



## Algorithms and Data Structures Summer Term 2021 Exercise Sheet 2

### Exercise 1: $\mathcal{O}$ -notation

Prove or disprove the following statements. Use the *set definition* of the  $\mathcal{O}$ -notation (lecture slides week 2, slides 11 and 12).

- (a)  $4n^3 + 8n^2 + n \in \mathcal{O}(n^3)$
- (b)  $2^n \in o(n!)$
- (c)  $2 \log n \in \Omega((\log n)^2)$
- (d)  $\max\{f(n), g(n)\} \in \Theta(f(n) + g(n))$  for non-negative functions  $f$  and  $g$ .

### Exercise 2: Sorting by asymptotic growth

Sort the following functions by their asymptotic growth. Write  $g <_{\mathcal{O}} f$  if  $g \in \mathcal{O}(f)$  and  $f \notin \mathcal{O}(g)$ . Write  $g =_{\mathcal{O}} f$  if  $f \in \mathcal{O}(g)$  and  $g \in \mathcal{O}(f)$  (no proof needed).

$\sqrt{n}$	$2^n$	$n!$	$\log(n^3)$
$3^n$	$n^{100}$	$\log(\sqrt{n})$	$(\log n)^2$
$\log n$	$10^{100}n$	$(n+1)!$	$n \log n$
$2^{(n^2)}$	$n^n$	$\sqrt{\log n}$	$(2^n)^2$

### Exercise 3: Stable Sorting

A sorting algorithm is called stable if elements with the same key remain in the same order. E.g., assume you want to sort the following strings where the sorting key is *the first letter by alphabetic order*:

[“tuv”, “adr”, “bbc”, “tag”, “taa”, “abc”, “sru”, “bcb”]

A *stable* sorting algorithm must generate the following output:

[“adr”, “abc”, “bbc”, “bcb”, “sru”, “tuv”, “tag”, “taa”]

A sorting algorithm is not stable (with respect to the sorting key) if it outputs, e.g., the following:

[“abc”, “adr”, “bbc”, “bcb”, “sru”, “taa”, “tag”, “tuv”]

- (a) Which sorting algorithms from the lecture (except `CountingSort`) are *not* stable? Prove your statement by giving an appropriate example.
- (b) Describe a method to make any sorting algorithm stable, without changing the *asymptotic* runtime. Explain.

## Exercise 4: Running time

Give an asymptotically tight upper bound for the running time of the following algorithm as a function of  $n$ .

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 $s \leftarrow 0$   
for  $i = 1$  to  $n$  do  
   $j = 1$   
  while  $j < i$  do  
     $s \leftarrow s + i \cdot j$   
     $j \leftarrow 2 \cdot j$ 
```

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