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Adaptive Neuro-fuzzy inference system based estimation of EAMA elevation joint error compensation

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ABSTRACT

EAMA (EAST Articulated Maintenance Arm) is an articulated serial robot arm working in experimental advanced superconductor tokamak for the inspection and maintenance. This paper implements algorithms to calibrate the synchronize deflection and estimate its signal for the robot control. The retrieval has two distinct tasks, a shaft rotation direction signal processing and a discrete data classification, meanwhile neuro network and expert system are applied for completing these separate tasks respectively. In this paper the use of Adaptive Neuro-fuzzy Inference System for estimating the compensation error from an unformulated cluster of data that has unneglectable nonlinearity is presented. The simulation result shows that the root mean squared error is significant improved, the final results satisfy the accuracy.

1. Introduction

EAMA (EAST Articulated Maintenance Arm) is a long articulated flexible robot for the experimental advanced superconductor tokamak vacuum vessel (VV) [1]. Its maintenance services include geometrically enclosed space inspection and graphite tile friction cleaning for the Plasma Facing Components (PFCs) of the EAST vessel [2]. As shown in Fig. 1, this segment composites with a rotation and elevation joints, for such complex mechanisms the accurate and reliable operations in work space are required [3]. It is not always easy to acquire the exact model from the sensed results to manage the remotely control by using error compensation. The use of intelligent hybrid system is growing rapidly with successful applications in process control, especially for model-less application. In most case, the Adaptive Neuro-fuzzy Inference System (ANFIS) architecture is employed to model nonlinear functions, estimate nonlinear components in on-line control system, and forecast a chaotic time series, which produce significant improvement in the results [4]. Many researches have been applied on ANFIS senseless estimation [5], modeling hydrological time series [6], model forecasting [7,8]. For rotation, Extended Kalman Filter has been adopted to estimate the compensation error in the curve fitted idealized model of the difference between reference data and experiment measurement [9]. However for elevation, it is more suitable to use Adaptive Neuro-fuzzy Inference System modeling and forecasting the error in EAMA joints.

This paper presents the use of Adaptive Neuro-fuzzy Inference System to estimate the compensation error from an unformulated cluster of data. First, two distinct sub-tasks, shaft rotation direction signal processing and serial data modeling are presented then neuro network and expert system are investigated to solve these separate tasks respectively. After this introduction, the rest of the paper is organized as follows: Section 2 formulates the target model analysis, error sources. Section 3, 4 present Adaptive Neuro-fuzzy Inference System algorithm strategy, objectives and test results. Finally, the last section outlines the main conclusions.

2. Error source and model analysis

In the segment 4 of the manipulator there are two AS5047D incremental sensors, which are illustrated in Fig. 2(a) [10]. The microchip is fixed on the bear housing and the magnet is attached to the shaft, which axis of the magnet must be aligned on the center of the package as shown in Fig. 2(b). As the assembly error in the gap between the inner ring and outer ring, it results a difficulty of axis aligning when rotor is running. When the Anti-rotational mounting of the encoder is not proper, the missing or extra counts could be caused by the mechanical factor listed below [11].

- Coupling is not tight and slipping.
- Slippage and incorrect tension could happen, when belt is used.
- Incorrect wheel for the application or working incorrectly.
- Roughness or side movement turning encoder shaft can mean a bad bearings, which can cause erratic readings.

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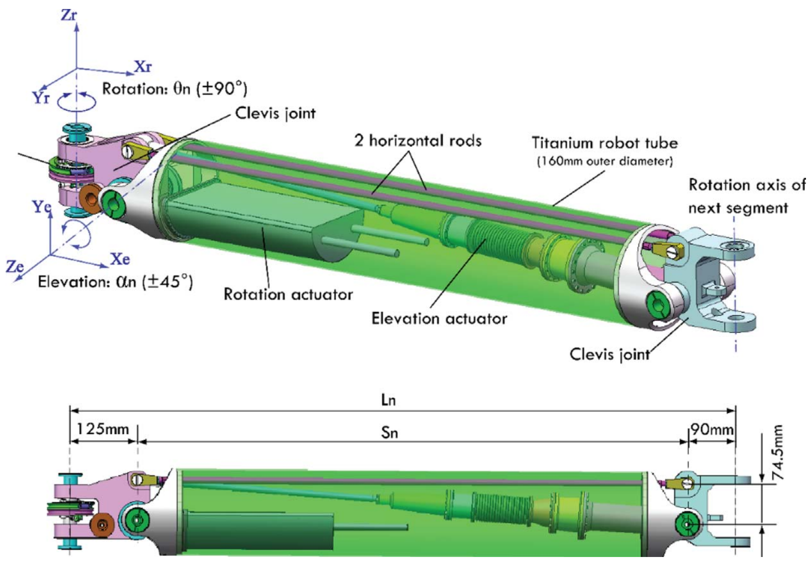

