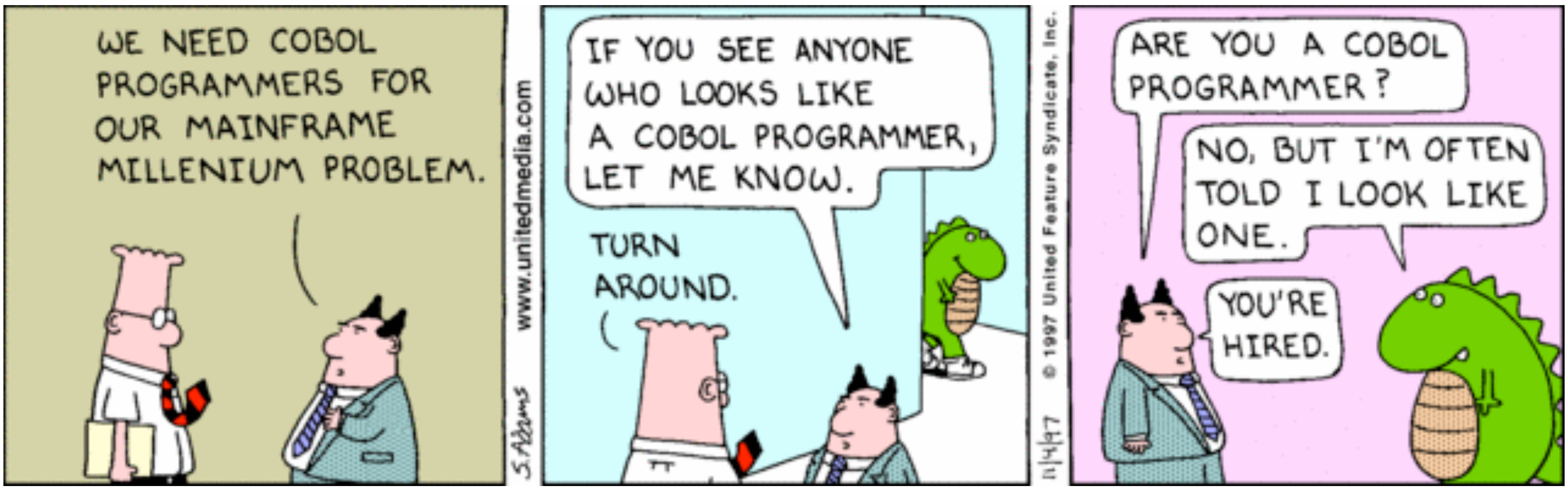
Introduction to Computer Science

CSCI 109



Andrew Goodney

Spring 2018

Readings

St. Amant, Ch. 5

Where are we?

Date	Topic		Assigned	Due	Quizzes/Midterm/Final
20-Aug	Introduction	What is computing, how did computers come to be?			
27-Aug	Computer architecture	How is a modern computer built? Basic architecture and assembly	HW1		
3-Sep	Labor day				
10-Sep	Data structures	Why organize data? Basic structures for organizing data		HW1	
11-Sep	Last day to drop a Monday-only class without a mark of “W” and receive a refund or change to Pass/No Pass or Audit for Session 001				
17-Sep	Data structures	Trees, Graphs and Traversals	HW2		**Quiz 1** on material taught in class 8/20-8/27
24-Sep	More Algorithms/Data Structures	Recursion and run-time			
1-Oct	Complexity and combinatorics	How "long" does it take to run an algorithm.		HW2	**Quiz 2** on material taught in class 9/10-9/24
5-Oct	Last day to drop a course without a mark of “W” on the transcript				
8-Oct	Algorithms and programming	(Somewhat) More complicated algorithms and simple programming constructs			**Quiz 3** on material taught in class 10/1
15-Oct	Operating systems	What is an OS? Why do you need one?	HW3		**Quiz 4** on material taught in class 10/8
22-Oct	Midterm	Midterm			**Midterm** on all material taught so far.
29-Oct	Computer networks	How are networks organized? How is the Internet organized?		HW3	
5-Nov	Artificial intelligence	What is AI? Search, plannning and a quick introduction to machine learning			**Quiz 5** on material taught in class 10/29
9-Nov	Last day to drop a class with a mark of “W” for Session 001				
12-Nov	The limits of computation	What can (and can't) be computed?	HW4		**Quiz 6** on material taught in class 11/5
19-Nov	Robotics	Robotics: background and modern systems (e.g., self-driving cars)			**Quiz 7** on material taught in class 11/12
26-Nov	Summary, recap, review	Summary, recap, review for final		HW4	**Quiz 8** on material taught in class 11/19
7-Dec	Final exam 11 am - 1 pm in SGM 123				**Final** on all material covered in the semester

Side Note

- Two things funny/note worthy about this cartoon
- #1 is COBOL (we'll talk about that later)
- #2 is ??

"Y2k Bug"

- Y2K bug??
- In the 1970's-1980's how to store a date?
- Use MM/DD/YY
  - More efficient – every byte counts (especially then)
- What is/was the issue?
- What was the assumption here?
  - "No way my COBOL program will still be in use 25+ years from now"
- Wrong!

Agenda

- What is a program
- Brief History of High-Level Languages
- Very Brief Introduction to Compilers
- ”Robot Example”
- Quiz

What is a Program?

- A set of instructions expressed in a language the computer can understand (and therefore execute)
- *Algorithm*: abstract (usually expressed 'loosely' e.g., in English or a kind of programming pidgin)
- *Program*: concrete (expressed in a computer language with precise syntax)
  - Why does it need to be precise?

Programming in Machine Language is Hard

- CPU performs *fetch-decode-execute* cycle millions of time a second
- Each time, one instruction is fetched, decoded and executed
- Each instruction is very simple (e.g., move item from memory to register, add contents of two registers, etc.)
- To write a sophisticated program as a sequence of these simple instructions is very difficult (impossible) for humans

Machine Language Example

ex1.c

```c
int main()
{
	int x = 5;
	while(x > 0)
	{
		x = x - 1;
	}
}
```

Machine Language Example

ex1.c

```c
int main()
{
    int x = 5;
    while(x > 0)
    {
        x = x - 1;
    }
}
```

3872	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
3916	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
3960	00000000	00000000	554889E5	C745FC00	000000C7	45F80500	0000837D	F8000F8E	0E000000	8B45F883	E8018945
4004	F8E9E8FF	FFFF8B45	FC5DC390	01000000	1C000000	00000000	1C000000	00000000	1C000000	02000000	800F0000
4048	34000000	34000000	B00F0000	00000000	34000000	03000000	0C000100	10000100	00000000	00000001	00000000
4092	00000000	00015F00	0500025F	6D685F65	78656375	74655F68	65616465	7200216D	61696E00	25020000	00030080
4136	1F000000	00000000	801F0000	00000000	2D000000	64000000	00000000	00000000	47000000	64000000	00000000
4180	00000000	4D000000	66030100	05BADA59	00000000	01000000	2E010000	800F0000	01000000	8B000000	24010000
4224	800F0000	01000000	01000000	24000000	2F000000	00000000	01000000	4E010000	2F000000	00000000	01000000
4268	64010000	00000000	00000000	02000000	0F011000	00000000	01000000	16000000	0F010000	800F0000	01000000
4312	1C000000	01000001	00000000	00000000	20005F5F	6D685F65	78656375	74655F68	65616465	72005F6D	61696E00
4356	64796C64	5F737475	625F6269	6E646572	002F5573	6572732F	676F6F64	6E65792F	7372632F	63733130	392F0065
4400	78312E63	002F7661	722F666F	6C646572	732F6E30	2F5F3368	5F633132	31363337	66633535	66763476	32313932
4444	38303030	30676E2F	542F6578	312D3065	33623133	2E6F005F	6D61696E	00000000	00000000		

