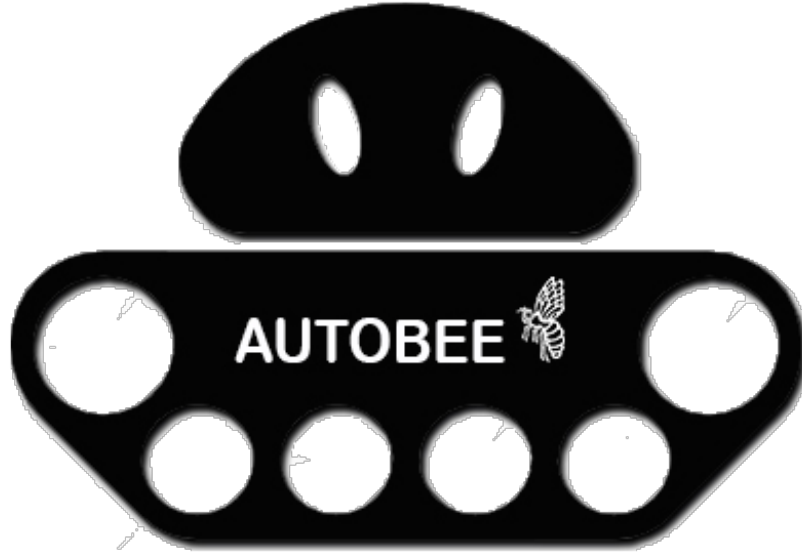


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**Istanbul Technical University**

**Autobee Unmanned Ground Vehicle Team**

**Advisor : Dr. Ali İmre AYDENİZ**

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## 1. Introduction

Autobee team was founded in 2015-2016 academic year and incorporated 6 members from different disciplines. In this year, we have changed our laboratory and professor who had no time to work on the autobee project. In this aspect, we had some difficulty about the place where we are working and equipment. Last year, team was used laboratory items, but this year we have spent a lot of time to find a place to work and bought item with finding sponsors.

This year we were working on some improvements to the software, equipment, and especially mechanical design. Also, our 2 friends took unmanned ground vehicle design topic as an undergraduate thesis. We have decided to create a caterpillar robot which gives us some opportunities as easy to drive in rough ground, more stable and hard to build.

## 2. AutoBee

A Autobee was established on 2016 and team members were consist of 6 people. Last year on 2016 challenge, we got good results but not the best. With that experience, we are aiming to build the new vehicle and making up a shortage. Team members are shown below in Tablo 1.



Figure 1 2016 Session

Tablo 1 Team Members

Student Name	Department	Degree	Project Duty
Giray UZUN	Control and Automation Eng.	Graduate	Mission Planner & Navigation
Özgür ERBULAN	Mechatronics Engineer	Graduate	Motor Control
Yunus Emre SERTTAS	Mechanical Engineer	Undergraduate	Mechanical Design
Yunus Emre ÇAM	Mechanical Engineer	Undergraduate	Mechanical Design
Furkan ELITOK	Control and Automation Eng.	Undergraduate	Team Captain
Tuncay ADIGUZEL	Naval Engineering	Undergraduate	Vibration Test
Mucahit OLMAZ	Mechanical Eng.	Undergraduate	Mechanical Gimbal

### 3. Auto-Nav Challenge Competition

#### 3.1 Objectives

A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while maintaining a minimum of speed of one mph over a section and a maximum speed limit of five mph, remaining within the lane, negotiating flags and avoiding the obstacles on the course. The Basic Course will be primarily sinusoidal curves with series of repetitive barrel obstacles. A waypoint pair for the course will be provided prior to competition. It is mandatory for a team to complete the Basic Course to move to the Advanced Course. Maximum time for the Basic Course will be 5 minutes with a measured distance of approximately 500 feet. Pending successful running of the Basic Course the team will move on to the Advanced Course. For the Advanced Course, there will be complex barrel arrangements with switchbacks and center islands. These will be adjusted for location between runs. Direction of the obstacle course will change between runs.

#### 3.2 Project Process

Robot Operation System has been used in the project and with the help of the OpenCV and ROS libraries, image processing and GPS control has been made. The flow chart of the project is given in Figure 2.

Last year we left our robot in America; because, it was not portable and it was cumbersome. From last year we have just motors. We built our robot on CATIA at this year.

