Application of Autonomous Underwater Vehicle for civil structure inspection

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Contents

Introduction

- Bridges that cross waterways often have foundation and substructure elements located in water to provide the most structurally stable design
- To ensure safety of the bridge, It is important that the entire bridge is inspected at a specified interval
- Unfortunately, the conditions of substructure and foundation located below the waterline are not as easily determined as the environment under water is harsher and affects the inspecting official's mobility and visibility
- Some sophisticated technological innovations like remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and under-water manipulators can be used for this purpose
- Autonomous Underwater Vehicle (AUV) is a pre-programmed vehicle that performs a variety of tasks as required in various fields
- Some of the tasks are- Underwater target acquisition, underwater mine detection, cleaning ocean garbage, cleaning oil spills, etc.
- But still, AUVs are not widely commercialized due to many open problems. One such problem is vehicle localization or the means of knowing AUV's own position

Objective

The primary aim of the research work is

- To develop and validate dynamic model of an AUV.
- To determine hydrodynamic coefficients by test or by predictive method.
- Identifying objects from their features, and measuring distance of the object from the AUV.
- To develop and validate localization algorithms using inertial and velocity measurements.
- Path planning and developing control strategy.
- Inspection of underwater civil structure

Literature review

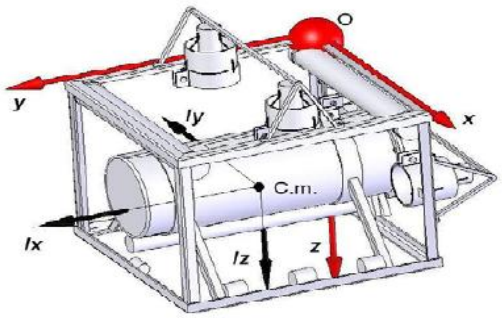
In an unknown environment, localization and path planning are two important tasks for navigation of unmanned system.

- To increase the applicability of the sensor information, many researchers have combined various types of sensors to achieve better localization and navigation results (Bison et al. (1997)).
- Different types of localization for an AUV using odometry from DVL data, INS data or by using optical data through cameras can be found in Durrant-Whyte and Bailey (2006), Bailey and Durrant-Whyte (2006).
- Rawlinson and Jarvis (2008) considered the map as topological instructions and the database of the nodes with the corresponding motion.
- Based on the given map of the environment, Bhattacharya and Gavrilova (2008) used the Voronoi diagram for path planning and smooth the path for better obstacle avoidance by iterative refinement.
- Stutters et al. (2008) stated that geophysical enable methods are helpful to localize and navigate AUVs over large operation areas.
- Binney et al. (2010) developed a path planning method for AUVs by generating near-optimal paths from the predesignated time intervals so as to maximize mutual information.

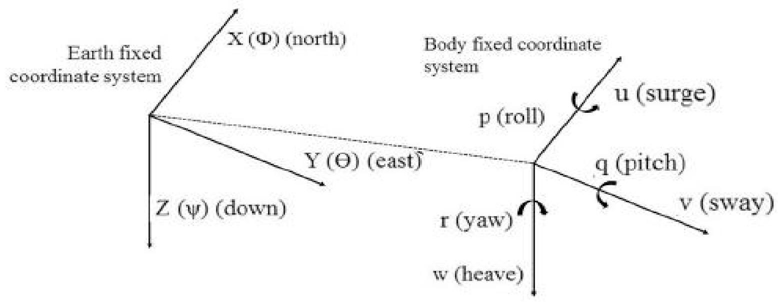
Kinematics and Dynamics

Kinematic model of a robot is the mathematical correlation between the inertial, non-inertial frame and links of a robot which describes the position, velocity and acceleration of different parts of the robot with respect to some frame of reference.

Dynamic model correlates forces and moments with the position and velocity of the robot.



Underwater vehicle



Reference system

Kinematics and Dynamics

The interaction between the motion of an AUV and different related forces and torques can be expressed as:

$M\dot{v} + C(v)\, v + D(v)\, v + g(\eta) = \tau$

where $M = M_{RB} + M_A$; M_{RB} and M_A are the constant inertia and added mass matrix of the AUV respectively,

$C(v) = C_{RB}(v) + C_A(v)$; $C_{RB}(v)$ and $C_A(v)$ are the Coriolis and Centripetal matrix of the rigid body, and the added mass respectively, $D(v)$ is the Damping matrix containing drag and lift terms, $g(\eta)$ is the vector of restoring forces and moments which includes gravitational and buoyancy forces, and τ is the vector of body fixed forces from the actuators.

DOF	Motion Descriptions	Positions and Orientations	Linear and Angular Velocities
1	Motions in the X-direction (surge)	X	u
2	Motions in the Y-direction (sway)	Y	v
3	Motions in the Z-direction (heave)	Z	w
4	Rotations about the X-axis (roll)	ϕ	p
5	Rotations about the Y-axis (pitch)	θ	q
6	Rotations about the Z-axis (yaw)	Ψ	r

Development of localization algorithm

- One way for identifying AUV's position autonomously is by identifying objects lying on the floor of ocean or some other objects in underwater environment. Measurement of AUVs position relative to a known position of landmark is involved in the process.
- The problem can be formulated as a filtering/estimation problem of the AUV states of which position of a landmark is one among others.
- With the model and measurements available, a Bayesian filtering method will be adopted first to find the AUV position.
- The nonlinear dynamic/kinematic model may be linearized around an operating point and a filter can be developed based on the linearized model.
- If the linear approximation of the model is well behaved and system and measurement noises are Gaussian, the estimation of solution to the localization problem (with respect to landmark) can also be solved by Kalman filtering (Extended Kalman filtering (EKF)).

Underwater inspection using sonar

- Sonar is a device that detects the distance of a target by a sound wave. Since electromagnetic wave is transmitted faster and farther than sound wave in the air, radar is capable of detecting ground and marine object, and corresponding equipment for underwater use is sonar.
- Sonar is a common technique that has been put to practical use. There are various types of sonar such as single/multi beam side scan sonar (SSS), synthetic aperture sonar (SAS) and ultrasonic cameras (image sonar) depending on the operating method, number of beams and processing technology.
- In the case of underwater survey and underwater structure inspection, the scan zone is post-processed to obtain three-dimensional images and survey data in the water.
- A detail inspection requires image processing capability. It involves feature extraction and feature comparing capabilities.

Cont…

- Depending on the application, the detailing of the feature is required. So once the images are obtained from sonar, they will go through image processing.
- Initially, this part will be started with shape and size of the image sent to the memory of AUV. This image will be used as a real time object detector, artificial intelligence techniques like supervised learning are incorporated for the smooth developing of optimized data filtering.
- This type of smoothing of data helps the AUV to perform logically in inspecting the underwater object.

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THANK YOU