LOW COST ROV FOR HYDRAULIC MEASUREMENTS AND NAVIGATION WITHIN THE CANALS/RIVERS

Nagla KS
Department of Instrumentation and Control Engineering
Robotics Lab., Dr B. R. Ambedkar National Institute of Technology,
Jalandhar, (PB) INDIA
ksnagla@gmail.com

MoinUddin
Department of Instrumentation and Control Engineering
Robotics Lab., Dr B. R. Ambedkar National Institute of Technology,
Jalandhar, (PB) INDIA
prof_moin@yahoo.com

Dilbag Singh
Department of Instrumentation and Control Engineering
Robotics Lab., Dr B. R. Ambedkar National Institute of Technology,
Jalandhar, (PB) INDIA
drdilbag@gmail.com

ABSTRACT

This paper presents the design methodology and kinematics of the low cost ROV designed for measurement applications within rivers and canals. Monitoring under water is a desirable parameter for various applications like recovery of the object, search and rescue operation, marine research, underwater station keeping for parameter measurement (Velocity and depth of water) and observations of cracks in dam etc. In the first part of the paper, various underwater environment monitoring techniques have been stated. The second part deals with the design methodology and kinematics of Robot. Feasibility analysis to the vision and flow measurement instruments had been presented in the third part. The developed robot is very simple, low cost and rugged in structure. The robot has specially been designed to monitor within the canals and rivers up to the depth of ten meters.

Keywords: Underwater ROV, Underwater Optical and Sonar Vision System, ROV Kinematics, underwater measurements

1. INTRODUCTION

Field robotics is concerned with the development of robotic tools for use in non-accessible and often dangerous environments, whether on or under land, air or sea. Automatic underwater robotic vehicles are currently receiving a considerable amount of attention around the world, as they allow all to explore the work in area which is, beyond our reach. These vehicles will now have significant importance in environment control and monitoring in aquatic agriculture and the utilization of offshore resources. Underwater robots have two main components mobility and monitoring system including imaging system. Several advance sensing technologies have been integrated to the existing underwater system. Important categories of sensors for underwater are optical vision and sonar sensing for navigation, various flow, temperature and depth technologies are in use for underwater environmental technologies.

Many sensors are directional in nature such as flew sensor. It is very difficult to continually monitor the flow in highly dynamic and turbulent behaviors of flow of water in canals and river due to its geographical and structural constraints. Hence the orientation of underwater ROV is very important for correct observation.

Sonar imaging offers a natural alternative to optical imaging. However there are several problems associated to achieve the goal of building underwater sonar cameras. It is found that the problem is the result of a combination of factors such as slow speed of sound, lack of good quality of underwater sonar lenses and the coherent nature of sonar sources. This leads to effect the scanning speed, complexity and resolution of the sonar. Unfortunately neither the optical vision nor sonar imaging system individually can perform both the tasks in different environmental situations. Due to the opacity of the water to light, the long-range visual tasks are typically better accomplished with sonar. On the other hand due to high resolution and fast frame rate video camera systems is usually used.

The performance of sonar imaging system can be determined by considering various practical criteria. Resolution is an important factor to measure. Range resolution is also an important criterion for most imaging system as it may be defined similarly as resolvable distance between two points distance in range. Additional criteria for characterizing underwater imaging system performance concern not only azimuthal resolution but also range and detection capability. Optical properties of rivers/canals not only depends upon the composition of particles already dissolved in water but also depends upon the geographic nature of river/canal i.e. crossings by fords, bridges, ferries or tunnels.

The biological organs like bacteria, phytoplankton etc. and organic materials like salt, clay etc. usually are the major determiner of both the absorption and scattering properties of water is responsible for most of the temporal and spatial variability in the medium.