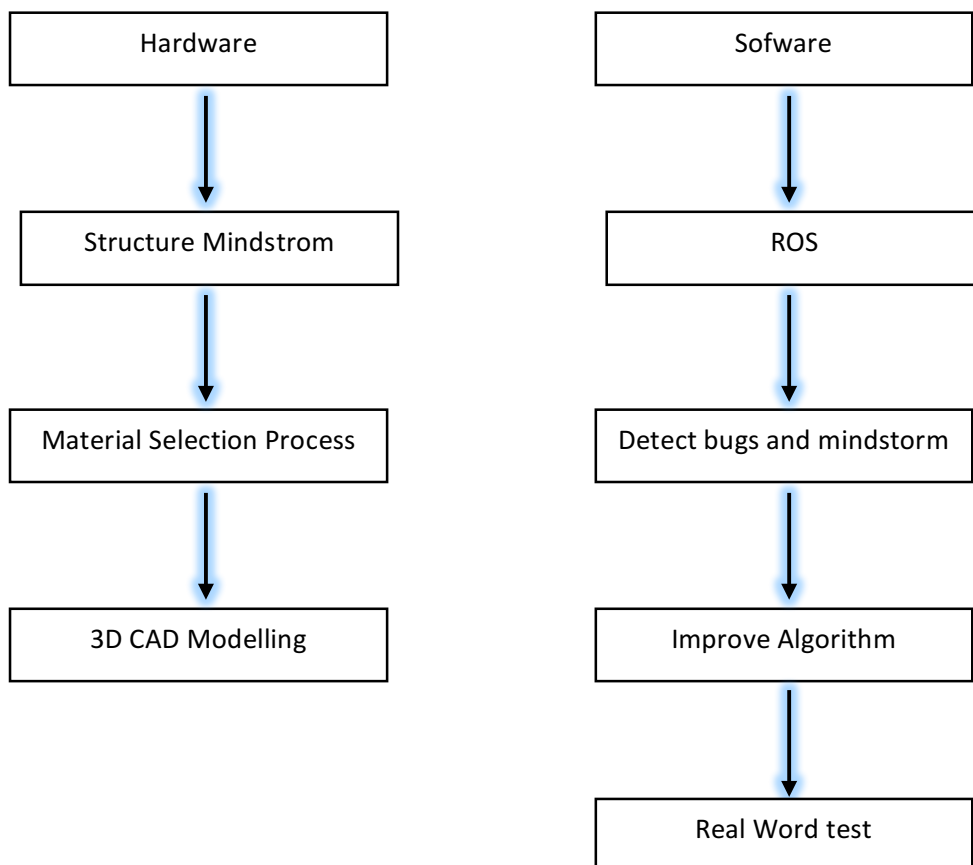


Figure 2 Flow Chart

The following figure shows the basic structure of the vehicle. LIDAR, GPS, and Camera directly connected to the laptop. Laptop and Arduino have bi-directional communication. Receiver, motor driver and safety light connected to Arduino mega. Emergency stop cuts the power of motor driver.

