THE DESIGN, DEVELOPMENT AND IMPLEMENTATION OF AN UNMANNED GROUND VEHICLE(UGV)

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ABSTRACT

This paper presents a tracked Unmanned Ground Vehicle (UGV) design, capable of autonomous navigation in rough terrain. The UGV is designed and developed for exploration and operation in remote spaces. The proposed UGV is able to drive through a variety of rough terrains and navigate through height changes on surface. The mechanical structure of the UGV consists of tracked locomotion system used for high friction and ground contact, supported by side arms that can operate independently to maintain stability, and overcome difficult terrains. To fully exploit the vehicle's mobility and enable fully autonomous operation, controls algorithms have been developed that also reduce the complexity of vehicle operation. Mobility behaviours include: operator assisted remote controlling, adaptive gaits and obstacle detection.

Key Words: Unmanned Ground Vehicle (UGV), off-road robot

1. INTRODUCTION

An unmanned ground vehicle (UGV) is a piece of mechanized equipment that moves across the surface of the ground and serves as a means of carrying or transporting something. In the present day world, number of research activities are going on in the field of unmanned vehicles, which includes unmanned ground vehicles (UGVs), unmanned aerial vehicles(UAVs) and unmanned water vehicles(UWVs).

The UGV system generally consists of three main parts such as vehicle control system, navigation system and obstacle detection system. UGVs can be used for many applications where it may be inconvenient, dangerous, or impossible to have a human operator present. Space exploration, material handling, and transportation, medical transport of food and patients and future combat vehicles are areas that traditionally have been emphasized and the laboratory results are beginning to find application in the real world

UGVs, in varying sizes to meet mission capability requirement, are today saving lives and providing critical supporting capabilities in current military operations worldwide.

This paper presents a tracked design of an autonomous unmanned ground vehicle that has the ability to travel through rough terrains, detect and respond to obstacles and adapt to height changes. It is operated remotely when traveling in rough terrains and programmed to take logical decisions when an obstacle is detected.

The design of the UGV is 30cm x 30cm size and 9 cm height. The weight of the robot is approximately 5 kg. It consists of two main tracks, 4 side arm tracks and a moving sensor panel at the top that consists of four ultrasound sensors.

The main intention of this design is to achieve the given goals below.

- Easy manoeuvrability in rough terrains
- Detection and avoidance of obstacles in basic geometrical shapes
- Adapting to sudden height changes

The reason for using tracks instead of wheels was to achieve a bigger surface contact with the terrain. This, in turn, increase the efficiency of the UGV to travel in rough terrains. The maximum ground clearance is 21 mm. Hence this can overcome on gravel terrains limited to this ground clearance. Another special feature is that the UGV was programmed to respond to specific height changes and climb inclined surfaces. Overall the UGV was designed and programmed in such a manner that it functions to the maximum efficiency.

2. DESIGN AND IMPLEMENTATION

The design of the UGV prototype is given in the figure 01. The design mainly consists of two main tracks, four articulated side arm tracks and a moving sensor panel. The prototype is made of acrylic which makes it lighter and stronger.

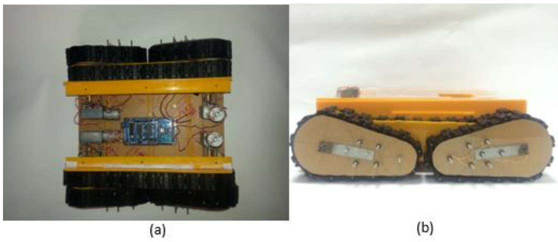

Figure 1: Top view (a) and the side view(b) of the prototype

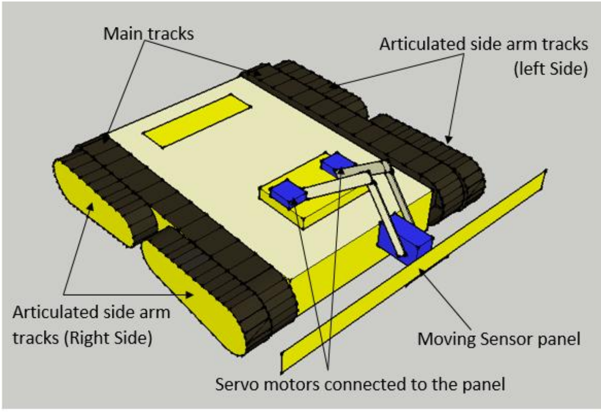

Figure 2: Mechanical sketch of the prototype

All the tracks in left and right are connected to each other hence when 120 rpm DC motors rotate, it makes all the tracks rotate including the side arm tracks. Since left and right side 120 rpm motors function independently, the robot can be controlled easily. During a requirement arises to deploy the side arms, the track attached to the arms rotate independently to the position it assumes. Rotary encoders are used for the four side arms to accurately determine the position it assumes. The left and right motor pairs are connected to motor shields that are connected to the microcontroller. The UGV base

