

# Simulator Dynamic Positioning System with Azimuthal Thruster

Robson C. Santos, Christian N. Barreto, Gerson G. Cunha, Severino J. C. Neto

**Abstract**—This paper aims to project the construction of a prototype azimuthal thruster, mounted with materials of low cost and easy access, testing in a controlled environment to measure their performance, characteristics and feasibility of future projects. The construction of the simulation of dynamic positioning software, responsible for simulating a vessel and reposition it when necessary. Validation tests were performed in the form of partial or complete system. These tests validate the system manually or automatically. The system provides an interface to the user and simulates the conditions unfavorable positioning of a vessel, accurately calculates the azimuth angle, the direction of rotation of the helix and the time that this should be turned on so that the vessel back to position original. A serial communication connects the Simulation Dynamic Positioning System with Embedded System causing the user-generated data to simulate the DP system arrives in the form of control signals to the motors of the propellant. This article addresses issues in the marine industry employees.

**Keywords**—Azimuthal Thruster, Dynamic Positioning, Embedded System.

## I. INTRODUCTION

LISTED on the navigation history that the propellers used on ships and large boats became popular from 1827 by becoming a more efficient way to create thrust and move the ships of the time [1]. The conventional system formed by the propeller and the rudder (which diverts the flow of water giving guidance to the vessel) although widely used, does not have enough versatility to many requirements in the current nautical, for example, the Dynamic Positioning Systems. This system is widely used in the oil industry, to ensure the correct and precise positioning of platforms, rigs, ships, tugs etc. [2].

A major advance in this technology was the azimuthal propellers, consisting of a propeller that can direct the water flow 360° around a vertical axis. As a result, the vessel is able to move with more ease and efficiency, offering more control to operators.

The azimuth thrusters, well known as thrusters, are widely used in Dynamic Positioning Systems or DP systems [3].

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Dynamic Positioning Systems are computer systems that utilize sensors such as GPS (Global Positioning System) and a compass to automatically control the propulsion system of a vessel so that it remains in this position as the operator wishes [2].

## II. THE DEVELOPMENT OF PROTOTYPE

The development of this paper aims primarily the construction of a prototype of an azimuth thruster that was mounted with low-cost materials and easy access. The prototype was made so that it can test it in a controlled environment to measure their performance, characteristics and viability of future projects.

To control the propellant has been developed a dynamic positioning simulation software that controls the azimuth propeller. This software is responsible for simulating a vessel that can be found within the desired location or not in accordance with the coordinates of the computer mouse. If not in the desired position, this software should calculate the required reaction of the propellant so that the vessel can return to the desired location.

### A. Direct Current Motors

Direct current motors are widely used in industry and experimental robotics due to its versatility and ease of making your activation. This motor has permanent magnets stator and coils in its rotor. These coils are driven by a mechanical switch, which reverses the polarity of the same as the rotor spins [4].

Based on the constructive configurations of the motor, one needs to reverse its direction of rotation, thus it was necessary to reverse the polarity of the current at its terminals. The angular velocity of the shaft is proportional to the input voltage at the terminals of this motor. The characteristics described above allow the easy actuation of the DC motor, making it ideal for use in this project.

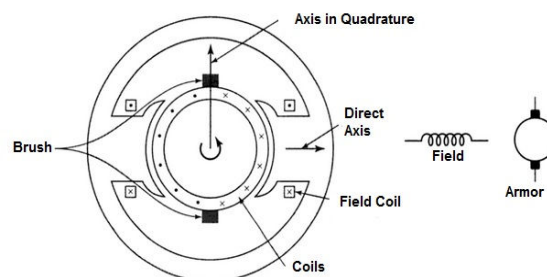


Fig. 1 Scheme of a DC motor

The DC motor characteristics be allowed in the prototype used a power stage to activation the same through Arduino commands. The following can be observed and analyzed the DC motor schema.

### B. Power Stage

Generally, the potency stage switches the electric current to the DC motor in accordance with a low power signal sent by the controller and are used as one relay module for Arduino. Its objective is to rotate the DC motor in both directions [4].

The most suitable switching circuit for this kind of actuation is called H-Bridge, which consists of four switches that are actuated in order to reverse the polarity of the motor terminals [5].

