Autonomous Underwater Vehicle control

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Abstract

In this paper the system control design stages for an autonomous underwater vehicle are presented. The vehicle must be able to sail on sea surface, following a path without losing its route and once a position is reached, a dive following a perpendicular path to the surface is carried out. A two level system control are proposed. The primary level will control the navigation of the vehicle where a linear controllers are proposed. Whereas in secondary level guidance system, collision system, start, stop and abort mission events will be ordered by neuro-fuzzy control.

The implementation of these algorithms will be supported by a Motorola Coldfire family microcontroller (MCF5272).

1. Introduction

In order to specify the vehicle dynamic behaviour in a fluid environment is essential to have a coordinate system.

An autonomous underwater vehicle according to [1] can be considered as a rigid body with six degrees of freedom. Therefore, in order to represent its motion six independent coordinates will be needed, they are represented in figure 1.

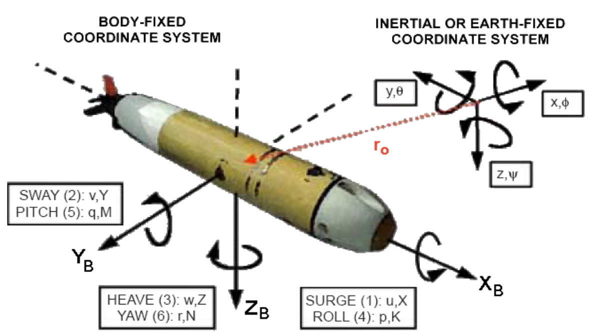

Figure 1. Body-Fixed and Internal Coordinate Systems

The surge, sway and heave motions are represented on XB, YB and ZB axes placed on the vehicle. Whereas roll, pitch and yaw motions are represented on the reference inertial coordinate system placed on ground.

Table 1 summarizes the nomenclature used in [2] for describing the underwater vehicle motion, forces and moments.

Translation	Force	Linear Vel.	Position
Surge	X	u	x
Sway	Y	v	y
Heave	Z	w	z
Rotation	**Moment**	**Angular Vel.**	**Angle**
Roll	K	p	Φ
Pitch	M	q	θ
Yaw	N	r	ψ

These motions, forces and moments defined, in section 2 giving rise to the basic equations of the marine vehicle model. Section 3 defines the navigation and control system structure proposed. Finally, section 4 justifies the implantation of different control algorithms.

2. Model Representation for underwater vehicles.

In order to carry out the control system design, first, it's necessary to have a hydrodynamic model of the vehicle.

Model representation for underwater vehicles is based on Newton's fisrt law:

$$M\dot{v} = \sum_{i=1}^{n} F_i \qquad (1)$$

where M is the system inertia matrix (equivalent to the mass) and is the derivative of the vector formed by velocity components (equivalent to the acceleration).

$$\nu = [u, v, w, p, q, r]^T \qquad (2)$$

Components of (2) represent linear velocities due to the translational motion (u,v,w) and angular velocities due to the rotational motion (p, q, r).

The sum of all forces and moments is represented by the following vector:

$$F_i = [X_i, Y_i, Z_i, K_i, M_i, N_i], (i = 1, \dots, n) \qquad (3)$$

Starting from (1) the submarine motion dynamic equations with respect to the body coordinates system can be obtained and they can be represented in vectorial and compact form [1]:

$$M_{RB}\dot{\nu} + C_{RB}(\nu)\nu = \tau_{RB} \qquad (4)$$

where MRB is the inertia and mass matrix and CRB is the Coriolis and centripetal matrix, both due to rigid body dynamic. •RB is the external forces and moments generalized vector that is formed by the different hydrodynamics forces and moments produced by the hull motion into the water, the ones due to the control surfaces (rudders, fins, etc.), the ones generated by propulsion systems and the ones due to environmental disturbances (waves, wind and currents).

In agreement with this representation the Naval Postgraduate School of Monterey (California) has created a model for the autonomous underwater vehicle called PHOENIX [3]. This model available in Marine GNC library [4], will be the base of our research to test the control algorithms and create an adjusted model of our vehicle Cormoran [5].

3. Guidance and navigation system.

In this paper, a control system structured in two levels for an autonomous underwater vehicle is proposed. A primary level that will control the vehicle navigation through linear controllers, and a secondary level in charge of the guidance system, collision system, and the start/stop/abort events of the mission, through neuro-fuzzy controllers.

In figure 2, the proposed control structure is represented.

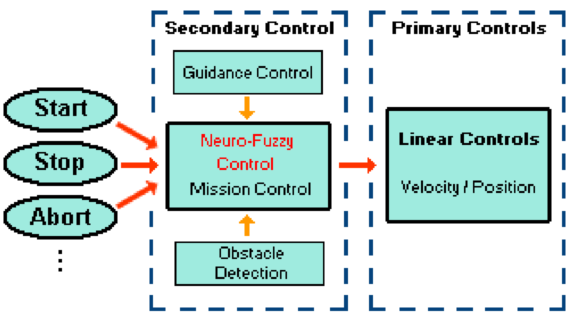

Figure 2. Control structure of an AUV.

Next, a control system proposal is presented for guidance and navigation system.

The system is bases on common ones used in marine vessels [1] and it is built of by three independent blocks identified as guidance system, control system and navigation system. These systems interact between them by transmission of several signals and data represented in the figure 3.

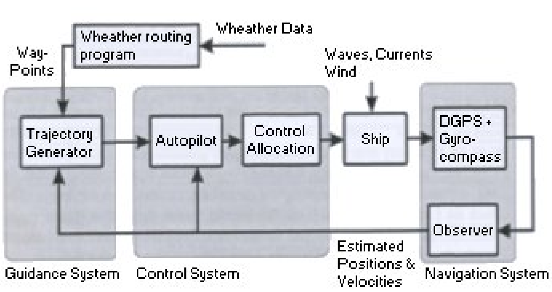

Figure 3. Guidance, Navigation and Control.

