Foundations of Programming Languages

2OPM Assembly (1/3): Introduction

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17. Oktober 2014

2OPM: Two-Operand Pseudo-MIPS

- Synthetic Assembly Language
- Based on MIPS64, but most instructions use only two operands:

```
add $t0, $t1 #$t0 := $t0 + $t1
```

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- Synthetic Assembly Language
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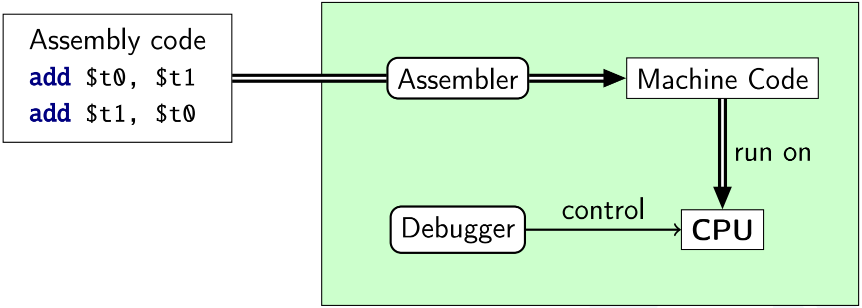
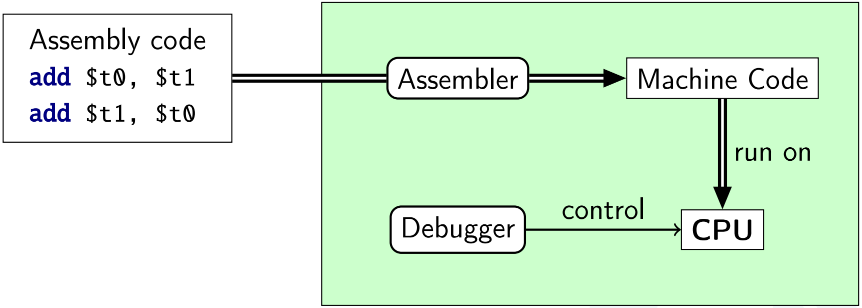
  ```
  add $t0, $t1 #$t0 := $t0 + $t1
  ```
- 16 Registers
- Translates (mostly) directly to Intel 64-bit machine code
  $\Rightarrow$ Suitable CPU can execute instructions directly

Easier than Intel assembly, almost as efficient

Using 2OPM


Assembly code
add $t0, $t1
add $t1, $t0
Assembler
Machine Code
run on
Debugger
control
CPU

Using 2OPM



Assembly code

```
add $t0, $t1
add $t1, $t0
```

We will also use 2OPM in a language implementation

2OPM Registers

2OPM features 16 general-purpose registers:

Name	**Purpose**
`$v0`	Return **V**alue
`$a0`, `$a1`, `$a2`, `$a3`, `$a4`, `$a5`	**A**rguments
`$s0`, `$s1`, `$s2`, `$s3`	**S**aved registers
`$t0`, `$t1`	**T**emporary registers
`$sp`	**S**tack **P**ointer
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Plus $pc:

- *Program Counter*, address of next instruction
- can't be referenced directly

Purpose defined by *convention*

Intel 64-bit Registers

64-bit x86 features 16 general-purpose registers:

Name	Purpose
`%rax`	Return Value
`%rdi`, `%rsi`, `%rdx`, `%rcx`, `%r8`, `%r9`	Arguments
`%rbx`, `%r12`, `%r13`, `%r14`	Saved registers
`%r10`, `%r11`	Temporary registers
`%rsp`	Stack Pointer
`%rbp`	Frame Pointer
`%r15`	Global Pointer

Plus `%rip`:

- *instruction pointer*, address of next instruction
- can't be referenced directly

Historical naming; we will use the 2OPM names

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Plus $pc

Basic Operations

```
li    $t0, 2      # $t0 := 2
```

- `li $r, v`
  Load 64 bit value `v` into `$r`

Basic Operations

```
li    $t0, 2      # $t0 := 2
move  $t1, $t0    # $t1 := $t0
```

- `li $r, v`
  Load 64 bit value `v` into `$r`
- `move $r0, $r1`
  Copy contents of `$r1` into `$r0`

Basic Operations

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li    $t0, 2     # $t0 := 2
move  $t1, $t0   # $t1 := $t0
add   $t0, $t1   # $t0 := $t0 + $t1
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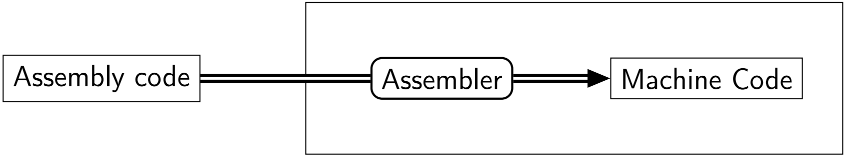
Operate on registers only

Machine Code



```
li      $t0, 2              49 ba 02 00 00 00 00 00 00 00
move    $t1, $t0            4d 89 d3
add     $t0, $t1            4d 01 da
```

CPU directly executes machine code

Operational Semantics

$$\text{Register file } \rho = \left\{ \begin{array}{ccc} \texttt{\$v0} & \mapsto & \dots \\ \texttt{\$t0} & \mapsto & \dots \\ & \dots & \\ \texttt{\$gp} & \mapsto & \dots \end{array} \right\}$$

Read: $\rho(\texttt{\$r})$
Update: $[\texttt{\$r := x}]\rho$

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Rule for add not quite accurate!

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$$\textbf{add}\ \$r_0, \$r_1 | \rho \longrightarrow \varepsilon | [\$r_0 := \rho(\$r_0) \boxplus^{64} \rho(\$r_1)]\rho$$

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Additional operations for:

- Arithmetic: **`sub`**, **`mul`**, **`div_a2v0`**

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Semantics of realistic CPUs can be complicated!

Bit-Logic

- Negation: **`not`**
- Bit-Shift: **`sll`**, **`srl`**, **`sra`**
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Immediate Operations

```
li  $t0, 8
srl $t1, $t0
```

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Equivalent

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li  $t0, 8
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```
srli  $t1, 8
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(but doesn't modify `$t0`)

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li  $t0, 8
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Immediate operations:

- **addi**, **subi**
- **slli**, **srli**, **srai**
- **andi**, **ori**, **xori**

Summary

- 2OPM: synthetic assembly language
- Uses 16 general-purpose registers plus program counter
- Most operations use two register operands
- Operations for loading (**`li`**), copying (**`move`**)
- Basic arithmetic with combined division/modulo
- Bit-wise operations
- *Immediate* operations with register plus immediate operand available in many cases
- Describing semantics requires *register file*

Instructions are more fully described in documentation