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Development of a Cost-Effective Underwater Robotic Platform for Operating both AUV and ROV Mode

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***Abstract*— This paper presents the design and implementation of an underwater robotic platform that can operate in both Autonomous Underwater vehicle (AUV) and Remote Operated Vehicle (ROV) mode. In recent years, there is a need of underwater robotic vehicle for marine life research, mineral exploration and finding sediment pollution level. In most cases, the price of commercially available AUV or ROV is beyond reach for an individual researcher from developed countries. On the other hand, the sophistication level of commercial vehicle might be unnecessary for many researchers, as they intended to use the vehicle for single research purpose. In this paper, we describe the design and implementation detail of simple, lightweight, low cost robotic platform.**

***Keywords*— autonomous underwater vehicle, remote operated underwater vehicle, robotics.**

I. Introduction

Underwater robotic platform become much popular among marine research industries. Due to low labor cost, many developed countries become the first choice of industrial investment. Factories are growing in number and in most cases the wastes are disposed into water such as lake, small river etc [5]. Therefore, there is a need of monitoring the sediment pollution level, condition of marine life and other aspects of those water spaces. In this paper we present, the development of a low cost underwater robotic platform that can be implemented from locally available materials and easily deployable for monitoring close and open water. The developed vehicle can operate both in AUV and ROV mode. The designed vehicle has six DOF and it can transmit audio-visual data from underwater. The vehicle also has the ability to pick underwater sediment sample. In AUV mode, the vehicle can follow a pre-programmed path and collect images. The vehicle is easy to deploy and recover for a small team.

II. Design Parameters

Based on project requirements, few design parameters are set for underwater robot vehicle. These parameters are mention in below.

- Design a cost effective underwater robotic platform that should operate only within clam water, such as lake, pond or small river etc.
- The robot should have the ability to work on both ROV and AUV mode by using common mechanical and electronics platform.
- The remote sensing ability.
- Robot would have six DOF and ability to maintain neutral buoyancy.
- Robot would have the ability to capture audio-visual data from underwater and transmit it to surface while operating on ROV mode.
- Robot would have the ability of picking sediment sample from underwater.

III. Hardware Design

Hardware of TAREQ is designed is such way that, it can be implemented by using locally available materials and also with minimum cost. All the systems of robot designed individually and they combined them together at end.

A. Water proof Hull Design

The initial step of design is a waterproof hull, which would protect the complete system from getting wet. The material of the hull must be sturdy enough to sustain underwater pressure and easy for processing (cut, drill, seal etc). Few materials chosen and finally an 18" cylinder shape P.V.C pipe chosen as hull. The bow and stern sections of robot made by using off-self pipe fixture equipment. The hull of the robot designed to operate maximum 15ft underwater. Although, field testing shows the hull integrity over 20ft.

Figure 1 Three Dimensional Model of Robotic Platform

Initially, few trim tanks considered for making the robot stable. Later it found that, controlling the individual trim tank would increase the complication of the project. So instead of trim tank, a set of weight placed inside robot.

Two P.V.C pipes uplift the hull, protect it from downward collision and also work as stand. The small grove on the edge of the pipe allows the mud to enter inside and the robot can take it back to surface for analysis.

