Design of Unmanned Underwater Vehicle (UUV) For Precision Targeting Using Simple PID-Controler

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ABSTRACT

A model of an Unmanned Underwater Vehicle (UUV) for precision targeting using simple PID controller has been designed. The system has been assumed to have two-dimensional character, such that the mechanical control mechanism would be performed solely by rudder. A GPS/IMU system was employed in the model to provide the exact location and current trajectory direction and will be used to compared between the instantaneous correct direction and instantaneous current direction. This difference would drive PID control system to give correct angle deflection of the rudder.

Some parameters of the PID controller has to be well-tuned employing several schemes including the Routh-Hurwitz stability criterion.

Keywords: UUV, PID Controller, Precision Targeting, GPS, IMU

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Nomenclature:

θ : drift angle
G : centre of grafity
F : rudder force
T : propeller thrust
R_x : resistance (drag)
R_y : additional resistance due to turning motion
J : Moment inertia polar from M' to G
η : $\Delta\theta = \theta_0 - \theta_1$.
α : rudder deflection angle
ρ : instantaneous radial curvature

INTRODUCTION

About two-third of the earth are covered by oceans. About 37% of the world population lives within 100 km of the ocean (Cohen, et al., 1007). The ocean is generally overlooked as we focus our attention on land and atmospheric issues, we have not been able to explore the full depth of the ocean and its abundance living and non-living resources. However a number of complex issues due to the unstructured, hazardous undersea environment make it diffcult to travel in the ocean. The demand for advanced underwater robot technologies is growing and eventually lead to fully autonomous, spacialized, reliable underwater robotic vehicles. A self-contained, intelligent, decision-making AUV is the goal of current research in underwater vehicles.

Hwang, et al.(2005) have proposed an intelli-gent scheme to integrate inertial navigation system / global positioning system (GPS) with a constructive neural network (CNN) to overcome the limitation of current schemes, namely Kalman filtering. The results has been analyzed in terms of positioning accuracy and learning time. The preliminary results indicates that the positioning accuracy were improved by more than 55%, when the multi-layer-feed-forward neural network and CNN based scheme were implemented.

Huang and Chiang (2008) have proposed low cost attitude determination GPS/INS integrated navigation system. It consists of ADGPS receiver, NCU, low-cost MEMS IMU. The flight test results shows that the proposed ADGPS/INS integrated navigation system give reasonable navigation performance even when anomalous GPS data was provided.

Koh et al. (2006) have discussed a design of control module for UUV. Using modelling, simulation and experiment, the vehicles model and its parameters have been identified. The mode cotroller gain values was designed using non-linear optimizing approach. Swimming pool tests have shown that the control module was able to provide reasonable depth and heading action keeping.

Yuh (2000) has surveyed some key areas in current state-of-the-art underwater robotic technology. Great efforts has been made in developing AUVs to overcome challenging scientific and engineering problems caused by the unstructured and hazardous ocean environment. In 1990, 30 new AUV have been built worldwide. With the development of new materials, advanced computing and sensory technologies, as well as theoretical advancement, R&D activities in the AUV community increased. However, this is just the beginning for more advanced, yet practical and reliable AUVs.

Abdel-Hamid et al. (2006) have employed offline pre-defined fuzzy model to improve the performance of integrated inertial measurement units (IMU) utilizing micro-electro-mechanical-sensors (MEMS). The fuzzy model has been used to predict the position and velocity error, which were an input to a Kalman filter during GPS signal outage. The test results indicates that the proposed fuzzy model can efficiently compensate for GPS updates during short outage.

PROBLEM DEFINITION

The focal point of this paper is the development of Indonesia defense technology. The Indonesia defense technology should not depend strongly on foreign technology, we had to develop our own technology. The components of our military technology should be able to be found in the open market without any fear becoming the victim of embargo.

Therefore we have to initiate our basic defense technology ourshelves, in which we had to create product based on alternatif strategy, avoiding of further advancement of foreign technology but further strengthen on our basic military technology.

In this paper we present the development of basic torpedo steering control using simple controller but the end result should have high precision capability.

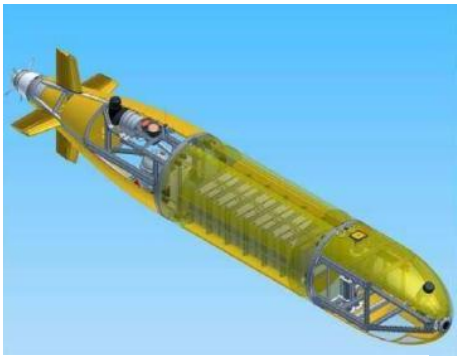

Fig.1. A torpedo is one of the unmanned underwater vehicles, one of the branch of defence technology

MODELING SOLUTIONS

The torpedo system have the hull, where it had centre of gravity, centrifugal force and acceleration have taken place. The system, is assumed to have only two-dimensional in character, has a rudder into which the resulting control action is operated to have movement direction toward the right target

