IN3: What is a Compiler

CMPT 379
Compilers

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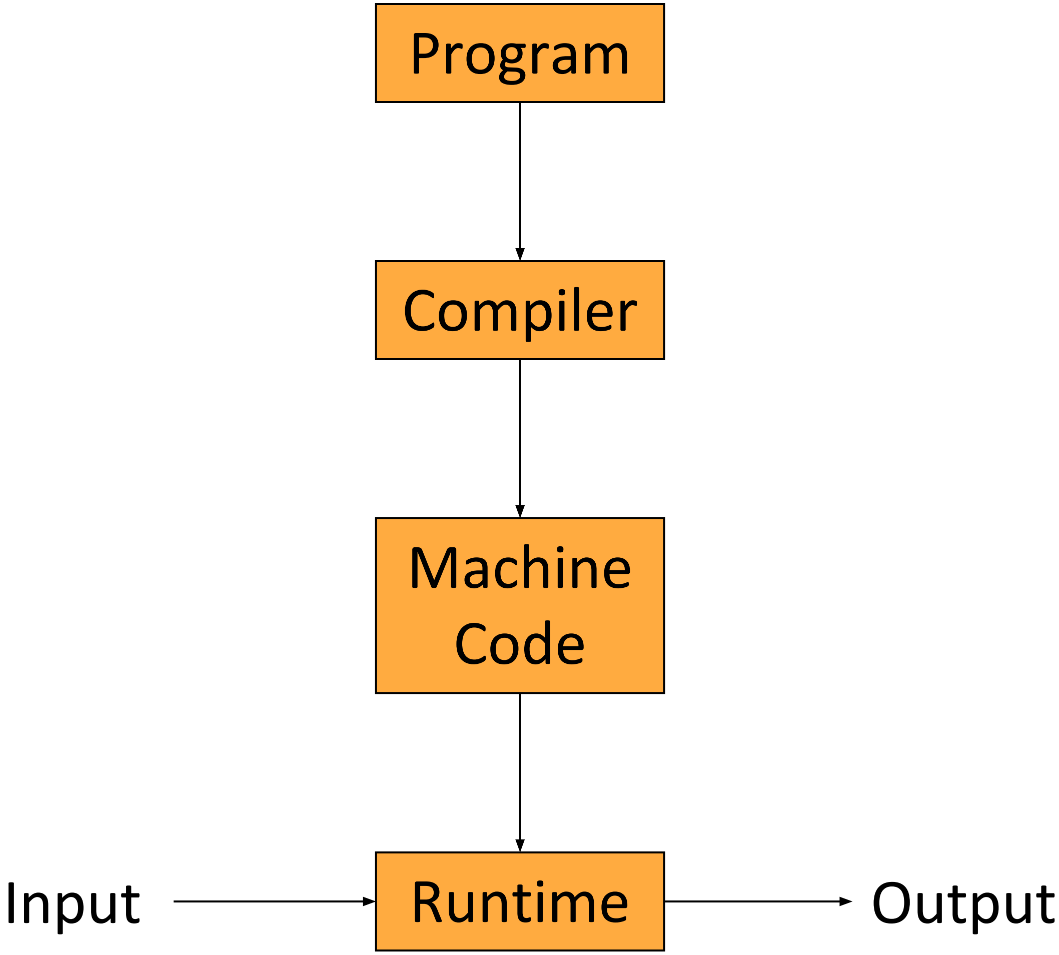
http://anoopsarkar.github.io/compilers-class/