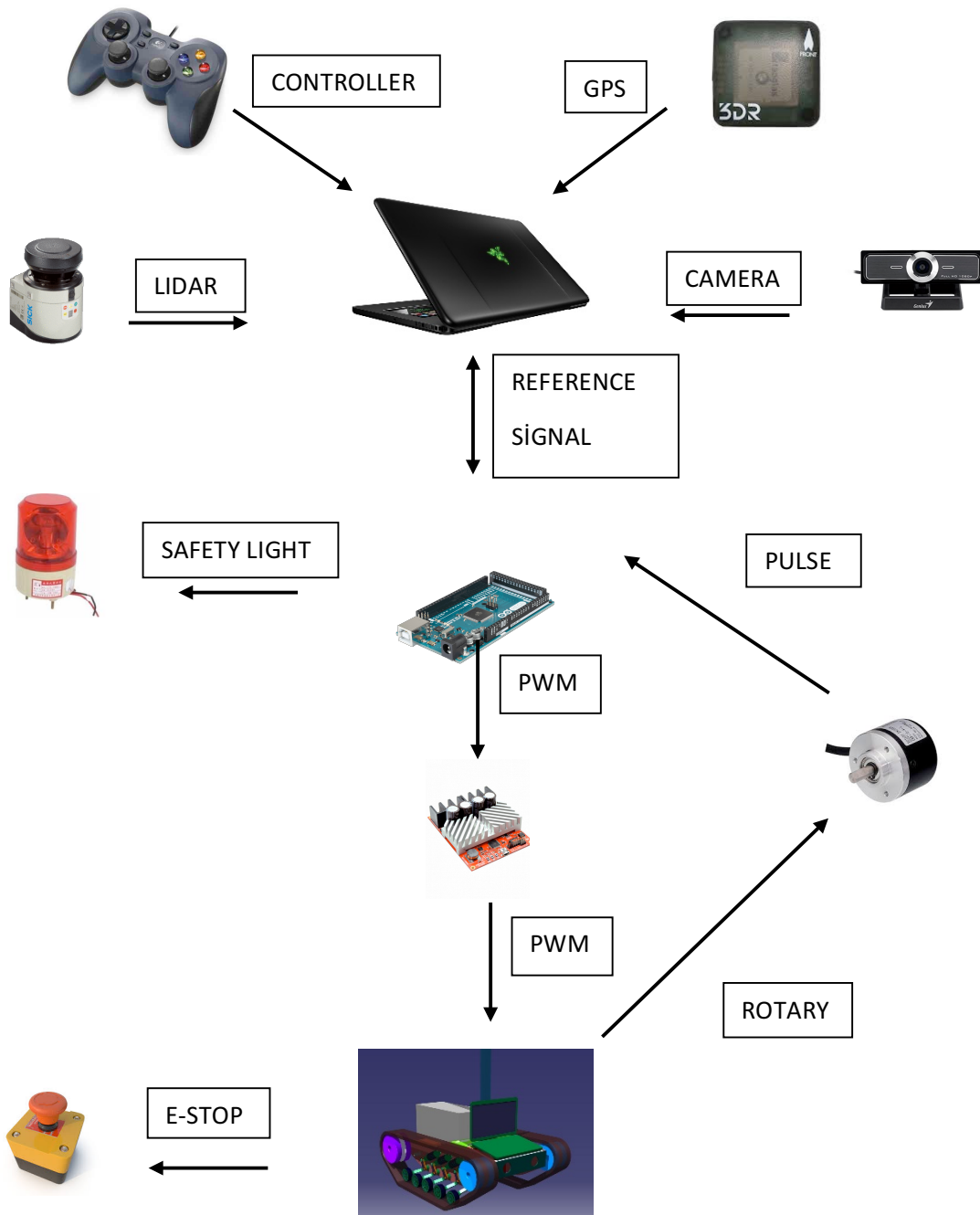


Figure 3 Hardware Scheme

## 4. Image process

In order to manipulate image from webcam, ROS and OPENCV bridge were used. The first step was to generate bird's eye view from an image.



Figure 4 Standart image

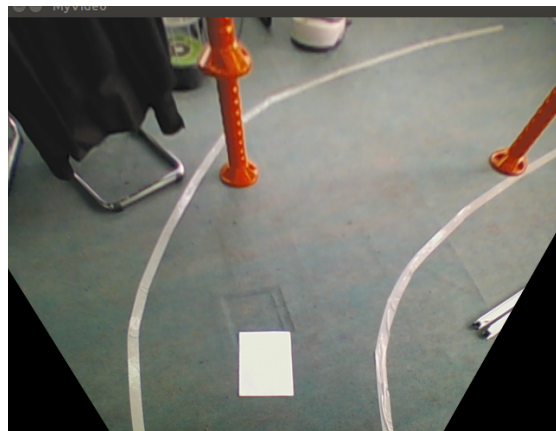


Figure 5 Bird's eye image

On bird's eye image, we changed our color space from blue-red-green color space to HSV color space which means

H = Hue

S = Saturation

V = Value

In HSV, it is easier to represent a color than in BGR color-space. After that, we applied a threshold for each individual HSV channel to detect white lane on the grass. (Figure 6)

