TEKNOFEST

AVIATION, SPACE AND TECHNOLOGY FESTIVAL

AGRICULTURAL UNMANNED GROUND VEHICLES COMPETITION

CRITICAL DESIGN REPORT TEMPLATE

TEAM NAME

AGRO-DEV TEAM

PROJECT NAME

IMAGE PROCESSING BASED WILD HERB DETECTION AND DESTRUCTION TOOL

APPLICATION ID

1077436

Contents

1. Team Organization

Figure 1 - Team Organization

As seen in the image above, our team consists of 4 people. We decided to start this project together with our friends and consultant who are experienced and knowledgeable in their fields. As a team, we have been working on agricultural robots for the last year. Each of our team members has their own special abilities, but our most important feature is our tendency to teamwork, our understanding, and our ability to work and progress faster and more innovatively when we are together. Apart from these, when it comes to our individual skills, first of all, our consultant Şakir Taşdemir has a general knowledge of the subject of this project and is knowledgeable and effective in many subjects such as autonomy, image processing, artificial intelligence, mechanical structure and design. Our team captain, Berkant Aslan, is knowledgeable about every aspect of our project. He is very talented and knowledgeable, especially in subjects such as Image Processing and Artificial Intelligence, which we think will challenge us the most. Our other team member, Hasan Ağaçayak, is also knowledgeable in every aspect of our project. He is very talented and knowledgeable, especially in subjects such as Autonomous and Image Processing. Finally, our other team member, Hüseyin Ağaçayak, is also knowledgeable about every aspect of our project. He is very talented and knowledgeable, especially in subjects such as Artificial Intelligence, Mechanical Structure and Design.

2. Preliminary Design Report Evaluation

As a result of the preliminary design report evaluation as a team, deficiencies were identified. These deficiencies were distributed according to abilities and these deficiencies were corrected. These shortcomings of ours are as follows: It would be better if the report explains in detail what each team member is knowledgeable about and what duties they will take part in. The image processing and plant recognition part can be expanded a little further. The reason for these changes is the deficiencies observed in the evaluation of the preliminary design report.

Our final budget plan is shown in the table below.

Module Names	Component Model	Number of Units	Unit price (₺)	Total price (₺)
Microcontroller	Jetson Nano	1	9.393,98	9.393,98
Microcontroller	Raspberry Pi 4GB	1	4.659,61	4.659,61
Autonomous Module	Pixhawk	1	10.000,00	10.000,00
ESC Module	1PCS Brushed Electric Speed Controller	1	1.720	1.720
Control	10 Kanal 2.4Ghz Digital Control	1	2.078,06	2.078,06
HDMI 7" Display	7 Inch HDMI IPS LCD Display	1	2.218,40	2.218,40
Motor	Geared DC Motor	4	672,60	2.690,40
Temperature Sensor	LM35	2	33,63	67,26
Wheels	RC Car Wheel	4	334	1.336
Power Distribution Module	Power Level Display	1	9,37	9,37
Battery	22.2V 5200mah 40C Lipo	1	2.128	2.128
GPS	Ublox GYGPSV1 NEO-8M GPS	1	334,46	334,46
Distance Sensor	Lidar Sensor	1	72,48	72,48
Distance Sensor	Ultrasonic Sensor	1	43,93	43,93

Camera	Camera (Adaptive with Jetson Nano)	2	500,00	1.000,00
Wireless Communication	Antenna	1	110,82	110,82
Chassis	Structure of the Car	1	500,00	500,00
Total	-	-	-	**38.362,77**

Table 1 - Budget Plan

3. Vehicle Features

Our project will be the best solution against wild herb control with new technologies. In the Deep Learning Design section, the data set will be prepared for deep learning training in which the Yolov5 Darknet Neural Network Model will be used, by creating a data set from wild herb and real plant data taken from the internet and real-life plots, and 2-class labelling of each data as wild herb and others. Together, the average accuracy rate will be above 90%.

Since millimetres precision will not be required in mechanical design, DC motor(s) will be used for the movement of the wheels. A suitable system will be developed for the vehicle to turn and it will be possible to automatically navigate through the products in the entire field. By moving back and forth according to the detected wild herbs, the wild herb will be removed from the soil by moving the wild herb in front of the cameras and by ensuring that the important point of the wild herb area detected in the real-time image frames reaches the point where the spray application will reach. To remove the wild herb from the soil, thanks to the appropriate sensor and powerful system, it will be descended from the soil to the root and its connection with the soil will be cut off. The root of the wild herb remaining in the soil cannot prevent the wild herb from sharing the nutrients of the plants and affecting the yield. That's why we decided on this app.

