AUTOMATIC HARVESTING SYSTEM FOR RIPE TOMATOES

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ABSTRACT: This paper presents some of the existing work on this topic, the calculations used to select the appropriate motors for robot functionality, and some examples of ripe tomato detection.

KEYWORDS: algorithms, tomatoes, autonomy, detection

1. Introduction

Artificial intelligence (AI) represents the ability of a system or robot to mimic the human mind as closely as possible, make decisions, and achieve goals in the most efficient way possible.[1]

AI analyzes existing data and can predict future actions, thus becoming autonomous. It operates similarly to humans by learning new things, applying them, and adapting along the way to become as efficient as possible.[1]

Agricultural work has shown its disadvantages with climate change and with the professional preferences regarding the jobs that humans want to do, resulting in a considerable decrease in the number of people engaged in harvesting various crops. Additionally, the working conditions offered by the environment/greenhouse are difficult to tolerate, which can affect human health, reduce performance and productivity, and even lead to additional medical expenses.

Given the above, the purpose of this paper is to develop an autonomous robot that harvests ripe tomatoes, with a minimum operating time of 8 hours, high accuracy in detecting ripe tomatoes, and a efficiency at least equal to that of humans in terms of the number of tomatoes harvested per minute. The objectives will be achieved with carefully selected components, offering system rigidity, necessary speed of operation, and precision of functionality. The detection of ripe tomatoes will be done using the Roboflow and Google Colab websites, a USB camera connected to a Raspberry Pi, and the OpenCV library in the Python programming language.

2. Current stage

In this chapter, the current progress of the paper and the 3D model of the system will be presented.

In terms of algorithms used for programming the system, only the code for detecting ripe tomatoes and the code for detecting distance using ultrasonic sensors exist.

In terms of the prototype, the mechanical and physical components are present, printed, and modeled up to 90%. After researching existing projects, analyzed by specific parameters such as the duration of operation, robot autonomy, harvesting speed, sensors used for detection and movement, mode of locomotion, effector type, and size dimensions, the 3D model of the autonomous robot was designed and created.

