Design of Yacht Course Controller

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Abstract: Due to the strong nonlinearity and uncertainty, the impact on autopilot dynamic constraints, and wave interference, it is a formidable task to design a yacht course controller with excellent performance. To solve this problem, a nonlinear control strategy of active disturbance rejection is suggested, and the adaptive ability of the auto disturbance rejection controller is improved online by genetic algorithm. Experiment shows the yacht heading controller has strong robustness and adaptability of environmental interference.

Keywords: Yacht course, Genetic algorithm, Active disturbance rejection controller.

1. INTRODUCTION

Yachts autopilot will execute the design optimization process, saving a lot of energy, manpower and time.

The PID algorithm is applied to the ship course control, while it is sensitive to the high frequency interference, resulting in the frequent movement of the rudder, lack of ships and marine dynamic conditions adequacy. In addition, adaptive control, with high costs, parameter adjustment difficulties, in addition to non-linear vessels can not ensure good control effect.

ADRC (ADRC), does not depend on the plant model. It is the solution of nonlinear, an effective method of uncertainty strong interference, coupling, large delay. However, the ADRC requires a lot of arguments, and since the anti-rejection controller performance and parameters of the selection of a great relationship. ADRC adjust some parameters need to be online, so the inconvenience, changes in the actual operation and parameters. Such a method is called a genetic algorithm.

This paper presents a new anti-rejection control technology and simulation research yacht heading controller type since genetic algorithm showed good results achieved in the yacht and environmental perturbation parameter perturbations [1-6].

2. YACHT STEERING MODEL AND DISTURBANCE MODEL

2.1. Yacht Model

Yachting control mathematical model is as follows.

\[
\begin{align*}
    m(\dot{u}_G - v_G r) & = X \\
    m(\dot{v}_G + \dot{u}_G r) & = Y \\
    I_{zz} \dot{r} & = N - x_G Y
\end{align*}
\]

where,

- \( m \): Yacht Quality
- \( I_{zz} \): The yacht movement of inertia of the yawing moment
- \( u_G \): yacht longitudinal speed
- \( v_G \): yacht horizontal speed
- \( r \): yacht turn head angular velocity
- \( x_G \): the longitudinal coordinates of the center of the ship in the attached coordinate system

\[
\begin{align*}
    X, Y & : \text{external force acting on the hull} \\
    N & : \text{the external torque acting on the hull}
\end{align*}
\]

\[
\begin{align*}
    X & = (X_H' + X_P' + X_R') \frac{L}{2} dU^2 \\
    Y & = (Y_H' + Y_P' + N_P') \frac{L}{2} dU^2 \\
    N & = (N_H' + N_P' + N_R') \frac{L}{2} \dot{U} dU^2
\end{align*}
\]

where,

- subscripts \( H \): hull
- subscripts \( P \): propeller
- subscripts \( R \): rudder.

For \( X \) and \( N \), however, as it is difficult to separate the contribution of hull and propeller, these force components are expressed as \( Y_H' \) and \( N_H' \), respectively.
2.2. Disturbance Model

In this article, uniform random wave disturbance is used only for the display is as follows:

$$\omega = (4.58H_1 + 3.44H_2)$$  \hspace{1cm} (3)

Where $H_1$ and $H_2$ are of the uniform distribution U(0,1).

3. TWO-ORDER ADRC

ADRC controller consists of three main parts: “Tracking Differentiator (TD)”, “Nonlinear Feedback (NF)” and “Extended State Observer (ESO)”.

4. IMPROVE ADRC CONTROLLER

There are a great relationship since the performance of the anti-rejection controller and its parameters are determined by experiment choice. Extensive simulation studies show that ADRC entirely through the “separability” design principle, namely, a part of individually designed TD ESO and error feedback, combined into a complete ADRC. Among them, many of the parameters are the same parameters, as well as stock options three parameters can be automatically generated, just manually set. So inconvenient changes in practice and parameters. Control the use of genetic algorithms, a control method is called genetic algorithm. In this method, can be automatically adjusted. In this paper, a genetic algorithm controller design, it can automatically based on approximation and optimization. In this design, and as input. Adaptive interference suppression parameters line changes to the rules of the genetic algorithm under control, to meet the different requirements of the times and improved ADRC control performance. Based on the above analysis, the design of the structure of ADRC genetic algorithm shown in Fig. (1).

Fig. (1). Genetic Algorithm ADRC.

Using genetic algorithm to solve the optimization problem that need to be addressed when coding scheme, genetic manipulation methods, adapt to function set is very important, because it is the judge the individual's ability to adapt to the rules is to ensure that the best individual reflects the solution of optimization problem is the key. The fitness function is closely related to the specific research questions, and it should be the essence of the problem and easy to calculate.

1) Optimization of objective function

Aiming at the problem of optimization of ADRC, control system for comprehensive evaluation of the dynamic performance and static performance (e.g., response speed, regulating time, overshoot and steady-state error) and according to the principle of minimum energy consumption, the target function, this paper selected error absolute value of the absolute value of the time integral performance index of ITAE and control volume, namely:

$$J(e) = \int_0^T (|\tau| y(\tau - v_o) | + |u|)d\tau$$  \hspace{1cm} (4)

The fitness function takes its reciprocal. The optimal control parameter is the controller parameters corresponding to the maximum fitness function.

2) Coding and genetic manipulation

Codings: the individual coding format uses real number coding, which can avoid the common binary form need to encode and decode the trouble. The expression of the individual is composed of ADRC parameters $\{k_p, k_d\}$.

Genetic operation: a simple single point cross way. Variation of adaptive variation. When the adaptation degree is high, the mutation rate is decreased, the adaptation degree is low, the mutation rate is increased. Choose the proportion of common choice and optimal retention strategy. Elitist strategy can guarantee the failure so far the best individual will not be crossover and mutation of genetic operation, it and other ways of selecting matched is to ensure that the genetic algorithm global search to the optimal value of an important guarantee.
5. SIMULATION RESULTS

Due to space limitations, only two simulation results are possible (Figs. 2, 3).

From the two pictures we can get the conclusion:

1) dynamic accuracy (conversion) process control and static accuracy (heading) is a small time course very high conversion angle.

2) Under normal working conditions, set the course change, the rudder angle tracking quickly and the change is small, the heading tracking is fast and accurate. In the case of uniform random disturbance, the rudder angle is frequent but the heading tracking is still accurate.

So the new designed yacht course controller has strong nonlinear robustness under parameters and conditions of uncertainty, course tracking is fast and smooth, so as to achieve high-precision yacht curriculum objectives.

CONCLUSION

A new nonlinear GA ADRC yacht course controller is designed. It is strictly robust nonlinear characteristics of the yacht, and parameter perturbations, uncertainty disturb the system, and the system, if not dynamic modelling. Under normal working conditions, set the course change, the rudder angle tracking quickly and the change is small, the heading tracking is fast and accurate. In the case of uniform random
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disturbance, the rudder angle is frequent but the heading tracking is still accurate. So it is perfect as a yacht heading controller.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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