Program

Compiler

Machine Code

Input

Runtime

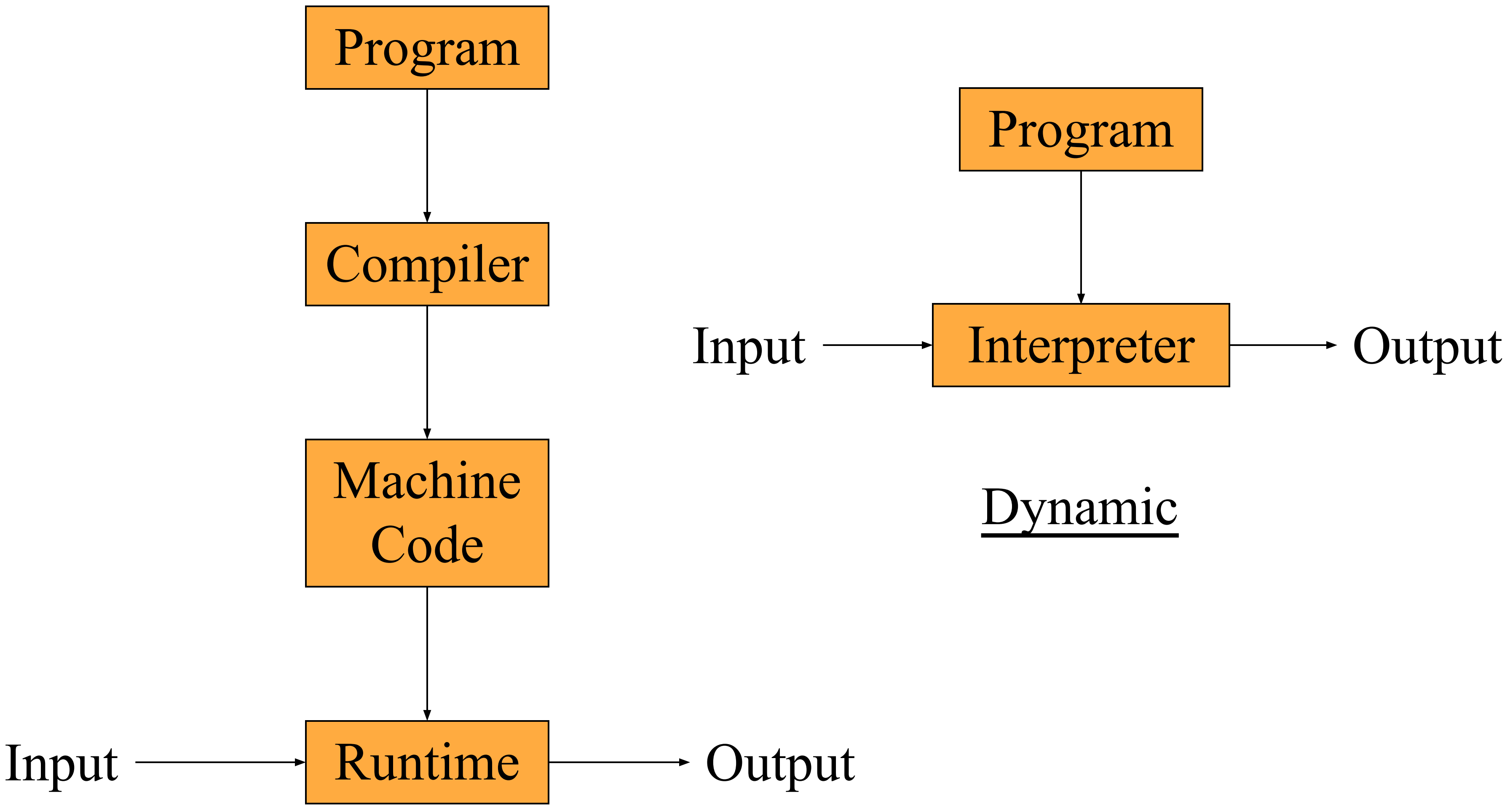
Output

Compilers

- Analysis of the source (front-end)
- Synthesis of the target (back-end)
- The *translation* from user **intention** into intended **meaning**
- The requirements from a Compiler and a Programming Language are:
  - Ease of use (high-level programming)
  - Speed

