Dibris Dipartimento di Informatica, Bioingegneria, Robotica e Ingegneria dei Sistemi

Research Track II

Assignment I

Statistical Analysis of Python Robot Simulator

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Abstract

This report is about conducting a statistical analysis to assess the better performance of two unique algorithms (my algorithm and my professor's algorithm) in completing a given task. The exact assignment in this case is a pygame simulation of a robot with the goal of completing laps of the designated track (circuit), while periodically carrying silver tokens through its lifting mechanism to a point behind it as it moves through the circuit. This statistical analysis of the behaviour of two alternative algorithms is based on Python Robotics Simulator for the first assignment of Research Track I.

1 Introduction

The aim of this project was to code a Python script capable of making a simulated holonomic robot sequentially grasp and released some targets (Silver tokens) inside of an arena composed of golden tokens. This Assignment aims at comparing and testing the Behaviour of the robot considering two different implementations of the code:
- My Code Repository
- Professor's Code Repository

2 Robot's Environment

This is a simple, portable robot simulator developed by Student Robotics. Some of the arenas and the assignment has been modified for the Research Track 1 course. In this simulator the robot will spawn inside an arena composed of squared tokens of two different colors Silver token and Golden token.

1. Golden tokens: Walls of the simulator are made of Golden tokens.

2. Silver tokens: Silver tokens are randomly placed in the arena which the robot has to collect.

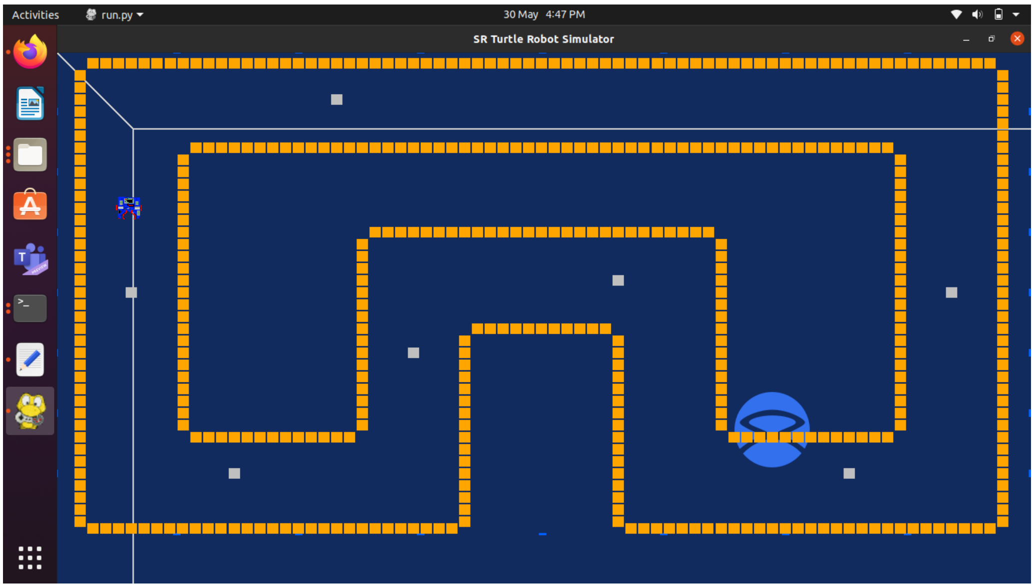

Figure 1: The Arena

3 Methodology

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 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.

3.1 Environment Setup

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

- 7 **Silver Tokens**
- 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.

3.2 Data Collection

The data collected are related to my personal project and to the professor's 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.
- **Distance from golden token:** measures of distance from the robot to the walls (golden tokens).

At each iteration of the control cycle, the robot's distance from the golden tokens was measured. To reduce the time required for the robot to complete a lap, I write a function that begins a chronometer when the robot gets the first silver token and stops it when the robot grabs the last. (that in the first configuration is the seventh, in the second the eighth, and so on).
For each configuration, it was determined to collect data from five robot laps, both for my solution and the professor.
To have comparable data, data from each occurrence (collection of 5 laps) has been regarded as 'valid' only if the robot completed the laps without heading clockwise and without slamming into the barriers.

4 Hypothesis

The hypothesis is usually considered 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 sample data offer such support for a hypothesis that generalization can be made. This hypothesis testing enables us to make probability statements about a population parameter(s). The hypothesis may not be proved absolutely, but in practice, it is acceptable if it has withstood critical testing.

4.1 Null Hypothesis & Alternative Hypothesis

We frequently discuss null hypotheses and alternative hypotheses in the context of statistical analysis. If we compare method A to method B in terms of superiority and proceed on the premise that both ways are equally good, this assumption is known as the null hypothesis.
In contrast, if we believe that method A is superior or method B is inferior, we are expressing what is known as an alternative hypothesis.

- Null hypothesis: $\mathbf{H_0}$
- Alternative hypothesis: $\mathbf{H_a}$

If our sample data do not support this null hypothesis, we should infer that something else is true. The alternative hypothesis is what we come at after rejecting the null hypothesis. In other terms, the alternative hypothesis refers to the collection of alternatives to the null hypothesis.

