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PREDICTION OF THE PAVEMENT SERVICEABILITY RATIO OF RIGID HIGHWAY PAVEMENTS BY ADAPTIVE NEURO-FUZZY

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Abstract

In this study, an Adaptive Neuro-Fuzzy Inference System (ANFIS) model has been developed in order to predict Present Serviceability Ratio (PSR) which is one of the important parameter used in designing rigid pavements. In modeling Slope Variance (SV), Cracking (C) and Patching (P) were used as input parameters and PSR was used as output parameter ANFIS model compared with experimental (measured) parameters and determined that correlation was perfect between them. It was determined that can be able to use ANFIS model for predicting PSR used practically in designing rigid pavements depending on SV, C and P with low error rates within a short period of time without any experimental study and measurement.

Key Words: Rigid Pavements, Present Serviceability Ratio, Adaptive Neuro-Fuzzy Inference System

1. Introduction

It is difficult to say when first started pavement management systematically. According to several people Pavement Management System (PMS) applied using Engineering Principles has been started with American Association of State Highway Officials (AASHO) roadway test in 1956-1960. PMS is based on using present serviceability (riding quality) of pavements in pavement tests. How to predict riding quality and how to apply this by applicators was an important problem. The solution was defined simply in the study "The Pavement Serviceability-Performance Concepts" published in Highway Research Bulletin 250 in 1960 by Carey and Irick. First a group of pavement user will determine riding quality in selected area according to their own ideas. Then physical measurements were measured in the same pavement section. After then answers were found from the relationship between riding quality for physical condition and physical measurements. Several engineers predict these rates from 1 to 5 (failed, poor, fair, satisfactory, and good). This rating named Pavement Serviceability Ratio (PSR). After rating for each section, it was examined that whether the pavement acceptable or not [1].

In this study two models were developed in order to predicting PSR which is one of the important parameters used designing rigid pavements using ANFIS method and developed models compared with each other.

2. Present Serviceability Ratio (PSR)

Pavement is evaluated with riding satisfaction or dissatisfaction and also as a result of evaluation maintenance, rehabilitation or renew decisions are taken. Researchers think that to

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find pavement performance as examining parameters shown below based on AASHO road test by Carey and Irick;

- According to respond of tools measuring pavement physical condition during experiment
- According to visual or mathematical interpretation of conditions that characterized factors like cracking, patching, shoulder conditions and pavement color.

AASHO road test in early 1960s showed clearly what can be the problems for performance prediction of pavement section. At that time panel rating technique described expert overviews was used for determining performance predictions of sections.

The formula used for determining the present serviceability index of 49 rigid pavement sections by AASHO is shown below [2];

$$p = 5.41 - 1.80 \log (1+ SV) - 0.09 \sqrt{C+P} \qquad (1)$$

p = PSI (Present Serviceability Index)
SV= (Slope Variance) Longitudinal Corrugation Measurement
C and P = Cracking and Patching

It has been observed that pavement performance (serviceability) decrease with time because of traffic and environmental effects from AASHO road tests. Serviceability Index is a value between 0 and 5. While serviceability index is 5 when the pavement first constructed after at the end of the particular use reduce and reach to last serviceability index (PCI) and when the pavement performance reduce (or become extinct) pavement has been completed its life. Pavement performance can be increased with overlay [3].

3. Adaptive Neuro-Fuzzy Inference System

The ANFIS is the abbreviated of adaptive neuro-fuzzy inference system. Actually, this method is like a fuzzy inference system with this different that here by using a back propagation tries to minimize the error. The performance of this method is like both Artificial Neural Network (ANN) and Fuzzy Logic (FL). In both ANN and FL case, the input pass through the input layer (by input membership function) and the output could be seen in output layer (by output membership functions). Since, in this type of advanced fuzzy logic, neural network has been used, therefore, by using a learning algorithm the parameters have been changed until reach the optimal solution. Actually, in this type the FL tries by using the neural network advantages to adjust its parameters. As we know, the different between real and network output in ANN is one of the common method to evaluate its performance. Therefore, ANFIS uses either back propagation or a combination of least squares estimation and back propagation for membership function parameter estimation [4].

