Research Track 2: data analysis

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0. Introduction

This last part of the Research Track 2 assignment is about data analysis. We were asked to conduct a statistical analysis on the first assignment of Research Track 1 course, choosing some parameters to compare our solutions with the solution proposed by professor Carmine Recchiuto.

0.0. Tools used for the statistical analysis

To carry out the 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, I decided to use this software since it provides functions for statistical tests and provides an extensive library for graphs .

0.1. Environment setup

To have different configurations of the placement of the silver tokens I decided to use four different arena configurations with different number of tokens, to manually change the number of silver tokens I had to edit the file **sunny_side_up_arena.py.** In particular, I setup four arenas with:

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

The position of the tokens is fixed, meaning that in each configuration I just added another token, keeping the others in the same position as in the previous.

0.2. Collection of data

The data collected were those relating to both projects: the personal one and the solution given by the professor.

Data gathered are the following:

- **Lap time**: measure of the time needed by the robot to complete a lap, obviously it depends on the number of silver tokens.
- **Distance from golden token**: measure of the distance of the robot from the closest golden token.

Measures of the distance of the robot from golden tokens were taken at each iteration of the control cycle.

To take the time that the robot need to complete a lap I decide to implement a function that starts a chronometer when the robot grab the first silver token and stop it when the robot grab the last (that in the first configuration is the seventh, in the second the eighth, and so on).

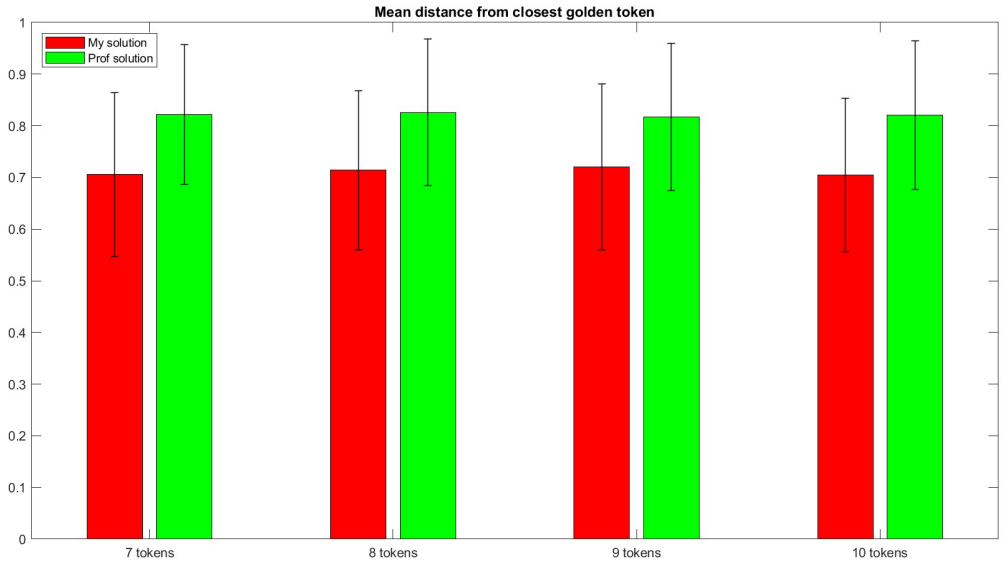
For each configuration it has been decided to take the data from five laps of the robot, both for my solution and for the one of the professor.

It is important to point out that, to have data that are comparable, data from each instance (collection of 5 laps) has been considered ‘valid’ only if the robot completed the laps without going clockwise and without crashing into the walls.

1. Results

1.0. Mean distances

After the collection of all the data about distances, all the averages were made for each configuration of the arena circuit. I decide to make a comparison between the overall distance from the walls for each configuration, and plot it using a bar plot in Matlab.

