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APPLICATION OF GENETIC ALGORITHMS ON SHIP CONTROL SYSTEMS

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ABSTRACT
Artificial intelligence based ship control systems such as fuzzy logic, neural networks and genetic algorithms. Nowadays, Genetic algorithms (GAs) are being used in a widespread way in optimization problems. In this paper, the course keeping autopilot using genetic algorithm is applied to stabilize the yaw motion of the containership. The simulation and optimization of the ship control systems with genetic algorithm have been obtained by running computer software programmed. Simulation results indicate that the autopilot system with genetic algorithm is able to obtain good performance in cases of rough sea conditions.
Keywords: Ship Simulation, Control System, Genetic Algorithms.

1. INTRODUCTION
The problem of the course keeping has been widely studied by numerous authors [1, 2, 3]. Most work has focused on the system using classical Proportional-Integrative-Derivative (PID) controllers. This type of PID autopilots was first presented by Minorsky [4]. This controller is widely used in marine engineering control systems. A ship autopilot designed based on the PID control is simple, reliable and easy to construct. However, the autopilot performance in various environmental conditions is not satisfactory [5]. In order to improve the performance of the controller, Genetic algorithms [6, 7] which are the optimization technique based on the principles of natural evaluation and population genetics have been employed in the ship motion control research to minimize output error. The first step in the genetic algorithms is to generate a random population, where each individual is represented as a set of parameters. The next step of the algorithm involves evaluating the fitness function, which indicates the quality of each individual. After the fitness function is evaluated in every generation of the genetic algorithms, three main operators which called selection, crossover and mutation are applied. Selection is used to select the individuals from the population, according to their fitness value. The Crossover operator mixes randomly the features of two individuals by the combination of their genes. There are several crossover techniques such as one-point crossover, two-point crossover, uniform crossover, etc. The main aim of mutation operator is replaced the character of genes randomly. Genetic algorithms have also found widespread used in controller optimization particularly in the fields of fuzzy logic [8] and sliding mode controllers [9]. The application of genetic algorithms to PID parameter optimization is better tuning technique than Zegler-Nichols technique [10]. The objective of this paper is to accomplish changes of yaw motion with minimal overshoot and with minimal oscillation.

2. CONTAINERSHIP MODEL

A container ship's autopilot system can be designed from the course-keeping. The autopilot is required to be robust and insensitive to changes in ship dynamics and external disturbances. The equation of motion for a container ship has been obtained from Newton's second law. The dynamic model of the ship is given in Figure 1.

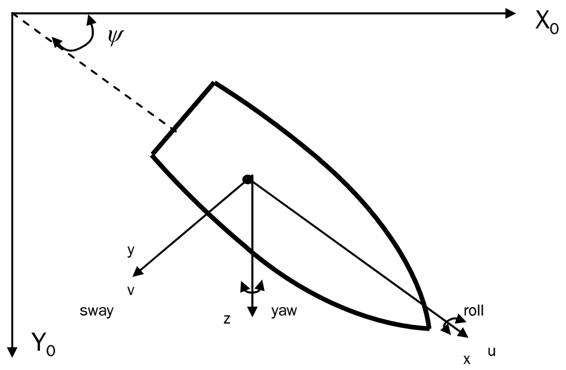

Figure1. Ship motion coordinate system

In this figure, translational motions in the x, y and z directions are called surge, sway and heave, respectively. The rotational motions are roll, pitch and yaw rate about the x, y and z directions. The general ship equations of motion can be expressed in compact form as [1]:

$$M\,\dot{\nu}+C(\nu)\nu+G=\tau \qquad (1)$$

where M is the inertia matrix, $C(\nu)$ is a matrix of Coriolis terms and G is the restoring matrix. $\nu=[u,v,w,p,q,r]^T$ is the body-fixed linear and angular velocities vector and $\tau=[X,Y,Z,K,M,N]^T$ is a generalized vector of external forces and moments. For course-keeping problems 6 degrees-of-freedom (DOF) model is simplified and reduced to 3 DOF model. The mathematical model of a container ship used in this study is described in detail in [2]. The equation of motion represents the linear equation describing the ship motion in three-degrees-of-freedom:

Sway: $$(m-Y_{\dot{v}})\,\dot{v} = Y_v v+Y_\phi\phi+Y_p p+Y_r r+Y_\delta\delta \qquad (2)$$

Roll: $$(I_x-K_{\dot{p}})\,\dot{p} = K_p p+K_v v+K_r r-mg\,GM\,\phi+K_\delta\delta \qquad (3)$$

Yaw: $$(I_z-N_{\dot{r}})\,\dot{r} = N_r r+N_\phi\phi+N_p p+N_v v+N_\delta\delta \qquad (4)$$

The above described mathematical model gives a good approximation of the maneuvering behavior of a container ship. Where v is the sway velocity; p, r respectively are the roll and yaw rates. Y_v, K_p and N_r indicate the hydrodynamic coefficients of sway, roll and yaw moments, respectively; m is the mass of the ship; g is the gravity constant; I_x and I_z respectively are the moment of inertia about the x-z axis; and GM is the ship metacentric height, which indicates the restoring capability of a ship in roll motion, rudder angle is represented by δ. The rudder force and moments are represented by the terms Y_δ, K_δ and N_δ in the corresponding rightparts of equation (3).

