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University of Genova

Statistical Analysis

Second Assignment - Statistical Analysis

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Contents

Abstract

This study involves a statistical examination of two different strategies used to control a robot on a predetermined circuit, where silver tokens are randomly located. I wanted to figure out which strategy allows the robot to finish the circuit faster and cover less distance.

The two methods tested were the initial assignment's implementation and a newly proposed one.
I gathered data from several tests examining the robot's performance under both strategies. Two key measurements were used: the time taken to complete a lap and the actual distance traveled by the robot during each lap.

Each strategy was tested in two different arenas, with 10 trials performed in each arena for each method.
I also modified the original arena layout to test how flexible the strategies were for the two changes. The same measurements were collected in these modified conditions.
This data will help us determine which strategy performs better overall.

Introduction

The objective of this project is to implement and analyze two different methodologies for maneuvering a robot through a maze filled with gold and silver boxes. The robot's mission is to navigate in a counterclockwise direction, circumvent the golden boxes, and seize the silver ones.

This study aims to perform an in-depth statistical analysis of two distinct robot control mechanisms: the first one devised during RT1 Assignment 1, and the second one, an alternative approach provided by the Professor, serving as a comparative benchmark.

This dual approach to navigation strategy allows us to examine the strengths and weaknesses of each system and assess the robot's overall efficiency.
The goal is to enhance the robot's proficiency in collecting silver boxes while adeptly avoiding golden ones, thus optimizing the success rate in the task at hand.

Steps of a Statistical Analysis

Here is how I do it:

Defining the Hypothesis:
I aim to collect specific data from experiments that examine the robots' behavior, and then determine which one performed "better" under those conditions. To do this, I modified both codes, which enabled me to record the running time and calculate the actual distance the robot traveled in each round.

Designing the Test and Collecting Data:
The experiments took two things into account:

- Lap time: The lap time test calculates the start and end of the lap, and the time difference between them, and all these values are recorded.

- Distance:
I assumed that the robot always started from the same position. This function computes the Euclidean distance between two robot positions, the previous one and the current one, and then updates the previous one.

Statistical Analysis:

For comparing the time taken, I use certain tests (called T-tests).
I have included a decision rule for each type of T-test when I was 95% sure (α of 0.05).
This rule helps us figure out when I can say one method is better.

Implementation of Statistical Analysis:

As a null hypothesis, H_0 states that robot controllers are equally good in two specific arenas.

In both cases of the analysis, I wanted to see if $\mu_{assignmentS} = \mu_{assignmentM}$ in both cases of the analysis.

After checking for statistical validity, I rejected this hypothesis by demonstrating that one is better in terms of lap time (speed), or distance travelled (efficiency in driving).

To analyze our data, I employed MATLAB software.

Next, I calculated the following statistical parameters:

- μ: the average value of all the recorded data
- σ: the standard deviation[1] of all the recorded data

Upon obtaining μ and σ, I visualized the results through various plots:

- One plot displayed the unsorted data along with the calculated mean value μ
- Another plot featured a histogram alongside its corresponding normal distribution, which was derived using the calculated μ and σ
- Lastly, I have created a few boxes for benchmarking.

[1] MATLAB's standard deviation function was used for the calculation.

Simulated plot with ten simulations

For this study, we collected data from ten different environments. Each environment had a unique configuration where we removed boxes in varying orders for each simulation.

In each scenario, the robot was tasked to complete a single lap. The data procured from these different sets were systematically analyzed to generate meaningful insights for our study.

- **Visualization of lap time data:**

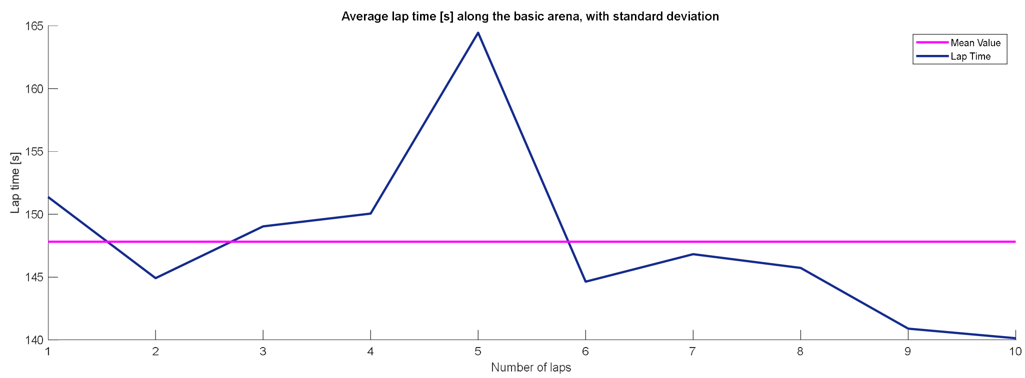

Figure1: Lap time [s] along the basic arena and mean value with a standard deviation. – Algorithm 1

