



Design and Implementation of Pd based Controller for Accurate Tracking/Heading Angle

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Abstract

The undesirable effects of the sea on the marine vessel became more noticeable when significant changes were introduced to the design and development of the ship. In order to accurately determine the heading angle of the ship various controllers like PD, pi, pid, predictive and adaptive controllers can be used. Predictive controllers provide accurate heading angles but the computation time becomes a huge challenge. PI controller promises stability but the steady state response time is more. In this work, we have made an attempt to evaluate PD, pi, and PID controller operation for a ship model and it has been inferred that PD is most suitable among the variants for producing the heading angle.

1. Introduction

An autonomous surface vehicle can be defined as any water surface vessel that can function without a crew to direct it. Ship course control plays an important role in autonomous navigation. Based on autonomous course keeping problem the rudder angle of a surface vehicle has to be decided. Recently many control approaches are proposed for controlling the vessel such as PID control, internal model Control(IMC), feedback linearization method, adaptive neural control, back stepping strategy, sliding mode control, adaptive-neural sliding mode control, fuzzy adaptive, control method adaptive- neural backstepping control, fuzzy-sliding mode control, Adaptive-direct Lyapunov method, and so on^[2].

Before designing the vessel the classical modeling of the ship has to be analyzed. There are many classical ship modeling techniques such as Nomoto model^[1], Norrbinn model, Bech Model etc. nomoto model can be used for modeling ship dynamics, which support all six degrees of freedom and can adjust to very small rudder angles. While designing an autonomous vehicle the collision of the vessel has to be avoided because ship collision is the major type of marine time accident which can cause loss of life, property and environmental damage. Most of the modern ships are equipped with various marine navigation aid systems such as AIS, VHF^[2], and GPS.

In addition, dynamic positioning also depends on actuator constraints. The actuator effectiveness faults have to be compensated by the controller used and it is noted that saturated

PD controller is capable of doing it.^[3]XU HAI JUN explains that line of sight guidance law is capable of guiding the ship to an expected wave point accurately^[4]. Taking into account of all the points gathered in the literature survey an open loop ship model is implemented to analyze the collision avoidance capability of the autonomous ship. Further, the ship model is simulated for various controllers along with sea disturbance to decide the best among

them.

2. Objective

To build an efficient autonomous surface vehicle prototype with the modular integration of an independent GPS system assisted with an ultrasonic sensor.

3. General Layout

Arduino mega 2560 – it is the microcontroller used to implement the control and collision avoidance algorithm. It is powered using dc supply.

Ultrasonic sensor – it is used to detect any object that may collide with the ship. It has been incorporated along the sides of the ship to avoid any possible collision.

Motor driving circuit – the motors used to drive the ship has to be provided with the required power to run the ship in the presence of a load, for this purpose current driver circuits are used.

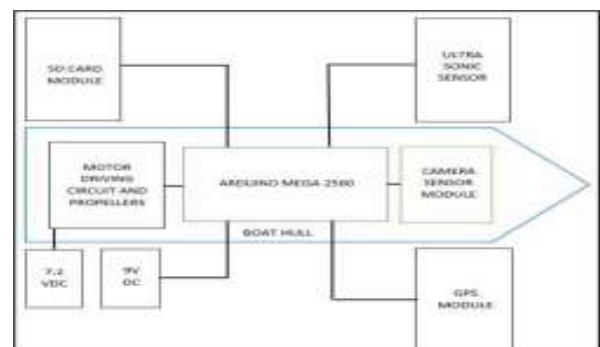


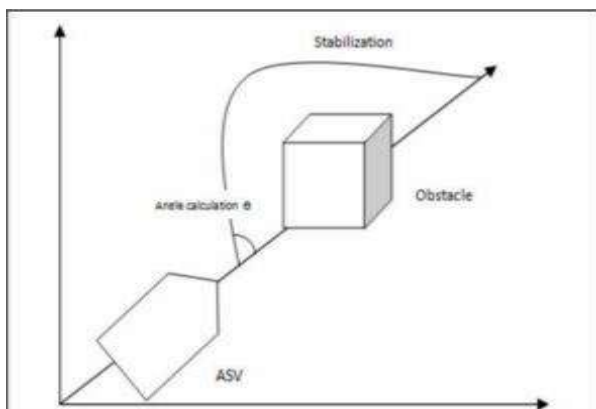
Figure 1 general layout

GPS module –it is used for tracking the ship.

