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SUMMARY OF DOCTORAL THESIS

Thesis title: **The Overall Optimization Control for The Vessel Dynamic Positioning DP System Based on The Genetic Algorithm GA**

Major: Automation and Control Engineering

Code: 9520216

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1. Thesis summary

Marine transportation is becoming increasingly significant in the country's economic development, also in the fields of oil and gas exploration and production. Weather conditions and operating locations in the oceans are changing all the time, creating numerous risks that make the operation and exploitation of marine vehicles extremely difficult. Because the DP can maneuver vessels, easily change and maintain vessel coordinates without requiring other auxiliary systems such as anchors, regardless of sea depth, and is not limited by seabed topography. However, the vessels, especially service vessels, using dynamic positioning systems (DP) intention obtain higher accuracy and efficiency than other types of steering systems when positioning at sea. Enhancing the quality of vessel maneuvering, mooring, and positioning control is a difficult challenge (due to limitations such as sea depth, time and working mode, and controllability). Increasing the self-adaptability of the vessel's control system to function in changing positions, while guaranteeing safety and lowering operating costs, is a critical challenge. Furthermore, by merging advanced technologies with intelligent control theories, the DP system will be able to better respond to errors caused by internal and external noise, model errors, and other nonlinear system properties, hence increasing the vessel's performance in operating modes.

It can be noted that DP studies are being produced in accordance with the trend of applying DPs by surveying generations of DPs, domestic and international research, and evaluating important academic and technical application conditions. Artificial intelligence in control optimization to ensure system safety, energy savings, improved accuracy, and long-term stability. Therefore, the thesis poses the research issue "The overall optimization control for the vessel dynamic positioning DP system based on the genetic algorithm GA" to address the following points: a) Analyze, synthesize, evaluate, and identify deviations between the ideal model and the actual model of the DP system during the control process, taking into account the influence of environmental disturbances, parameter and model error, and other undesirable effects; b) Propose solutions to improve DP system response quality by determining the optimal set of control parameters, as well as optimizing DP system based on Fuzzy technical foundation. multilayer fuzzy and interactive fuzzy; c) Proposing a solution of robust optimal control to not only adapt the model and parameter error, optimize the control structure but also ensure the performance of robust stability for the DP system.

To achieve the aforementioned goals, the thesis first performs an overview analysis of error handling solutions and modern ship motion control techniques. The problems in studying ship motion control were recognized as a result of these factors, which are primarily produced by undesirable influences and impacts on the vessel, such as waves, wind, currents, and frequency oscillations. The main reasons for the nonlinearity of the control object are model and parameter errors. Next, a multi-layer fuzzy algorithm is proposed, which initially assists the system is becoming softer and more adaptive in control, well with the number of membership functions increasing as the number of fuzzy layers rises, hence improving the system's optimization capabilities. The thesis, on the other hand, develops the problem of optimizing the control structure for the DP system using the Particle Swarm Optimization method (PSO) and expands the study under working conditions, gathering results by simulation has proved the feasibility. Also, in this research direction, the thesis develops and implements a genetic algorithm (GA) to optimize the fuzzy adaptive control structure, as well as continuing to test the simulation under simulated weather and error situations. The collected findings are positive and serve as a foundation for the construction of the thesis' primary method. Finally, to help the system increase its robustness, the author proposes and develops a more comprehensive solution with a robust adaptive control model for DP based on the GA optimization algorithm. Theoretically, the proposed controller with constraints proven is stable asymptotically with the Lyapunov criterion. Regarding algorithm testing and simulating on Matlab software, the results show that the system's response ensures stable stability in most cases with different weather conditions.

