vg101: Introduction to Computer Programming

RC 2

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2019/5/26

Outline

- Function handles
- Pseudorandom numbers
- File IO
- Recursion and iteration
- Practices

Function Handles

1. Basics:

   - Definition: `f = @(x) expressions`
   - Multiple inputs: `f = @(x, y) x^2 + y^2`
   - Multiple outputs: not explicitly supported, but can be realized by

     ```
     f = @(x, y) [x^2 + y^2, x - y];
     res = f(2, 3);
     a = res(1);
     b = res(2);
     ```

   - Function call: `f(args)`

2. Usage: `<demoFuncHandle.m, myLess.m, mySort.m, mainFuncTools.m>`

   > 1. pass a function to another function.
   > 2. specify call back functions.
   > 3. construct handles to functions defined inline instead of stored in a program file.
   > 4. call local functions from outside the main function.

3. *Digression*: `syms`, create symbolic variables and functions `<demoSyms.m>`

   1. `syms var1 ... varN` create symbolic variables `var1`, ..., `varN`, separate variables by spaces.
   2. `syms f(var1, ..., varN)` creates the symbolic function `f` and symbolic variables `var1`, ..., `varN` representing the input arguments of `f`.

Pseudorandom Numbers

- `rand(n, m)`: $n \times m$ matrix of random numbers in normal distribution
- `randi([min, max], n, m)`: $n \times m$ matrix of random integers in `[min, max]`
- `randn(n, m)`: $n \times m$ matrix of random numbers in standard normal distribution
- `random('name', parameters)`: generate random numbers following the distribution `name`, parameters may vary depending on the distribution

- Names
  1. **Normal**
  2. **Uniform**
  3. Binomial
  4. Poisson
  5. ...
- Parameters: dependent on the distribution types (documentation)

- `rng`: `<demoRng.m>`
  - `rng(seed)`: seeds the random number generator
  - `s = rng; rng(s);` stores the current random state in `s`, and restores the random state from `s`. Useful for reproduction
- `randperm(n)`: random permutation

File IO

- Open and close a file:
  1. `fid = fopen(filename, permission)`

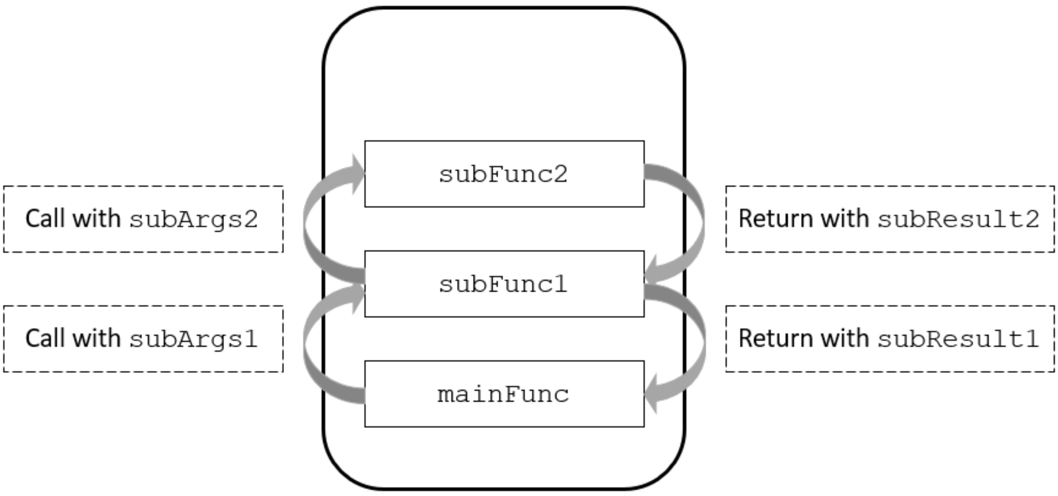
     `permission`:
     - `r`: read only
     - `w`: write to a new file
     - `a`: append to new/existing file
     - `r+`: read and write
     - `w+`: read and overwrite
     - `a+`: read and append
  2. `fclose(fid)`: **DO remember to close the file!**
- Writing to a file: `fprintf(fid, format, variables)`
- Read from a file: `<demoFileIO.m>`
  1. `fscanf(fid, format, size)`: read with format and size
  2. `fgetl(fid)`: read a line
  3. Useful functions:
     - `frewind(fid)`: point to the start of the file
     - `split(line)`: split a line using spaces

