FACULTY OF ELECTRICAL-ELECTRONICS

MULTIDISCIPLINARY DESIGN PROJECT

RESULT REPORT

Project Title: : Placing Two-Dimensional Objects in an Area with Certain Boundaries with a Three-Axis Robot			
Project Result Report Delivery Date: 05.01.2024			
No.	**Project Team Name, Surname**	**Section (ELM/EHM/BLM/KOM)**	
one	**Osman KADIM**	BLM	
2	**Amirkia Rafiei OSKOOEI**	BLM	
3	**Hilal AKPINAR**	ELM	
4	**Beytullah ÿANLI**	ELM	
5	**Berkant ÖZKAN**	EHM	
6	**Yasin KAPUKIRAN**	COM	
7	**Yeliz YANIK**	BME	
Consultant Ercan ÿZGÿ		ELM	

Project Result Report Delivery Date

5.01.2024

Note: The form must be filled in Arial 10 font and should not exceed 10 pages in total. **PREFACE**

Solving the package placement problem poses a significant optimization requirement in many applications in the logistics and packaging industries. In this project, we discuss the process of developing and implementing an optimization algorithm to best fit packages of certain sizes into a given space.
In the first stage of our project, we examined the existing methods in detail by conducting a literature review. This comprehensive review allowed us to compare the achievements of various algorithms and choose the most suitable method. The selected algorithm will then be tested on different data sets and its performance will be evaluated. In the second stage, we will develop a mechanical design that can draw the outputs of the algorithm on paper. This design, in which different approaches such as robot arms and CNC systems will be used, will reveal the interaction of the algorithm in the practical application process. After the design is realized, the outputs of the algorithm will be taken through a microcontroller and the drawing process will be carried out by controlling the stepper motors in the design. This project is addressed as a whole, starting from the theoretical framework of package placement optimization to practical application and mechanical design stages. The results obtained will offer an innovative approach that has the potential to increase efficiency in logistics and packaging processes.

SUMMARY

The purpose, scope, method(s) used, result(s) and management scheme of the work carried out within the scope of the project should be stated clearly and concisely. The abstract should be limited to 450 words or one page.

The project summary

In the initial phase of the project, an optimization algorithm will be developed to optimally place a set of packages of certain dimensions, for example, on an A4 size paper. In order to create this algorithm, first a comprehensive literature review will be conducted and the details of existing methods will be examined in detail; Their achievements will be compared. Then, the most appropriate method will be selected and coded, and the outputs of the algorithm will be tested on different data sets and their success will be observed. In the next phase of the project, a mechanical design that can draw the outputs of the algorithm on paper will be made. Different approaches such as robotic arm or CNC can be used for this design. After the selected design is realized, the output of the algorithm will be taken through a microcontroller and the drawing will be made by controlling the stepper motors in the design. This structure will be tested only on a specific dataset and its design will be evaluated.

This will ensure that the packages are optimally placed in the given space.

Key Words: CNC, hardware, software, optimization, stepper motor

1. INTRODUCTION

The purpose, scope, method(s) used, and result(s) of the project are written in detail. Depending on the nature of the design, elements such as economy, environmental problems, sustainability, manufacturability, ethics, health, security, social and political problems should also be examined.

In this project, it is aimed to optimally place two-dimensional objects in a two-dimensional space with defined boundaries, taking up the least amount of space.

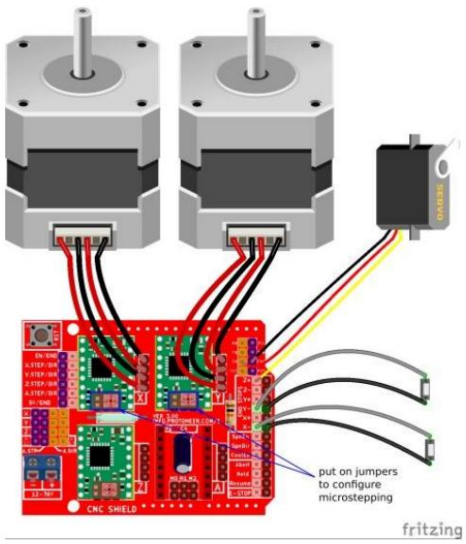
The main goal of our project is to create an optimization software that will provide the most efficient arrangement of two-dimensional objects in a specified area and to provide the ability to draw on paper using a robot. This robot will be able to make the precise movements necessary to cut or draw labels in a certain area. It will be designed as follows. We focused on a solution that involved the integration of a robot capable of three-axis movement and supported by optimization algorithms. For this purpose, we first conducted a literature review and examined various methods in detail and determined the most appropriate optimization method. According to the optimization method we chose, we used the hyperpack algorithm, which ensures that two-dimensional objects cover the minimum area in the most optimal way.