Assembly Language Example

- Machine code is impossible, assembly language is very hard

ex1.c

```c
int main()
{
    int x = 5;
    while(x > 0)
    {
        x = x - 1;
    }
}
```

```asm
        push    rbp
        mov     rbp, rsp
        mov     dword [rbp+var_4], 0x0
        mov     dword [rbp+var_8], 0x5

loc_100000f92:
        cmp     dword [rbp+var_8], 0x0
        jle     loc_100000faa

        mov     eax, dword [rbp+var_8]
        sub     eax, 0x1
        mov     dword [rbp+var_8], eax
        jmp     loc_100000f92

loc_100000faa:
        mov     eax, dword [rbp+var_4]
        pop     rbp
        ret
```

How to Program

- Machine code is hard
- Assembly doesn't scale
- Need to use High Level Language

High Level Languages

- High Level Languages let us express algorithms in “English like” syntax
- Provide *tons* of abstractions that let us:
  - Define basic data types (text, integers, floating point) and operations
  - Define abstract data types (trees, graphs, lists, whatever!)
  - Interact with users (GUIs)
  - Interact with OS for file I/O, network I/O
- Provide a full compile/execution stack:
  - code -> assembly -> machine code
  - code -> byte code -> VM (-> machine code)

High Level Languages

Language Rank	Types	Spectrum Ranking
1. Python		100.0
2. C++		99.7
3. Java		97.5
4. C		96.7
5. C#		89.4
6. PHP		84.9
7. R		82.9
8. JavaScript		82.6
9. Go		76.4
10. Assembly		74.1

Oct 2018	Oct 2017	Change	Programming Language	Ratings	Change
1	1		Java	17.801%	+5.37%
2	2		C	15.376%	+7.00%
3	3		C++	7.593%	+2.59%
4	5		Python	7.156%	+3.35%
5	8		Visual Basic .NET	5.884%	+3.15%
6	4		C#	3.485%	-0.37%
7	7		PHP	2.794%	+0.00%
8	6		JavaScript	2.280%	-0.73%
9	-		SQL	2.038%	+2.04%
10	16		Swift	1.500%	-0.17%

https://spectrum.ieee.org/

https://www.tiobe.com/tiobe-index/

High Level Language History

- To understand where we are in 2018, we need some history
- 1950's many "main frame" computers were being built
- Programmed in machine code
  - Usually using punch-cards!
- Error prone, costly (human resources)
- Lots of people/projects, but two stand out:
  - Grace Hopper (US Navy and others)
  - John Backus (IBM)

Rear Admiral Dr. Grace Hopper

- Many accomplishments in the field of computer science
- Pioneered the idea that programmers should write code in English like syntax: “It’s much easier for most people to write an English statement than it is to use symbols. So I decided data processors ought to be able to write their programs in English, and the computers would translate them into machine code.”
- Pioneered the idea that code should be compiled to machine code

A-0

- Dr. Hopper’s work towards ”English” programming was incremental
- 1952 at UNIVAC released A-0
- Linked together precompiled sub-routines with arguments into programs
- Probably the first “useful” compiled language
- Subroutines had a number, arguments were given
- 15 3 2; 17 3.14;
- 15 = power(3, 2); 17 = sin(3.14)
- Can’t find existing example of this version

A-2

- Dr. Hopper followed up with A-1 and then A-2 in 1953
- Even closer to our modern idea of a programming language
- Still can't find code examples
  - https://www.mirrorservice.org/sites/www.bitsavers.org/pdf/computersAndAutomation/195509.pdf

BASIC ELEMENTS OF THE A-2 COMPILER SYSTEM

Four basic elements are fundamental to the operation of the A-2 Compiler System. They are:

1. Sub-Routines
2. Library
3. Pseudo-Code
4. Compiler

SUB-ROUTINES. A sub-routine may be defined as a set of instructions necessary to direct the computer to carry out a well defined mathematical or logical operation. For our specific purposes it is a list or set of "C-10" coded instructions. A typical sub-routine may be one that is coded to calculate the sine of an angle, or perform the four basic arithmetic operations of addition, subtraction, multiplication, or division.

LIBRARY. A library is an ordered set or collection of standard and proven sub-routines. In the A-2 Compiler System, these sub-routines are permanently recorded and stored on magnetic tape in alphabetical order.

PSEUDO-CODE. Pseudo-code is a special code which must be translated into computer code if it is to direct the computer. The A-2 Compiler Pseudo-Code is intelligible to the Compiler System only (unintelligible to the computer itself).

THE COMPILER. The A-2 Compiler is a Master Routine which translates the pseudo-code into computer code (C-10). This translation must always be performed prior to the actual solution of the problem since Univac will only execute coded instructions expressed in its own language.

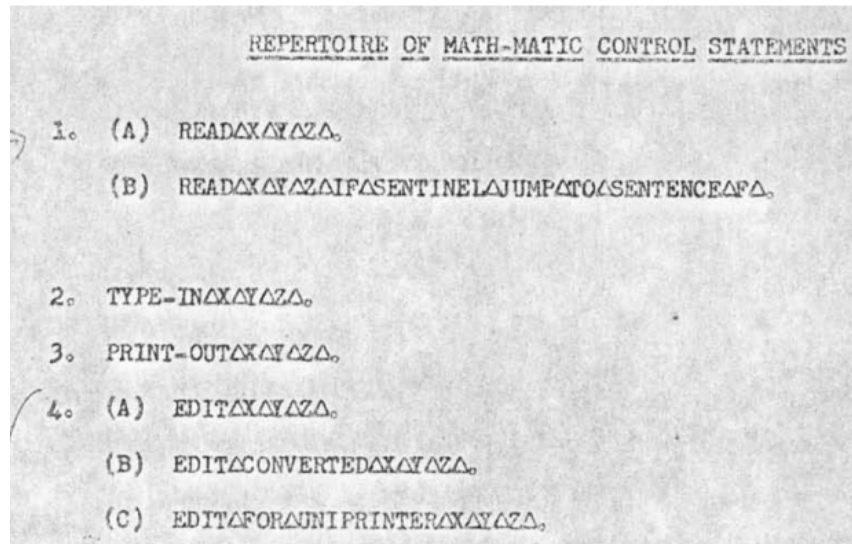
More Hopper Quotes

In answer to questions from J. W. Backus, Dr. Hopper showed how to code the evaluation of the scalar product of two vectors. She said that matrix operations were coded using a special matrix library.

E. A. Voorhees asked whether the compiler was used because people were dissatisfied with the machine. Dr. Hopper replied that the reason was solely to simplify and shorten coding. A 3-address code was used merely because it

A series continued

- Work continued on the A series of languages
- A3 and AT3 could compile for more than one machine – high level code was "portable"



REPERTOIRE OF MATH-MATIC CONTROL STATEMENTS

1. (A) READΔXΔYΔZΔ.

   (B) READΔXΔYΔZΔIFΔSENTINELΔJUMPΔTOΔSENTENCEΔFΔ.

