Foundations of Programming Languages

2OPM Assembly (2/3): Advanced Operations

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Looping: Jumps and Conditionals

Compute factorial of `$t1` in `$t0`:

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Assembly
li      $t0, 1
mul     $t0, $t1
subi    $t1, 1
bnez    $t1, -21     # If $t1 <> 0, then ...
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- **bnez** `$r, n`:
  if $\$r \neq 0$, then $\$pc := \$pc + n$
  (conditional jump)

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Machine code	Assembly		
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`49 81 eb 01 00 00 00`	**subi**	`$t1, 1`	
`49 83 c3 00 0f 85 eb ff ff ff`	**bnez**	`$t1, -21`	# If $t1 <> 0, then ...

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Jump distances like -21 hard to compute by hand

Labels

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Exactly the same program as on the last slide

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  - **beqz** `$r0,` ℓ # Jump if `$r0` = 0
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  - Analogous: **`bnez`**, **`bgtz`**, **`blez`**, ...

Operational Semantics for jumps is quite complex, won't be covered here

Memory access

Load: **ld** `$r0, d($r1)`
Store: **sd** `$r0, d($r1)`

- `d`: 32 bit (signed) *displacement*
- Operation accesses memory address `d` + `$r1`
- Reads or writes 64 bit string to/from `$r0`

Finding the largest element

- Starting at address $a0:
- Search for largest 64-bit (8-byte) element in $a1 entries
- Store result in $v0

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⇒       li      $v0, 0            # initial result
        move    $t0, $a1
        slli    $t0, 3            # x « 3 ≡ x × 2^3 = 8x
        add     $t0, $a0          # last addr. plus 64-bit word
loop:
        beq     $t0, $a0, end
        ld      $t1, 0($a0)       # load from memory
        addi    $a0, 8            # advance to next element
        blt     $t1, $v0, loop    # found bigger element?
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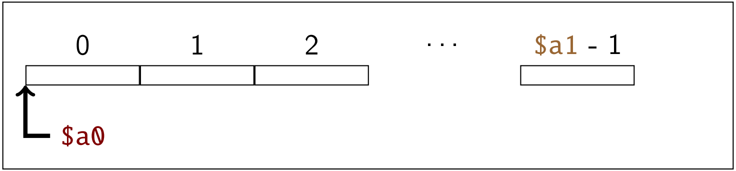
Finding the largest element

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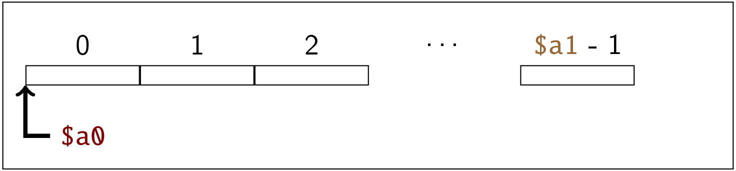


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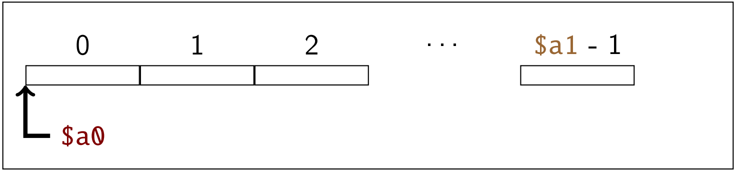


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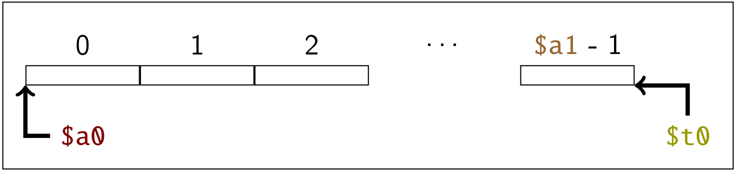


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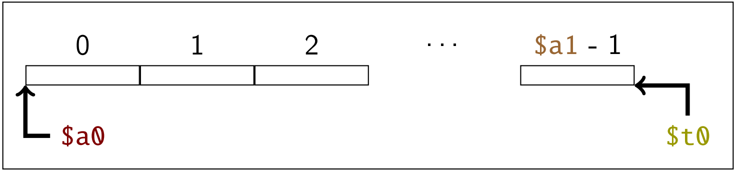


