A Stable Self-Structuring Adaptive Fuzzy Control Scheme for Continuous Single-Input Single-Output Nonlinear Systems

by

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Abstract

Adaptive fuzzy control has been an active research area in the past decade. Fundamental issues such as stability, robustness, and performance analysis have been solved. However, one main drawback is the generally fixed structure of the fuzzy controllers, which are normally chosen by trial-and-error in practice. Few attempts to develop self-structuring AFC have been reported, and important issues such as stability, computational efficiency, and implementability have not been investigated thoroughly. In particular, the stability of the system when the structure changes has not been proven. Thus, a more effective self-structuring AFC scheme is desirable.

The main objective of the research is to develop a stable self-structuring AFC scheme for continuous-time single-input-single-output (SISO) uncertain nonlinear systems.

A novel online self-structuring adaptive fuzzy control scheme that is applicable for a number of classes of continuous SISO nonlinear systems is proposed. The applicable classes include affine nonlinear systems, non-affine nonlinear systems, and nonlinear systems in triangular forms. The main features of the proposed control scheme are:

- It needs less restriction on the controlled plants and no restriction on the design parameters.
- It employs a modified adaptive law that guarantees explicit boundedness of adaptive parameters and control action.
- The self-structuring algorithm is relatively simple and guarantees explicit boundedness of the number of rules generated.
- Only triangular membership functions are generated and only 2 membership functions are allowed to overlap to increase the interpretability of generated fuzzy controllers.
- High-gain observers are used when not all the states are measurable and the design of observers is completely separated from the design of controllers.
- For nonlinear systems in triangular forms, only one fuzzy system is needed (unlike the back-stepping approach where one fuzzy system is needed at each step).
• An approximation error estimator and an automatic switching mechanism can be used to further increase the robustness and computational efficiency.

The stability of the overall system, especially when the structure changes, is guaranteed using the Lyapunov stability technique. The overall system is stable in the sense that all the variables are bounded (including number of rules generated) and the tracking error is uniformly ultimately bounded. The proposed control algorithms are implemented in Matlab and Simulink for ease of simulation and practical application. Numerous simulation examples are performed to demonstrate the theoretical results.

The proposed control scheme makes practical application of AFC easier. Designers need to specify only a few design parameters and no longer have to specify the controller structure by trial and error. A simulation or application can be quickly and easily implemented using the developed controllers in Simulink.

**Publications**

As part of this research, the following papers have been published:

**Journal papers:**


**Conference papers:**

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Abbreviations

AFC: Adaptive Fuzzy Control
AIC: Adaptive Intelligent Control
ANNC: Adaptive Neural Network Control
CSTR: Continuous Stirred Tank Reactor
FLC: Fuzzy Logic Controller
GUI: Graphical User Interface
MIMO: Multi Input Multi Output
NN: Neural Network
SISO: Single Input Single Output
SSAFC: Self-Structuring Adaptive Fuzzy Control
SSDAFC: Self-Structuring Adaptive Fuzzy Control
UUB: Uniform Ultimate Boundedness or Uniformly Ultimately Bounded