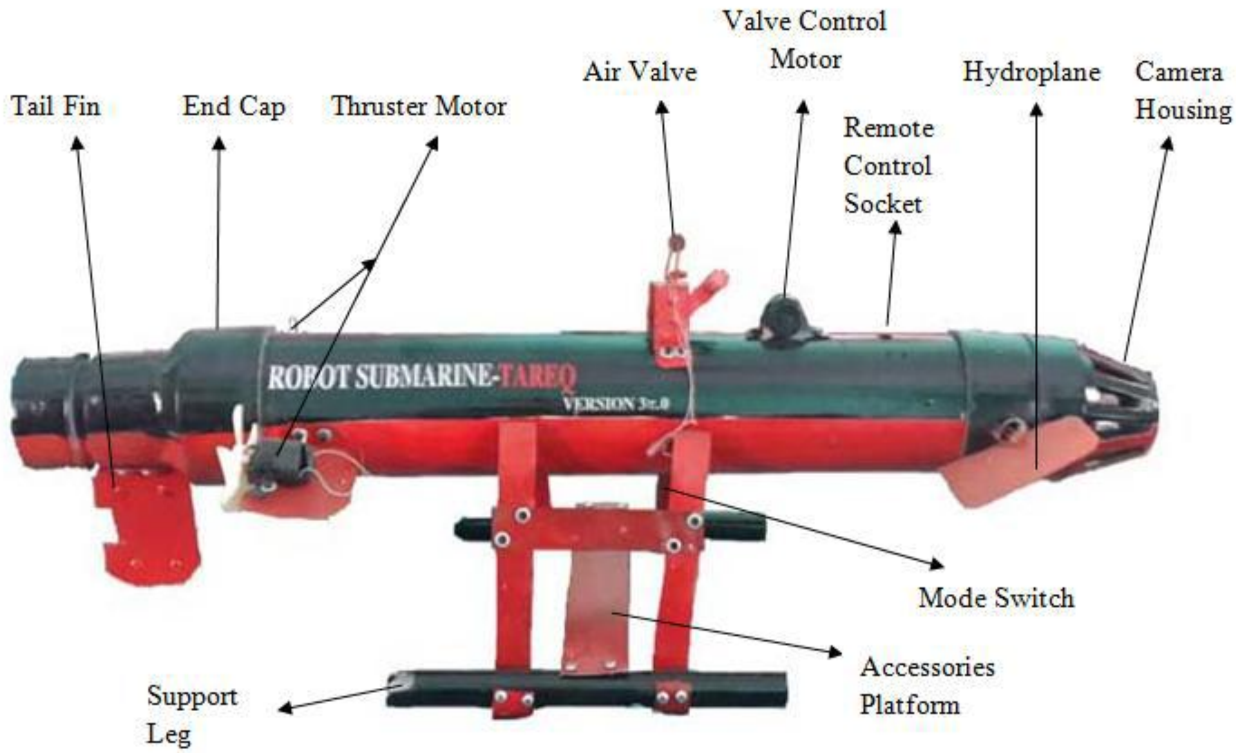

Figure 2 Finished Hardware

B. Propulsion System Design

The robot has six DOF. The forward and backward motion provided by two 12V, 1.5A motors. These motors are also responsible for turning the robot left and right horizontally. Precautionary steps taken for making the motor waterproof.

For upward and downward motion, the robot uses both static and dynamic diving method. A 9V DC motor, controlling two frontal hydroplane's tilt angle; making the robot goes up and down at 10□ max. The robot able to perform dynamic diving only when it is in motion.

A variable MBT made by compressible bladder material, helps the robot perform static diving. A motor controlled valve placed on top of the robot, releases the air from the MBT and allows water to enter inside and make the robot submerge. Depending on the volume of water inside MBT, the robot able to maintain neutral buoyancy. A 12V DC air pump used to compress the bladder. Force the water out from the MBT and make the robot surface.

Figure 3 Completed Hardware with Electronics Assembled

C. Power Source

The robot TAREQ requires DC power source for running its electronics and actuators. The robot uses five DC motors and other electronics control circuits. The motor consumes extreme power while they are under load. So the batteries can run out of energy almost instantly, which cause the system failure. Inside robot, 4.7V, 2A smaller sized NiCad batteries connected in series and parallel for providing few times more power than the required. It makes sure the robot would sustain for longer operation period.

IV. IV. Electronic Design

The electronics system allows the vehicle operate both in ROV and AUV mode. In both cases, Atmel 8051 microcontroller processing unit controls the actuators of the robot. An external toggle switch on the vehicle tells the microcontroller, which mode the vehicle supposes to run. If the switch is on, then robot runs on AUV mode; else on ROV mode.

A. ROV Mode

In ROV mode, operator can control the robot by using a remote, which connected with the vehicle with a set of wires. The four switches of remote can generate sixteen codes and user can send a specific code to vehicle. The microcontroller inside vehicle, analyze the code and runs the specific actuator accordingly. A modified web camera used in robot, which transmits real time image and sound to the computer. Although the live experiment shows, the camera faces serious signal loss, while the cable is over 14ft.

B. AUV Mode

In AUV mode, the robot use light radar sensor for sensing the surrounding environment. The robot has two front facing light radar, which emits high frequency red light. When the light strikes the bubbles or any frontal, barrier then it scatter and come back to receiver. The receiver section of the radar made by using LDR (Light Detecting Resistor). The radar able to detect barrier within 0.5" – 4". The problem with this radar is, the vehicle get less response time for obstacle avoidance and safe maneuver. So the vehicle needs to move relatively slow speed.