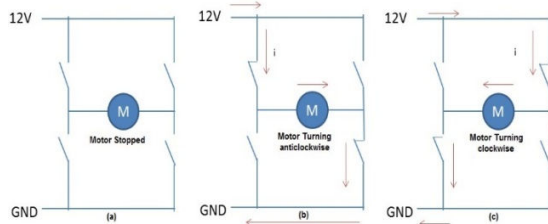


Fig. 2 Electrical scheme of an H-Bridge: (a) Motor stopped, (b) Motor turns clockwise, (c) Motor turns counterclockwise

In Fig. 2 (a) can be checked with keys that open the current does not pass through the motor (M in the figure), so it remains stopped. In Fig. 2 (b) it is verified that with the two keys closed the motor turns clockwise. In Fig. 2 (c) it is observed that with the other two keys closed the motor turns in the counterclockwise direction.

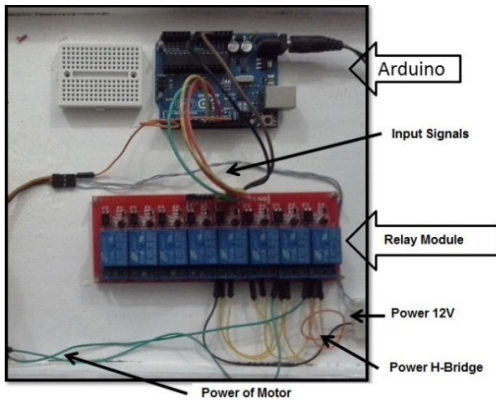


Fig. 3 Power stage - Connecting the H-Bridge

The relays module Arduino need to be connected such that the function as the relay H-Bridge. Thus, wires became interconnected to the contacts NO (normally open) relay and the board of signal inputs were still connected, the digital outputs of the Arduino. In Fig. 3 can be seen the most important points mentioned. Observe the relay module, the deck plate Arduino UNO, the connections to the H-Bridge power and input signals.

### C. Servomotors

Servomechanisms are devices which react linearly to an input (input) producing a linear output (output) and can be fed back in order to improve the transient response, the steady state response and to avoid possible disturbance and noise [9].

Servomotors are electromechanical mechanisms that have a proportional response to a command utilizing the theory of control systems for this purpose [10].

In the project, we used a servomotor of aeromodelling much used in experimental robotics. The motor has a low cost and still have great ease of implementation. The following is demonstrated servomotor model used in the project.



Fig. 4 Constructive aspect of a servomotor

The servomotor control was realized using a 5V power signal in the form of a square wave. When this square wave has the peak period of 1 ms, the motor axis moves to the  $-90^\circ$  position, when the input signal has peak time of 2ms, the motor axis moves to the  $+90^\circ$  position and any time intermediate peak (between 1ms and 2ms), the motor axis is positioned proportionally (from  $-90^\circ$  to  $+90^\circ$ ). Such a characteristic can be determined according to Fig. 5. This servomotor has a 5V supply and potency stage, used to turn on power control signals to drive the motor. The same is embedded in the encapsulation equipment.

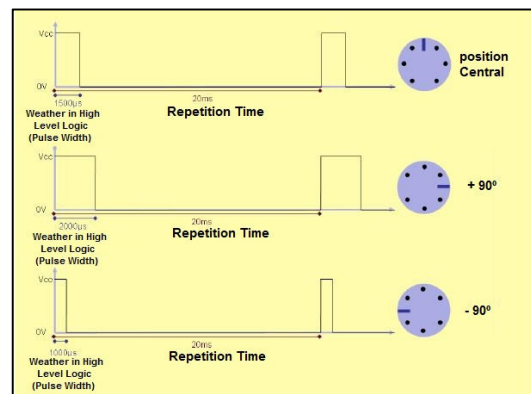


Fig. 5 Electrical signal required to actuation of servomotor

### D. Embedded Systems, Microcontrollers and Arduino

The embedded system is a microprocessor-based system fully encapsulated which has its functioning dedicated to the system it controls and it works an autonomous way [6].

The microcontroller is often called a "computer on a chip". This popular jargon occurs because the microcontroller is a computer with reduced proportions and encapsulated in a chip, therefore, does not require high processing power [7].

In the system was used Arduino module. The Arduino has become popular among students of engineering since 2005 when it was created. This device consists of an electronic platform of free hardware prototyping. In other words it consists of a board mounted with an Atmel microcontroller, with all peripherals (inputs and outputs, USB, crystal oscillator, buttons, etc.) and with support for recording via the Arduino IDE platform ROM installed on a personal computer [8].

