Tutorial4.3

Assignment 3

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Assignment3

- Sorting One-Dimensional Arrays
- create an ARMv8 assembly

language program that implement

this algorithm(insertion sort)

```
#define SIZE 50

int main()
{
          int v[size], i, j, temp;

          //initialize array to random positive integers, mod 256
          for(i = 0; i < SIZE; i++){
                    v[i] = rand() & 0xFF;
                    printf("v[%d]: %d\n", i, v[i]);
          }

          //sort the array using an insertion sort
          for (i = 1; i < SIZE; i++)
          {
                    temp = v[i];
                    for (j = i; j > 0 && temp < v[j-1]; j--)
                    {
                              v[j] = v[j-1];
                    }
                    v[j] = temp;
          }

          //print out the sorted array
          printf("\nSorted aray:\n");
          for (i = 0; i < SIZE; i++)
                    printf("v[%d]: %d\n", i, v[i]);

          return 0;
}
```

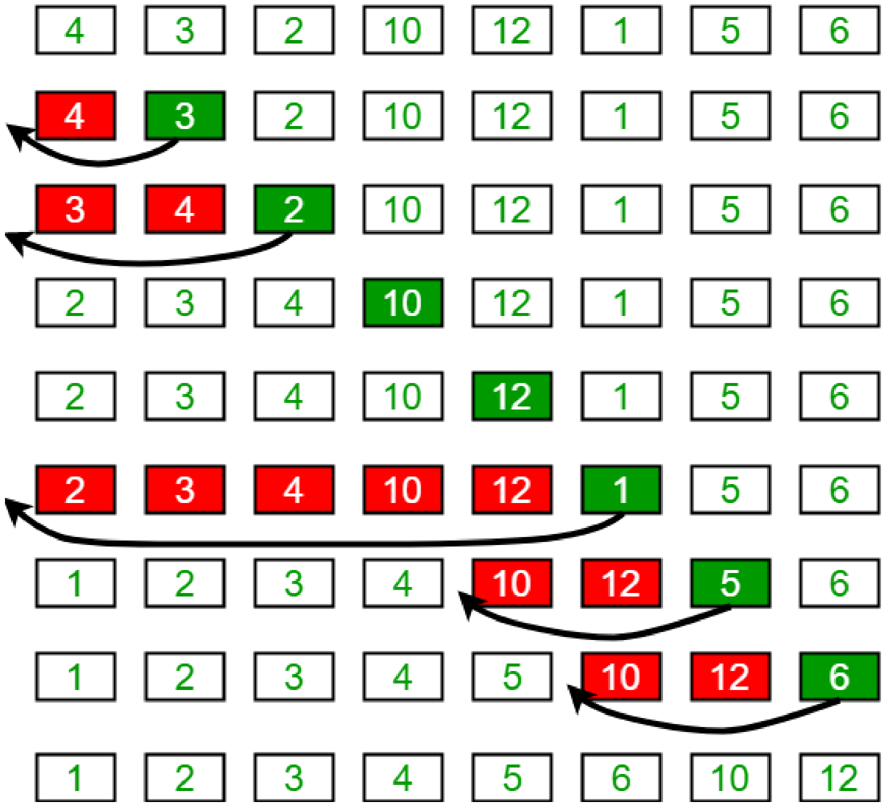
requirements

- Create space on the stack to store all local variables
- Use m4 or assembler equate for all stack variables offsets
- Optimization(loop, addressing mode)
- always read or write memory when using or assigning to the local variable
- name the program *assign3.asm*
- run the program in *gdb*, first display the contents of the array before sorting, and then displaying it again once the sort is complete. use script to capture the *gdb* session

insertion sort

- Insertion sort is a simple sorting algorithm that works the way we sort playing cards in our hands.
- Algorithm
  - insertionSort(arr, n)
  - Loop from i = 1 to n-1
  - Pick element arr[i]
  - insert it into sorted sequence arr[0…i-1]

Insertion Sort Execution Example



4	3	2	10	12	1	5	6
4	3	2	10	12	1	5	6
3	4	2	10	12	1	5	6
2	3	4	10	12	1	5	6
2	3	4	10	12	1	5	6
2	3	4	10	12	1	5	6
1	2	3	4	10	12	5	6
1	2	3	4	5	10	12	6
1	2	3	4	5	6	10	12

Pseudo-random

- the program always generates the same sequence of numbers using *rand()*, and such they are not truly random
- because *rand()* always use the algorithm, there are a lot of ways to improve this function(STS)
- this is not a problem for your assignment

macros, equates and register aliases

macros

```
//.asm

//define macros for stack variables and registers
define(size, 50)
define(array_size, 200)
define(alloc, -224)
define(delloca, 224)
define(fp, x29)
define(lr, x30)
define(offset, x19)
```

equates

```
//.s

        //define equates for stack variables
        size = 50
        array_size = size * 4
        alloc = -(16 + array_size) & -16
        dealloc = -alloc

//define register aliases
fp      .req    x29
lr      .req    x30
```

show array in gdb

- x/nd $fp+offset
- n can be the SIZE of the array
- offset is the base address of the array

review

- allocate/deallocate memory for variables

```
stp    fp, lr, [sp, alloc]!
mov    fp, sp
…
ldp    fp, lr, [sp], dealloc
ret
```

- store value. read value, change value

```
mov    Wn, #imm
str    Wn, [fp, offset]
ldr    Wn, [fp, offset]
//change value of Wn
str    Wn, [fp, offset]
```

- access ith element

```
mov    Wn, #i
ldr    Ws, [base_address, Wn, SXTW, 2]
//change value of Ws
str    Ws, [base_address, Wn, SXTW, 2]
```

loop with two conditions, nested loop

- j > 0 AND temp < v[j-1] ➔ j<=0 OR temp >= v[j-1] (then jump out)
- write loop2 inside loop1

```
//sort the array using an insertion sort
      for (i = 0; i < SIZE; i++)
      {
            temp = v[i];
            for (j = i; j > 0 && temp < v[j-1]; j--)
            {
                  v[j] = v[j-1];
            }
            v[j] = temp;
      }
```

loop2

endloop2

loop1

in assembly

```
             //set i = 0 before loop1
loop1:
             //...
             //loop1 body
             //...

             //set j = i before loop2
loop2:       //test in the beginning
             //if j <= 0 branch to endloop2
             //if temp >= v[j-1] also branch to endloop2
             //...
             //loop body2  :v[j] = v[j-1]
             //...
             //branch to loop2

endloop2:
             //v[j] = temp;
test1:       // i < SIZE?
             // branch to loop1 if the condition meets
```

work period

Functionality		
Loop to initialize array	2	______
Display of unsorted array	2	______
Outer loop of sort	2	______
Inner loop of sort	2	______
Comparison of array elements	2	______
Exchange of array elements	2	______
Display of sorted array	2	______
Use of macros/equates for stack variable offsets	4	______
Optimization	4	______
Script showing *gdb* session	2	______
Complete documentation and commenting	4	______
Design quality	2	______