4.2 Mean distances

Following the gathering of all distance data, all averages for each configuration of the arena circuit were calculated. I decided to compare the total distance from the walls for each arrangement and plot it in Matlab using a bar plot.

It is evident that in each configuration, my robot's distance from the walls is on average less than that of the supplied solution, implying that my robot is closer to the walls than the proposed answer.
It is also worth noting that the average distance from the walls is unaffected by the number of silver tokens, as the robot maintains roughly the same distance from the walls in all configurations.

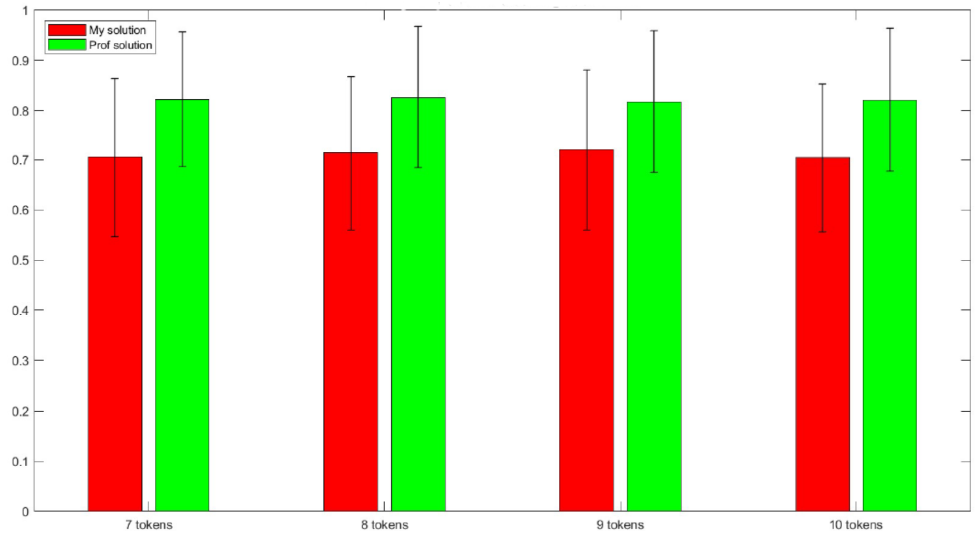

Figure 2: Mean Distance from Nearest Golden Token

4.3 Mean Time

In the meanwhile, I estimated the average time required to complete a lap for each arena layout, and the contrast between my mean timings and the solution is represented using a bar plot.

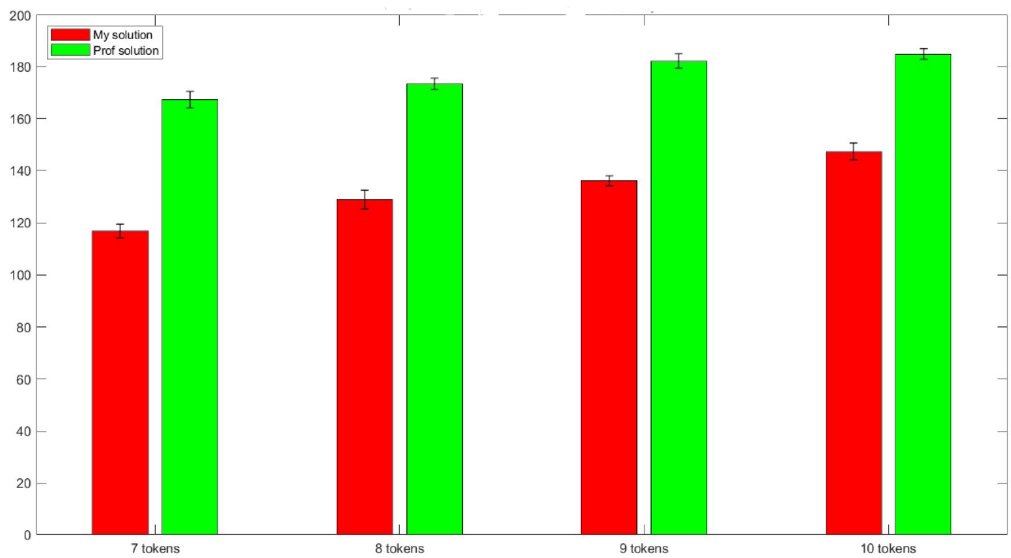

Figure 3: Mean Time Elapsed to make an Entire Lap

In this situation, I discovered that my robot was substantially quicker than the offered solution's robot for each configuration. Obviously, the value of the time required to complete a lap relies on the number of silver tokens, and I discovered that increasing the number of silver tokens increases the time required to complete a lap for both my solution and the offered solution.

4.4 Lap Time

As shown in the image below, it is evident that, in general, regardless of the number of tokens, the robot is quicker in the way given by me. This certainly depends on how the algorithm for moving the robot in the environment was developed, as both my solution and the professor were run on the same system and under the same conditions.

