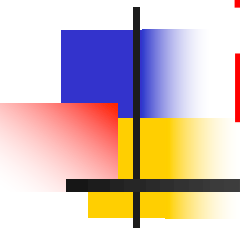

Programming Languages CSCI 4430 Fall 2022

www.cs.rpi.edu/~milanova/csci4430/

Instructor: Ana Milanova

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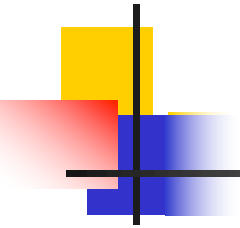
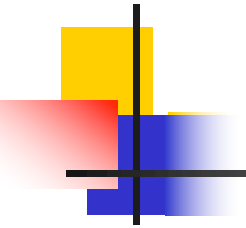
Email: proglang@cs.lists.rpi.edu



Lecture Outline

- Introduction: the rules
  - We are back in the classroom!
- Programming language spectrum
- Why study programming languages?
- Compilation

Read: Scott Chapter 1



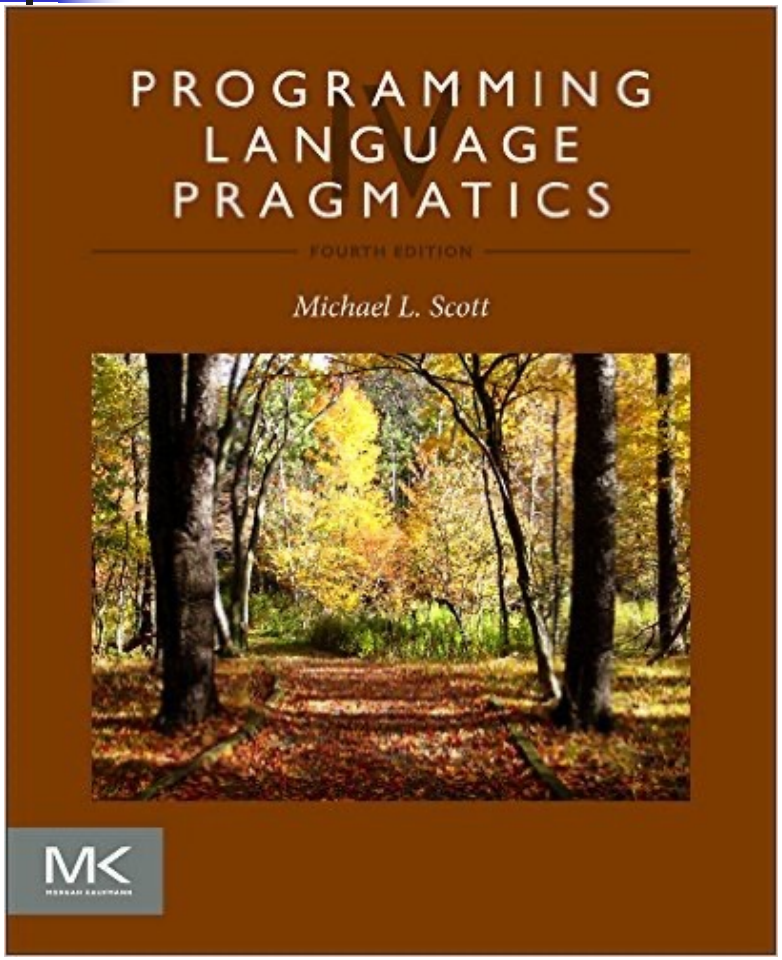
Introduction

- Course webpage

  https://www.cs.rpi.edu/~milanova/csci4430

  - Schedule, Notes, Reading
    - Schedule, lecture slides, assigned reading, and homework links
  - Submitty
    - Homework and quiz submission and grades (Rainbow grades)
    - Discussion forum

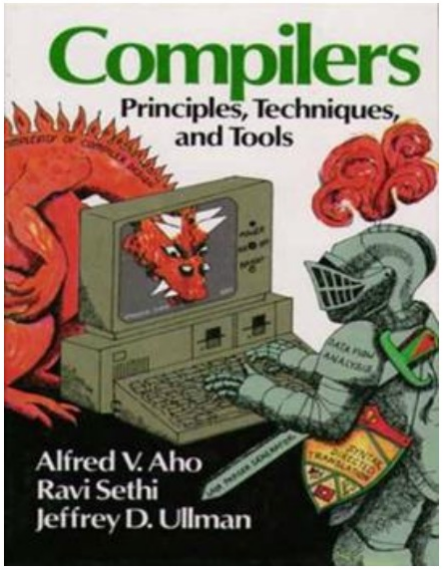
Introduction

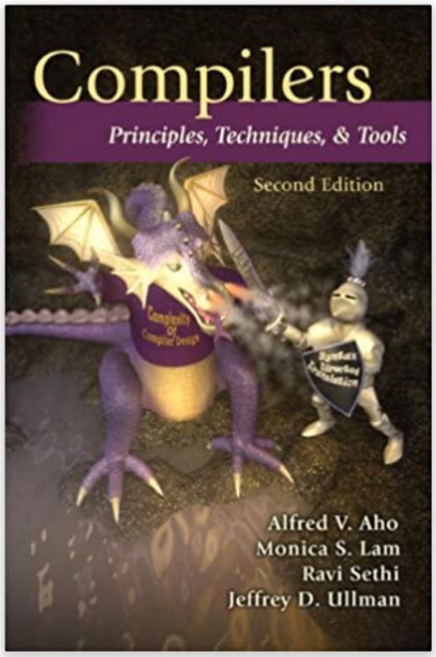


- Required textbook
  - **Programming Language Pragmatics,** 4th Edition, by Michael Scott, Morgan Kaufmann, 2015

