Research Track 2 Report

1st Francesco Rachiglia
DIBRIS, Robotics Engineering
University of Genoa
Genoa, Italy
6478122@studenti.unige.it

2nd Romina Contreras
DIBRIS, Robotics Engineering
University of Genoa
Genoa, Italy
4221560@studenti.unige.it

***Abstract*—This document is used as the report for the Research Track II course. The assignment consists of comparing two algorithms developed in the previous Research Track I course, aiming to verify if the hypothesis made a priori. This is achieved through statistical methodologies acquired during the course. The following sections will provide an in-depth examination of the two algorithms and descriptions of the testing environments employed. Moreover, the statistical analysis methods used in this study will be outlined. The document will conclude with the results obtained by our computation.**

***Index Terms*—robotics, algorithm, statistics,**

I. Introduction

In the robotics world, conducting statistical studies is useful for defining design criteria and subsequently developing technologies that meet those criteria.
The aim of this project is to analyze the performance of the algorithms created during the Research Track 1 class and determine if there are any substantial differences in performance times between them. Additionally, we will assess whether the algorithms demonstrate robustness when the natural environment is altered, assessing whether they maintain functionality or encounter failure.
The main goal is to systematically gather every single token and put it together. The task is considered complete when all tokens have been gather.
In the following section, there is a description of both algorithms that were chosen for the statistical analysis.

II. Algorithm Description

A. ***Algorithm A:*** This algorithm starts searching for the nearest token, once it has found the nearest the gripper looks for the center of the arena and drives towards it. Once a token is collected the code of the token is put in a list which tells which token is already taken in order to don't take it again. Once all the token are in the center of the arena, the gripper turns around itself until it computes 360 degree looking for token not taken yet. If there is no token in the arena to take, the algorithm end.

B. ***Algorithm B:*** This algorithm starts by examining all neighboring tokens and adds them to a central list (which is the core on which the algorithm relies). This list is updated each time the algorithm acquires a new token. After acquiring a token, the algorithm moves it to any position and takes the first code of the token, which will then be used to position subsequent tokens at the same point where the last acquired token was left. The algorithm terminates when the list of acquired tokens is equal to the list of tokens seen.

III. Environment Description

For the evaluation, three different environments were used, each of this have different quantities of tokens (respectively six, four and nine) and different arrangements of the tokens within the arena. The tokens are in static positions and equidistant from the center of the arena. This is done to observe the robustness of the algorithms.
Providing various arrangements provides an insights into the quality of the algorithm and its adaptability.

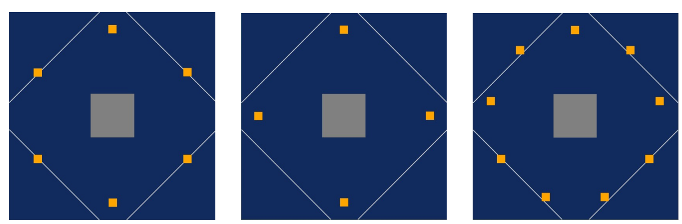

Fig. 1: Environments used in the simulations

In the following sections are shown the results obtained and the analysis computed to compare the two algorithms.

IV. Results

To compare the two algorithms it has been chosen to use the time to compute the task (bring all the token in one place), it has been computed thirty observations of each environment for both *algorithmA* and *algorithmB*.

The following tables show the different times obtained in the environments.

Algorithm A times in different environments:

Environment 1	Environment 2	Environment 3
87,033	190,578	118,176
88,066	174,487	121,286
91,603	187,023	118,942
90,106	174,184	123,217
94,223	173,609	127,051
88,888	199,044	129,853
83,351	185,997	143,342
98,938	191,058	121,955
92,378	190,103	126,691
88,675	179,826	139,929
⋮	⋮	⋮
92,188	176,196	138,998

Algorithm B times in different environments:

Environment 1	Environment 2	Environment 3
171,135	103,482	262,303
162,087	113,986	234,668
170,106	101,472	500,000
164,078	109,953	233,665
172,118	102,468	500,000
175,114	101,985	225,143
166,607	96,941	239,696
165,089	103,975	250,214
157,573	100,505	500,000
167,581	107,514	249,223
⋮	⋮	⋮
161,583	104,501	251,698

The figures below show the trend of the times obtained in fifteen observations.

