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Speed Scheduling of Autonomous Railway Vehicle Control System using Neuro-Fuzzy System

Aiesha Ahmad, M.Saleem Khan, Khalil Ahmed, Nida Anwar and Atifa Athar

Abstract— This paper presents the speed scheduling system of autonomous railway vehicles using neuro-fuzzy system. Speed maintaining and scheduling system is considered integral part for successful development of autonomous railway vehicle control system. This work focuses on development of intelligent speed scheduling system to successfully cope with constraint of different conditions by improving performance and stability as compared to existing control systems of railway vehicles. This intelligent speed scheduling system has ability to learn, take decision and act according to hard conditions; junction track information (JTI), crossing gate information (CG) and track clearance (TCL), and flexible conditions; vehicle tilting (VT), track condition (TC) and environment monitoring (EM), uses neuro-fuzzy system (NFS) comprising main features of fuzzy inference system (FIS) and artificial neural network (ANN). Artificial neural network (ANN) and fuzzy inference system (FIS) are used to solve complex real time speed scheduling problems intelligently by learning, adaptation and human knowledge incorporation. The proposed speed scheduling system learns and adapts automatically under uncertain situations of railway track system. This helps to maintain successfully the speed of railway vehicles with environment monitoring, time scheduling and minimizes the risk of overturning.

Index Terms— Autonomous Railway Vehicle, Control System, Environment Monitoring, Learning and Adaptation, Neuro-Fuzzy System, Railway Track System, Speed Scheduling.

1 INTRODUCTION

ADVANCEMENT in railway vehicles technology has been increased from last few years to facilitate passengers by improving performance with speed, time scheduling, traffic control and passenger management [1]. The importance of control, management and monitoring for railway vehicles progress gradually under modern solution of embedded systems, software based computer aided control systems, sensors and data communication technologies. Different methods are used to control speed at different stages under different conditions for high speed railway trains like the development of eddy current brake system (ECB) by generating constant torque with control algorithm and intelligent dispatching system using neuro-fuzzy technique [2], [3]. The design and development of agent base autonomous railway vehicle control system is considered important for flexible and well established network to enable collaboration between centralized and distributed systems of railway tracks [4].

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In these autonomous railway control systems, agents are defined as condition monitoring units with capability to collect information independently and control system autonomously according to their design control [5].
The monitoring and control of railway vehicles are mainly focused on speed management and scheduling, traffic control and time scheduling. Speed scheduling plays vital role for successful development of autonomous railway control system by focusing on hard conditions; junction track information (JTI), crossing gate information (CG) and track clearance (TCL), and flexible conditions; vehicle (VT) tilting, track condition (TC) and environment monitoring (EM). To maintain information about track condition with support of acceptable ride quality and tilting of trains around curved tracks with speed adjustment have been done through some sensors, mathematical modular technique and kalman filtering for data estimation and tracking in existing systems. The complexity and dynamic nature of autonomous railway control system is needed some sophisticated method with domain knowledge representation, automatic learning and adaptation for successful handling of uncertain situations during running on track.

Intelligent systems incorporate the main features of artificial intelligence like learning and decision making under uncertain situations by using previous knowledge [3], [6], [7]. To make autonomous railway control system more flexible and accurate, it's necessary to develop intelligent speed scheduling system using neuro-fuzzy techniques. Neuro-fuzzy system consists of key features of fuzzy inference systems like capability to perform uncertain reasoning under incorporation of human knowledge and artificial neural network to learn and adapt in uncertain situations that form the hybrid intelligent system. The proposed intelligent speed scheduling system for high speed railway vehicles will be able to learn and adapt under uncertain situations of hard and flexible conditions by adjusting speed according to the requirement with high safety, performance and time management.

The arrangement of this research paper is as follows: section 2 describes the brief introduction of fuzzy inference system (FIS), Artificial Neural Network (ANN) and Neuro-Fuzzy systems (NF). Structure of proposed speed scheduling system is discussed in section 3 with design model of proposed system and MAT Lab simulation while section 4 consists of results and discussion of Design model of intelligent speed scheduling system. Conclusion and future work are discussed in section 5.

