report.md

實驗三 實驗結報

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實驗名稱

ARM Assembly II

實驗目的

熟悉基本 ARMv7 組合語言語法使用

實驗步驟

Postfix Arithmetic

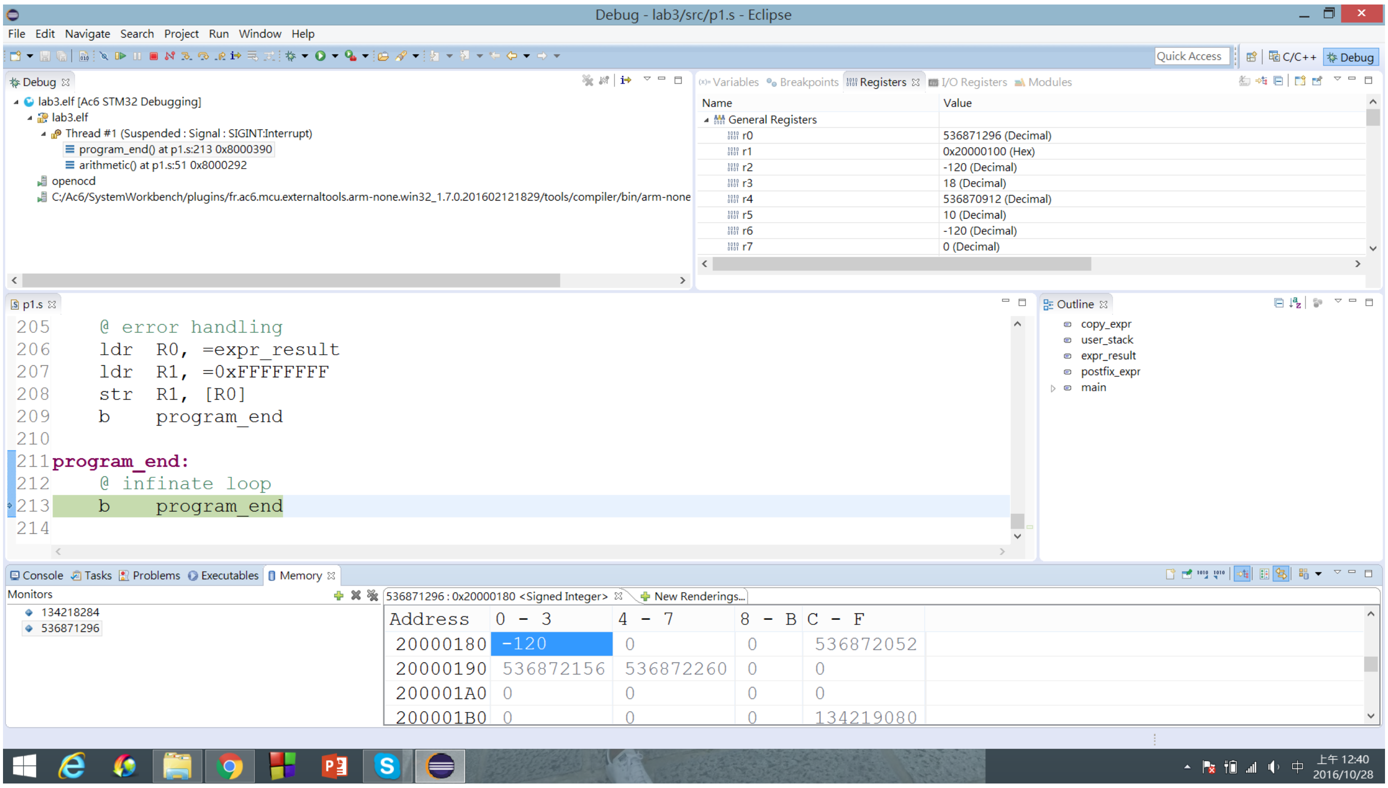
```
    .syntax unified
    .cpu cortex-m4
    .thumb

.data
    copy_expr:   .zero  256
    user_stack:  .zero  128
    expr_result: .word  0

.text
    .global main
    postfix_expr: .asciz  "-100 10 20 + - 10 +"

main:
    ldr  R0 , =postfix_expr
    mov  R1, 0x0
    bl   strlen

    ldr  R0 , =postfix_expr
    ldr  R1 , =copy_expr
    bl   memcpy

    ldr  R0 , =user_stack
    msr  msp , R0
    ldr  R2 , =postfix_expr
    mov  R3, 0x0
    ldr  R4 , =copy_expr
    b    arithmetic

arithmetic:
    @ arithmetic -related
    ldrb R1 , [R2, R3]
    cmp  R1, 0x0
    beq  arithmetic_end
    cmp  R1, 0x20    @ '[space]'
    beq  duplicate_spaces
    ldrh R1 , [R2, R3]
    ldr  R9, =0x202B
    cmp  R1, R9      @ " +"
    beq  addition
    cmp  R1, 0x2B    @ "\0+"
    beq  addition_last
    ldr  R9, =0x202D
    cmp  R1, R9      @ " -"
    beq  substraction
    cmp  R1, 0x2D   @ "\0-"
    beq  substraction_last
    add  R0, R4, R3
    mov  R5, R0
    push {R2, R3, R4, R5}
    bl   atoi
    pop  {R2, R3, R4, R5}
    push {R1}
    sub  R1, R0, R5
    add  R3, R1
    b    arithmetic

addition:
    @ arithmetic -related
    pop  {R5}
    pop  {R6}
    add  R6, R5
    push {R6}
    add  R3, 0x2
    b    arithmetic

addition_last:
    @ arithmetic -related
    pop  {R5}
    pop  {R6}
    add  R6, R5
    push {R6}
    b    arithmetic_end

substraction:
    @ arithmetic -related
    pop  {R5}
    pop  {R6}
    sub  R6, R5
    push {R6}
    add  R3, 0x2
    b    arithmetic

substraction_last:
    @ arithmetic -related
    pop  {R5}
    pop  {R6}
    sub  R6, R5
    push {R6}
    b    arithmetic_end

duplicate_spaces:
    @ arithmetic -related
    add  R3, 0x1
    b    arithmetic

arithmetic_end:
    @ arithmetic -related
    pop  {R2}
    ldr  R1, =user_stack
