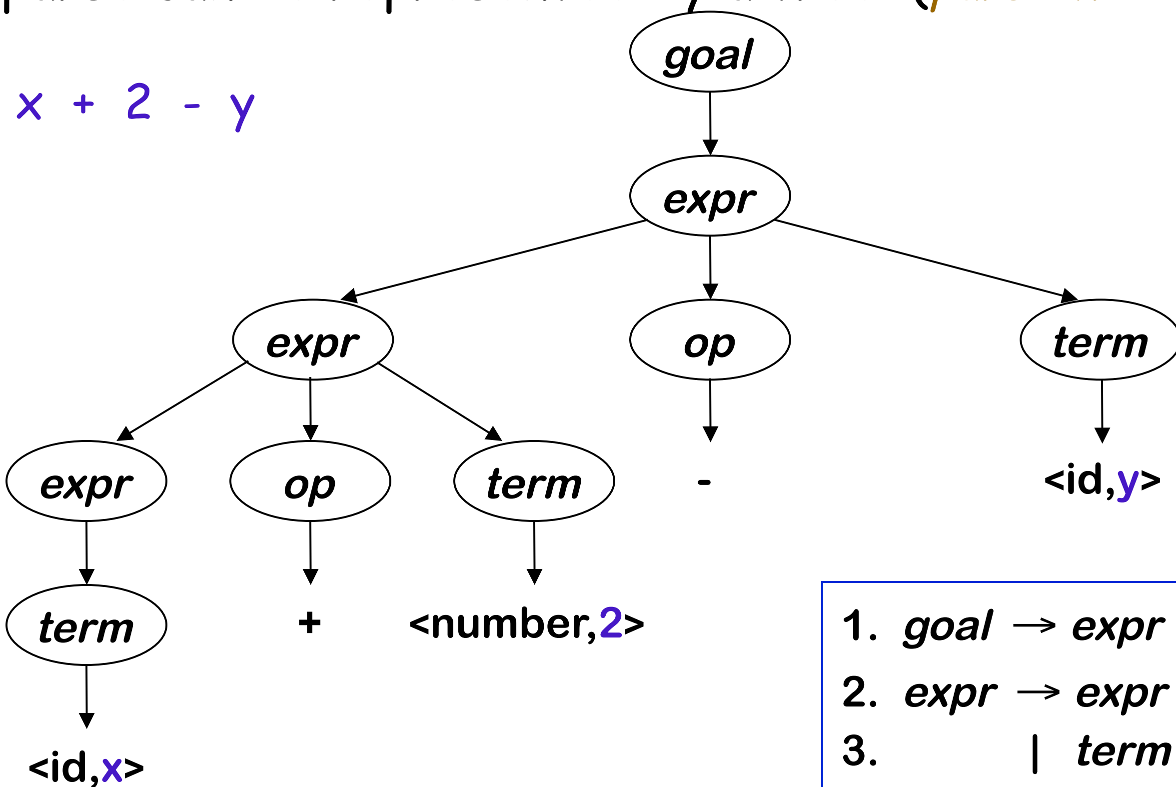
| Production | Result |
|---|---|
| | *goal* |
| 1 | *expr* |
| 2 | *expr op term* |
| 5 | *expr op* y |
| 7 | *expr* - y |
| 2 | *expr op term* - y |
| 4 | *expr op* 2 - y |
| 6 | *expr* + 2 - y |
| 3 | *term* + 2 - y |
| 5 | x + 2 - y |

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

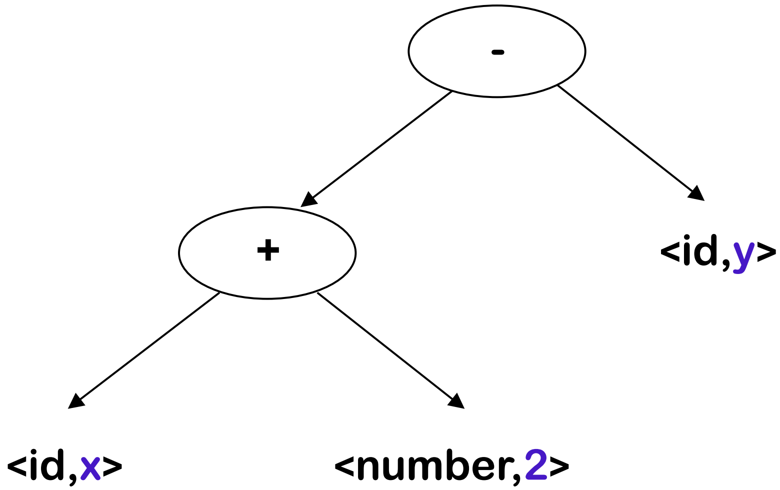



This contains a lot of unneeded information.

