Design and Development of Autonomous Surface Exploring Vehicle

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ABSTRACT

For social, economical, or political reasons, unstructured environments may have to be studied and explored. However, the areas that need to be studied may not be safe (areas with dangerous radioactive materials or front lines in battle fields) and may pose problems including loss of life, for a human to explore by himself physically. For these and other similar reasons, autonomous surface exploring Vehicles are of paramount importance. In this work, design and development of a four wheeler Autonomous Surface Exploring Vehicle, which can be used for scientific data collection and/or for Military applications in small scale is described.

General Terms

Autonomous Vehicle

Keywords

Autonomous, unstructured environments, data collection, Dynamic analysis, Surface exploring vehicle.

1. INTRODUCTION

Robotic systems began the era of space exploration with series of spacecraft including Mariner, Ranger, Surveyor, and Lunakhod [1]. Robotics enables current missions on planetary surfaces, on orbit & deep space, on Medical field, on Agricultural field and other vast and wide areas of applications. During last decade, there has been significant progress toward a supervised autonomous robotic capability for remotely controlled scientific exploration of planetary surfaces [2]. While unmanned (water) surface vehicles-USV date back at least to World War II, it is only in the 1990's that a large proliferation of projects appears, Corfield and Young (2006). This is in part due to the technological progress, but also driven by a paradigm shift of the US Navy with a much stronger focus on littoral warfare and anti-terrorism missions.

With the National Aeronautics and Space Administration's (NASA) renewed commitment to space exploration , particularly missions on mars and the return to the Moon, greater emphasis is being placed on both human and robotics exploration. In reality, even when humans are involved in the exploration, human tending of space assets becomes cost-prohibitive or simply not feasible, and therefore, increasingly in future missions, remote mission assets will be required to work autonomously [3]. Moreover much of the mission control work on the earth will be performed by fully computerized systems operating with little or no human intervention. In addition certain exploration missions will require robots that will be capable of venturing where humans simply cannot be sent. Thus robotic vehicles that cannot be tended all the time by humans will be required to work autonomously.

Although autonomy will be very critical for future advanced missions, it will be essential that these missions exhibit autonomic properties. Autonomy alone, without autonomicity will leave the vehicles vulnerable to harsh and difficult environment in which they have to explore, and in which, most likely, performance will degrade or will not be able to recover from faults. Ensuring that exploration vehicles are endowed with autonomic properties will increase the survivability and therefore the likelihood of success of these missions [3].

The research and development effort building AGVs so far has focused on developing vehicles that operate on limited terrain conditions and on applications where speed is not an important issue. These vehicles are not conducive for use in battle fields. The US congress has chartered the Defense Advanced Research Projects Agency (DARPA) to bridge this gap and produce AGVs that can be used in front lines by 2015 [4].

This paper work came out by attempting to design and develop a four wheeler Autonomous Surface Exploring Vehicle, which can be used for scientific data collection and/or for Military applications in small scale. To achieve this, the vehicle is designed to detect obstacles for autonomous steer, and for data collection/ surface exploration, it is designed to have a means of telemetry system.

2. DESIGN ASPECT OF THE VEHICLE

The vehicle comprises of four important parts, i.e. mechanical structure, steering system, drive system and telemetry system. This section describes the overall mechanical structure of the vehicle.

In the design of the mechanical structure of the vehicle, the suspension systems were mounted on a chassis and support structure was designed to fix the frame on the chassis. In the design, an attempt has been made to provide the vehicle with roof structure itself used as chassis. From the preliminary design of the structure the vehicle is fabricated in the laboratory. The vehicle is a four wheel and the structure of the vehicle is analyzed for its strength using finite element package, ANSYS for static as well as dynamics loads. The results obtained through the finite element analysis were presented graphically [5].

2.1 Static analysis

FEM analysis of the structure has been done with different loads by using two different materials. One by using mild steel with Young modulus, E=210 GPa and poisons ratio μ =

0.30 and other with aluminum with E = 70 GPa and μ = 0.33. For different loads deflection, stress and bending moment (BM) diagram have been compared.