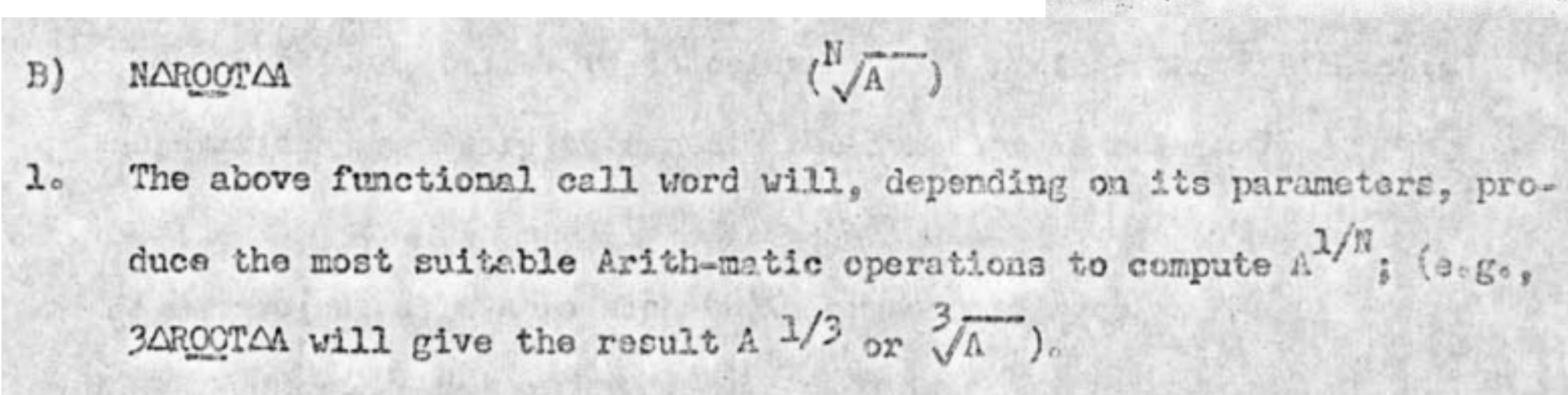
2. TYPE-INΔXΔYΔZΔ.

3. PRINT-OUTΔXΔYΔZΔ.

4. (A) EDITΔXΔYΔZΔ.

   (B) EDITΔCONVERTEDΔXΔYΔZΔ.

   (C) EDITΔFORΔUNIPRINTERΔXΔYΔZΔ.



B) NΔROOTΔA ($\sqrt[N]{A}$)

1. The above functional call word will, depending on its parameters, produce the most suitable Arith-matic operations to compute $A^{1/N}$; (e.g., 3ΔROOTΔA will give the result $A^{1/3}$ or $\sqrt[3]{A}$).

Flow-Matic

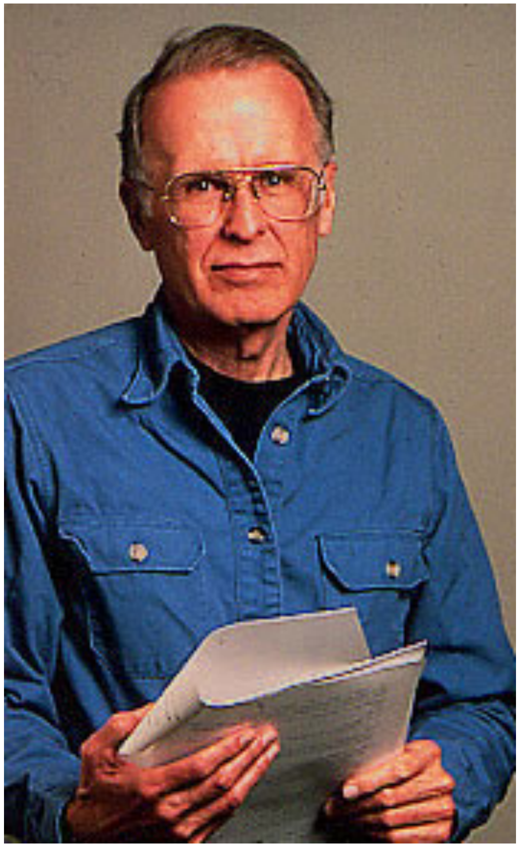
- B-0 “Flow-Matic”
- Internet is amazing! We have the Flow-Matic advertising handout.

A-series, B-o lineage

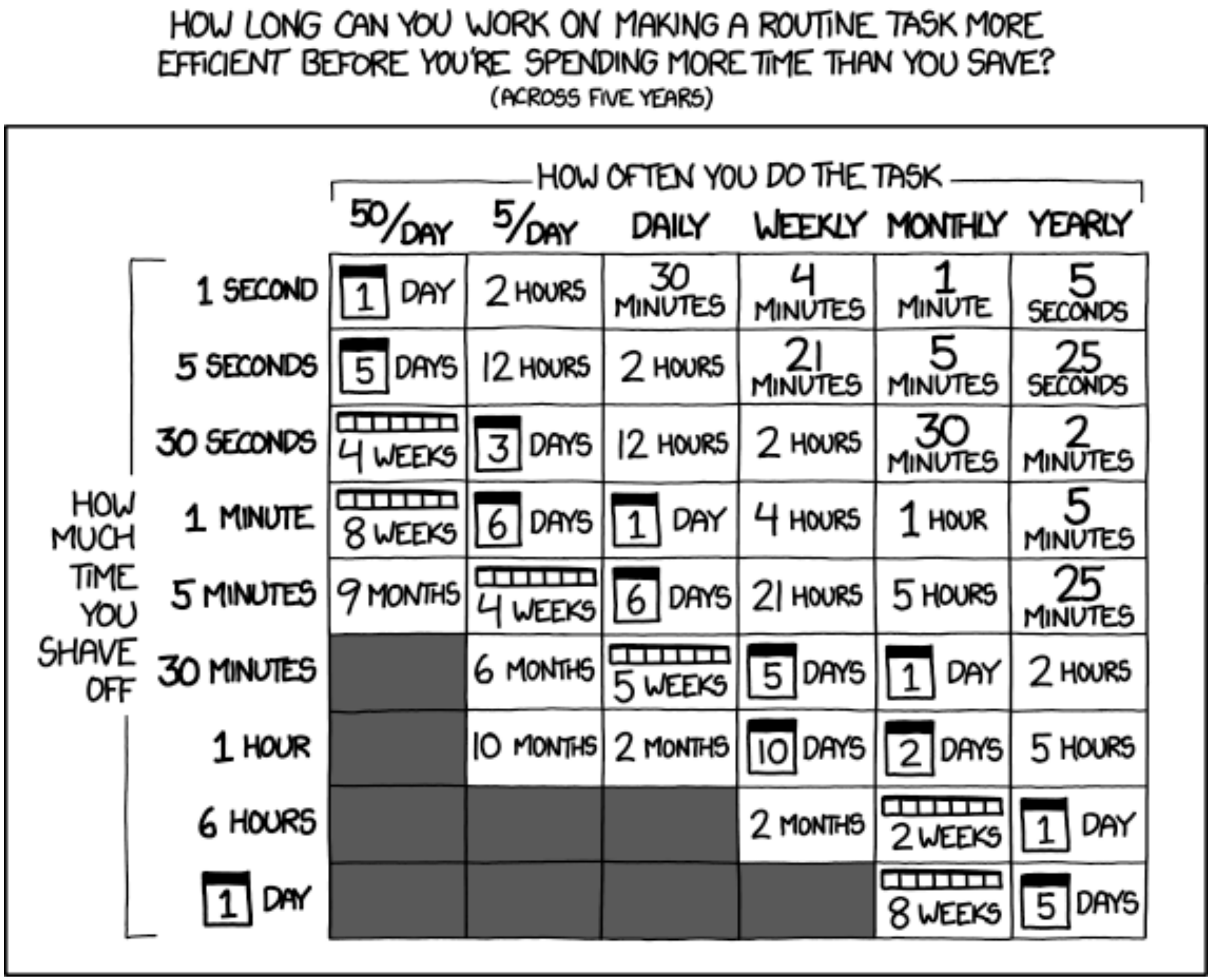
- The A-series and B-0 brings us to our first living fossil COBOL
  - “Common business-oriented language”
- Designed for business processing, not computer science
- “COBOL has an English-like syntax, which was designed to be self-documenting and highly readable.”
- Released in 1959
  - Still in heavy use: financial industries, airlines