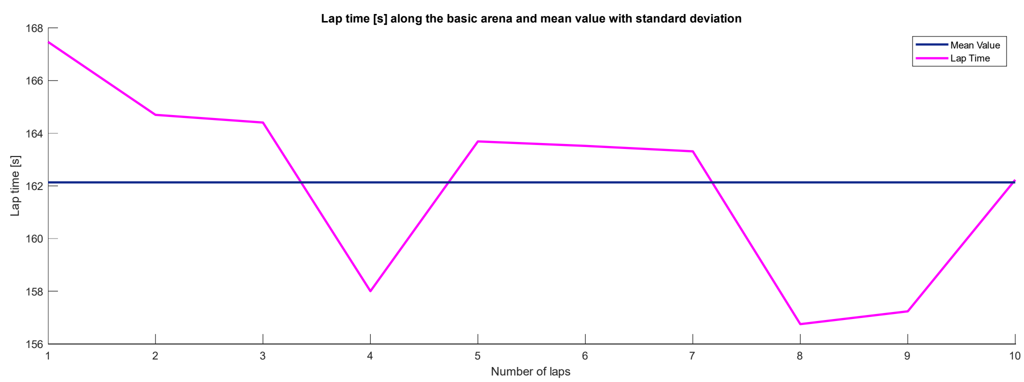

Figure2: Lap time [s] along the basic arena and mean value with a standard deviation. – Algorithm 2

- Visualization of lap distance:

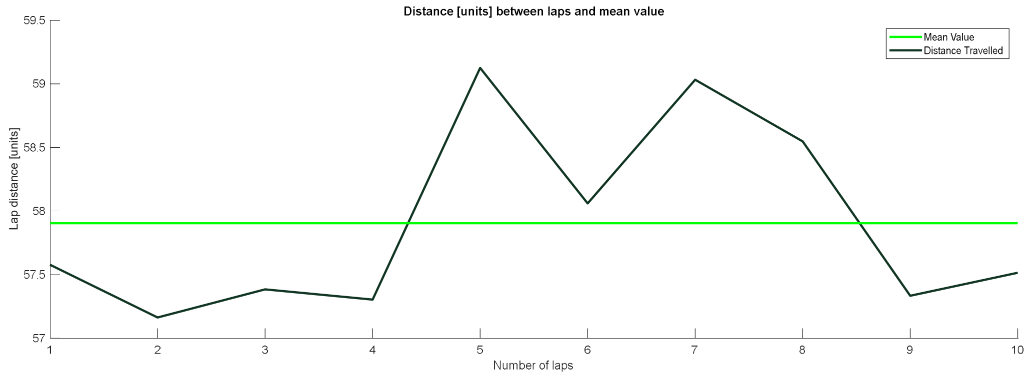

Figure 3: Averaging the lap distances [units] along the basic arena with a standard deviation is presented. - Algorithm 1

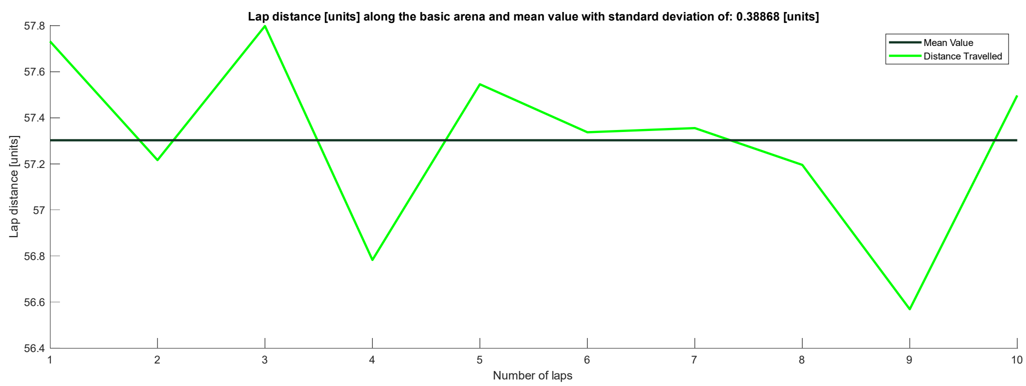

Figure 4: Averaging the lap distances [units] along the basic arena with a standard deviation is presented. - Algorithm 2