2 Overview of Fuzzy Inference System, Artificial Neural Network and Neuro-Fuzzy System

Fuzzy inference system, artificial neural network and Neuro-fuzzy system provide the control strategies for the Various systems to run autonomously.

2.1 Fuzzy Inference System

There has been rapid growth in fuzzy logic and fuzzy set theory from last few decades to deal successfully with complex uncertainties inputs in many real time processes to achieve definite outputs (or solution/ decision) [6], [8], [9]. Basically fuzzy inference system (FIS) or fuzzy model is a famous computing framework that consists the idea of fuzzy IF-THEN Rules, and the selection of fuzzy rules. Fuzzy set theory deals with membership functions and fuzzy reasoning to perform inference mechanism upon the rules and given facts to obtain reasonable solution. The actual purpose of fuzzy inference is mapping of inputs to a given output using fuzzy logic that provides the base for better, quicker and more accurate decision/output (s) as compared to traditional approach. Fuzzy inference system is not only capable to deal with knowledge in linguistic rules from human experts but also improve performance by adapting itself using numeric data [10]. Artificial Neural Network (ANN) cannot deal with linguistic values which gives advantage to FIS over ANN. Fuzzy inference system further divided into three categories such as Bank Inference System, Medical Inference System and Boiler Controller System, on the basis of wide range of successful applications in different domains [8].

2.2 Artificial Neural Network

Artificial Neural Network (ANN) is considered as one of main areas in Artificial Intelligence (AI) to make systems intelligent with learning capability. It is inspired by biological nervous system as human brain has amazing parallel processing ability with effectively handling of incomplete and imprecise information [9]. The ANN is composed of number of neurons (or processes) that communicate with each other through weighted connections. Artificial Neural Network follows some rules which help to adjust the weights of connections on the basis of data. There are two main techniques used in ANN learning paradigm: Supervised Learning; which consists of input-output pairs for training to minimize the weights of connection between ANN outputs and Training data output, Unsupervised Learning; focused on input data sets with solution state space and adjust connections on the basis of output neurons with highest activation output [7]. ANN and FIS are widely used in the field of predication, identification, diagnostics and the control of linear and nonlinear systems.

2.3 Neuro-Fuzzy System

Neuro-Fuzzy System combines the advantages of FIS and ANN, therefore it is considered as powerful approach in area of Hybrid Intelligent systems to handle complex real time problems successfully [9], [11]. It is like neural network with equivalent functionality of fuzzy inference system because it has ability to combine the parallel learning and computation abilities of neural network with knowledge representation and explanation like humans of fuzzy model. This approach increases the transparency of neural network with infusion of learning capability in fuzzy models.

3 Strucutre of Proposed Speed Scheduling System

The proposed speed scheduling system consists of preloaded information of track in form of root chart and intelligent design to cope with uncertain conditions successfully. Railway track system receives two main inputs (hard and flexible conditions) from environment and uses sensors to differentiate between these inputs. In case of flexible conditions (FC): VT, EM and TC observed through sensors and given to FIS. These sensors are capable to monitor environment monitoring (EM), track condition (TC) and vehicle tilting (VT) individually by subdividing into 0 to 5 volt in which 0 volt represents the absence of these flexible conditions with no speed adjustment while from 1-5 volt shows gradual increase in these conditions with respective decrease in speed, like 5 volt represents worst condition with slow speed. Hard conditions (HC) like JTI, TCL and CG are sensed through sensors at particular distance and ultimately stop the train whatever adjusted speed may be after existence of flexible conditions. Brief description of input versus output is shown in Table 1 of railway vehicle speed scheduling.

The speed scheduling is achieved by using back-propagation algorithm in neuro-fuzzy for learning and

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successful management of uncertain situations.

