2-D Arrays, Macros and Procedures in PeANUt Assembler

- ref: [PeANUt Spec, sect 4]
- two-dimensional arrays
- macro definitions and usage
- the stack revisited
- procedures:
  - arguments
  - without local variables
- other issues:
  - revise 2008 MSE, Q1

Two-dimensional Arrays

- multi-dimensional arrays are the main data structure in sci./eng. applications
- in C, implemented via row-major ordering:
  - i.e. 2-D element **ws[i][j]** is addressed as if 1-D element **ws[i∗N+j]**, where **N** is length of a row (**ws[i]**)
- e.g. an array of strings (of length up to **N−1**)

```
N         =  4       ;    #define N 4
M         =  2       ;    #define M 2
MN        =  8       ;        /* MN = M*N */
ws:  block   MN      ;    char ws[M][N];
i:   data    1       ;    int i = 1;
j:   data    2       ;    int j = 2;
                     ;
     load    i       ;    ws[i][j] = 'x';
     mul     #N      ;
     add     j       ;
     storexr         ;    /*XR=mem[i]*N+mem[j]*/
     load    #'x'    ;
     store   *ws     ;
```

ws:	
	'x'
i:	1
j:	2

PeANUt Macros

- important (yet simple) concept, widely used in the C language
- neither instructions nor procedures! Essentially, just a ‘shorthand’ or ‘placeholder’
- macros are expanded by the assembler (as in C), not translated
  - i.e. exist only in the assembly language level
- definitions must be inserted at the top of a program
- can be good programming style, especially if they correspond to meaningful (high level language) operations
- are best for ’straight-line’ code (don’t use macros with branches etc.)

PeANUt Macro Example: macro.ass

- definitions:

```
macro Get (x)                          ; read next char into x
        trap     #2                    ; (read next char into AC)
        store    x                     ; (Memory[x] = AC)
endmacro

macro Set2 (x, e1, op, e2)             ; perform x = e1 + e2
        load     e1                    ; (AC = <value of e1>)
        op       e2                    ; (AC = AC op <value of e2>)
        store    x                     ; (Memory[x] = AC)
endmacro
```

- `Get(x)` and `Set2(x,e1,op,e2)` can be called as follows:

```
        Get      (ch)                  ;   scanf("%c", &ch);
        Set2     (n, ch, sub, #'0');  n = ch − '0';
```

- these are expanded to (see macro.lst, produced by assembler):

```
        trap     #2
        store    ch
        load     ch
        sub      #'0'
        store    n
```

PeANUt Macros – Beware!

- beware of the following:

```
Get('0')
Set2(n,sub,ch,#'0')
```

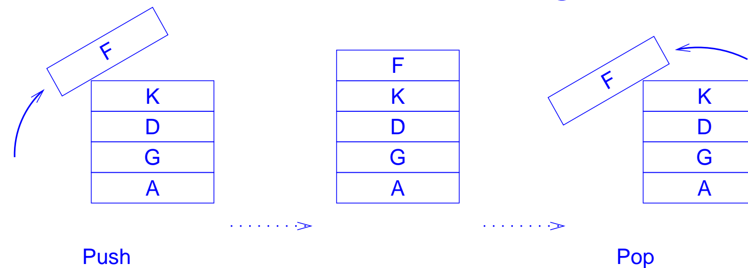
- which is expanded to:

```
trap    #2
store   '0'      ; run-time error?
load    sub      ; assembly error
ch      #'0'     ; assembly error
store   n
```

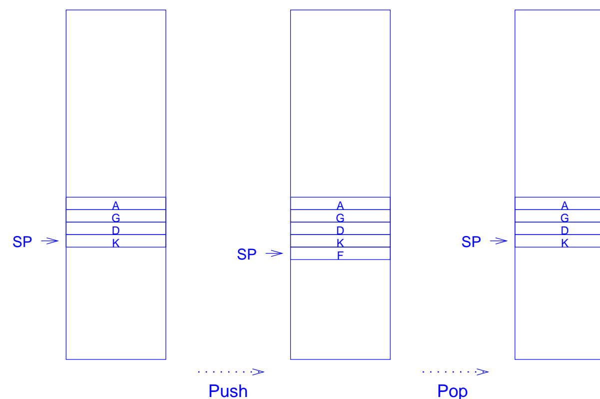
- good use of macros can ’abstract’ some low level details and can clarify the program’s structure
- bad use of macros can obscure what is going on and be the origin of many errors