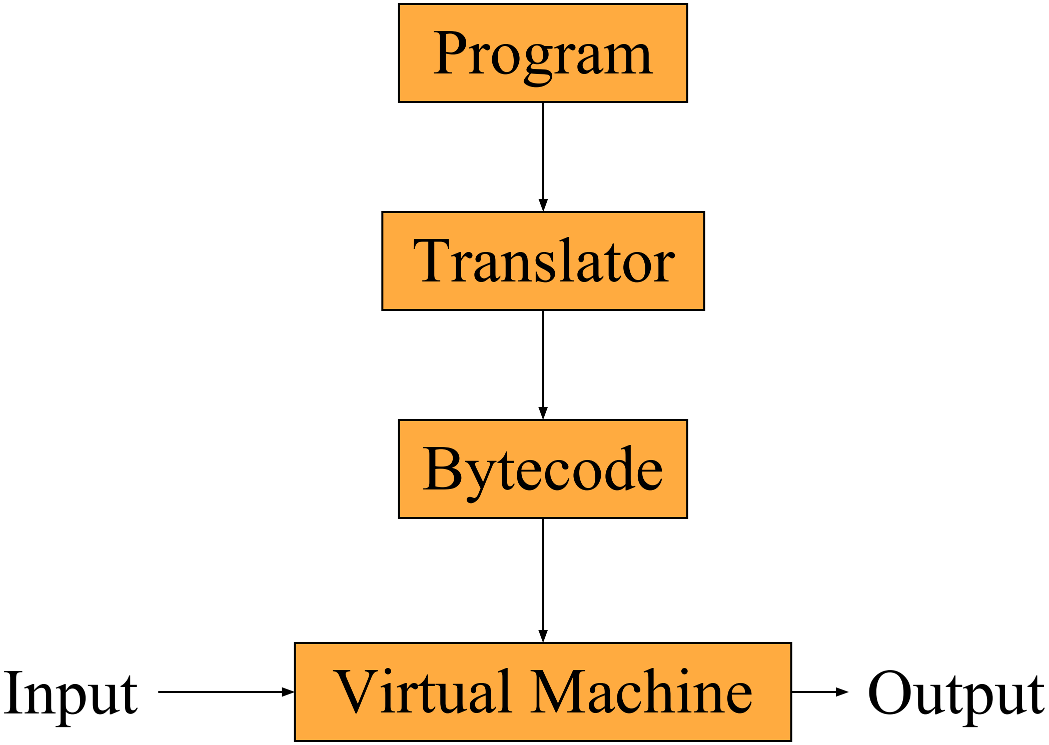
Cousins of the compiler

- “Smart” editors for structured languages
  - static checkers; pretty printers
- Structured or semi-structured data
  - Trees as data: s-expressions; XML
  - query languages for databases: SQL
- Interpreters (for PLs like lisp or scheme)
  - Scripting languages: perl, python, tcl/tk
  - Special scripting languages for applications
  - “Little” languages: awk, eqn, troff, TeX
- Compiling to Bytecode (virtual machines)