Deflection diagram in mild steel and aluminum structure with 70 kg load is shown in Figure 1 and 2 respectively. It is observed that deflection is more at the roof structure on wind screen side of front and back of the vehicle. However deflection is more for the aluminum material and deflection pattern is same for both the cases [5].

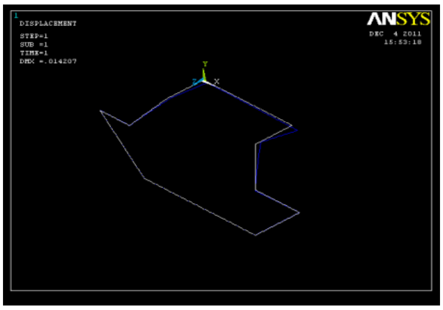

Figure 1 Deflection Diagram in Mild Steel with 70 kg Load.[5]

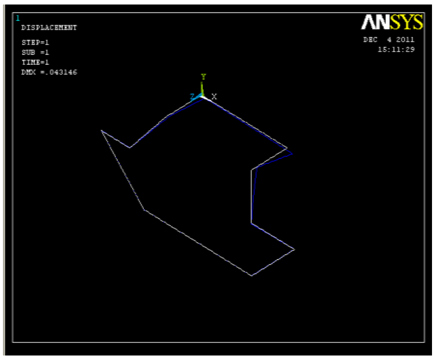

Figure 2 Deflection Diagram in Aluminum with 70 kg Load.[5]

Figure.3 and 4 illustrate the bending moment diagram for mild steel and aluminum for 70 kg load. It is observed that maximum bending moment occurs at the top of the structure in the wind screen side. The same pattern of bending moment is obtained in both the cases for the mild steel and aluminum.

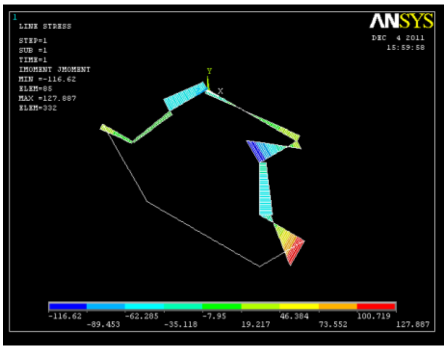

Figure 3 Bending Moment Diagram in Mild steel with 70 Kg Load. [5]

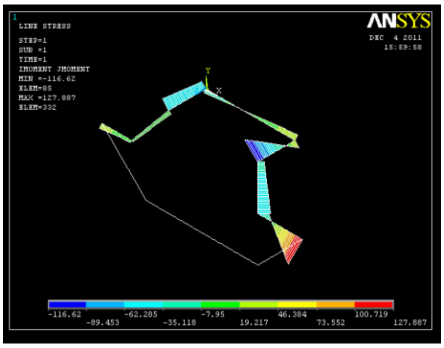

Figure 4 Bending Moment Diagram in Aluminum with 70 Kg Load [5].

Similar analysis is performed for loads of 100kg and 120kg of the two selected materials and the result of the analysis is presented in the following tables bellow.

Table 1 Loads, Deflection, Stress and BM for Aluminum [5]

Load(Kg)	**Max deflection(mm)**	**Max stress(N/m^2)**	**Max B moment(Nm)**
70	0.0431	0.662×10^8	127.8
100	0.0616	0.946×10^8	182.6
120	0.0739	1.14×10^8	219.13

Load(Kg)	**Max deflection(mm)**	**Max stress(N/m^2)**	**Max B moment(Nm)**
70	0.0142	0.468×10^8	127.88
100	0.02028	0.669×10^8	182.695
120	0.0243	0.803×10^8	219.234

Table 2 Loads, Deflection, Stress and BM for Mild Steel [5]

2.1 Dynamic Analysis of the Structure

Dynamic transient analysis of the structure has been carried out using ANSYS 11.0 considering mild steel structure. Deflection v/s frequency graph is shown below. Green line is corresponding to 70 kg, blue line 100 kg and red line 120 kg load respectively. It is observed that the time elapsed for the deflection increases in the case the load is allowed to act on the front side of the structure corresponding to impact load. It is also observed that as impact load increases deflection also increases. However the deflection due to load is not linear [5].