As for electronic design, both Artificial Intelligence and vehicle movement will be provided by using Jetson Nano. Cameras and all electronic connections will be made with Jetson Nano, and Jetson Nano will be sufficient for this project. Cameras suitable for field conditions will be found and used.

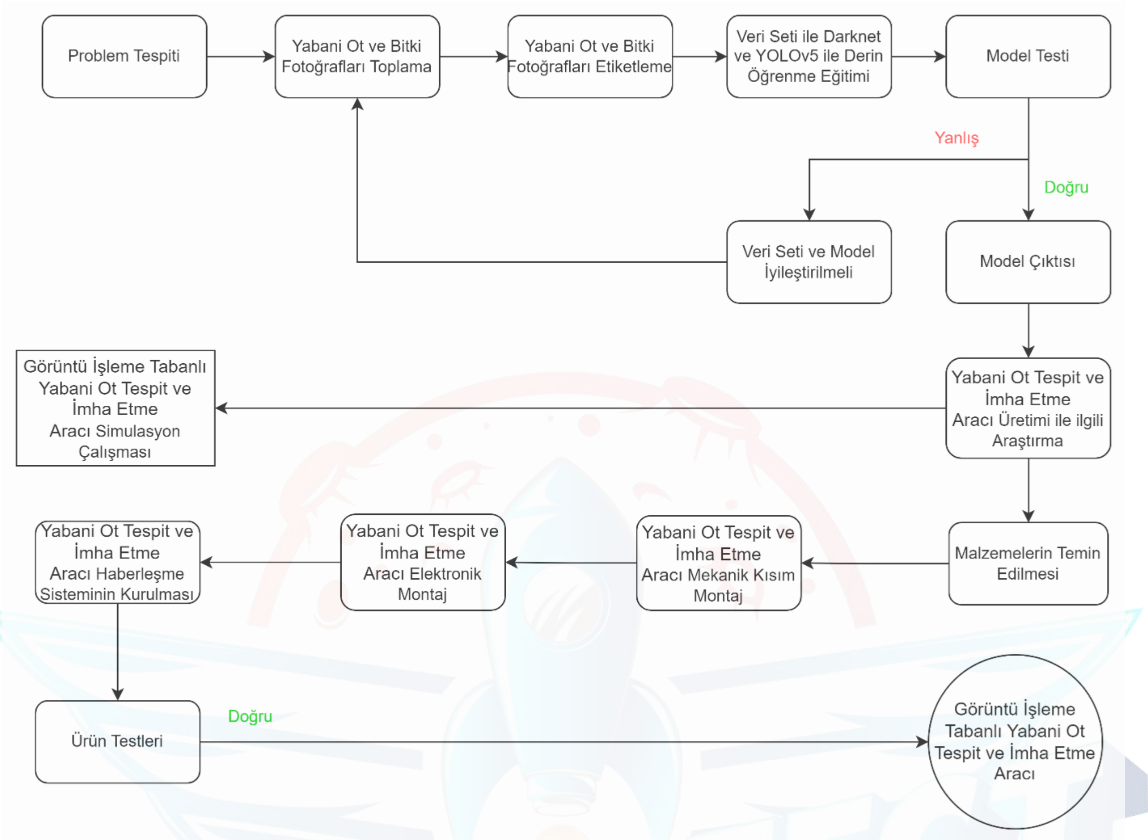

Figure 2 - Working Diagram of the Vehicle

IMAGE PROCESSING BASED WILD HERB DETECTION AND DESTRUCTION TOOL							
Work Package Name	**Starting date**	**End Date**	**Time**	**2022**	**2023**		
				December	**January**	**February**	**March**
WORK PACKAGE 1 - Software	**9.12.2022**	**10.1.2023**	**1 Ay**				
1.1. Preparing a data set by taking photos of wild herbs and plants from the internet and real life							
1.2. Data Augmentation with our Python program that we have prepared							
1.3. Tagging the Data Set on the local network with the Make Sense application							
1.4. Deep Learning Training Process with YoloV5 Darknet Algorithm, Average Accuracy Rate must exceed 90%, if not, the data should be increased or removed and improved.							
1.5. Model Test (Our model must pass the tests)							

