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Lecture 4
Decisions

FIT 1008
Introduction to Computer Science

Objectives for this lecture

- To put the MIPS branch and jump instructions into context

- To understand how they are used to translate **selection** (if-else)

- To see the MIPS instruction format

Blast from the past: the **goto** statement

- A **label** is an identifier for a program position (i.e., for a line of code)

- The **goto** statement performs an unconditional jump to its label argument

- It promotes code whose control flow is **extremely difficult to understand**

- That is why it is not supported by many languages, including Python

- However, in MIPS the equivalent **jump** instruction is all we've got!

If Python had a `goto` statement …

```
# Code could be this ugly!?

      print(1)
      goto apple

   orange:
      print(3)
      goto pomegranate

   apple:
      print(2)
      goto orange

   pomegranate:
      print(4)
```

Jump Instructions

- jump (go) to label

```
j foo              # set PC = foo
                   # so, go to foo
```

- jump to label and link (remember origin)

```
jal foo            # $ra = PC+4; PC = foo, so same
                   # but setting a return address
```

- jump to address contained in register

```
jr $t0             # set PC = $t0, so go to the
                   # address contained in $t0
```

- jump to register and link (remember origin)

```
jalr $t0           # $ra = PC+4; PC = $t0, same
                   # but setting a return address
```

MIPS **jump** instruction

```
                # print number 1
                j   apple
orange:         #print number 3
                j   pomegranate
apple:          #print number 2
                j   orange
pomegranate:
                # print number 4
                # exit system call
```

Selection

- **Selection** is how programs **make choices**

- In Python, with **if**, **if-else**, **if-elif-else** (like switch cases)

- Achieved by selectively not executing some lines of code

negative.py

```
n = int(input("Enter int: "))

if n < 0:
        print("Negative")
```

Comparison Instructions

- set less than

```
slt $t0,$t1,$t2      # if $t1<$t2 then $t0=1
                     # else $t0 = 0
```

- set less than immediate

```
slti $t0,$t1,1       # if $t1<1 then $t0=1
                     # else $t0 = 0
```

- Note: comparisons are performed by the ALU, so comparison instructions are really arithmetic ones

Conditional Branch Instructions

- branch if equal to

```
beq $t1,$t2,foo      # if $t1==$t2 goto foo
```

- branch if not equal to

```
bne $t1,$t2,foo      # if $t1!=$t2 goto foo
```

Conditional Branch Instructions

Pseudo Instructions

- branch if less than

```
blt $t1, $t2, foo     # if $t1<$t2 goto foo
```

- branch if less than or equal to

```
ble $t1, $t2, foo     # if $t1<=$t2 goto foo
```

- branch if greater than

```
bgt $t1, $t2, foo     # if $t1>$t2 goto foo
```

- branch if greater or equal to

```
bge $t1, $t2, foo     # if $t1>=$t2 goto foo
```

negative.py

```
n = int(input("Enter int: "))

if n < 0:
        print("Negative")
```

negative.asm

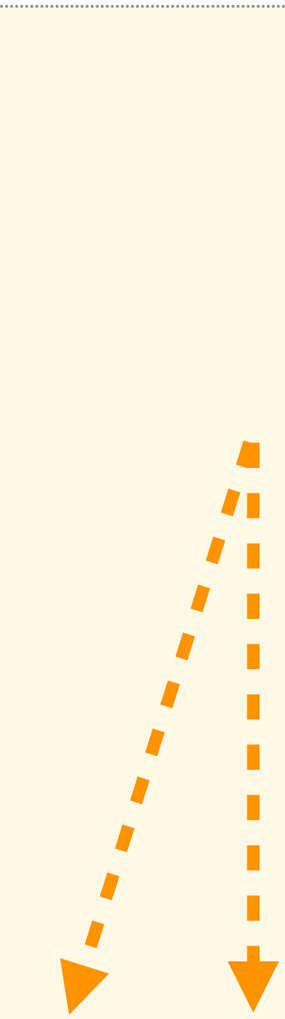
Let's look at this

```
        # read n

        # if n ≥ 0 goto exit

            # print negative

    exit:

        # exit
```

negative.asm

```
                .data
prompt:     .asciiz   "Enter int: "
negative:   .asciiz   "Negative"
n:          .word      0

                .text
        la      $a0, prompt   # print prompt
        add     $v0, $0, 4
        syscall

        addi  $v0, $0, 5      # read n
        syscall
        sw      $v0, n
```

