Simulation tool for a submersible autonomous system

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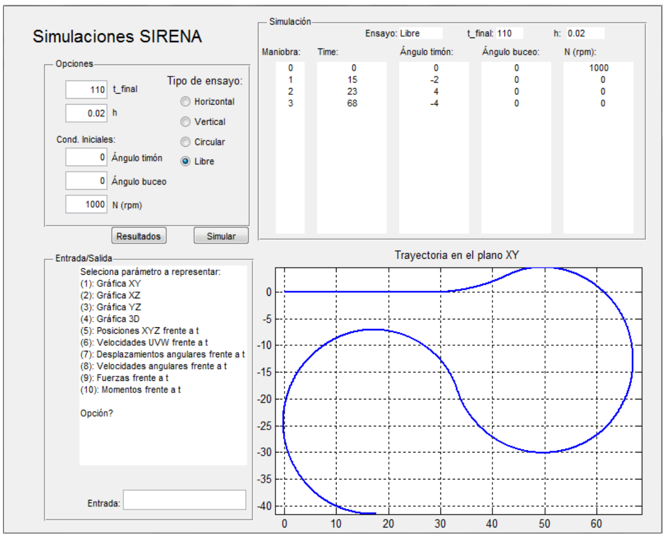
Abstract *– This article explains one of the assignments developed in SIRENA's project. This project is a collaborative work created and carried out exclusively by students for creating an AUV (Autonomous Underwater Vehicle) powered by solar energy. The following lines summarizes the assignment of simulate the system's dynamics, using theoretical studies which provides the submersible's equations.*

Keywords *– Submersible, submarine, simulation, MatLab, SIRENA.*

I. INTRODUCTION

Simulations are a useful tool because some reasons. It allow to know the performance of the system before constructing it, therefore, simulation tools have a strong influence in the process of taking decisions about technical aspects, improving additional safety on the ground testing. It also reduce costs, avoiding to repeat design and/or construction stages.

The program used is MatLab. Through several scripts, theoretical equations are implemented, and every classical movement can be simulated, allowing to realize tests and visualize results with a graphical interface, which is shown at Fig 1.



110 t_final
0.02 h
Cond. Iniciales:
0 Ángulo timón
0 Ángulo buceo
1000 N (rpm)

