USM Mini Remotely Operated Vehicle: Vehicle Development& Integration

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Abstract

This paper describes the development of vehicle design and hardware integration of the Mini remotely Operated Vehicle developed by members of USM Robotics Research Group. The project is funded by Ministry of Science, Technology and Innovative of Malaysia (MOSTI) under supervisory of National Oceanographic Directorate (NOD). Discussion in this paper will be focusing on the vehicle design, development and integration of the Mini-ROV, with highlight on the hardware integration and interaction between mechanical and electrical subsystems.

Keywords:

Mini Remotely Operated Vehicle, Vehicle Design Main Control Unit, Single board computer, Propulsion System,

Introduction

An underwater exploration has never been stopped since the innovative achievement of many machines for underwater purpose. The unmanned vehicle such as Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) are amongst the most utilized underwater machines that have been invented and improved in many years ago. Each year new design are being developed either for commercial use or scientific and education purposes. A remotely operated vehicle is a tether based underwater vehicle, can be deployed either for shallow water exploration or deep water submergence. An ROV can submerge deeper into the water, depending on how deep it is design to submerge. A deep submergence ROV normally used in offshore industry, with several ROVs may have been deployed to investigate the deep ocean for scientific and education purposes. Shallow water ROV is a common use underwater vehicle for monitoring and inspection. Ship hull, seafloor piping system and damn wall are examples where these types of ROV can be deployed to do the inspection task. The deployment of ROV replaces human as divers, thus reduces the risk of human diving into the water. Common devices such are sensors, vision, propulsion and control unit are installed in an ROV. in the next section, there are the brief description about the mission planning and system design, follows by discussion on sensor module, main control unit and propulsion system.

Mission Strategy and Planning

System Design and Description

The goal of the project is to develop and achieve a complete and functional system of a mini class remotely Operated Vehicle. The design approach adopted the modular methods, which each module is developed individually, tested and integrated into one system. The Mini-ROV is a tethered underwater vehicle, with supervisory control is established between the main control unit on the vehicle and surface control station. The vehicle is equipped with two underwater cameras and two High Induce Charge (HID) lights to aid the vehicle' vision while operating underwater.. Six thrusters are being used as the vehicle propulsion, with four of them are configured for the lateral motions and the other two are for vertical motions. The four lateral thrusters are configured in vector in order to achieve higher Degree of Freedom (DOF). All thrusters are driven by a stacked of individual high current motor driver. The mini-ROV is powered by 240 Vac from the generator on the surface, with two cores of AWG 13 stranded multiply copper wire insulated in a cross link elastomeric jacket as the power line. The mini ROV adopted the Power Line Communication (PLC) as the communication module; with a network line is established between the on-board computer and the surface computer using the TCP/IP communication. For intelligent system, two common sensors are used, the gyro-compass and depth sensor. Table 1 summarizes the specifications and characteristics of the mini-ROV.

Table 1: Mini-ROV Specifications

Class	Mini ROV
Weight in air	35 kg
Weight in fresh water	
Designated depth	100 m
Propulsion	6 thrusters, 110W
Sensors	Depth, gyro
Power Mode	Tether, Battery
Communication	PLC
On-board Control Computer	Mini-ITX
Surface Control Computer	Industrial Computer with Touch screen LCD monitor
Vision	Underwater camera, HID light

Vehicle Design

The vehicle design is an open frame box shape, consists of three major parts; the chassis, the enclosure and the buoyancy. The chassis, or the framework is a composition of parts, assembled together to build the complete chassis. Screws and nuts are used to join all the parts, which these parts are easily to assemble and dismantle. The chassis is made from an aluminum alloy material, which providing the vehicle a stronger, durable and lighter body. Aluminum alloy 1100 is chose because it has high number of strength to weigh ratio. It is also a noncorrosive material and very suitable to use in harsh environment. The chassis is also designed to hold the equipments such as the enclosure, thrusters, HID lights, cameras and buoyancy material. The chassis also designed in such manner that it distributes the mass of the vehicle evenly.

The enclosure, also made of aluminum alloy 1100, housed the main control unit. The enclosure is made by folding and welding the aluminum alloy into a box shape. The wall thickness is 5mm, giving the protection of pressure in 100 meter depth. The enclosure has an opener, with thickness of 10 mm, with flange sealed with a special high pressure rubber and tightened with 14 pieces of stainless steel screws and nuts. The enclosure body is having a number of flush holes for mounting the connectors for thrusters, cameras and HID lights.