1.6. IoT Application							
WORK PACKAGE 2 - Simulation	**10.1.2023**	**31.1.2023**	**3 Weeks**				
2.1. Simulation testing by combining our System and Artificial Intelligence algorithm in the Gazebo Simulation Field Environment							
WORK PACKAGE 3 - Mechanical	**9.12.2022**	**10.2.2023**	**2 Months**				
3.1. Supply of chassis and mechanical part materials							
3.2. Drawings of parts to be produced and assembled as required by the project							
3.3. Providing wheel and engine connection							
3.4. Installation of Wheel Turning Mechanism							
3.5. Providing Signs and Preparing Direction Signs							
WORK PACKAGE 4 - Electrical-Electronics and Communication	**9.12.2022**	**10.2.2023**	**2 Months**				
4.1. Supply of all electrical-electronic materials such as Jetson Nano, Camera, Raspberry Pi 4, RC Remote, LM35 Temperature Sensor, Emergency Buttons, cables, etc.							
4.2. Providing the electronic connection of the engines of the wheels carrying the chassis and operating testing							
4.3. Battery Temperature Control and operating test							
4.4. Emergency button connection and operation test							
4.5. RC Control Production, Communication Connection and Operation Test							
4.6. Raspberry Pi 4 Linux Installation							
WORK PACKAGE 5 - Test	**10.2.2023**	**24.3.2023**	**2 Weeks**				
5.1. Combining Artificial Intelligence, Mechanical and Electrical-Electronic Parts and Performing Working Tests							
WORK PACKAGE 6 - Competition	**March 2023**						

Table 2 - Work-Time Graph

Figure 3 - General Design Image of the Vehicle

First, we need to choose the engine that best suits our vehicle. We need information about some criteria to determine the engine that suits us best. These are technical information such as duration of use, weight of the vehicle, size of the wheel and obstacle status. We can determine this technical information as an approximate estimate.

In case of an obstacle, which is one of the required criteria, our vehicle can be used in fields, gardens, etc. Since it is used in terrains, our vehicle can be used on rugged terrains and on a 10-degree vertical and 15-degree horizontal plane, as written in the competition specifications. For this reason, we need to put 4 engines in our vehicle, and we can put 150mm diameter wheels. In addition, our vehicle must complete the track in a maximum of 50 minutes and will weigh approximately 25kg. Therefore, our vehicle must reach a certain estimated speed.

Considering these criteria, the engine we want to use is a 20W, 24V and 345rpm engine. When we calculated using 4 motors, we found a torque value of 2.2144n/m. With this torque, the force transmitted to the wheels will be approximately 30N. In this case, this engine selection and wheel selection is suitable for our vehicle.
For our vehicle not to have problems when driving on the ground, the appropriate chassis thickness will be selected so that the vehicle is not heavy, and the walking system will be designed with the appropriate thin wheel thickness so that the vehicle can move easily on the soil.

