RT2 Data Analysis

Marco Macchia, mat. 4687564

0. Introduction

This final part of the Research Track 2 assignment deals with data analysis. We were asked to perform a statistical analysis on the first assignment of Research Track 1 course, selecting some parameters to compare our solutions to a given solution.

0.1. Tools for the statistical analysis

In order to carry out a good and reliable statistical analysis I developed the code in MATLAB 2022a, which provided all of the essential information for appropriate statistical testing and the creation of interesting graphs.

0.2. Arena setup

In order to make different configurations of the placement of the silver tokens I choose to use four different arena configurations with different number of tokens, instead of making their position randomic. In particular, I setup four arenas with:

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

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

0.3. Data collection

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

The following are the most important data gathered:

- **Elapsed time** : depending on the environment arena, the time taken by the robot to complete a lap of the circuit using a control loop in the assignment code.
- **Distances** : golden coins were used to represent distances between the robot and the walls.

At each iteration of the control cycle, the robot's distance from golden tokens was measured, taking into consideration the number of circuit laps the robot was moving on.

In addition, I calculated the time it takes the robot to complete a lap (more accurately, the time begins when the robot obtains the first silver token and ends when the robot collects the final one) five times, implying that the robot completes five laps. For each arena configuration, distances and timings were measured.

1. Results

In most cases, the *hypothesis* is thought to be the most important tool in research. Its major purpose is to generate fresh ideas for experiments and observations. Simply explained, a hypothesis is a statement that makes an unproven prediction about something. It's a form of **educated assumption**; in fact, many studies (in robotics and other subjects) are designed specifically to test hypotheses. Hypothesis testing is a common approach for determining if a sample of data provides enough evidence for a hypothesis to allow for generalization. As a result of hypothesis testing, we can make probability claims about population parameters (s).

The hypothesis may not be proved absolutely, but in practice it is accepted if it has passed a critical testing.

1.1. Basic concepts

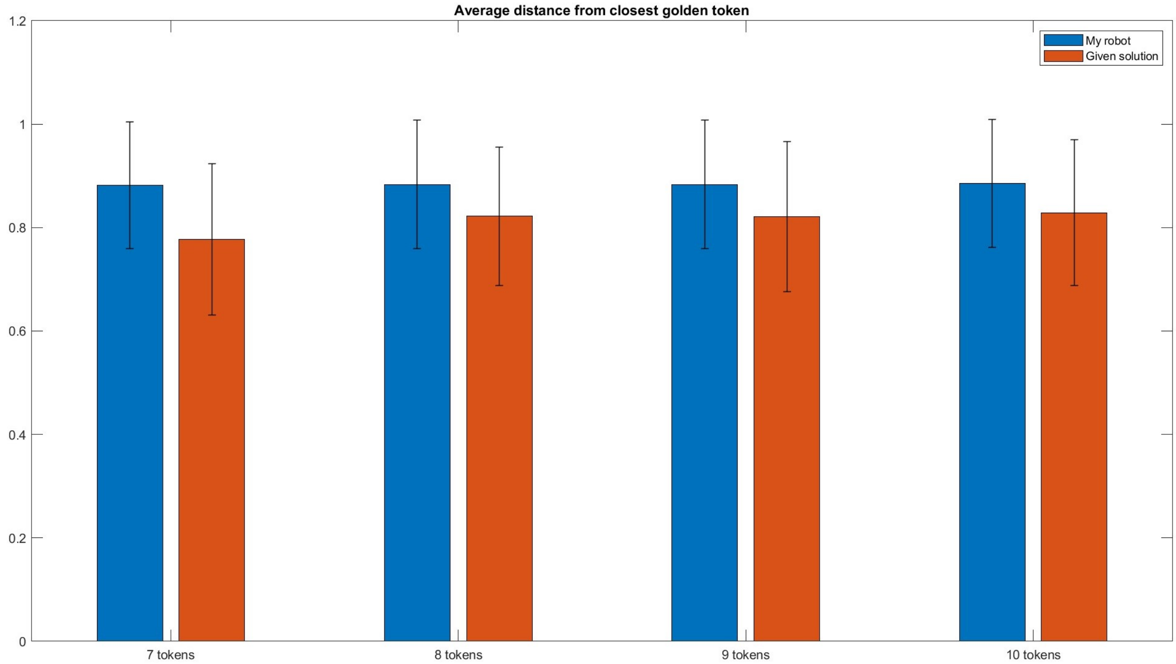
Basic concepts in the context of testing of hypotheses **need to be explained**.