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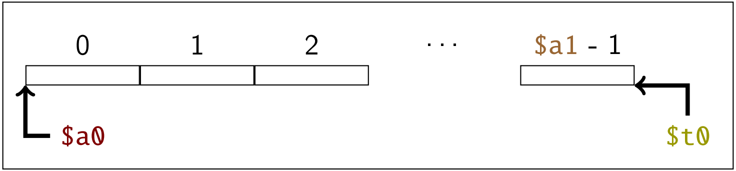


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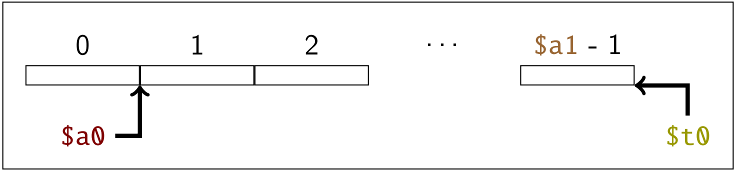


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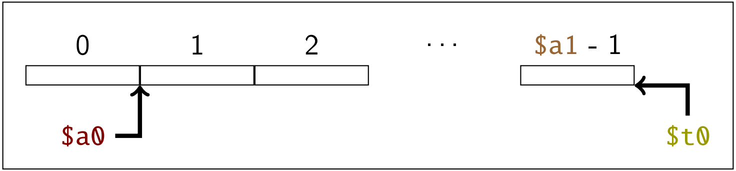


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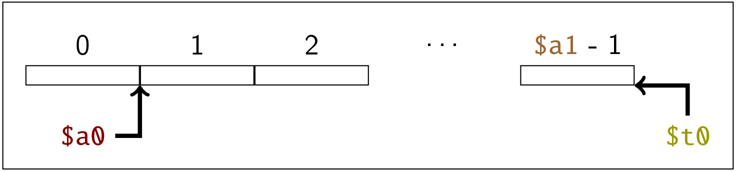


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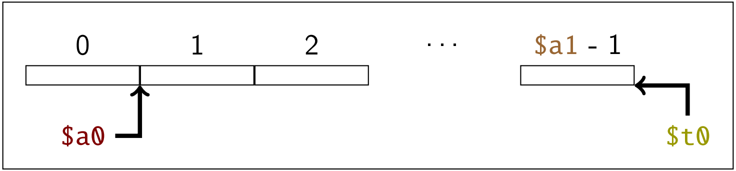


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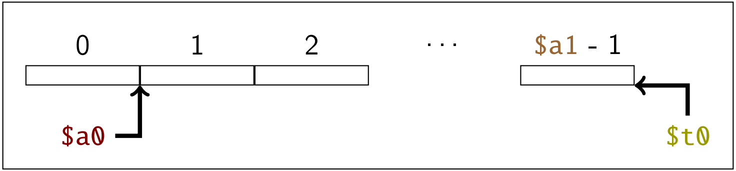


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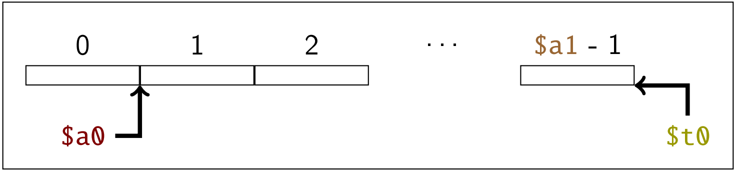


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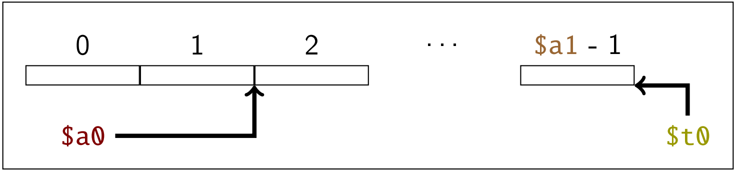


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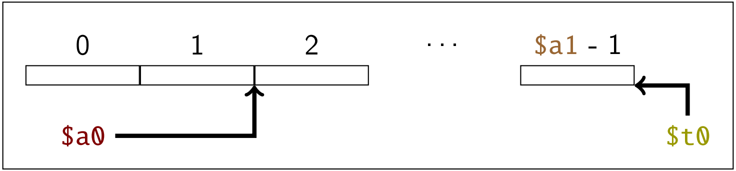