In future robot would use OS-3000 compass and this device can determine the pitch, roll and yaw of the vehicle. This sensor would connect with a separate microcontroller for decoding the sensor output and feed this output to mother microcontroller.

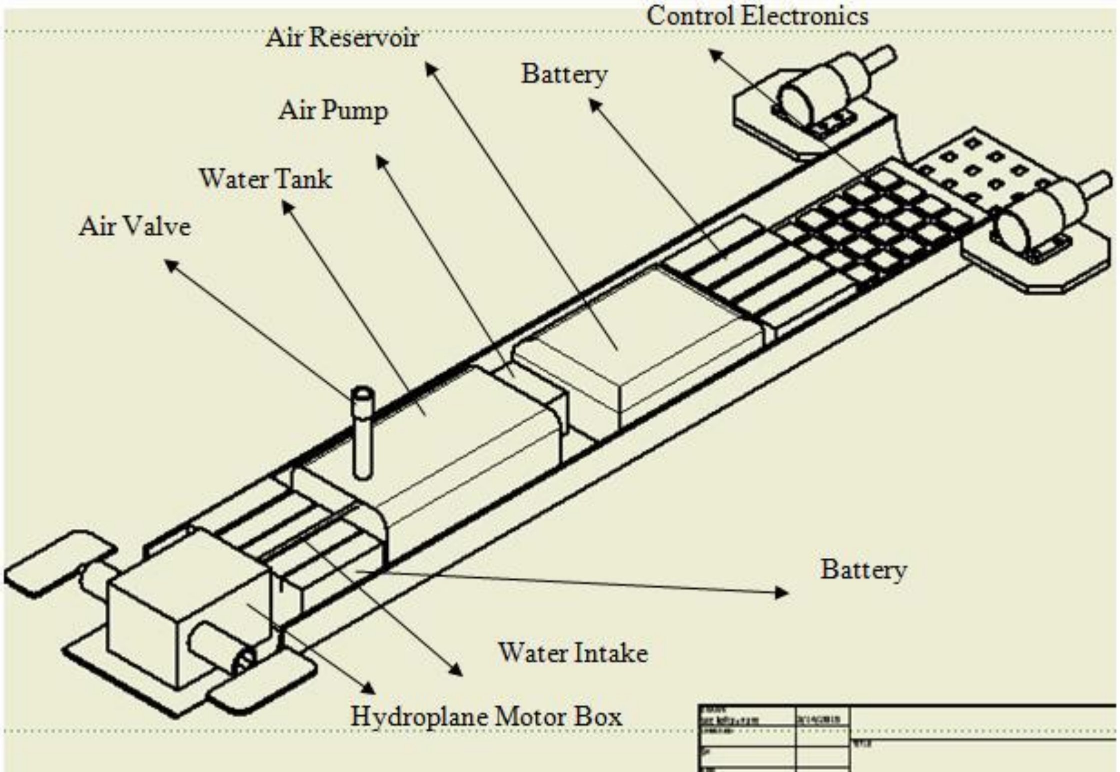

Figure 4 Inside Equipments of the Vehicle

In present, robot uses dead reckoning method for finding its position. The odometric method only based on shaft encoder's tick counts. So without the compass, gyroscope and tilt sensor, the location of the robot would be highly inaccurate. So robot uses initially programmed area map alongside the dead reckoning method. This combined effort reduces the location error and serves the basic purpose.