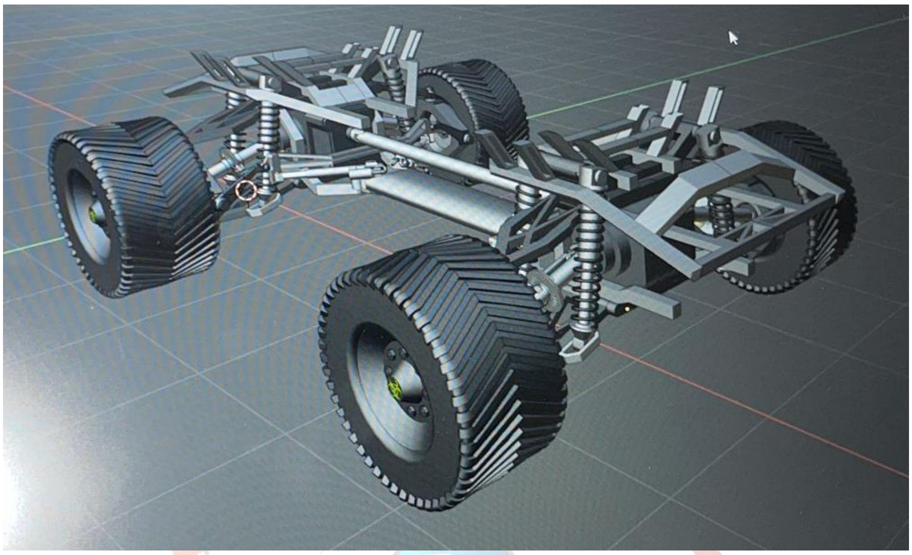

Figure 4 - Mechanical Walking System of the Vehicle

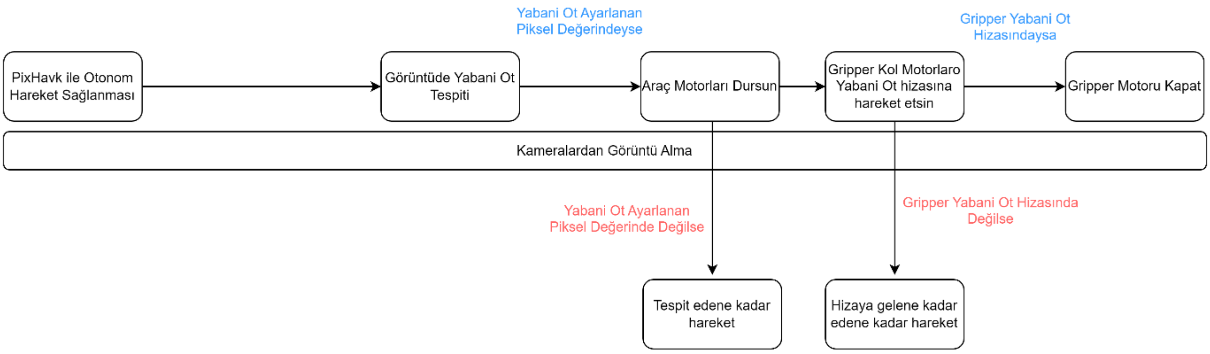

Figure 5 - Electronic Diagram of the System

Pix-hawk and Jetson Nano connection will be connected via Uart. The control electronic card will be used. Linux will be installed on the IoT System RaspberyPi4 and displayed on a 7-inch HDMI screen. The camera will be provided with a USB connection. Motors will be connected to Jetson Nano and Motor Driver. Thanks to the spray mechanism, electronic connections will be provided that will be activated when the wild herb detected by deep learning is applied.

The power drawn from our system will be distributed from the energy source thanks to the 30V 90A power module. In our system, the motors will draw the most, and since the motors operate at 24V and support high amperage such as 90A, this power module will serve our purpose.

In this system, we preferred rechargeable Lipo batteries. In this way, cost and energy will be saved with long-lasting use. In addition, our selected battery will be 6S cellular, 22.2V 5200mah 40C.

The term Li-Po emerged as the abbreviation for Lithium Polymer batteries. It is a type of rechargeable Lithium-Ion battery that uses polymer electrolyte instead of liquid electrolyte. Lipo batteries are widely used in RC vehicles (remote control car, drone, etc.) and robotic applications.

In this system, since the motors will draw the most power (80W) and the power of the Jetson Nano card (10W), it will draw approximately 100W total power from our system. By dividing this drawn power by 22.2V, i.e. I=P/V, we found 4.5A. The battery we use draws 5.2A. These choices may change as the project develops.

The motors will be connected to the wheels and mounted on the chassis as shown in Figure. All electronic connections will be made inside the vehicle and will be protected against external influences.

Figure 6 - General Mechanical Design Image of the Vehicle

Detection will be performed using the previously trained model on the snapshot that comes with the image provider on Jetson Nano. There are many types of cameras as image providers. Cameras are selected according to the project. USB Cable cameras can be connected to the computer via a USB cable. In this way, the camera system ensures operation without any disruption in the desired process.

CNN is a deep learning algorithm often used in image processing. The convolution process provides low and high important feature extraction by applying filters on the image. Feature Map is produced as output.