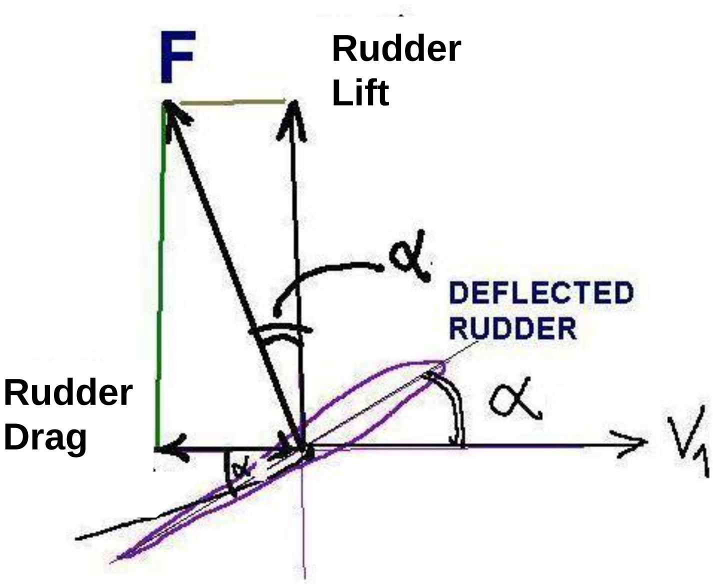

Fig. 2. Several possible trajectory for UUV which its current direction θ_1 toward the reference direction θ_0. The response could be a) the wrong trajectory due to not enough correction capability, b) and c) provide enough coorection in such away the response could be smooh character or sinusoidal character, and d) the wrong trajectory due to too much correction capability.

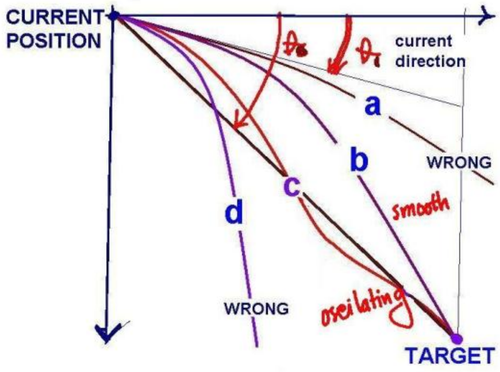

Fig. 3. Deflection of the rudder (α) as a response of the control system. The rudder produced rudder lift and rudder drag.

a. The Governing Equations

The complete system of the forces acting on the torpedo vessel at any instant are shown on Fig. 4. The ρ was the instantaneous radius of curvature of the path. Let the components of F and R in the direction of the X and Y axes denoted by the corres subscripts and let the inertia forces be denoted as shown, then we have the governing equations (Rossell and Chapman, 1958)

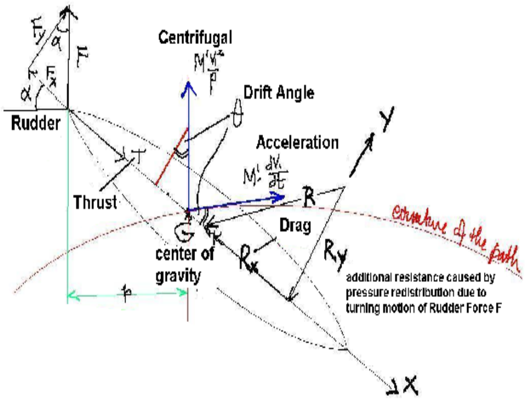

Fig. 4. The complete system of the forces acting on the vessel at any instant. The applied force were the rudder force F, hull resistance R, and the propeller thrust T

$$M' \frac{dv_i}{dt} \cos\theta = M' \frac{v_i^2}{\rho} \sin\theta + R_x + F_x - T \quad (1)$$

$$M' \frac{dv_i}{dt} \sin\theta = - M' \frac{v_i^2}{\rho} \cos\theta + R_y - F_y \quad ..(2)$$

$$J' \frac{d^2\eta}{dt^2} = F.p - R.q = N \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

b. For steady turning:

$$M' \frac{v_i^2}{\rho} \sin\theta + R_x + F_x - T = 0 \ \ldots\ldots\ldots\ldots.(4)$$

$$- M' \frac{v_i^2}{\rho} \cos\theta + R_y - F \cos\theta = 0 \ \ldots\ldots\ \ldots(5)$$