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

# The Front End

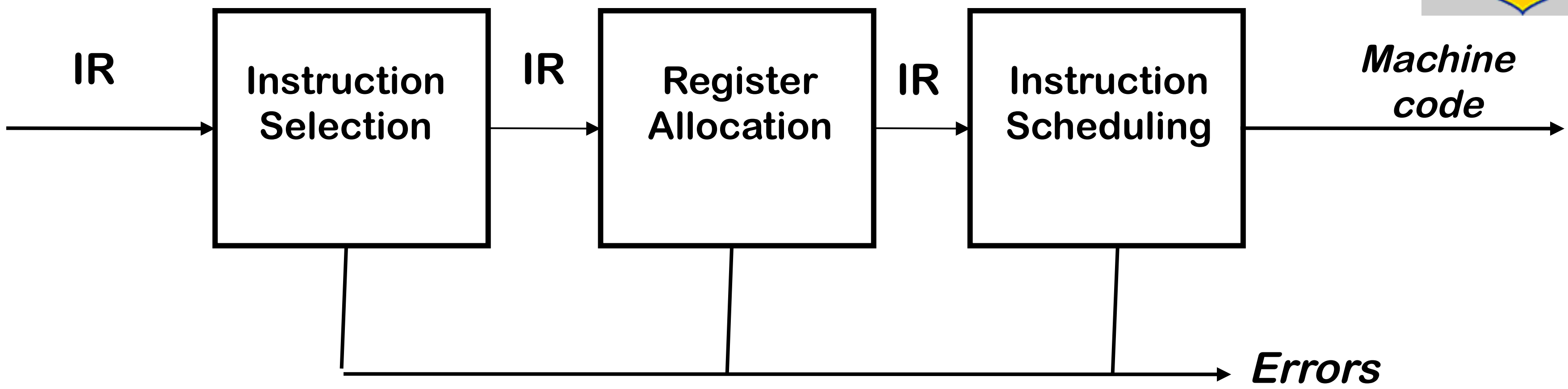
Compilers often use an *abstract syntax tree*