Recursion and Iteration

- Call stack

```
function mainResult = mainFunc(mainArgs)

    subResult1 = subFunc1(subArgs1);
    mainResult = subResult1;

end

function subResult1 = subFunc1(subArgs1)
```

```
    subResult2 = subFunc2(subArgs2);
    subResult1 = subResult2;

end

function subResult2 = subFunc2(subArgs2)

    subResult2 = subArgs2;

end

```



- Recursion
  1. What is this function for?
     - Accept inputs
     - Return expected outputs
     - Regardless of how it computes the outputs
  2. Given such existing function (with a somehow "reduced" problem), how can you compute the results for the original problem?
  3. Basic components of a recursive function:
     1. Base case
     2. Recipe to compute the result for the current problem from a solution of a slightly smaller problem
  4. Analogy: mathematical induction
  5. Example: factorial (suppose n is a positive integer)

```
function fact = myFactorial(n)

    if n == 1
        fact = 1;
    else
        fact = n * myFactorial(n - 1);
    end

end
```

Q: What is the call stack for factorial of 5 using recursion?

- Iteration
  1. Solve problem using loops
  2. Any self-recursive algorithm can be transformed into its iterative version.

     Q: What is the iterative version of factorial?

```
function fact = myFactorial(n)

    fact = 1;
    for i = 1:n
        fact = fact * i;
    end

end
```

  3. Why is iterative algorithms should be preferred in MATLAB, C and C++? (Memory)

     e.g., `myFibonacci(n)`

```
function fib = myFibonacci(n)

    if n == 1 || n == 2
        fib = 1;
    else
        fib = myFibonacci(n - 1) + ...
            myFibonacci(n - 2);
    end

end
```

Some values are calculated and stored more than once.

Q: What is the iterative version of the Fibonacci function?

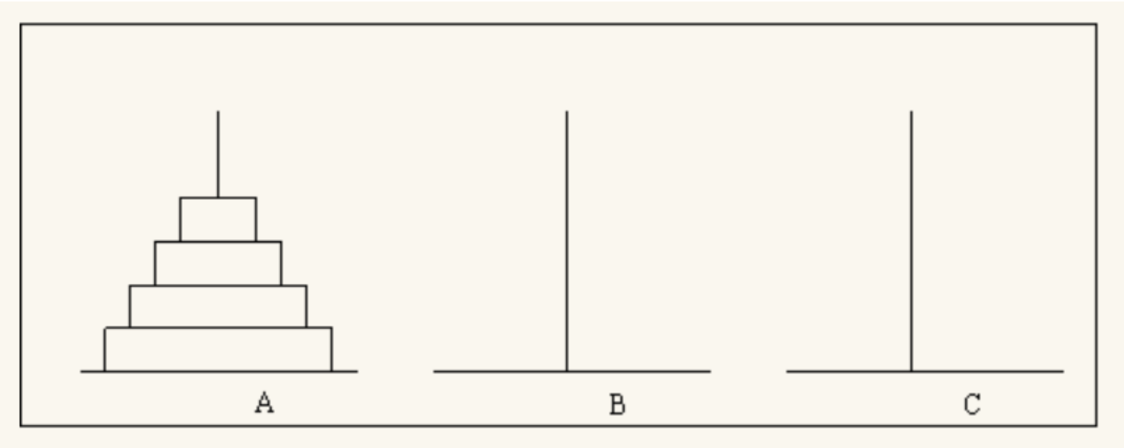
Practices

1. *Merge Sort*.

