

## Opening remarks

So far

- Basic blocks.
- Control Flow Graphs.
- Dominators, Loops
- Liveness analysis
- Register allocation (linear scan, Kempe, spilling)
- Optimizations in the basic block.
- Peephole optimizations

Announcements:

- Assignment 6 is due in ten days.

Today

- Runtime management - Procedure calling



## Runtime management

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## Parameter passing

Call-by-value

- store values, not addresses
- never restore on return
- arrays, structures, strings are a problem

Call-by-reference

- pass address
- access to formal is indirect reference to actual

Call-by-value-result

- store values, not addresses
- always restore on return
- arrays, structures, strings are a problem



## Parameter passing - varargs

What about variable length argument lists?

- 1 if caller knows that callee expects a variable number
  - 1 caller can pass number as 0<sup>th</sup> parameter
  - 2 callee can find the number directly
- 2 if caller doesn't know anything about it
  - 1 callee must be able to determine number
  - 2 first parameter must be closest to FP

Consider `printf` :

- number of parameters determined by the format string
- it assumes the numbers match



# MIPS procedure call convention

Registers:

Number	Name	Usage
0	zero	Constant 0
1	at	Reserved for assembler
2, 3	v0, v1	Expression evaluation, scalar function results
4–7	a0–a3	first 4 scalar arguments
8–15	t0–t7	Temporaries, caller-saved; caller must save to preserve across calls
16–23	s0–s7	Callee-saved; must be preserved across calls
24, 25	t8, t9	Temporaries, caller-saved; caller must save to preserve across calls
26, 27	k0, k1	Reserved for OS kernel
28	gp	Pointer to global area
29	sp	Stack pointer
30	s8 (fp)	Callee-saved; must be preserved across calls
31	ra	Expression evaluation, pass return address in calls



# MIPS procedure call convention

Philosophy:

*Use full, general calling sequence only when necessary; omit portions of it where possible (e.g., avoid using fp register whenever possible)*

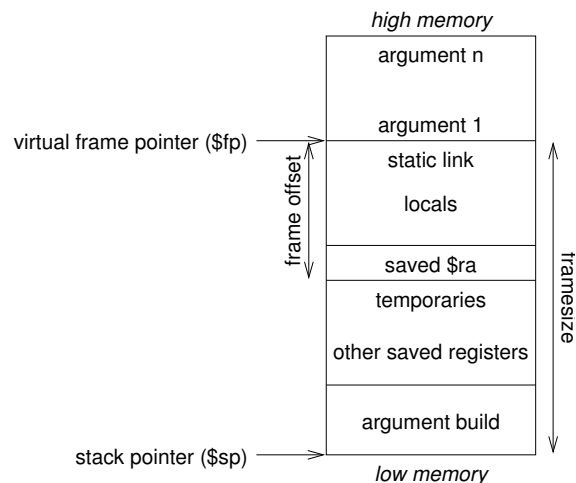
Classify routines as:

- non-leaf routines: routines that call other routines
- leaf routines: routines that do not themselves call other routines
  - leaf routines that require stack storage for locals
  - leaf routines that do not require stack storage for locals



# MIPS procedure call convention

The stack frame



The "locals" can be accessed by a callee.

# MIPS procedure call convention

Pre-call:

- 1 Pass arguments: use registers \$a0 ... \$a3; remaining arguments are pushed on the stack along with save space for \$a0 ... \$a3
- 2 Save caller-saved registers if necessary
- 3 Execute a jal instruction: jumps to target address (callee's first instruction), saves return address in register \$ra



## MIPS procedure call convention

### Prologue:

#### 1 Leaf procedures that use the stack and non-leaf procedures:

##### 1 Allocate all stack space needed by routine:

- local variables
- saved registers
- sufficient space for arguments to routines called by this routine

```
subu $sp,framesize
```

##### 2 Save registers (\$ra, etc.):

```
sw $31,framesize+frameoffset($sp)
```

```
sw $17,framesize+frameoffset-4($sp)
```

```
sw $16,framesize+frameoffset-8($sp)
```

where `framesize` and `frameoffset` (usually negative) are compile-time constants

#### 2 Emit code for routine



## MIPS procedure call convention

### Epilogue:

#### 1 Copy return values into result registers (if not already there)

#### 2 Restore saved registers

```
lw reg,framesize+frameoffset-N($sp)
```

#### 3 Get return address

```
lw $31,framesize+frameoffset($sp)
```

#### 4 Clean up stack

```
addu $sp,framesize
```

#### 5 Return

```
j $31
```



## Closing remarks

### What did we do today?

- Runtime management
- Parameter passing