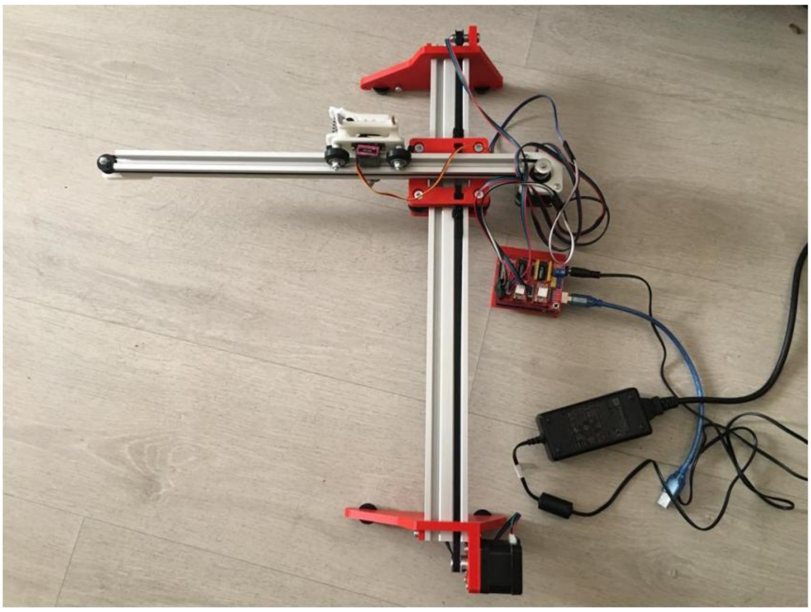
We performed various tests using different data sets to evaluate the performance of the developed software. These tests showed us how successful the software was in placing a package, as we mentioned in the results section.

Packaging problems arise because large objects are identified as empty and must be filled with small objects. Cutting problems are characterized by large objects that need to be cut into small pieces. This approach is the solution to most cutting and packaging problems by minimizing cut loss or waste.
Using optimization in drawing or cutting labels provides economic savings to the user. Because with optimal placement, space is used effectively and it aims to prevent waste of resources.

This developed project enables the best use of storage space and at the same time encourages the efficient use of economic resources and aims to reduce additional costs. Preventing resource waste and using economic resources efficiently is an environmentally sustainable approach. Reducing the energy consumed and decreasing transportation costs contribute to reducing the carbon footprint. Optimizing the cutting and drawing processes in the project increases the safety of employees' working environments and contributes to reducing the workload.

Our project aims to arrange two-dimensional objects in a certain area in a way that takes up minimal space by using a three-axis robot; It takes into account all conditions such as safety, sustainability, efficiency and environmental factors. Our goal is to develop this project, which has an effective and sustainable design, as an example for future studies.





2. MATERIALS, METHODS AND MANAGEMENT ORDER

The methods and research techniques applied in the project are explained. The methods and techniques used are stated in the project management plan. It is explained whether it is suitable for achieving the envisaged goals and objectives. If there are changes, they are explained. The work packages specified in the management plan and the level of task distribution are clearly stated.

