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Fuzzy Approach for Examining the Performance of Driver

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Abstract: Soft Computing can be used for the analysis of driver's performance which may help the licensing authorities to make a better judgment about the skills of a driver. We have used Fuzzy Logic in the proposed system. The readings (engine rpm, engine load, vehicle speed and acceleration) are obtained from the car using sensors and are used as input for the fuzzy system. Fuzzy C-Means Clustering (FCM) with unsupervised learning is used for obtaining input membership functions. The fuzzified parameters are fed into the Fuzzy Inference System (FIS) along with the rule base to obtain a crisp output as a final result. The crisp output gives degree of correctness along with a report on driving skills of a driver.

Keywords: Fuzzy C-Means Clustering, Membership function, Fuzzy Inference System, fuzzification, unsupervised learning.

I. INTRODUCTION

In India, travelling by roads is considered dangerous, as people drive fast, cross speed limits and overtake others without signalling. Poor driving skills are the reason for the increasing number of accidents [1]. So there is a need to monitor driver's behaviour. Also the procedure of issuing driving license does not account for judging the overall performance of a driver. The existing Indian licensing authority is based on a human decision about the driver and fails to provide the detailed analysis of the errors made. The Inspector of motor vehicles conducts the test of competence to drive vehicle, as per the procedures laid down under the rule 15 of Central Motor Vehicle Rules, 1989 [2]. After satisfaction about the driving skills, he passes his recommendations regarding the issue of driving license. In an attempt to solve this problem, fuzzy logic approach is used.

The readings are obtained from car using On Board Diagnostic port (OBD-II) over the Controller Area Network (CAN) bus. This system can be implemented for any Light Motor Vehicle having OBD-II port. This system uses four readings taken from the car which are processed to obtain a decision about his driving skills. These readings are Engine rpm (rpm), Engine load (unit less), Vehicle Speed (m/s), and acceleration (m/s^2).

Set of readings are recorded during practical experiments which decides the threshold(value for a driver to be considered good for driving). The readings are stored in the Secure Digital (SD) card issued to the driver in a .dat file and are examined for a short period of time. After loading the .dat file, the readings are stored in the form of matrix of size 1386 x 4. Further processing of this data grades the driver as good or bad along with the degree of correctness.

The driver's skills can be examined manually by comparing readings to the ideal set of readings but that implies use of strict boundaries. Fuzzy System overcomes this limitation as it allows flexible boundaries for each set of readings. In fuzzy logic, a set of user defined rules can be written which provides relation between different types of input readings expressed in the form of fuzzy IF-THEN rules. This helps to examine all the factors affecting the performance of the driver.

The remaining paper is organized into different sections. Section II discusses about the clustering used for input readings. Section III discusses about fuzzification, Section IV about Fuzzy Inference System and Section V about defuzzification. Section VI discusses about the Soft Computing Technique used for this approach. The steps involved in the computing along with the block diagram for entire system implementation is shown in Fig.1. The results obtained and conclusion is discussed in Section VII and VIII respectively.

II. CLUSTERING

Clustering is a process of classifying data into groups based on similarities among the individual data items. Clustering methods are of two types [3]: Fuzzy K-Means and Fuzzy C- Means. Fuzzy K-means Clustering generates partitions such that each data point is assigned to only one cluster. Fuzzy C- Means Clustering [4] allows the data to belong to several clusters simultaneously, with different degrees of membership (between 0 to 1). The readings used in this application are highly correlated, which suggests the data belongs to more than one cluster i.e. Fuzzy C-Means Clustering should be used.

III. FUZZIFICATION

Fuzzy Logic System [5] is used for dealing with uncertainty. Imprecise data and vague statements such as low, medium and high are accepted by Fuzzy Logic System and a decision is provided. Fuzzification is the first step in the fuzzy inference process. It is applied to the

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input readings which converts crisp inputs into fuzzy values. Crisp inputs are exact inputs measured by sensors and passed into the fuzzy system for processing after normalizing. These inputs have to be processed by the FIS and have its own group of membership functions or sets to which they are transformed. Fuzzy sets can accommodate 'degree of membership' of the reading in the set, as value between 0 and 1.

IV. FUZZY INFERENCE SYSTEM

Fuzzy Inference System is used for transmitting a given input value to an output based on the rules defined, which form the knowledge base. There are two types of FIS [5]: Takagi-Sugeno-Kang FIS and Mamdani FIS. Mamdani FIS is used in this system as it is more compact and computationally efficient fuzzy approach and it expects the output membership functions to be fuzzy sets. The fuzzified values are fed into the Mamdani FIS along with the rule base applied to it. Rule base involves simple IF-THEN rules which are formulated and are added to the system. Based upon the rules the decision is made. The basic FIS can take either fuzzy inputs or crisp inputs, but the outputs it produces are always fuzzy sets.

V. DEFUZZIFICTION

The proposed system requires the output to be a crisp value. Defuzzification method is adopted to extract a crisp value from the output produced by FIS that best represents a fuzzy set. It reduces the collection of membership function values into a singular quantity. Many methods of defuzzification [5] are available: Max-membership principle, Centroid method, Weighted average method, Mean–max membership, Centre of sums, Centre of largest area, and First of maxima or last of maxima. The most prevalent Centroid method is used for computing in this application.