4. Hardware Specifications

1. Arduino Mega 2560
2. 4-Pin Ultrasonic Module Hc-Sr04
3. IC L293D motor driver
4. DC Motors x 2
5. GPS Ublox 6M Module
6. RC Boat hull
7. OV7670 CMOS Camera
8. SD Card Module
9. 7.2v and 9V DC Power supplies

In the main hull, an Arduino board along with an L293D motor driver is placed to control both the dc motors for guiding the boat in the required direction. Since there is no rudder we use different delays in motor movements to change the direction of the ship. In order to make the ship autonomous and to avoid obstacles, we make use of an obstacle avoidance algorithm. In this algorithm every time when an obstacle is encountered, the course angle heading to the destination is calculated. If the destination is $180 < \theta < 360$, the boat moves left. If the destination heading is $0 < \theta < 180$, it moves to the right of the obstacle. In this algorithm, both GPS and obstacle avoidance is brought together.



V. Flow Chart

- The pins of the control board are initialized for sensors and other peripherals.
- The destination coordinates are loaded.
- The ship is allowed to move forward towards the destination until an obstacle is sensed.
- When an obstacle is found the course angle for right or left movement is determined.
- Next, the shortest distance to the destination is determined and the ship follows the shortest path.
- Now the distance to the destination is calculated if the distance is less than 200m then stop else find course angle change needed and change the direction.
- After changing the path the body is allowed to stabilize

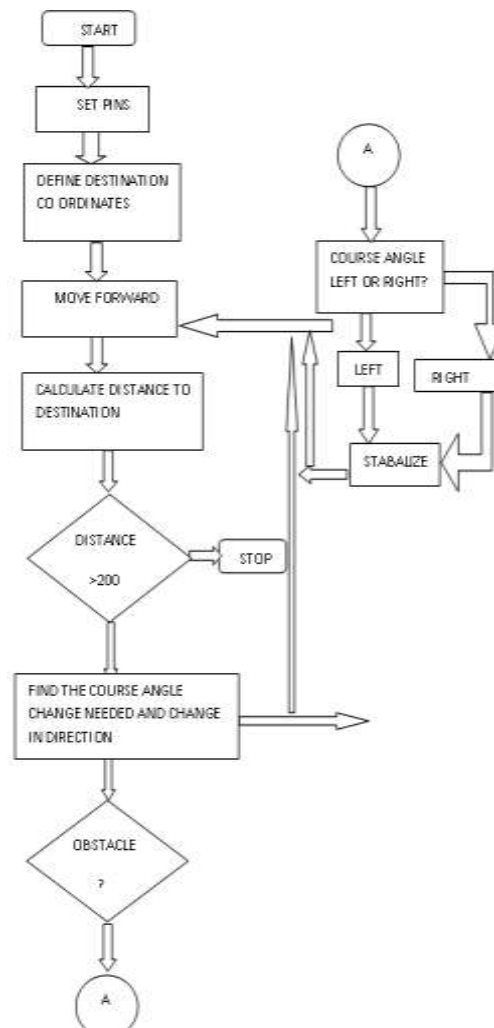


Figure2:. Obstacle a voidance



Figure 3.Ship prototype avoiding a collision

5. Results

Further simulation is done to decide the best control algorithm for tracking the ship taking into account of the sea disturbances. There are some wave mathematical models namely Bretschneider spectrum, Pierson-Markowitz(P-M) Spectrum, Modified Pierson-Markowitz, and JONSWAP spectrum. In order to consider Sea disturbances, modified Pierson Markowitz Spectrum (P-M) is used which will take into account of both high and low tides.

