Research Track II - Statistical Analysis

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0. Introduction

This last part of the Research Track 2 task is about data analysis. I was asked to perform a statistical analysis of the first task of the Research Track 1 course, select some parameters and compare the solution with the solution proposed by Professor Carmine Recchiuto.

0.0. Which tool did I use to perform the analysis?

In order to carry out an optimal statistical analysis I used **MATLAB 2022a** as the main work environment in which I develop the code to get all the necessary info to make a valid statistical testing and to obtain interesting graphs.

0.1. Arena set up

Instead of randomizing the positions, I decided to use four different arena configurations with different numbers of silver tokens.
In particular, I have set up the following four arenas:

- **7** tokens (*standard arena*)
- **8** tokens
- **9** tokens
- **10** tokens

The tokens' position is always fixed**.** That is each time you add one token, the other tokens remain in the same position as in the previous configuration.

0.2. Data collection

The data collected are related to my personal project and to professor project.

The most essential information obtained is as follows:

- **Elapsed time** : measurement of the time taken by the robot to complete a lap using a control loop code (in the first assignment of Research Track 1) and that depends on the surrounding environment.
- **Distances** : measures of distance from the robot to the walls (golden tokens).

The robot's distance measurement from the Golden Token was made at each iteration of the control cycle, taking into account the number of lap in which the robot is moving on**.**

I managed to get the time it takes for the robot to complete a lap (specifically**,** the time was initialized when the robot grabbed the first silver token and stopped when the robot grabbed the last one of the specific configuration). So the robot will make 5 round. The **measured** distances and times were taken for each arena configuration.

1. Results

1.0. Preface

Hypothesis is usually considered as the principal instrument in research. Its main function is to suggest new experiments and observations.
Simply put, a hypothesis is a statement which makes a prediction about something which is not proven. It is a kind of **educated guess**; in fact, many experiments (in robotics and other fields) are carried out with the deliberate object of testing hypotheses.
Hypothesis testing is the often used strategy for deciding whether a sample data offer such support for a hypothesis that generalization can be made. Thus hypothesis testing

enables us to make probability statements about **population parameter(s)**.
The hypothesis may not be proved absolutely, but in practice it is accepted if it has withstood a critical testing.

1.1. Basic concepts

Basic concepts in the context of testing of hypotheses **need to be explained**.

Null hypothesis and *alternative hypothesis*: In the context of statistical analysis, we often talk about **null hypothesis** and **alternative hypothesis**. If we are to compare method A with method B about its superiority and if we proceed on the assumption that both methods are equally good, then this assumption is termed as the **null hypothesis**.
As against this, we may think that the method A is superior or the method B is inferior, we are then stating what is termed as **alternative hypothesis**. The **null hypothesis** is generally symbolized as H_0
and the **alternative hypothesis** as H_a.
If our sample results do not support this **null hypothesis**, we should conclude that something else is true. What we conclude rejecting the null hypothesis is known as **alternative hypothesis**. In other words, the set of alternatives to the **null hypothesis** is referred to as the **alternative hypothesis**. If we accept H_0, then we are rejecting Ha and if we reject H_0, then we are accepting H_a.

1.2. Average distances

After all distance data were collected**,** all averages for each arena circuit configuration were generated. I decided to compare the average distances from the walls of each configuration and plot them in a bar graph.

