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SUMMARY INFORMATION OF DOCTORAL DISSERTATION

Title of doctoral thesis: **Research and development of intelligent control algorithms based on recurrent fuzzy neural networks for nonlinear system control application.**

Major: **Control and automation engineering** Code: **9520216**

Ph. Student: **Le Minh Thanh**

Science instructor: **1. Assoc. Prof. Dr. Nguyen Chi Ngon**
2. Dr. Nguyen Quang Sang

Name of training facility: **Ho Chi Minh City University of Transport**

1. Scientific arguments need to be solved in the dissertation

The content of this dissertation aims to answer the following basic scientific questions:

- Is it possible to calibrate the controller's optimal parameters online?
- Can a recurrent fuzzy neural network be used to compensate for a traditional PID controller on a given nonlinear object?

2. Objective of the dissertation

2.1. Overall objective

To develop an intelligent control algorithm using recurrent fuzzy neural networks to control nonlinear objects, illustrated with trajectory tracking control for a 3-degree-of-freedom (3-DOF) Delta robot, through simulation and experiment.

2.2. Detail objectives

- Research and develop the equations of motion of an experimental nonlinear system, the Delta 3-DOF robot: build the equations of forward kinematics, inverse kinematics and dynamics of the Delta 3-DOF robot
- Design the FUZZY-PID and GA-PID controllers to control the nonlinear system following a preset trajectory to have a basis for evaluating the quality of control with the proposed algorithm.
- Research on building a single neural adaptive PID controller based on a fuzzy recurrent neural network identifier to control nonlinear systems.
- Recommended supervisory controller (Supervisory Control) using recurrent fuzzy neural network controller (RFNNC), combined with PID to control the nonlinear system to follow a preset trajectory. At the same time, improve the control quality by using the recurrent fuzzy neural network identifier (RFNNI), to identify the nonlinear system back to the recurrent fuzzy neural network controller for self-adaptive control. equipped with a PID controller, responsible for creating a large initial voltage to rotate the arms of the entire nonlinear system. Research algorithms are applied to control trajectory tracking Delta 3-DOF robot on MATLAB/Simulink, to compare and evaluate the results achieved by 4 controllers and verify the RFNN-PID combined monitoring control algorithm, in orbit tracking control of Delta 3 robot- DOF in nominal state and changes in object parameters.
- Design and manufacture the Delta 3-DOF robot model and experiment with real-time control of the controllers built on MATLAB/Simulink, to control the Delta 3-DOF robot orbit via the transmission and reception protocol. UART data.

3. Limitations of the dissertation

The dissertation focuses on researching the MIMO nonlinear system - Delta 3-DOF robot and developing a structural optimization algorithm, along with the parameters of a recurrent fuzzy neural network, to control and follow the object's trajectory. nonlinearity, to improve the control quality of the entire closed-loop system.

4. Subject and scope of research

- *Research subjects*: MIMO and SISO nonlinear systems are possible mathematical description using a nonlinear state model.

- *Research scope:* Focusing on researching mathematical description methods for MIMO nonlinear systems is the Delta 3-DOF robot. Research published works at home and abroad in the fields of nonlinear control, adaptive control, genetic algorithms and fuzzy control as a foundation for evaluating the research quality of the proposed algorithm is a combined RFNN-PID monitoring control algorithm. At the same time, research soft computing tools to verify the correctness of the algorithm proposed in the thesis and experiment on a real nonlinear system model, which is closed-loop orbit tracking control of Delta robot and stable control. Determine liquid flow on RT020 system.

5. Research methods and approaches

The thesis was carried out with the following research methods:

- Research documents: collect documents from scientific sources in the industry in prestigious domestic and international scientific journals related to the research content of the thesis; Analyze and synthesize documents from the sources collected above, determine the advantages of the nonlinear system control method to use as a scientific basis for the thesis, and at the same time improve the shortcomings in the document.

- Research Solid works and CorelDRAW software to design drawings and cut Delta 3-DOF robot mechanical frames.

- Research Proteus software to design, simulate and construct control circuits for Delta 3-DOF robots.

- Experimental model of nonlinear system dynamics using Delta 3-DOF robot. Simulation results are performed on MATLAB/Simulink.

- Information processing: observe system response and adjust controller parameters (if any) to satisfy control quality criteria such as: setting error, transit time. degree and overshoot.

6. Scientific and practical significance of the dissertation

6.1. Scientific significance

Research proposes a monitoring control algorithm RFNN-PID: in which the RFNNC recurrent fuzzy neural network controller combined with the PID controller and RFNNI identifier is used to observe erroneous parameters output number of the nonlinear system to update and adjust the optimal input parameters to control the nonlinear system according to the preset signal so that the tracking error approaches zero, reduces overshoot and is less affected by noise.

6.2. Practical significance

Verifying the practical applicability of the RFNN-PID supervisory control algorithm to control the proposed nonlinear system using soft calculation tools and experimenting on a real nonlinear system model is tracking control. Delta 3-DOF robot closed-loop orbit and on the Gunt-Hamburg RT020 flow stabilization system.

7. New contributions of the thesis

7.1. Theoretically

- Develope a neural network adaptive control algorithm based on the SNA-PID recurrent fuzzy neural network identifier to control the nonlinear system following given trajectories.
- Build a supervisory control algorithm using the RFNNC recurrent fuzzy neural network combined with a PID controller to control the nonlinear system to follow the trajectory. At the same time, evaluate and select an appropriate recurrent fuzzy neural network structure in controlling nonlinear systems.

7.2. About practice

- Simulate FUZZY-PID, GA-PID and SNA-PID controllers to control the nonlinear system following a preset trajectory to meet quality criteria.
- Simulate the supervisory control unit using the RFNNC recurrent fuzzy neural network, combined with the PID to control the nonlinear system following a preset trajectory to meet quality criteria.
- Improve the quality of the supervisory controller by using the RFNNI recurrent fuzzy neural network identifier, to identify the nonlinear system back to the recurrent fuzzy neural network controller for self-updating control. adapted to the PID controller, which is responsible for creating a large initial voltage to rotate the arms of the nonlinear system to follow a preset trajectory.
- Experimental application on two real nonlinear system models: one is to control the Delta robot to follow circular and figure 8 orbits, and at the same time, experiment on the second nonlinear system model is to control the traffic stabilization system RT020 liquid.

8. Structure of the thesis

The thesis is organized including an Overview section; Chapter 1 presents adaptive PID control based on recurrent fuzzy neural network to control nonlinear systems; RFNN-PID combined supervisory control based on a fuzzy recurrent neural network identifier to control a nonlinear system is Chapter 2. Chapter 3 presents the research method of manufacturing and experimenting with control on a nonlinear system. , and present the results and conclusions.

Ho Chi Minh City, March 29, 2024

Science instructor **PhD. Student**

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