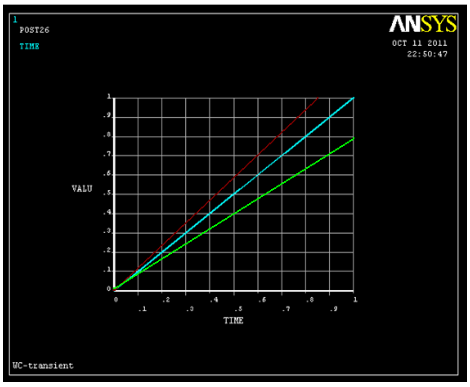

Figure 5 Deflection v/s Frequency Plot of the Structure Using Mild Steel with Different Loads [5].

From the analysis carried out it is found that mild steel have better load carrying capacity while offering lesser deflection as compared to aluminum.

An aluminum structure, built to the same standards, weighs roughly 35% to 45% less than the same in steel. This is less of an issue for larger vessels which are able to carry necessary displacement for whatever material choice is made. For smaller vessels however, the weight of the hull structure is very much an issue. When alloy is designed to the same standards as steel (ABS Lloyds or other similar classification society), it is made to be higher in overall strength. The reason for this is that aluminum reaches its “endurance limit” sooner than steel in terms of flexure. Therefore the rigidity of the structure (deflection) becomes the limiting design criterion for an aluminum structure and this forces a higher than necessary overall yield and tensile strength.

One advantage of steel is that between the yield point of mild steel (around 52249.6 N/cm^2) and the ultimate tensile failure point (around 87082.7 N/cm^2) there is quite a large plastic range (around 34833.1 N/cm^2) or roughly 40% of the ultimate strength), permitting a steel vessel to endure deflection without failure, so permitting considerable ability to absorb energy. Hence the mild steel hollow pipe has been chosen for the construction of the chassis.

3. STEERING SYSTEM

The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. When a vehicle is going straight the wheels or tracks all point in the same direction and rotate at the same speed, but only if they are all the same diameter. The turning requires some change in this system. This can be obtained by many methods some popular methods [6, 7]. Due to its simplicity, we have used a simple Ackerman’s steering mechanism. The steering system is modified and endowed with rack and pinion arrangement so as to be suitable for autonomous steer.

3.1 Schematic Arrangement

In this project according to the schematic as shown in the figure 6, the components of the Ackermann’s steering system are fabricated and implemented. In this system, Rather than the preceding "turntable" steering, where both front wheels turned around a common pivot, each wheel gained its own pivot, close to its own hub. While more complex, this arrangement enhances controllability by avoiding large inputs from road surface variations being applied to the end of a long lever arm, as well as greatly reducing the fore-and-aft travel of the steered wheels.

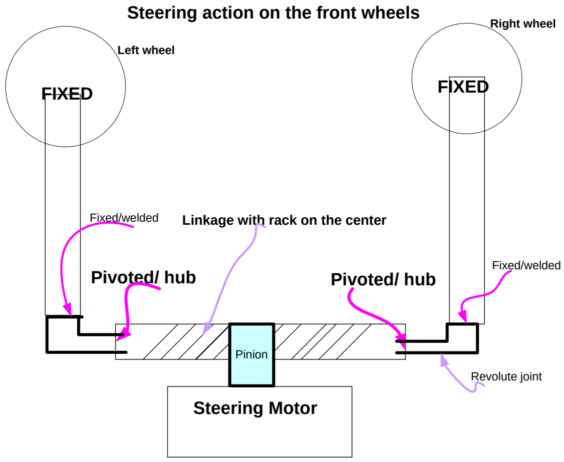

Figure 6 The Schematics of Modified Ackermann’s Steering System

A linkage between the hubs (pivot points) moves the two wheels together, and by careful arrangement of the linkage dimensions the Ackermann geometry could be approximated.

Depending up on the sensory signals, the steering motor is expected to rotate autonomously. As a result of this, the pinion coupled on the shaft of the motor is rotated so that, by the very nature of the Rack-and-Pinion arrangement, linear movement of the linkage (between the two wheels) is obtained. Thus steering action is established.

3.2 Steering electronic control

Figure 7 bellow shows the overall block diagram of the electronic control unit for autonomous steer.