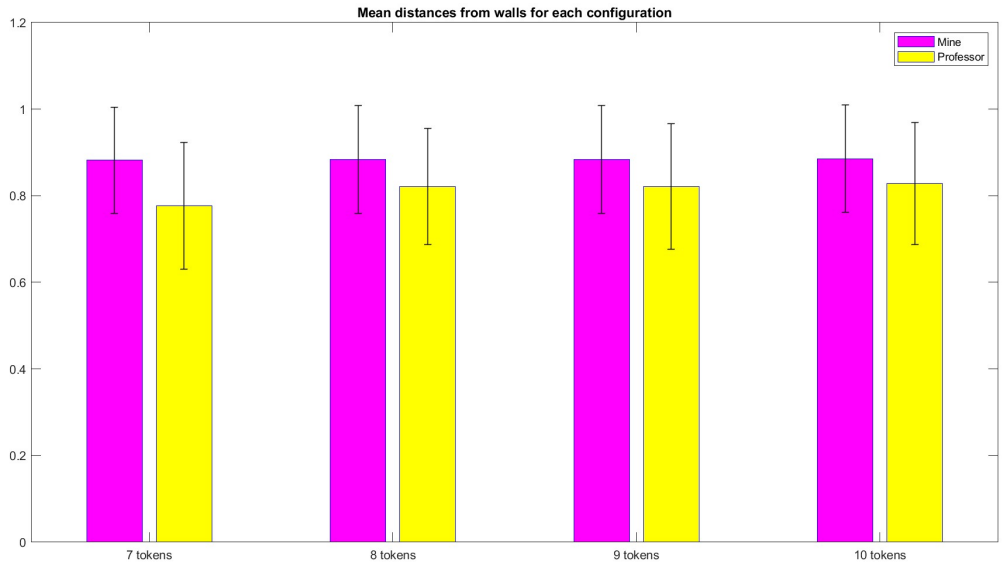

Image 1.2.1 : comparison between the robot's professor and my robot about mean distances

It is clear that in each configuration**,** the distance from the walls to my robot is on average large compared to the Professor robot. That is, my robot is far from the wall with respect to the one of the Professor. This is probably due to the different approach to the silver token that I developed, to some particular parameters (threshold, etc.) and so on.

1.3. Average times

After collecting all the time data, calculate the average time elapsed to complete the five laps for each configuration in the arena. Again, the comparison between my average time and the average time of the Professor is shown in a bar graph.

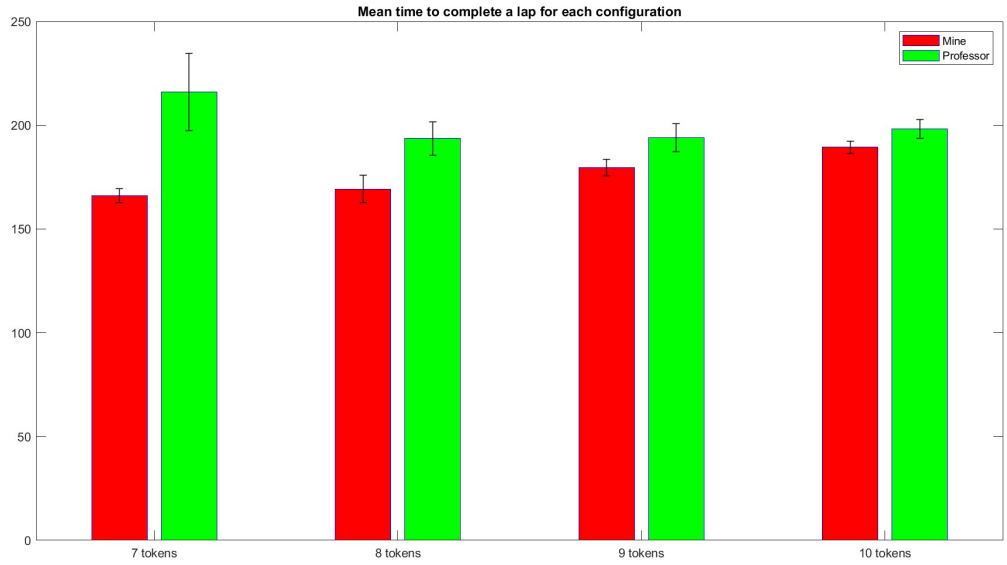

Image 1.3.1 : comparison between the robot's professor and my robot about mean times

Thanks to this analysis I found that for each configuration my robot was slightly faster than the robot of the Professor.

Moreover the robot of the Professor, not considering the case with 7 tokens, spends about the same amount of time completing a full lap, but my robot's elapsed time increases with the number of tokens.

NB: There is a **substantial decrease** of the average time from the 7 tokens configuration to the 8 tokens one. This is probably due to some interferences happened during the 5 laps in the 7 tokens configuration, to the performance of the PC and so on.