TABLE 1
OVERVIEW OF I/O RELATION

INPUT						OUTPUT
Flexible Conditions			Hard Conditions			Speed
TC	EM	VT	JTI	CG	TCL	
L	M	L	N	N	Y	Stop
L	L	H	N	Y	N	Stop
H	L	L	Y	N	N	Stop
VH	H	L	N	Y	Y	Stop
L	L	L	Y	Y	N	Stop
L	H	H	Y	N	Y	Stop
H	L	H	Y	Y	Y	Stop
L	L	L	N	N	N	V.Fast
L	L	M	N	N	N	Fast
M	M	L	N	N	N	Fast
L	L	H	N	N	N	Average
M	VH	L	N	N	N	Slow

3.1 Design Model of Intelligent Speed Scheduling System

This neuro-fuzzy based proposed speed scheduling system will be capable to reduce speed by increasing time after comparing with root chart in uncertain environment. Then it will compare the increase time with root chart estimated time to reach next junction and increase speed to its maximum possible limit to overcome the delay time after handling uncertain situation. The learning capability of proposed system will mature by handling uncertain situations with passage of time that ultimately increase the accuracy and response time. The design model of the proposed speed scheduling is shown in Fig. 1.

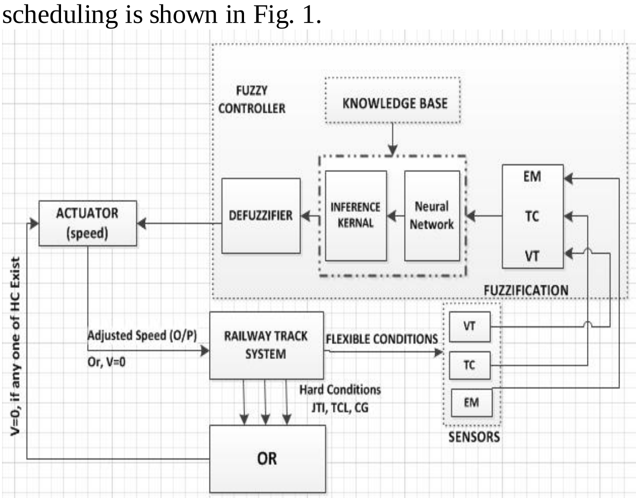

Fig. 1. Neuro-Fuzzy Based Intelligent Speed Scheduling System.

3.2 Speed Scheduling With Fuzzy Inference System

Basic structure of speed scheduling system with hard conditions (HC) and flexible conditions (FC) using fuzzy logic is shown in Fig. 2 which is first step towards neuro-fuzzy technique.

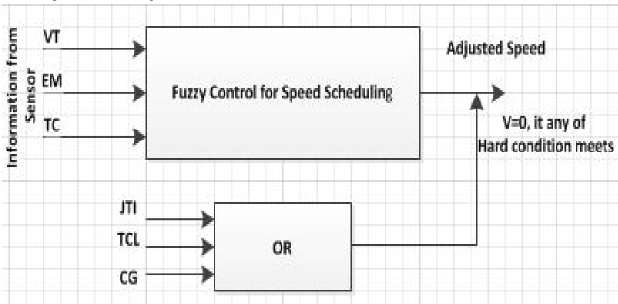

Fig. 2. Block Diagram of Speed Control System.

The two main conditions, HC and FC are further categorized into six input variables; Junction Track Information (JTI), Crossing Gate Information (CG) and Track Clearance (TCL) come under HC, and Vehicle Tilting (VT), Track Conditions (TC), Environment Monitoring (EM) are related to FC and categorized by sensors. Fuzzy control system is used to adjust speed quickly and precisely in the presence of any flexible condition or delay due to any hard condition after comparing with root chart. The fuzzy control system for the proposed speed scheduling system consists of fuzzifier, inference kernel with knowledge base including database, rule base and output membership functions, and defuzzifier block shown in Fig.3.