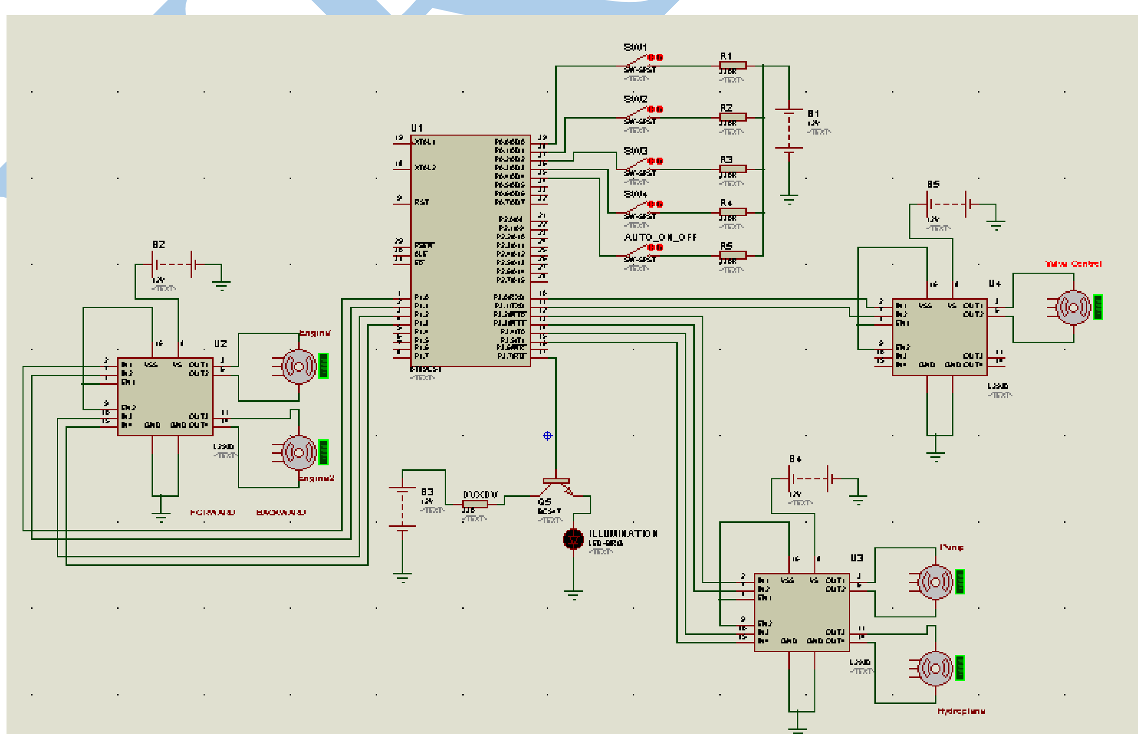

Figure 5 Control Circuit Diagram of the Robot

V. V. SOFTWARE DEVELOPMENT

The software for the robot written for Atmel 8051 microcontroller. In initial step, the program checks the hardware switch, if the AUV mode is on or off. If the AUV mode is off then the program waits for the user command. User can generate 4-bit long sixteen-code segment, by using the remote control. The microcontroller receives the code and find out the meaning of the code. Then it activates the related actuators for movement. For example, if the microcontroller receives code word 0001, then it means move forward. Therefore, after receiving the code, the microcontroller would send pulse to motor driver IC and activate the thruster motor for moving forward.

On the other hand, if the AUV mode hardware switch were on, then the microcontroller would turn on the mission program, initially written in memory. This program comes with an area map data and a possible path, which robot should follow. The area map is subdivide into grids and each grid is scaled to 3X3 meters physical map size. The control program knows the initial grid of deployment and by knowing the distance travel by every 25 ticks. The vehicle uses wave front navigation algorithm for navigation purpose. From the experimental data, control program also knows the turn angle for every 12 ticks. The microcontroller would simply activate or deactivate it actuators, for following the path.

