https://doi.org/10.36375/prepare_u.iei.a116

Design and Development of Underwater ROV for Dam Inspection

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Abstract - India is a developing country that relies heavily on agriculture. A large number of dams have been built to store water and use it when it is required for agriculture. Physical inspection is currently performed outside of the dam, but it is not done efficiently inside the dam due to a lack of technology to reach the bottom of the dam and the wall inside the water. Keeping those criteria in mind, this project has created a vehicle (robot) that can dive into the dam water and take video and possibly photographs to verify the consistency of the wall's condition. This system includes a camera for capturing damage and estimating the need for wall reinforcement. It helps to identify the weaker or damaged part of the dam wall. Outside the Dam, a monitoring system is installed to collect data from the ROV and determine if additional action is required for additional inspections. Since there isn't enough light in the deeper parts of the dam, lighting is needed. It is recommended to have a small pump to get the water so that the consistency of the water can be checked at any time. This vehicle can assist the community in maintaining high-quality water in a dam for human consumption while reducing the risk of human injury during an inspection.

Keywords – Robot; ROV; Underwater vehicle; Unmanned; Inspection; Image processing;

INTRODUCTION

Humans are aware that our planet's water surface is larger than its land surface. The water surface covers approximately 36 crore square kilometers, accounting for roughly 3/4 of the total surface area of our earth. As a result, maintaining this massive flow of mass is critical, as this massive flow of mass can not only sustain the Earth's vegetation and atmosphere but can also kill them in a fraction of the time if let loose. Dam building is one method of preserving these masses. India, as a developing country with approximately 5334 dams, is heavily reliant on water supplies for agricultural production. This number is subjected to increase as time progresses. Humans are unable to inspect these dams manually because they are not only time-consuming but also carry a risk factor. As a result, both government agencies and private firms are developing advanced autonomous vehicles to operate remotely i.e., ROV (Remotely Operated Vehicle).

The electric power from the source is distributed among the vehicle's components in ROVs. In general, all ROVs are equipped with cameras and the ability to sense the images captured. The vehicle dynamics and structure, as well as ML, are the two key broad aspects that are discussed in this vehicle. In this research, the structure of the vehicle is made of PVC water pipes. These materials, on the other hand, cannot withstand sudden and significant impacts, but they are lightweight and are efficient for buoyancy.

Darryn Sward, Jacquomo Monk, and Neville Barrett [1] described that the spatial scale and length of stresses on marine environments The type of ROV method used tends to be a good predictor of the types of surveys that can be used in studies as well as the performance of ROV deployments. They discovered that the ROV is the best tool for more research after discovering subtle yet significant gaps in the use of ROVs as a tool for visually surveying deep-water marine environments. D. Yoerger et al., [2] described that a remotely operated vehicle (ROV) supervisory control system prototype is represented. Supervisory control is a paradigm for human-computer collaboration. The supervisory control system is broken down into many main components. It has a monitoring capability for evaluating performance and detecting undesirable changes, as well as an interface that enables the human operator and the computer system to jointly determine the desired vehicle trajectory.

Rahimuddin, Hasnawiya Hasan, Haryanti A Rivai, Yanu Iskandar [3] said that with the discovery of more oil supplies, underwater activities have increased. Engineers are looking for oil and gas deposits in deep water due to a disparity between demand and supply. On the other hand, the high risk of operating in a deep underwater environment will put humans in danger. As a result, several research activities are creating underwater vehicles, such as ROVs (Remotely Operated Vehicles), to replace human labor. Luis Govinda García-Valdovinos et al., [4] said that underwater remotely operated vehicles (ROVs) are used for a variety of shallow and deep-water missions, including marine science, oil and gas extraction, mining, and salvage. In the case of automatic control, acoustic and inertial sensors provide state input to the ROV, which is used in conjunction with a controller strategy to perform tasks such as station-keeping and auto-immersion/heading, among others.

Rui Nian et al., [5] described that for ocean surveys, fish ethology is a promising discipline. One ROV-based system

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is developed to execute the underwater task tasks using customized sensors. The use of homomorphic filtering and wavelet decomposition to create underwater imaging models is the first use of one image quality enhancement tool. To gain a better understanding of fish behavior. The simulation results show that the built scheme performs exceptionally well in terms of both robustness and effectiveness. Santiago Rúa1 and Rafael E. Vásquez [6] said that this paper aims to create a simulation of the underwater remotely operated vehicle Visor3's low-level control system. Visor3 presents its 6-DOF mathematical model using two coordinated systems: Earth-fixed and body-fixed frames. The extended Kalman filter (EKF), which uses the model's linearization to estimate the current state, is used to create the nonlinear model-based observer. Simulink® simulations are used to verify the behavior of the observer. A trajectory that explains shifts in the and yaw components were used in an experiment. Two algorithms are contrasted to accomplish this task: a multiloop PID and a PID with gravity compensation. The Visor3 6-DOF mathematical model is used to evaluate these controllers and the nonlinear observer.