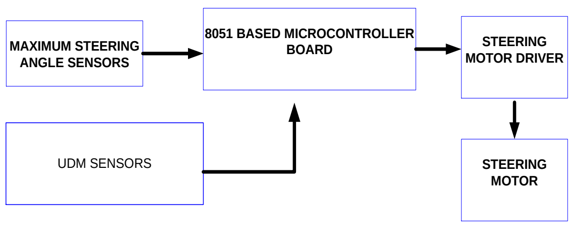

Figure 7 Block Diagram of the Electronic Control Unit.

In the system four ultrasonic distance measurement (4m range) sensor are used (that are fitted on front side, left, right and back side) selected and for maximum steering angle detection two IR sensor modules are used. The controller is selected to be 8051 microcontroller board. Based on the algorithm developed, figure 8, the steering action is initiated.

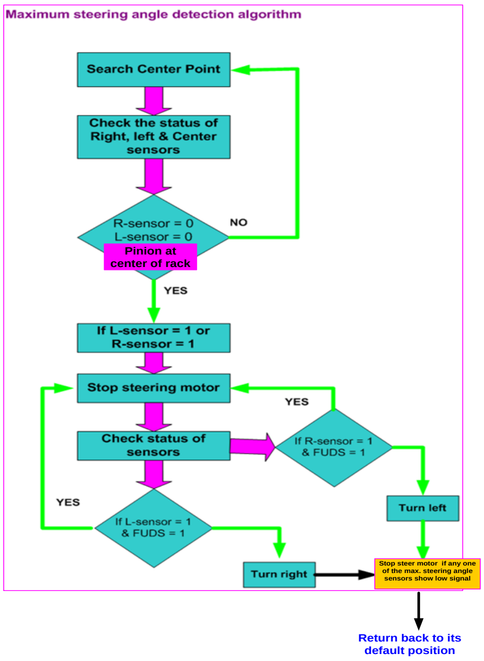

Figure 8Flow Chart of the Control Algorithm.

4. DRIVE SYSTEM.

From the initial vehicle parameters such as total mass, required linear speed, wheel radius, surface considered and associated cost and complexity, we preferred to use a single centre drive mechanism.

4.1 Mechanical Design of the drive system

From initial analysis performed, we preferred to use Super Hercules DC Motor with torque of 23Nm and having an internal planetary metal gearbox. The Motor is operated at 12V on board dc power supply and capable of drawing 15A current at full load.

Figure 9 The Drive System.

The torque of the motor is enhanced by a properly designed and fabricated gear drive mechanism. From the analysis performed, the gear drive mechanism is designed to provide a gear ratio of 2.57. Thus a transmission shaft is designed and selected that could transmit a minimum of 59Nm torque to the back wheels of the vehicle. Hence, for the total mass of the vehicle 108Kg (with safety factor), surface considered ($\mu = 0.3$) & for a maximum speed of the vehicle 2m/s , the designed drive system provided a successful result.

4.2 Electronic Control unit for the Drive System

The electronic control unit should be capable of monitoring the drive motor depending up on signals from four ultrasonic distance measurement (UDM) sensors that are fixed at left, right, rear and front side of the vehicle. Further depending up on the sensory signals and the drive algorithm (Figure 11) developed the microcontroller module commands the motor driver module. Thus the motor can be rotated clockwise (forward), counterclockwise (reverse) or can be stopped autonomously. The overall block diagram of the control unit is shown in the figure 10 bellow.

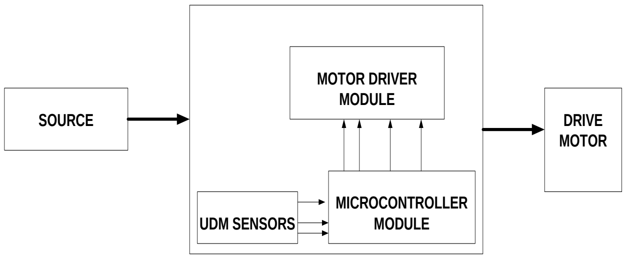

Figure 10 Block Diagram of the Electronic Control Unit.

The following figure shows the algorithm developed.