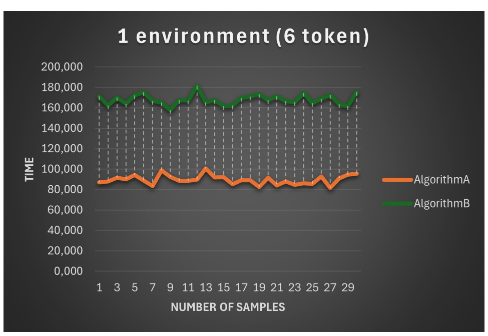

Fig. 2: Environment with 6 token

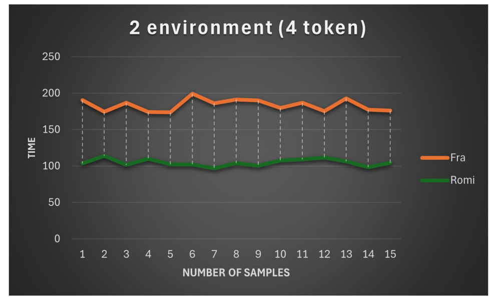

Fig. 3: Environment with 4 token

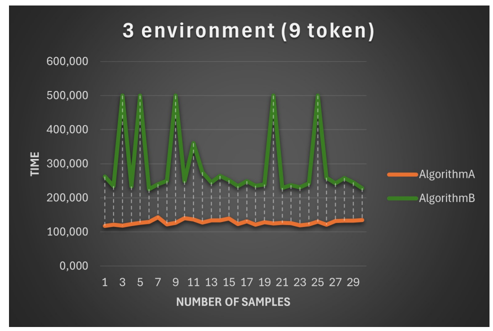

Fig. 4: Environment with 9 token

It can be observed that *AlgorithmA* takes less time in the first and third environments, whereas *AlgorithmB* performs better in the second environment.

V. Statistical results

A. Hypothesis

- Null hypothesis H_0: Both algorithm have comparable processing time across all the selected environment.
- Alternative hypothesis H_a: One of the algorithm exhibits significantly faster processing times compared to the other one across the selected environments.

To analyze the results obtained, we employed the *T-test*. This statistical method allowed us to compare the data sets from the different algorithms, providing insights into any significant differences in their performance.

B. Test

The *T-test* was used to compare two different population that means, indicating that observations in one sample can be paired with observations in the other sample. Specifically, it was employed to compare the time taken by the robot to gather all the tokens at a single point.

To test the null hypothesis that the true mean difference is zero, the following procedure is applied:

1) Compute the difference between one observations of *AlgorithmA* and one from *AlgorithmB*

$$d_i = y_i - x_i$$

2) Compute the mean difference $\overline{d}$ of the samples

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_i$$

where n is the number of samples and d_i is the differences between the observation

3) Compute the standard deviation of the difference s_d, and use this value to determine the standard error of the mean difference:

$$SE(\bar{d}) = \frac{s_d}{\sqrt{n}}$$

4) Calculate the t-statistic, which is given by:

$$T = \frac{\bar{d}}{SE(d)}$$

(The t-distribution represents the standardized distances between sample means and the population mean when the population standard deviation is unknown, and the observations come from a normally distributed population.)

5) Use tables of the t-distribution to compare your value for T to the t_{n-1} distribution.

t-test table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

Fig. 5: T-test Table

VI. Analysis

A. First Environment

The results of the *paired t-test* indicate that the null hypothesis must be rejected, as the p-value is less than 0.05. This low p-value provides strong evidence against the null hypothesis. Specifically, in this environment with six tokens, the t-value is 57.28, leading us to accept the alternative hypothesis.

B. Second Environment

In the second environment, applying the *paired t-test* has shown that the null hypothesis should be rejected due to a p-value below 0.05. This significant result suggests strong evidence against the null hypothesis. The t-value in this environment, which involves four tokens, is 48.56, thereby supporting the acceptance of the alternative hypothesis.

C. Third Environment

For the third environment, the *paired t-test* results indicate that the null hypothesis must be rejected, as evidenced by a p-value lower than 0.05. This outcome provides robust evidence against the null hypothesis. In this setting, with nine tokens, the t-value is 8.96, which leads to the acceptance of the alternative hypothesis.

VII. Conclusion

It can be conclude that, based on the hypotheses stated, it is evident that the two algorithms manifest distinct characteristics in their performance across various environments.

AlgorithmA appears to outperform *AlgorithmB* in environments 1 and 3, whereas *AlgorithmB* demonstrates superior efficacy in environment 2. These findings suggest that the algorithms exhibit different behaviors and are better suited for specific environmental conditions.

Moreover, it can be argued that *AlgorithmA* performs better in scenarios with a higher number of tokens, while the second algorithm excels in environments with fewer tokens.