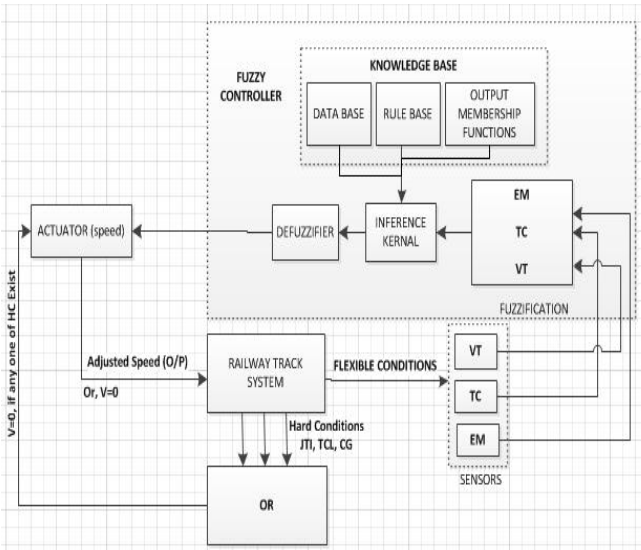

Fig. 3. Fuzzy Control Speed Scheduling.

The crisp values of input variables (VT, TC and EM) are reached to fuzzifier after passing through sensors to identify the types of these input variables [12]- [13]. In fuzzifier, comparison of input crisp values up to certain levels is done by generating linguistic values (Low, Medium, High and

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Very High) against each input variable. These linguistic values are passed to inference kernel connected with knowledge base.

In knowledge base, key feature of database is to manipulate fuzzy data and provide essential definitions to describe the linguistic control rules which help the rule base to define the control goals and control policy of particular system such as speed scheduling of railway vehicle in this scenario while output membership functions define the strength of output variables with formulation to adjust speed. After receiving feedback from knowledge base, the next step of inference kernel is to simulate the human decision with fuzzy logic rules to make the control decision in term of adjusted speed, the final outcome. In the next step, defuzzifier maps fuzzy output variable (Slow, Average, Fast and Very Fast) to a crisp value which finally comes to railway track system after passing through actuator.

3.3 Speed Scheduling With Adaptive Neuro-Fuzzy Inference System

Learning capability of speed scheduling system with FIS shows its better performance with quick response in uncertain situations as compared to previous methods. Adaptive neuro-fuzzy inference system (ANFIS) is used to adjust speed according to the requirement with learning capability to manage successfully uncertain situations. ANFIS only supports Takagi/Sugeno type fuzzy inference system which generates single output. Training data set with 400 values for training of flexible conditions with respect to speed is used in ANFIS. The ANFIS model structure with three inputs (VT, TC and EM) shown in Fig. 4, with output speed. Each input further categorizes into four membership functions with 64 fuzzy rules and back propagation learning algorithm.

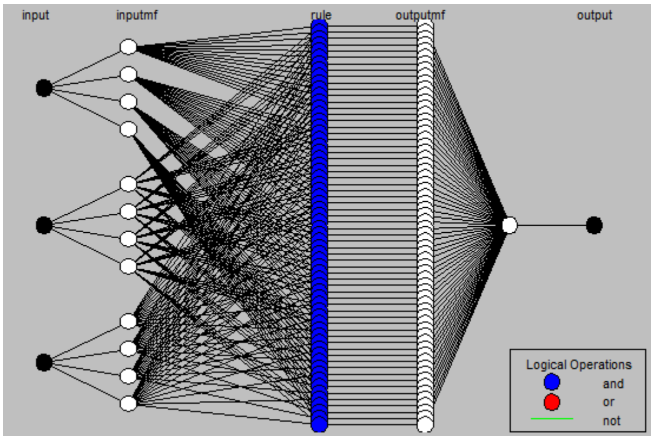

Fig. 4. ANFIS Model Strucutre for Speed Scheduling of Railway Vehicle.