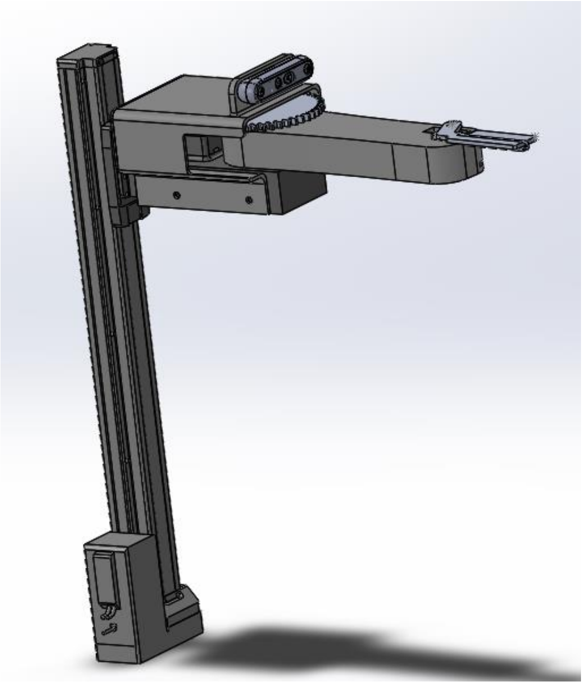

Fig. 2.1 - 3D model of the robotic harvesting arm

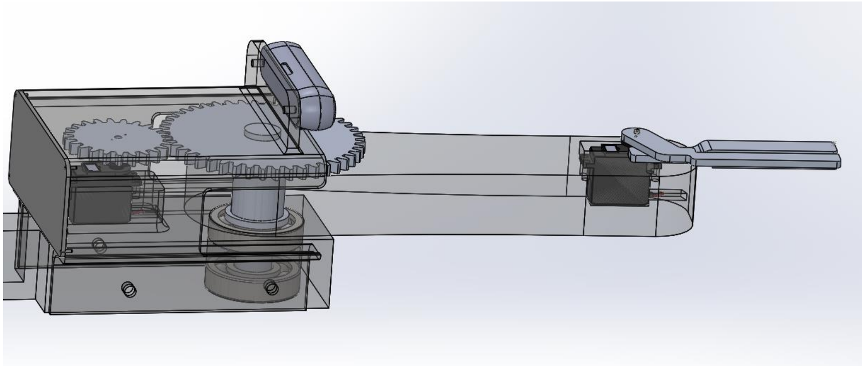

Fig. 2.2 - 3D model of the robotic arm - interior view

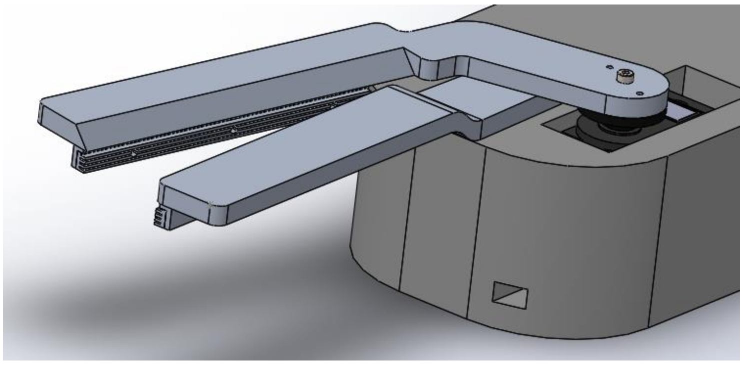

Fig. 2.3 - The effector - designed to grip the stem after cutting

3. Technical report

In this chapter, calculations for the motors used to rotate the arm and the cutting tool are presented.

3.1.1 Calculation of the rotating arm motor - To avoid the high load directly applied to the motor shaft, a gear wheel transmission mechanism was used, thus making the rotation of the robotic arm possible."

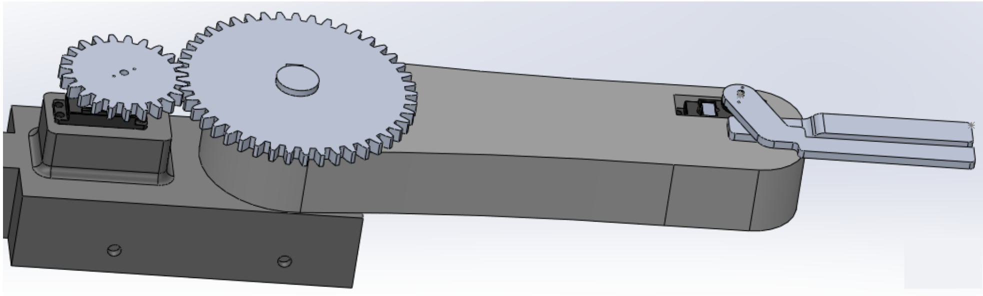

Fig.3.1.1 – Gear wheel transmission, 3D representation

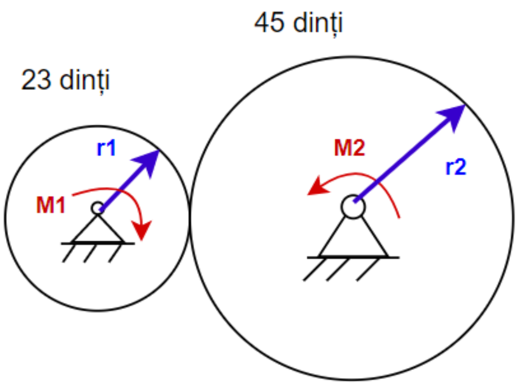

Fig.3.1.2 – Strength diagram for the gear transmission

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 3718398.09	Ixy = 30288.99	Ixz = -5429829.49
Iyx = 30288.99	Iyy = 39167810.17	Iyz = -41349.40
Izx = -5429829.49	Izy = -41349.40	Izz = 37526816.90

Fig.3.1.3 – Moment of inertia to be overcome by the motor (obtained from SolidWorks program)