Merge sort is a sorting algorithm that utilizes the divide and conquer strategy. Given an array A of numbers, it sorts the elements in ascending order. In each function call, it divides the array into two sub-arrays with (roughly) equal sizes. Then it calls itself on these two sub-arrays. The returned sub-arrays are then in their correct orders, respectively. Then in the original function call, the two ordered sub-arrays are merged into a single array, ensuring the ascending order by putting the smaller element at the starts of two sub-arrays in the merged array. Write a function that implements this algorithm.

2. ***The Hanoi tower.***

   There are three rods, A, B, and C, together with n disks on rod A. Rods B and C are originally empty. With the help of rod B, one can move all the disks on rod A onto rod C, without placing any larger disk on another smaller disk.

   The algorithm is described as follows.

   1. Base case: if there is only one disk on rod A, remove that disk directly onto rod C.
   2. If there are $n > 1$ disk on rod A, then move $n - 1$ disks from rod A to rod B with the help of rod C, place the largest disk on the bottom of rod A to rod C, then move the $n - 1$ disks from rod B to rod C with the help of rod A.

   Write a function `myHanoi(n)` that takes the number of disks n as input, and output the sequence of actions to a file `hanoiOut.txt` in the following format:

   > Step n: move disk m from rod X to rod Y.

   n is the current step number, m is the disk number starting from the smallest disk, X and Y are certain rods. One sentence per line. For instance, `myHanoi(3)` should output:

   > `hanoiOut.txt`
   >
   > ```
   > Step 1: move disk 1 from rod A to rod C.
   > Step 2: move disk 2 from rod A to rod B.
   > Step 3: move disk 1 from rod C to rod B.
   > Step 4: move disk 3 from rod A to rod C.
   > Step 5: move disk 1 from rod B to rod A.
   > Step 6: move disk 2 from rod B to rod C.
   > Step 7: move disk 1 from rod A to rod C.
   > ```

3. ***Solving Sudoku.***

In the most Sudoku setting, a 9×9 board is divided in to nine 3×3 blocks. The player is required to fill the board with numbers $1 \sim 9$, with the each number appearing exactly once in each row, column, and 3×3 block. A recursive approach (although not as efficient as the *Dancing Links Algorithm*, for your interest...) is described as follows. Suppose we start from an empty board, with some positions filled as the clues. The function takes a position as an input, and outputs whether the problem can be solved using current placement.

1. Base case: if all the cells are filled, then the Sudoku is solved.
2. For the next empty position to be filled, for each possible number $1 \sim 9$, if that number is valid to put in the cell, then place the number in this position and call the solving function with this current position. If the function returns `true` with this call, then return `true`.
3. After trying all the values, return `false` at the end.

Write a function that reads from a file named `sudokuIn.txt` containing a 9×9 matrix, with 0 indicating empty position, and numbers $1 \sim 9$ indicating a number in that position. Then it displays a completely filled Sudoku board as the solution. A sample input with its solution is shown below.

> `sudokuIn.txt`
>
> ```
> 0 0 3 9 0 0 7 6 0
> 0 4 0 0 0 6 0 0 9
> 6 0 7 0 1 0 0 0 4
> 2 0 0 6 7 0 0 9 0
> 0 0 4 3 0 5 6 0 0
> 0 1 0 0 4 9 0 0 7
> 7 0 0 0 9 0 2 0 1
> 3 0 0 2 0 0 0 4 0
> 0 2 9 0 0 8 5 0 0
> ```

		3	9			7	6	
	4				6			9
6		7		1				4
2			6	7			9	
		4	3		5	6		
	1			4	9			7
7				9		2		1
3			2				4	
	2	9			8	5		

1	5	3	9	8	4	7	6	2
8	4	2	7	3	6	1	5	9
6	9	7	5	1	2	8	3	4
2	3	8	6	7	1	4	9	5
9	7	4	3	2	5	6	1	8
5	1	6	8	4	9	3	2	7
7	6	5	4	9	3	2	8	1
3	8	1	2	5	7	9	4	6
4	2	9	1	6	8	5	7	3