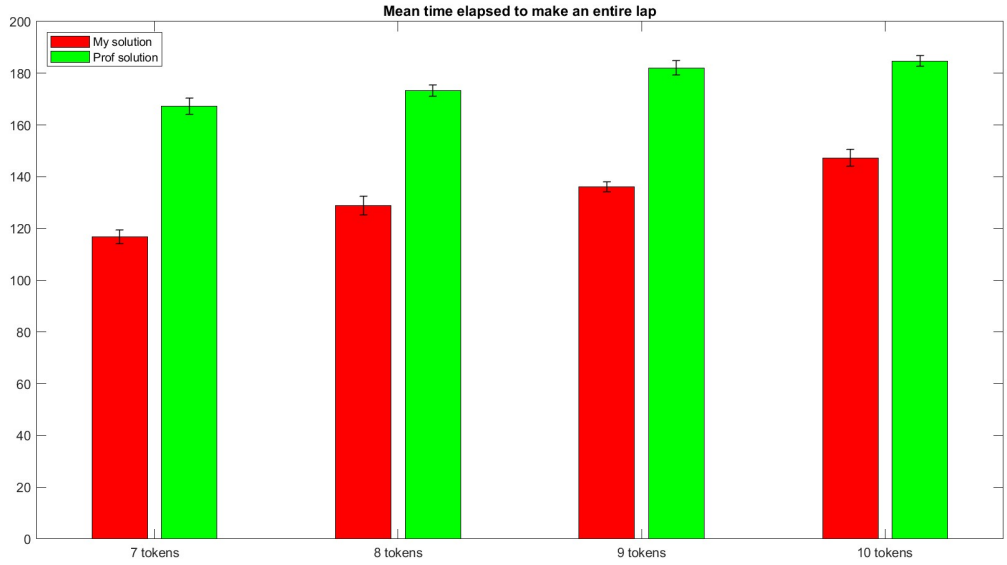


It is clearly visible that in each configuration the distance from the walls of my robot is on average lower with respect to the given solution, meaning that my robot goes closer to the walls than that of the proposed solution.

It is also important to note that on average the distance from the walls doesn't depend on the number of silver tokens, since in the different configurations the robot keeps about the same distance from the walls.

1.1. Mean times

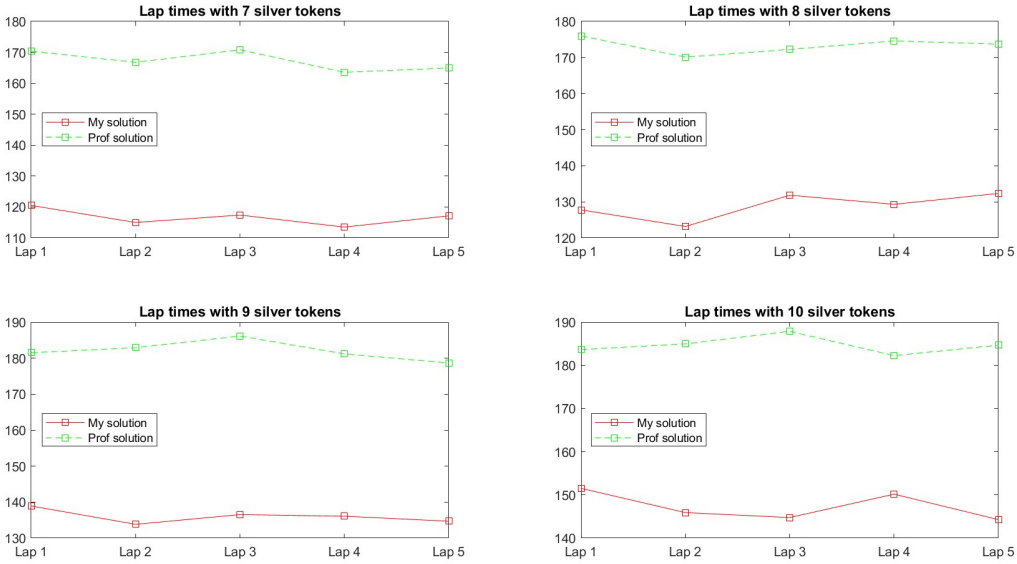
Also for the mean time, I computed the average time elapsed to make a lap for each configuration of the arena, again the comparison between my mean times and the ones of the solution is plotted using a bar plot



In this case I found that for each configuration my robot was much faster than the robot of the given solution. Obviously the value of the time to complete a lap depends on the number of silver tokens, and I also found that both for my solution and the given solution increasing the number of silver tokens the time needed to complete a lap increases.