The guidance system is in charge of calculating the desired reference in every moment, position, velocity and acceleration of the submarine that will be used in the control system. The control system determines the necessary action of the forces and moments that is necessary to be provided to the submarine to satisfy the control target. Finally, the navigation system is in charge of determining the position, route, and distance covered.
This control structure implementation is carried out in the MATLAB SIMULINK environment comes given in figures 4 and 5.

In figure 4, only the primary control is represented, which uses linear PID controls for the control system, a GPS with gyroscope for navigation system and a block that simulates the disturbances caused by the wind, waves and currents

In figure 5 the module npsauv.m is presented which implements the PHOENIX autonomous underwater vehicle. This model has the following inputs: d_r, d_bs, d_bp, d_s, n and d_b, where the first four correspond to control surface deflections from the rudder, port, and starboard bow planes, and the stern plane. The remaining two arise from propeller rotational rate and buoyancy adjustment. The output model provides position, orientation, linear velocity and angular velocity vectors.

This model is only configured to realize exclusively simulations to sail on the surface and with direction changes.

4. Physical implementation.

Finally, the control algorithm implementation will be done through a Motorola Coldfire family microcontroller platform (MCF5272) [6]. This microcontroller is considered as a high speed and high performance device, in addition it is a low cost and a low power up, a relevant feature for autonomous equipment.

References.

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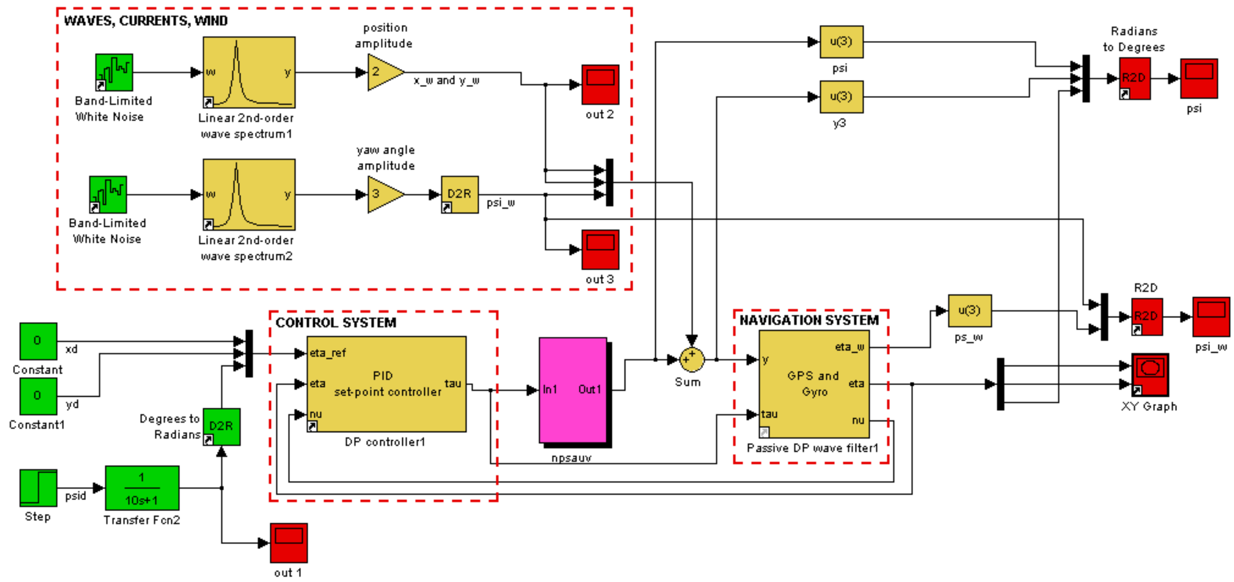

Figure 4. Primary Control.

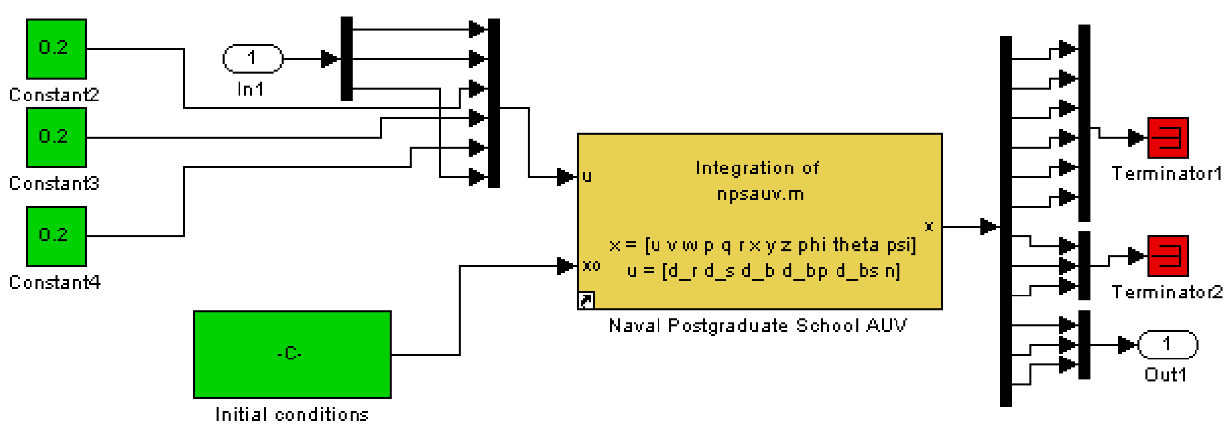

Figure 5. Autonomous Underwater Vehicle model