If n ≥ 0 goto exit



```
        lw    $t0, n        # if n >= 0 goto exit
        slt   $t1, $t0, $0
        beq   $t1, $0, exit
        la    $a0, negative     # print negative
        addi  $v0, $0, 4
        syscall
exit:   addi  $v0, $0, 10       # exit program
        syscall
```

even.py

```
n = int(input("Enter int: "))

if (n % 2 == 0):

    print(n, 'is even')

else:

    print(n, 'is odd')
```

even.asm

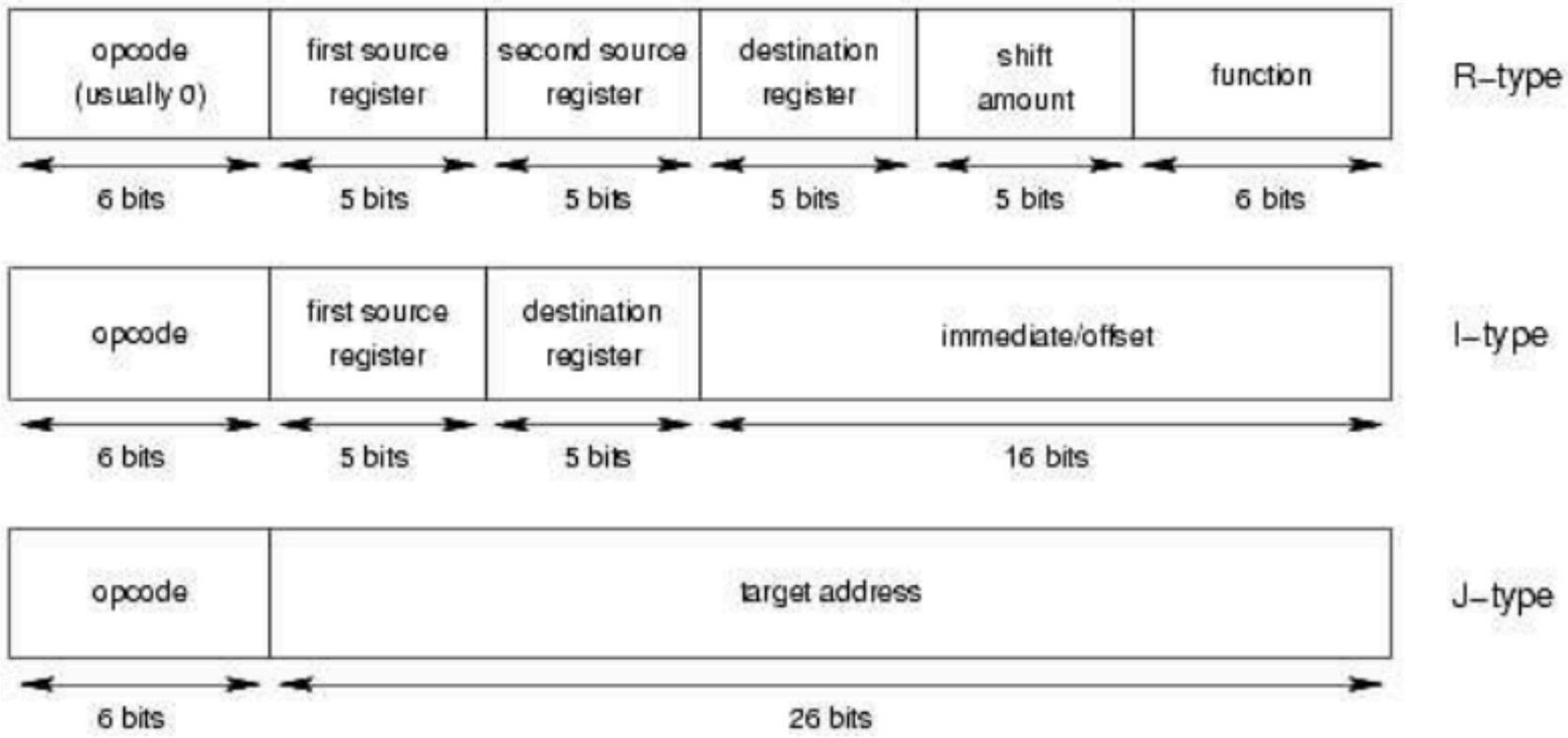
```
        # setup strings and global variable

        # compute n % 2

        # if n % 2 ≠ 0 goto else

        # print n is even

        # goto exit

else:

        # print n is odd

exit:

        # exit
```

Let's look at this

if – else statement

```
# compute n % 2
lw     $t0, n
addi   $t1, $0, 2
# $t0 = n % 2
div    $t0, $t1
mfhi   $t0
# if $t0 <> 0
goto else
bne  $t0, $0, else
```