Fig. 1. EAMA segment prototype mechanism structure.

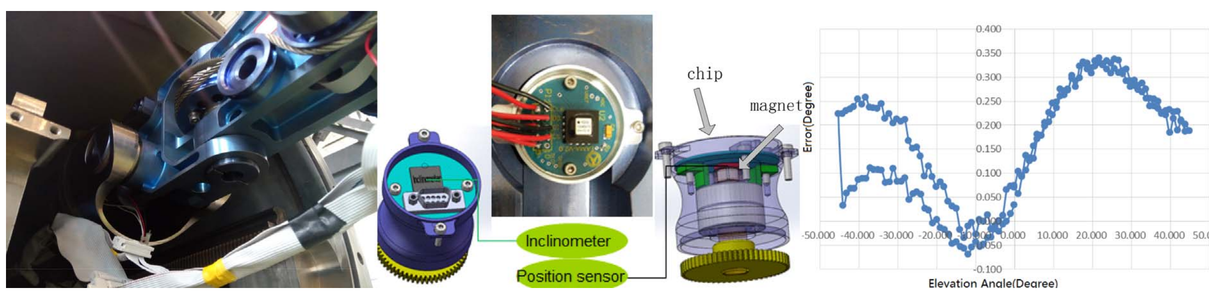

Fig. 2. (a) Joint structure, (b) Mechanical installation of AS5047D, (c) Elevation Angle Error.

We measured a retrieve turn from 0 ° to + 45 ° and travel inverse to − 45 ° then back to 0 °. The sample period is united from reference encoder and demo board. The rotation speed is settled to 1 ° per second. The results of segment 4 drawn in Fig. 2(c) are aligned to a certain amplitude region, which adhere to unregulated non-linearity with a significant discontinues. This data model is hard to be curve fitted or data driven. The intelligent artificial algorithm is always an available option to solve this problem.

3. Adaptive Neuro-fuzzy inference system

3.1. Neuro network and fuzzy system

Fuzzy logic provides a mathematical ability to capture the sort of uncertainties associated with cognitive processes, which is difficult to acquire from increment measurement. Artificial neuro systems can be understood as simplified mathematical model of learning systems and they work as parallel distributed computing networks (Table 1).

3.2. Adaptive Neuro-fuzzy inference system

The ANFIS is a class of adaptive network [12], which is functionally equivalent to FISs. The basics of ANFIS are introduced in detail in many mathematical related research [13–15]. As the pseudo code shown in Table 2, it is a very powerful approach for building complex and non-linear relationship between a set of input and output data sets, which includes the follow issues[16].

- Fuzzy model type selection.
- Model input and output variables selection.
- Fuzzy model structure identification, which includes determination of the number and types of membership functions for the input and output variables and the number of fuzzy rules.
- Antecedent and consequent membership functions parameters identification.

Table 1
Comparison of neuro network and fuzzy system.

Neuro Networks	Fuzzy Systems
no mathematical model necessary	no mathematical model necessary
learning from scratch	priori knowledge essential
several learning algorithms	not capable to learn
black-box behavior	simple interpretation and implementation

Table 2
ANFIS Pseudo-Code.

Pseudo-code of ANFIS

Set (Number Of Inputs, 3);
Set (Number Of Outputs,1);
Set (Number Of MF,2, 3, 3);
Set (Type of MF, trimf)
For input: = 1 to Number Of Inputs do
Begin
Read (TrainingData);
Determine (TrainingDataNumber);
Calculate (NumberOfRules);
Identifying (antecedent, consequent);
Identifying (consequent parameters);
CreateRules;
Set (EpochNumber,40);
Learning;
Testing;