

# Computer Lab 1

## Computational Statistics

Linköpings Universitet, IDA, Statistik

2022 XI 09

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Kurskod och namn:	732A90 Computational Statistics
Datum:	2022 XI 08—2022 XI 15 (lab session 9 XI 2022)
Delmomentsansvarig:	Krzysztof Bartoszek, Bayu Brahmantio, Jaskirat Marar, Shashi Nagarajan
Instruktioner:	<p>This computer laboratory is part of the examination for the Computational Statistics course</p> <p>Create a group report, (that is directly presentable, if you are a presenting group), on the solutions to the lab as a <b>.PDF</b> file.</p> <p>Be concise and do not include unnecessary printouts and figures produced by the software and not required in the assignments.</p> <p><b>All R code should be included as an appendix into your report.</b></p> <p>A typical lab report should 2-4 pages of text plus some amount of figures plus appendix with codes.</p> <p>In the report reference <b>ALL</b> consulted sources and disclose <b>ALL</b> collaborations.</p> <p>The report should be handed in via LISAM</p> <p>(or alternatively in case of problems e-mailed to bayu_dot_brahmantio_at sign_liu_dot_se, jasma356_at sign_student_dot_liu_dot_se, shashi_dot_nagarajan_at sign_@liu_dot_se, or krzysztof_dot_bartoszek_at sign_liu_dot_se),</p> <p>by <b>23:59 15 November 2022</b> at latest.</p> <p>Notice there is a deadline for corrections <b>23:59 22 January 2023</b> and a final deadline of <b>23:59 12 February 2023</b> after which no submissions nor corrections will be considered and you will have to redo the missing labs next year.</p> <p>The seminar for this lab will take place <b>29 November 2022</b>.</p> <p>The report has to be written in English.</p>

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## Question 1: Be careful when comparing

Consider the following two R code snippets

```
x1<-1/3; x2<-1/4
if (x1-x2==1/12){
  print("Subtraction is correct")
}else{
  print("Subtraction is wrong")
}
```

and

```
x1<-1; x2<-1/2
if (x1-x2==1/2){
  print("Subtraction is correct")
}else{
  print("Subtraction is wrong")
}
```

1. Check the results of the snippets. Comment what is going on.
2. If there are any problems, suggest improvements.

## Question 2: Derivative

From the definition of a derivative a popular way of computing it at a point  $x$  is to use a small  $\epsilon$  and the formula

$$f'(x) = \frac{f(x + \epsilon) - f(x)}{\epsilon}.$$

1. Write your own R function to calculate the derivative of  $f(x) = x$  in this way with  $\epsilon = 10^{-15}$ .
2. Evaluate your derivative function at  $x = 1$  and  $x = 100000$ .
3. What values did you obtain? What are the true values? Explain the reasons behind the discovered differences.

## Question 3: Variance

A known formula for estimating the variance based on a vector of  $n$  observations is

$$\text{Var}(\vec{x}) = \frac{1}{n-1} \left( \sum_{i=1}^n x_i^2 - \frac{1}{n} \left( \sum_{i=1}^n x_i \right)^2 \right)$$

1. Write your own R function, `myvar`, to estimate the variance in this way.
2. Generate a vector  $x = (x_1, \dots, x_{10000})$  with 10000 random numbers with mean  $10^8$  and variance 1.
3. For each subset  $X_i = \{x_1, \dots, x_i\}$ ,  $i = 1, \dots, 10000$  compute the difference  $Y_i = \text{myvar}(X_i) - \text{var}(X_i)$ , where `var`( $X_i$ ) is the standard variance estimation function in R. Plot the dependence  $Y_i$  on  $i$ . Draw conclusions from this plot. How well does your function work? Can you explain the behaviour?
4. How can you better implement a variance estimator? Find and implement a formula that will give the same results as `var()`?

## Question 4: Binomial coefficient

The binomial coefficient “ $n$  choose  $k$ ” is defined as

$$\binom{n}{k} := \frac{n!}{k!(n-k)!} = \frac{(k+1)(k+2) \cdots (n-1)n}{(n-k)!},$$

where  $n$  and  $k$  are an arbitrary pair of integers satisfying  $0 \leq k \leq n$ . Consider the three below R expressions for computing the binomial coefficient. They all use the `prod()` function, which computes the product of all the elements of the vector passed to it.

- A) `prod(1:n) / (prod(1:k) * prod(1:(n-k)))`
- B) `prod((k+1):n) / prod(1:(n-k))`
- C) `prod(((k+1):n) / (1:(n-k)))`

1. Even if overflow and underflow would not occur these expressions will not work correctly for all values of  $n$  and  $k$ . Explain what is the problem in A, B and C respectively.
2. In mathematical formulae one should suspect overflow to occur when parameters, here  $n$  and  $k$ , are large. Experiment numerically with the code of A, B and C, for different values of  $n$  and  $k$  to see whether overflow occurs. Graphically present the results of your experiments.
3. Which of the three expressions have the overflow problem? Explain why.