Ingredients, Methods and Order of Administration

Used materials

2 x nema 17
1 x servo
1 x arduino 1
x cnc shield
2 x stepper motor
1 x 12v adapter
2 x 20 Teeth GT2 6mm Pulley - 5mm Shaft
2 x GT2 6mm Threadless Bearing - 5mm Pulley
1 x GT2-6mm Belt - 2m
7 x 625zz wheels 3 x
eccentric nut 6mm
8 x 6mm spacer
4 x M3 10mm bolts
2 x M4 8mm bolts
8 x M4 12mm bolts
1 x M5 10mm bolt
4 x M5 50mm bolts
5 x M5 30mm bolts
9 x M5 safety nut
20 x M5 washers
10 x M4 channel6 nuts
2 x M3 80mm straight shaft
1 x pen spring
2 x pen axis thin spring

Applied Methods and Techniques

1. Literature Review (Week 1-5):
- A comprehensive literature review was conducted to gain an in-depth understanding of the historical development and background of CNC machines. This survey included extensive research covering the evolution of CNC technology over time and the technology's changing role in industrial use.
- A research was conducted on the CNC XY Plotter Machine to examine its applications in 2D drawing technology using Arduino and CNC shield technologies.

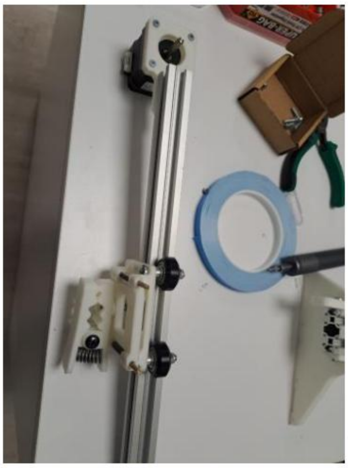
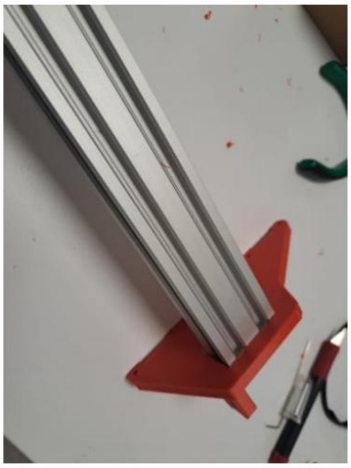
2. Management Plan (Week 6):
- Studies were carried out to determine the steps, goals and strategies that will ensure the effective management of the project, organization or process.

3. Optimization (Week 7-8-9):
- Research was carried out to increase the performance of the CNC Drawing Machine by making adjustments to the software code, and these improvements were implemented. Comparative tests were conducted to measure the results of the improvements and the results were documented.

4. Robot Design followed by Testing and Control (Weeks 10-11-12-13):
- Mechanical components were jointly designed and the required material was listed.
- 3D printed parts were determined and printed.
- Rail thickness and rail thickness for both mechanical coins and pen to move easily. The use of a movable wheel structure was preferred.
- By assembling hardware components using screws, 3D printed parts and silicone stability was achieved.
- Motors are connected to the Arduino Uno in the most optimal way via jumpers for controlled movements. connected.
- Integrated three-stage motor is used for precise control of the X, Y and Z axes, allowing controlled up and down

Provides downward movements.

- Coded the software of the CNC Drawing Machine using Arduino Uno and CNC shield technologies.
- Algorithms provide precise pencil movements in the X and Y axes by synchronizing the movements of the stepper motors. makes movements possible.
- Control system to ensure compliance with designed specifications and efficient operation. Many tests were done. All problems identified during the testing phase have been resolved.


5. Result (Week 14)

- The entire process was documented, from design changes to hardware and software integration, even testing procedures. The final report summarizing the project's objectives, methods used, results obtained and these results has been completed.

3. RESULTS

It is explained using tables, figures and graphs that the project's targeted outputs have been achieved.

3.1 Shape Placement Performance

The success of the optimization solution implemented within the scope of the project was tested on the test class created by Hopper and Turton. This test class named C consists of 21 tests consisting of different numbers of shapes in different sizes. Figure 1 provides detailed information with the test data set.

Test problems

Problem category	Number of items	Optimal height	Object dimensions
C1	16 or 17	20	20×20
C2	25	15	40×15
C3	28 or 29	30	60×30
C4	49	60	60×60
C5	72 or 73	90	60×90
C6	97	120	80×120
C7	196 or 197	240	160×240

Figure 1 Hopper-Turton Test Data Set

In the table below, the success rates of our code written using the HyperPack algorithm, the time spent in the insertion process and the numbers of the excluded shapes are given. The test was repeated 5 times on a computer with an Intel i7-8750 processor and 16 GB RAM.