The terms **null hypothesis** and **alternative hypothesis** are frequently 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 assumption that both ways are equally good.

In contrast, we may believe that method A is superior or method B is inferior, in which case we are proposing an alternate hypothesis. The null hypothesis is denoted by H_0, while the alternative hypothesis is denoted by H_a.
We should conclude that something else is true if our sample data do not support this null hypothesis. The alternative hypothesis is what we come up with after rejecting the null hypothesis. In other terms, the alternative hypothesis refers to the set of alternatives to the null 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. Mean distances

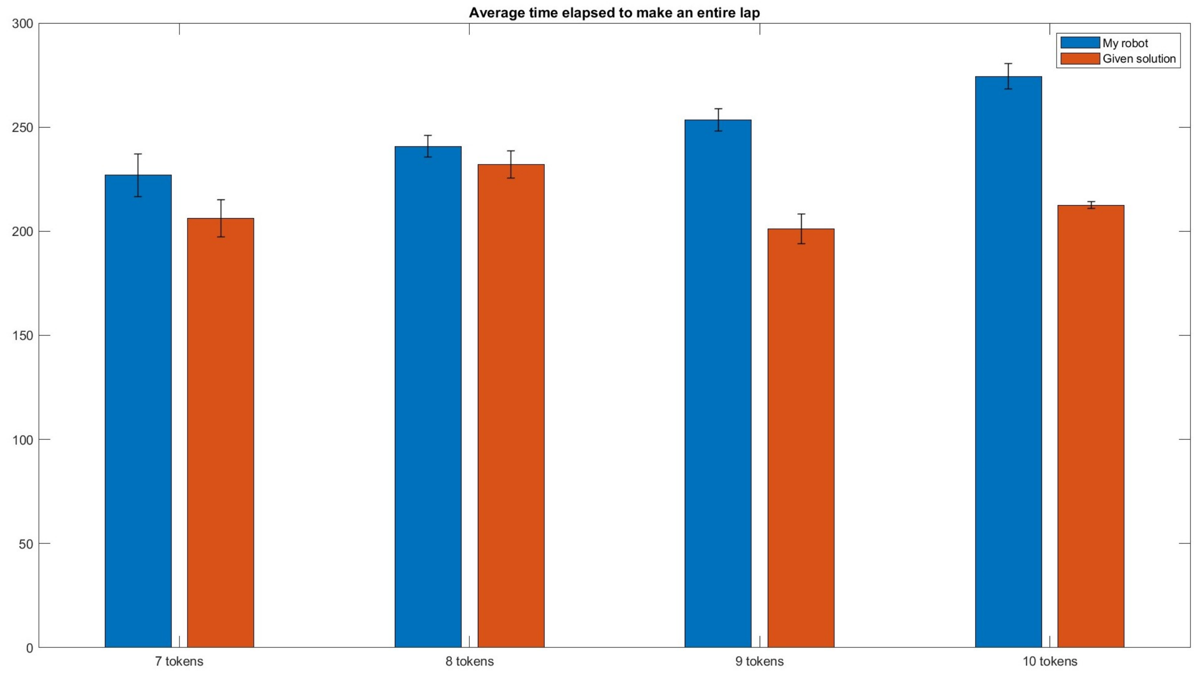
After collecting all the data regarding the distances, all the averages were made for each configuration of the arena circuit. I decide to make a comparison between the averall distance from the walls for each configuration, and plot it using a bar plot.



It is clearly visible that in each configuration the distance from the walls of my robot is on average higher with respect to the given solution, meaning that my robot stay further from the walls.

