CPS311: COMPUTER ORGANIZATION

An Example of A MIPS Program Using Procedures and Parameters

```
/*
 * This module implements a procedure (solve) that computes the roots of a
 * quadratic equation that has integer roots, returning them to the caller.
 * The arguments are the coefficients of the quadratic equation (input) plus
 * the two roots (output).  It also returns a status code to the caller:
 *
 *   0 - Computation successful and root values are valid
 *   1 - Roots are not integers (roots values are truncated)
 *   2 - Roots are complex (root values invalid)
 *   3 - Overflow occurred during computation (root values invalid)
 *
 * Register usage:
 *
 *   Parameters:  $4 = A (by value)
 *                $5 = B (by value)
 *                $6 = C (by value)
 *                $7 = first root (by reference)
 *                $8 = second root (by reference)
 *   Return value:$2
 *   Temporaries: $2, $3
 *
 * *** This version of the program does not incorporate overflow handling
 * *** code.  It will crash if overflow occurs in computing the discriminant.
 *
 * R. Bjork - written 2/1999 last revised 9/2019
 */
    # The .section assembler directive is used to break a program into
    # sections.   Executable code goes in the .text section.
        .section .text
    # *** ENTRY PROTOCOL STARTS HERE ****
    # Each procedure needs to have its entry point declared as a label; if
    # it is called from outside this module its entry point must also be
    # declared as a global symbol (for the linker).   The name should
    # also be declared by a .ent directive (for the debugger).
        .ent     solve
        .globl   solve
    solve:
    # Upon entry, a non-leaf procedure must allocate a frame on the
    # stack, and save its parameters and return address, as well as any
    # callee-saved registers it intends to use.      (None in this case)
    # The frame may also be used to hold local variables. (None in this
    # case) The size of the frame must be a multiple of 16
    # The .frame and .mask directives provides information for the debugger
    # about the structure of the frame.
    # The first argument of .frame indicates what register is used to point
    # to the frame (either the stack pointer or some other register set
    # aside for that purpose); the second gives the size of the frame, and
    # the third argument indicates what register holds the return address
    # for the procedure (almost always $31).
        .frame   $sp, 32, $31
```

```
# The mask directive specifies what registers are saved in the stack
# frame, and where the register save area begins relative to the
# start of the frame.  The first argument is a bit mask with 1's
# in bit positions corresponding to registers that are saved.  Only
# registers in the callee saved set ($16 and up) normally appear in
# the mask.   (The only register this procedure needs to save in this
# group is the return address - $31).  The second argument indicates
# the offset from the high end of the frame ($sp + size) to the slot
# where the highest numbered register specified in the mask is saved.
# In this case, $31 is saved 24 prior to the high end of the frame,
# so the offset is -24. (Note that it is stored to 8(#sp), because
# 32 - 24 = 8.)

    .mask    0x80000000, -24

# The code that follows actually creates the frame and saves the
# registers in it.

    addi $sp, -32

    sw   $31, 8($sp)
    sw   $4, 12($sp)
    sw   $5, 16($sp)
    sw   $6, 20($sp)
    sw   $7, 24($sp)
    sw   $8, 28($sp)

# *** ENTRY PROTOCOL ENDS HERE ***

/* Compute the discriminant (put in $2).  Registers already contain
 *  the correct parameters
 */

    jal compute_discr

    /* Test for negative discriminant */

    slt $3, $2, $0
    beq $3, $0, d_ok       # Non-negative, so go on
    addi $2, $0, 2         # Status value for complex roots
    b    fini          # Exit

d_ok:

/* Compute square root of discriminant (put in $2) */

    add $4, $2, $0         # Put discriminant in $4 as parameter
    jal compute_sqrt       # $2 now contains sqrt(discriminant)

/* Compute the roots */

    lw   $4, 12($sp)       # First parameter = A
    lw   $5, 16($sp)       # Second parameter = B
    add $6, $0, $2         # Third parameter = sqrt(discriminant)
    jal compute_roots # $2 and $3 now contain the roots

/* Save the roots in location specified by caller */

    lw   $7, 24($sp)       # Restore return parameter addresses
    lw   $8, 28($sp)
    sw   $2, 0($7)         # Store first root
    sw   $3, 0($8)         # Store second root
```

```
/* Check to be sure they are integers - if not, status code will
 * indicate that a warning about truncation is needed.