FORTRAN

- John Backus at IBM developed FORTRAN
  - FORmula TRANslation
- First high-level language, proposed 1954, compiler delivered 1957
- "Much of my work has come from being lazy. I didn't like writing programs, and so, when I was working on the IBM 701, writing programs for computing missile trajectories, I started work on a programming system to make it easier to write programs."
- Backus won a Turing Award, among many other accolades



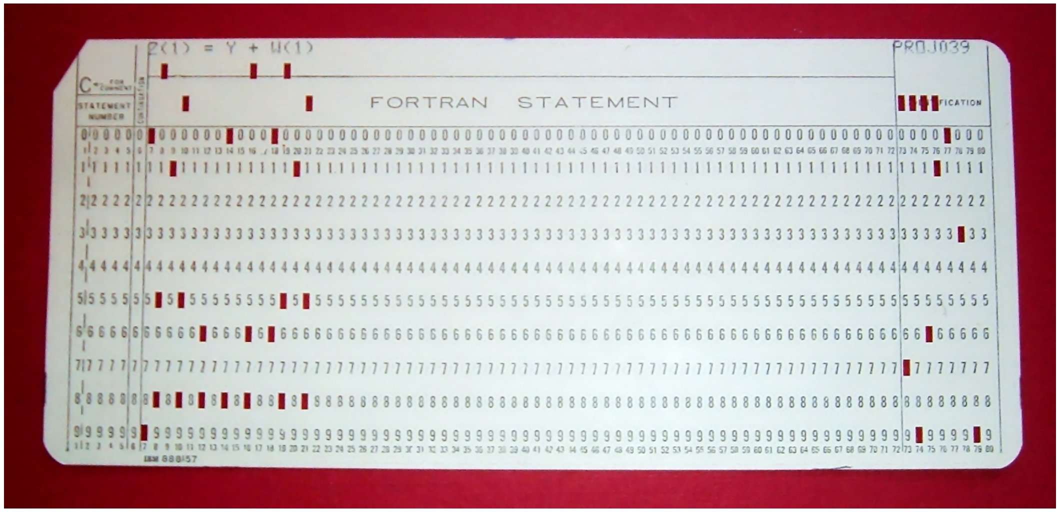
Being lazy isn't all bad…



https://xkcd.com/1205/

FORTRAN

- FORTRAN was adopted by academics and scientific computing community
- Originally programmed on punch cards
- Many developments in compilers were driven by the need to optimize FORTRAN -> machine code generation



https://upload.wikimedia.org/wikipedia/commons/5/58/FortranCardPROJ039.agr.jpg

FORTRAN Example

A Program in FORTRAN 77

```
 Program Example

C Fortran Example program
C Input:  An integer, ListLen, where ListLen is less
C         than 100, follows by List_Len-Integer values
C Output: The number of input values that are greater
C         than the average of all input values
      INTEGER INTLIST(99)
      INTEGER LISTLEN, COUNTER, SUM, AVERAGE, RESULT
      RESULT = 0
      SUM = 0
      READ *, LISTLEN
      IF ((LISTLEN .GT. 0) .AND. (LISTLEN .LT. 100)) THEN
C Read Input data into an array and compute its sum
        DO 101 COUNTER = 1, LISTLEN
          READ *, INTLIST(COUNTER)
          SUM = SUM + INTLIST(COUNTER)
  101   CONTINUE
```

```
  program cable
!
! this program computes the velocity of a cable car on a thousand-foot
! cable with three towers
!
  integer :: totdis, dist, tower

  write(*,1)
  1 format('1', 9x,'cable car report'/' ','distance', 2x,'nearest tower', 2x, &
         'velocity'/1x,2x, '(ft)', 19x, '(ft/sec)')

  totdis = 0

  do while (totdis <= 1000)

    if (totdis <= 250) then
        tower = 1
        dist = totdis
    else if (totdis <= 750) then
        tower = 2
        dist = iabs(totdis - 500)
    else
        tower = 3
        dist = 1000 - totdis
    end if

    if (dist <= 30) then
        vel = 2.425 + 0.00175*dist*dist
    else
        vel = 0.625 + 0.12*dist - 0.00025*dist*dist
    end if

    write(*,40) totdis, tower, vel
 40 format(' ',i4,11x,i1,9x,f7.2)

    totdis = totdis + 10

  end do

  end
```

COBOL, Fortran...

- Hopper and Backus’ work gave us high-level, compiled languages
- English-like syntax
- Portable across many machine types
  - By 1963 ~40 FORTRAN compilers existed for various machines
  - Write code one, run any where
- Led to an explosion in languages developed by industry and computer scientists
- One more family is worth visiting

BCPL

- Basic Combined Programming Language
  - Martin Richards, Cambridge 1966
  - Originally intended to “bootstrap” or help write compilers for other languages (how meta!)
  - Progenitor of the curly brace!
  - Supposedly the first ”Hello World” program was in BCPL

```
GET "LIBHDR"

LET START() = VALOF {
        FOR I = 1 TO 5 DO
                WRITEF("%N! = %I4*N", I, FACT(I))
        RESULTIS 0
}

AND FACT(N) = N = 0 -> 1, N * FACT(N - 1)
```

B

- B – stripped down version of BCPL
- Developed at Bell Labs circa 1969 by Ken Thomson and Dennis Ritchie
- Gave us = for assignment, == for equality, =+ for “plus-equals”, ++ and -- for increment/decrement

```
/* The following function will print a non-negative number, n,
   to   the base b, where 2<=b<=10.  This routine uses the fact that
   in the ASCII character set, the digits 0 to 9 have sequential
   code values.  */

printn(n, b) {
        extrn putchar;
        auto a;
        if (a = n / b)        /* assignment, not test for equality */
                printn(a, b); /* recursive */
        putchar(n % b + '0');
}
```

B is followed by C

- Bell Labs developed original version of UNIX in assembly language
- Wanted to re-write UNIX in high-level language for PDP-11
- B couldn’t work well on PDP-11
- Dennis Ritchie expanded B into C (that we know and love)
- Designed with a simple compiler in mind
- Designed to give low-level access to memory
- Parts of UNIX rewritten into C in early 1970’s are still around in macOS (40+ years later!)

C code

- C gave us Objective-C, C++
  - Swift, Rust
- Syntax directly influenced Java, C#

ex1.c

```c
int main()
{
	int x = 5;
	while(x > 0)
	{
		x = x - 1;
	}
}
```

High Level Programming as an Abstraction

- High-level languages based on some observations:
  - Machine code/assembly is too hard to program effectively
  - In the end we don’t care about the details of the computer
- High-level languages program an ’abstract machine’
  - Simple programming model, simple memory model, sequential execution, etc.
  - The machine doesn’t exist, but that doesn’t matter
- High-level languages translate, or compile code from the ’abstract machine’ to the real computer

Very Brief Introduction to Compilers

- All high level languages must be compiled in some sense
- High level languages are a sequence of statements
  - Each statement stands for some number of assembly language (or machine language) statements
- At a high-level the compiler merely translates from a known set of statements to a known set of assembly language statements
- However, the statements can be lexigraphically complex and we need to consider things like memory, variables, functions, the stack…etc.
- Also we need to consider how to compile code for different machine (architectures)
  - C-code can run on fastest super-computer and smallest microcontroller