    mov  R9, sp
    cmp  R1, R9
    bne  error
    ldr  R0, =expr_result
    str  R2, [R0]
    b    program_end

memcpy:
    @ R0: source address
    @ R1: destination address
    push {lr}
    b    memcpy_inner

memcpy_inner:
    @ called by memcpy
    ldrb R2, [R0]
    cmp  R2, 0x0
    beq  go_back
    cmp  R2, 0x20 @ '[space]'
    it   eq
    bleq space_to_zero
    strb R2, [R1]
    add  R0, 0x1
    add  R1, 0x1
    b    memcpy_inner

space_to_zero:
    @ called by memcpy
    mov  R2, 0x0
    bx   lr

go_back:
    @ called by memcpy
    pop  {pc}

strlen:
    @ R0: start address of the string
    @ R1: string length (return)
    ldrb R2, [R0]
    cmp  R2, 0x0
    it   eq
    bxeq lr
    add  R0, 0x1
    add  R1, 0x1
    b    strlen

atoi:
    @ R0: start address of the string
    @     start address of the next token (return)
    @ R1: integer value (return)
    ldrb R1, [R0]
    mov  R2, 0x0  @ is_negative flag
    cmp  R1, 0x2B @ '+'
    beq  atoi_pos
    cmp  R1, 0x2D @ '-'
    beq  atoi_neg
    cmp  R1, 0x0
    beq  error
    mov  R1, 0x0
    b    atoi_inner

atoi_pos:
    @ called by atoi
    add  R0, 0x1
    mov  R1, 0x0
    b    atoi_inner

atoi_neg:
    @ called by atoi
    add  R0, 0x1
    mov  R1, 0x0
    mov  R2, 0x1
    b    atoi_inner

atoi_inner:
    @ called by atoi
    ldrb R3, [R0]
    cmp  R3, 0x0
    beq  atoi_end
    cmp  R3, 0x3A @ character after  '9'
    bge  error
    cmp  R3, 0x2F @ character before  '0'
    ble  error
    sub  R3, 0x30 @ '0'
    mov  R9, 0xA
    mul  R1, R9
    add  R1, R3
    add  R0, 0x1
    b    atoi_inner

atoi_end:
    @ called by atoi
    add  R0, 0x1
    cmp  R2, 0x0
    bne  additive_inverse
    bx   lr

additive_inverse:
    @ called by atoi
    mov  R9, 0x0
    sub  R1, R9, R1
    bx   lr

error:
    @ error handling
    ldr  R0, =expr_result
    ldr  R1, =0xFFFFFFFF
    str  R1, [R0]
    b    program_end

program_end:
    @ infinate loop
    b    program_end
```