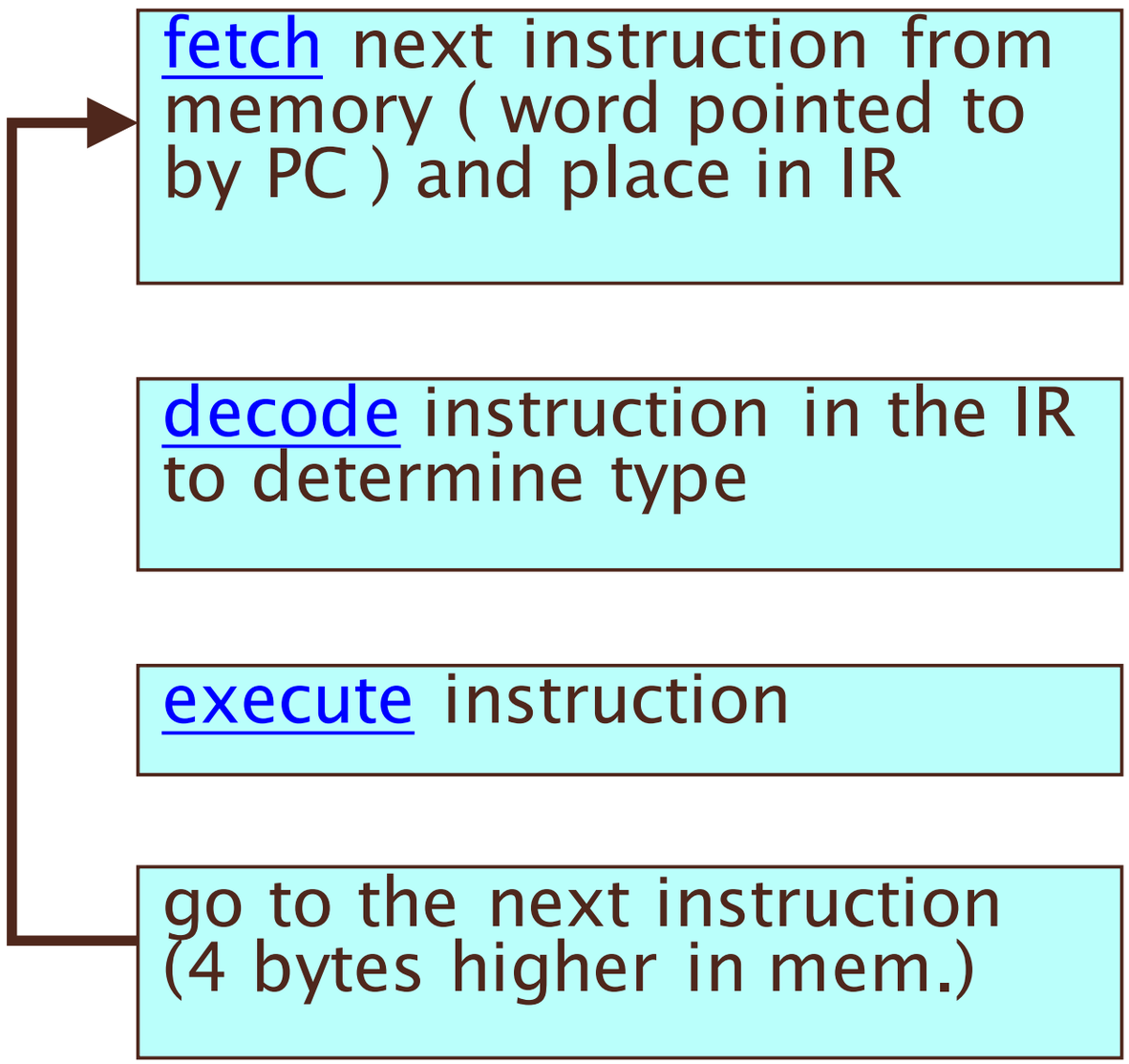
```
    # print n
    # print even
    j exit
else:
        # print n
        # print odd
exit:
        # exit
```


opcode
(usually 0)
first source
register
second source
register
destination
register
shift
amount
function
R–type
6 bits
5 bits
5 bits
5 bits
5 bits
6 bits
opcode
first source
register
destination
register
immediate/offset
I–type
6 bits
5 bits
5 bits
16 bits
opcode
target address
J–type
6 bits
26 bits

Remember?

MIPS Instruction Execution

Programs are run by the MIPS hardware performing
fetch-decode-execute cycles



instruction at mem[PC] is: 0x**21250003**

0b10000100100101000000000000000011

0010 0001 0010 0101 0000 0000 0000 0011

001000 00101 01001 0000000000000011

fetch next instruction from memory (word pointed to by PC) and place in IR

decode instruction in the IR to determine type

execute instruction

go to the next instruction (4 bytes higher in mem.)