F.A. Azis, M.S.M. Aras, M.Z.A. Rashida [7] made sure that unmanned Underwater Remotely Operated Vehicle (UUROV) issue identification is investigated and described in this paper (ROV). After researching many literature reviews and study events, the following is the issue identification that was discovered. The major problem statements, such as control system, underactuated situation, pose recovery or station holding, coupling problems, and communication technique, will be addressed in-depth in this article.

DESIGN REQUIREMENTS FOR THE DEVELOPMENT OF ROV

Since the design requirements apply to a particular problem statement and the product. The method, or experience that design specifications for one project can vary from those for another. While designing any product or service, the designer must have the vision of the product, the price, the scope of the product, and the time period to complete the task. It must eventually, aims for the complete product with quality and results with higher accuracy. The Engineer in marketing, electrical engineering, mechanical engineering, and software engineering all share a common vision and set of priorities for the targeted requirements in each project. Each engineer would be able to comprehend the specifications and set practical goals for the end product. Considering the importance of the underwater ROV, some points were listed which need to be taken care of while designing the ROV for underwater operations

A Quick Deployment

Underwater ROVs can be deployed at any time due to their lightweight nature and simple technology. Since ROVs are often deployed at a moment's notice, this is a must-have feature. This enhancement also has the benefit of saving time. This is particularly useful in an emergency to speed up the work for fast completion. It should be easy to deploy in an emergency case without any delay and it can help cases where the human divers cannot reach.

B Minimal Maintenance

As this product is used in unwater water, maintenance is a serious issue when compared land operated ROV. It must have been designed to withstand the harsh water quality and always water environment. As a designer, better to select the suitable material to withstand the maximum period to stay in the water.

C Video Recording Capability

The ROV takes a picture using a camera and video recording capabilities are the impressive features as part of the functions. To ensure hassle-free use of these machines, the ROVs must have some essential qualities, one of which is image and video capture. It is capable of producing high-resolution video, with a resolution of 5Mp in our case. An ROV can be deployed in dark and muddy waters to capture data, which can then be checked for evidence and results later.

D Fit into Confined Areas

An ROV will maneuver and inspect small and difficult-to-reach areas depending on their size. This feature allows the ROV to capture detailed information in small, isolated areas. When gathering data that would otherwise be unavailable to divers, this will act as an added advantage to research studies.

E Safety

ROVs provide a safe way for divers to explore risky environments, whether from the shore or in the water. An ROV can be used to capture remains and data in underwater locations. This can be controlled from the shore as well as by divers to closely look at any specific issue at any specific location.

F Easy to Use

A handheld controller is commonly included with mini ROVs, which significantly reduces the learning curve. Every machine that is invented or manufactured must be user-friendly and simple to operate. The same is true of ROVs. It can take as little as a few minutes to become familiar with the controls, a few hours to become competent at piloting, and a weekend to become an expert.

G Cost Effectiveness

For any product, it must be cost-effective to reach the entire society to get benefits. Though some products are meant for the common application, as an Engineer, the product designed must be cost-effective. The failure of the product does alone with technical failure. There are cases when the product gets failed because of the over price and high materials which are not necessary in some cases.

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MODELING AND DESIGN

For any product, after estimating the parameters of each part, it is better to design and see that it looks as per our expectations for the product. Once the modeling is done and the redesign can be executed for further improvement based on environmental factors such as smooth flow, reduction of resistance, and less energy consumption for a voyage. Therefore, any product, modeling, and designs are very important. Additionally, the product life cycle was planned as per figure 1 which includes from design to testing with enhancement.

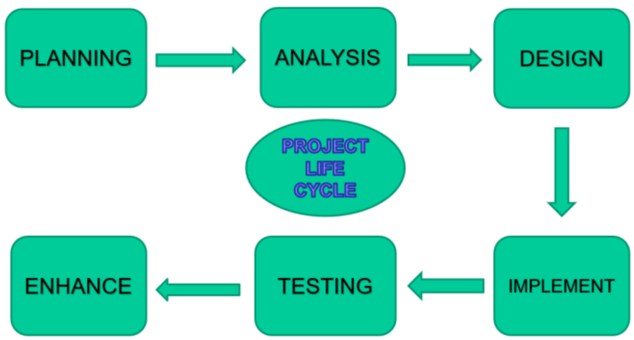

Fig-1: ROV life cycle

A Modelling

The remotely operated vehicles are planned to use underwater operation where the hydrodynamic flow plays a major role in energy consumption. Considering that each part has been designed to reduce the drag force, refer to Figure 2. Four propellers are planned to use which are place on top of the ROV surface which helps to move the vehicle up and down. One propeller is fitted behind the vessel to move forward and back by changing the direction of the propeller.

