

# Bayesian Data Analysis – Assignment 9

## General information

- The recommended tool in this course is R (with the IDE R-Studio). You can download R **here** and R-Studio **here**. There are tons of tutorials, videos and introductions to R and R-Studio online. You can find some initial hints from **RStudio Education pages**.
- Instead of installing R and RStudio on your own computer, see **how to use R and RStudio remotely**.
- When working with R, we recommend writing the report using R markdown and the provided **R markdown template**. The template includes the formatting instructions and how to include code and figures.
- Instead of R markdown, you can use other software to make the PDF report, but the same instructions for formatting should be used. These instructions are available also in **the PDF produced from the R markdown template**.
- Report all results in a single, **anonymous** \*.pdf -file and return it to **peergrade.io**.
- The course has its own R package `aaltobda` with data and functionality to simplify coding. To install the package just run the following (upgrade="never" skips question about updating other packages):

```
1. install.packages("remotes")  
2. remotes::install_github("avehtari/BDA_course_Aalto",  
    subdir = "rpackage", upgrade="never")
```

- Many of the exercises can be checked automatically using the R package `markmyassignment`. Information on how to install and use the package can be found **here**. There is no need to include `markmyassignment` results in the report.
- Recommended additional self study exercises for each chapter in BDA3 are listed in the course web page.
- Common questions and answers regarding installation and technical problems can be found in Frequently Asked Questions (FAQ).
- Deadlines for all assignments can be found on the course web page and in peergrade. You can set email alerts for the deadlines in peergrade settings.
- You are allowed to discuss assignments with your friends, but it is not allowed to copy solutions directly from other students or from internet. You can copy, e.g., plotting code from the course demos, but really try to solve the actual assignment problems with your own code and explanations. Do not share your answers publicly. Do not copy answers from the internet or from previous years. We compare the answers to the answers from previous years and to the answers from other students this year. All suspected plagiarism will be reported and investigated. See more about the **Aalto University Code of Academic Integrity and Handling Violations Thereof**.
- Do not submit empty PDFs or almost empty PDFs as these are just harming the other students as they can't do peergrading for the empty or almost empty submissions. Violations of this

rule will be reported and investigated in the same way was plagiarism.

- If you have any suggestions or improvements to the course material, please post in the course chat feedback channel, create an issue, or submit a pull request to the public repository!

### Information on this assignment

This assignment is related to Chapter 9. The maximum amount of points from this assignment is 3.

**Note!** This assignment build upon assignment 7, so be sure that assignment 7 is correct before you start with this assignment. You can ask TAs for help to check that your assignment 7 answer is good.

**Reading instructions:** Chapter 9 in BDA3, see **the reading instructions for Chapter 9**.

**Grading instructions:** The grading will be done in peergrade. All grading questions and evaluations for assignment 9 can be found **in the rubric**

**Reporting accuracy:** For posterior statistics of interest, only report digits for which the Monte Carlo standard error (MCSE) is zero. *Example:* If you estimate  $E(\mu) = 1.234$  with  $\text{MCSE}(E(\mu)) = 0.01$ , you should report  $E(\mu) = 1.2$ .

**Installing and using CmdStanR:** See the Stan demos on how to use Stan from R. The university Ubuntu desktops have the necessary libraries installed so there should be no need to install anything. To install Stan on your laptop, see the instructions below.

In R, install package `cmdstanr`. Installation instructions on Linux, Mac and Windows can be found at <https://mc-stan.org/cmdstanr/>. Additional useful packages are `loo`, `bayesplot` and `posterior` (but you don't need these in this assignment). For Python users, the `Arviz` library may be relevant.

Stan manual can be found at <https://mc-stan.org/users/documentation/>. From this website, you can also find a lot of other useful material about Stan.

To use `markmyassignment` for this assignment, run the following code in R:

```
library(markmyassignment)
assignment_path <-
  paste("https://github.com/avehtari/BDA_course_Aalto/",
        "blob/master/assignments/tests/assignment9.yml", sep="")
set_assignment(assignment_path)
# To check your code/functions, just run
mark_my_assignment()
```

## Decision analysis for the factory data (3p)

This exercise is an example of a decision analysis (DA). In a broad context, this means optimizing over different decisions that lead to different outcomes that all have different utilities. In a Bayesian context, this means using posterior distributions to make decisions.

In this exercise, you work as a data analyst in the company that owns the six machines that have produced the data in the `factory` dataset. To access the data, just use:

```
library(aaltobda)
data("factory")
```

Your task is to decide whether or not to buy a new (7th) machine for the company. The decision should be based on our best knowledge about the machines.

The following is known about the production process:

- The given data contains quality measurements of single products from the six machines that are ordered from the same seller. (columns: different machines, rows: measurements)
- Customers pay 200 euros for each product.
  - If the quality of the product is below 85, the product cannot be sold
  - All the products that have sufficient quality are sold.
- Raw-materials, the salary of the machine user and the usage cost of the machine for each product cost 106 euros in total.
  - Usage cost of the machine also involves all investment and repair costs divided by the number of products a machine can create. So there is no need to take the investment cost into account as a separate factor.
- The only thing the company owner cares about is money. Thus, as a utility function, use the profit of a new product from a machine.

As noticed in the previous assignment, the hierarchical model fits best with the dataset, so use it to compute the utilities. The assumptions for the hierarchical model are the same as in assignment 7 and 8. If you did things correctly then, solving the assignment only requires you to change the "generated quantities"-block in the Stan-code to compute the correct predictive samples for products of all 7 ( $= 6 + 1$ ) machines.

Your task is the following:

1. For each of the six machines, compute and report the expected utility of one **product** of that machine. Below is a test case on how the utility function should work (and that you can test with `markmyassignment`).

**Note!** The expected utility should be computed from the quality measurements of the **products** of each machine, not from the means of the qualities of each machine.

**Note!** This is just a test case to test that your utility function works. In the report, you should report the expected utility using your posterior draws from Stan.

**Note!** The value below is *only* a test case, you need to use correct draws from the predictive distribution in the final report.

```
y_pred <- c(123.80, 85.23, 70.16, 80.57, 84.91)
utility(draws = y_pred)
## [1] -26
```

2. Rank the machines based on the expected utilities. In other words order the machines **from worst to best**: X(worst), X, X, X, X, X(best), where each X should be a number of a machine. Also briefly explain what the utility values tell about the quality of these machines. E.g. Tell which machines are profitable and which are not (if any).
3. Compute and report the expected utility of the products of a new (7th) machine.
4. Based on your analysis, discuss briefly whether the company owner should buy a new (7th) machine.
5. As usual, remember to include the source code for both Stan and R (or Python).