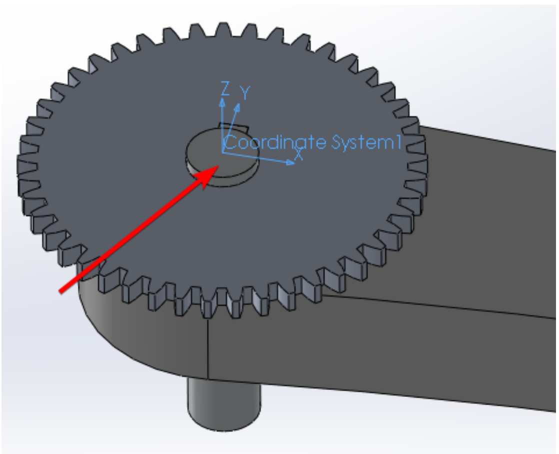

Fig.3.1.4 – Moment of inertia calculated around the OZ axis

$$Z1 := 23 \qquad Z2 := 45 \qquad i := \frac{Z2}{Z1} = 1.957$$

$$J := 0.0375\ kg \cdot m^2$$

$$t := 0.1\ s \qquad \eta := 10\ rpm \qquad r1 := 37.5\ mm \qquad r2 := 70.5\ mm$$

$$w1 = 2 \cdot \pi \cdot \frac{\eta}{60} = 1.047\ \frac{rad}{s} \qquad w1 := 1.047\ \frac{rad}{s}$$

$$w2 := \frac{w1}{i} = 0.535\ \frac{rad}{s}$$

ε = angular acceleration

$$\varepsilon_2 := \frac{w2}{t} = 5.351\ \frac{rad}{s^2} \qquad M2 := \varepsilon_2 \cdot J = 0.201\ N \cdot m$$

$$M1 := \frac{M2}{i} = 0.103\ N \cdot m \qquad M1 = 1.046\ kgf \cdot cm$$

Fig.3.1.5 - shows the calculation of the torque required for the servo motor in the gear transmission assembly

To move the robotic arm, the 'OKY8107 SPRINGRC' motor from SpringRC company was chosen.[2] It was selected with a higher torque because we have considered a big safety factor to compensate for the natural phenomena that were simplified. The torque is 3kg/cm at a supply voltage of 6V, which means a torque of 0.294Nm.

Fig.3.1.6 - The motor selected for the gear wheel mechanism[2]

3.2 Calculation of the motor for the cutting blade

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 2490627.28	Ixy = 3053160.23	Ixz = 4686846.11
Iyx = 3053160.23	Iyy = 32264874.41	Iyz = 735345.60
Izx = 4686846.11	Izy = 735345.60	Izz = 32232675.99

Fig.3.2.1 – Moment of inertia to be overcome by the motor (obtained from SolidWorks program)

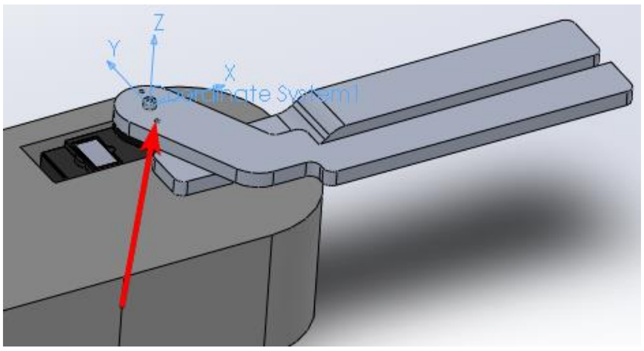

Fig.3.2.2 – Moment of inertia calculated around the OZ axis

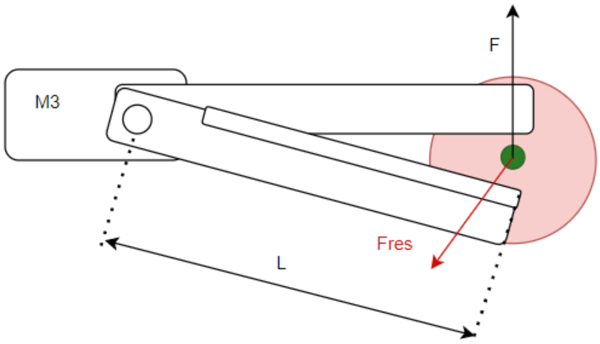

Fig.3.2.3 – The resistance diagram of the scissors

$t := 1\ s \qquad \eta := 0.3\ rpm$

$w = 2 \cdot \pi \cdot \frac{\eta}{60} = 0.031\ \frac{rad}{s} \qquad w := 0.031\ \frac{rad}{s}$

ε = angular acceleration

$\varepsilon := \frac{w}{t} = 0.031\ \frac{rad}{s^2}$

$J := 0.0322\ kg \cdot m^2 \qquad L := 134.4\ mm$

$m := 4.1\ kg$

$F - Fres = 0 \qquad Fres := m \cdot g = 40.207\ N$

$F := Fres$

$M := F \cdot L + J \cdot \varepsilon = 5.405\ N \cdot m \qquad M = 55.114\ kgf \cdot cm$

Fig.3.2.4 – Calculation for the motor needed to cut the stem

The motor chosen after the calculations is the "Servo Power HD WH-65KG" produced by PowerHD[3] with a torque of 65 kg*cm at a supply voltage of 8.4V.