求最大公因數並計算最多用了多少 Stack Size

```
    .syntax unified
    .cpu cortex-m4
    .thumb

.data
    result:   .word  0
    max_size: .word  0

.text
    .global main
    m: .word  0x5E
    n: .word  0x60

main:
    ldr  r2, =m
    ldr  r0, [r2]
    ldr  r3, =n
    ldr  r1, [r3]

    mov  r11, sp       @ r11: start of stack
    mov  r10, 0x0      @ r10: max stack size

    push {r0, r1, lr}
    bl   gcd
    pop  {r0, r1, r9}

    ldr  r3, =result
    str  r2, [r3]

    ldr  r3, =max_size
    str  r10, [r3]

    b    forever

gcd:
    ldr  r0, [sp]      @ param a
    ldr  r1, [sp, 0x4] @ param b

    mov  r7, sp
    sub  r8, r11, r7
    cmp  r8, r10
    bgt  update_r10
    b    gcd_final

update_r10:
    mov  r10, r8

gcd_final:
    cmp  r0, 0x0
    beq  return_b
    cmp  r1, 0x0
    beq  return_a

    mov  r2, 0x1
    and  r3, r0, r2
    and  r4, r1, r2

    mov  r8, 0x1
    eor  r3, r8        @ r3: bool , a is even
    eor  r4, r8        @ r4: bool , b is even

    ands r2, r3, r4
    bne  case_1

    cmp  r3, 0x0
    bne  case_2

    cmp  r4, 0x0
    bne  case_3

    b    case_4

return_a:
    mov  r2, r0
    bx   lr

return_b:
    mov  r2, r1
    bx   lr

case_1:
    asr  r0, r0, 0x1
    asr  r1, r1, 0x1
    push {r0, r1, lr}
    bl   gcd
    pop  {r0, r1, r9}
    mov  r8, 0x2
    mul  r2, r8
    mov  pc, r9

case_2:
    asr  r0, r0, 0x1
    push {r0, r1, lr}
    bl   gcd
    pop  {r0, r1, r9}
    mov  pc, r9

case_3:
    asr  r1, r1, 0x1
    push {r0, r1, lr}
    bl   gcd
    pop  {r0, r1, r9}
    mov  pc, r9

case_4:
    cmp r0, r1
    bgt a_is_bigger
    sub r2, r1, r0     @ b - a
    mov r1, r0
    mov r0, r2
    b   case_4_final

a_is_bigger:
    sub r0, r1         @ a - b

case_4_final:
    push {r0, r1, lr}
    bl   gcd
    pop  {r0, r1, r9}
    mov  pc, r9

forever:
    b    forever
```