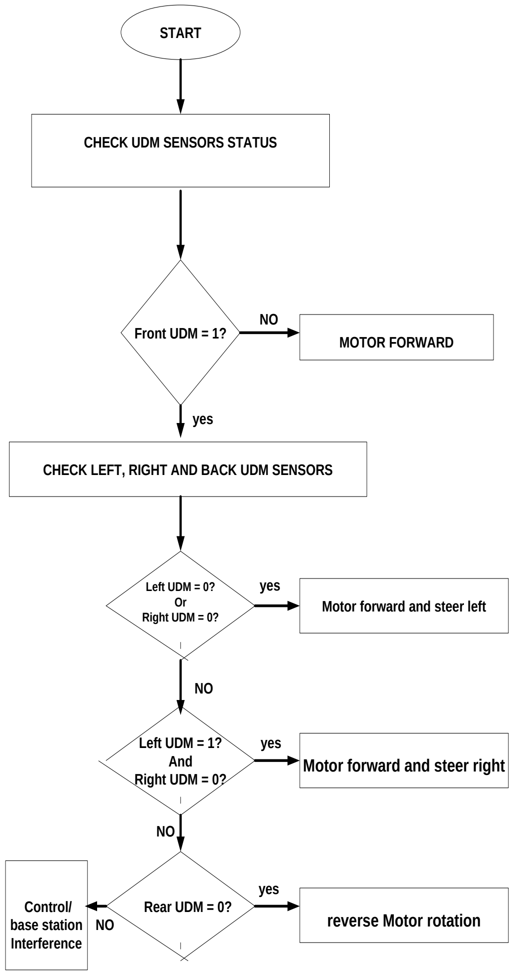

Figure 11 Flow Chart of the Algorithm for the Drive System.

5. TELEMETRY SYSTEM

For enabling the vehicle to collect data and send back to the control station, we have selected a video signal from the on board of the vehicle. Today, a number of airborne video systems exist. They all have their specific pros and cons but Due to the general characteristics making video to a valuable sensor [8], we have selected the *EasyCAP USB 2.0 Video. Capture with Audio*, it can capture High-quality video and audio file direct by USB 2.0 interface without sound card.

The following picture (figure 12) shows the mounted camera and the receiver that is interfaced with a laptop at the control station.

Figure 12 Picture Showing the Mounted Wireless Camera on the Vehicle.

Figure 13 Picture Showing the Receiver Interfaced with a Laptop at the Control Station.

Thus using the camera online surface exploration can be done at a remote place and decisions can be executed accordingly. That is from the online video that the camera transmits to the control station, it is possible to supervise the vehicle and take the necessary actions. As it is discussed in the drive control algorithm, in section IV, when the vehicle is at a difficult condition to maneuver autonomously, the program jumps to the control interference subroutine so that the vehicle can be controlled and directed remotely.

The following picture shows the sample of data capture in the control room.

Figure 14 Sample of Captured Data.

6. RESULTS AND DISCUSSIONS

The vehicle is designed and assembled as shown in the figure 15 bellow and it is practically tested for the initial preferred parameters.

It is found out that the linear speed of the vehicle is around 3m/s and the vehicle is comfortably driving itself on a plain surface. The vehicle is found out to be capable of maneuvering through unstructured environments and simultaneously sending data to the control station.

Further it is found out that for a small inclination of the surface the transmission shaft tends to bend out and as a result of this the gear drive system is unable to transfer the power correctly.

7. CONCLUSIONS

- An autonomous surface exploring vehicle is designed and developed that can be used for surface exploration and/ or for military applications.
- The vehicle is made to work in automatic and semi-automatic mode, which has the provision to be controlled remotely from a control station.
- The vehicle can be easily configured to be used as a means of transport for handicapped / aged individuals

8. FUTURE WORK

As a future advancement of work, the following can be considered.

- The bulk mechanical constraint can be reduced so that more flexibility for design modifications can be achieved. And also, the power consumption associated with its mass can be greatly reduced.
- A provision to self power the system using solar energy can be incorporated and as a result remote exploration can be enhanced.
- Further, exploration for all terrain environments can be considered and implemented

9. ACHNOWLEDGMENT

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