The handbook of optics [1], lists the different types of water as running canal, bay, coastal and deep ocean water. A prominent feature of this list is the increase in light propagated as one moves from the inshore water to the deep ocean similar effect has been observed in canals/rivers. For under water optical imaging, it is important to consider the environmental parameters that dictate the propagation of light in water. Parameter that effects the performance of the system falls in to two categories i.e. 1). System characteristics, 2). Characteristics of the medium. It is important to choose a source of light having a wavelength that closely match with the attenuation (absorption) of the water, in which the system will be operated. It is desirable to maximize the intensity of the light in the spot on the target. Numbers of different approaches have been taken by the researches in predicting the outcome of underwater optical imaging. Underwater navigation method for artificial underwater landmark (AUL'S) which are recognized by vision system Son-Cheol YU [2] implemented in the underwater robot. CCD based vision system was introduced to improve reliability of underwater vision system.

David B. Marco [3] and others researcher from novel postgraduate school center for AUV has developed an underwater vehicle fixed with wide angle video camera is located in the nose and connected with the digital recorder. A CCD camera fitted in a canvas diving [4] bubble filled with clean water or any other suitable transparent material has been used to identify the sunk cars, buses or boats in shallow water.
There are large numbers of commercial underwater imaging systems ranging from hand held cameras to sophisticated underwater video cameras, which are integrated with light on a single platform. Naval postgraduate school center for AUV, Montery [5] has used an advanced system in AUV, a fixed focus wide angle video camera is located on the robot which is connected to recorder. The image has been produced by interfacing camera with computer. Ura labs [6] used a single CCD camera and an acoustic sensor to determine the relative positioning of the underwater cable with respect to the AUV in 3-dimentional space.
Oceanographic expedition in Black Sea [7] completed the task with two different robots consisting of both sonar and CCD imaging system. Center for costal and sea mapping Durhan, USA used video imaging mosaicing [8] where a good quality of image has been acquired by using sequential video frames to construct a video mosaic map from which multi-scale measurement has been achieved. [9,10] Have used more sophisticated hardware and software.

There has been significant recent progress in underwater vision system using sonar. Ocean bottom mapping, detection of objects, localization of targets, tracing of the targets and estimation of rainfall etc, are required a particular form of sonar. High resolution images are required for several applications . Sonar's [11] like side scan ,multi beam ,Bathymetric, Doppler, Chirip sonar, SAS (synthetic aperture sonar) ,SAR (synthetic aperture radar) has been extensively used. Sonar with increased resolution [12] including the lower frequencies are used by NATO SACLANT undersea research center within a multinational joint research program for underwater mine detection.

Recently space born SAR,s (Synthetic aperture radar) [13] have demonstrated the ability to obtain high spatial resolution image on which bathymetric features could be identified and provided the potential of surveying shallow water bathymetry independent of weather conditions. Thus methods for surveying shallow water, bathymetric by SAR or SAS has been studied extensively [14]. Several variations exist which allow not only bottom reflection but also bathymetry [15]. Geophysicist, geologists, archeologists, marine biologists and physical oceanographers have used high precision acoustics survey. GLORI-B [16] A deep side scan sonar surveyed device which is able to produce bathometric measurement and images of sea floor up to 30km wide has been used. Others used Chirp side scan sonar [17,18] which utilizes pulse comparison techniques to produce long transmission pulses and achieves long range without resultant decrease in across-track resolution. Finally it is observed that there are five generations of side sonar technique which is currently available [19] as shown in table 1.

Table 1.Generations of Side Sonar

1^{st} generation	Analog electronics, single beam acoustics.
2^{nd} generation	Hybrid analog/digital electronic, single beam acoustics.
3^{rd} generation	Digital electronics, single beam acoustics
4^{th} generation	Digital electronics and multi beam acoustics
5^{th} generation	Digital electronics and synthetic aperture acoustics

2. VEHICLE DESCRIPTION

Description of main hardware components of underwater remote operated vehicle is given as follows.

2.1 Dimensions and Endurance

The weight of vehicle is 55kg. and is approximately 1.37 m long, .457 m wide and .610 m in height. A steel pipe is used to construct the frame of the vehicle. Two air tight leak proof fiber barrels of diameter 15.24 cm with length of 1.22 m has been fixed over the vehicle. The central part of the vehicle is fitted with the flood light, CCD camera and two flow transducers. Blade thrusters with one HP motor is used to provide the thrust in forward direction only. The uplift and sink motion of the robot has been controlled by using air tube fitted over the robot. The air inside the tube is controlled manually in order to reduce the cost. The Robot has been primarily designed for shallow water operations and can operate safely down to the depth of 20 meter. However, the vehicle may attain more depth with increase in the length of control cable.