Static

Dynamic



Program

Translator

Bytecode

Input

Virtual Machine

Output

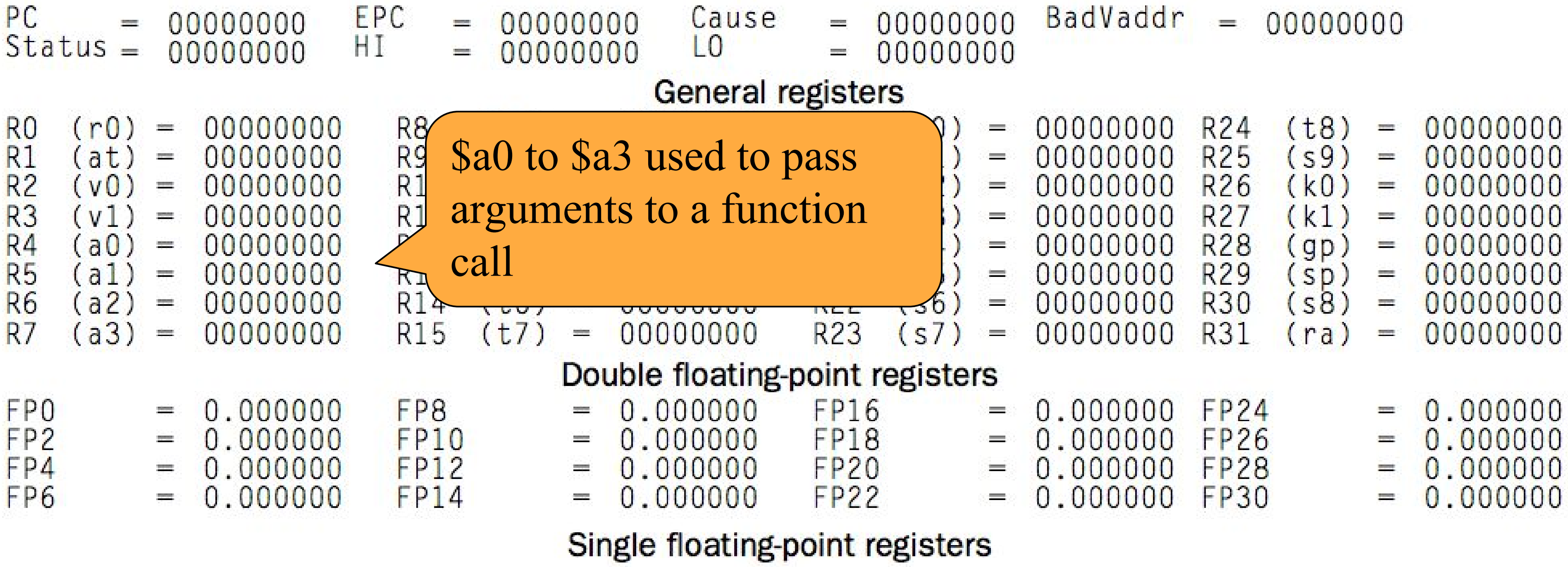
Static/Dynamic

Context for the Compiler

- Preprocessor
- Compiler
- Assembler
- Linker (loader)