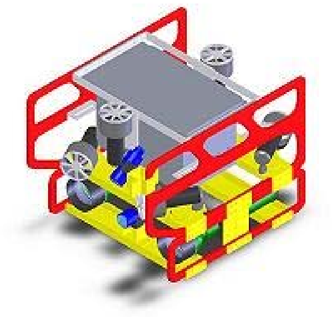


Figure 1: Three dimensional views of Mini-ROV

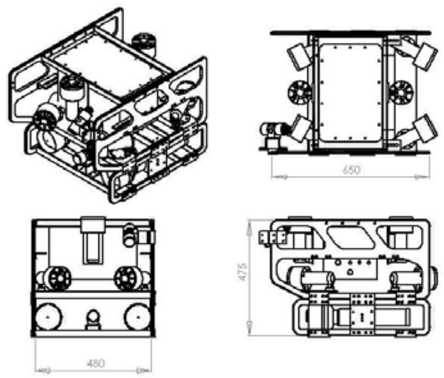


Figure 2: Two dimensional views of Mini-ROV

Main Control Unit (MCU)

Main control unit is a composition of electrical and electronics devices. These devices are stacked together inside a backplane and interconnected with each other.

Table 2: Main Control Unit Devices

Item	Description
PMU	Supply various levels of voltage
Single Board Computer	Data & video handling
Gyro-compass	Provide directional and location data
Motor driver	Driving the thrusters in dual directions
Depth sensor	Pressure based sensor which gives input on vehicle depth below sea level.
PLC	Establish networking between on-board computer & surface computer
Video grabber	Grab video signal from camera

The mini-ROV is powered by 240V ac from the surface. Thus the most important is to manage such big amount of power and distribute it amongst devices inside and outside the vehicle. The Power Management Unit (PMU) receives and converted the ac voltage into multiple levels of dc voltage. This multiple level voltage conversion is crucial because each electrical and electronic device and equipment is having different power properties. Several devices such as the thruster and HID require high operating voltage and current. But few components like gyro-compass and on board computer require lower voltage and ampere.

Single board computer is the center for data handling. It receives processes and transmits the control command and video signal between the vehicle up to the surface control station and vice versa. The board is a Mini ITX form factor motherboard, with features equivalent to the normal desktop computer. It has 2.0 GHz Intel Core2 Duo microprocessor with 3 GHz of memory capacity. The mini ITX is chose because of its powerful feature and small dimension, about 170mm x 170 mm. It also has various input and output terminals such as the COM port, parallel port, USB port and general purpose I/O. The mini ITX is responsible for:

- Execute control command received from the surface computer
- Receive sensor data and transmit to surface computer
- Receive video signal and show it on the screen
- Networking peripheral for PLC

Two sensors, gyro-compass and depth sensor are used as part of intelligent system in the mini-ROV. Gyro-compass shows the direction of the mini-ROV while operating underwater. It is a common device in any marine vessel; operate by pointing to the true north. The gyrocompass used in the mini-ROV is a digital compass which uses high precision anisotropic magneto resistive magnetic 3-axis sensors. The Z-axis measurement allows the compass to calculate the azimuth even when the compass is tilted at certain angle. The compass accuracy is 0.1degree for heading and covers all range for pitch and roll.

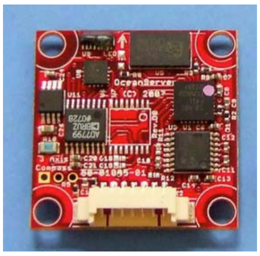


Figure 3: Oceanserver Gyro-compas

The depth sensor for mini-ROV is a pressure base transducer. It measures the gauge pressure and converted the measured data into an output range of 1V to 5V. The transducer is made of stainless steel material and can measure pressure value up to 700 bars. The depth pressure is mounted on the enclosure body, with the open tip is exposed to the water environment. The sensor shared the same connection with the gyro-compass and connected to the COM port.

Figure 4: MSISensor Depth Transducer

Six individual motor drivers are used to drive the 110W thrusters respectively. To drive the thruster, the driver must supply maximum 28.8 V and continuous minimum 3 A to give the thruster sufficient thrust force to drive the mini ROV. the drivers are stacked into one tier and one communication module. This communication module, which is using the parallel port, is responsible to receive the control signal and at any time will relay the information to the driver to drive the respective thruster.

The Power Line Carrier (PLC) is used as the communication module in the mini-ROV. Power Line Communication (PLC), also known as power line carrier, mains communication, power line telecom or power line networking, is a system for carrying data on a conductor that is used for electric power transmission. Electrical power is transmitted over high voltage transmission lines, distributed over medium voltage and used inside buildings at lower voltage. All power line communications systems operate by impressing a modulated carrier signal on the wiring system. The PLC used in the mini-ROV has data rate of 200 mbps and very suitable for transmitting wide band information such as video streaming data.