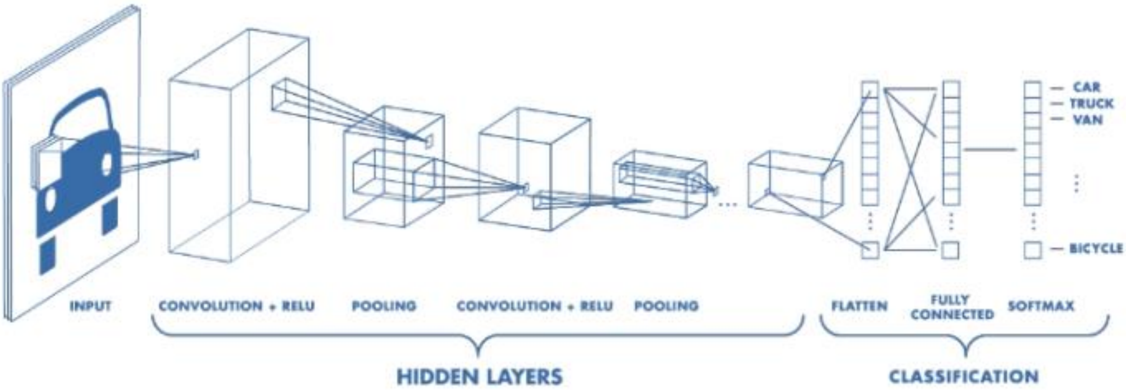

Figure 7 - CNN Structure

Since the Rectifier (ReLu) function gives the best results in terms of the speed of Neural Network training, this function has started to be used as the activation function. When the ReLu function is applied to the Feature Map using the formula, a result as follows is produced.

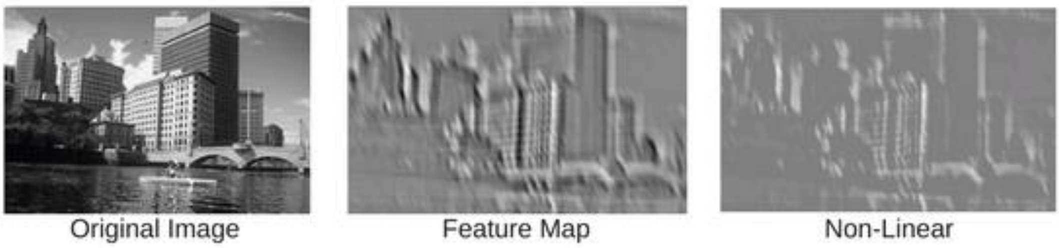

Figure 8 - Feature Map and Non-Linear Outputs

$$\boxed{f(x) = \max(0, x)}$$

ReLu Function

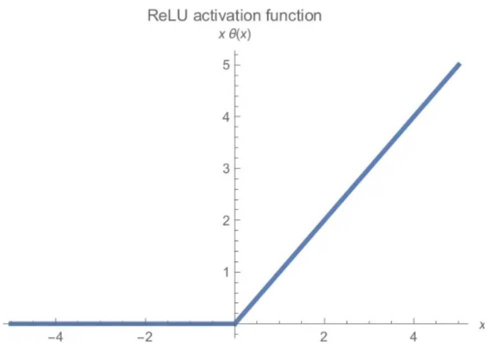

Figure 9 - ReLu Function

Classification errors will be tried to be minimized in education. The model will be improved by optimizing with back propagation using the loss values obtained thanks to the Loss Functions found using the Mean Square Error Formula in Formula 2. The closer this value is to 0, the better the model will be.

$$\mathbf{C} = \mathbf{1/m} \sum (y - a)^2$$

Mean Square Error Formula

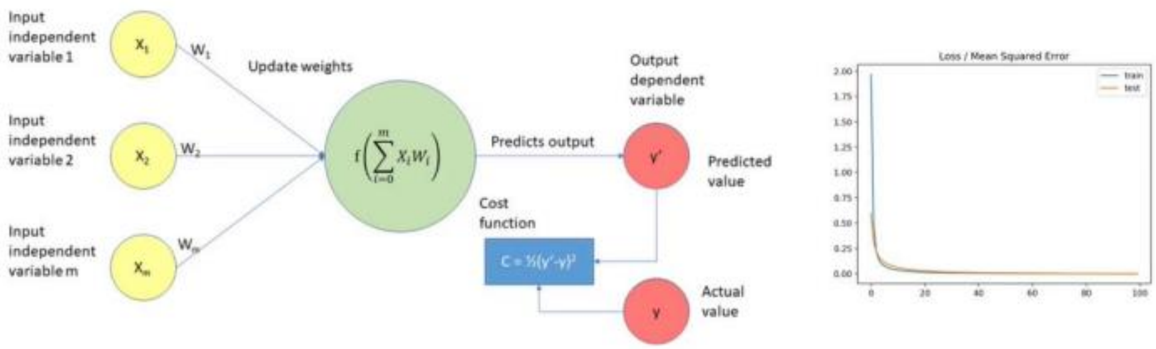

Figure 10 - Darknet Algorithm

Darknet is a high-performance open-source framework for implementing neural networks. Since the found photos will be processed with 416-416 pixels with the YOLOv5 Darknet algorithm, images with pixels below this value will be removed from the data set.