MIPS CPU

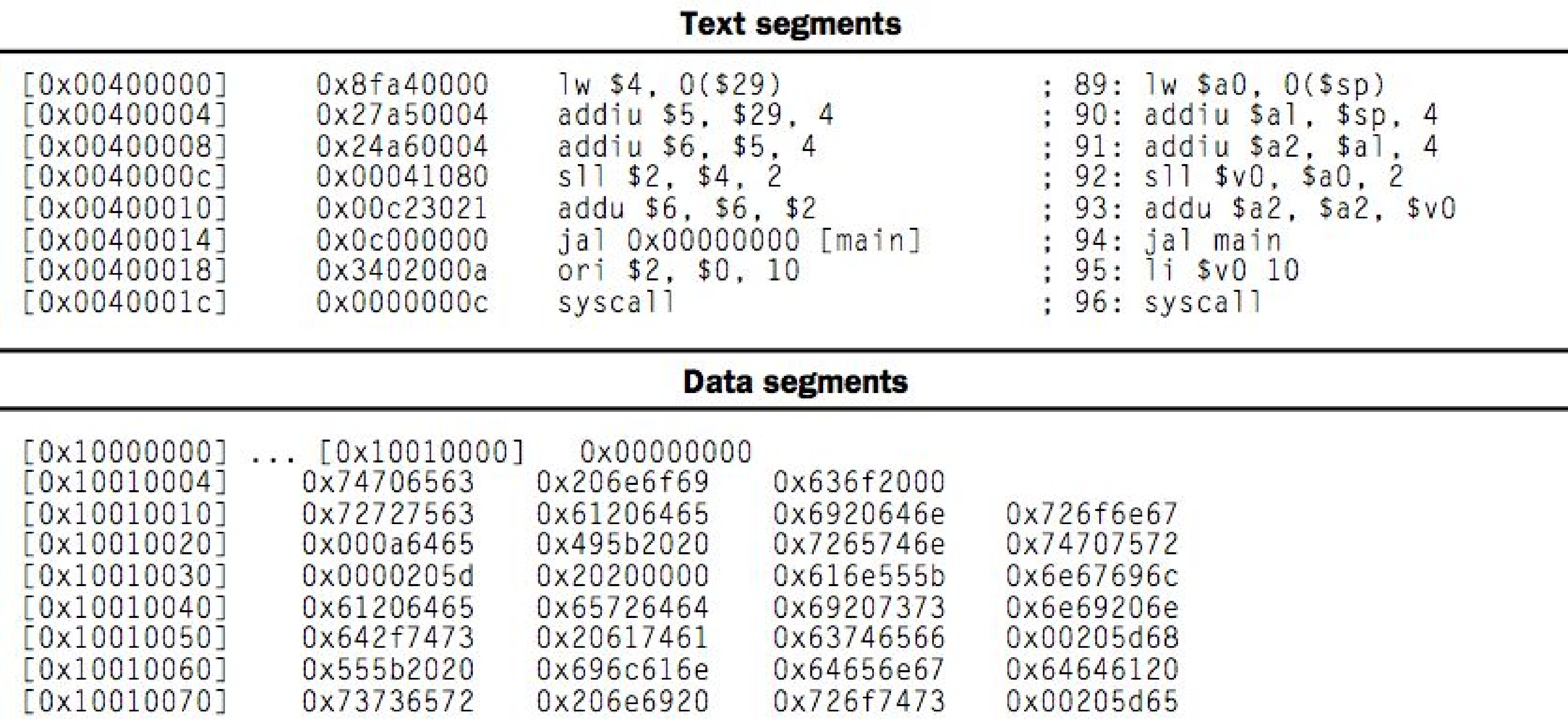
Program Counter



```
PC     = 00000000   EPC    = 00000000   Cause  = 00000000   BadVaddr = 00000000
Status = 00000000   HI     = 00000000   LO     = 00000000
                              General registers
R0  (r0) = 00000000   R8                   0)  = 00000000   R24  (t8) = 00000000
R1  (at) = 00000000   R9                    )  = 00000000   R25  (s9) = 00000000
R2  (v0) = 00000000   R1                    )  = 00000000   R26  (k0) = 00000000
R3  (v1) = 00000000   R1                    )  = 00000000   R27  (k1) = 00000000
R4  (a0) = 00000000                         )  = 00000000   R28  (gp) = 00000000
R5  (a1) = 00000000   R1                    )  = 00000000   R29  (sp) = 00000000
R6  (a2) = 00000000   R14               (s6)  = 00000000   R30  (s8) = 00000000
R7  (a3) = 00000000   R15 (t7) = 00000000   R23 (s7) = 00000000   R31  (ra) = 00000000
                         Double floating-point registers
FP0      = 0.000000   FP8      = 0.000000   FP16     = 0.000000   FP24      = 0.000000
FP2      = 0.000000   FP10     = 0.000000   FP18     = 0.000000   FP26      = 0.000000
FP4      = 0.000000   FP12     = 0.000000   FP20     = 0.000000   FP28      = 0.000000
FP6      = 0.000000   FP14     = 0.000000   FP22     = 0.000000   FP30      = 0.000000
                         Single floating-point registers
```

$a0 to $a3 used to pass arguments to a function call

MIPS CPU



Text segments

```
[0x00400000]    0x8fa40000    lw $4, 0($29)                  ; 89: lw $a0, 0($sp)
[0x00400004]    0x27a50004    addiu $5, $29, 4               ; 90: addiu $al, $sp, 4
[0x00400008]    0x24a60004    addiu $6, $5, 4                ; 91: addiu $a2, $al, 4
[0x0040000c]    0x00041080    sll $2, $4, 2                  ; 92: sll $v0, $a0, 2
[0x00400010]    0x00c23021    addu $6, $6, $2                ; 93: addu $a2, $a2, $v0
[0x00400014]    0x0c000000    jal 0x00000000 [main]          ; 94: jal main
[0x00400018]    0x3402000a    ori $2, $0, 10                 ; 95: li $v0 10
[0x0040001c]    0x0000000c    syscall                        ; 96: syscall
```