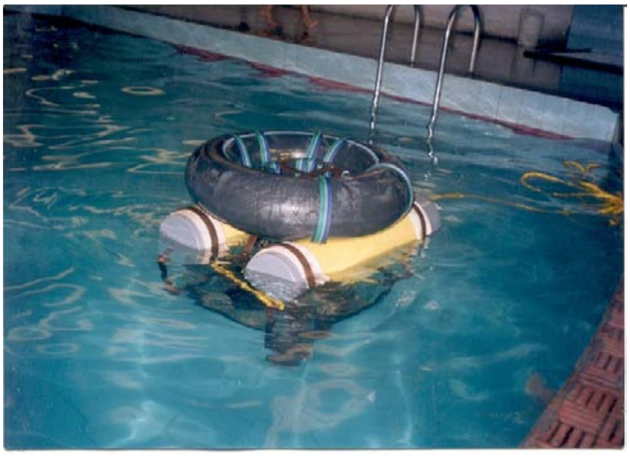

Figure 1 Underwater Robot in operation

3. KINEMATICS ANALYSIS

Kinematics has been obtained as the robot is placed in the canal and it is operated from ground station situated on the edge of the canal. The detail of the kinematics have been given in [20] The kinematic motion of the robot is shown in figure 2. Thus the basic transformation matrix T for the robot with respect to the co-ordinate frame $\begin{bmatrix} n & o & a \end{bmatrix}$ is written as

$$T=\begin{bmatrix} nx & ox & ax & dx \\ ny & oy & ay & dy \\ nz & oz & az & dz \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (1)$$

Where d is translation of robot, the orientation of the robot is specified by the 3×3 rotation sub matrix R

