Obstacle detection and avoidance system for GuanayII AUV

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Abstract—*In this paper, is presented the design of an algorithm for detection and avoidance of obstacles for Guanay II AUV. The obstacle detection system is based on a sonar and its use guarantees the safe navigation of AUV. The strategy of obstacle avoidance is performed based on Fuzzy reactive architecture for different forward speeds of the vehicle. Simulation results obtained by developing the algorithms in Matlab validate the design.*

Keywords—AUV Guanay II, sonar MK3, obstacle detection, acquisition and signal processing, automatic operation.

I. INTRODUCTION

Guanay II [1] is an autonomous underwater vehicle developed by SARTI group of the Polytechnic University of Catalonia, with the objective of providing a platform for measuring different oceanographic variables such as temperature and salinity of a water column, with high spatial and temporary resolution.

The control system implemented in Guanay II allows the vehicle to follow a predetermined path navigation [2]. In [2] the hydrodynamic model of the vehicle Guanay II in 3DoF: surge, sway and yaw is obtained. This model allowed the navigation control design, which is composed by an inner loop which regulates the forward speed of the vehicle and the yaw angle. An outer loop, that perform the tracking of the route of pre-established navigation with base in the laws of Pure-pursuit and Path Following. Finally, a simulator of vehicle navigation is developed in Matlab. This work did not consider any system of detection or avoidance of obstacle, which is the main goal of the present work.

II. DESIGN OF OBSTACLE DETECTION AND AVOIDANCE SYSTEM FOR AUV GUANAY II

To guarantee the safety of the AUV, an obstacle detection and avoidance system has been developed. It includes a sonar MK3 [3] and a management module and data processing, using an algorithm implemented in LabView. This algorithm performs the communication between the control systems of the vehicle with the sonar MK3, set the parameters of the sonar, acquires, processes and makes the detection of obstacles. The detection is achieved by analyzing the area scanned by the sonar, which is configured through the parameter of scan sector (Left Angle Limit and Right Angle Limit). This area is divided into three sectors and for each of the sectors the minimum distance between the AUV and the obstacle is established.

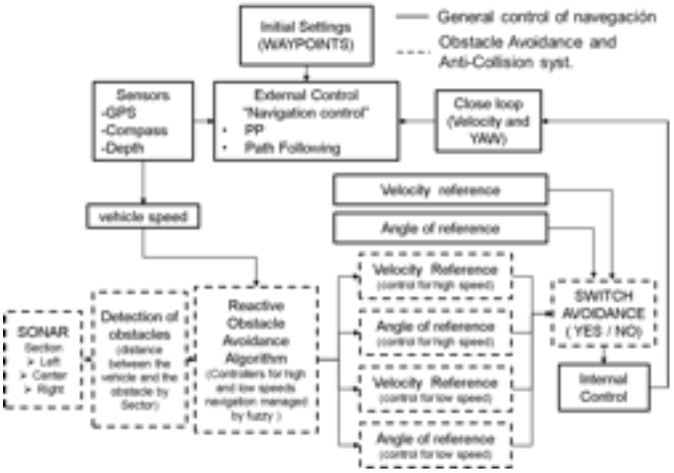
Through different tests, performed in the sea and in the laboratory and considering AUV specifications [4], we determined optimum values of the obstacle detection system. From these values we have obtained a model obstacle detection system that allows simulation in Matlab (See section III.B). Subsequently, we developed a Reactive Obstacle Avoidance Algorithm [5] [6]. That makes different control actions in function of on the forward speed of the vehicle. Controllers for high and low speeds navigation managed by fuzzy have been defined [6].This strategy allows greater maneuverability in vehicle navigation in confined spaces.

For each controller, are defined three input variables, which quantify the distance between the vehicle and the obstacle for the sector of the operating range of the sonar. These variables are called left, right, and center accordingly to the sector relative position. For each input variable there are defined three membership functions, one triangular and two trapezoidal, called low, medium and high risk of collision. The limits of the functions have been defined based on the maximum vehicle speed (1 m/s), the runtime of the obstacle detection software and the distance traveled by the vehicle during the runtime of the algorithm.

The rule base of each of the controls is composed of 27 laws and was built based on the COLREGS rules [7]. There have been defined, for each fuzzy controller, 2 output variables corresponding to the “reference direction” and the “reference speed”. The variable reference direction is composed of six membership functions of triangular type. The high speed controller has the output range between +/- 90 and the low speed control has the output range between +/- 180 degrees.

The variable of reference speed, is composed by three membership functions, one triangular and two trapezoidal with a range of 0 m/s to 1 m/s.

In Figure 1 it is depicted the control system block diagram of the vehicle, which includes the navigation system and the systems for detection and avoidance. As illustrated in Figure 1, the outer loop control is executed in parallel with the avoidance system, which in the presence of an obstacle in the path of the AUV takes control of navigation, creating new values of course and speed reference.

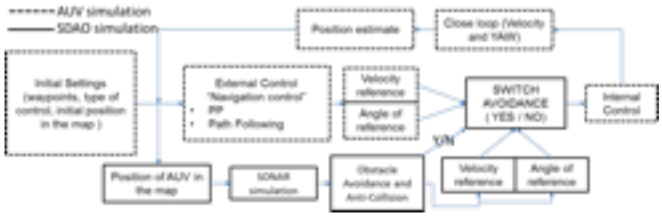


1. Block diagram of the control system of navigation and avoidance of AUV Guanay II

III. Simulation Environment Of Obstacle Detection And Avoidance System

This section describes main characteristics of different simulation environments for obstacle detection and avoidance. In Figure 2, we can see the block diagram of the simulation algorithm.