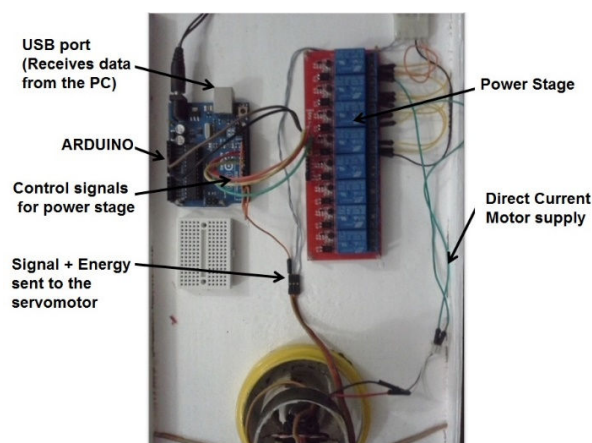


Fig. 6 Embedded system - thruster control

In this project, the embedded system is dedicated to the control of the azimuth thruster and uses the Arduino as microcontrolled platform. The microcontroller Atmel and its peripherals are responsible for receiving data from the computer, process them and send control signals to the engines and their power stages.

#### E. Azimuthal Thruster

The need to vessels which meet ever increasing requirements of movement in difficult places and precise positioning, the azimuth thrusters have been developed to meet this demand [3].

Generally speaking it consists of a helix used for boosting the vessel, that by means of an angulation control can direct the flow of water at 360 ° around the vertical axis. This characteristic allows the targeting of the water flow in any direction around the vertical axis, so that vessels can be controlled more precisely [2].

The Helix can be rotated by a motor with a mechanical transmission, electric or hydraulic motor. The energy used to propel the ship should be transmitted to helix (either by mechanical transmission, electrical wires or hydraulic connections).

The vertical axis, which makes the movement of azimuth angular, it is rotated by a control system. This system comprises: a motor (electric or hydraulic), which produces driving force to rotate the axis to the desired position; angular

encoder, which feeds the system and it measures in real time the actual axis position and the controller (analog or digital) that compares the current position of the axis to the desired position by the operator.

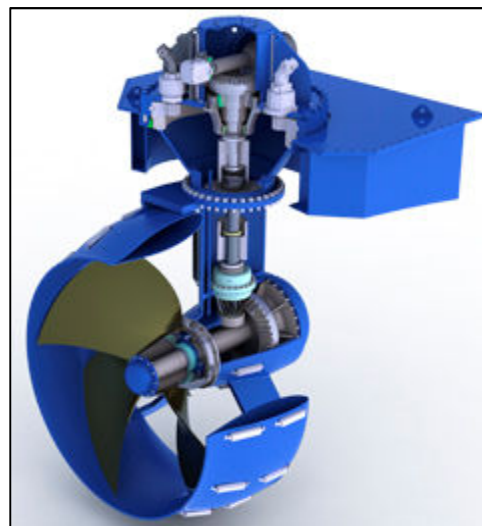


Fig. 7 Azimuthal thruster naval use

This type of thruster eliminates the need of the rudder and improves the performance and mobility of the vessel; it is widely used in modern ships and tugboats and including Dynamic Positioning Systems

#### F. Dynamic Positioning System

The dynamic positioning systems or DP system are widely used in ships, tugs, platforms and others. They are used for the vessel can maintain its position in relation to geographical coordinates, relative to another fixed point or in relation to a moving point without the need for fixing or anchoring points. Generally speaking the DP Systems are used to maintain the positioning of a vessel according to the requirements of the operators. Depending on the service need to make a vessel, the positioning requirements can vary, for example, positioning an oil well drilling rig. In this case, the platform must remain stopped for the geographic coordinates. Another example is a tank ship, which must remain stationary in relation to another vessel to be stocked [2].

### III. ANALYSIS OF THE PROBLEM

From the proposed objectives of this study, it was necessary to design, build, and test a prototype that simulates an azimuthal thruster. A software was developed to simulate a dynamic positioning system. Are addressed some needs and limitations that existed and had to be overcome to build the prototype.

Follows in the next section the needs and particularities of each part of the goal.

#### A. Utilization the Azimuthal Thruster

The study presumes that are disposed only low cost material expense for mounting of the prototype. The driving force that

best fit this situation was the direct current electric motors, as they are less complicated to its acquisition in the market, have low cost and require simple drive systems.

In the construction of the lower set of mounting a waterproof accommodation is required to accommodate the motor, the propeller fixed and connected to a vertical axis (azimuth axis) to its azimuthal rotation. Its construction PVC pipes used to house the direct current motor and propeller propulsion. A 100 mm diameter tube was cut and sealed with cap's, which houses the engine. A third cap 75 mm was used to improve the hydrodynamic giving tapered aspect at the back of the propellant.

