DESIGN AND DEVELOPMENT OF AN UNMANNED GROUND VEHICLE (UGV)

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This paper presents the design, development and implementation of an autonomous mobile robot or otherwise specifically termed as an Unmanned Ground Vehicle (UGV) which will be driven by a remote control whose signal will be transmitted in the form of IR. The prototype can be run on any unobstructed surface including smooth terrains, rough terrains and inclined surfaces**.** The UGV comprises of three major mechanical portions which include the steering (or driving) mechanism, rear wheel mechanism and of course the body (inclusive of the battery pack, circuit board and the central motor [origin of power transfer following the battery]). Thereby, a detailed report of a carefully fabricated prototype is set forth herewith.

1. INTRODUCTION

The unmanned ground vehicle (UGV) is a Russian originated concept which was introduced in the late 1930s during the winter war against Finland and soon after was popularized during the Second World War which lasted until the mid-1940s. Simply put, it is a vehicle that operates while in contact with the ground and without an onboard human presence. UGVs can be used for many applications where it may be inconvenient, dangerous, or impossible to have a human operator present. These were formerly and latterly very commonly used for military and explorative purposes. Generally, the vehicle will have a set of sensors to observe the environment, and will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle through teleoperation. However, our project is highly weighed on originality which is to say that during the course of our design, we were highly independent on its previous as well as current designs when it came to the actual physical structure. Yet we did do a fair amount of research and came up with the most appropriate mechanisms to accomplish each of the related tasks. In addition, our product is definitely not based on military or explorative domains but in all fairness, we did perfect justice to the definition of a UGV. Our product focuses largely on its ability to run on basically any given terrain, off-road maneuvering and being able to steer it according to the preference of the human controlling it. Hence our UGV runs by remote controlled means as opposed to making autonomous decisions based on the input of its sensors. Most of our implementation time was spent on the wheel mechanisms, that is, the perfecting of the steering and rear wheel compartments. Other major challenges which had to be overcome were issues with regard to power transmission, coding of the remote control, motor setup, servo setup, configuration of the body and component placement and assembly. A total of three DC motors were used for power transmission to the wheels and a couple of servos one for each wheel to enable steering. In comparison to a majority of other similar projects, the wheels of our UGV are driven from the power of one central motor unlike the more common solution of using four motors to run the four wheels. There are two reasons behind this choice. The first and the most obvious one is the reduction in the power requirement. Secondly, although the use of four motors present the tolerance of a high torque, it is difficult to make tight turns as the four motors need high synchronization and high control. But the use of a single motor resolves this complication. Nevertheless, this is turn means that the manner of power transfer in the unit is somewhat dissimilar to any regular technique. In simple language, we implemented a gear wheel mechanism with the aid of brass rods as shafts and universal joints all of which will be elaborated in the upcoming sections of the report.

2. DESIGN AND IMPLEMENTATION

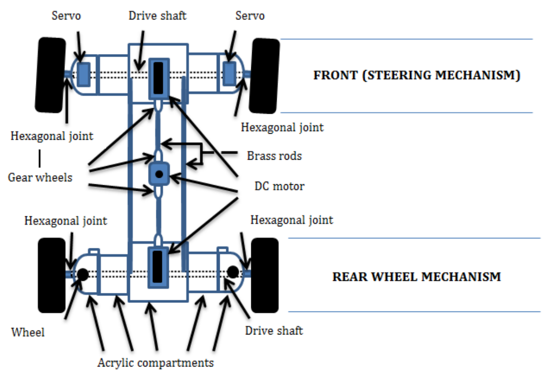


Figure 1:Mechanical sketch (Block diagram) (not drawn to scale)

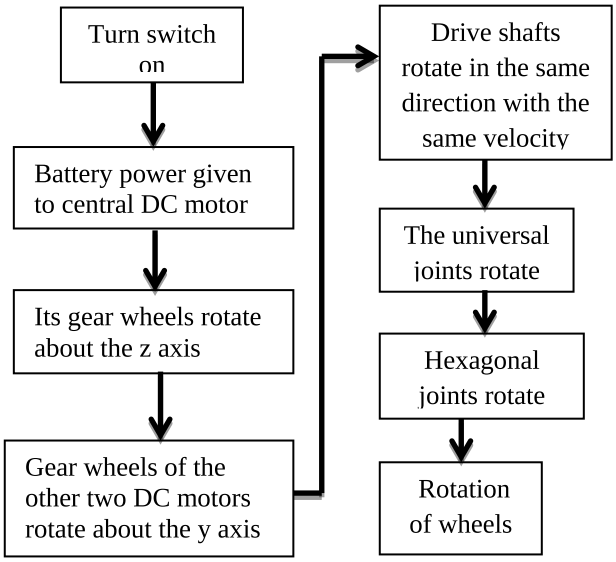


Figure 2.1: Overall sequence of events to drive the wheels of the UGV.