After training of 400 data sets, testing and checking data sets have applied for validation of training data to support our proposed speed scheduling system and shown in Fig. 5.

There are 54 testing data pairs against training of 400 data sets with average data error less than 4, which is very low. The testing data results are shown in Fig.6.

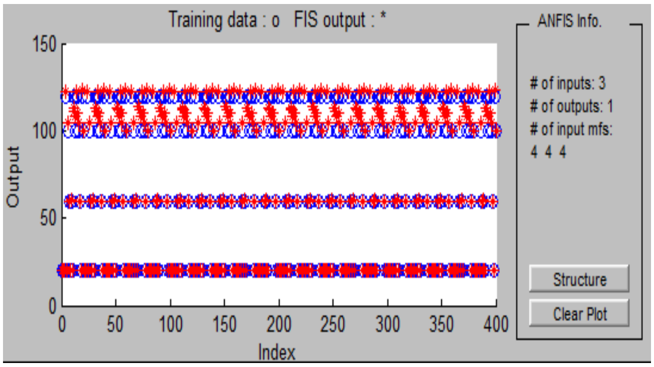

Fig. 5. ANFIS Model for Training Data with Soft Conditions.

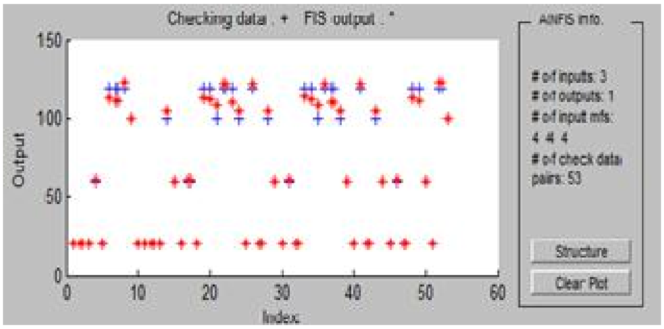

Fig. 6. ANFIS Model for Testing Data with Soft Conditions.

Checking data set with 53 check data pairs have done to show the authentication of training and testing data pairs. The checking data result has shown in Fig.7 that again shows minimum noise against the training data. After that, the importance of proposed intelligent speed scheduling system has been proved.

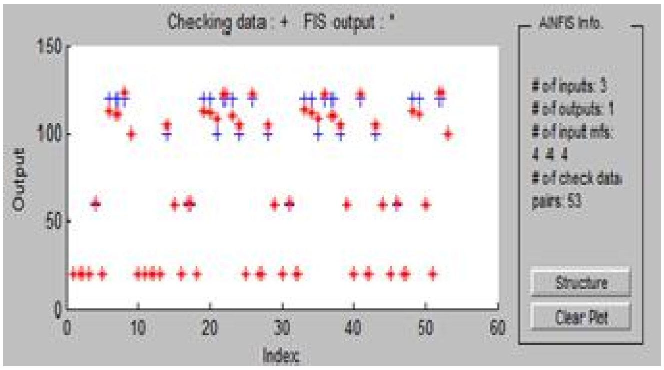

Fig. 7. ANFIS Model for Checking Data with Soft Conditions.

4 Results and Conclusion

The design scheme of the proposed speed scheduling system of railway vehicle has shown significant improvement using neuro-fuzzy system with MAT Lab. simulation as compared to earlier methods. Soft conditions like vehicle tilting, environment monitoring and

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track conditions are inversely proportional with respect to the speed and have shown substantial reduction of speed in both ways individually as well as combined effect of these inputs. The effect of these input conditions on speed is shown in Fig. 8 which is according to the design ratio of input and output conditions.

Fig.8 (a) shows with gradual increase in EM and VT, the speed is going to reduce.

Fig. 8 (b) has shown same results with EM on x-axis and TC on y-axis.

Fig. 8 (c) shows, at 0 Volt of VT and EM, the speed is maximum120 km/h, while with gradual increase in VT and EM values, speed is reducing and ultimately reaches at 20 km/h which is very low against highest values of VT and EM.

