

# Computer Systems Tutorial

November 10<sup>th</sup> 2023

**Exercise 1.** Determine the complexity of the following pieces of code in terms of big- $\mathcal{O}$  notation. For this, derive an expression to denote the number of steps which are needed to compute the pieces and identify the dominant term.

```
1  if (n == 1) {
2      return;
3  }
4
5  for (int i = 0; i < n - 1; i++) {
6
7      for (int j = 0; j < n - i - 1; j++) {
8
9          if (arr[j] > arr[j + 1]) {
10             // assume it takes
11             // constant number of steps
12             swap(arr[j], arr[j + 1]);
13         }
14     }
```

(a)

```
1  for (int i = 0; i < n; i++) {
2
3      // pow(x,y) raises x to the power of y
4      for (int j = 0; j < pow(2,i); j++) {
5
6          k = k * j;
7
8      }
```

(c)

```
1  for (int i = 0; i < n - 1; i++) {
2
3      for (int j = 0; j < n - i - 1; j++) {
4
5          if (arr[j] > arr[j + 1]) {
6              // assume it takes
7              // constant number of steps
8              swap(arr[j], arr[j + 1]);
9          }
10     }
11 }
12
13 for (int i = 0; i < n; i++) {
14
15     for (int j = 1; j < n; j = j*2) {
16
17         k = k + j;
18     }
19 }
20 }
```

(b)

```
1  int fibonacci(n) {
2
3      if (n <= 2) return 1;
4
5      return fibonacci(n-1) + fibonacci(n-2);
6  }
```

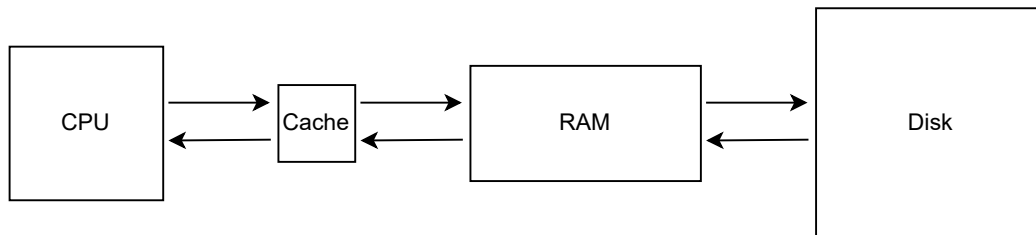
(d)

**Exercise 2.** Using Shunting yard algorithm build an RPN representation of the following arithmetic expression.

$$3 + 4 \times (2 - 1 \times 2)$$

Then, evaluate the expression using stack.

**Exercise 3.** A computer system has a cache, main memory, and a disk used for virtual memory. If a referenced word is in the cache, 20ns are required to access it. If it is in the main memory but not in cache, 60ns are needed to load it into cache (this includes the time to originally check the cache), and then the reference is started again. If the word is not in main memory, 12ms are required to fetch the word from disk, followed by 60ns to copy it to the cache, and then the reference is started again. The cache hit-ratio is 0.9 and the main memory hit-ratio is 0.6. What is the average time in ns required to access a referenced word on this system?



**Exercise 4.** Predict the Output of the following program.

```

1  int main(){
2      int x = 1;
3      if (fork() == 0) {
4          printf("Child has: %d", ++x);
5      } else {
6          printf("Parent has: %d", --x);
7      }
8      wait(NULL);
9      return 0;
10 }
```