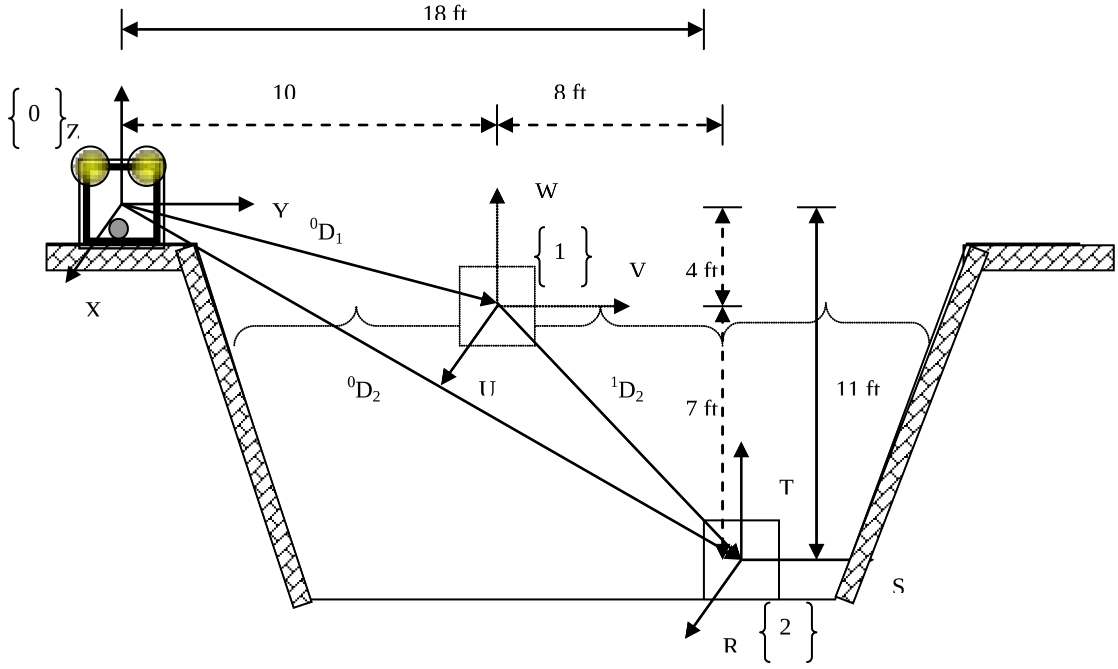

Fig. 3 Cross-section view of the canal and robot position

$$R=\begin{bmatrix} \hat{x}.\hat{u} & \hat{x}.\hat{v} & \hat{x}.\hat{w} \\ \hat{y}.\hat{u} & \hat{y}.\hat{v} & \hat{y}.\hat{w} \\ \hat{z}.\hat{u} & \hat{z}.\hat{v} & \hat{z}.\hat{w} \end{bmatrix} = \begin{bmatrix} nx & ox & ax \\ ny & oy & ay \\ nz & oz & az \end{bmatrix} \qquad (2)$$

The translation from frame {0} to frame {1} is given by following relation

$${}^0T_1=\begin{bmatrix} 1 & 0 & 0 & dx \\ 0 & 1 & 0 & dy \\ 0 & 0 & 1 & -dz \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (3)$$

The translation from frame {1} to frame {2} is given by following relation

$${}^1T_2=\begin{bmatrix} 1 & 0 & 0 & du \\ 0 & 1 & 0 & dv \\ 0 & 0 & 1 & -dw \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (4)$$

For translation from frame {1} to frame {2}is given by following relation. The overall translation will be achieved by following relation

$${}^0T_2={}^0T_1\times{}^1T_2 \qquad (5)$$

$${}^0T_2=\begin{bmatrix} 1 & 0 & 0 & dx+du \\ 0 & 1 & 0 & dy+dv \\ 0 & 0 & 1 & -dz-dw \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (6)$$

This is the final transformation matrix for underwater robot.

3.1 Case Study

The objective of the case study is find out the performance analysis of navigation in the canal and measurement of flow of water at particular point of interest. The cross section view of the canal is shown in figure 3. The transformation here shows the translations of robot from frame {0} to frame {1} and from frame {1}to frame {2} and the vehicle is rotated by 45 degree angle. Substituting the values in equations (6) we get the following results

$$^{0}T_{2}=\begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 18 \\ 0 & 0 & 1 & -11 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (7)$$

This is the final transformation for our case when the robot is 18 feet away from canal edge and at11 feet depth in water.

4. RESULTS AND CONCLUSIONS

We performed an experiment in canal to achieve the reasonable results. The depth of the canal observed to be nearly 18 feet. The following experiments have been performed.

- Observation of image quality by varying the angle of light source and camera
- Observation for flow under water
- kinematic analysis

With results we found that the quality of the image depends upon the angle of the flood light and camera. It also depends upon the nature of the water. The results have shown some errors in muddy water. The error has also been observed during flow measurement due to the wrong orientation of the vehicle. The flow measurement station keeping required the ROV to stationed parallel to the flow.

A desired survey of the present status of the underwater imaging techniques has also been done. It is very clear that the range of underwater light optical system is very low as compared to sonar based navigation system. However the advantages of optical imaging systems are available of high resolution and high frame rate but it is low in cost In order to increase the ranges some more sophisticated optical system will be required to be used. Optical imaging system is lagging behind the sonar imaging due to long range and some other associate factors.

In future the ROV can be modified by adding suitable sensors and there is large score in research for dynamic analysis and control of the ROV.

REFERENCES

[1] Michael Bass Editor; Handbook of Optics Vol. 1. Edition 1995.

[2] Son-Cheol YU “navigation of autonomous underwater vehicles base on artificial underwater landmark” IEEE proceeding pp 409-416.

[3] Marco, D.B“Current developments in underwater vehicle control and navigation” OCEANS 2000 MTS/IEEE Conference and Exhibition , Volume:2,11-14,Sept.2000, Page(s): 1011 -1016 .

[4] Botelho-Ribeiro, L.; “Underwater development methods for low visibility turbulent conditions” OCEANS, 2001. MTS/IEEE Conference and Exhibition , Volume:2,5-8Nov.2001,Page(s): 1080 - 1084 .

[5] Marco, D.B.; Healey, A.J.; “Current developments in underwater vehicle control and navigation” OCEANS 2000 MTS/IEEE Conference and Exhibition , volume:2,11-14,Sept.2000, Page(s): 1011 -1016 .