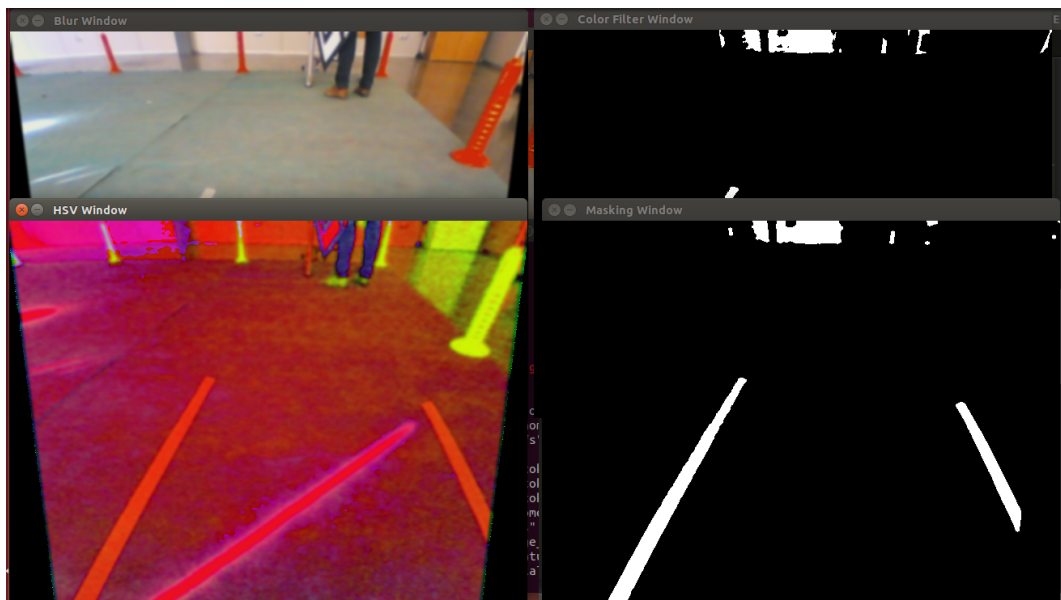


Figure 6 RGB -> HSV -> threshold

Finally, we got a binary image which consists of white lanes point and noises. To separate white lane from noise, we applied canny edge filter following hough transform. Hough is explained deeply in below;

- In general for each pixel  $(x_0, y_0)$ , we can define the family of lines that goes through that point as:

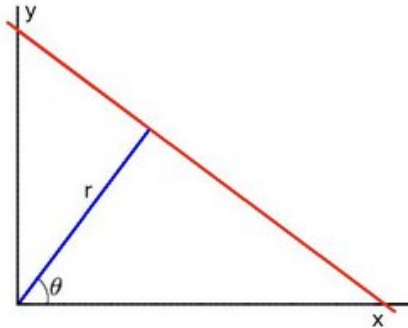


Figure 7 Polar coordinate and cartesian coordinate

- If for a given  $(x_0 - y_0)$  we plot the family of lines that goes through it, we get a sinusoid

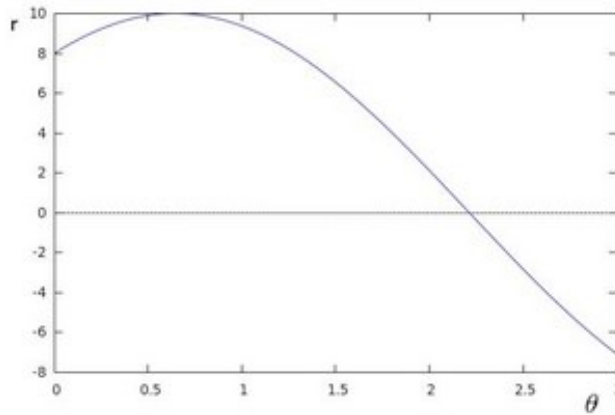


Figure 8 Sin wave for one point

- If the curves of two different points intersect in the plane  $\theta - r$ , that means that both points belong to a same line.

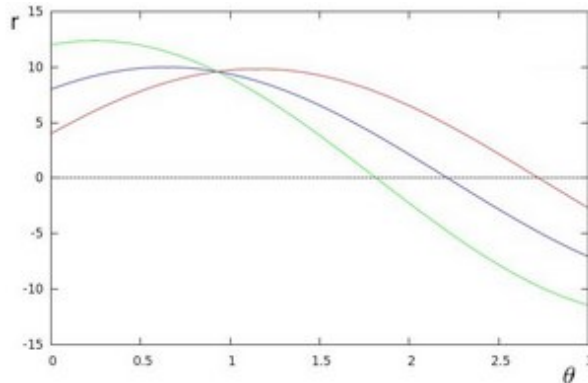


Figure 9 All sin wave for one point

- If the curves of two different points intersect in the plane  $\theta - r$ , that means that both points belong to a same line.

- It keeps track of the intersection between curves of every point in the image. If the number of intersections is above some *threshold*, then it declares it as a line with the parameters  $\theta - r_\theta$  of the intersection point.

End of “Hough Transform” we got image below;



*Figure 10 After Hough Transform*

After image processing, we are changing the coordinate system from cartesian to polar coordinate. That way gives us an image like LIDAR. Then we are comparing both data to select closest data. After all, below process we got data merged with LIDAR and IMAGE, so we can use our obstacle avoidance algorithm.