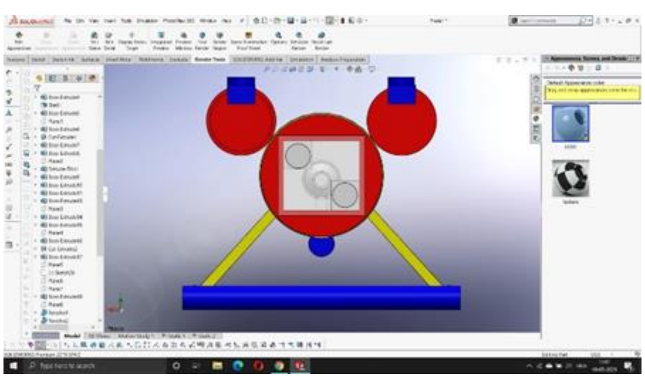

Fig-2: Modelling of ROV

Three-cylinder is used where the middle cylinder part is to accommodate forward and backward propeller placement. Another two-cylinder is used to place the four propellers for up and down motion. In addition to that, these two cylinders are provided for buoyancy purposes. While estimating the length of the cylinder, total buoyancy was estimated, and accordingly, cylinder volume was calculated. The difference between buoyancy force and self was maintained with a difference of less than 5%. So that it can be operated for less energy consumption. To place in the normal surface, leg type of support is provided, refer to figure-3. For modeling purposes, Solidworks software is used.

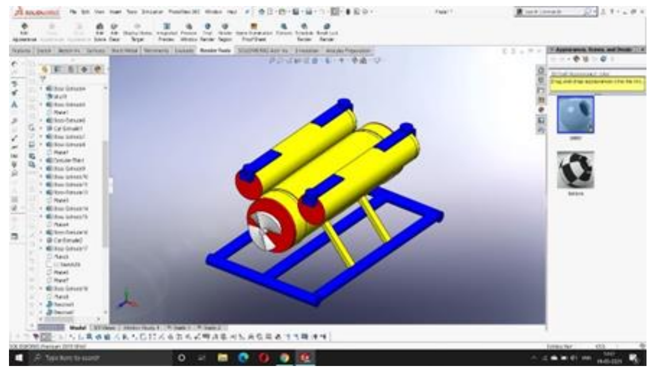

Fig-3: Overall view of underwater ROV

Solidworks were used to create the designs for this project which allows creating 2D and 3D diagrams. It is one of the most widely used CAD platforms, its user-friendly interface and easy-to-understand functionality that can be used for design creation. In comparison to other leading CAD tools on the market, the learning curve is shorter.

B Design

Three cylinders for the buoyancy force and supporting member to place on the normal surface are designed. The thrust required for the forward motion and heave motions are estimated and then the propeller was selected from the market. This ROV is designed to use to identify the crack at the Dam wall which is happening as image processing from the taken picture. There is a program written to process the images which can easily identify the crack. Using the development, any Dam can be saved from the risk factor. It also helps to reduce the risk to humans. As it was discussed, four propeller/thrusters are placed at the side cylinder and one propeller/thruster is placed at the mid cylinder which is used for the forward motion of the vehicle, refer to figure 4.

As an Engineer, the selection of material is equally important as design. For the underwater operation, always better to reduce the power consumption. For some of the ROV, only battery power will be used. In that case, power consumption must be very low which can reduce the operational period of the ROV. Keeping that in the design criteria, plastic material is selected and at the same time, the availability of material is also checked. Based on the market availability and cost estimation, plastic material is used for body construction. When it is targeted for

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commercial purposes, then better material can be used for the long life of the vehicle.