The Stack and Function Calls

- a fundamental programming concept!!
  - hence hardware support is needed (e.g. SP register, stack addressing mode)
- uses a (reserved) part of (normal) memory called the stack
  - a stack is accessed *LIFO* (Last In, First Out), e.g. pile of books



- recall the stack can be efficiently implemented as the memory pointed to by SP:



- enables return of control to caller, as well as to pass parameters and return values

Stack Addressing and Manipulation

- requires stack addressing mode (**!**): AOP = opspec + SP
- normally, opspec ≤ 0
- recall example:

	⋮
259	
260	15
261	-1
SP → 262	40
	⋮

```
load    !0      ; AOP = 262  OP =  40
mul     !−2     ; AOP = 260  OP =  15
store   !−3     ; AOP = 259  OP = 600
```

- the stack can be manipulated by software both implicitly:
  - via **call** and **ret** (SP is inc/decremented automatically)

  and explicitly, using instructions like:
  - **incsp #1**,
  - **store !−1**

Macro Examples for the Stack: stackmacro.ass

- Push item onto stack:

```
macro Push (e)                ; push value of e onto stack
                              ; (use before call proc. with value para
        load    e             ; (AC = <value referred by e>)
        incsp   #1            ; (SP = SP + 1; done last in case e=!num
        store   !0            ; (Memory[SP] = AC)
endmacro
```

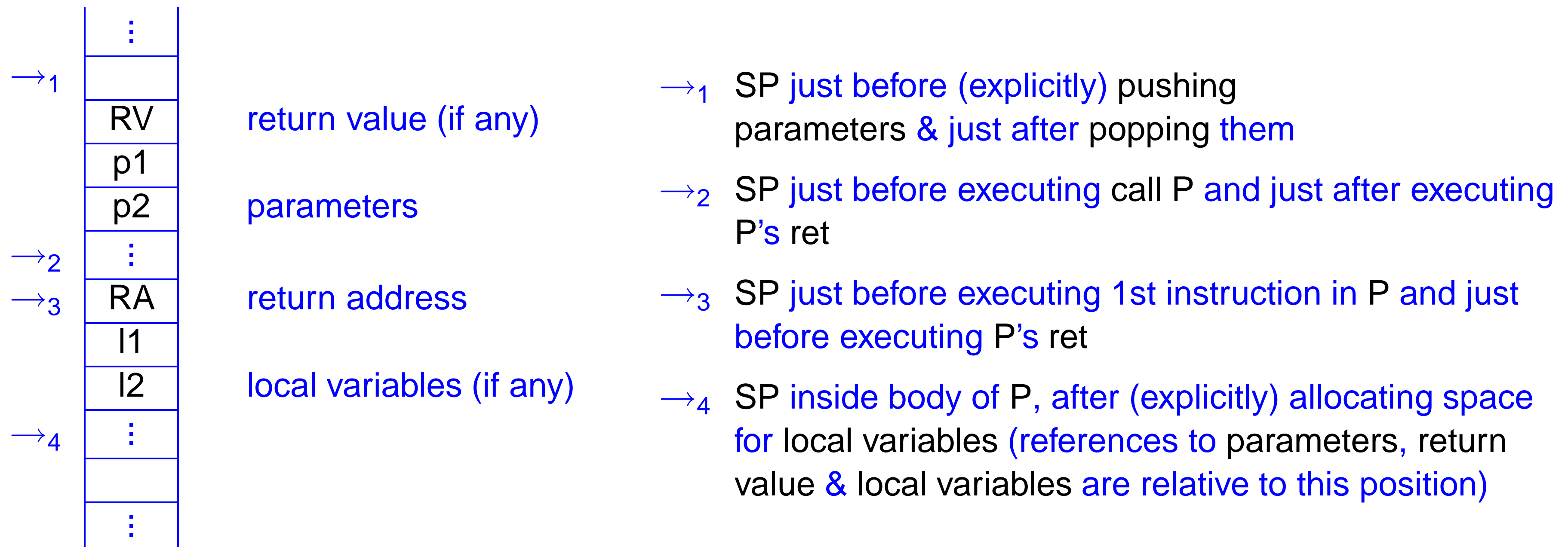
- Pop item from stack:

```
macro   Pop (n)               ; pop n elements of the stack
                              ; (use at end of call)
        incsp   #-n           ; (SP = SP - n)
endmacro
```