○ Horizontal
○ Vertical
○ Circular
● Libre

Ensayo: Libre t_final: 110 h: 0.02

Maniobra:	Time:	Ángulo timón:	Ángulo buceo:	N (rpm):
0	0	0	0	1000
1	15	-2	0	0
2	23	4	0	0
3	68	-4	0	0

```
Seleciona parámetro a representar:
(1): Gráfica XY
(2): Gráfica XZ
(3): Gráfica YZ
(4): Gráfica 3D
(5): Posiciones XYZ frente a t
(6): Velocidades UVW frente a t
(7): Desplazamientos angulares frente a t
(8): Velocidades angulares frente a t
(9): Fuerzas frente a t
(10): Momentos frente a t

Opción?
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Entrada:

Fig. 1 GUI

II. DESCRIPTION

The code has been implemented in order to make easy any modification of design aspects, and select which information to show: positions, velocities, accelerations or forces.

There is a script for hydrodynamic coefficients, a second one for physical properties, and the remainder implement the equations [1] and the MatLab GUI. The first two of them can be easily modified, facing every design change, or even for modeling a different AUV. It is therefore an open-simulation tool which provides useful information in the design tasks and prevents usual problems in following stages of the project.

This software has been developed from a code that simulates a commercial submersible, the REMUS 100 [2] [3]. The adaptation of this code for simulating a different vehicle demonstrates its flexibility and capability for changing dimensions, materials and components of the system, and external conditions, like environment's properties (salinity, temperature, etc.). The hydrodynamic coefficients and the external properties aforementioned are introduced according to previous stages of the project [4].

III. CALCULATIONS

As mentioned, the equations have been implemented from previous stages, but these expressions only provide forces and accelerations. In order to solve the differential problem, an appropriate algorithm must be used. The code implements the Runge-Kutta fourth-order method, which has a local error similar to Taylor methods without calculating derivatives in every loop. This provides a high calculation velocity, essential for this case because of that several iterations are needed for solving a large trajectory.

Runge-Kutta methods consist of calculating the value of a variable from a differential system like shown at Fig. 2.

$$\begin{cases} \dfrac{dy}{dt} = f(t, y) \quad a < t < b \\ y(a) = \alpha \end{cases}$$

Fig. 2 Differential system

Function f(t, y) is obtained from [4], and the successive values are obtained from the past result and an average of the values of the function into the interval $t_i < t < t_{i+1}$. In the forth-order case, the equation are the shown at Fig. 3.

$$k_1 = h \cdot f(t_i, y_i)$$
$$k_2 = h \cdot f(t_i + \frac{h}{2}, y_i + \frac{1}{2}k_1)$$
$$k_3 = h \cdot f(t_i + \frac{h}{2}, y_i + \frac{1}{2}k_2)$$
$$k_4 = h \cdot f(t_i + h, y_i + k_3)$$
$$y_{i+1} = y_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

Fig. 3 Runge-Kutta fourth order

This method has been implemented in MatLab under the name “rk4SIRENA.m”.

IV. RESULTS

All the results of the simulations are favorable. After yielding validates results for the submersible REMUS 100, SIRENA’s responses have been obtained for different maneuvers. The simulator can provide projected trajectories in each one of the spatial planes, tridimensional representations and several graphs for velocities and forces in front of time, in each instant of the simulation. In the following figures some of these representations are shown.

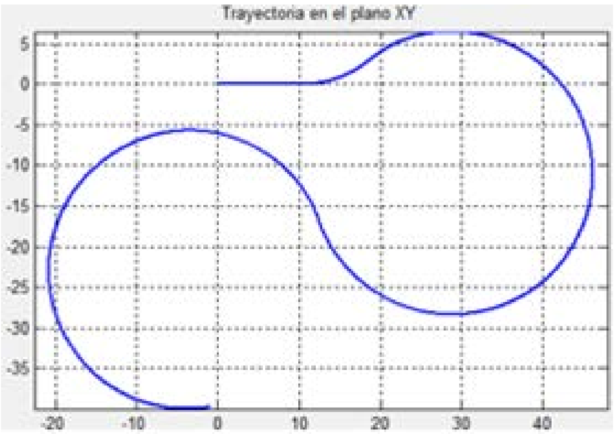

Fig. 4 Trajectory graphic

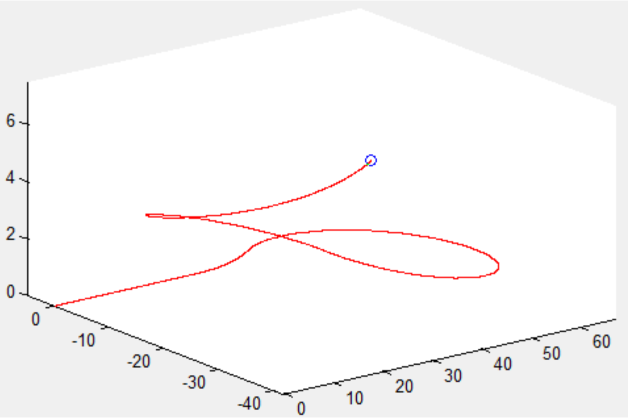

Fig. 5 Tridimensional graphic

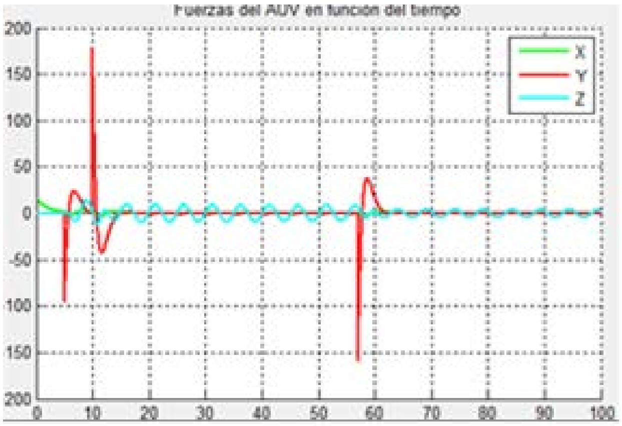

Fig. 6 Forces graphic

This information is used in several scopes of the project. Forces and moments are used as an approximation of the movement sensor’s readings which are built in the AUV. The code is also a prelude of the control software, considering that the control must include the equations of SIRENA’s dynamics, similar to the simulation scripts.

In the movement graphs appear the oscillations of the submersible during the advance of a theoretically straight trajectory, (Fig. 7, values have different scales in each axis) useful information for improving a non-lineal control. There is also an unexpected roll movement due to the torque generated by the propeller on the hull. This movement must be corrected with the control software by means of the rudder position, or any other correction methods.

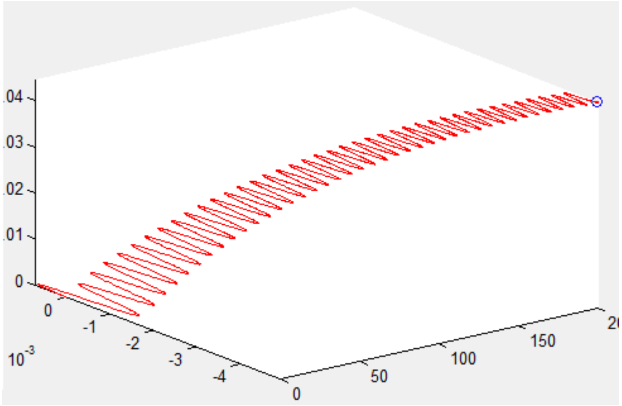

Fig. 7 Oscillations during the advance

V. REFERENCES

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