 */

    lw   $4, 12($sp)       # First parameter = A
    lw   $5, 16($sp)       # Second parameter = B
    lw   $6, 20($sp)       # Third parameter = C
    add $7, $2, $0         # Fourth parameter = first root
    add $8, $3, $0         # Fifth parameter = second root
    jal test_roots         # $2 contains 0 if roots OK, 1 if not

# *** EXIT PROTOCOL STARTS HERE ***

/* Exit protocol for solve.     When this point is reached, $2 must
 * contain the status code to be returned to the caller
 *
 */

# Upon exit, a non-leaf procedure must restore its return address and
# any callee-saved registers from the stack frame and then deallocate
# the frame.  (The parameters need not be restored).

fini:

    lw   $31, 8($sp)
    addi $sp, 32

# Return to caller

    jr   $31

# Each procedure must end with a .end directive

    .end solve

# *** EXIT PROTOCOL ENDS HERE ***

/*
 * The following local routine computes the discriminant.
 *
 * Parameters:         $4 = A
 *                     $5 = B
 *                     $6 = C
 * Return value:  $2
 */

# As a local routine, its name does not need to be declared global, and
# as a leaf routine, it does not need to save anything on the stack.
# A frame directive with a size of 0 indicates no frame.

    .ent compute_discr
    .frame   $sp, 0, $31

compute_discr:

    mulo $2, $5, $5    # Pseudoinstruction.  Assembler generates code to
                           # put 32-bit product in $2; check for overflow and
                           # raise an exception if one occurs.  #2 = B*B
    addi $3, $0, 4     # $3 = 4
    mulo $3, $3, $4    # $3 = 4*A - overflow checked
    mulo $3, $3, $6    # $3 = 4*AC - overflow checked
    sub $2, $2, $3         # $2 = B*B-4AC = discriminant - overflow checked

    jr   $31

    .end compute_discr
```

```
/*
 * The following local routine computes the integer square root of the
 * discriminant.
 *
 * Parameter:     $4 = discriminant
 * Return value:  $2 = integer square root (truncated if need be)
 *
 * Method: Successive testing of individual bits, starting with
 *      2^15 and working down to 2^0
 */

    .ent compute_sqrt
    .frame   $sp, 0, $31

compute_sqrt:

    add $2, $0, $0    # guess at square root 0 - initially 0
    ori $3, $0, 0x8000    # bit mask for trial bit

sqrt_loop:

    or   $2, $2, $3    # or in trial bit
    mul $5, $2, $2    # test to see if guess is now too big
    slt $5, $4, $5
    beq $5, $0, bit_ok
    xor $2, $2, $3    # set trial bit back to 0
    bit_ok:
    srl $3, $3, 1# move on to next bit
    bne $3, $0, sqrt_loop

    jr   $31

        .end compute_sqrt

/*
 * The following local routine computes the roots.
 *
 * Parameters:         $4 = A
 *                     $5 = B
 *                     $6 = sqrt(discriminant)
 * Return values: $2 and $3 = two roots
 *
 */

    .ent compute_roots
    .frame   $sp, 0, $31

compute_roots:

    add $4, $4, $4    # $4 = 2*A
    sub $5, $0, $5    # $5 = -B - overflow checked
    sub $2, $5, $6    # $2 = -B - sqrt(discriminant) - oveflow checked
    div $2, $2, $4    # $2 = first root
    add $3, $5, $6    # $3 = -B + sqrt(discriminant) - overflow checked
    div $3, $3, $4    # $3 = second root

    jr   $31

    .end compute_roots
```

```
/*
 * The following local routine tests the roots to be sure they are
 * integers
 *
 * Parameters:          $4 = A
 *                      $5 = B
 *                      $6 = C
 *                      $7 = first root
 *                      $8 = second root
 * Return value:  $2 = 0 if roots are integers, 1 if not
 *
 * Method - verify that A * sum of roots = -B, A * product = C
 *
 */

    .ent test_roots
    .frame   $sp, 0, $31

test_roots:

    add $2, $7, $8    # $2 = sum of roots
    mul $2, $2, $4    # $2 = A * sum of roots
    add $2, $2, $5    # $2 will be 0 iff A*sum of roots = -B
    bne $2, $0, not_int
    mul $2, $7, $8    # $2 = product of roots
    mul $2, $2, $4    # $2 = A * product of roots
    sub $2, $2, $6    # $2 will be 0 iff A*prod of roots = C
    bne $2, $0, not_int

    jr   $31          # Return with $2 = 0 - roots OK

not_int:

    addi $2, $0, 1
    jr   $31          # Return with $2 = 1 - roots not OK

    .end test_roots
```