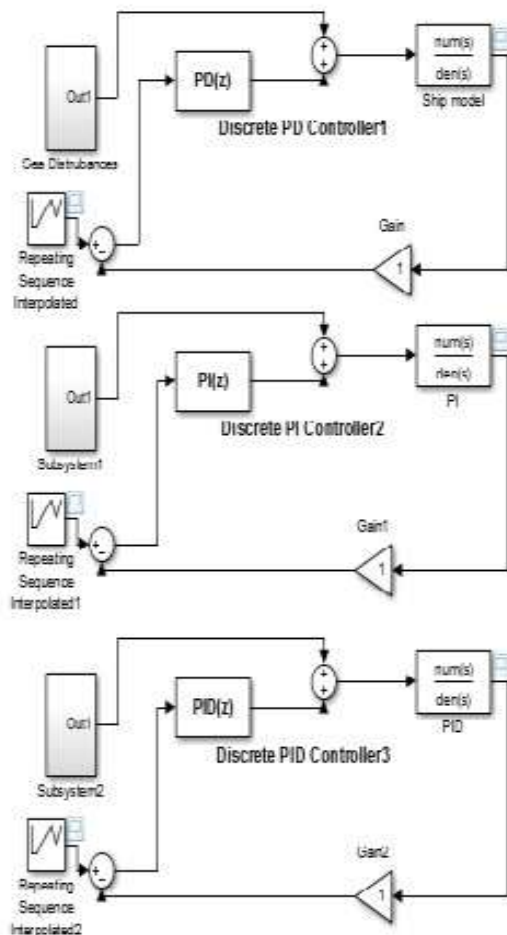


Figure 4: Simulink block diagrams

The above figure depicts the block diagrams of PD, PI and PID controlled ship respectively.

PD: This controller takes into account values of K_p and K_d alone to control the error rate and update the output.

PID: controller takes into account K_p , K_d , K_i values to control error rate and update the outputs and moves in a direction that will head towards the desired output.

In this block diagram, the heading angle is given as an input to ship model through the different controllers and sea disturbance is added to ship model and the resulting heading angle is given as a feedback. The error is calculated from the desired heading angle with the resulting heading angle and difference is given as input to the controller. The controller is tuned to get a proper output in spite of sea disturbances. The sea disturbances block in the diagram will produce different disturbances that occur in the sea. The controller is designed in such a way that it will overcome these disturbances and give the desired output. The results of this simulation are shown in fig 5 from which we conclude that PD controller is more useful in tracking the ship as the steady state response time is least for the PD controlled ship.

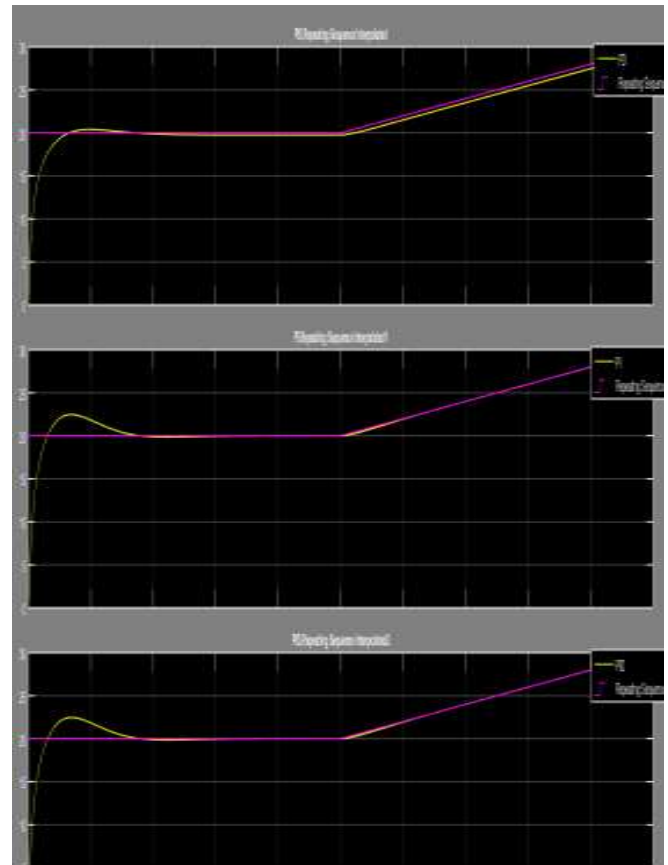


Figure 5 simulation results

FIGURE 5 describes the heading angle of the ship with variant controllers like PI, PD, and PID. The purple color line is the actual heading angle of the ship and the yellow line is calculated heading angle of the ship with the presence of the environmental disturbances.

6. Conclusion

The ship was deployed in a short water body i.e. swimming pool for the testing purpose with predefined heading angles. It was tested for different combinations of speeds for twin propellers. This was observed to efficiently detect and avoid the obstacle. Observing the simulation results(fig 5), we can conclude that the settling time for the PD controller is very less and we got to know that PD controller is most suitable to implement the above model by various simulations on MATLAB considering the disturbances. Hence this makes the ship adapt to changes rapidly.

7. Future Scope

By simulation results, we have learned that PD control is most suitable for efficient path tracking. Hence hardware implementation of PD control ship can be done. The disturbance due to six degrees of freedom can be considered by using the suitable sensor. A camera can be included to capture images for surveillance purpose and a wireless Ethernet module can be used to transfer images to the user. Solar panels can be used to provide power.

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