Fig.3.2.5 – The motor chosen for cutting the stem [3]

4. Algorithm for detecting ripe tomatoes

As mentioned in the introduction, automatic fruit detection was achieved by adding sets of images to the program provided by Roboflow[4], where they were labeled as ripe-tomato or unripe-tomato, and then trained. The data was then entered into Google Colab[5] for detailed GPU training, and the final files were added to the Python program, OpenCv with Darknet. The results obtained can be seen below.

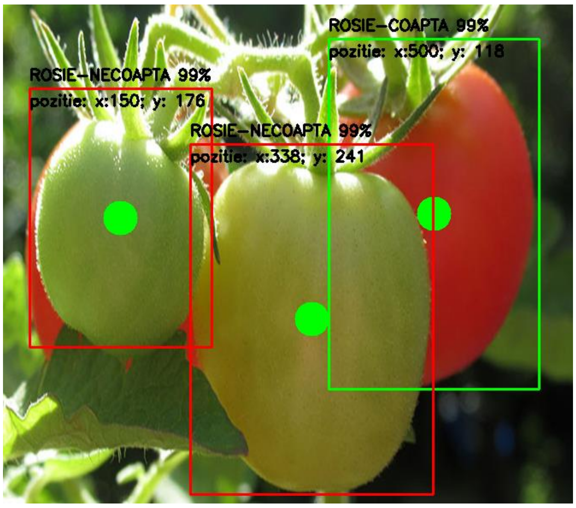

Fig.4.1 – The detection of the tomatoes -1

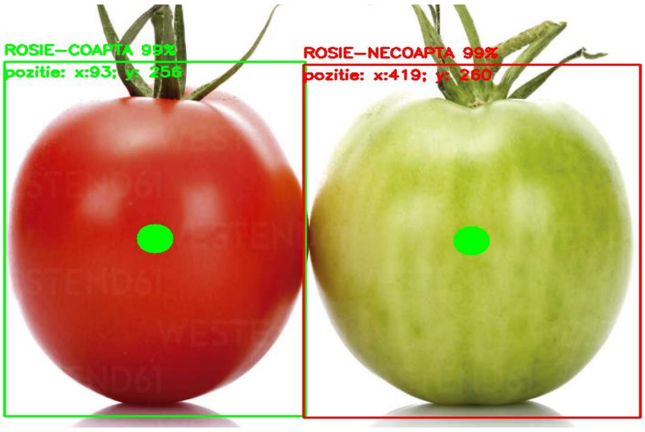

Fig.4.2 – The detection of the tomatoes -2

5. Conclusions

Based on the calculations presented above, an Arduino code will be developed to perform the rotation and translation movements of the robot. Knowing what types of motors are needed, the complete 3D system of the robot will be designed and assembled with the electrical components. Regarding the detection aspect, we can observe that the confidentiality is high but suffers from some omissions. To improve the prototype of this work, the following two options will be considered:

1. The room will exclusively contain tomatoes and will be properly lit.
2. The dataset will be expanded to differentiate between other fruits such as apples.

6. Bibliography

[1]https://www.colorful.hr/ce-este-inteligenta-artificiala-cum-functioneaza-tipuri-aplicabilitate-pe-piata-muncii/
[2] https://www.tme.eu/ro/details/oky8107/servomotoare/springrc/
[3]https://www.monsterhopups.de/Power-HD-WH-65KG-Servo-65-kg-HV-fuer-1/5-1/6-Metallgetriebe-Wasserdicht-Kugellager
[4] https://roboflow.com/
[5]https://colab.research.google.com/drive/1mzL6WyY9BRx4xX476eQdhKDnd_eixBlG