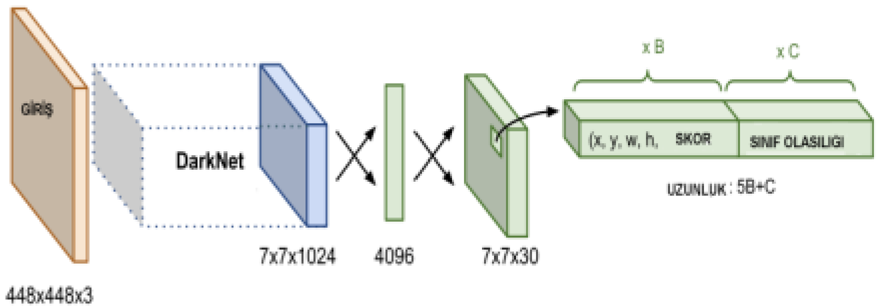

Figure 11 - Ayrıntılı CNN Yapısı

If it is observed that the data is not sufficient, we can perform data augmentation with the Python program we have written. Rotation, resolution change or illumination operations can be performed in order to derive data from the data we have.

Data set labelling will be done on the MakeSense site. In some images, multiple tagging will also be applied on the image. Since training will be done with YOLOv5 at the end of labelling, YOLOv5 format will be output. The "0" value at the beginning indicates the grade and the other 4 values indicate the location of the label on the image.

0 0.542553 0.465426 0.138298 0.109043

YOLO Tagging Format

In this project, there will be at least 2 classes: 1st Class should be wild herbs, 2nd Class should be stone and obstacle detection, and 3rd and subsequent classes should be crops planted on the land. This is important to avoid similarities between wild herb and crop.

The closer mAP (Mean Precision) is to 100%, the better the model will be. These values should also be checked during training.

Model training will be done on the Google Colab Platform, which offers us a powerful system.

Instead of using the last weight file from the output files, the best weight file can also be used.

The pixel values containing the wild herbs to be detected will be determined using the model. This will ensure that appropriate actions are taken according to the cherry blossom whose location is known.

The middle value of the detected pixel region of the detected wild herb will enable the vehicle to go to the place where the wild herb will be applied thanks to the engine movement, the spray mechanism will be moved towards the root area of the wild herb thanks to the motors and the spray engine will be activated and the wild herb will be sprayed.

Our system, which transfers battery temperature and driving-related information, will be mounted with a remote control. In the figure, we will be able to provide driving control by communicating driving information with our IoT Application in the Linux system on Raspberry Pi 4.

Gazebo Simulation Environment will be used for Simulation Testing, and in addition, thanks to the Rviz program that works integrated with Gazebo, we will enable the user to view the simulated robot model for ROS, record sensor information from the robot's sensors, and transfer camera images. We will make sure that our vehicle works correctly in the ROS and Simulation environment.

4. Sensors

Detection will be performed using the previously trained model on the snapshot that comes with the image provider on Jetson Nano. There are many types of cameras as image providers. Cameras are selected according to the project. USB Cable cameras can be connected to the computer via a USB cable. In this way, the camera system ensures operation without any disruption in the desired process.

In case the batteries overheat, the battery temperature will be controlled with the LM35 Temperature Sensor.

Lidar sensor will be used to detect obstacles in front of the vehicle, and ultrasonic sensors will be used to detect obstacles behind the vehicle.

5. Vehicle Control Unit

Control feature will be provided by providing the Remote Control and Communication section with Jetson Nano.

The connection between Jetson Nano and Pixhawk will be provided via the Uart communication port. After establishing the connection, communication between Jetson Nano and Pixhawk can be achieved using the MAVLINK protocol. Autonomous driving will be achieved by communicating with this protocol.

6. Autonomous Driving Algorithms

Autonomous driving will be achieved with the appropriate autonomous movements of the engines using Pix-hawk, which provides autonomous driving.

Thanks to direction signs, the entire field will be able to be visited. Thanks to the 2 cameras on the front, the field will show direction at the end of the plant. By controlling the distance (depth) with the plate placed in the figure, when the distance between the plate and the vehicle reaches the distance set in the appropriate range, it will make a turning movement according to the direction on the plate. will be dismantled.

7. Unique Features

The Yolo algorithm can process images at approximately 40-90 FPS (Frames per second). Therefore, it is quite faster than other methods. This shows that a video can be processed by the Yolo Algorithm in real time with a delay of a few milliseconds. Compared to R-CNN, another object detection method, Yolo is said to be 1000 times faster than RCNN and 100 times faster than Faster R-CNN. So, we will use this algorithm.