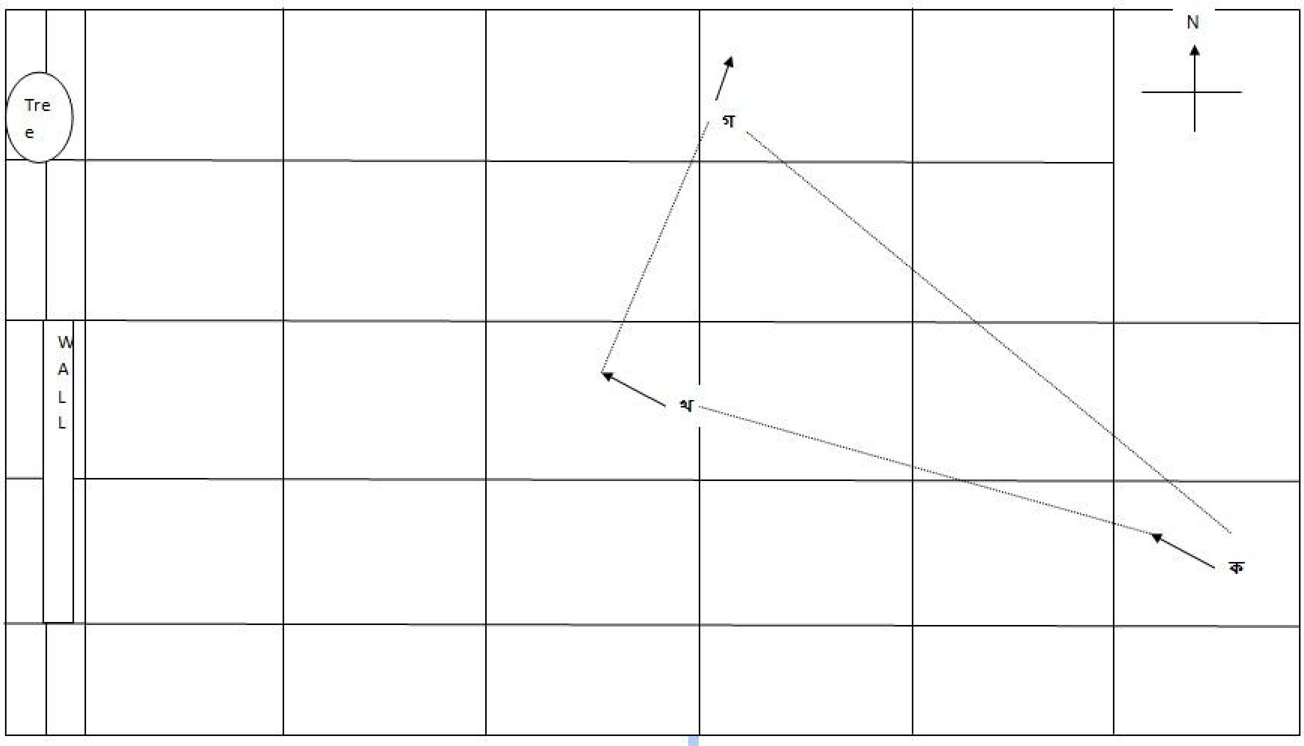

FIG 6: AUV Path Planning Mission Map

A. Sample Program

if(auto_sw==1) //automatic program begins { light_t1=0; //Provide indication that AUV mode is on light_t2=0; delay(); light_t1=1; light_t2=1; delay(); light_t1=0; light_t2=0; delay_motor(); //Delay for deployment time if(tick_count == 400) { motor1=0; motor2=0; //both motors stop } else sub_move(); //sub move straight - both motors running pump=1; //going underwater - pump on delay_motor(); //run pump until robot reach approx 5ft depth pump=0; //pump off if(tick_count == 300) { motor1=0; motor2=0; //both motors stop-sub move to destination } else sub_move(); //sub move forward in underwater delay_motor(); //delay for capture vedio motor1=1; //Single motor rotates for turning delay_motor(); delay_motor();
motor1=0; //motor 1 off

VI. VI. ROBOT PERFORMANCE

Both ROV and AUV mode tests conducted inside clam lake water. In AUV mode testing, surface map of the lake created before testing and the robot programmed to follow a certain path by using the map and light radar. The speed, turn and pitch angle, operational depth testing conducted during ROV mode.

Speed: The vehicle has the min speed 1 inch/sec and max 1.5 inch/sec both in AUV and in ROV mode. In AUV mode, the light radar can detect obstacle from a distance of 4”. Therefore, the slow speed allows the robot to have enough time for safe maneuver.

Pitch and yaw angle: Two frontal hydroplanes give the robot a pitch angle of ten degree in positive direction and 7 degree in negative direction. The thruster motor controls the yaw rate and for every 12 ticks counts, the robot can rotate single degree.

Operational depth: The robot is designed to have an operational depth of 15 ft. Field tests shows the robot can maintain operational depth of 20 ft. In AUV mode, the robot successfully operates under 5ft depth.

Path following and recovery: In path following testing, robot follows a certain path under 5ft depth. The test result shows the rate of error increment with time. In 25 minutes operation time, the robot surfaced 6ft away from its estimated surfacing point. However, this error rate would not effect much, as the robot is operating under confined area and the chances of loosing the device is very low.

VII. Conclusion & Future Update

This paper describes the design and implementation of a lightweight, cost effective robotic vehicle, which can be control both in ROV and in AUV mode. The robot has mechanical, electronics, and intelligent systems, which are easier to implement with the locally available materials. A compass with built in gyroscope, depth and tilt sensor can be added in future for improving dead reckoning ability. Navigation system accuracy can improve in future by using pseudolite array as beacons [4]. Robot would deploy these beacons while operating in ROV mode. Then use the signals from the beacons for correcting its position, while in AUV mode. In addition, in addition with forward facing camera, another bottom facing camera added in future. Together, the robot can use image processing and object recognition method for improving navigation accuracy.

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