Regarding the time on a single lap, it can be observed that they are constant, because the timings in different laps fluctuate by a few seconds in different configurations of silver tokens, so normally the robot completes a lap in the same time whether it is the first lap or the second lap, and so on.

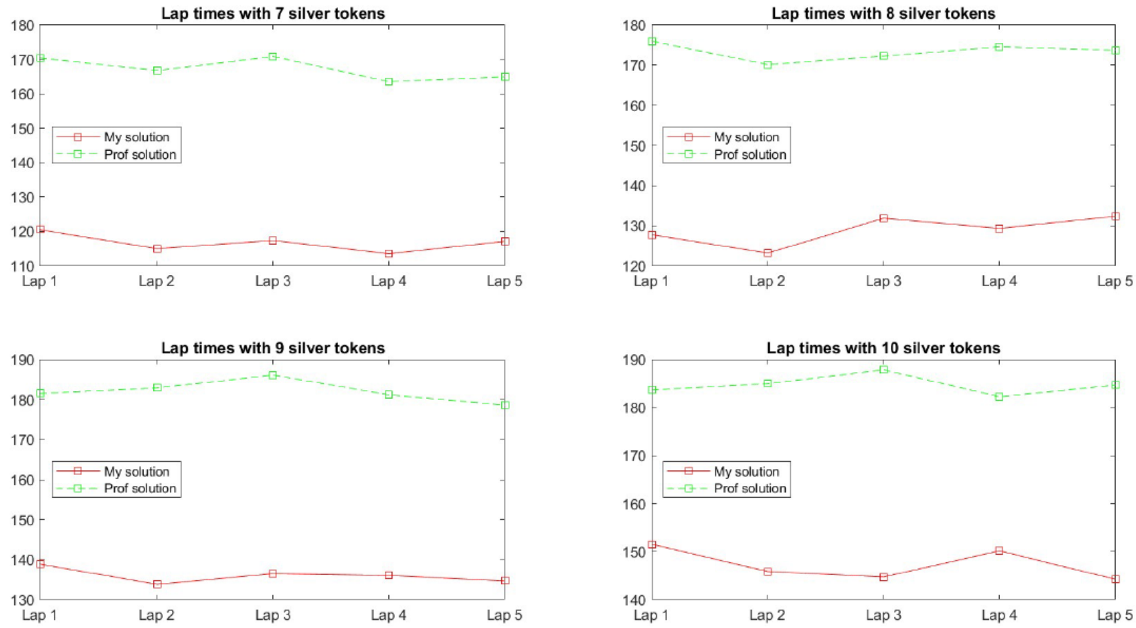

Figure 4: Lap Time Comparison

5 T-Test Analysis

A t-test (sometimes known as a Student's t-test) is a method for conducting hypothesis testing to evaluate the means of one or two populations. A t-test can be used to determine 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), which is what we're looking for.

We picked the paired sample test, as previously stated since we need to compare the same experiment with two

distinct implementations. Choose alpha as well. This is the default value; α indicates the likelihood of rejecting if the null hypothesis is true. A significance level of 0.05, for example, means that the risk of determining that there is a difference is 5%, even if no difference exists. As a result, this might be a type I mistake in the statistics. In terms of t-test output, it is feasible to determine that when H is equal to 0, there is a failure to reject the null hypothesis with the given α, and when H is equal to 1, there is a rejection of the null hypothesis with the given α.
The p-value is another output of the t-test that helps to understand whether the difference between the observed and hypothesized results is due to sampling randomness or if this difference is statistically significant, that is, difficult to explain by sampling randomness.
I do three t-tests, one for each arena layout, on the overall average distance from the walls, the mean duration, and the mean distance from the walls taken in a single lap.
For the first t-test, I compared the mean distance from the walls in each of the four arena configurations and for the two implementations, thus my data sets are made up of four items.

First T-test Result:

Parameter	Value
H	1
p	0.00015

I compared two data sets filled with the average lap time for each configuration for the second t-test, thus the two sets are formed of five components.

The Result is:

Parameter	Value
H	1
p	1.8e-18

In the above scenario, the value of p is most likely determined by the fact that the values found for time are considerably different, implying that the null hypothesis does not make sense.

For the last component of the t-test, I chose the mean distances for each lap and configuration, resulting in four t-tests in total. The code compared a data set with dimension 5 in each t-test.

Results are:

Parameter	7 Tokens	8 Tokens	Tokens	10 Tokens
H	1	1	1	1
p	0.00140	0.00096	0.00330	0.00013

6 Conclusion

The robot using my algorithm had a statistically significantly faster completion time and a statistically significantly greater distance from the walls compared to the robot using the professor's algorithm. Therefore, these results reinforce the effectiveness of my algorithm in enhancing both speed and safety in the robot's navigation of the maze.

However, it is important to note that this study only tested two algorithms and a limited range of parameters. Further research can explore additional algorithms and a wider range of parameters to better understand the impact of these factors on the robot's behaviour in the maze. Despite these limitations, this study provides valuable insights for designing efficient and safe algorithms for autonomous robots in complex environments.