Several fuzzy inference systems have been described by different researchers. The most commonly-used systems are the Mamdani-type and Takagi–Sugeno type, also known as Takagi–Sugeno–Kang type. In the case of a Mamdani-type fuzzy inference system, both premise (if) and consequent (then) parts of a fuzzy if-then rule are fuzzy propositions. In the case of a Takagi–Sugeno-type fuzzy inference system where the premise part of a fuzzy rule is a fuzzy proposition, the consequent part is a mathematical function, usually a zero- or first-degree polynomial function [5].

The rule base of ANFIS contains fuzzy if-then rules of Sugeno type. For a first order two-rule Sugeno fuzzy inference system, the two rules may be stated as:

Rule 1: If x is A1 and y is B1 then z is f1(x, y)

Rule 2: If x is A2 and y is B2 then z is f2(x, y)

Where;

x and y are the inputs of ANFIS, A and B are the fuzzy sets fi (x, y) is a first order polynomial and represents the outputs of the first order Sugeno fuzzy inference system. The architecture of ANFIS is shown in Fig. 4, and the node function in each layer is described below. Adaptive nodes, denoted by squares, represent the parameter sets that are adjustable in these nodes, whereas fixed nodes, denoted by circles, represent the parameter sets that are fixed in the system [6].

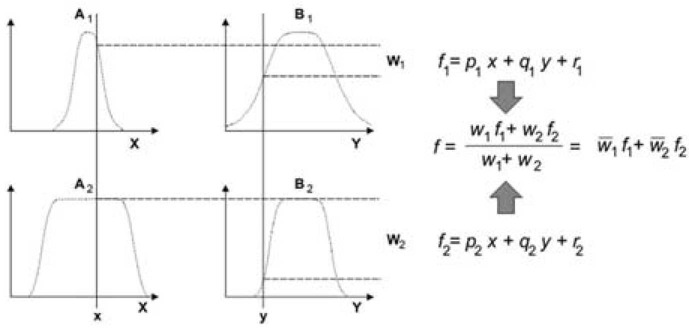

Figure 1. Fuzzy-reasoning scheme of ANFIS [7].

The hybrid learning algorithm of the ANFIS combines the gradient method with the least squares method to update the parameters. In the forward pass of the learning algorithm, consequent parameters are identified by the least squares estimate. In the backward pass, the error signals, which are the derivatives of the squared error with respect to each node output, propagate backward from the output layer to the input layer. In this backward pass, the premise parameters are updated by the gradient descent algorithm [6].

4. Developed ANFIS model

In this study, an ANFIS model has been developed in order to predict PSR which is one of the important parameter used in designing rigid pavements. In modeling Slope Variance (SV), Cracking (C) and Patching (P) were used as input parameters and PSR was used as output parameter. The model structure is shown in Fig. 2. In the model membership functions of input parameters have shown in Fig. 3, 4 and 5 respectively.