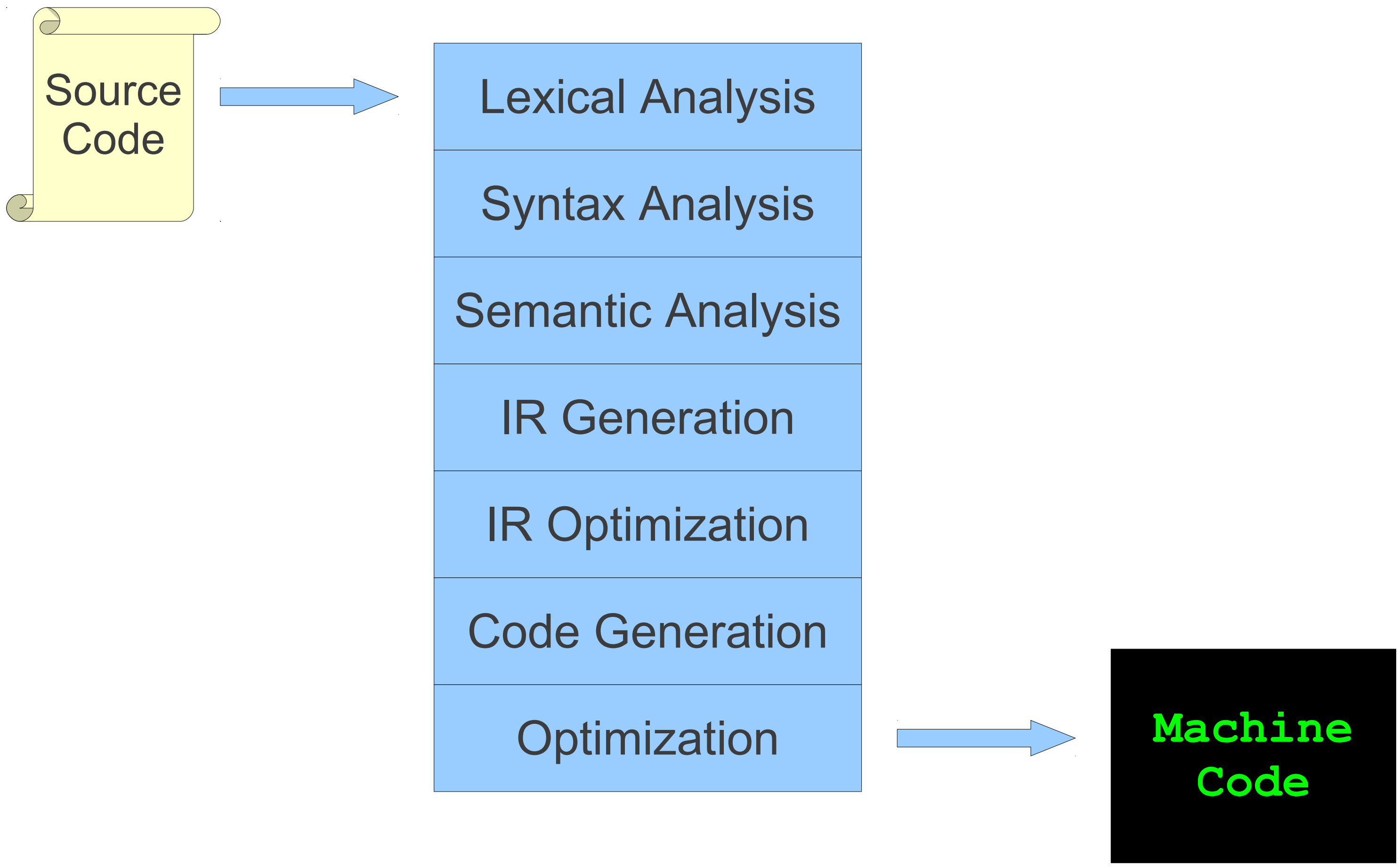
What is a compiler?

- Compiler is a piece of software
- Inputs:
  - High-level code
  - Target machine architecture
  - Optional inputs: OS type/version, memory size or restrictions, CPU specific optimizations, cache size, etc.
- Output:
  - Machine code (binary data) for execution on specific machine type

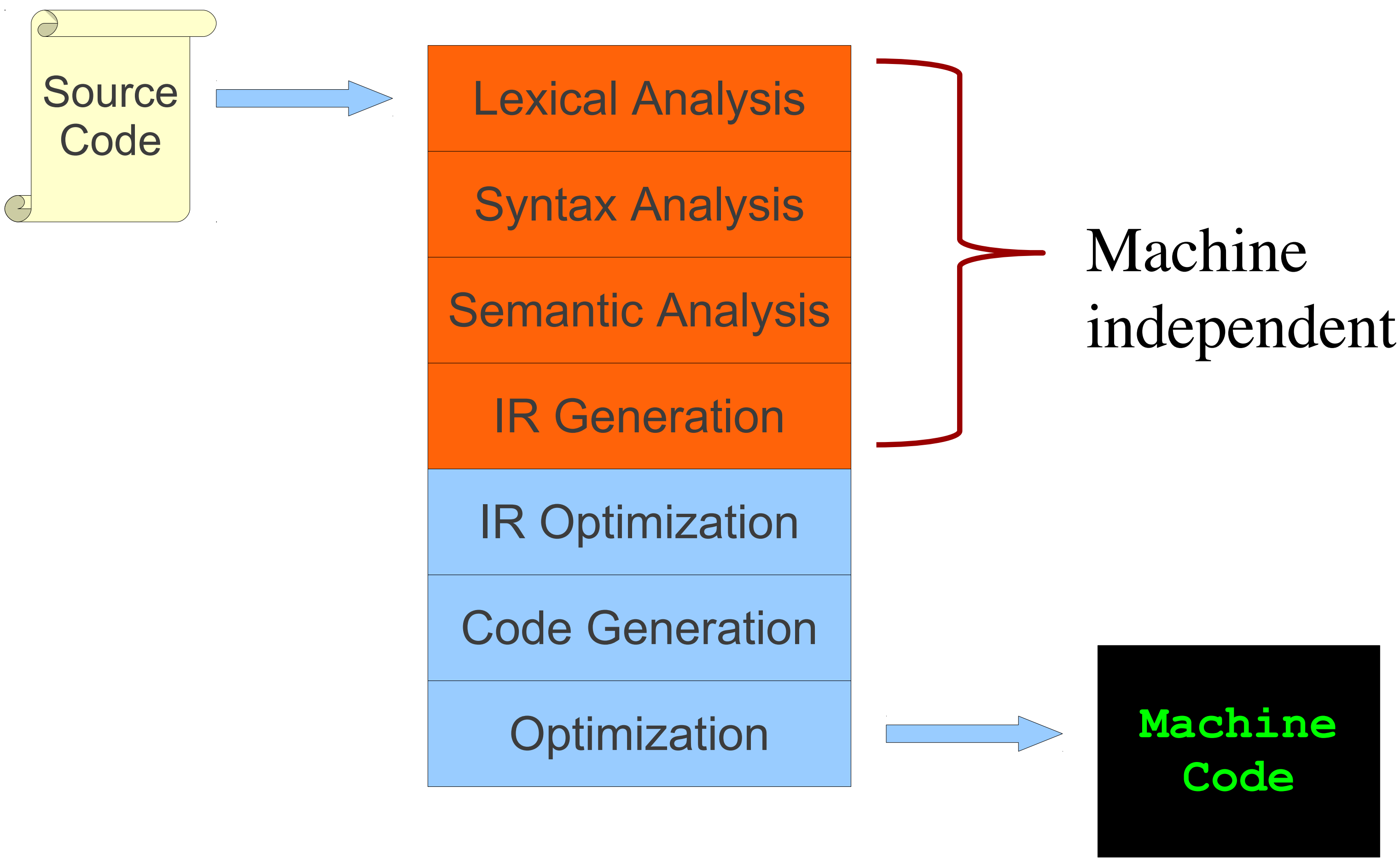
From Description to Implementation

- **Lexical analysis (Scanning):** Identify logical pieces of the description.
- **Syntax analysis (Parsing):** Identify how those pieces relate to each other.
- **Semantic analysis:** Identify the meaning of the overall structure.
- **IR Generation:** Design one possible structure.
- **IR Optimization:** Simplify the intended structure.
- **Generation:** Fabricate the structure.
- **Optimization:** Improve the resulting structure.