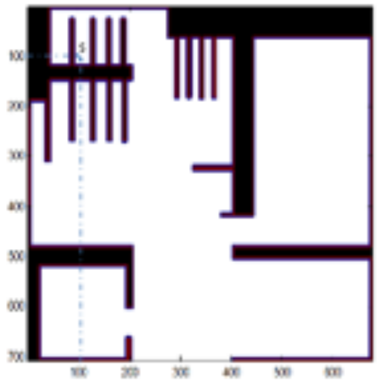
Since the Guanay II vehicle navigates regularly in the proximity of the coast of Vilanova i la Geltrú, the port of Vilanova i la Geltrú is used as simulation environment.



2. Block diagram of the simulation algorithm of the control system of navigation and avoidance of AUV Guanay II

A. *Simulation environment of the Vilanova i la Geltrú harbor (Barcelona - Spain)*

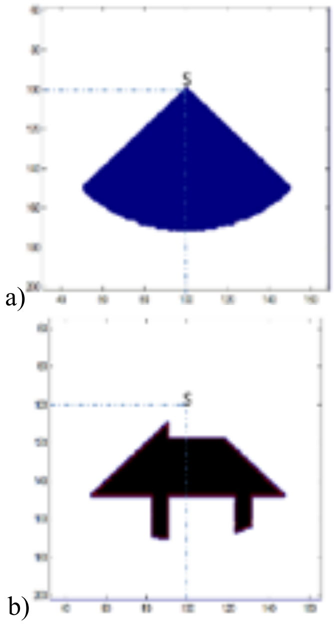
We have performed the simulation of the Vilanova i la Geltrú harbor. As of the satellite image obtained from google maps, it has drawn up a sketch of the most important points of Vilanova's harbor (Figure 3). This is used for simulate a navigation environment in the obstacle detector simulation. The sketch has a spatial resolution of 1 meter and includes a general area of 720m by 680m. Within this simulation is possible to insert objects of different shapes and sizes.



3. Map of the Vilanova i la Geltrú harbor (Barcelona - Spain)

B. *Simulation environment Obstacle Detection System (ODS)*

The sonar simulation is performed using the optimum values of the operating parameters found [4]. The simulation of the instrument is divided into two stages. The first generation of the beam (see Figure 4.a). The second, of emulation of the received signal, overlaying on the map (Figure 3) the signal generated at the point of measurement (Figure 4.a) and obtaining the common areas between the two, as you can see in Figure 4.b. The obstacle detection is performed by analyzing the area obtained, as explained in the previous section.



4. a) Generated area of 90º, formed by the combination of the beam generated by the sonar located on the X = Y = 100m, b) Response obtained by the SDO

C. *Simulation environment obstacle avoidance system*

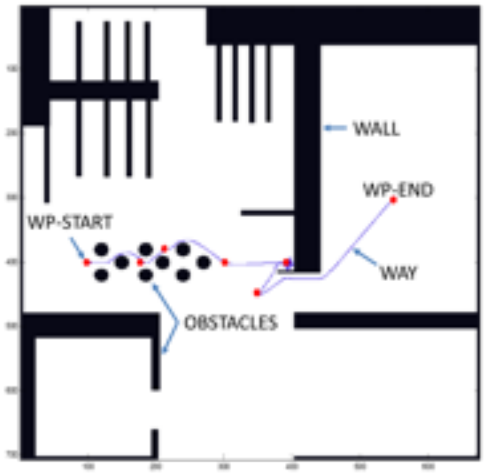
This algorithm has been implemented in a script using the Fuzzy Logic Toolbox of Matlab. The algothim is composed of two fuzzy controllers ("high" and "low" speed vehicle navigation), as explained in the previous section.

D. *Simulator obstacle detection and avoidance AUV Guanay II*

The detection and avoidance system (see Figure 2) works independently and in parallel to the navigation system (external control). This system takes as input the data acquired by the sonar, which is analyzed by the obstacle detection algorithm (section II). Once you have executed this algorithm the resulting data is used by the obstacle avoidance algorithm. If an obstacle is encountered in the path, the algorithm has been designed for changing the input source of internal control, ignoring received reference data generated by the external control and taking the reference data generated by the evasion system. (See Figure 5). The path used in the simulation allows us to evaluate the performance of the AUV in different circumstances such us: navigation between two objects, avoidance of obstacles in the path of navigation, avoidance and recovery of the trajectory, and the escape from dead lock such as corners.

IV. SIMULATION RESULTS

There have been different simulations with different obstacles, changing its location and shape. We have different waypoints strategically located which allow study and analyze the system behavior. The results are shown in Figure 5. By analyzing this image, it is observed how the vehicle avoid various obstacles, while performing correct navigation. Thus, for example, on encountering an obstruction (wall Figure 5), the vehicle automatically changes its direction, by navigating parallel to the wall while maintaining a safe distance.



5. The simulation result of navigation and of the obstacle detection and avoidance.

V. CONCLUSIONS

According with the studies carried as well as the results obtained in the works, concludes that the obstacle detection system developed for the experimental vehicle Guanay II using mechanical scanning sonar Micron Tritech MK3, It conforms to the physical characteristics and technical requirements of the vehicle.

The tests performed to validate the software designed to adjust the sonar's configuration settings and acquire, process and control the sonar's signals have allowed us to find the information that is needed and required for the development of the sonar simulation software. This algorithm takes into account the sonar's own configuration parameters, such as: Mechanical operating range, mechanical resolution of rotation, number of measurement points and distance.

The simulation obtained in this work allow us to verify the proper operation of the system, achieving obstacle detection, avoidance and navigation in confined spaces. Having validated the system operation, it is now possible to export obstacle avoidance algorithms to physical model of the Guanay II, for the corresponding tests in Vilanova shore.

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