Related to the experiment to verify the theory and towards the application of the proposed algorithm in practice, the thesis builds a physical model according to the model of the Happy Hunter, a type of service vessel, with a propulsion system including 3 propellers. In this hardware, the central processor receives the position and direction of the vessel, feedbacks the actual position and direction of the ship, and issues command to control the vessel's propulsion system to bring the vessel to the setting position. The system uses an embedded control center on Matlab through DSP processor F28379D. The process of acquiring and transmitting data in a sensor network uses wireless communication. Initial successful test results with the multi-layer fuzzy and interactive fuzzy algorithms. The robust adaptive fuzzy controller based on the GA algorithm is still in the process of test. The limitation on the processing speed of DSP F28379D is a weakness when the system runs many time-consuming algorithms such as GA and PSO at the same time. Experimental studies need to be carried out in standard test tanks to obtain accurate and reliable results, which is also the direction of study and application development of the thesis.

2. The new contributions of the thesis

- Identify model erroneous effectively by using a fuzzy adaptive interactive control solution. The proposed solution helps the DPs controller be more flexible during the operation process. Thereby, the control structure parameters are adjusted adaptively to eliminate the influence of the model erroneous.
- Optimize the control structure solution by using PSO and GA algorithms to improve the quality of DPs response. The operating parameters of the fuzzy adaptive controller are optimized, so the response quality is enhanced.
- Establish a multi-cascade fuzzy controller, making the system more adaptive in control with the number of membership functions increasing with the number of fuzzy cascades, thereby increasing the optimization ability of the control system under time-varying environmental conditions.
- Build a robust adaptive fuzzy control algorithm based on the GA optimization algorithm to help the DPs increase its stability when operating in the actual environment. The proposed controller with constraints is proven stable asymptotically with Lyapunov

criteria and tested on Matlab simulation. The results show that the DPs response guarantees long-term stability in most cases under different weather conditions.

3. Achievable results, scientific and practical significance

In order to achieve the proposed research goals, the thesis focuses on researching a solution to optimally control based on genetic algorithms to improve the accuracy and robust stability of the DPs control process. Due to the Ph.D. candidate having limited experience in actual vessel operations, it is difficult to establish the membership function for fuzzy controllers. But the adaptive algorithm has helped to overcome these disadvantages. The thesis has successfully built an overall optimal control solution for DPs operating in an actual environment, which serves in the study of control techniques and exploitation of marine vehicles. The thesis has proposed four solutions (expressed in Section 2) to realize the following points: identifying model errors caused by unexpected impacts, optimizing the control structure, and guaranteeing the overall stability of the DPs control. In addition, the thesis builds a physical model according to the Happy Hunter vessel model (a service vessel with a 3-propeller drive system) that conducts successful experiments with multi-cascade fuzzy and fuzzy adaptive interactive controllers as a basis for application development for the proposed solutions.

The proposed controllers have not yet solved all the practical problems in controlling DPs. These problems should carry out in much experimental research to obtain accurate results, which is also a development direction for the thesis. In terms of theory and experiment model, the thesis has achieved the set goals, the robust adaptive fuzzy control based on the genetic algorithm has both robust optimal with time-varying environmental conditions, has applied flexibly artificial intelligence in the design of DPs controller. The scientific significance of the thesis is confirmed through the research results compared to the latest publications at the same time, which meets the topicality and quality standards of international research. The author's research has been published in 02 papers on the prestigious WoS system, SCIE (IEEE Access IF3.367 - Q1, and Indian Journal of Geo Marine Sciences IF0.496 - Q4), 06 papers on the ESCI-Scopus system, and 15 papers in journals and conferences at home and abroad. These publications are the important research result of the thesis. It has high scientific significance for researchers in the field of control theory as well as marine science.

4. Thesis structure

The layout of the dissertation consists of introduction, 5 chapters and Conclusions and future research directions as follows:

Introduction

Chapter 1. Modeling of the vessel dynamic positioning system

Chapter 2. Surveying DPs based on fuzzy control technique

Chapter 3. Nonlinear control solution for vessel DPs based on fuzzy technique

Chapter 4. Robust optimal control of vessel DPs based on genetic algorithm

Conclusion and proposed research direction

Ho Chi Minh City, July 6th, 2022

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