Procedure Calls

- the procedure call convention determines the order of contents of the stack frame
- example C function declaration:

```
int P(int p1, int p2, ...) {
   int l1, l2, ...;
   ...
}
```



Procedure Call – Example without Local Variables

- function definition (in InOut.ass; `Write(c)` is equivalent to `printf("%c", c)`)

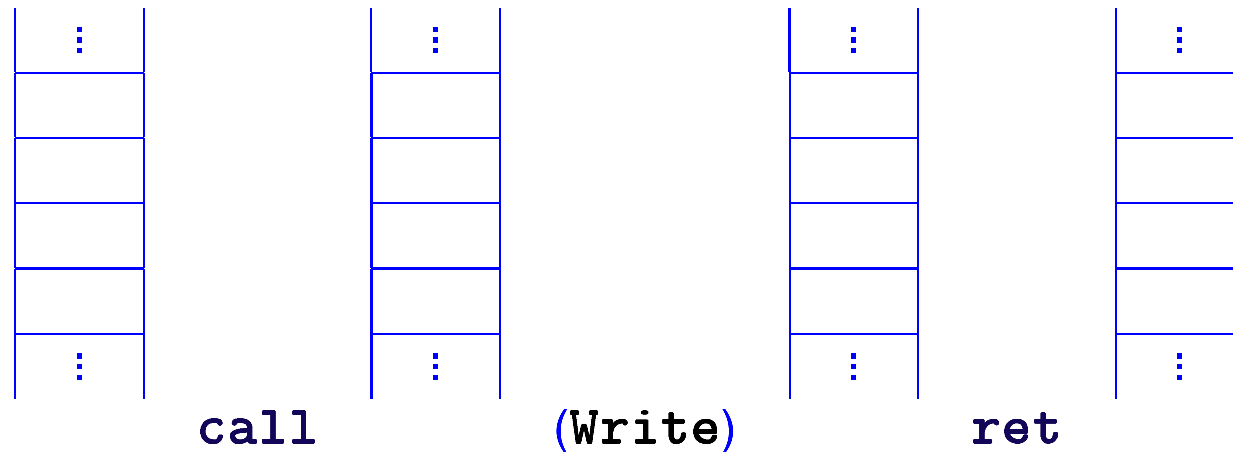
```
        ch      = -1    ; void Write(char ch) {
Write:                  ;
        load    !ch     ;   printf("%c",ch); /* AC=Mem[SP-1] */
        trap    #3      ;                    /* write AC to stdout */
        ret             ; }                /* PC=Mem[SP]; SP=SP-1 */
```

- call from procedure-example1.ass:

```
                        ; Write('a');
        load    #'a'    ;   /* Push(#'a') *//* AC='a' */
        incsp   #1      ;                    /* SP=SP+1 */
        store   !0      ;                    /* Mem[SP]=AC */
        call    Write   ;                    /* SP=SP+1;
                        ;                       Mem[SP]=PC;
                        ;                       PC=Write */
        incsp   #-1     ;   /* Pop(1) */     /* SP=SP-1 */
```

- remember: PC is incremented at the *beginning* of each instruction cycle

Procedure call – Example without Local Variables: Stack



- for local variables, function must allocate/deallocate upon entry/exit *(later. . .)*