If we examine the two optimization solutions, we see that both algorithms exceed 90% success rate in solving the problem. In addition, when the number of shapes increases in both algorithms, the calculation and placement time generally increases.

If we need to compare the efficiency of our HyperPack solution with the Local Search algorithm, the solution we implemented does not fall below 97% in terms of success. The Local Search algorithm goes down to 91%. While the Local Search algorithm worked faster in the first data sets, the times began to approach each other in the data sets where the number of shapes increased. Considering the success based on occupancy rate, the HyperPack algorithm is more successful than the Local Search algorithm. It would be more logical to use HyperPack in applications where occupancy is important. In transactions where speed is important, the Local Search algorithm can be used.

If we look at the comparison of the HyperPack algorithm within itself, we see that it takes approximately the same time to calculate in other data sets except the C1 data set. While a 100% success rate was achieved for the C3 data set, this rate generally remains at 99% in other data sets. However, as in the Local Search algorithm, as the number of boxes in the data set increases, there is no increase in time and no decrease in success rate.

In order to transfer the success in the field of optimization to the real world, an XY drawing robot was created using the Arduino UNO R3 board and CNC Shield. The optimization output is converted to Gcode format and run with the help of the Universal Gcode Sender program. In Figure 2, the data set is run for C4_1 data set.
The output of the optimization code is available.

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Table 1. Comparison of Local Search and HyperPack Algorithm

		Local Search Algorithm			HyperPack Algorithm		
Test Data set	Total Figure Number	place me success	Time(s)	Away Remaining Shapes Its number	place me success	Time(s)	Number of Excluded Shapes
C1_1	16	96%	0.038	13	100%	27,739	-
C1_2	17	96.5%	0.041	16	99%	28,989	0
C1_3	16	95.5%	0.047	14	100%	26,344	-
C2_1	28	96%	0.566	20	99.3%	60,005	23
C2_2	29	93.3%	1,089	13.23	99.3%	60,009	12,20
C2_3	28	97%	0.834	21	%one hundred	60	-
C3_1	25	92.6%	0.198	8	%one hundred	60	-
C3_2	25	96.3%	0.152	19	%one hundred	60	-
C3_3	25	97.5%	0.314	24	%one hundred	60	-
C4_1	49	91.9%	1,709	41,43	99.2%	60	22.45
C4_2	49	91.6%	2,174	48,48	99.6%	60	12
C4_3	49	96.6%	7,924	0.28	99.8%	60	21
C5_1	73	97.3%	30,815	33,69,70	99.5%	60,001	15
C5_2	73	95.5%	26,226	30.55	99.8%	60	22
C5_3	73	96.2%	42.95	15,44,45	99.5%	60,002	67
C6_1	97	92.3%	28,124	70,81,87	99.2%	60,005	5,23,24,47,58
C6_2	97	91.9%	42,959	62.93	99.3%	60,002	16,22,28,33,70,71.75
C6_3	97	94.4%	20,257	71,93,94	99.1%	60,001	2,34,37
C7_1	196	93.9%	60,002	172,179.180.181.182.183,184,187	97.7%	60,001	33,67,106,129,130, 133,145,152,153, 162,163,176,185, 191
C7_2	197	93.4%	60,006	136,184.192,193	99.1%	60,001	10,43,102,104,114, 145,168,171,172
C7_3	196	92%	38,349	172,176.180.183.185.193	98.4%	60,007	26,51,61,107,127, 134,138,142,147, 161,164,174,178

