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REGIONAL FUZZY CONTROL FOR NONLINEAR SHIP STEERING SYSTEMS

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Abstract. *This paper describes a fuzzy controller design for nonlinear ship steering systems. The nonlinear ship steering system is transformed into a regional Takagi-Sugeno (T-S) fuzzy model, which has similar dynamics to the original nonlinear system. The fuzzy region concept is used to partition the plant rules into several fuzzy regions so that only one region is fired at the instant at which each input vector is introduced. The proposed concept decreases the number of fuzzy control rules needed and cancels out the influence of some items. To improve the speed of response when deriving the stability conditions with the Lyapunov stability criterion, the decay rate constraint is imposed. In this fuzzy-region controller design with a linear matrix inequality (LMI) solver, all the stability conditions are represented in terms of LMIs. Finally, the feasibility and validity of the proposed method are illustrated with a numerical simulation example.*

Keywords: Ship steering systems, Fuzzy-region concept, Linear Matrix Inequality (LMI), Decay rate

1. **Introduction.** In this paper we introduce a novel T-S fuzzy model for a nonlinear ship steering system [1-5]. It is interesting to note that nonlinear controller design models must exhibit nonlinear interaction between three degrees of freedom (i.e., surge, sway and yaw), which are produced because of the main propellers aft on the ship. It has usually been assumed when solving the ship steering system control problem that the kinematic equations can be linearized about a constant yaw angle, meaning that linear theory and gain scheduling techniques can be applied [4]. Some modeling errors do occur during the system linearization.

Most researchers utilize fuzzy control techniques when designing nonlinear ship steering control systems. The T-S fuzzy model [3,6-13] includes a set of IF-THEN rules. These rules represent the linear input-output relations of nonlinear systems locally. The fuzzy controller design is based on the parallel distributed compensation (PDC) [3,6-13]. In the PDC control approach linear feedback gains are designed for each local linear model, and the overall control input is a blend of these linear feedback gains. Although the PDC concept plays an important role in the T-S fuzzy control problems, this method is subject to failure if the fuzzy model involves many plant rules [14,15]. This is because there are many LMIs [16,17] involved in optimization and many decision variables that need to be solved for simultaneously. Recently, some investigators have utilized a piecewise quadratic Lyapunov function [14,15] to analyze the stability of T-S fuzzy systems. However this