3. PID CONTROL FOR THE CONTAINER SHIP

This part deals with the design of an automatic steering system of a ship autopilot. The performance of the autopilot was detected by PD and Fuzzy Logic methods. This controller design uses to provide the course of the container ship. These control laws are simulated using the 3-DOF model.The PID controller was employed by Minorky [4]. This control is made by proportioning the rudder angle to the yawing angle. The control signal $\delta(t)$ of the PID controller is given by equation (5). The closed loop diagram of the feedback system is shown in Figure 2.

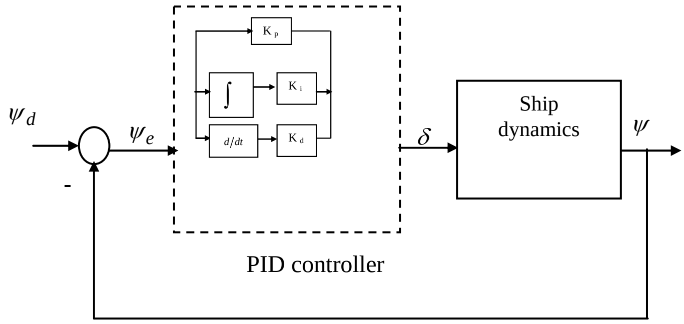

Figure2. Feedback control system with PD controller

Here, $\delta(t)$ is the control signal; ψ_d , ψ_e and ψ are the desired yaw value, the yaw error and the actual yawing, respectively. Consider a control law of PD type in the form:

$$\delta(t) = \left[k_p \psi_e(t) + k_d \frac{d\psi_e(t)}{dt} \right] \qquad (5)$$

The input to the ship dynamics consists of two components, $k_p\psi_e$ which is proportional to the error, $k_d \frac{d\psi_e}{dt}$ which is proportional to the derivative of the error and the purpose of the derivative term is mainly to increase the damping and to improve of the ship stability.

$$\psi_e(t) = \psi_d(t) - \psi(t) \qquad (6)$$

Here $k_p > 0$, $k_d > 0$ are proportionality and derivative constants, respectively. k_p is first tuned togive an adequate response speed, while the differential gain. k_d is used to decrease to overshoot. Tuning the integral gain k_i may remove steady state error.

4. SIMULATIONS AND DISCUSSION

The mathematical model of the ship dynamics as defined in equations (1) is considered. Numerical values for the model parameters are taken from Table 1.

Table 1. Container ship main data

Length between perpendiculars	L	175 (m)
Maximum beam	B	25.40 (m)
Design draft	T	8 (m)
Displacement volume	∇	21222 (m^3)
Metacentric height	GM	0.3 (m)

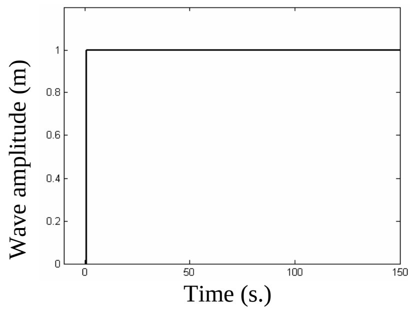

Figure3. Wave function

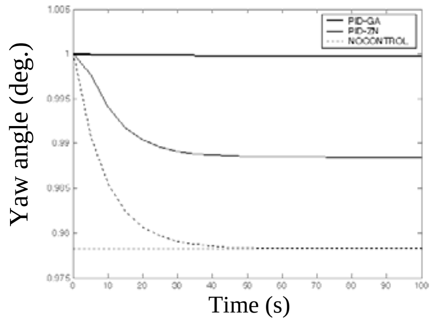

Figure4. Step response

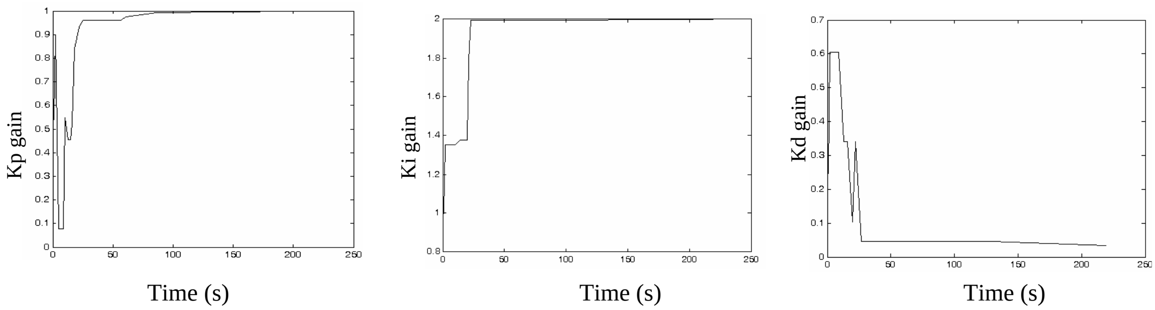

Figure5. Convergence of the genetic algorithm

Figure 4 shows the step response of the PID controller versus a genetic algorithm and Ziegler Nichols tuned PID controller. As shown in this figure, genetic algorithm performance better than Ziegler Nichols method. It can be seen from Figure 5 the genetic algorithm searched for the P, I and D gains.

5. CONCLUSION

The aim of this paper is to create a PID controller for the containership yaw autopilot that is tuned PID controller gains using genetic algorithm and Ziegler Nichols method. As can be seen from figures the genetic algorithm tuned PID controller proved to be a capable of controller.

6. REFERENCES

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