The video signal receive from the camera is an analog signal. Thus to be feed into the single board computer, it must be converted to digital signal which a computer could understand. Thus a video converter device is used to convert the analog signal to digital signal and is feed to the single board computer through the USB port.

Underwater Device

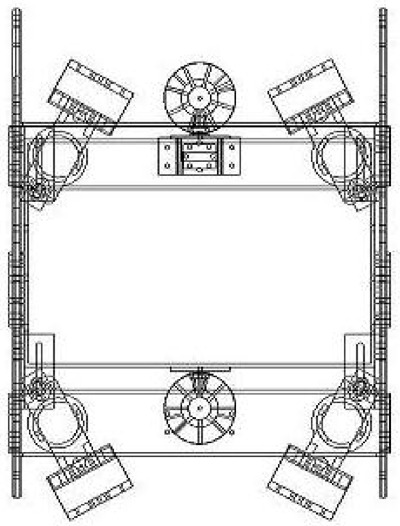
There are several devices that are mounted on the chassis which are left in water environment to serve their respective purposes.

Table 3: Underwater Device

Device	Description
Thruster	MROV propulsion system
HID Light	To aid MROV vision
Camera	Capture the underwater environment
Tether	Power supply and communication chain.

The mini-ROV propulsion system consists of six thrusters, with four in lateral position and the other two are in vertical position. The thruster is a dc brushed motor, supplied by Seaboitx.Inc is powered with 28V with 4A peak continuous current to generate maximum of 2.8kgf thrust power. The thruster adopted the current-load relationship for speed control. The more load is induced; the higher ampere will be drained. The purpose of having such six thrusters and vector propulsion is to generate as many of Degree of Freedom (DOF). DOF determines quantitatively directions that the vehicle can explore The MROV is able to generate at least 10 motions; forward, backward, side slip port, side slip starboard, spin port, spin starboard, up, down, left and right. The lateral thruster is configured at 45 degree each to achieve maximum thrust for each motion. Figure shows the vector configuration of the thrusters.

Front



Rear

Figure 5: Vector Propulsion

Figure 6: Seabotix BTD 150 thruster

To aid vision under the water, the mini-ROV is installed with the SuperSeaArc HID light from Deepsea. This 150w HID light has brightness of 12 000 lumens and color temperature of 7 000 °K. The Super SeaArc® 150w HID is 3-5 times more efficient (lumens/watt) than comparable tungsten-halogen lights while providing over twice the light output. With 7000 °K color temperature, it produces a very white light that penetrates further through seawater than conventional incandescent lamps. Since there is no filament to break, gas discharge lights are also less sensitive to vibration and shock than incandescent lights. The HID light is secured in anodized aluminum housing, rated at 4000 meters. It weights 3.0 kg in air and 1.7 kg in water. Two units are used for the mini-ROV

Figure 7: Deepsea SuperSeaArc HID

To capture images underwater and help the pilot navigates the MROV, the Multi-SeaCam 2060 from Deepsea is used. The 1/3-inch CCD image sensor is housed in titanium housing which is rated at 6000 meters down the sea level. It uses PAL format with fixed focus and wide angle. The depth of field (FOD) is 10 cm to infinity with resolution of 460 TV lines horizontal. Powered by range of 11Vdc to 30Vdc, it produces 1.1 lux illumination at f2.0 with signal to noise ratio more than 45 dB. It weighs at 459 grams in air and 112 grams in water. Two cameras are used, with each is configured at different perspective, to give more convenient and versatility in capturing images.

Figure 8: Deepsea MultiSeaCam

The Mini Remotely Operated Vehicle is a tethered underwater vehicle. It relies on cable for power supply and communication. Because the MROV is using the PLC base communication, it only requires the power cable to perform both, supplying power and establishing communication. The tether consists of two inner copper cores with 45 pieces of strands. It has 2.5mm² cross sectional area; equivalent to AWG 13 with current rated at 34 A. It is a highly flexible cable designed to withstand harsh environment like aquatic and stress. The cable weighs 17.5kg for 100 meter length with voltage rating at 450/750V rms. The insulation is a cross link elastomeric compound with cross linked elastomeric jacket. It operates in temperature ranging from -35°C to +85°C.

Figure shows the electrical interconnection between devices inside the MROV and at the surface control station.