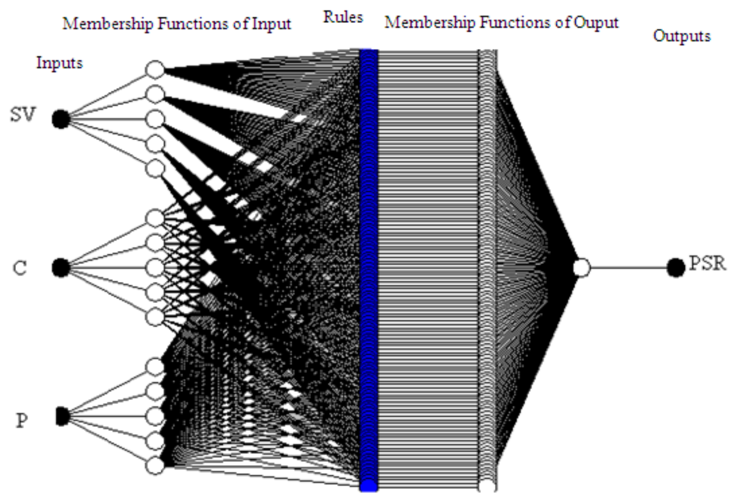

Figure 2. Developed model structure

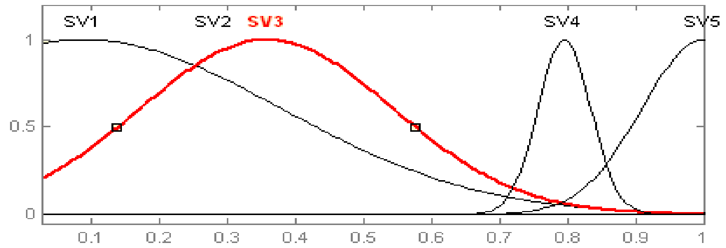

Figure 3. Membership function of input variable SV

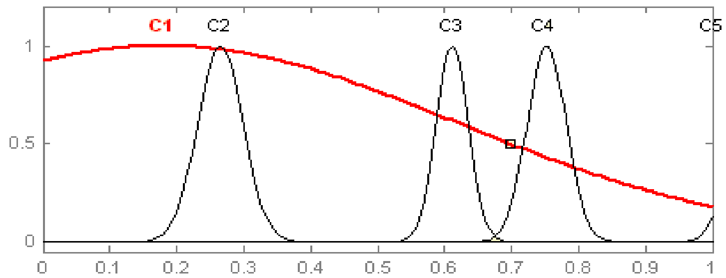

Figure 4. Membership function of input variable C

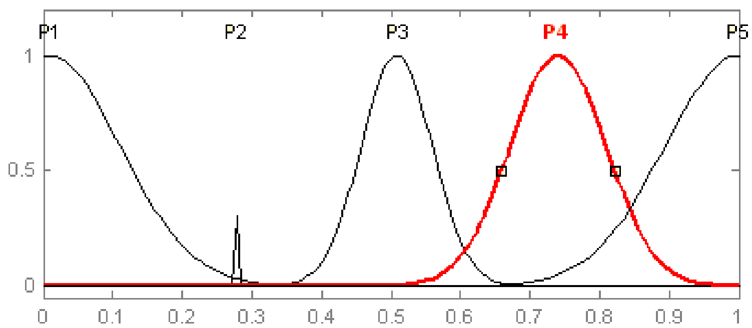

Figure 5. Membership function of input variable P

49 numbers of experimental data set obtained from AASHTO have been used in the study. 40 numbers of data set (about 80%) in training stage of model and 9 numbers of data set were used in test stage of model were processed. These experimental findings used as data group for Sugeno type adaptive fuzzy logic model a model predicted PSR has been developed.

Model makes possible comparing model results typing real data used in the study to the appropriate areas in solution monitor. Real data have been compared with the ANFIS data at the end of the model. Correlation between them has been determined.

Developed ANFIS model results compared with test results and have been tested. Graphics of relationship between prediction results and measured results for training and test sets have been shown in Fig. 6 and 7.

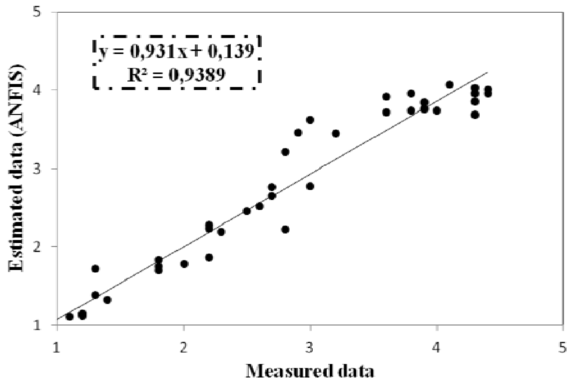

Figure 6. Relationship between training set measurement results and ANFIS model results

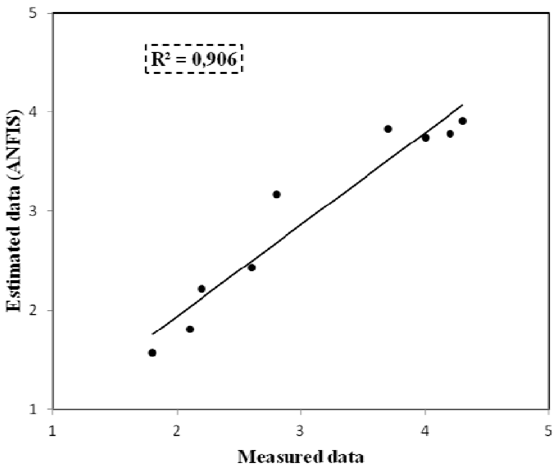

Figure 7. Relationship between testing set measurement results and ANFIS model results

5. Results

In this study, a model has been developed in order to predict PSR with ANFIS method and it has been researched that usability of ANFIS in PSR prediction. After finding successful ANFIS model prediction results compared with measured results.

As a result, when the prediction results of ANFIS compared with measurement results that can be used ANFIS model in predicting PSR practically at low error rates in a short time without any experimental study and measurement.

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