[6] Balasuriya, B.A.A.P.; Takai, M.; Lam, W.C.; Ura, T.; Kuroda, “Vision based autonomus underwater vehicle navigation: Underwater cable tracking” Y.; OCEANS '97. MTS/IEEE Conference Proceedings , Volume:2,6-9,Oct.1997 ,Page(s): 1418 -1424 .

[7] Coleman, D.F.; Newman, J.B.; Ballard, R.D.; “Design and implementation of advanced underwater imaging system for deep sea marine archelogical surveys” OCEANS 2000 MTS/IEEE Conference and Exhibition,Volume:1,Sept.2000 ,Page(s): 661 -665.

[8] Rzhanov, Y.; Huff, L.; Cutter, R.; “Improvement of image alignment using camera attitude information” Signal Processing and its Applications, Sixth International, Symposium on. 2001 , Volume: 2 , 13-16 Aug.2001,Page(s): 639 -642 .

[9] Zanoli, S.M.; Zingretti, P.; “Underwater imaging system to support ROV guidance” OCEANS '98 Conference Proceedings , Volume: 1 , 28 Sept.-1Oct.1998,Page(s): 56 -60 .

[10] Santos-Victor, J.; Sentieiro, J.; “ The role vision for underwater vehicle” Autonomous Underwater Vehicle Technology, 1994. AUV '94., Proceedings of the 1994 Symposium on , 19-20,July,1994.Page(s): 28 -35

[11] Dwyer, R.F.; “advances in sonar signal processing in 90,s” OCEANS '96. MTS/IEEE. 'Prospects for the 21st Century'. Conference Proceedings , Volume:1,23-26Sept.1996.Page(s): 364 -372.

[12] Pinto, M.A.; Bellettini, A.; Fioravanti, S.; Chapman, S.; Bugler, D.R.; Perrot, Y.; Hetet, A.; “experimental investigations into high resolution sonar system” OCEANS '99 MTS/IEEE. Riding the Crest into the 21st Century , Volume: 2 , Sept. 1999 ,Page(s): 916 -922 .

[13] Huang, W.G.; Fu, B.; Zhou, C.B.; Yang, J.S.; Shi, A.Q.; Li, D.L.; **“**Shallow water bathymetric surveys by spaceborne synthetic aperture radar” Geoscience and Remote Sensing Symposium, 2001. IGARSS '01. IEEE 2001 International , Volume: 6 , 9-13 July2001 Page(s): 2810 -2812.

[14] Griffiths, H.D.; Chapman, S.; “High resolution synthetic aperture sonar: trials and results” High Resolution Radar and Sonar IEEColloquium, 11,May1999.Page(s): 3/1 -3/4

[15] Singh, H.; Pizarro, O.; Whitcomb, L.; Yoerger, D.; “In-situ altitude calibration for high resolution bathymetric survey with underwater vehicle”Robotics and Automation, 2000. Proceedings. ICRA '00. IEEE International Conference on, Volume: 2 , April,2000.Page(s): 1767 -1774 .

[16] Russell beale “deep ocean bathymetry: Image with GLORI-B proceedings of IEEE.

[17] Turgut, A.; McCord, M.; Newcomb, J.; Fisher, R.; “Chirip sonar sediment characteristics at the northern gulf of Mexico littoral demonstration center experimental site” Oceans '02 MTS/IEEE, Volume:4,Oct.29-31,2002 Page(s):2248-2252.

[18] Schock, S.G.; LeBlanc, L.R.; “Some applications of the chirp sonar” OCEANS '90. 'Engineering in the Ocean Environment'. Conference Proceedings , September 24-26,1990 Page(s): 69 -75 .

[19] William H.Key “Side scan sonar Technology” OCEANS 2000 MTS/IEEE Conference and Exhibition , Volume:2,11-14Sept.2000 Page(s): 1029 -1033.

[20] Hyungwon Shim, Bong-Huan Jun, Pan-Mook Lee, Hyuk Baek, Jihong Lee, “Workspace control system of underwater tele-operated manipulators on an ROV”Ocean Engineering, Volume 37, Issues 11-12, August 2010, Pages 1036-1047.