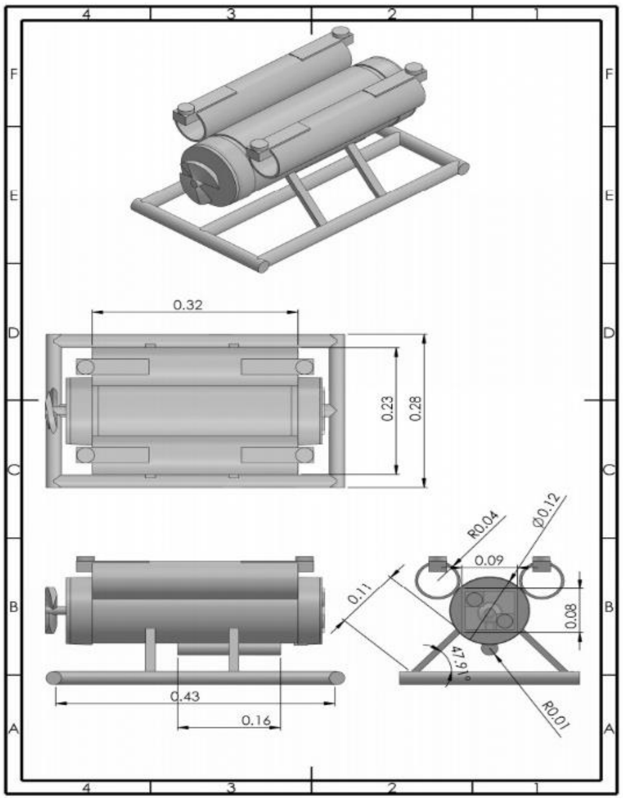

Fig-4: Measurement of underwater ROV

After the completion of modeling based on the design, the total weight was calculated and revised buoyancy force was estimated. All values are within the acceptable range and the final designed ROV is shown in figure 5.

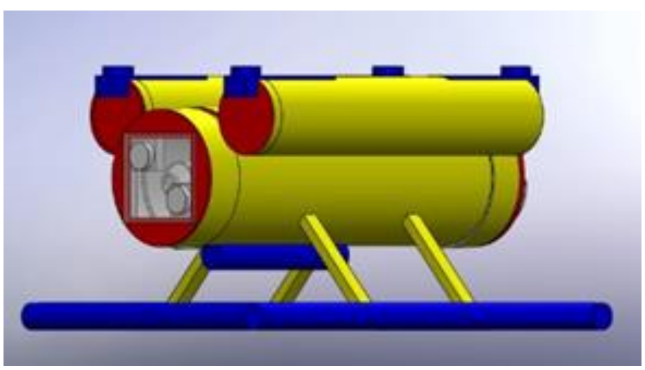

Fig-5: Isometric view of ROV

FABRICATION AND TESTING

The required ROV module, as well as the remote controller, has been built and configured. The necessary parameters are tested and validated, as well as the wiring and connections.

Fig-6: Fabrication of underwater ROV

When the ROV module is operated by the remote controller, the blades are tested for free rotations in both clockwise and anticlockwise directions. As a result, the ROV module is built to the dimensions mentioned below.

Fig-7: ROV front view

The crack detection module via the camera is checked for the required output. The crack detection module works in the given environment and the output is displayed.

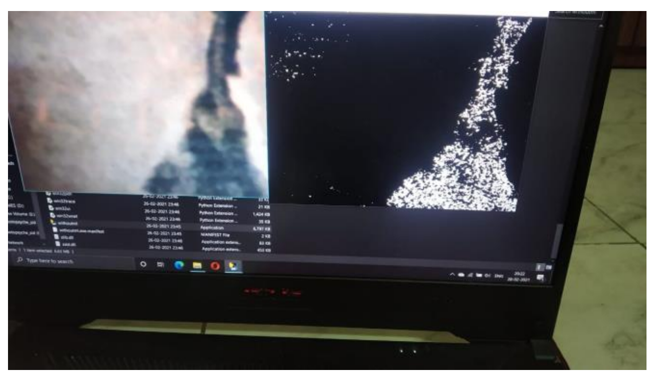

Fig-8: Crack detection module

CONCLUSION

Water plays a very vital role as an impeccable resource not only for agricultural purposes but also for important economic activities of a country. So, preserving this and storing them for future purposes via a dam is an undeniable fact. Dams cannot be always strong. It is subjected to distortions and disturbances as water along with other minerals reacts. Manual inspection of dams can be one solution to this problem. But with the kind of risk that is tagged along with it makes it a solution that needs to be reduced. It is to be noted that there have been more than 4000 large dam failures throughout the world from the year 2010. The kind of livelihood destroyed is immense. So, the need for an advanced autonomous vehicle like ROV would help reduce these mishaps in the future. Developed ROV has the potential to move to the depth of 50 m and it can be extended further by improving the body material of the ROV. It was tested for a small tank and it can easily identify the crack which can help to reduce the risk of the dam. Programming is developed to do image processing of the photo taken using the camera to identify the crack. The developed underwater ROV can help society to safeguard the dam in our nation.

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