## 5. Path Planning

We use Sick LMS111 LIDAR for obstacle avoidance since its quality is enough for us and laboratory gave us permission to use it. Sick is a 2D laser sensor and it has 50meter range. Ground clearance of laser sensor is 30 centimeters. The height of obstacles must be high than ground clearance of laser sensor. Thus, the laser sensor can detect easily the obstacles. We use Rviz for simulation of laser data. Rviz is a 3D visualization tool for ROS. The following picture is the indoor working area of the team. We have simulated the IGVC path like in the photo. We have used Optitrack motion capture system for fake GPS. We can see the vehicle position in the safe area and give a proper goal to go like competition via optitrack and the vrpn\_client node which is provided by clear path robotics. This system provides us fast and easy working environment.

The aim of the path planning is to reach the goal with optimal cost. Path planner selects the shortest path between waypoints and uses a secure route which is avoidance from the obstacle and stays in the lanes. We use "follow the gap algorithm that published on 2012. In the FGM algorithm, LIDAR detects obstacles and gaps. After the detection, biggest gaps is determined and the vehicle moves in that direction. The orientation of the vehicle is controlled by the proportional controller.



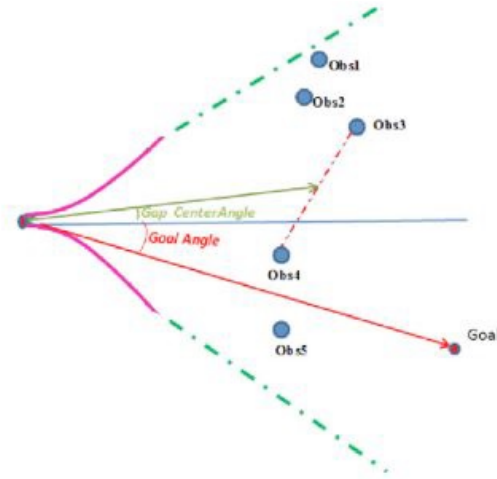


Figure 11 Path Planning

## 6. Mechanical Design

In order to accomplish a successful image processing, several parameters must be considered. The most important one is the stabilization of the camera which is used for image processing. Situations that can disturb this stabilization depends on ground condition, slope and vehicle's rigidity. Therefore, for an autonomous vehicle which moves by processing image mechanical design has great importance.

In this version of Autabee, it is aimed to minimize the vibration inputs from the ground and eliminate vibration disturbance from the high platform which contains sensor equipment such as GPS, camera, and lidar as much as possible. For this purpose, several vehicles and their wheel system researched. Finally, pallet system equipped with fully independent Christie suspension system is decided for to be used.

In our vehicle, the number of points which contact with the ground is increased in order to increase the degree of freedom. This provides the ability to overcome high obstacles and minimizes the reaction force from them. Hence, it can reach the speeds twice of a standard vehicle can. Besides, damping equipment which will damp the forces at the carrier wheel before they reach to the body and the suspension system will be assembled individually to each carrier arm. In this way, chassis will not effect from the big vibrations at the moving part.



Figure 13 Christie suspension

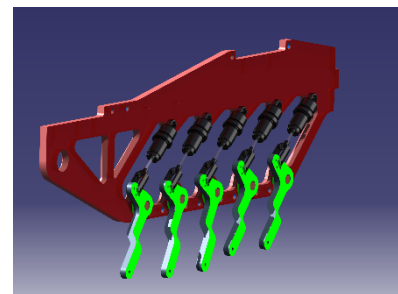
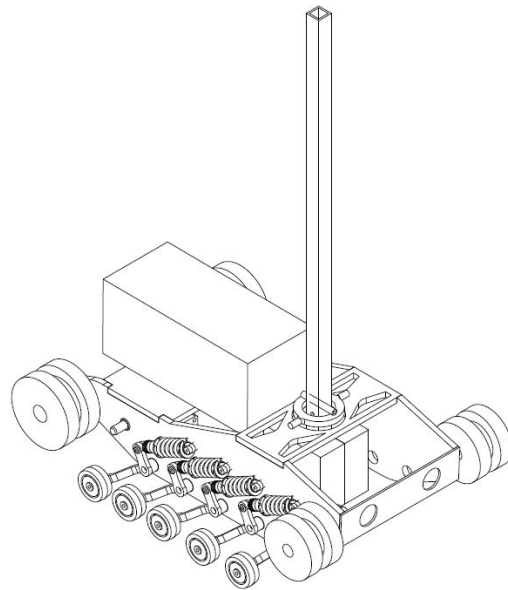