Thanks to our experience in Deep Learning and Image Processing, we will solve this problem completely uniquely by taking advantage of our experiences in our previous projects to reach the right result with our data sets that are ready and to be added, and to act according to the detected wild herb. One of the important features that distinguishes our project from other vehicles on the market is that, in addition to detecting wild herbs by using two cameras, we aim to perfect the obstacle avoidance situation by adding two cameras to the front of our vehicle to get rid of obstacles such as branches. We also aim to achieve a more effective result by adding the Lidar sensor and Ultrasonic sensor.

In the mechanical part, even if the vehicle encounters an obstacle, it will be able to spray the root of the wild herb detected at appropriate angles. In addition, by adding PID control to the spraying mechanism, our vehicle will be able to perform a smooth and error-free spraying process even if it is standing sideways.

8. Security precautions

1. For our project that can move autonomously, an operating test will be carried out in the Gazebo Simulation environment.

2. It can be controlled with a remote control when necessary.

3. Power signal cutter switch (emergency button) connected to the contactor on the system. When this button is pressed, the vehicle will turn off.

4. In case of overheating of the batteries, the battery temperature will be checked with the LM35 Temperature Sensor. If the temperature value reaches the warning level or dangerous level, a warning will be sent.

5. Lidar sensor will be used to detect obstacles in front of the vehicle, and ultrasonic sensors will be used to detect obstacles behind the vehicle.

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9. Simulation and Test

Wild herb images began to be tagged on the MakeSense site. The data set continues to be enriched.

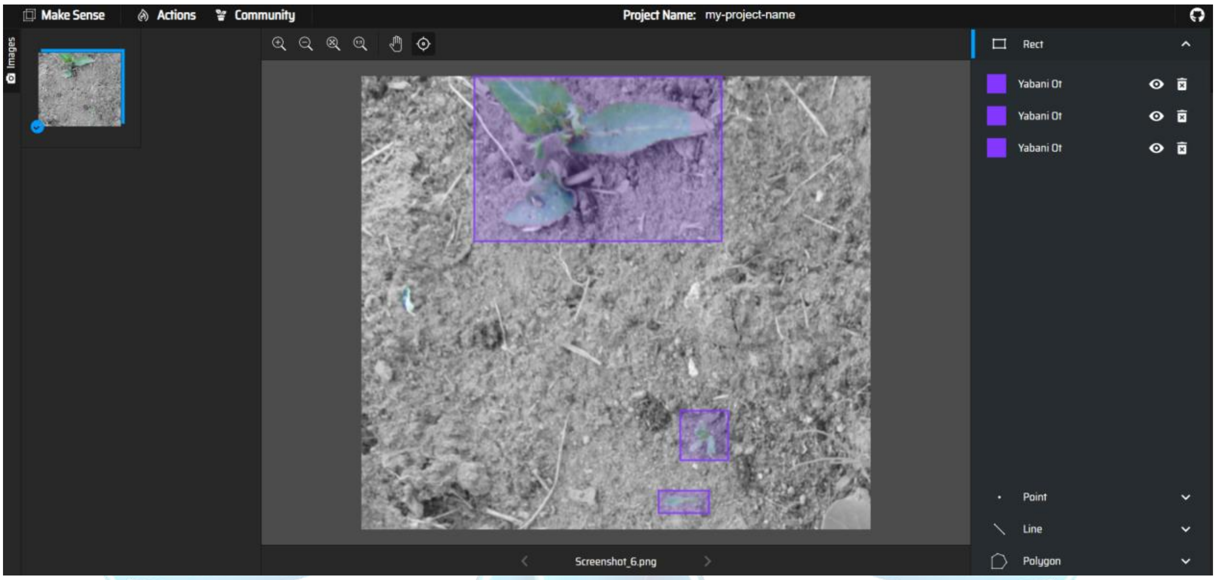

Figure 12 - Simulation and Test Sample Visual 1

Figure 13 - Simulation and Test Sample Image

Figure 14 - Simulation and Test Sample Visual 3

The training was completed in 8 hours on the Google Colab Platform, which offers us a powerful system.

The training result we have done for the wild herb data set we have is as shown in the graph.