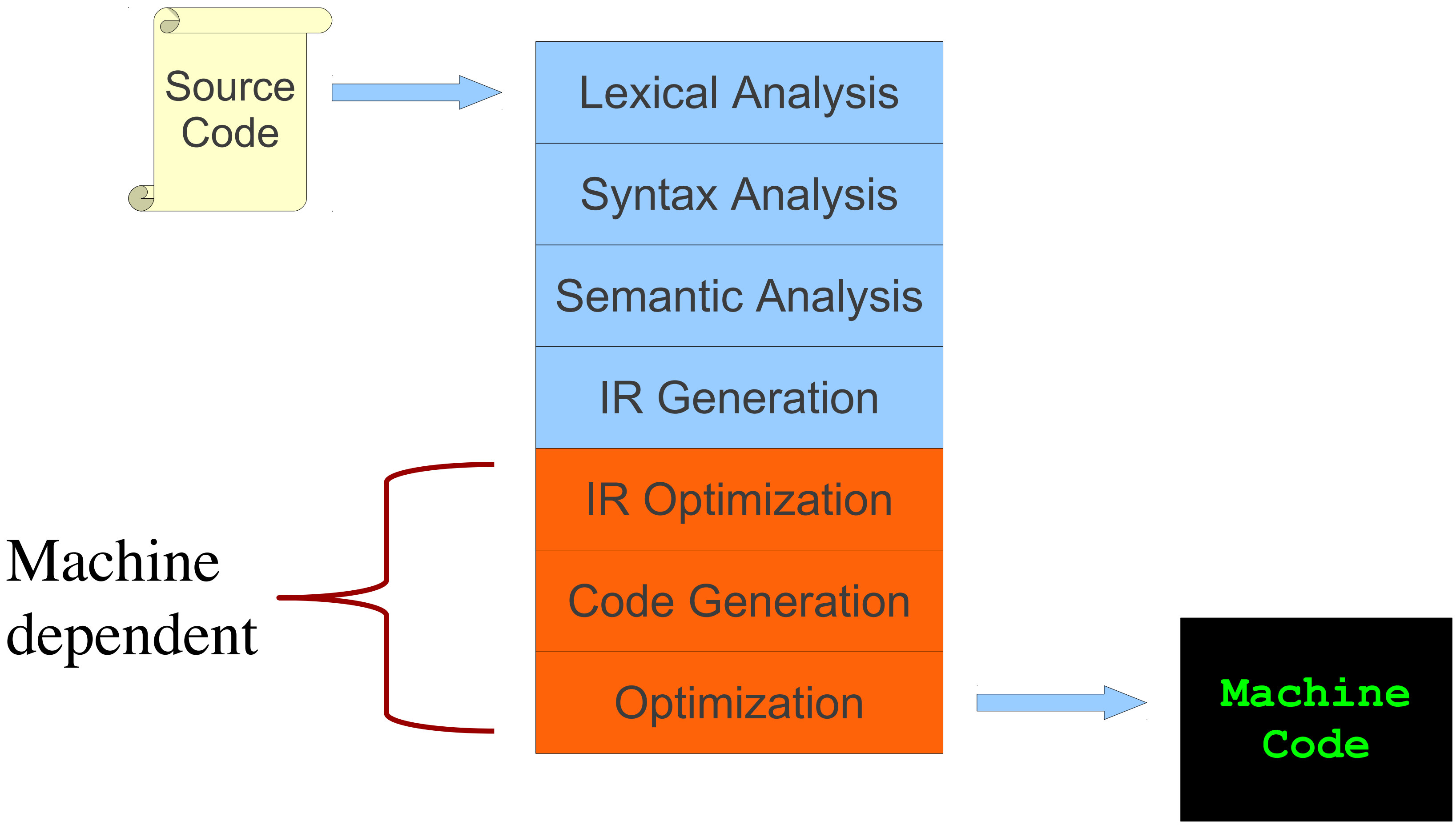
The Structure of a Modern Compiler



The Structure of a Modern Compiler



The Structure of a Modern Compiler



```
while (y < z) {
    int x = a + b;
    y += x;
}
```

Lexical Analysis
Syntax Analysis
Semantic Analysis
IR Generation
IR Optimization
Code Generation
Optimization

```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
T_While
T_LeftParen
T_Identifier y
T_Less
T_Identifier z
T_RightParen
T_OpenBrace
T_Int
T_Identifier x
T_Assign
T_Identifier a
T_Plus
T_Identifier b
T_Semicolon
T_Identifier y
T_PlusAssign
T_Identifier x
T_Semicolon
T_CloseBrace
```

