Lecture 4: MIPS Instruction Set

- Today's topic:
  - More MIPS instructions for math and control
  - Code examples

Immediate Operands

- An instruction may require a constant as input
- An immediate instruction uses a constant number as one of the inputs (instead of a register operand)
- Putting a constant in a register requires addition to register $zero (a special register that always has zero in it) -- since every instruction requires at least one operand to be a register
- For example, putting the constant 1000 into a register:

```
addi   $s0, $zero, 1000
```

Example

int a, b, c, d[10];

```
addi   $s0, $zero, 1000   # the program has base address
                          #  1000 and this is saved in $s0
                          # $zero is a register that always
                          # equals zero
addi   $s1, $s0, 0      # this is the address of variable a
addi   $s2, $s0, 4      # this is the address of variable b
addi   $s3, $s0, 8      # this is the address of variable c
addi   $s4, $s0, 12     # this is the address of variable d[0]
```

Memory Instruction Format

- The format of a load instruction:

destination register

source address

lw $t0, 8($t3)

any register

a constant that is added to the register in brackets

Memory Instruction Format

- The format of a store instruction:

source register

source address

sw $t0, 8($t3)

any register

a constant that is added to the register in brackets

Example

Convert to assembly:

C code: d[3] = d[2] + a;

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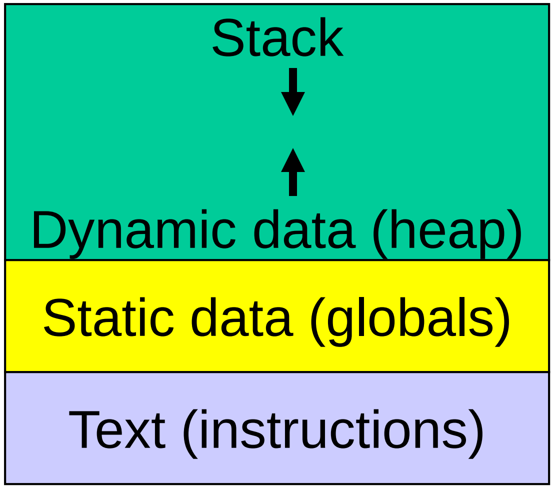
Assembly: # addi instructions as before

```
lw    $t0, 8($s4)     #  d[2] is brought into $t0
lw    $t1, 0($s1)     #   a  is brought into $t1
add   $t0, $t0, $t1   #  the sum is in $t0
sw    $t0, 12($s4)    #  $t0 is stored into d[3]
```

Assembly version of the code continues to expand!

Memory Organization

- The space allocated on stack by a procedure is termed the activation record (includes saved values and data local to the procedure) – frame pointer points to the start of the record and stack pointer points to the end – variable addresses are specified relative to $fp as $sp may change during the execution of the procedure
- $gp points to area in memory that saves global variables
- Dynamically allocated storage (with malloc()) is placed on the heap



Another Version

Convert to assembly:

C code: d[3] = d[2] + a;

Assembly:

```
lw    $t0, 20($gp)    # d[2] is brought into $t0
lw    $t1, 0($gp)     # a is brought into $t1
add   $t0, $t0, $t1   # the sum is in $t0
sw    $t0, 24($gp)    # $t0 is stored into d[3]
```

Recap – Numeric Representations

- Decimal $35_{10} = 3 \times 10^1 + 5 \times 10^0$
- Binary $00100011_2 = 1 \times 2^5 + 1 \times 2^1 + 1 \times 2^0$
- Hexadecimal (compact representation)

  0x 23 or $23_{hex} = 2 \times 16^1 + 3 \times 16^0$

0-15 (decimal) → 0-9, a-f (hex)

Dec	Binary	Hex	Dec	Binary	Hex	Dec	Binary	Hex	Dec	Binary	Hex
0	0000	00	4	0100	04	8	1000	08	12	1100	0c
1	0001	01	5	0101	05	9	1001	09	13	1101	0d
2	0010	02	6	0110	06	10	1010	0a	14	1110	0e
3	0011	03	7	0111	07	11	1011	0b	15	1111	0f

Instruction Formats

Instructions are represented as 32-bit numbers (one word), broken into 6 fields

R-type instruction add $t0, $s1, $s2

000000	10001	10010	01000	00000	100000
6 bits	5 bits	5 bits	5 bits	5 bits	6 bits
op	rs	rt	rd	shamt	funct
opcode	source	source	dest	shift amt	function

I-type instruction lw $t0, 32($s3)

6 bits	5 bits	5 bits	16 bits
opcode	rs	rt	constant

Logical Operations

Logical ops	C operators	Java operators	MIPS instr
Shift Left	<<	<<	sll
Shift Right	>>	>>>	srl
Bit-by-bit AND	&	&	and, andi
Bit-by-bit OR	|	|	or, ori
Bit-by-bit NOT	~	~	nor

Control Instructions

- Conditional branch: Jump to instruction L1 if register1 equals register2:   beq   register1, register2, L1
  Similarly, bne and slt (set-on-less-than)

- Unconditional branch:
  j   L1
  jr $s0   (useful for large case statements and big jumps)

Convert to assembly:

```
if  (i == j)
    f = g+h;
else
    f = g-h;
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  j L1
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Convert to assembly:

```
if (i == j)                bne   $s3, $s4, Else
    f = g+h;               add   $s0, $s1, $s2
else                       j     Exit
    f = g-h;        Else:  sub   $s0, $s1, $s2
                    Exit:
```

Example

Convert to assembly:

```
while   (save[i] == k)
     i += 1;
```

i and k are in $s3 and $s5 and
base of array save[] is in $s6

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```
Loop:  sll    $t1, $s3, 2
       add    $t1, $t1, $s6
       lw     $t0, 0($t1)
       bne    $t0, $s5, Exit
       addi   $s3, $s3, 1
       j      Loop
Exit:
```

Registers

- The 32 MIPS registers are partitioned as follows:
  - Register 0 : $zero always stores the constant 0
  - Regs 2-3 : $v0, $v1 return values of a procedure
  - Regs 4-7 : $a0-$a3 input arguments to a procedure
  - Regs 8-15 : $t0-$t7 temporaries
  - Regs 16-23: $s0-$s7 variables
  - Regs 24-25: $t8-$t9 more temporaries
  - Reg 28 : $gp global pointer
  - Reg 29 : $sp stack pointer
  - Reg 30 : $fp frame pointer
  - Reg 31 : $ra return address

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