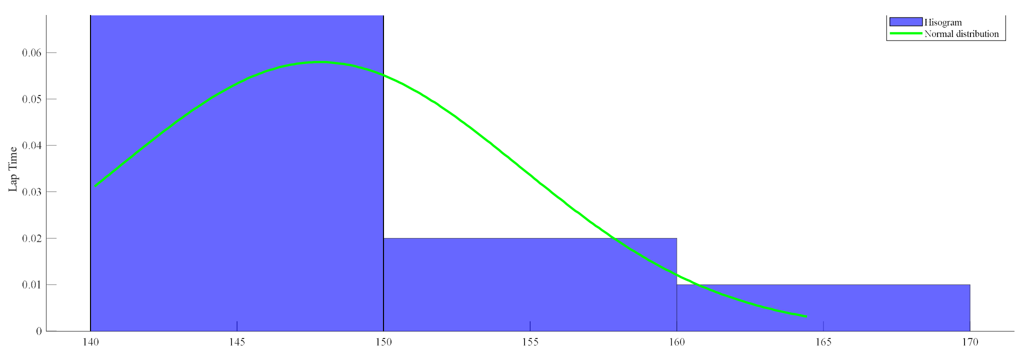

Figure 5: Lap time histogram and probability density function. - Algorithm 1

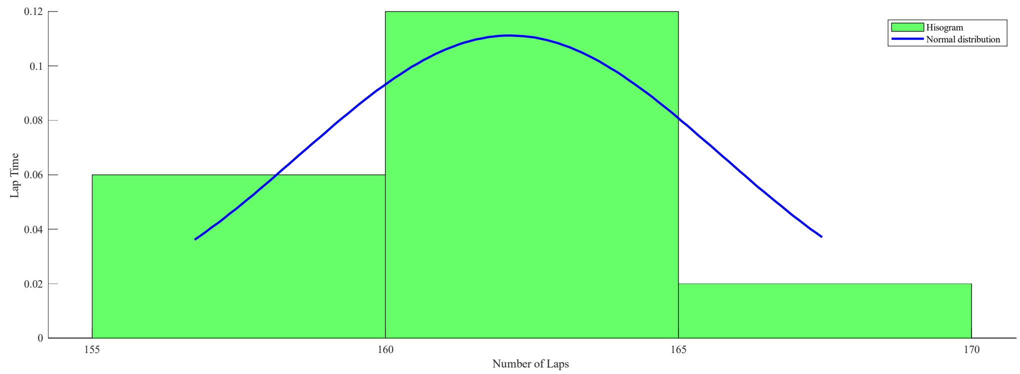

Figure 6: Lap time histogram and probability density function. - Algorithm 2

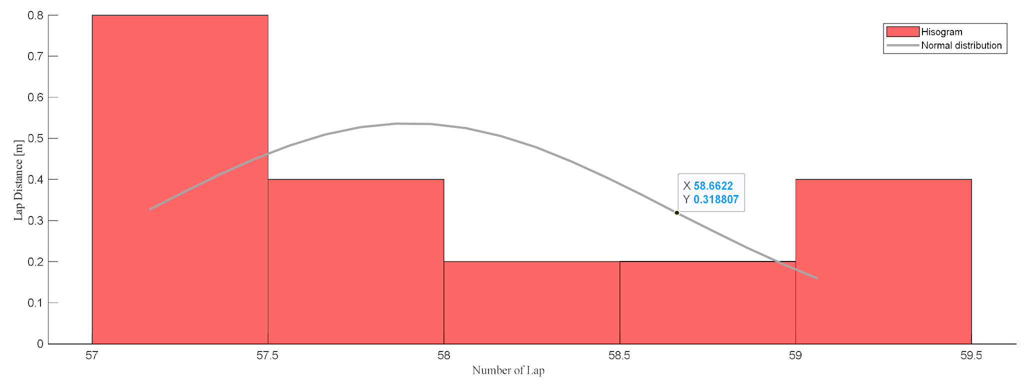

Figure 7: Lap time histogram and probability density function - Algorithm 1

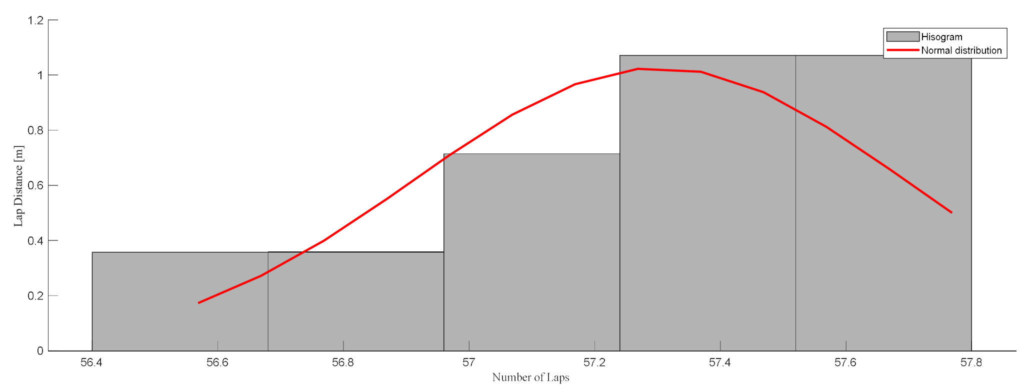

Figure 8: Lap time histogram and probability density function - Algorithm 2

Lilliefors Test

The Lilliefors Test is particularly apt for our study as it is designed to verify the null hypothesis that the sample data originates from a normal distribution. Intriguingly, it does not demand a predefined expected value or variance, which offers us more flexibility.

The process behind the Lilliefors Test is as follows:

- Firstly, we estimate the population mean and variance based on our collected data.
- Secondly, we calculate the maximum discrepancy between the empirical distribution function of our data and the cumulative distribution function of a normal distribution using our estimated mean and variance.
- Finally, we examine if this maximum discrepancy is statistically significant enough to warrant rejecting the null hypothesis.

After acquiring these results, I performed two separate tests to determine whether the two distributions were similar or not:

- For the distribution that accepted the null hypothesis (H0), we conducted a ***T-Test.***