Lexical Analysis

Syntax Analysis

Semantic Analysis

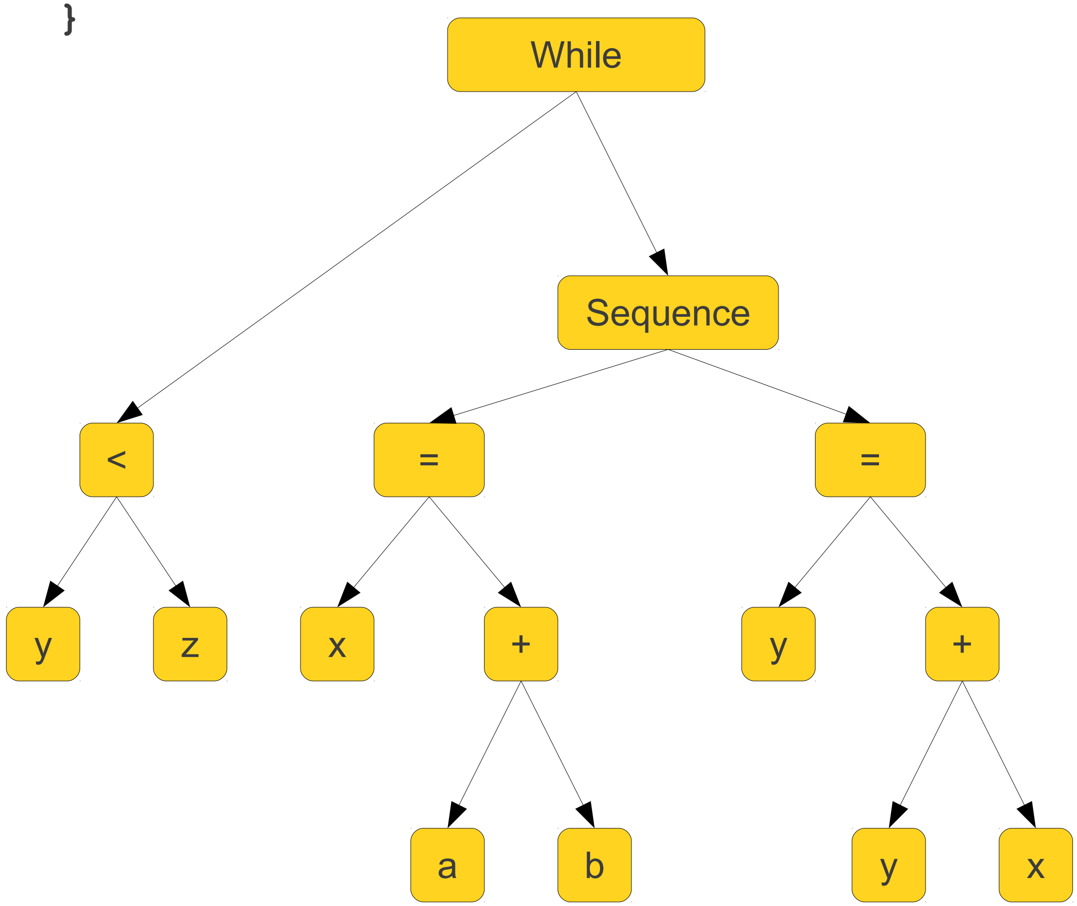
IR Generation

IR Optimization

Code Generation

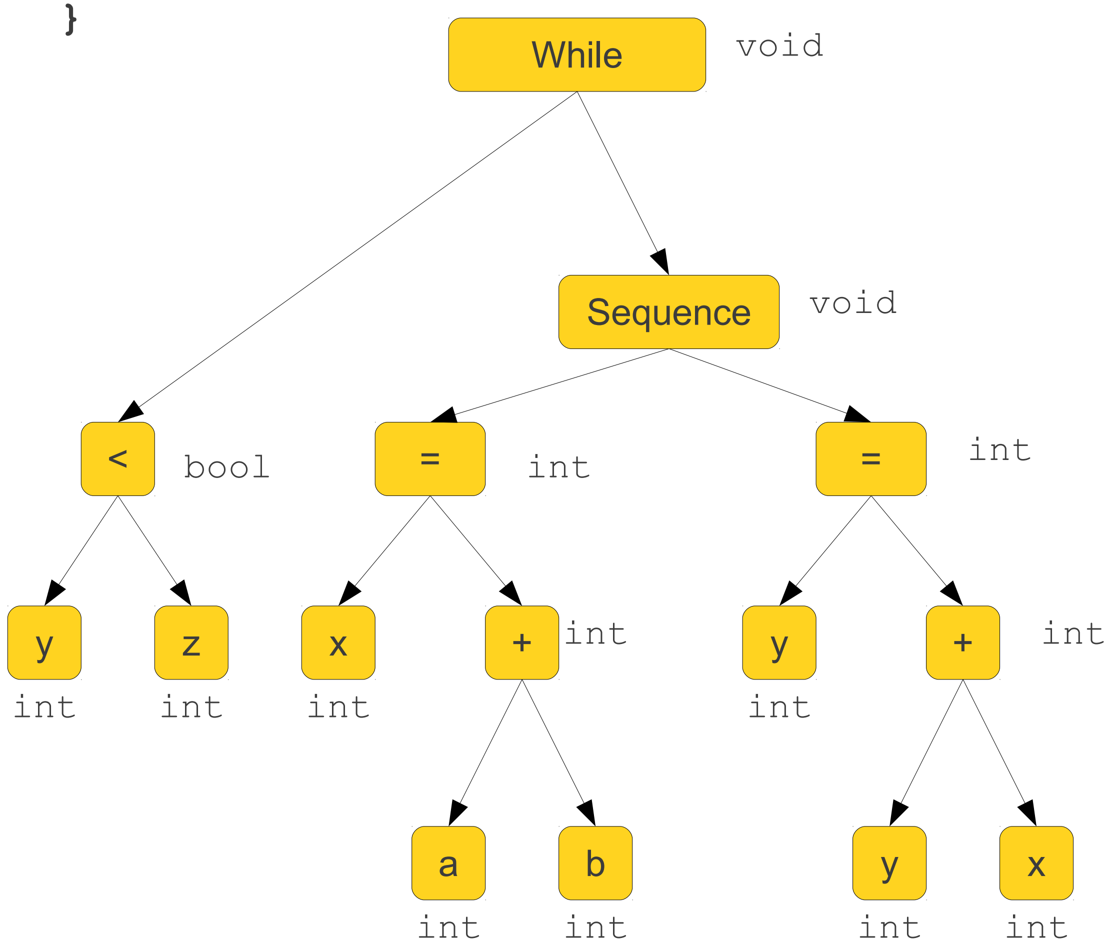
Optimization

```
while (y < z) {
    int x = a + b;
    y += x;
}
```



- Lexical Analysis
- **Syntax Analysis**
- Semantic Analysis
- IR Generation
- IR Optimization
- Code Generation
- Optimization

```
while (y < z) {
    int x = a + b;
    y += x;
}
```



```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
Loop: x   = a + b
      y   = x + y
      _t1 = y < z
      if _t1 goto Loop
```

- Lexical Analysis
- Syntax Analysis
- Semantic Analysis
- **IR Generation**
- IR Optimization
- Code Generation
- Optimization

```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
      x   = a + b
Loop: y   = x + y
      _t1 = y < z
      if _t1 goto Loop
```

- Lexical Analysis
- Syntax Analysis
- Semantic Analysis
- IR Generation
- **IR Optimization**
- Code Generation
- Optimization

```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
      add $1, $2, $3
Loop: add $4, $1, $4
      slt $6, $1, $5
      beq $6, loop
```

- Lexical Analysis
- Syntax Analysis
- Semantic Analysis
- IR Generation
- IR Optimization
- **Code Generation**
- Optimization

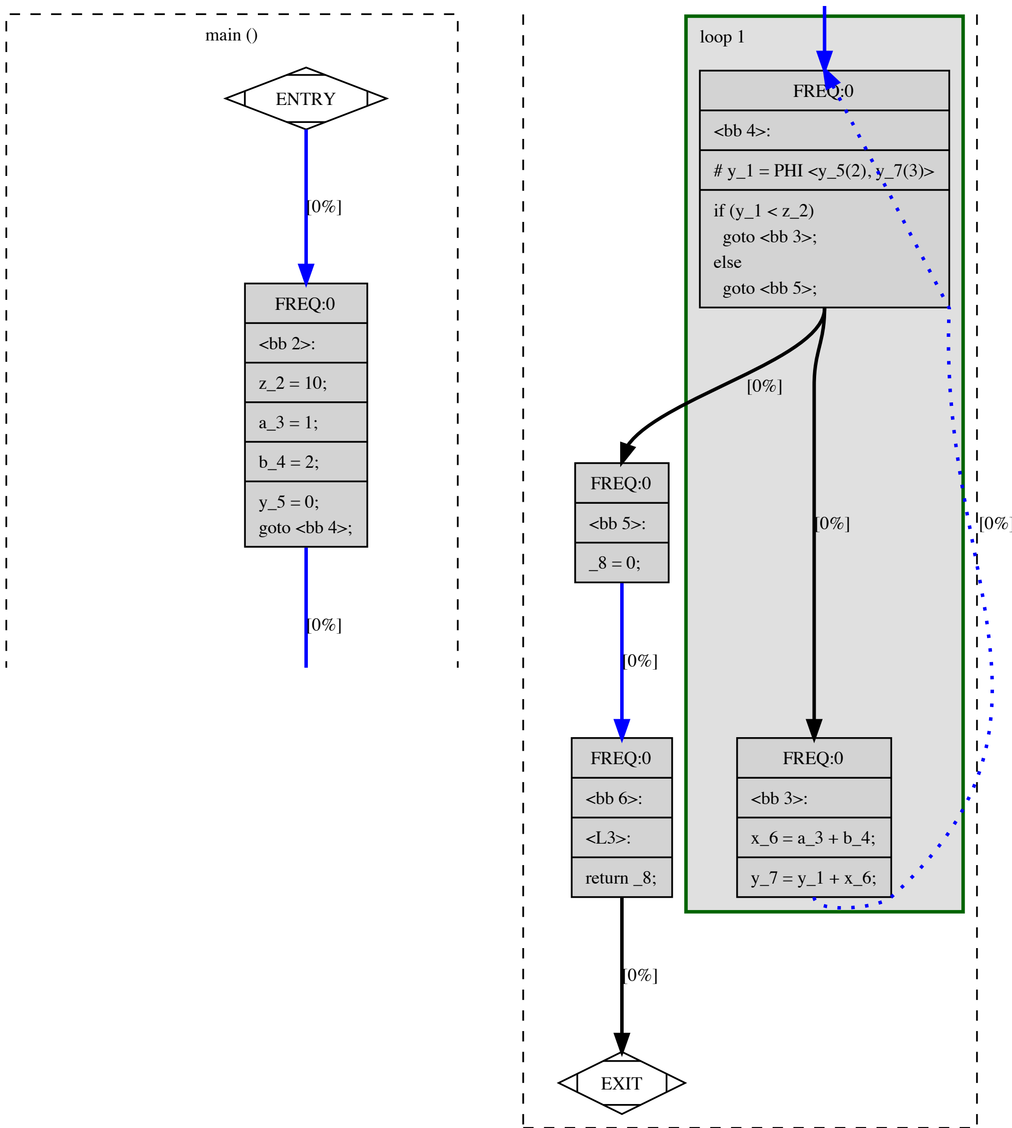
```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
      add $1, $2, $3
Loop: add $4, $1, $4
      blt $1, $5, loop
```

