Instruction Types

Computation:

- arithmetic (e.g., add)
- logical (e.g., xor)
- compare (e.g., set if not equal)

Data transfer:

- load
- store

Control

- branch
- jump

MIPS Computation Instructions

Opcode	rd, rs, rt
Opcode	rt, rs, immed

- rd: destination register (modify)
- rs: source register (read-only)
- rt: source/destination register (read-only/modify)
- immed: 16-bit signed value (constant)

MIPS Computation Instructions

Some examples:

```
add    $8, $9, $10      # $8 = $9+$10
addi   $t0, $t1, 20     # $t0 = $t1+20
addu   $8, $9, $10      # $8 = $9+$10
sub    $t5, $0, $t5     # $t5 = -$t5
and    $8, $9, $10      # $8 = $9&$10
slt    $8, $9, $10      # if $9<$10, $8 = 1,
                        else $8 = 0
slti   $8, $9, -6       # if $9<-6, $8 = 1,
                        else $8 = 0
```

The GPRs are used to store the result of a condition.

Alternative architecture: **condition codes**

- special 1-bit registers that store the result of specific conditions
  - whether the result is zero
  - whether the result is negative

The machine does not know if a value is signed or unsigned (the bag of bits) --- you have to specify this by using the appropriate instruction

Instruction Encoding

ISA defines the formats for instructions

- what fields they contain
- the size of the fields
- the field values & what the values signify

Being a RISC, MIPS has few (3) instruction formats

- all instructions are the same length,
  32 bits
- most formats have similar fields
  for example: an opcode, at least one source register
- fields that are common to more than one format have the same location in the instruction
  for example: the opcode is always first
- fields that are common to more than one format are the same size
  for example: the opcode is always 6 bits

Knowing the instruction formats, shows us how the CPU processes instructions

- bridge between architecture & implementation

R-type Format

For arithmetic, logical, comparative instructions with register operands

31 26		20 16		10 6	0
opcode	rs	rt	rd	shamt	func
	25 21		15 11		5

- **opcode, func** = operation
  - opcode = a computational instruction
  - func = which computation
- **rs, rt** = source operands
- **rd** = destination operand
- **shamt** = shift distance in bits

`add $8, $9, $10`

0	9	10	8	unused	32

`xor $11, $12, $13`

0	**12**	**13**	**11**	unused	38

`sll $10, $16, 4`

0	unused	16	10	4	0

I-type Format

For arithmetic, logical, comparative instructions with one register operand & one constant operand

31 26		20 16	
opcode	rs	rt	immed
	25 21		15 0

- **opcode** = operation
  - opcode = a computational instruction
- **rs** = source operand
- **rt** = destination operand
- **immed** = constant, ± 2^{15}
  - sign-extended when used (replicate msb)

Using an immediate value is faster than loading the constant from memory & saves using a register

`ori $8, $9, -256`

13	9	8	-256