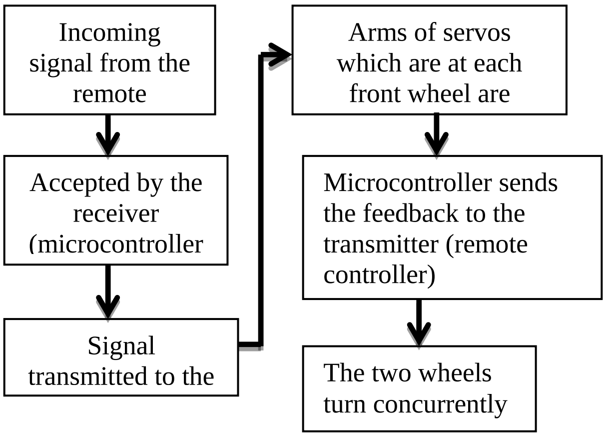


FIgure 2.2: The simple flow diagram below indicates how the steering is done.

2.1. Technical operation

The following section illustrates the mechanism of the UGV from the technical perspective and the respective procedure we undertook over the course of our project

Wheel mechanisms

The most challenging technical portion of our project was the design of the front and rear wheel mechanisms. Hence we gave our initial priority to this task by assigning two members out of the four in our group to work on each mechanism, thus making sure that the two jobs went in parallel with each other. The following features are common for both the front and rear wheel systems:

The common components used for the assemblage of each system comprised of hinges, acrylic compartments, universal joints, two brass rods and a DC motor.

To attach the wheels, hexagonal joints were used so that the wheels can be changed with ease (without changing the joint and the wheel all together we can simply replace the wheel).

We used universal joints to allow the drive shaft to move up and down, and hence allow for suspension travel. The angle of inclination ranges from the horizontal position up to 45°.

Brass rods were used to make the connections of the drive shaft (connections from the universal joints to the DC motor in between).

A gear wheel mechanism was implemented to run the DC motors and consequently rotate the wheels. This mechanism works in a way similar to the one shown in figure 3.1 (of course the gear wheels we used were comparatively a lot smaller in magnitude).

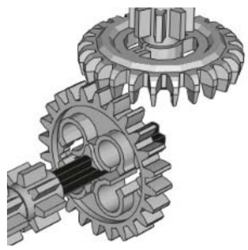


Figure 3.1-Gear wheel mechanism

The steering mechanism differs with the rear wheel mechanism up to a certain extent. To perform steering, two servos were used. (A servo for each wheel).

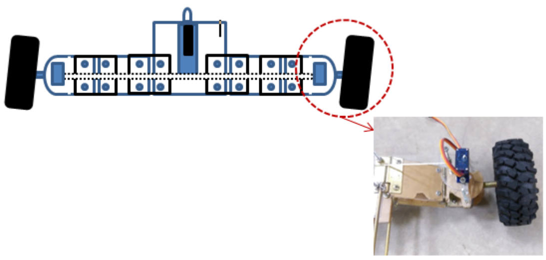
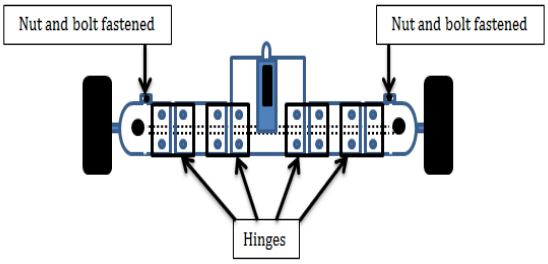


Figure 3.2.a-Steering mechanism



For the **rear wheel** drive, nut and bolt were used to restrict steer enabling motion.

Figure 3.2.b-Rear wheel mechanism

Power transmission

We centrally placed a DC motor to provide power for both the drive shafts as shown in figure 3. The rotational motion of the central axle is influenced by this motor which in turn drives the shafts and as mentioned earlier, it operates by means of a gear wheel mechanism

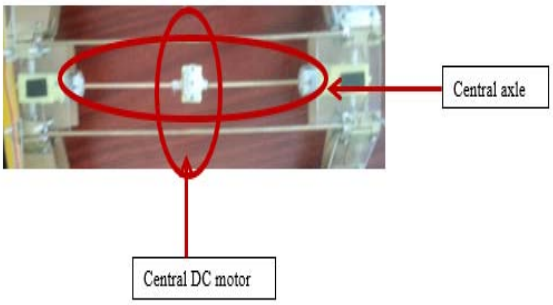


Figure 3.3-Power transmission

2.2. Problem solving

This is an elaboration of the problems we encountered during the course of our project and how we overcame them.