Introduction

- Recommended textbook
  - **Compilers: Principles, Techniques, and Tools,** 2nd Edition, by **A. Aho**, M. Lam, R. Sethi and **J. Ullman**, AW, 2007 (Dragon Book)





Aho and Ullman 2020 Turing Award citation:

For fundamental algorithms and theory underlying **programming language implementation** and for synthesizing these results and those of others in their highly influential books, which educated generations of computer scientists.

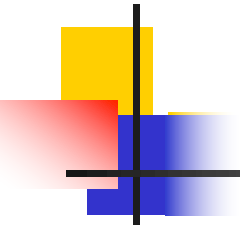
Introduction

- Syllabus

  https://www.cs.rpi.edu/~milanova/csci4430/syllabus.html

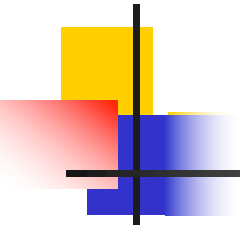
  Topics, outcomes, policies, and grading
- 2 midterm exams and a final exam: 50%
- 7 homework assignments: 42%
- 8 quizzes: 8%

- 1% attendance and participation



Introduction

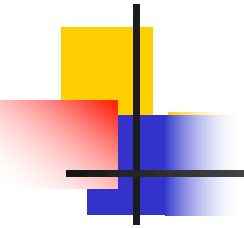
- Lectures are live here in DCC 308 Tuesdays and Fridays 2:00–4:00pm
  - If you are unable to attend due to medical reasons, please notify us by September 9th
- Fall 2020 pre-recorded lectures are available at https://mediasite.mms.rpi.edu/Mediasite5/Channel/programming_languages
- PDF notes: https://www.cs.rpi.edu/~milanova/csci4430/schedule.html



Introduction

- Homework is due at 2pm on the due date
- Submit typed homework as a PDF electronically in Submitty
- Submit programming homework in Submitty for autograding

- Homework, including submission instructions, will be posted at
  - https://www.cs.rpi.edu/~milanova/csci4430/schedule.html

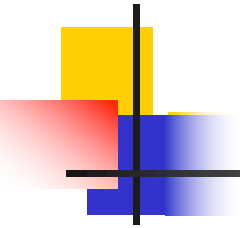


Introduction

- Homework is due at 2pm on the due date

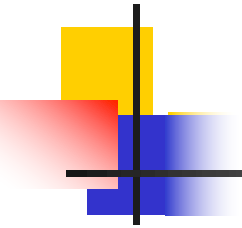
- 6 late days in total
- 2 late days at most per homework

- Extensions only with a formal excuse note from your class dean. See syllabus for details.



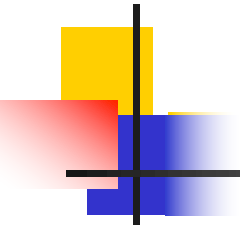
Introduction

- 9 quizzes during scheduled class hours
  - Quiz dates are marked in Schedule
- Will cover material of previous weeks
- Quiz will show on Submitty at 2pm, 10-15min
  - Multiple choice and short answer, upload text file
  - Work in groups is encouraged (4-5 people)
    - Physical attendance not required but encouraged
  - Do not post questions or discussion on public sites/channels!



Introduction

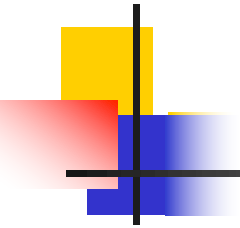
- Exams will be in person in DCC 308
  - If unable to attend due to medical reasons, please notify us by September 9th
- Quiz or exam makeup will be arranged only after we have received an excuse note from your class dean. See syllabus for details.



Introduction

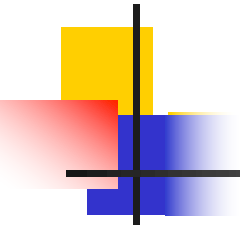
- We plan for ample office hours on Mondays, Wednesdays and Thursdays. TBD.

- Instructor office hours
  - Mondays 12:30-2:30pm in Lally 314. Please wear a mask
  - Immediately after class on Tuesdays and Fridays



Other Notes

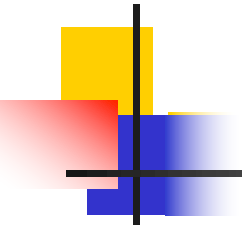
- Asking questions
  - First, go to Submitty forum
    - Do not post code on forum
    - You cannot post code to any website
  - Second, go to office hours
    - Sessions are individual, run through Submitty queues
- We will not be answering questions coming in late at night or in the morning on day HW is due



Other Notes

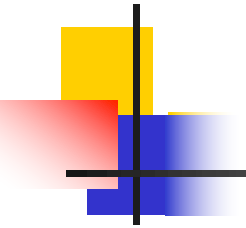
- Submitty forum
  - Announcements – check regularly
  - Ask all non-personal questions on the forum
  - Check out prior messages before you post a question – the answer is probably already there

- Mailing list proglang@cs.lists.rpi.edu (instructors)
  - Personal questions (extensions, grade disputes, etc.)
  - Unsolicited debugging emails to instructors or mailing list will likely go unanswered!