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

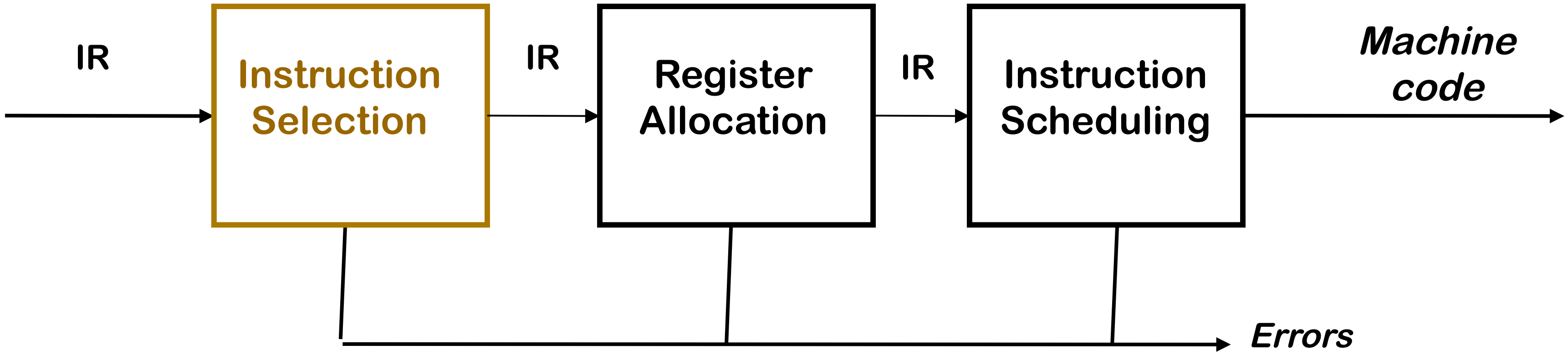



Responsibilities

- 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

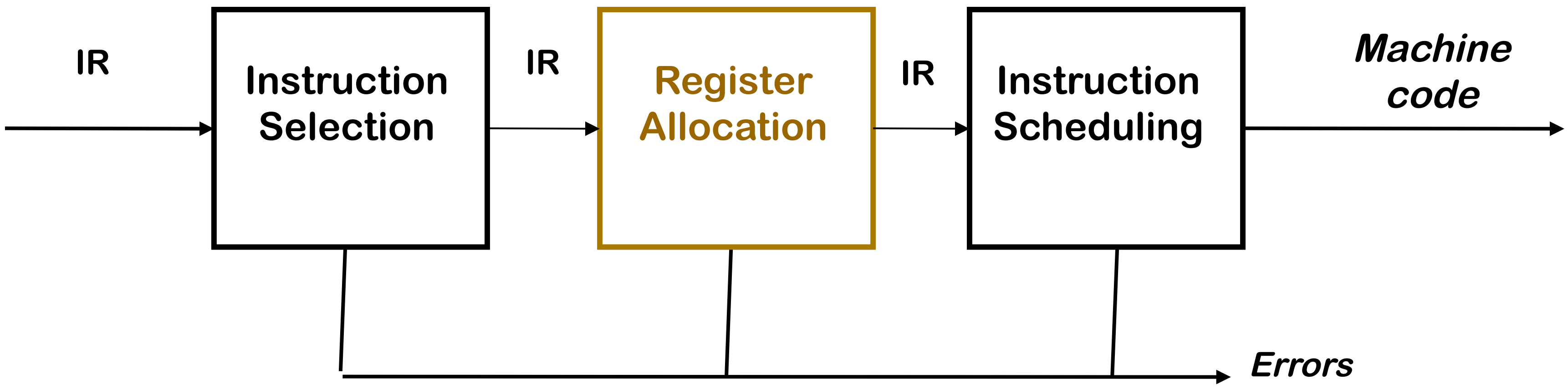
# The Back End




## 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

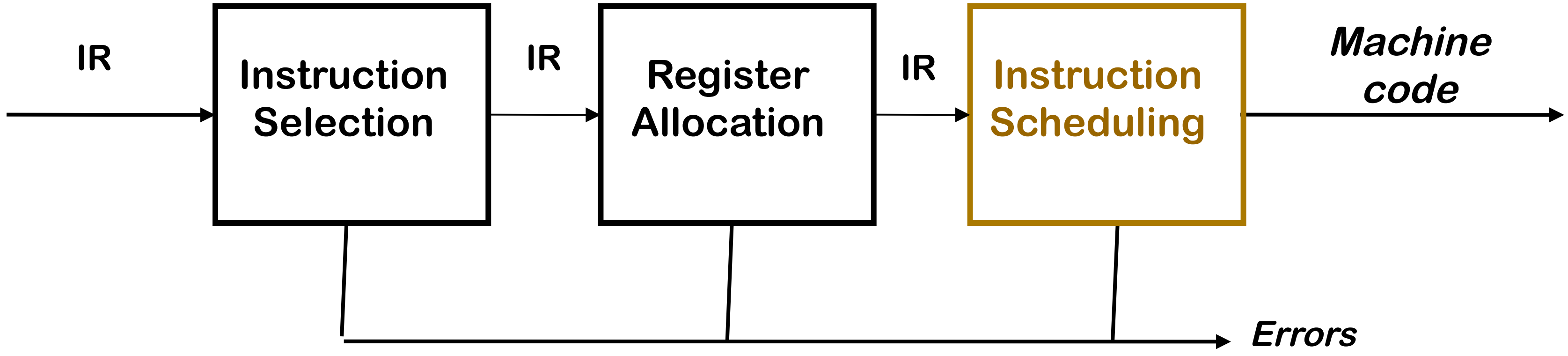