1.2. Lap time comparison

As you can see in the figure below it is clear that in general is possible to conclude that, regardless of the number of token, the robot is faster in the solution proposed by me. This obviously depends on how the algorithm to move the robot in the environment has been implemented since both my solution and that of the professor have been executed on the same machine and with the same conditions. Regarding the time on the single lap it can be seen that they are consistent, since in the different configurations of silver tokens the times in different laps changes by few seconds, so generally the robot complete a lap in the same time whether it is the first lap or the second lap, and so on.



1.3. T-test introduction

A **t-test** (also known as Student's t-test) is a tool for evaluating the means of one or two populations using hypothesis testing. A t-test may be used to evaluate whether a single group differs from a known value (a one-sample t-test), whether two groups differ from each other (an independent two-sample t-test), or whether there is a significant difference in paired measurements (a paired, or dependent samples t-test) that is our case.

1.4. Needed concepts

Some terms in the context of hypothesis testing need to be clarified.
Alternative hypothesis and *null hypothesis*: The terms null hypothesis and alternative hypothesis are often used in statistical analysis. The null hypothesis is what we call the idea that if we compare method A to method B in terms of superiority and proceed on the premise that both ways are equally good.
In contrast, we may believe that method A is superior or method B is inferior, in this case we are proposing an alternate hypothesis.

The **null hypothesis** is usually represented 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.

1.5. T-Test

As said before I selected a **paired sample** t-test, because I have to compare the same experiment with two different implementations. I also choose $\alpha = 0.05$ which is the standard value (α is the significance level, it represent the probability of rejecting the null hypothesis when it is true. For example, a significance level of 0.05, as in our case, indicates a 5% risk of concluding that a difference exists when there is no actual difference, so it represent the possibility of a type I error in statistics).

About the output of the t-test it is possible to state that **H** equal to 0 means a failure in rejecting the null-hypothesis with the given significance level α while **H** equal to 1 means the rejection of the null-hypothesis with the given level of significance α. The other output of the t-test is the **p-*value*** which basically measure the strength of the evidence that a result is not just a likely chance occurrence (under the assumption that the null hypothesis is correct).

I make different t-test, related to the overall average distance from the walls, the average time and the average distance from the walls taken in a single lap, all of three for each arena configuration.

In particular, for the first t-test I compared the mean distance from the walls taken in each one of the four arena configuration and for the two implementations, so my data sets are composed by four elements.

The result of the first t-test is:

	Value
H	1
p	0.00015

For the second t-test I compared two data set filled with the average lap time for each configuration, so the two sets are composed by five elements.

The result here is:

	Value
H	1
p	1.8e-18

Probably in this case the value of p depends on the fact that the values obtained for the time are very different, so probably the null-hypothesis doesn’t make sense.

For the final part of t-test I select the mean distances for each lap and for each configuration, so I made in total four t-tests. In every t-test the code compared a data set with dimension 5.

Here’s the results:

	7 tokens	8 tokens	9 tokens	10 tokens
H	1	1	1	1
p	0.00140	0.00096	0.00330	0.00013

3. Conclusions

Concluding it is possible to state that, for the parameters considered, the statistical analysis confirmed what I expected looking at the robot running into the environment:

- Regardless of the number of silver tokens using the algorithm developed by me the robot take less time to complete a lap.
- The robot keeps an higher distance from the walls using the algorithm developed by the professor.
- The distance from golden token does not depend on the number of silver tokens.
- The time on the single lap depends on the number of silver tokens.

The first two assumptions has also been confirmed by the results of the t-tests.