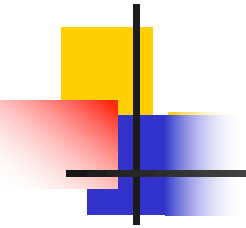
Other Notes

- Debugging and homework help in office hours
  - Instructor, TA and mentor office hours will be finalized by beginning of next week



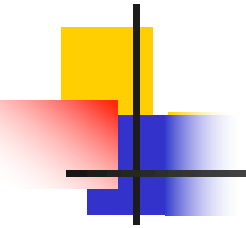
Academic Integrity

- In short, do not copy and do not post solutions or code on public forums or repos
- Excessive similarities between homework submissions will be considered cheating and handled accordingly
- I trust you. Submitty has advanced plagiarism detection tools that course stuff runs regularly



How to Study

- Read textbook chapter in advance of lecture
  - Chapters are announced on Schedule page
- Read/listen lecture and read textbook chapter immediately after class
  - Lecture pdfs will be available shortly before class
- Solve exercises in lectures
- Form study groups
- ASK QUESTIONS – in class, on forum



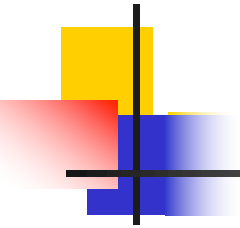
Course Topics

- Programming language syntax: Scanning and parsing
- Programming language semantics: Attribute grammars
- Naming, binding and scoping
- Data abstraction and types
- Control abstraction and parameter passing
- Concurrency

- Logic-oriented language: Prolog
- Functional languages: Scheme and Haskell
- Imperative languages
  - An object-oriented language: Java
  - A dynamic language: Python

Course Topics

- Schedule at www.cs.rpi.edu/~milanova/csci4430/schedule.html
- Lists major and minor topics
- Homework links, dates and due dates
- Quiz and exam schedule



Lecture Outline

- Introduction to the course
- Programming language spectrum
- Why study programming languages?
- Compilation

The Programming Language Spectrum

- Imperative languages
  - Von Neumann languages: Fortran, C,…
  - Object-oriented languages: Java, C++, Smalltalk,…
  - Dynamic languages: Perl, Python, PHP,…
- Declarative languages
  - Functional languages: Scheme/Lisp, ML, Haskell
  - Logic languages: Prolog
  - There are other declarative languages: e.g., dataflow languages

The Programming Language Spectrum

- Imperative languages
  - Evolved from the von Neumann Architecture
  - Variable
  - Assignment Statement