1.4. Lap Times

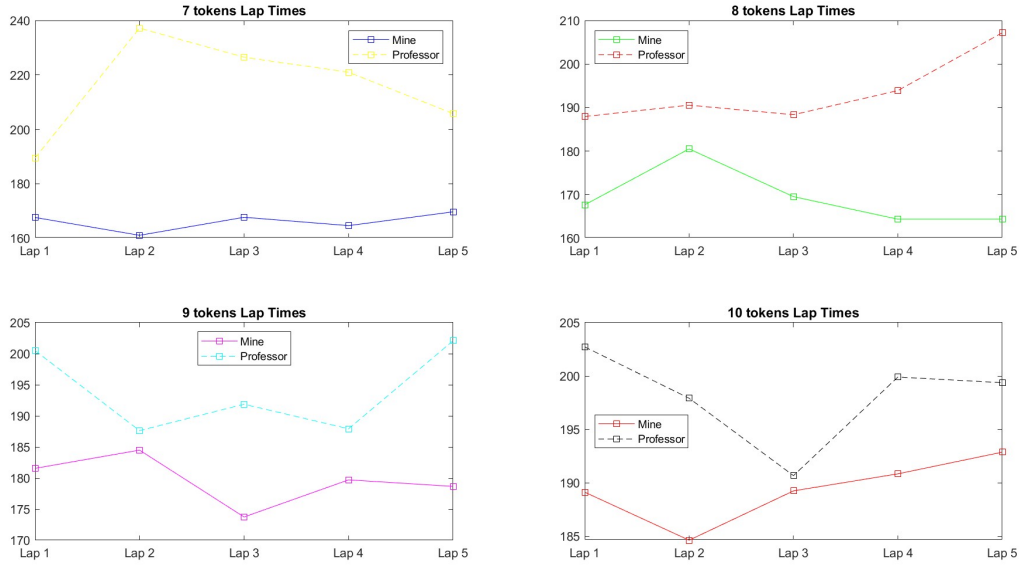

Image 1.4.1 : lap time comparison considering the different configurations

As you can see from the figure above, we can generally conclude that my robot is faster than robot's professor, regardless of the number of tokens.

Of course, this depends on how the algorithm for moving the robot in the environment was implemented. This is because both my solution and the professor ran on the same machine under the same conditions.

Between my robot and robot's professor there is a substantial consistent difference in lap times, as I said before, except for particular cases in which the graphic lines seems to coincide, meaning that there is a little difference between the times in that particular lap in that particular configuration. The major difference is highlighted in the standard configuration with 7 silver tokens.

1.5. T-Test

The t-test (also known as the Student's t-test) is a tool for assessing the means of one or two populations using a hypothesis test. A t-test is needed to evaluate whether a single group deviates from known values (1 sample t-test), whether the two groups are different from each other (2 independent sample t-tests), or whether exists a significant

difference between the paired measurements (paired or dependent sample tests), which is our case.

As mentioned earlier, we chose the paired sample test because we need to compare the same experiment with two different implementations. Also select alpha. This is the default value; α is the significance level, which represents the probability of rejecting if the null hypothesis is true. For example, a significance level of 0.05 indicates that the risk of concluding that there is a difference is 5%, even if there is no actual difference. Therefore, this represents a possible type I error in the statistics.

Regarding the output of the t-test it's possible to evaluate that when **H** equal to 0 there is a failure in rejecting the null-hypothesis with the given α, whereas when **H** is equal to 1 there is a rejection of the null-hypothesis with the given α.

The other output of the t-test is the **p-*value*** that helps to understand if the difference between the observed and the hypothesized result is due to the randomness introduced by the sampling, or if this difference is statistically significant, that is, difficult to explain by means of the randomness due to the sampling.

Different t-test were made, related to the average time, to the overall average distance from the walls and the average distance from the walls regarding a single lap.

This was done for each arena configuration.

Initially I compared the mean distance from the golden token taken in each arena configuration and for the two implementations, so I had a four elements data set.

The result of the first t-test is:

	Value
H	1
p	0.00970

For the second t-test I compared two data set filled with the average lap time for each arena configuration, so I had a five elements data set, of course considering the two

sets.

The result here is:

	Value
H	1
p	3.39e-05

In the end I chose the mean distances for each lap and for each arena configuration, so I made four t-tests.

Results:

	7 tokens	8 tokens	9 tokens	10 tokens
H	1	1	1	1
p	3.93e-04	0.03591	0.00351	0.00788

3. Conclusions

The main objective of this statistical part of the project is to find particular differences between my algorithm and algorithm's prof that "guide" the robot inside the environment. I have taken lots of data, making sure to have the same condition during the acquisition (fully charged PC, plugged into the power outlet), since I know results are non-deterministic, so I wanted to decrease the inconsistencies due to the performances of the PC (even if there are).

In the end I found that there are substantial differences about lap times and distances from golden tokens. In fact my robot keeps an higher distances from the walls; this is very important since many wall-crush can be avoided. My robot also, despite of the number of the silver tokens, is faster than the robot's professor in concluding laps.

All these assumptions that I made at the beginning of the project were convalidated due to the statistical tests that I have done.