# The Back End




## 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

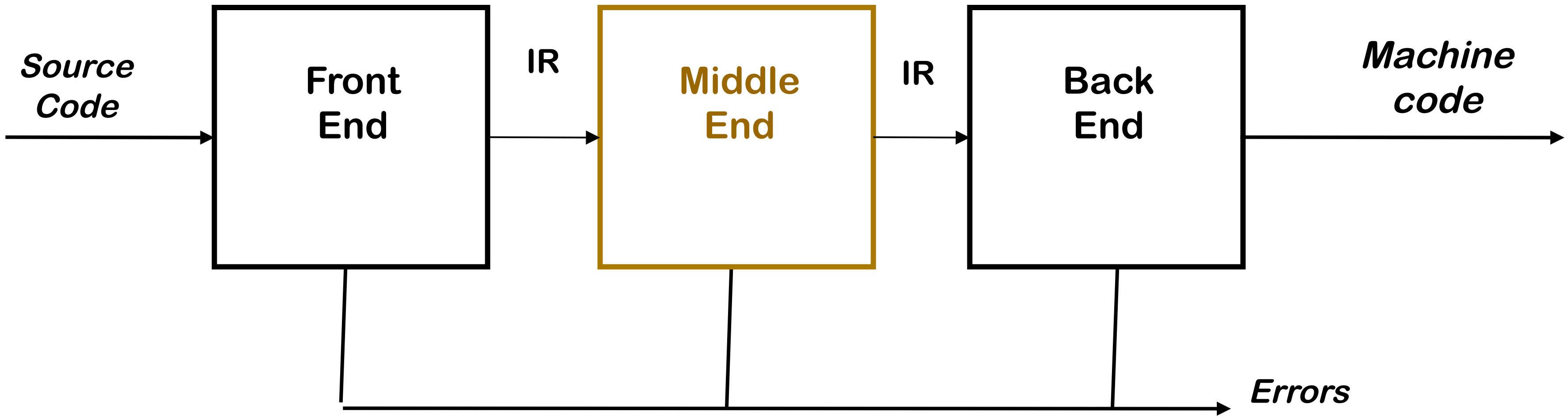
# The Back End




## Instruction Scheduling

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

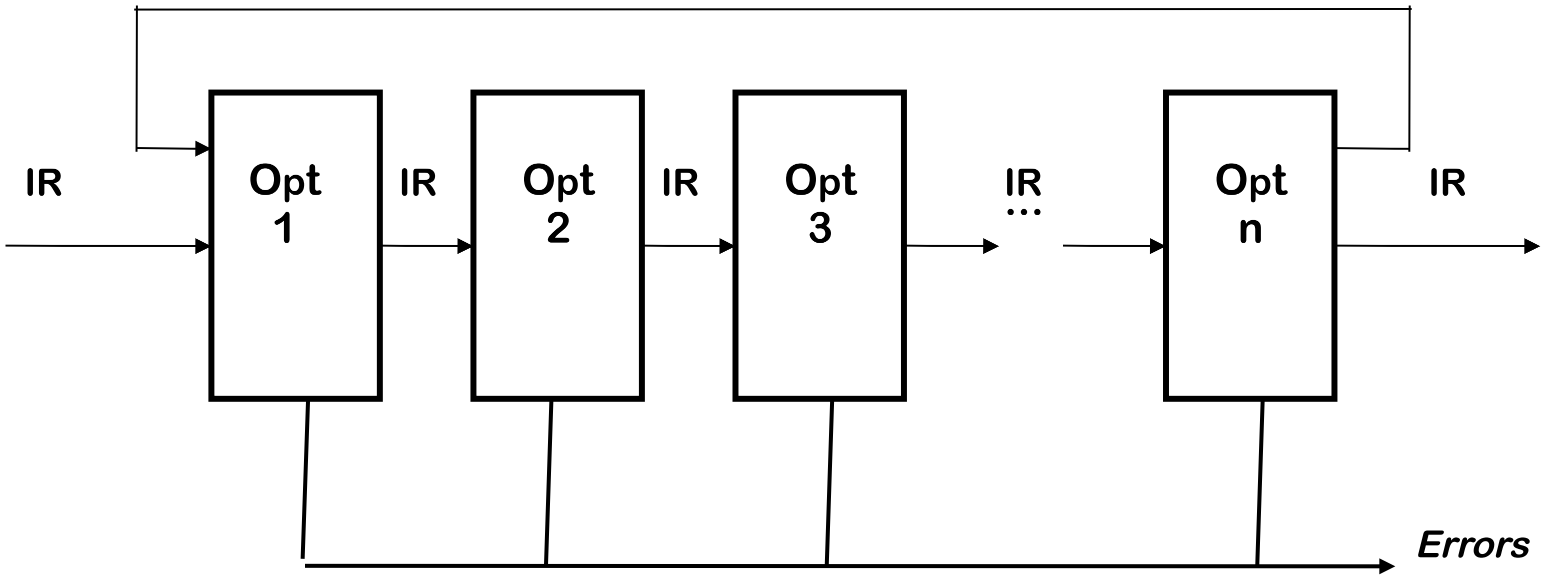
# Traditional Three-pass Compiler




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 this Friday (9/09)