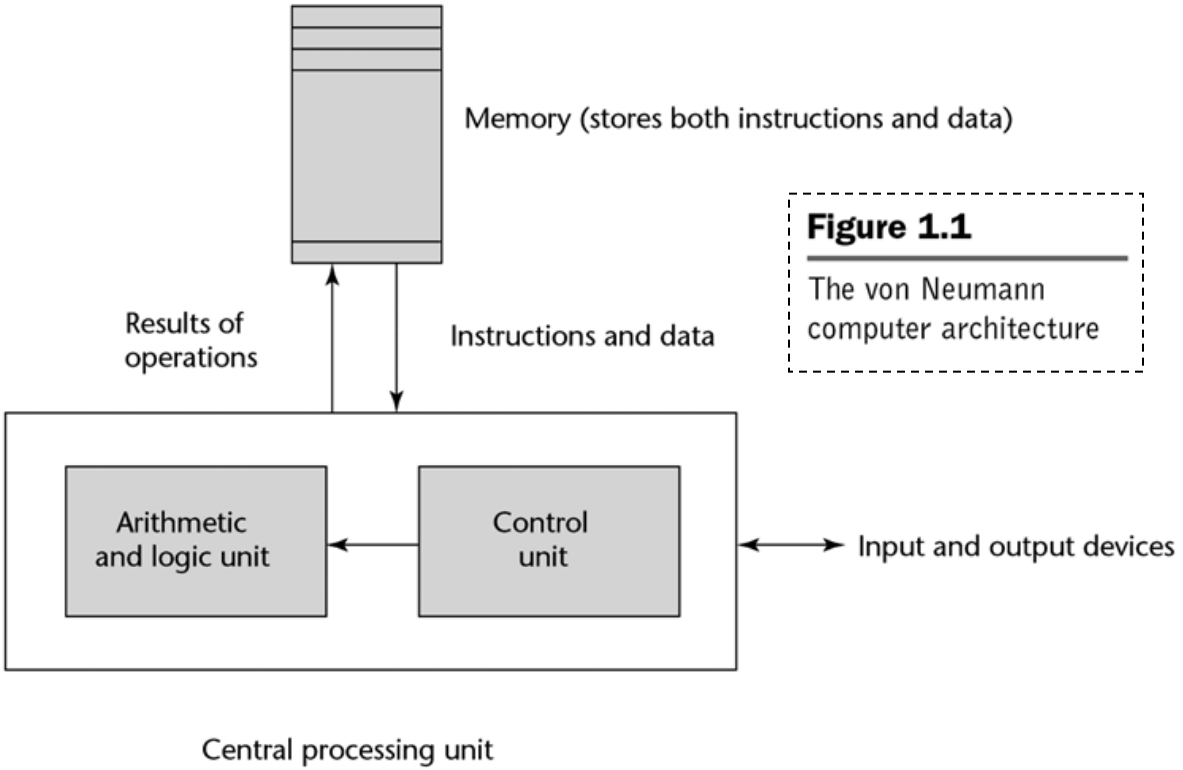


Figure 1.1
The von Neumann computer architecture

The Programming Language Spectrum

- Imperative languages
  - Most widely popular programming style
    - FORTRAN, C, C++, C#, Java, Python, Visual BASIC, Perl, JavaScript, Ruby, etc.
  - Variable and assignment statement are central concepts
  - Program is a sequence of statements:

    j := i – j;

    k := j * l;

    - Execution is a sequence of transitions on memory state

The Programming Language Spectrum

- FORTRAN was invented in mid-1950
- John Backus, the inventor of FORTRAN, wrote the following paper in 1979: "Can programming be liberated from the von Neumann style? A functional style and its algebra of programs"
  - Problems with imperative languages
    - Difficult to understand programs
    - Difficult to reason about correctness of programs

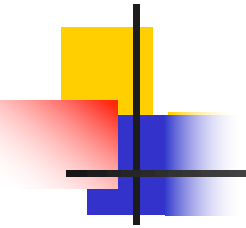
The Programming Language Spectrum

- John Backus 1977 Turing award citation

  … contributions to the design of practical **high-level programming systems**, notably through his work on **FORTRAN**, and for seminal publication of formal procedures for the specification of **programming languages**.

- More history…
  - 1969: Hoare logic and program verification
  - 78-79: Enthusiasm cools, Perlis' paper, Backus' paper
  - 1980-ties and onward: Functional languages

The Programming Language Spectrum



- Functional Programming
  - Main alternative to imperative programming
    - Lisp/Scheme, ML/OCaml, Haskell
  - Program consists of function definitions + evaluation expr

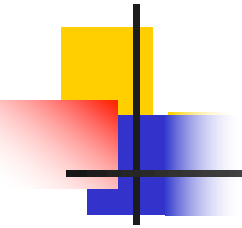
    (fun3 (fun2 (fun1 data)))

    (fun3 (fun2 data2))

    (fun3 data3)

    data4
    - Execution is a sequence of function applications (i.e., reductions)
- Logic Programming
  - Perform queries against knowledge base
  - Prolog, Datalog, SQL

An Example: Inner Product



- Inner product in FORTRAN:

```
1. C := 0;
2. for I := 1 step 1 until N do
3.   T := a[I]*b[I];
4.   C := C + T;
```

- Illustrates state-transition semantics

An Example: Inner Product

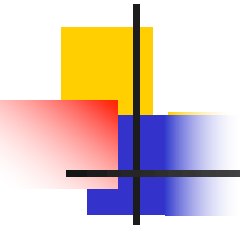
- Inner product in FP:

Function composition

Def IP = (Insert +) ° (ApplyToAll *) ° Transpose

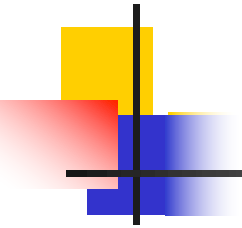
IP <<1,2,3>,<6,5,4>> is
(Insert +) ((ApplyToAll *) (Transpose <<1,2,3>,<6,5,4>>))
(Insert +) ((ApplyToAll *) <<1,6>,<2,5>,<3,4>>)
(Insert +) <6,10,12>
28

- Illustrates reduction (applicative) semantics



Why Study Programming Languages

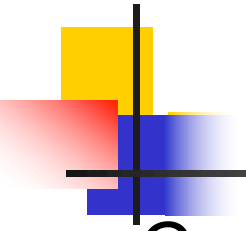
- Goal of the course: learn to analyze programming languages
  - What are the questions we ask when facing a new programming language
  - Helps learn new languages, choose the right language for a problem, understand language features, design languages