Data segments

```
[0x10000000] ... [0x10010000]   0x00000000
[0x10010004]    0x74706563   0x206e6f69   0x636f2000
[0x10010010]    0x72727563   0x61206465   0x6920646e   0x726f6e67
[0x10010020]    0x000a6465   0x495b2020   0x7265746e   0x74707572
[0x10010030]    0x0000205d   0x20200000   0x616e555b   0x6e67696c
[0x10010040]    0x61206465   0x65726464   0x69207373   0x6e69206e
[0x10010050]    0x642f7473   0x20617461   0x63746566   0x00205d68
[0x10010060]    0x555b2020   0x696c616e   0x64656e67   0x64646120
[0x10010070]    0x73736572   0x206e6920   0x726f7473   0x00205d65
```

What we understand

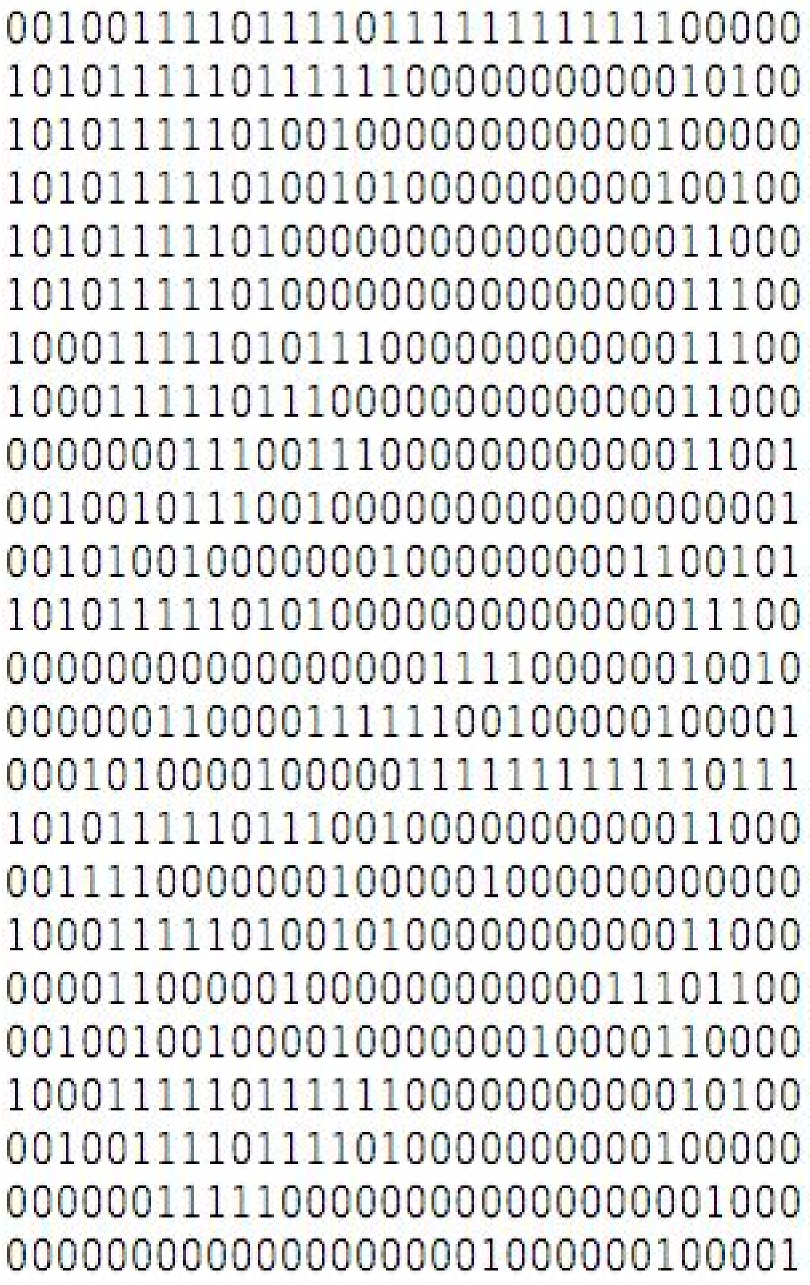
```
#include <stdio.h>

int main (int argc, char *argv[]) {
   int i;
   int sum = 0;
   for (i = 0; i <= 100; i++)
      sum = sum + i * i;
   printf (”Sum from 0..100 = %d\n", sum);
}
```