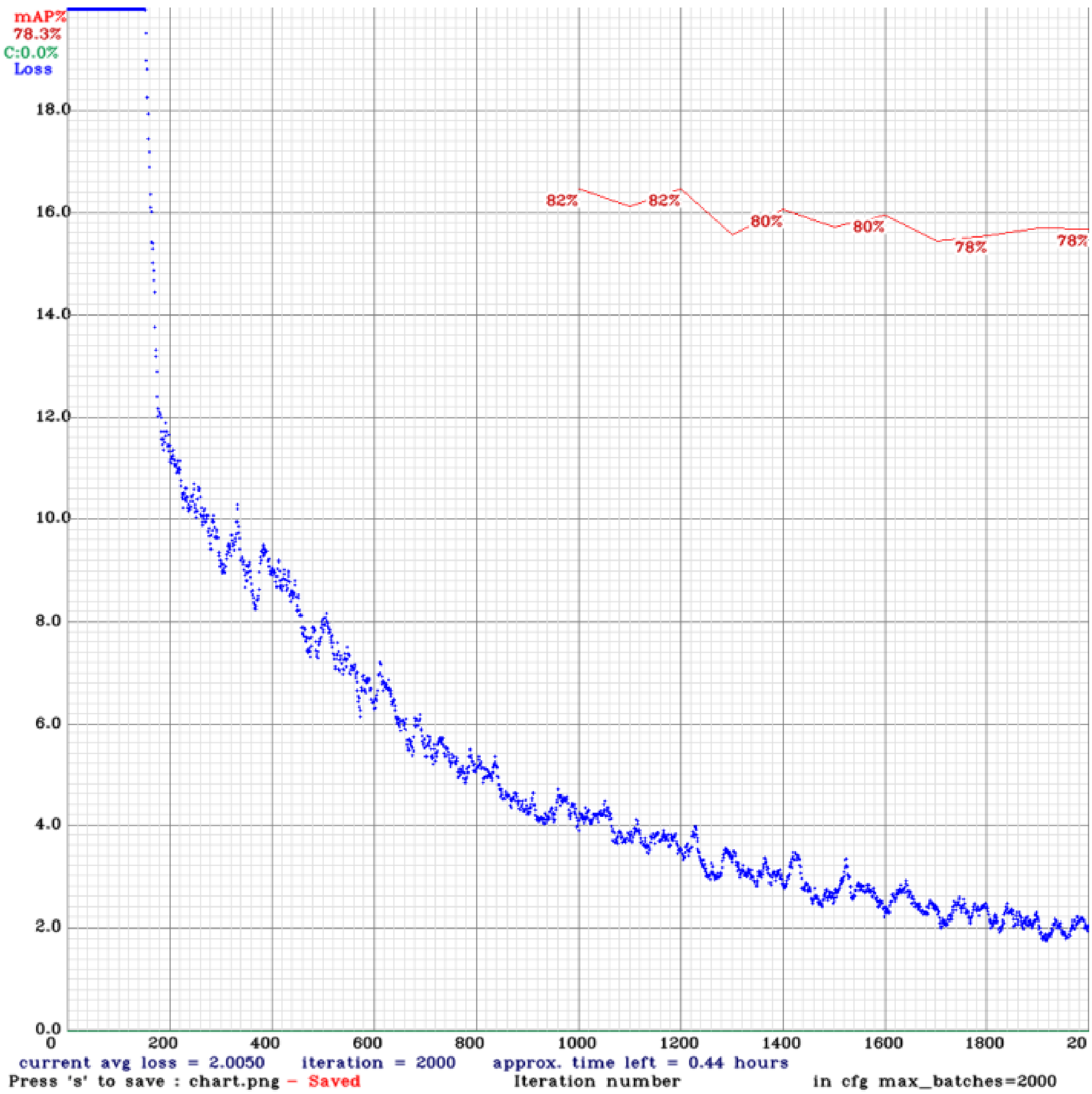

Figure 15 - Training Result

As seen in the graph, it is seen that the error value decreased from very high values to the average error value of 2.00 at the end of the 2000th iteration. The mAP Value increased to 80% on average, with the highest value being 82% in the 1000th and 1200th Iterations. To improve, unlabelled data must be labelled, and the number of iterations must be increased. The results can be further improved by choosing weights with a value of 82% mAP. Instead of using the last weight file from the output files, the best weight file can be used.

Figure 16 - Test Result

Results could not be added because the Gazebo Simulation Environment for Simulation Testing is under construction.

10. References

1. Internet https://www.smartera.com.tr/gercek-zamanli-nesne-takibireal-time-object-detection-w-yolo-python/ Access Date: 27.06.2022

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