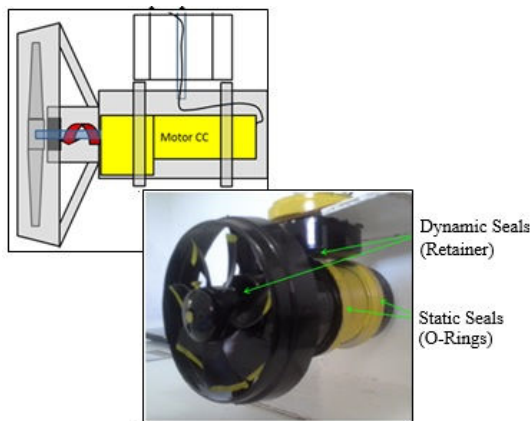


Fig. 8 Croqui and Prototype of the Lower Set

Regarding the upper assembly, it is intended to support the lower assembly, accommodate and rotate the servomotor from the bottom set commands. The thruster was mounted with a 100 mm PVC pipe with a cap and closed at the bottom.

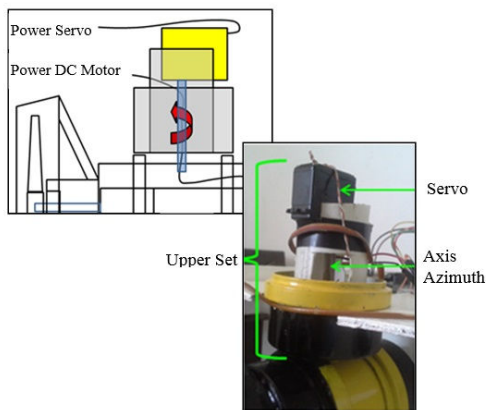


Fig. 9 Croqui of Superior Set

Has assembled a structure to secure the servomotor and center the azimuth axis with 75 mm PVC pipe, soon after, was arranged a bearing that is a bearing, to give robustness to the axis, but allow rotation. The construction of the azimuth axis needed to be machined so that the wires pass through the inside.

The upper set is intended to support the lower set, and also accommodate the servomotor, which will rotate the lower

assembly according to the command. In a similar way this part of the thruster was mounted with a 100 mm PVC pipe with a cap and closed at the bottom.

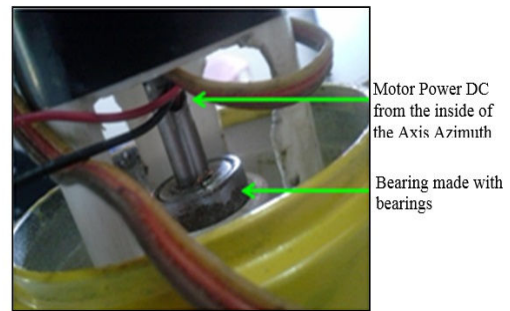


Fig. 10 Detail of Superior Set

#### IV. EMBEDDED SYSTEM

The embedded system is designed using an Arduino Uno, which aims to receive user-generated data on a computer, interpret them and send electrical signals to the drive motor and servo motor.

The program uses serial port control instructions, define the speed that data is received (baud rate), defines how many characters will be received at a time and still the header information that will define the message start.

TABLE I  
 COMMUNICATION PROTOCOL - DATA GENERATED BY THE SOFTWARE THAT WILL BE READ BY ARDUINO

Character 1	Character 2	Character 3
0 - 180	0, 1 or 2	0 -100

In Table II, the character 1 is used to actuate the servomotor that controls the angle of the thruster rotates. This character can assume decimal values from 0 to 180 and will be interpreted by the Arduino to send a proportional PWM signal to the servomotor.

The character 2 was utilized to actuate the DC motor to rotate the thruster; this character can assume the values 0, 1 or 2, Arduino as interpreted by Table II.

The character 3 was utilized to inform the time the propellant stays on until the vessel back to its home position. This value ranges from 0 to 100 is proportional to the distance traveled by the ship.

TABLE II  
 MOTOR STATUS AND PROPELLER SPIN

Character 1	Motor DC Situation
0	Motor rotating clockwise
1	Motor off
2	Motor rotating in-clockwise

From this interpretation, the Arduino sends electrical signals to switch the power stage, which will send the voltages and currents required for the DC motor rotate as the command. All this interpretation by the Arduino is the result of the embedded system design firmware programming codes.

## V. POSITIONING SYSTEM DYNAMIC SIMULATION

The simulation system consists of software that user uses commands to move the thruster described in the prototype and also simulate a dynamic positioning system.

The software was programmed in Visual Basic platform for enabling the GUI and have several graphic components such as buttons, text boxes, and scroll bars, and can be easily used and programmed. The choice to use this platform is given by the fact that the stress can concentrate only on the essential functions of the programming system, such as for example pusher angle calculations, motor drives, serial communications, etc.