Lecture Outline

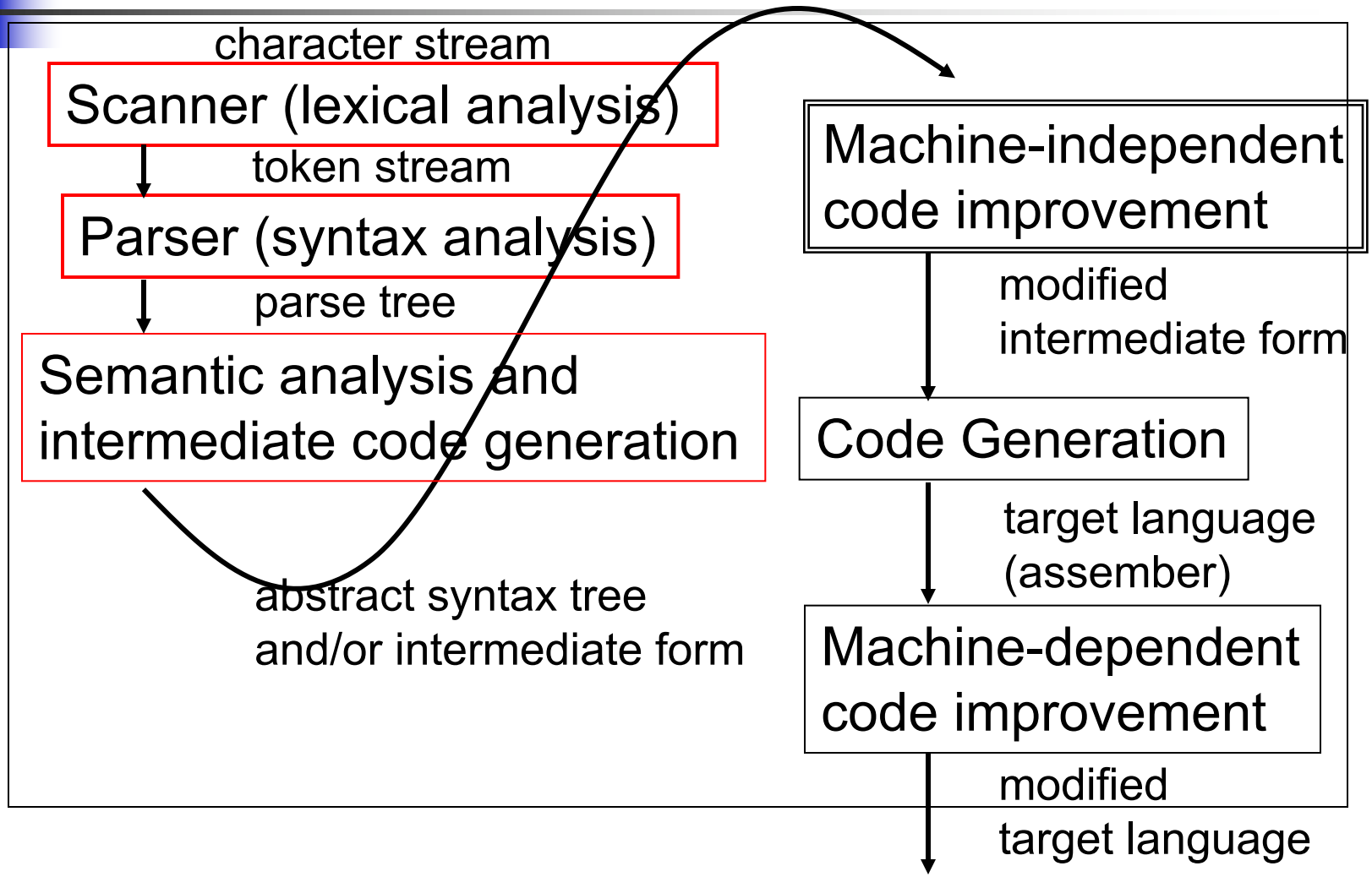
- Introduction to the course
- The programming language spectrum
- Why study programming languages
- Compilation

