Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(11):99-102

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Sliding Mode Multi-ANFIS (SMANFIS) Control for Vision Robot

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Abstract The SMANFIS includes sliding mode controller (SC) and multitude adaptive network fuzzy inference system (MANFIS). The MANFIS controller can compensate the estimation error then to control the vision robot to follow the desired path. The simulation results show that the proposed SMANFIS controller has good performance for the vision robot.

Keywords ANFIS, Fuzzy neural network control, Vision robot

1. Introduction

Fuzzy neural networks (FNN) technologies have been used in many areas. Many different types of FNNS have been proposed in every areas of research. In this paper, the Adaptive network based fuzzy inference system (ANFIS) [1] is used. It has been used in every area of reasearches widely and successfully for the reason of it possesses efficient learning ability and easy implementations. Its related applications can be found in [2-4]. However, by using the ANFIS controller alone, better performences cannot be easy achieved, so in this paper, another combination of multi-ANFIS (MANFIS) approach is proposed to deal with a control prolem of vision robot. This MANFIS controller comprises many ANFIS controllers such as to obtain better robust, decoupled and adaptive performances. Besides, a sliding mode controller (SC) [5-7] is combined with this MANFIS to do as controller which is proposed sliding mode multi ANFIS (SMANFIS) controller. The MANFIS controller is used to mimic a controller, and the SC is designed to compensate for the approximation error between the optimized or desired MANFIS controller and the controller. The ANFIS controller is reliable and suitable offline fuzzy adaptive learning algorithms which is served as a basis for constructing a set of fuzzy if-then memory and then use the appropriate provisions of the membership functions to generate fuzzy associated memory (FAM) to serve as fuzzy rules. A SC is added to relax the requirement for the uncertain bound in an estimation mechanism. At last, the performances of comparisons between the ANFIS and the proposed SMANFIS for vision robot are shown to present the good performance and stable stability. Simulations results for vision robot control have also verified that the proposed design method can achieve better control performance, stability and robustness.

2. SMANFIS controller design

Consider a typical control model as below:

$$\dot{\boldsymbol{x}} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{B}\boldsymbol{u} + \boldsymbol{d} \quad (1)$$

All of $\boldsymbol{A}$ and $\boldsymbol{B}$ will be depended on states and time variations. A $\boldsymbol{u}_f$ is denoted as a controller. In this paper, the following expressions of parameters will be described for every single states respectively and will not be represented as bold type of words.

Since the system parameters are supposed to be unknown and disturbed and a controller is supposed to be exist but it is difficult to be achieved and designed. In general, many methods are used by combining some traditional control methods such as PID (proportional integral derivative), fuzzy, neural networks, etc. with sliding mode control. In this paper, ANFIS controller will be designed to combine the sliding mode control to do as an ideal controller. The role of sliding mode control is designed to overcome disturbances and the output error between the ANFIS controller and the ideal controller.

The ANFIS has been developed and verified many years. It is a reliable self learning algorithm to construct many fuzzy if-then rules with correct membership functions. Meanwhile, it can generate the corresponding fuzzy associated memory (FAM) which can be easy to imply the system input-output relations.

The ANFIS theorem is demonstrated as follows.

$$R_i : If\ x_1\ is\ A_{i1}\ \ ...and\ x_n\ is\ A_{in}$$

$$then\ u_i = p_{i1}x_1 + .. + p_{in}x_n + p_i \qquad (2)$$

where R_i is the ith fuzzy rules, i=1, 2,..,r; A_{ij} is the fuzzy set in the antecedent part corresponded by the ith fuzzy rule and jth input variable and $p_{i1},..., p_{in}$, p_i are the fuzzy consequent part parameters. Finally, the output u can be calculated by using general Sugeno defuzzified method.

The self learning algorithm developed in [1] is base on least squares estimate (LSE) and gradient descent (GD) approaches which can be applied to many areas. The human knowledge input for output pairs should be fed into ANFIS in advance then some other same fuzzy reasoning can be achieved automatically. The real implementation of 2-inputs 1-output ANFIS is shown in Fig. 1 which has 3 membership functions for every two inputs such that there are nine fuzzy rules. In practical operation, many inputs and outputs can be added in ANFIS design window under the requirements of system. This design method is called as multi-ANFIS (MANFIS) in this paper. The advantages of MANFIS are easy implementation, decoupled, robust and reliable. The simplest real implementation for two-inputs two-outputs MANFIS can be got by using many ANFIS to do controller.

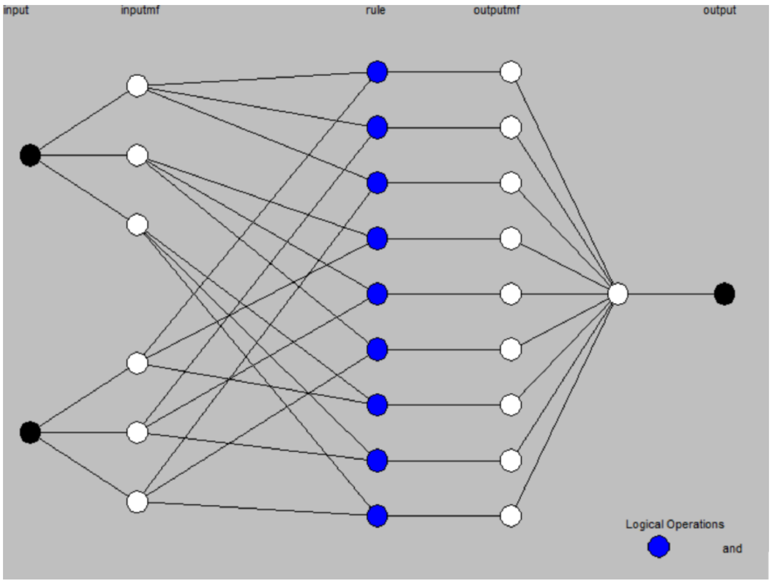

Figure 1: Two-inputs one-output ANFIS real implementation diagram

The useful property of MANFIS is its ability to near mapping of linear or nonlinear system responses by self learning. According to the universal approximation theorem, optimal MANFIS controller u^*_{manfis} is exist. The reasonable error bound is assumed by human knowledge during observation. Therefore, a bound is set to guarantee system stability. After defining the bound, the sliding mode controller can be designed to compensate