實驗結果與問題回答

Postfix Arithmetic



```
lab3.elf [Ac6 STM32 Debugging]
  lab3.elf
    Thread #1 (Suspended : Signal : SIGINT:Interrupt)
      program_end() at p1.s:213 0x8000390
      arithmetic() at p1.s:51 0x8000292
  openocd
  C:/Ac6/SystemWorkbench/plugins/fr.ac6.mcu.externaltools.arm-none.win32_1.7.0.201602121829/tools/compiler/bin/arm-none
```

Name	Value
General Registers	
r0	536871296 (Decimal)
r1	0x20000100 (Hex)
r2	-120 (Decimal)
r3	18 (Decimal)
r4	536870912 (Decimal)
r5	10 (Decimal)
r6	-120 (Decimal)
r7	0 (Decimal)

p1.s

```
    @ error handling
    ldr  R0, =expr_result
    ldr  R1, =0xFFFFFFFF
    str  R1, [R0]
    b    program_end

program_end:
    @ infinate loop
    b    program_end

```

Outline: copy_expr, user_stack, expr_result, postfix_expr, main

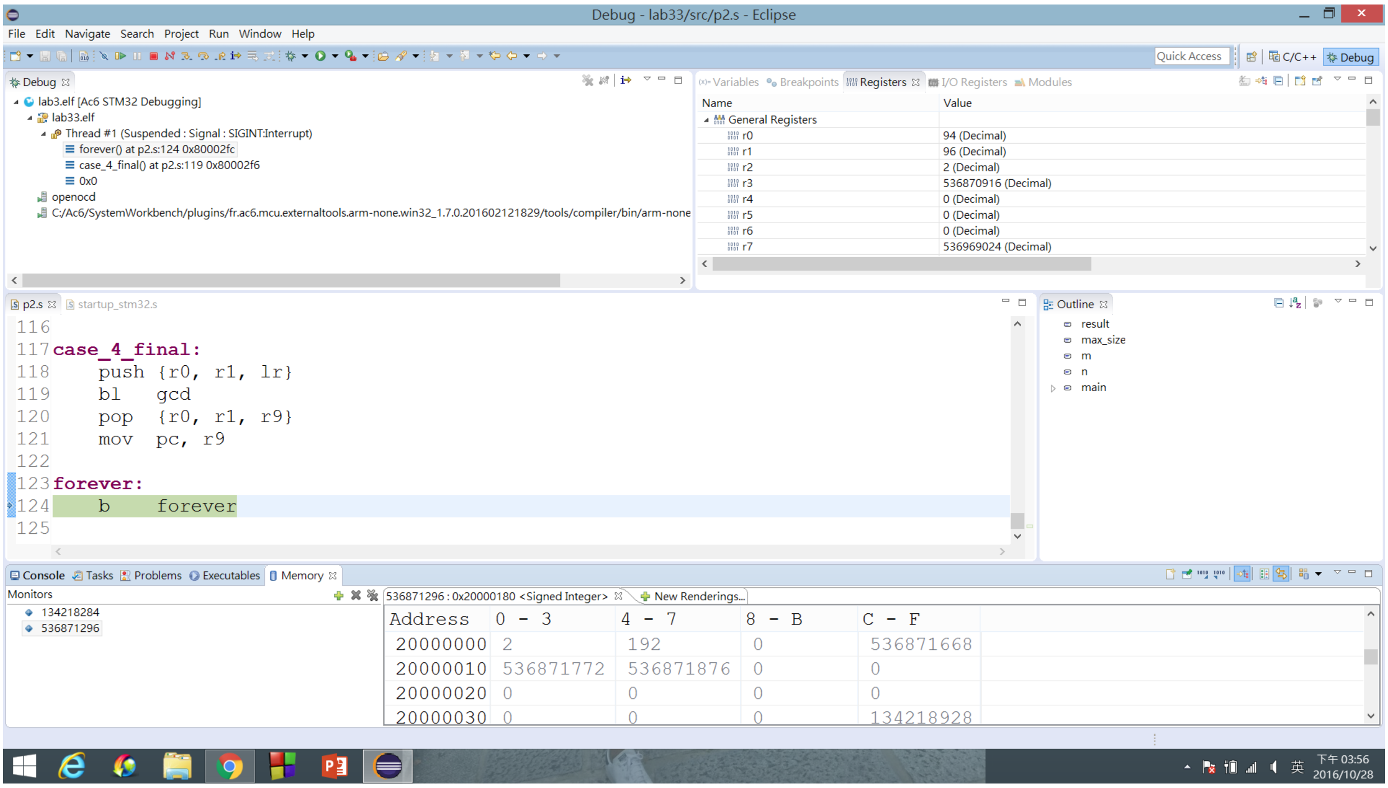
Monitors: 134218284, 536871296

536871296 : 0x20000180 <Signed Integer>

```
Address   0 - 3      4 - 7      8 - B C - F
20000180  -120       0          0     536872052
20000190  536872156  536872260  0     0
200001A0  0          0          0     0
200001B0  0          0          0     134219080
```

- 先執行 `strlen` ，但是這個步驟其實沒有什麼意義，只不過是為了展示我們有正確地實作出 `strlen` 而已。
- 再執行 `memcpy` ，將 `postfix_expr` 從唯讀的 text segment 複製到可寫入的 data segment，同時將所有的空格取代為 `\0` 。
- 最後執行 `arithmetic` ，依照 postfix 的規則操作 stack，如果遇到運算元會先呼叫 `atoi` 將其轉換為數值。