In the main system screen is an image of a map containing a representative illustration of a ship, a circle that surrounds it and the upper right corner, the control of serial communications.

Below can be observed the option to use the automatic navigation system, this option you can use the dynamic positioning properly. Further down in the right corner, you can choose the manual control of the azimuth thruster. This option is also available on ships and platform when you want the intervention of the driver in navigation.

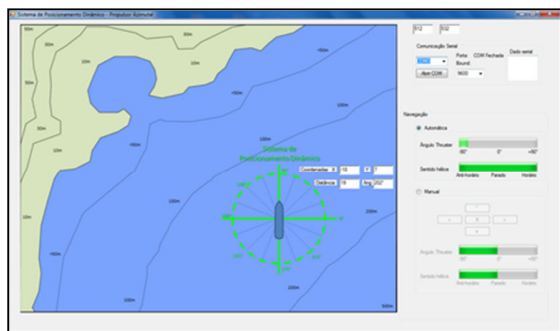


Fig. 11 Dynamic Positioning Simulation System

The navigation simulation map which has the highest predominance of home screen aims to illustrate and make the user experience more similar as possible to a DP system. This map can be found illustration of a vessel, which simulates ideal position of the vessel. This is the desired point the vessel to be or more specifically is the Cartesian coordinate (0,0). The circle surrounding the vessel is the limit which the vessel may not exceed the tolerance of the DP system. If the vessel depart from the circle (out), the thrusters will be activated to compensate for the deviation, returning to the starting position.

The serial communication control is used to configure the serial communication with the Embedded System and must be set the parameters as standard Arduino. Integration of the Thruster with the Simulation System

The serial communication connects the Dynamic Positioning System Simulation with the Embedded System causing the user-generated data in the simulation of the DP system comes in the form of control signals to the pusher engines. The function of the serial communication is to connect the DP simulator with the Embedded System, making

the data generated by the user from reaching the thruster as electrical controls.

All functions were tested using the software hoping the reaction of the propellant. Was tested Auto Navigation System, which from a click of the mouse, simulating a displacement of the vessel, the thruster reacted by turning to the correct angle and rotating the propeller in the correct direction according to the calculations of the computer. It was also tested the Navigation System Manual, the user by clicking on the respective buttons, it was found that the thruster rotated to the correct angle and turned the propeller in the right direction.

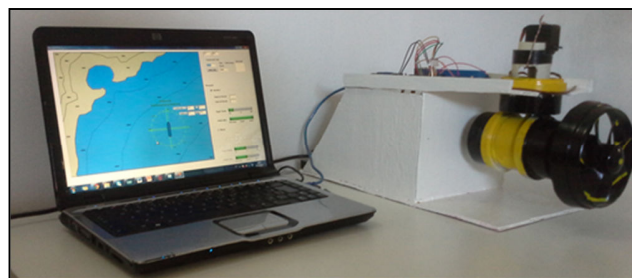


Fig. 12 System Mounted and Interconnected

## VI. OBTAINED RESULTS

The prototype, in general behaved in an excellent way in relation to tests performed, responding well to commands from the operator and the simulator system.

### A. Manual Navigation Test

The navigation tests were done activating the buttons to rotate the thruster from the initial position to the position +90° and then to position -90° and further to intermediate positions in this range. It was also activated the propeller in three possible conditions: off, rotating clockwise and rotating in-clockwise. The tests were repeated several times and the model responded effectively.

### B. Navigation Automatic Test

In automatic navigation test the user clicked in a coordinated of the screen, outside the bounding circle, so that it expected a reaction of the thruster that would cancel the simulated disorder. It was noted that the calculations were made and the results in the text boxes were observed. The thruster turned to angle the calculation and the propeller turned in the right direction.

## VII. CONCLUSION

The prototype, in general behaved well in relation to tests performed, responding well to commands from the operator and the simulator system and were addressed various issues that actually are employed in the marine industry.

It can be seen also that this model, although financially limited, proved to be able to respond favorably to simulated disorders.

With the development of this project, it became clear that the programming platforms like Visual Studio have the

resources to implement a fact of Dynamic Positioning System. To do so would require that the simulator of this project, stop being a simulator and passed to receive real sensor data and send data to drivers.

The power supply was another important design detail because it needed to be the best. The power supply was chosen as the power requirements and current drawn by the prototype. The choice to use a source computer met the advantage of meeting with spare power demand (current drawn), have the voltage 12V and have low cost.

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