**CS 61C Summer 2010**
**Section 101**

**Week 6 – MIPS Machine Code**

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*The Stored Program Concept*

- All programs (instructions) are just data represented by combinations of bytes!
- Any block of memory can be code. Consequently, self-modifying code is possible!
- The Program Counter (PC) is a special register (not directly accessible) which holds a pointer to the current instruction.

*Instruction Formats*

MIPS instructions come in three tasty flavors!

**R-Instruction format (register-to-register).** Examples: addu, and, sll, jr

| op code | rs | Rt | Rd | shamt | funct |
|---|---|---|---|---|---|
| 6 bits | 5 bits | 5 bits | 5 bits | 5 bits | 6 bits |

*See green sheet to see what registers are read from and what is written to*

**I-Instruction Format (register immediate)** Examples: addiu, andi, bne

| op code | rs | Rt | immediate |
|---|---|---|---|
| 6 bits | 5 bits | 5 bits | 16 bits |

*Note: Immediate is 0 or sign-extended depending on instruction (see green sheet)*

**J-Instruction Format (jump format)** For j and jal

| op code | address |
|---|---|
| 6 bits | 26 bits |

KEY: An instruction is R-Format if the op code is 0. If the opcode is 2 or 3, it is J-format. Otherwise, it is I-format. Different R-format instructions are determined by the "funct".

1. How many instructions are representable with this format?

If opcode is 2 or 3, they are the two J instructions.
If opcode is 0, then each funct code uniquely defines an instruction. So there are 64 R-instructions.
If opcode is any other number, they are I-instructions. There are 64-3 = 61 of them.
Thus we have a total of **127** instructions.

2. What could we do to increase the number of possible instructions?

Add more instruction formats (say opcode 4 is A-instruction format, define new fields, and so on).
Expand more bits, i.e. go to 64-bit architecture.
Reduce only 16 or less registers, and thus gives more room for opcode.

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*MIPS Addressing Modes*

- We have several **addressing modes** to access memory (immediate not listed):
  - **Base displacement addressing**: Adds an immediate to a register value to create a memory address (used for lw, lb, sw, sb)
  - **PC-relative addressing**: Uses the PC (actually the current PC plus four) and adds the I-value of the instruction (multiplied by 4) to create an address (used by I-format branching instructions like beq, bne)
  - **Pseudodirect addressing**: Uses the upper four bits of the PC and concatenates a 26-bit value from the instruction (with implicit 00 lowest bits) to make a 32-bit address (used by J-format instructions)
  - **Register Addressing:** Uses the value in a register as memory (jr)

3. You need to jump to an instruction that is 257Mb up from the current PC. How do you do it? (HINT: you need multiple instructions)

Note that the gap is too large for jump to work. We can use lui and ori to load the absolute address into register $at, then use jr.

4. Given the following MIPS code (and instruction addresses), fill in the highlighted instructions (you'll need your green sheet!):

```
0x002cff00: loop: addu $t0, $t0, $t0      |  0 | 8  | 8  | 8  |  0 | 0x21 |

0x002cff04:       jal  foo                |  3 |         0xC0001          |

0x002cff08:       bne  $t0, $zero, loop   |  5 |  8  |  0 |   0xFFFD      |
...

0x00300004: foo:  jr $ra           $ra=_____0x002CFF08_____
```

5. What instruction is `0x00008A03`?

0000 0000 0000 0000 1000 1010 0000 0011

000000 00000 00000 10001 01000 000011 → R-type

sra $s1 $0 8

Bonus Question: Every woman in a village of fifty couples has been unfaithful to her husband. Every man in the village instantly knows when a woman other than his wife has philandered (you know how small towns are) but not when his own wife has ("always the last to know"). The village's no-tolerance adultery statute requires that a man who can prove his wife is unfaithful must kill her that very day. No man would dream of disobeying this law. One day, the queen, who is known to be infallible, visits the village. She announces that at least one wife has been unfaithful. What happens?