Assembly language

```
 .text
.align 2
.globl main
main:
  subu $sp, $sp, 32
  sw $ra, 20($sp)
  sd $a0, 32($sp)
  sw $0, 24($sp)
  sw $0, 28($sp)
loop:
  lw $t6, 28($sp)
  mul $t7, $t6, $t6
  lw $t8, 24($sp)
  addu $t9, $t8, $t7
  sw $t9, 24($sp)
  addu $t0, $t6, 1
  sw $t0, 28($sp)
  ble $t0, 100, loop
  la $a0, str
  lw $a1, 24($sp)
  jal printf
  move $v0, $0
  lw $ra, 20($sp)
  addu $sp, $sp, 32
  jr $ra
.data
.align 0
str:
.asciiz "The sum from 0 .. 100 is %d\n"
```

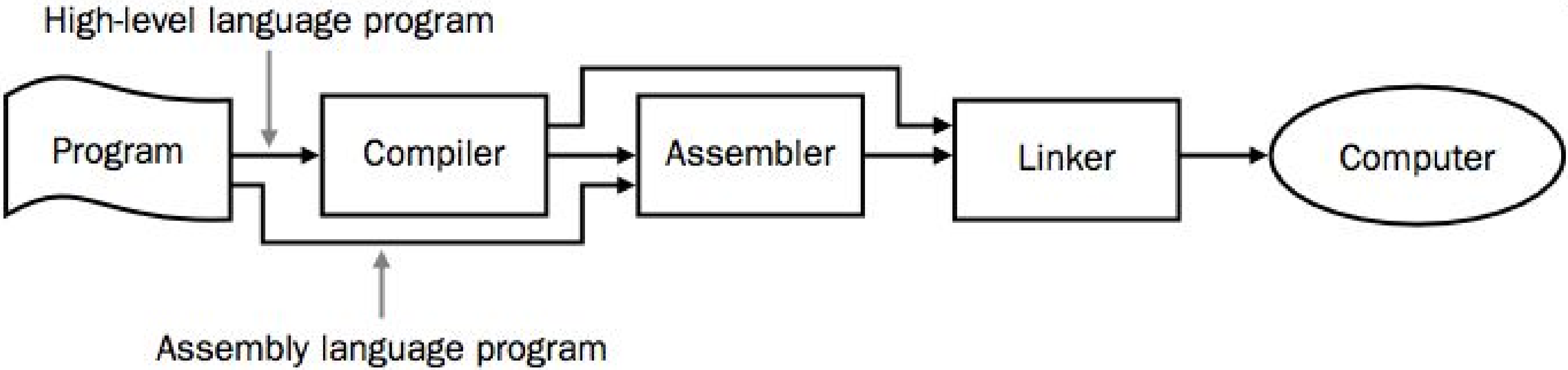
A one-one translation from assembly to machine code