Compilation and Interpretation



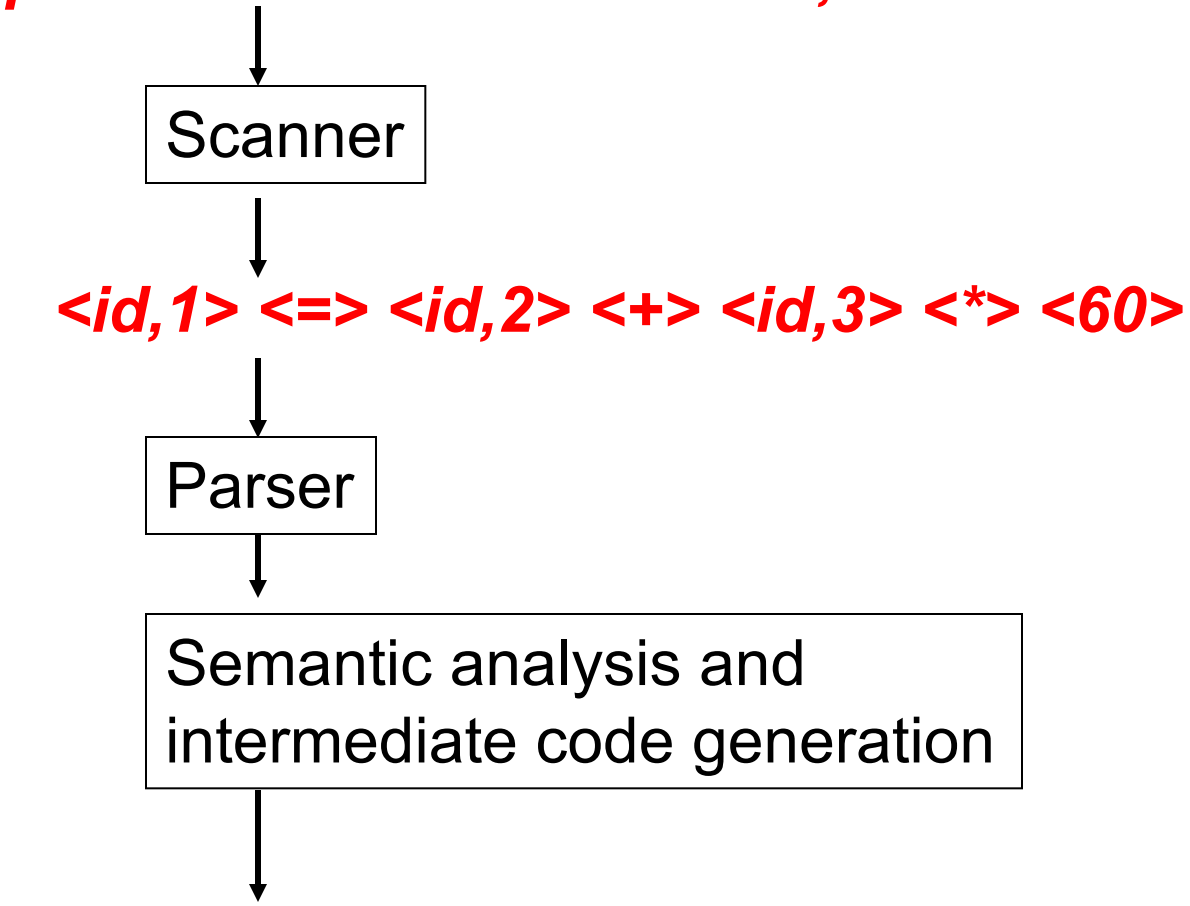
- Compilation
  - Compiler
  - A “high-level” program is translated into executable machine code
- Pure interpretation
  - Interpreter
  - A program is translated and executed one statement at a time
- Hybrid interpretation
  - Both a compiler and an interpreter
  - A program is “compiled” into intermediate code; intermediate code is “interpreted”

Compilation



Compilation

position = initial + rate * 60;