- For the distribution that rejected the null hypothesis (H0), we utilized the ***Wilcoxon Rank Test.***

The resultant plots obtained are:

Figure 9: Simulated lap times for assignmentS and assignmentM controllers.

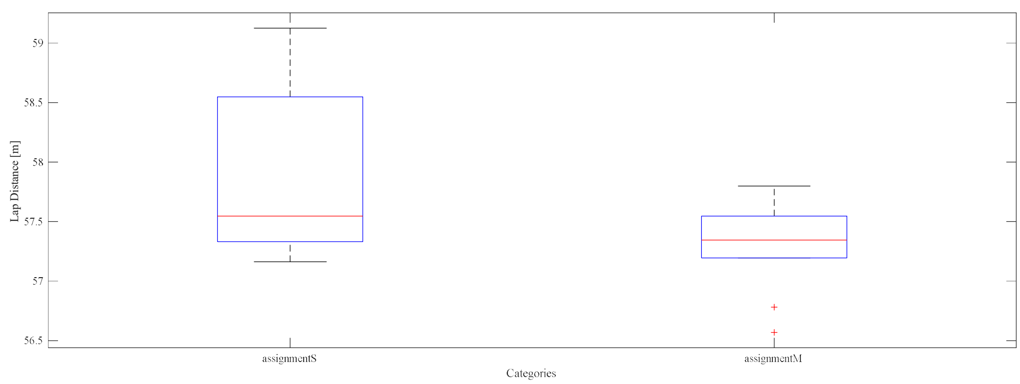

Figure 10: Simulated lap distance for assignmentS and assignmentM controllers.

Conclusion:

Our investigation initially began with a null hypothesis, suggesting equal performance between the two controllers, precisely stating:

$$\mu_{assignmentS} < \mu_{assignmentM}.$$

Having concluded our tests, it is time to assess the validity of this hypothesis.

To determine the superior algorithm, we must examine the final results. Here is what we found:

For the lap distance, we accepted the null hypothesis (H0). This means both algorithms perform similarly in terms of the distance covered in the circuit.

For the lap time, we rejected the null hypothesis (H0), suggesting differences in how the algorithms operate. To further understand these differences, we compared the mean lap times for the two cases:

$$\mu_{assignmentS} < \mu_{assignmentM}.$$

Based on these findings, overall, the **assignmentS**[2] algorithm outperforms the **assignmentM**[3] algorithm. This conclusion is drawn from the fact that both algorithms cover the same distance, but the assignmentS algorithm records a shorter lap time ($\mu_{assignmentS} < \mu_{assignmentM}$), indicating better performance.

[2] **AssignmentS:** Our professor's algorithm.
[3] **AssignmentM:** My algorithm.