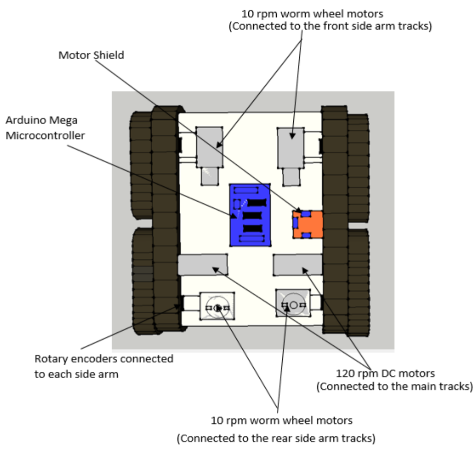

Figure 3:Top with of the proposed UGV design

consists of two DC 120 rpm motors, four 10 rpm worm wheel motors connected as shown figure 04. (not to scale)

The system block diagram of the prototype is given below.

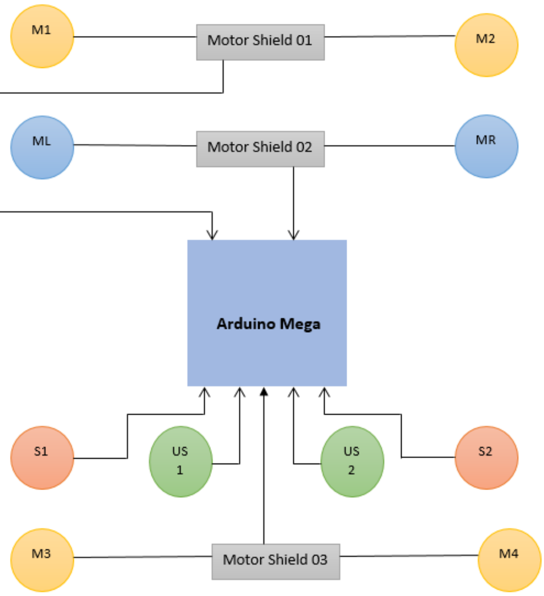

Figure4: System Block Diagram

M1, M2, M3, M4 - 10 rpm worm wheel motors
ML, MR – left and right 120 rpm motors
S1, S2 – servo motors connected to the sensor panel
US1, US2 – ultrasound sensors

In general, the structure of the UGV consists of the following main parts.

2.2 Platform

The platform provides locomotion, utility infrastructure and power for the robotic system. The configuration has a strong influence on the level of autonomy and interaction a system will have in an unstructured environment; highly configurable and mobile platforms are typically the best for unstructured terrain.

The UGV was designed considering the requirements needed to drive through rough gravel sort of terrains without any interferences. To make this possible, two continuous tracks have been used. These tracks have many advantages including the move on uneven terrain or when it's needed high traction. Compared with wheels, continuous tracks have high performance and optimized traction system, which is a plus in power delivery efficiency. The two tracks are connected to four 120 rpm motors and two cogwheels are connected to each track to improve the interaction between the motors and the tracks. Using the tracks, the UGV is able to move forward, backward and change the driving direction to any angle by changing the speed of the motors.

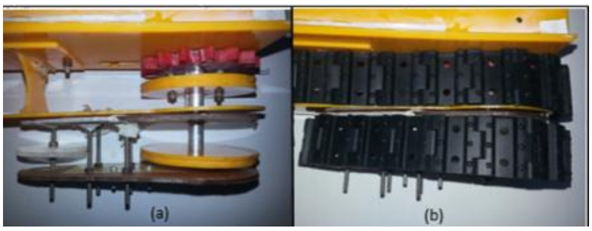

Figure 5: Connection of main track and side arm track without(a) and with(b) the continuous track.

2.3 Sensors

A ground robot needs to have sensors in order to perceive its surrounding, and thus, permit controlled movement. The UGV consists of a moving panel with four ultrasound sensors fixed.
The moving sensor panel is made of acrylic and servo motors are connected to the panel to make it move. It can take inclinations up to a maximum of 90 degrees. The panel is tested for its mobility and is removable from the main vehicle. Because of the movement of the panel, it is easier to detect the height of the obstacles and overcome them.

2.4 Articulated Side Arms

Figure 6: Deploying side arms to overcome an obstacle in the ground

The other specific feature of this UGV is that it consists of four robotic articulated side arm tracks that could convert the robot into various navigation configurations to overcome different terrain challenges. The side arms are connected to 10 rpm worm wheel motors which allows the side arms to rotate 360 degrees clockwise or counter clockwise. Four rotary encoders are connected to each arm in order to calculate the rotation angle. These side arms provide better mobility in highly cluttered environments. However, they are efficient but more difficult to control precisely when navigating steep slopes. The UGV has a moving sensor panel which is fixed on the top. The sensor panel consists of ultrasound sensors that is used to detect obstacles. When the UGV is moving, the sensor panel will constantly move up and down in order to detect any obstacle in the path. The height changes will be detected and the side robotic arms will be operated automatically when it comes to a slope or a stair of an average size. The UGV is able to detect and overcome obstacles at a maximum height of 30 cm including its height.