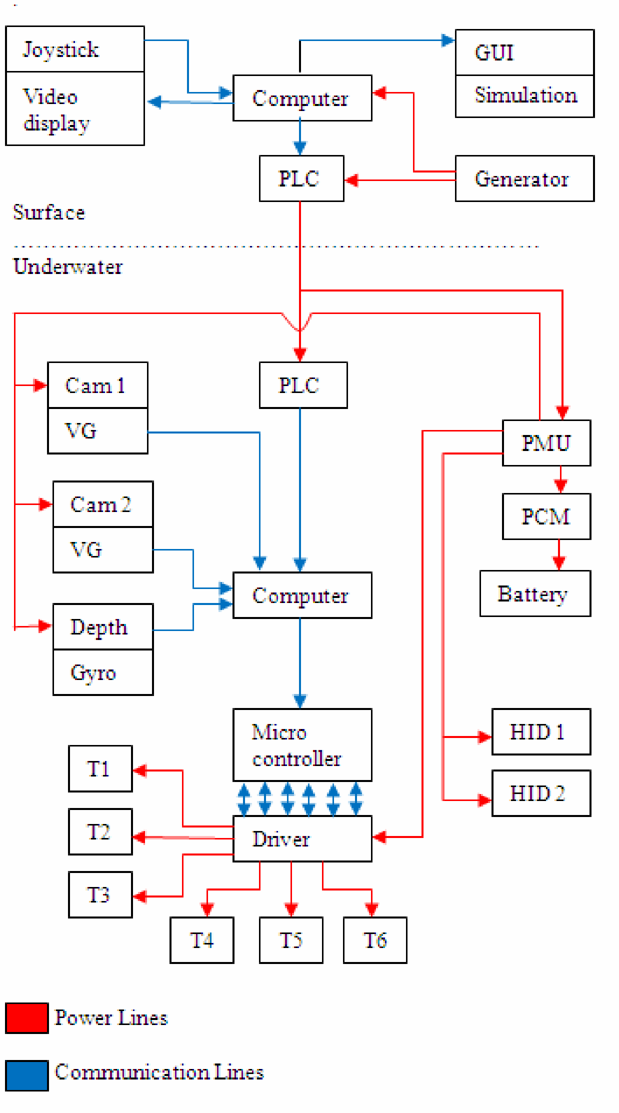


Figure 9: Electrical Interconnection between Devices

Surface Interconnection

On the surface station, two computers are being used for monitoring and control. These computers are independent from each other and possess two different IP address. Two IP addresses are for communicating with two pairs of PLC modem. On control computer, a joystick controller is attached through a USB port, to execute any desired motion. The signal form the joystick controller is sent to the control software to be processed and proceed by broadcasting the control signal to the on-board computer inside the mini-ROV through the PLC network connection. The control computer also installed with simulation software to simulate the mini-ROV condition. In the monitoring computers, a GUI is installed together with video software to monitor the video information from the vehicle. Both computers are having power from generator, which become the power source for the PLC to establish network connection through cable between the surface control station and the Main Control Unit inside the mini-ROV.

On-board Interconnection

Inside the mini-ROV, all devices interconnection are packed inside the Main Control Unit (MCU). The supplied power will enter the Power Management Unit (PMU), in which distribute them to the respective device that acquire power. Form PMU, the PLC modem tapped the power line connection to acquire the network connection. Video grabbers are connected to the computer by USB port while sensors are connected to computer serial port. Communication module for motor driver received control signal from parallel port, where at the same motor drivers are loaded with high current voltage, ready to burst into thrusters. Outside the vehicle, wet mateable connectors are connecting thrusters from the inside out. HID lights are controlled directly from PMU, just by switching from the joystick controller. Battery with Protection Circuit Module (PCM) is charged by PMU and serves as power supply for failure mode.

Further Works

There are numbers of improvement can be made towards in future. First improvement is to make a more reliable, high pressure sustainable enclosure to house the main control unit. The buoyant material can be improved instead of using the polyurethane block because it cannot sustain high pressure. The tether used in the project is not neutral buoyant in nature. Thus some modification is needed to make the tether neutral buoyant. Without neutral buoyancy, the cable is causing drag to the vehicle and is affecting the vehicle motions.

Conclusion

In this paper there are discussions about the mission strategy and planning, which briefly explain the objective and system design and description. The discussion expands to several modules in the mini-ROV such as vehicle design, devices in the Main Control Unit (MCU) and sensor module. The discussion also covers the vector configuration of thrusters applied in the propulsion system. Throughout the paper, we have seen which modules are integrated to achieve a complete fully operational Mini-ROV system. Control is established using Power Line Carrier and is presented in different paper.

Acknowledgment

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