for the effect of response error and is designed as $u_s = E\,\mathrm{sgn}(s)$, where E is represented as a reasonable error bound and s is a sliding surface. The sliding surface is based on the tracking error e.
Regarding the sliding surface, many researches have proposed their useful methodologies. Among these methods, the integral type sliding function is used widely which is defined as

$$s = e + k\int_0^t e\,d\tau\,. \tag{3}$$

For the system uncertainties and response error are exist, the controller u_f of every single input can be obtained by some easy manipulations such that it will be a type of a Hurwitz polynomial which mathematical roots will lie definitely in the left half of open complex plane, this means $\lim_{t\to\infty} e(t) = 0$. Because the system is time variant or time delay, the controller u_f can be designed to cope with these considered terms. Finally, the control law of sliding mode MANFIS (SMANFIS) can be achieved as

$$u_f = u_{manfis} + u_s \tag{4}$$

where u_{manfis} is the controller of MANFIS and u_s is the sliding mode controller which is designed as $u_s = E\,\mathrm{sgn}(s)$. The inputs of the system controller are s and $\dot{s}$.
The most useful property of MANFIS is its ability to learn and memorize linear or nonlinear mapping relations. For simplicity, the parameters of MANFIS are all designed by human knowledge in advance. By the fuzzy universal approximation theorem, there should exist an optimal MANFIS such that

$$u^*_{manfis} = u_{manfis} + \beta \tag{5}$$

where β is represented as the design error and is assumed to be bounded by $0 \le |\beta| \le E$ where E is a positive number. From the aforementioned sliding mode controller $u_s = E\,\mathrm{sgn}(s)$ which is designed to compensate for the design error β.

3. Simulation results

Consider a vision robot walking on O-XY plane. The considered dynamic state space equation is shown as below [8, 9].

$$\begin{aligned} \dot{\boldsymbol{x}} &= \boldsymbol{Ax} + \boldsymbol{Bu} \\ \boldsymbol{y} &= \boldsymbol{Cx} \end{aligned} \tag{6}$$

An SMANFIS is designed to control the vision robot. The design purpose is that the vision robot can be controlled by captured image to decide a desired path to avoid collision obstacle. The input variables of SMANFIS are designed by using the aforementioned sliding surfaces of robot velocity and azimuth angle (s_v, s_ϕ) and their derivative values ($\dot{s}_v, \dot{s}_\phi$). The outputs are u_v, u_ϕ which are the torques implemented to vision robot to get desired velocity (v_d) and azimuth angle (ϕ_d), respectively. Based on the SMANFIS design concept, both of u_v and u_ϕ are combined with u_l and u_r which are forced to left and right wheels controlled by the SMANFIS controller.
Two inputs and two outputs are designed for SMANFIS controller, one is control of the velocity and the other is control of the angle. Suitable tuned weightings, fuzzy if-then rules and membership functions are achieved to get favorable tracking performance and the sliding mode controller is used to obtain better tracking performance. The corresponding FAM is achieved to serve as programming data when the practical test is implemented.

The simulations are manipulated with two obstacles to get desired path and the sampling time of simulation is set as 5 ms. The simulation results are shown as in Fig. 2. Compared SMANFIS with ANFIS, it is revealed that the better performances are achieved.

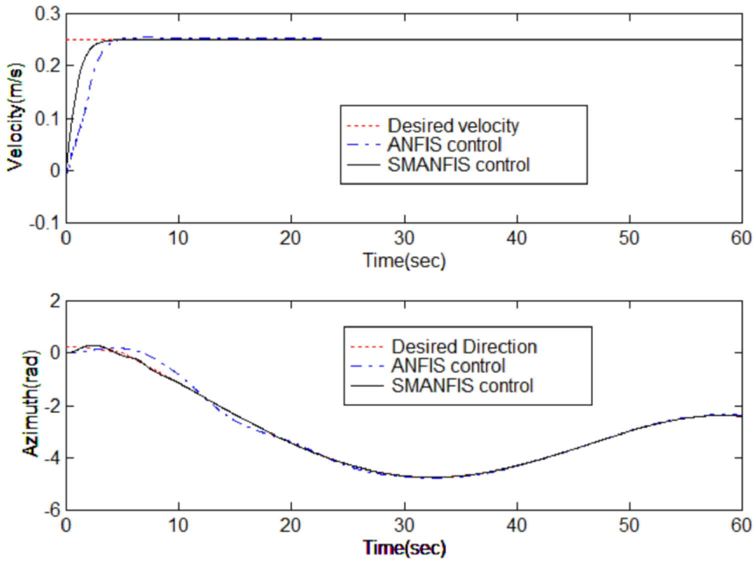

Figure 2: Vision robot control results

4. Conclusion

This paper demonstrates that the control of vision robot can possess ability of following a desired path. A SMANFIS controller has been developed in this paper. It is composed of an MANFIS controller and a SC. The simulation results show that the proposed SMANFIS controller possesses good performance, robustness and stability guaranteed ability for the vision robot.

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