Opcode 8 is “add immediate”,
source reg is $5,
“target” reg is reg $9,
add amount is 3

Send reg $5 and -3 to ALU,
add them, result to reg $9

PC = PC + 4

MIPS Instruction Format

- Remember: every MIPS instruction is 32-bits in size and occupies 4 bytes of memory
- Remember: each instruction contains
  - opcode
    - operation code: specifies type of instruction
  - operands
    - values or location to perform operation on
      - registers
      - immediate (constant) numbers
      - labels (addresses of other lines of program)

MIPS Instruction Format

R (for "register") format instruction: three registers

```
sub $t0, $t1, $t2
```

subtract the contents of register $t2 from the contents of register $t1; put the result in register $t0

I (for "immediate") format instruction: two registers and one immediate operand

```
addi $v0, $a2, 742
```

add the immediate number 742 with the contents of register $a2; put the result in register $v0

J (for "jump") format instruction: has a line label (an address) as its only operand

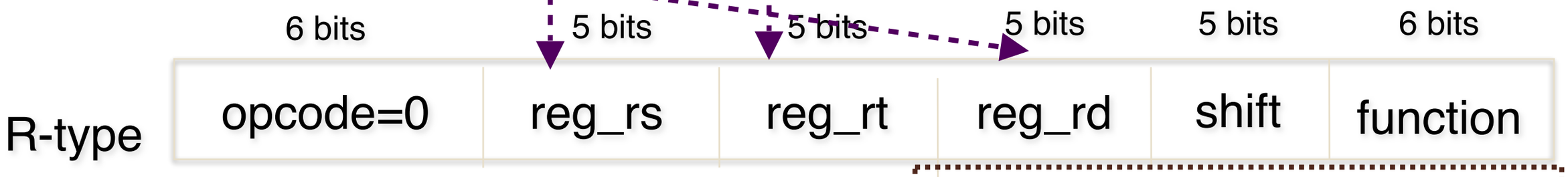
```
j foo
```

jump (go) to the line with the label foo and continue running from there

MIPS Instruction Format

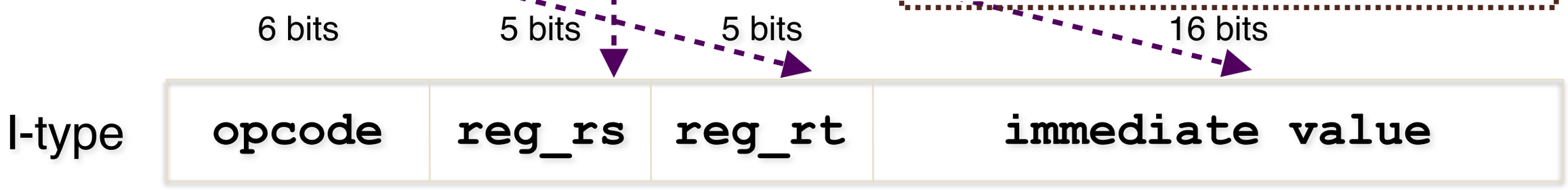
R (for "register") format instruction: three registers

```
sub $t0, $t1, $t2
```



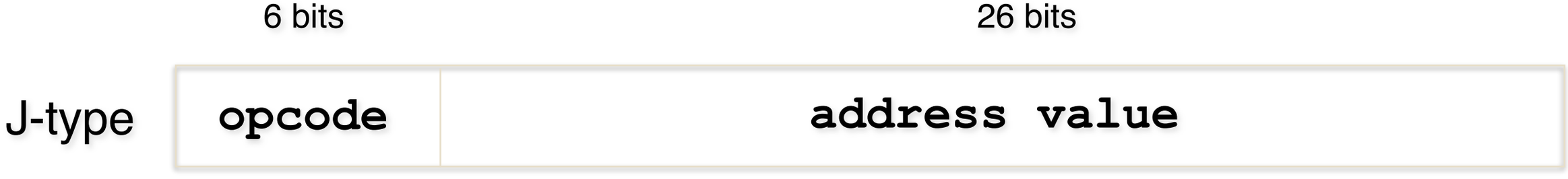
I (for "immediate") format instruction: two registers and one immediate operand

```
addi $v0, $a2, 742
```



J (for "jump") format instruction: has a line label (an address) as its only operand

```
j foo
```



I-type Instruction: Example

opcode determines how remaining bits are to be interpreted as operands

Instruction's components encoded in binary

opcode (6 bits): 001000_2
(8_{10}) means "add immediate"

Summary

- MIPS branch and jump instructions
- Selection
  - if-else
- Iteration (loops)
  - while
  - for
- Instruction Format
  - R type
  - I type
  - J type