1.3. Mean times

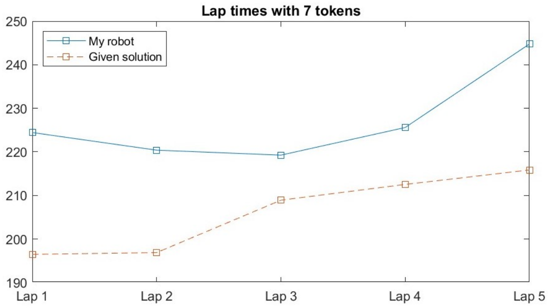
After gathering all of the data on the timings, I compute the average time elapsed to make a lap for each configuration of the arena. Also in this case the comparison between my mean times and the ones of the solution is plotted using a bar plot

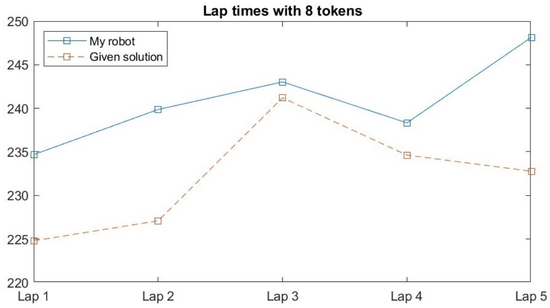


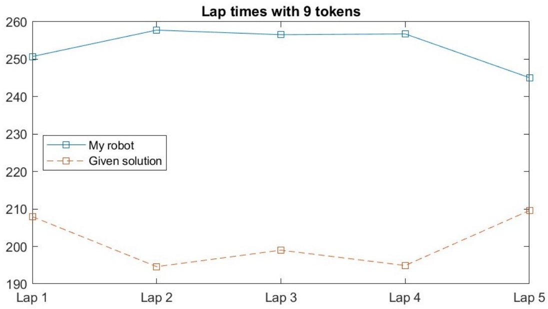
Here I found that for each configuration my robot was slower than the robot of the given solution. Moreover the robot of the given solution, apart from the case with 8 tokens, spends more or less the same amount of time in making a full lap, while the time elapsed by my robot increases according to the amount of tokens.

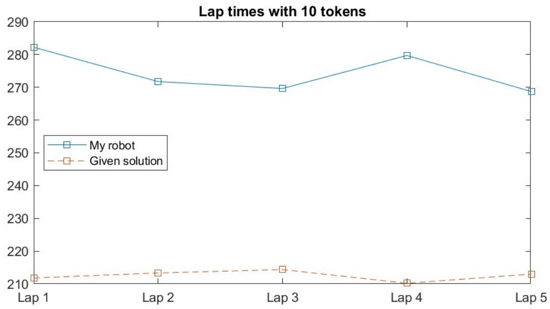
1.4. Lap time comparison

After taking the time elapsed to make an entire lap, I decided to plot this data using a line graph, which is useful to compare my solution with the given one. Here you can see the results:









The graph immediately highlights that my robot is always slower then the one provided. In particular, while the time is similar in the 7 token and 8 token configurfation, my time gets higher and higher as run with the 9 token and 10 token configuration. So I can firmy conclude that my robot is slower than the one of the given solution.

1.5. T-Test

A t-test (also known as a Student's t-test) is a hypothesis-testing technique for analyzing the means of one or two populations. A t-test can be used to see if a single group differs from a known value (a one-sample t-test), if two groups differ from each other (an independent two-sample t-test), or if there is a significant difference in paired measurements (a paired, or dependent samples t-test), as in our instance.

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 (when the null hypothesis is true, the significance level α represents the chance of rejecting it. For example, a significance level of 0.05, as in our situation, suggests a 5% chance of concluding that a difference exists when there is none, indicating the likelihood of a type I statistical error).

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 **p-value**, which effectively measures the strength of the evidence that a result is not merely a likely chance occurrence, is another output of the t-test (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 compare 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	0.00780

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	0
p	1.98e-06

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	0.00049	0.01481	0.00621	0.00498

3. Conclusions

The tests presented above highlights some differences bewteen my robot and the one of the given solution. In particular:

- My robot stays **further from the walls** than the one of the given solution. I can therefore conclude that my robot is safer and more cautious.
- My robot takes **more time** to make a lap then the other. I can say that my robot is slower and *less efficient* then the other.
- While the robot of the given solution takes more or less the same amount of time regardless the number of tokens, my robot spends an amount of time that is proportional to the number of tokens.

The first and the second conclusions can be validated with the t-test I've made, meaning that all the data gathered has a statistical meaning, and therefore the conclusions are valid.