We had to figure out a design which would make our job of fixing and replacement as easy and efficient as possible without disrupting the entire network around it. Our way around this issue was to use acrylic in the form of compartments and hinges to combine them and allow for motion. The use of hinges made it extremely easy for us to disassemble parts and make physical alterations wherever required during testing. One such instance was when we needed to change the dimensions of certain compartments especially at the extreme ends of the shaft in order to compensate for the load transferred by the wheels, the axle and other adjacent components and also to make sure that the angle of inclination of each wheel is similar and within the formerly calculated range. Moreover, it was important that the system was balanced around the symmetrical axis. In order to make this possible, the dimensions of the compartments and positioning of the hinges had to be consistent on both sides. Thereby, our design enabled physical debugging in a convenient manner.

The next question was what intermediary component to use between the drive shaft and the wheel on one end and between the drive shaft and DC motor on the other in order to make allowance for steering and suspension respectively. After some queries, we decided to use universal joints to overcome this problem. Suspension was definitely a requirement for both rear and front wheel mechanisms. With the use of universal joints we managed to implement an angle of inclination ranging from the horizontal position(0°) up to a maximum of 45°. Steering was enabled too by the use of universal joints as it successfully transmits rotary motion and gives leeway to the horizontal rotation of the two front wheels. Although this was unnecessary for the rear wheels, we used universal joints there too in order to make the design consists.

The next problem arose due to the implementation of the above solution, which was the unnecessary freedom of motion of the rear wheels. In order to restrict this, nut and bolt was used to fasten the two wheel axles of the rear wheels to the adjacent acrylic compartment.

Moving on, the next uncertainty was which material to use for the shafts. Our initial solution was the use of antiquated radio antennas. But this didn't work out as planned once again due to the lack of strength. Our next pick were brass rods. Due to its excellent properties in strength, hardness, wear resistance and corrosion resistance, this material turned out to be ideal.

The issue afterwards was as to how we should drive the shafts. The best solution we came up with was by means of a gear wheel mechanism.

2.3 Analysis

The placement of the battery and circuit board

The steering end has a higher weight compared to the rear end. Therefore we placed the circuit board (which is lighter than the battery pack) closer to the rear end, and the battery pack closer to the front.

Let the end to end length of the UGV be **L**
Let the weight of the battery pack be $\mathbf{W_b}$
Let the weight of the circuit board be $\mathbf{W_c}$

Taking moments about the center;

$$W_b*y = W_c*(L-y)$$

$W_b = 202g$
Wc = 75g

Overall torque

rpm of central motor = 240
ratio of gear mechanism= 48:1
Therefore output from gear mechanism = 240/48 = 5
radius of wheel = 47.5 mm

$$2\pi * 0.0475 * 60/5$$

=3.58

3. TEST RESULTS, DEBUGGING AND DISCUSSION

Our **initial** design and calculations failed due to two reasons:

i. The dimensions we considered weren't compatible with our overall requirement.
ii. The material we initially planned on using for the body of the UGV was Aluminium. We implemented and tested this design using an Aluminium clad and it unfortunately failed due to lack of strength. Hence we couldn't proceed any further.

Our alternative was acrylic which we used in the form of several compartments assembled together to produce the required mechanical layout for the front and rear wheel mechanisms.

Furthermore, we performed calculations for the placement of the circuit board and battery pack using the principle of moments which state that the anticlockwise moments about a point of a body should be equal to the clockwise moments about that same point for the body to be in equilibrium.

Towards the later stages, we encountered two major issues. Firstly, the power of the two servos turned out to be inadequate. Hence we had to replace those with a couple of servos of code **MG995** whose dimensions and weight are larger than the formerly used servos. This meant that we had to make compensations for the acrylic part on which the servos were held. Secondly, the power of the central DC motor also turned out to be incompatible. The alternative we considered was to replace the DC motor with a high powered one.

4. CONCLUSION

In this paper, the design, development and implementation of a remote controlled UGV (unmanned ground vehicle) are presented. Although we have completed our proposed plan of development we intend take a step forward by making a few more alterations and upgrades in the near future. We plan to implement an autonomous decision making module by installing a couple of senses including the sharp sensor (to add obstacle avoidance and motion sensing) and a gyro sensor (to sense changes in orientation). In addition, we are hopeful in our future efforts to add a GPS module and a camera to enable mapping of the surrounding environment.

REFERENCES

[1] N. Vandapel, R. R. Donamukkala, M. Hebert, " Unmanned Ground Vehicle Navigation Using Aerial Ladar Data", The International Journal of Robotics Research January 2006 vol. 25 no. 131-51