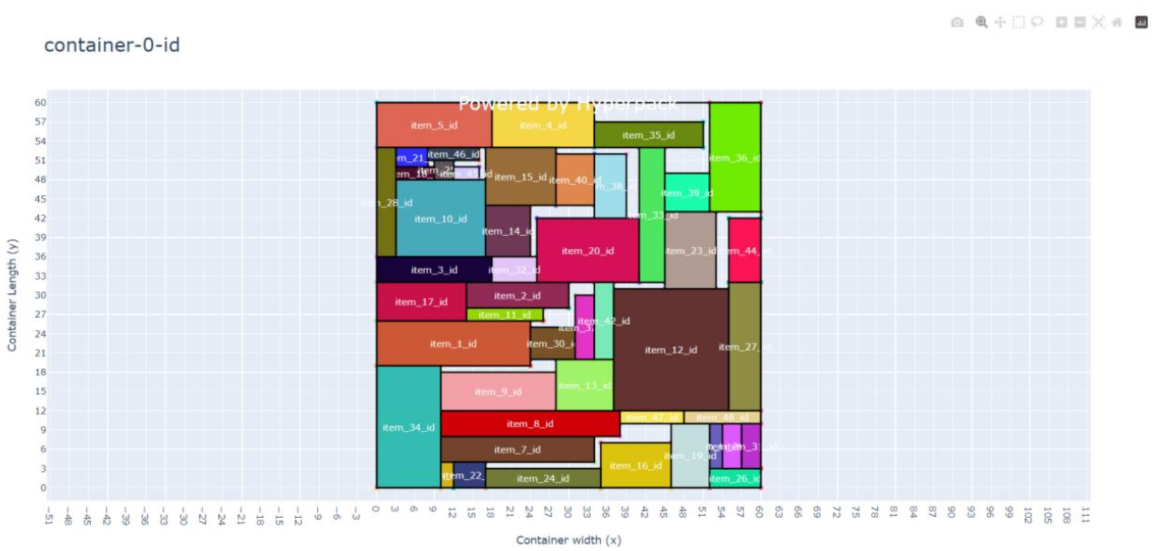
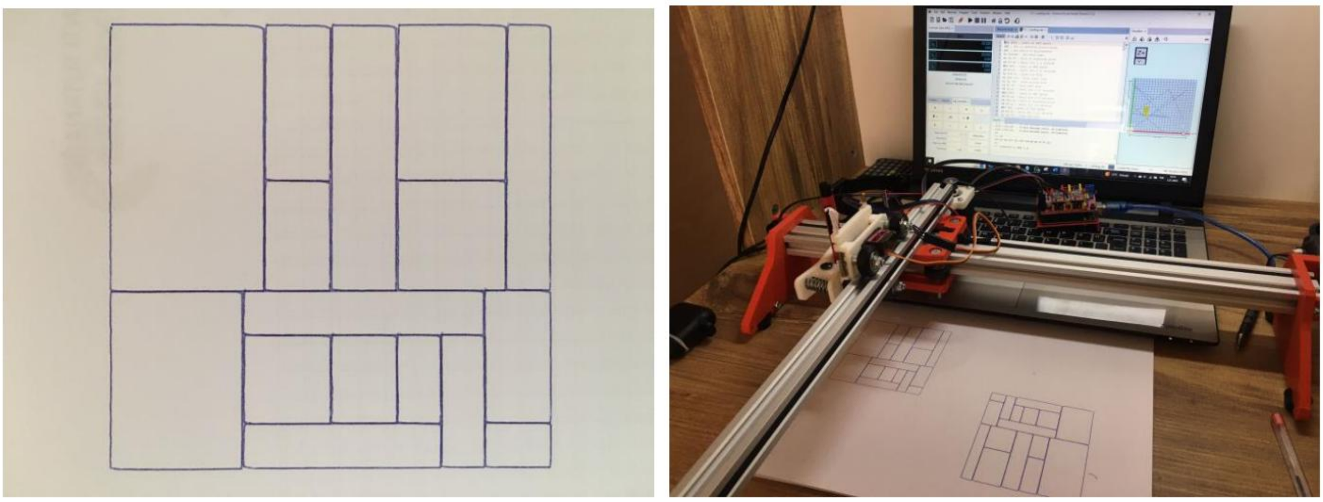


Figure 2 Optimization Output for Dataset C4_1

The output received is run in Gcode format with Universal Gcode Sender, allowing the robot to draw. The servo and step motors in the robot provide movement along the axes and the rising and falling movement of the pen using the commands they receive. Thanks to movement along the axes, the position to be drawn is determined precisely. Thanks to the rising and falling movements of the pen, the pen only touches the paper surface when drawing. Figure 3 shows the drawing made for C1_1 data.



The drawing for C1_1 data in Figure 3