Conversion into instructions for the Machine



```
00100111101111011111111111100000
10101111101111110000000000010100
10101111101001000000000000100000
10101111101001010000000000100100
10101111101000000000000000011000
10101111101000000000000000011100
10001111101011100000000000011100
10001111101110000000000000011000
00000001110011100000000000011001
00100101110010000000000000000001
00101001000000010000000001100101
10101111101010000000000000011100
00000000000000000111000000010010
00000011000011111100100000100001
00010100001000001111111111110111
10101111101110010000000000011000
00111100000001000001000000000000
10001111101001010000000000011000
00001100000100000000000011101100
00100100100001000000010000110000
10001111101111110000000000010100
00100111101111010000000000100000
00000011111000000000000000001000
00000000000000000001000000100001
```

MIPS
machine language
code


High-level language program
Program
Compiler
Assembler
Linker
Computer
Assembly language program

Linker

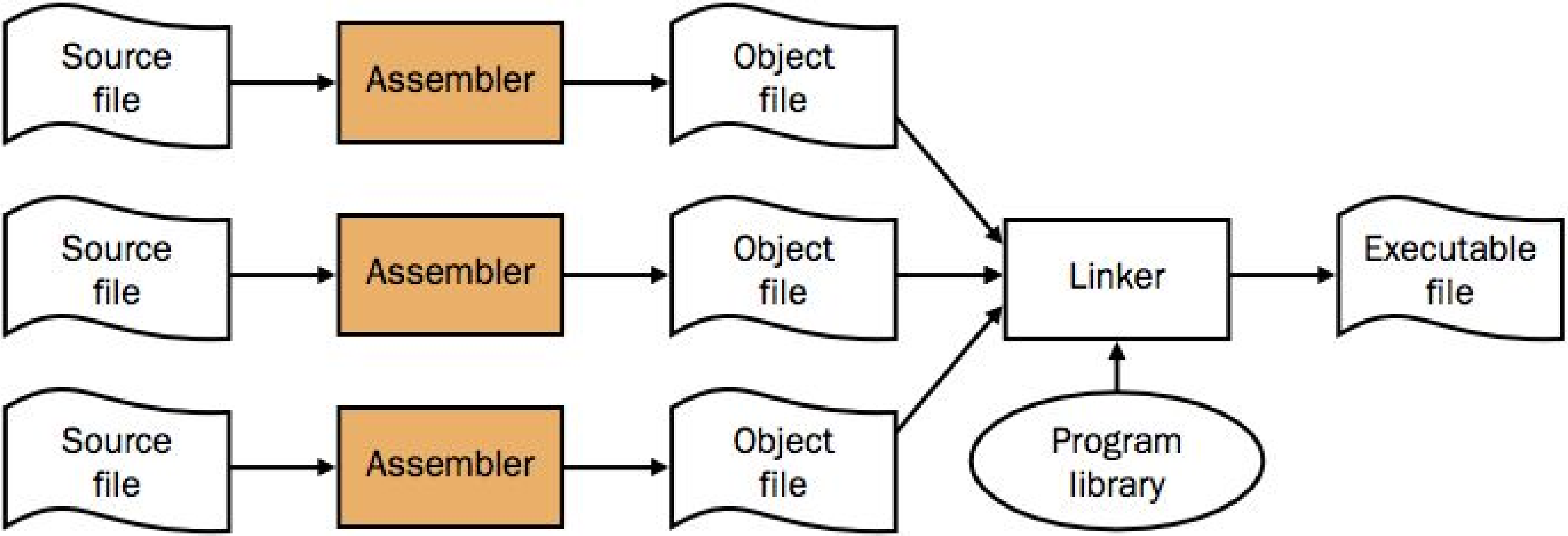
```
 .data
str:
        .asciiz "the answer = "
.text
main:
        li $v0, 4
        la $a0, str
        syscall

        li $v0, 1
        li $a0, 42
        syscall
```

Local vs. Global labels

2-pass assembler and Linker

The UNIX toolchain

`as, ar, ranlib, ld, …`


Source file
Assembler
Object file
Source file
Assembler
Object file
Source file
Assembler
Object file
Linker
Executable file
Program library