Figure 12 Christie suspension 3D CAD

Another parameter which will cause to obtain false data from image processing by disturbing the stabilization of sensors and separating geometrical centers of a camera. The high platform will be placed on top of a stick which will be held by a stabilizer with two degrees of freedom. Stick will remain its perpendicular position even if the tracks are on uneven ground hence it will keep camera's and vehicle's geometrical centers on the same alignment. This will prevent

false image processing by making camera's distance to the right and left lines, same with the vehicle's geometrical center. When the vehicle is climbing a slope, disturbance at the image's perspective will be prevented by the same stabilizer with the help of counter-momentum. In order to create counter momentum, extra weight is necessary under the high platform carrier. This would increase vehicle's total weight which is undesired. By using batteries for this purpose, undesired weight is prevented. Weights can cause high platform carrier stick to move uncontrolled when the vehicle is accelerating or braking. This will be prevented by placing 4 motion constraining shock absorbers. In addition, any input from the ground will be absorbed the second time where the first absorption provided by moving gear.



*Figure 14 CAD Design*

Two electrical motors are used for moving the car. In order to decrease rpm and increase torque provided by motors, a reducer is used. Heavy parts such as a motor, reducer are placed at the back side of the vehicle for keeping the center of mass at the rear side. Because of this, traction wheels placed at the back side of the vehicle. The track can loosen up because of the road conditions and carrier wheel positions. To prevent this a spring added to carrier wheel which will keep the track stretched on wheels.

## 7. Motor Control

Motor specification and motor photo are shown below;

Properties	Value
Power	500W
RPM	4600
Volt	24V
Current(No load)	5A

Figure 15 Motor properties



Figure 16 Motor and encoder

We are using ARDUINO MEGA2560 to control motor speed with PI controller. For this purpose; we mounted quadrature encoder which is 400 pulse on the motor shaft. That mounted apparatus and coupling were printed with the homemade 3D printer.

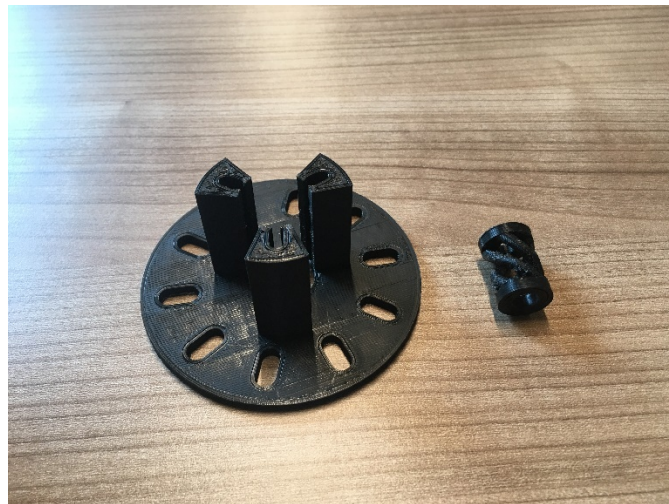


Figure 17 Encoder coupling and mounted item

We are giving reference signal from master PC with a rosserial-arduino package which allows us to link ARDUINO and ROS on PC.

## 8. Failure Modes

Since we use a GPS that designed for hobby drones, lost of GPS signal is a problem that we could encounter. In this situation, the algorithm will stop the vehicle until gas comes back. Another problem could be bright sunshine. Even we protect the camera from a sun, it may affect vision. In this case, the incoming frame is regulated. In the case of inability to follow the path, we will reduce upper limit of linear velocity.

## 9. Vehicle Cost

Quantity	Equipment	Amount ( \$ )	Cost to team ( \$ )
1	GPS	200	0
2	DC Motor	500	0
2	Encoder	50	0
1	LIDAR	5000	0
1	Motor controller	300	0
1	Battery	100	100
1	Mechanical Equipment	500	200
2	Back Wheel	80	0
2	Front Wheel	35	0
1	Laptop	1500	0
1	E-stop	15	0
1	Cooler Fan	35	0
1	Usb port	10	10
1	Radio Contoller	300	300
1	Arduino Mega	30	30
1	Camera	46	46
1	Electronic Equipment	100	100
<b>TOTAL</b>		<b>8801</b>	<b>786</b>

*Figure 18 Vehicle cost*