$F.p - R_y.a \neq N \rightarrow 0$ then $R_y = (F.p - N)/a$.. (6)

c. The Result Equation for Controlling

From (5) one found

$$- M' \frac{v_i^2}{\rho} \cos\theta + F\cos\alpha \left[\frac{p - N/F}{a.\cos\alpha} - 1 \right] = 0$$

then

$$\rho = \frac{M' v_1^2}{F.\cos\alpha \left\{ \frac{p - N/F}{a.\cos\alpha} - 1 \right\}} \cos\theta \ \ldots(8)$$

and from (4) one found

$$\rho = \frac{M' v_1^2}{T - (F_x - R_x)} \sin\theta \ \ldots\ldots\ldots\ldots\ldots\ldots.(9)$$

therefore

$$\tan\theta = \frac{T - F.\sin(\alpha. - Drag}{F.\cos\alpha \left[\frac{p}{a.\cos\alpha} - 1 \right]} \ \ldots\ldots\ldots..(10)$$

d. Controlled System

The negative feedback controlled system for the whole torpedo system are illustrated on Fig. 5. The flow for unmanned underwater vehicle dynamics, such as torpedo, have been modelled as input (α) – output (θ) system.

In the torpedo vehicles we could use several difference ways to measure current direction (θ_1) such as using GPS and IMU system. The result of current direction (θ_1) would be compared with reference direction (θ_0) and then one can find the instataneous angle difference $\Delta\theta$

$$\Delta\Theta = \Theta_0 - \Theta_1$$

We use combination of GPS / IMU to determine the current torpedo direction, by calculating the reference direction between the target reference point and the current torpedo location measured by GPS/IMU syatenm.

The current torpedo direction are measure as the tangent line of current trajectory. The resulting instantaneous direction angle differences will be inputed to tha PID controller.

d. Sensitivity criteria

The complete control system using simple PID controller to control the flow of torpedo dynamics in order to hit the target precisely are presented in Fig. 5.

The instantaneous direction angle difference (Δθ)to drive the PID controller to produce precise rudder deflection angle (α) have been illustrated in Fig. 6.

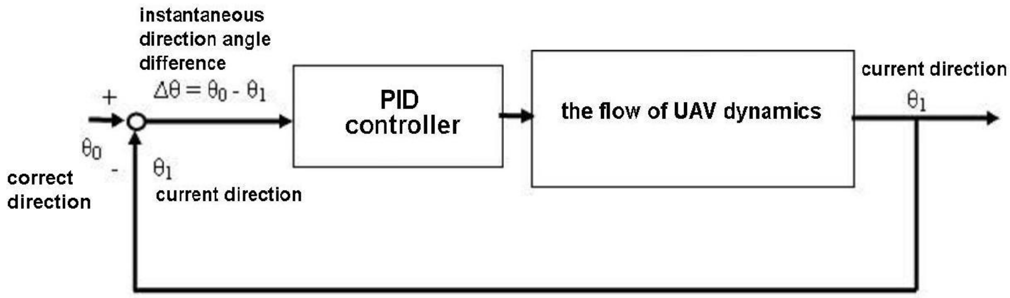

Fig. 5. The complete control syatem using simple PID controller to control the flow of UUV dynamics to hit the target precisely.

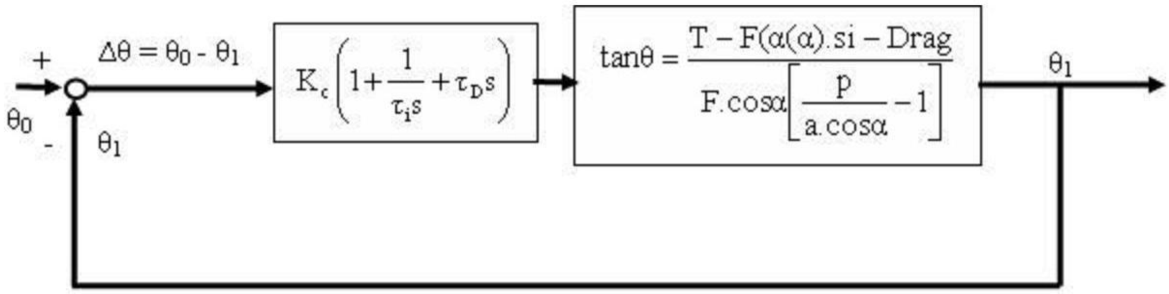

Fig. 6. The instataneous direction angle difference drove PID controller to produce precise rudder deflection angle.

In the system, presented on Fig. 6 or formulated on Eq. (10) contains some functional characteristic of the rudder, F, Fx, Fy, and of the hull drag Rx, Ry which have to be supplied with the actual data.

At last some parameter to be adjusted for the PID controller, K, τ_i, and τ_D could solve using Root location, Routh stability criterion, and Hurwitz stability criterion.

CONCLUSIONS

In conclusion, precision targeting for unmanned underwater vehicles such as torpedo using simple controller have been designed. It consists of PID controllers manipulating the control surface to get the right direction toward the target precisely.

The process block diagram have to be analyzed using fluid flow dynamics force balances. The resulting fluid dynamics for torpedo syatem, the ID controller can be designed and tunned using Routh-Huruwich stability criteriaon.

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