- 錯誤處理的部份， `-100·10abc·+·-·10·+` 或 `-100·10·20·+·-·1000` 皆會判斷為錯誤， `··-100··10·20··+·-·-10···+·` 則能夠正確計算。（符號 `·` 表示空格。）

求最大公因數並計算最多用了多少 Stack Size



```
lab3.elf [Ac6 STM32 Debugging]
  lab33.elf
    Thread #1 (Suspended : Signal : SIGINT:Interrupt)
      forever() at p2.s:124 0x80002fc
      case_4_final() at p2.s:119 0x80002f6
      0x0
  openocd
  C:/Ac6/SystemWorkbench/plugins/fr.ac6.mcu.externaltools.arm-none.win32_1.7.0.201602121829/tools/compiler/bin/arm-none
```

Name	Value
General Registers	
r0	94 (Decimal)
r1	96 (Decimal)
r2	2 (Decimal)
r3	536870916 (Decimal)
r4	0 (Decimal)
r5	0 (Decimal)
r6	0 (Decimal)
r7	536969024 (Decimal)

p2.s

```

case_4_final:
    push {r0, r1, lr}
    bl   gcd
    pop  {r0, r1, r9}
    mov  pc, r9

forever:
    b    forever

```

Outline: result, max_size, m, n, main

Monitors: 134218284, 536871296

536871296 : 0x20000180 <Signed Integer>

```
Address   0 - 3      4 - 7      8 - B  C - F
20000000  2          192        0      536871668
20000010  536871772  536871876  0      0
20000020  0          0          0      0
20000030  0          0          0      134218928
```

- 依照 Stein's algorithm 計算 GCD，每次呼叫函式之前，都會先將函式的兩個參數及當前的 link register 存進 stack，函式回傳之後再將它們取出。

- 因此每進入一層遞迴，便會多占用 12 位元組的 stack 空間。

心得討論與應用聯想

- 第一題的 `postfix_expr` 長度（包含 `\0`）必需是 4 的倍數，否則在 assemble 時會出現錯誤（沒有 alignment）。
- 第二題的 `max_size` 應該沒有標準答案，因為題目並沒有限制 stack 只能存放哪些資料。
- 這門課不但讓我學了微處理機，還讓我學了危機處理，雖然這門課已經改為選修了，不過我一定會推薦學弟妹來修的。