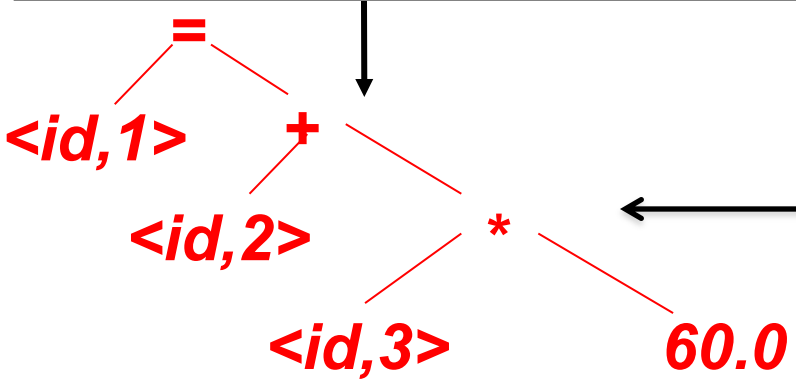


Symbol table

1. ***position***, …
2. ***initial***, …
3. ***rate***, …

Compilation

Semantic analysis and intermediate code generation

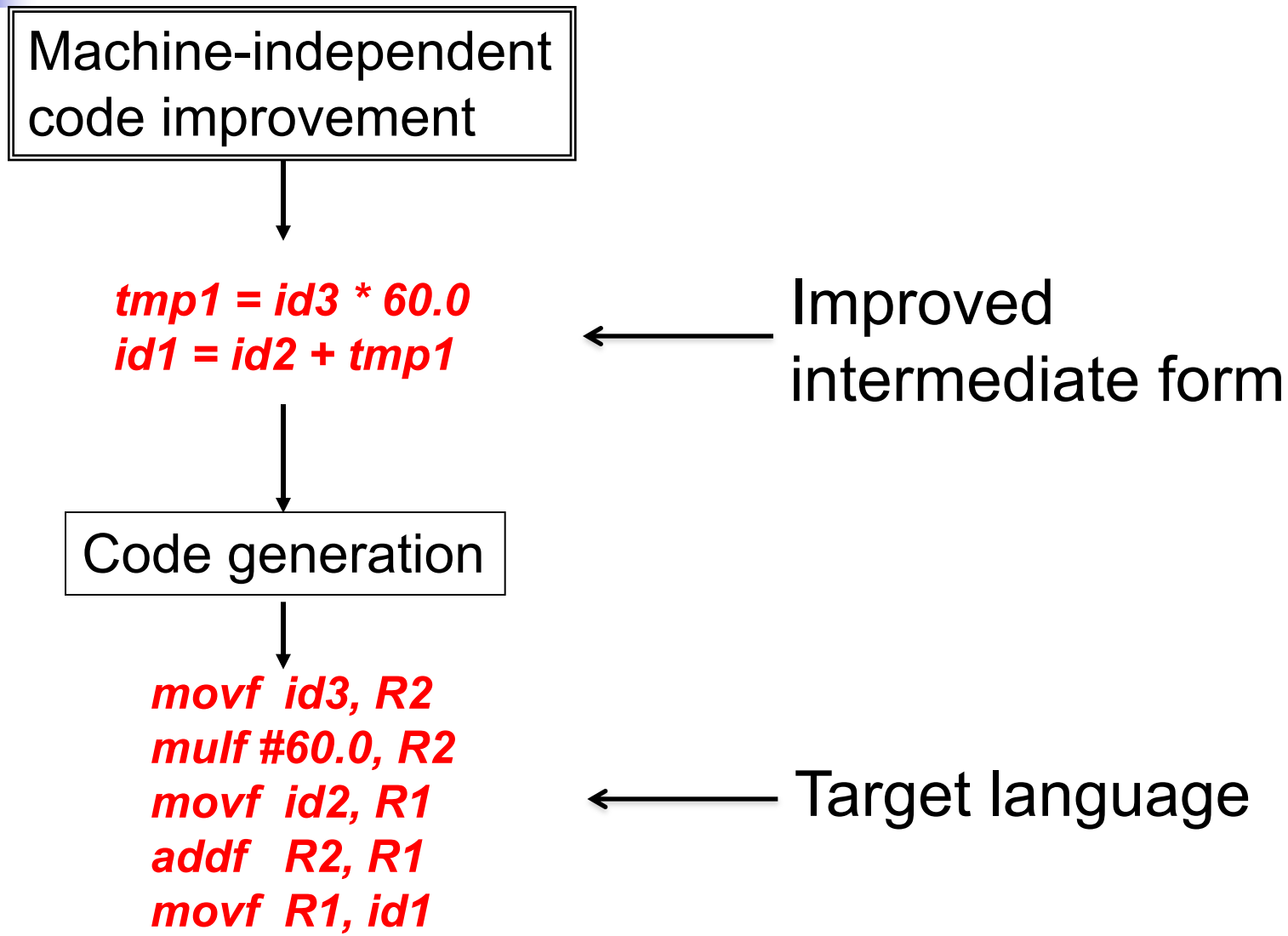


Abstract Syntax Tree

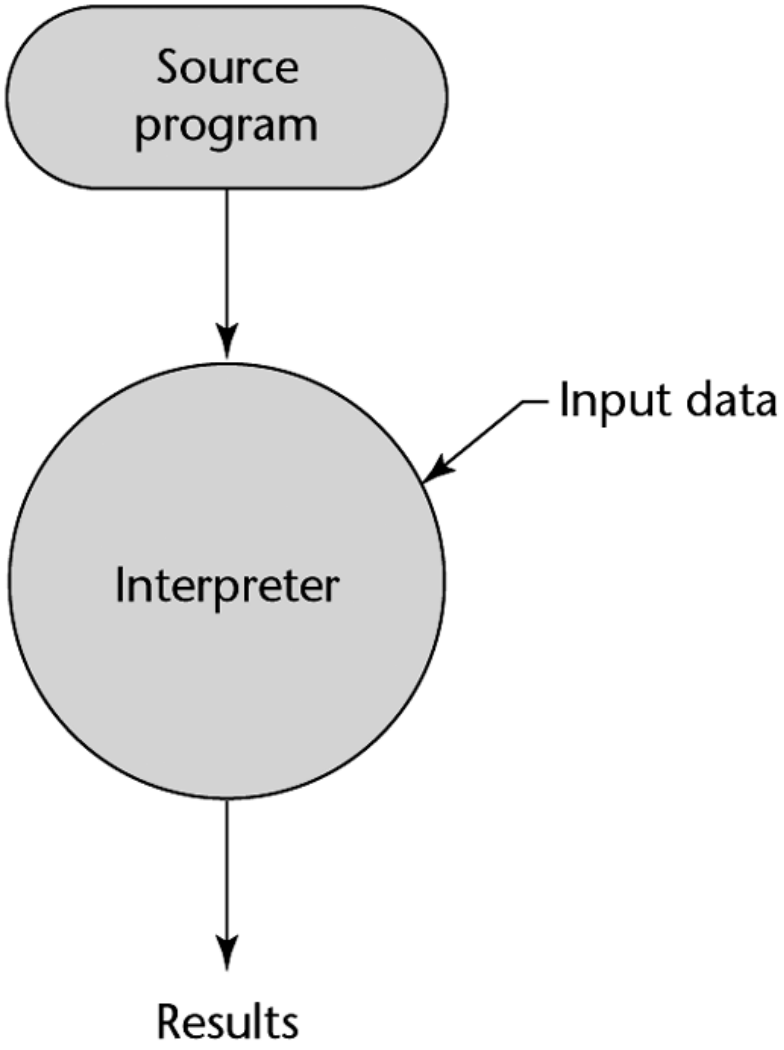
```
tmp1 = id3 * 60.0
tmp2 = id2 + tmp1
id1 = tmp2
```

Intermediate form (three-address code)