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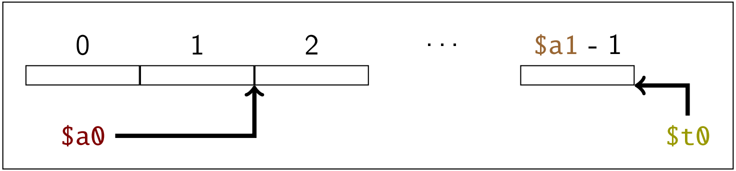


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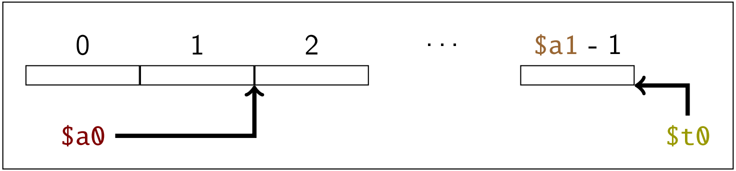


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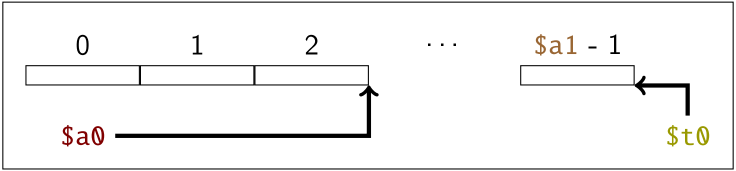


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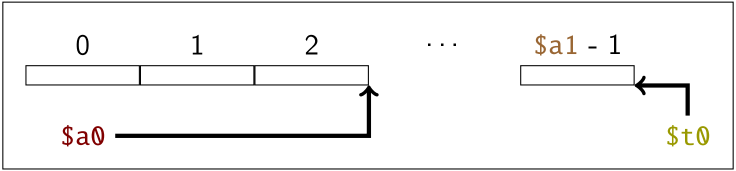


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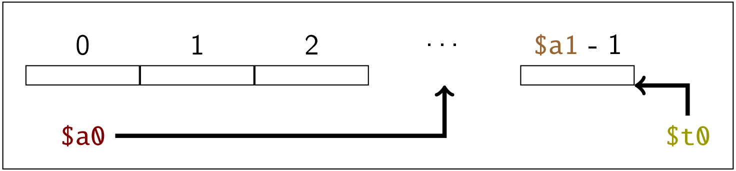


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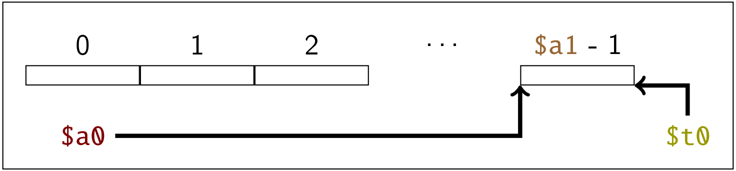


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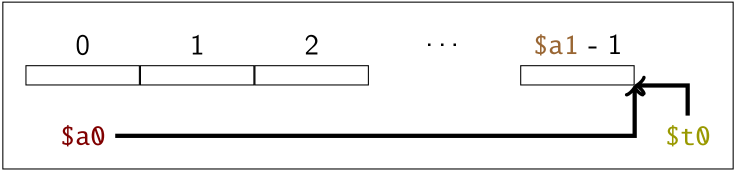


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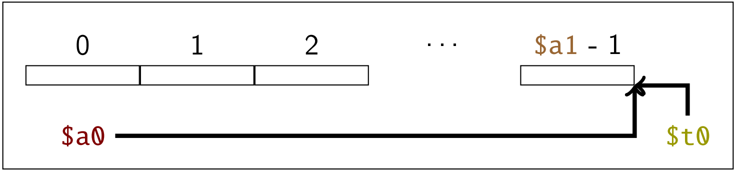


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        li    $v0, 0            # initial result
        move  $t0, $a1
        slli  $t0, 3            # x « 3 ≡ x × 2^3 = 8x
        add   $t0, $a0          # last addr. plus 64-bit word
loop:
        beq   $t0, $a0, end
        ld    $t1, 0($a0)       # load from memory
        addi  $a0, 8            # advance to next element
        blt   $t1, $v0, loop    # found bigger element?
        move  $v0, $t1
        j     loop
⇒ end:
```

Summary

- Memory access via `ld` (load) and **sd** (store)
- Conditional and unconditional jumps available
  - Conditional jumps for comparing two registers
  - Conditional jumps for comparing one register with zero
- Operational semantics for full assembly language quite complex