The basic step climbing procedure is explained in figure 7.

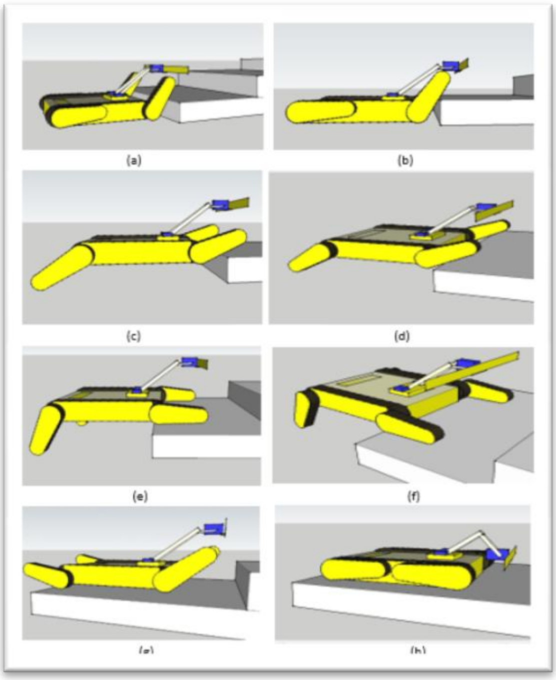

Figure 7: Deploying side arms to overcome an obstacle in the ground

The stair / obstacle approach begins with the front track beams of the UGV rotated to match the obstacle angle and the back track beams flat on the ground. As it is driven forward, the front tracks are better able to grab the lip of the first stair and get initial traction. As the UGV continues to drive forward and climb the stairs, the front track beams are rotated downwards towards the level position to increase traction and the back track beams will rotate accordingly. At this point the UGV continues to climb the stairs as it would a standard slope.

2.4 Control

The level of autonomy and intelligence of the UGV depends largely on its control systems. The programming for the UGV is done using the

Arduino software. Arduino mega microcontroller is fixed to the base of the robot. The UGV is controlled via a computer interface remotely.

The basic operation procedure is given below.

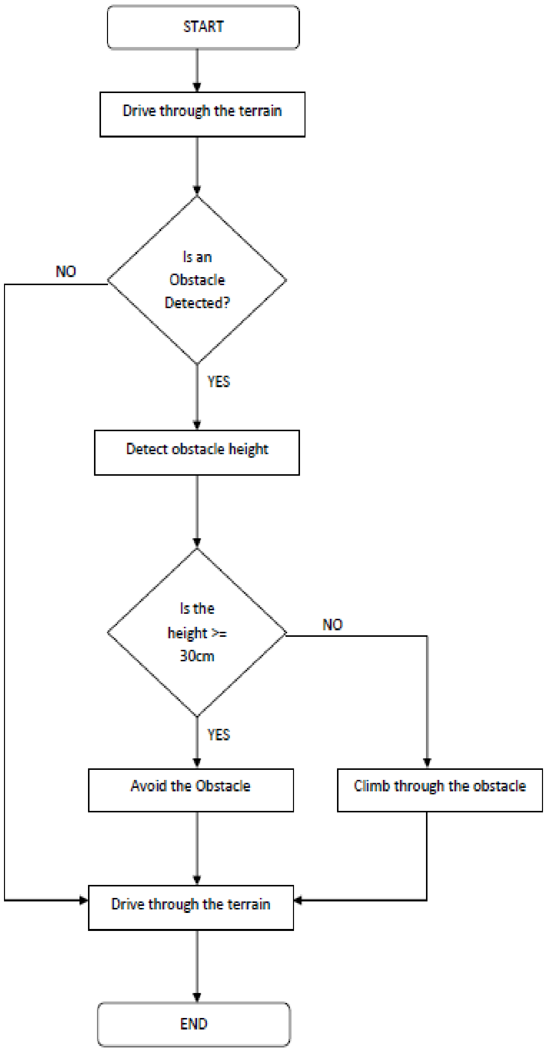

Figure8

3. CONCLUSION

The goal of UGV research is to produce a machine capable of carrying out operations in the absence of, or with minimal, human direction. In order to achieve the objective of operating autonomously in environments where direct human intervention is not feasible, self-diagnosis of faults and fault tolerance are the characteristics that UGVs must have. In this paper, a successful design of an Unmanned Ground Vehicle with some additional features such as responding to height changes autonomously is presented. As future works, using a camera attached to the UGV to receive a live feed and using more reliable sensors have been recognized as main improvements.

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