- Lexical Analysis
- Syntax Analysis
- Semantic Analysis
- IR Generation
- IR Optimization
- Code Generation
- **Optimization**

Simple Example in C

```c
int main()
{
    int z = 10;
    int a = 1;
    int b = 2;
    int y = 0;
    while(y < z)
    {
        int x = a + b;
        y += x;
    }
}
```


main ()
ENTRY
[0%]
FREQ:0
<bb 2>:
z_2 = 10;
a_3 = 1;
b_4 = 2;
y_5 = 0;
goto <bb 4>;
[0%]
loop 1
FREQ:0
<bb 4>:
# y_1 = PHI <y_5(2), y_7(3)>
if (y_1 < z_2)
goto <bb 3>;
else
goto <bb 5>;
[0%]
[0%]
[0%]
FREQ:0
<bb 5>:
_8 = 0;
[0%]
FREQ:0
<bb 3>:
x_6 = a_3 + b_4;
y_7 = y_1 + x_6;
FREQ:0
<bb 6>:
<L3>:
return _8;
[0%]
EXIT

Simple Example

```
        ; ================ B E G I N N I N G   O F   P R O C E D U R E ================

        ; Variables:
        ;    var_4: -4
        ;    var_8: -8
        ;    var_C: -12
        ;    var_10: -16
        ;    var_14: -20
        ;    var_18: -24


                     _main:
0000000100000f60         push       rbp
0000000100000f61         mov        rbp, rsp
0000000100000f64         mov        dword [rbp+var_4], 0x0
0000000100000f6b         mov        dword [rbp+var_8], 0xa
0000000100000f72         mov        dword [rbp+var_C], 0x1
0000000100000f79         mov        dword [rbp+var_10], 0x2
0000000100000f80         mov        dword [rbp+var_14], 0x0

                     loc_100000f87:
0000000100000f87         mov        eax, dword [rbp+var_14]                    ; CODE XREF=_main+69
0000000100000f8a         cmp        eax, dword [rbp+var_8]
0000000100000f8d         jge        loc_100000faa

0000000100000f93         mov        eax, dword [rbp+var_C]
0000000100000f96         add        eax, dword [rbp+var_10]
0000000100000f99         mov        dword [rbp+var_18], eax
0000000100000f9c         mov        eax, dword [rbp+var_18]
0000000100000f9f         add        eax, dword [rbp+var_14]
0000000100000fa2         mov        dword [rbp+var_14], eax
0000000100000fa5         jmp        loc_100000f87

                     loc_100000faa:
0000000100000faa         mov        eax, dword [rbp+var_4]                     ; CODE XREF=_main+45
0000000100000fad         pop        rbp
0000000100000fae         ret
                        ; endp
```

Typical Programming Sequence

Algorithm (typically natural language or pseudocode)

The human act of programming or software development

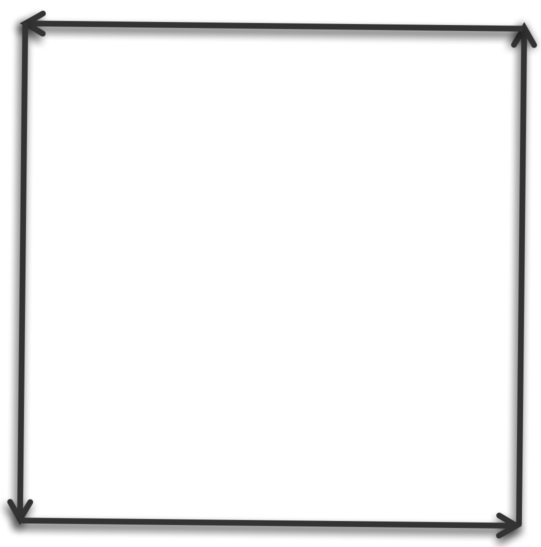
High-level program (source code: Java, C++, C, …)

The act of compilation (happens automatically inside the computer)

Low-level program or (machine code: assembly)

Robot Example (St. Amant, pp. 86)

Make a robot move along the outline of a square and report the distance it has moved



Robot Example

- What is the most simple version of this program possible?

Program Design and Refinement

Version 1: move, turn, move, turn etc.

```
To follow a square path:
        Move 8 inches forward
        Turn left
        Move 8 inches forward
        Turn left
        Move 8 inches forward
        Turn left
        Move 8 inches forward
        Turn left
        Output the number 32 as a result
```

Block

Robot Example

- What is missing from this program?
- Is it very useful?
- Observations?

Program Design and Refinement

Version 1: move, turn, move, turn etc.

To follow a square path: 1

Move 8 inches forward 2

Turn left 3

Move 8 inches forward 4

Turn left 5

Move 8 inches forward 6

Turn left 7

Move 8 inches forward 8

Turn left 9

Output the number 32 as a result 10

Block

Robot Example

- Programming concept: basic block (or just block)
- Series of instructions that will be executed start to finish
  - Once you enter a basic block, all instructions will be excecuted
- All programs are made up of a set of basic blocks tied together in a particular order

- Can we continue to improve the program?

Looping

Version 2: repeat move, turn, 4 times

To follow a square path: 1

Do the following 4 times in a row 2

Move 8 inches forward 3

Turn left 4

Output the number 32 as a result 5

Robot Example

- Programming Concept: Looping
- Basic blocks are often repeated in a ‘loop’, we can identify the loops in the high-level language
- Gives us looping structures like ’for’ and ‘while’
- Makes code simpler to read and more flexible (e.g. #loops is now variable instead of hard-coded)

Introducing Variables

Version 3: repeat move, turn, 4 times. Total distance is updated each time and produced as output

To follow a square path:

Set the total distance to 0

Do the following 4 times in a row

Move 8 inches forward

Turn left

Add 8 to the total distance

Output total distance

Robot Example

- Programming Concept: variables
- Named items in a program that can take on different values at different points of a program
- Naming is for us, the programmer. Makes code easier to build and debug

If-then-else

Version 4: repeat move, turn, 4 times. Total distance is updated each time and produced as output. Side length and total distance in inches, clockwise is true or false

To follow a square path of a given

side length, clockwise or not:
Set the total distance to 0
    Do the following 4 times in a row
        Move 'side length' inches forward
        If clockwise
            then turn right
        else turn left
        Add 'side length' to the total distance
    Output total distance

Robot Example

- Programming Concept: control flow
- Statements that evaluate the state of variables and change the course of program operation
- Let the programmer control the order in which basic blocks are executed
- If, if-else, and similar

Summary

- ‘High-level’ programming are designed for human convenience
- ‘High-level’ programming is an abstraction to make programming easier
- ‘High-level’ programs are ‘block’ structured
- One ‘high-level’ statement produces many ‘low-level’ instructions
- ‘Low-level’ programs (machine language) are what really run on a the CPU