Compilation



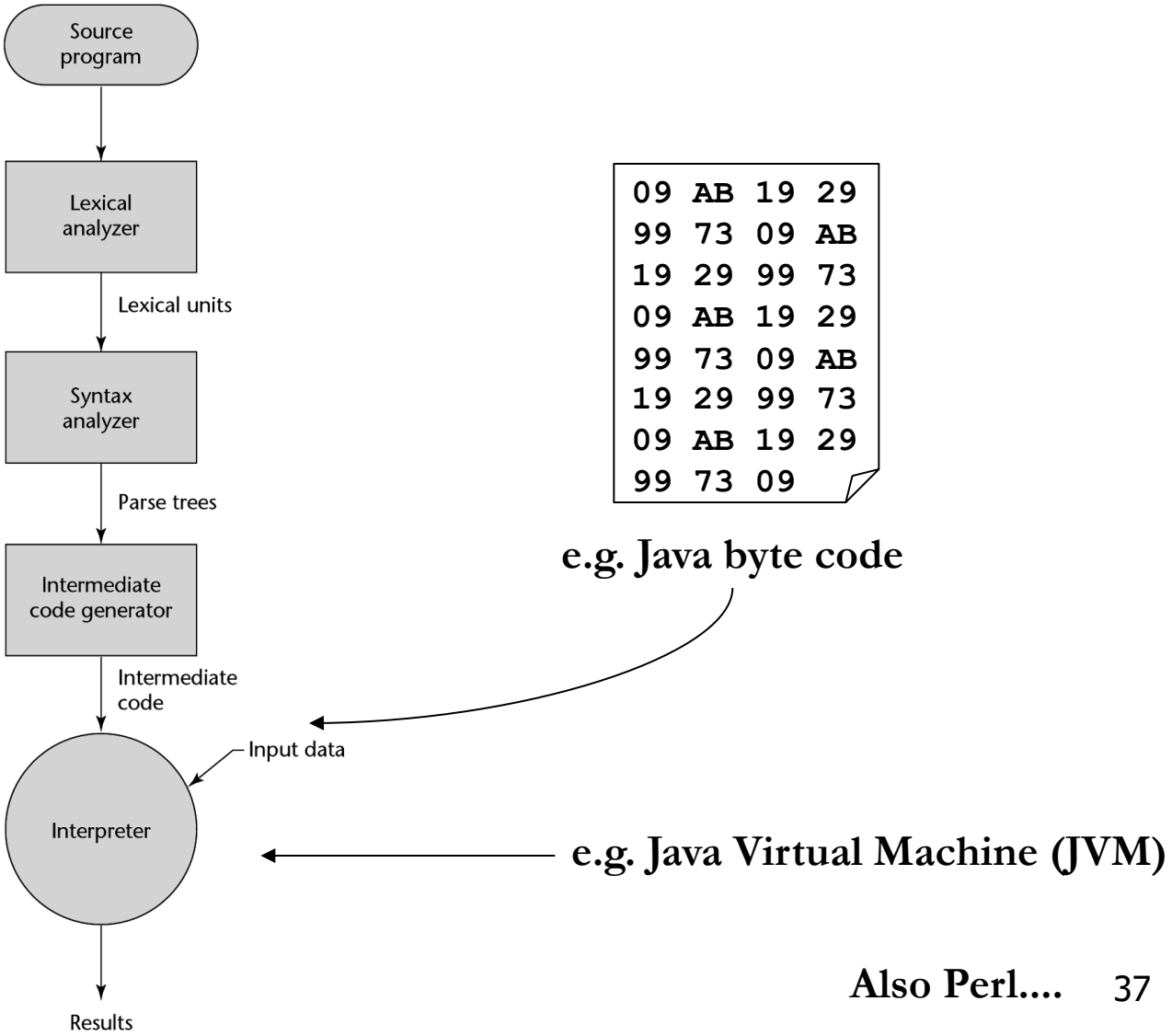
Interpretation



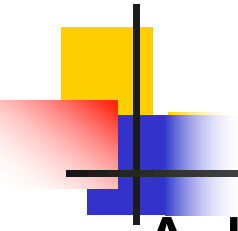
e.g. BASIC

```
REM
COMMENT
LET X = 5
LET Y = 8
PRINT X
PRINT Y
LET Z = X
PRINT Z
...
```

Hybrid Interpretation

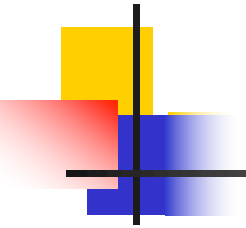


Also Perl....



Compilation vs. Interpretation

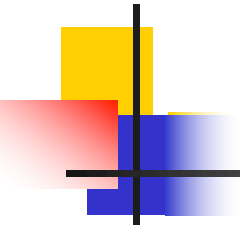
- Advantages of compilation?
  - Faster execution
- Advantages of interpretation?
  - Greater flexibility
    - Dynamic code generation and execution, sandboxing



Compilation vs. Interpretation

- A language can be implemented using a compiler or using an interpreter
  - One can build a compiler for Lisp and one can easily build an interpreter for C or Fortran

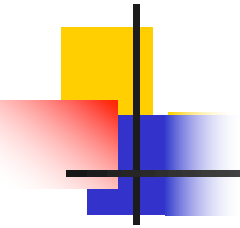
- However, language features (determined during language design) have significant impact on “compilability” and the decision “compiler vs. interpreter”



Next Class

- We will review regular expressions and context free grammars

- Read Chapter 2.1 and 2.2 from Scott's book



The End