Fig. 8 (d) shows the same results with TC and EM (as discussed with VT and EM).

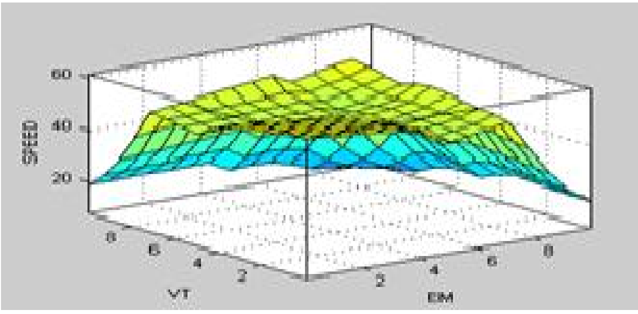

Fig.8. (a) Plot between Environment Monitoring and Vehicle Tilting.

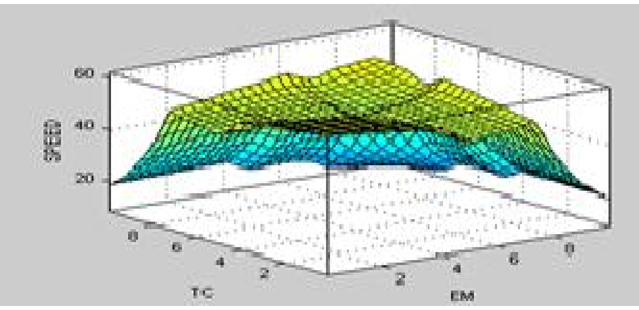

Fig.8. (b) Plot between Environment Monitoring and Track Conditions.

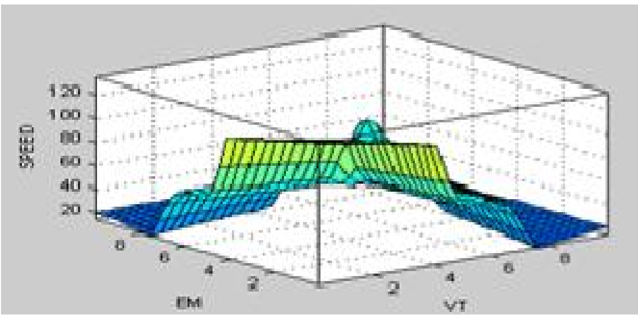

Fig.8. (c) Plot between Vehicle Tilting and Environment Monitoring.

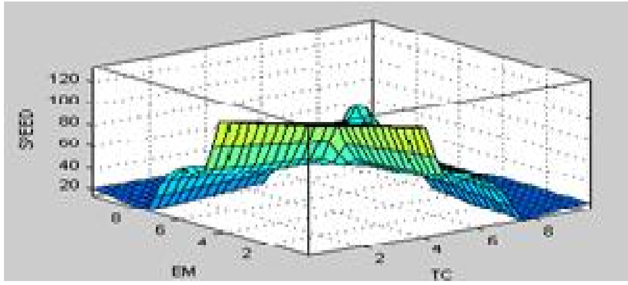

Fig.8. (d) Plot between Environment Monitoring and Track Conditions.

Figure 8 (a to d) MAT Lab Simulation Results.

5 Conclusion And Future Work

Speed scheduling of railway vehicle has shown substantial improvement by focusing on hard and flexible conditions with learning capability due to neuro-fuzzy technique. In order to overcome on issues and make railway control system more secure and accurate, there is a need of some intelligent system to adjust speed according to situation which is the main part of railway control system. The MAT Lab. results have shown that this intelligent design model will work successfully in real time environment for speed scheduling of railway vehicles. In future, it will help to design whole railway control system intelligent with learning capability of neuro-fuzzy technique to develop secure and intelligent railway control system. State of the art Microelectronics technology can be used to develop FPGAs based control chips for this autonomous railway control system.

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