VI. SOFT COMPUTING

A detailed approach for the proposed method using fuzzy logic system is discussed. Fig. 1 depicts the basic block diagram of Fuzzy Logic system describing the steps involved in the analysis of the problem.

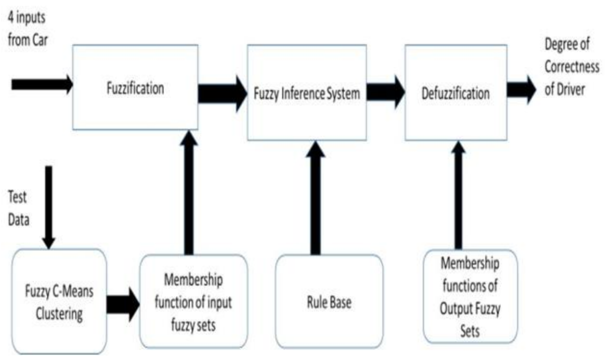

Fig.1. Fuzzy Logic Model for examining the car driver's performance

Test data is the set of readings provided initially to the system for proper clustering. Test data after normalizing is clustered using FCM algorithm. FCM is done to group the readings that are close to each other and such groups are identified in an unsupervised manner i.e. no information is provided to the algorithm beforehand as to which reading belongs to which cluster. FCM is based on minimization of the objective function (K_m) as shown in (1).

$$K_m = \sum_{i=1}^{N}\sum_{j=1}^{C}(u_{ij})^m \left\|x_i - c_j\right\|^2 \qquad (1)$$

Where, m is any real number greater than 1, x_i is the i^{th} reading of N readings, u_{ij} is the degree of membership of $x_i$in the cluster j, N is the number of input readings and C is the number of clusters, c_j is the j^{th} cluster of C clusters and ||*||is norm expressing the similarity between measured data and the centre. In the proposed system, four readings are to be clustered where x is input readings for engine rpm, engine load, vehicle speed and acceleration clustered separately and m is 2. Each type of input is divided into five clusters.

Fuzzy partitioning is carried out through an iterative optimization of the objective function shown in (1), with the update of membership u_{ij} shown in (2) and the cluster centres c_j shown in (3):

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\left(\frac{2}{m-1}\right)}} \qquad (2)$$

$$c_j = \frac{\sum_{i=1}^{N} {u_{ij}}^m x_i}{\sum_{i=1}^{N} {u_{ij}}^m} \qquad (3)$$

This iteration will stop when there is a termination criterion between 0 and 1, where k is the iteration steps. This procedure converges to a local minimum or a saddle point of K_m.

The FCM algorithm [4] used is composed of the following steps:

1. Initialize U= [u_{ij}] matrix, U(0). U(0) is obtained initially after random selection of cluster centres.
2. At k-step: calculate the centres vectors C(k) = [c_j] with U(k)
3. Update U(k), U(k+1)
4. If || U(k+1) - U(k) ||<ξ then STOP; otherwise return to step 2. Where, ξ is the error function.

For every input reading, clustered raw data generated needs to be converted into parameterized membership functions which are used by Fuzzy Logic System in the fuzzification process. In the proposed system,we have used triangular and trapezoidal membership functions. Clustered raw data conversion into triangular and trapezoidal membership function requires extraction of parameters (a, b, c, d for trapezoidal and a, b, c for

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triangle). An algorithm [6] is used for approximating into these membership functions. Mean Square Error (MSE) is calculated for every cluster of each input. Five membership functions one for each cluster are identified by the different linguistic variables used in further steps. MSE is calculated for triangular as well as trapezoidal membership function and which ever has less value for MSE is used for approximation of data.

$$\mathrm{MSE} = \left(\frac{1}{n}\right) * \left(\sum_{i=0}^{n} (w_i - y_i)^2\right) \quad (4)$$

Where, n represents total number of readings in selected cluster, w_i is the actual value of degree of membership of i^{th} data in the selected cluster, y_i is degree of membership obtained for i^{th} data in approximated membership function. The input readings are normalized and are mapped to different membership functions for the respective input. The degree of membership for different linguistic values of variable defined by membership functions is calculated. Figure 2, 3, 4 and 5 shows the input membership function for engine rpm, engine load, vehicle speed and acceleration respectively. The input point having degrees of membership in various clusters is also shown.

One by one each reading is fuzzified and used further. Fuzzified values and rule base defined in Mamdani FIS are combined to get rule strength. Using the ideal values obtained for different gears and clusters to which they belong, different rules for ideal and error cases are defined. Two membership functions are defined for fuzzy output sets as ideal and non-ideal. The ideal sets of readings are mapped to the ideal function and error readings get mapped to non-ideal function. Fig.6 depicts the output membership functions. The rule strength is evaluated using fuzzy AND operator. The output membership functions are clipped according to the rule strength which are combined finally into a single function using fuzzy OR operator.
This function is then defuzzified using centroid method to obtain defuzzified value. The centroid can be calculated using (5).

$$z^* = \int \frac{\mu_c(z) z dz}{\mu_c dz} \quad (5)$$

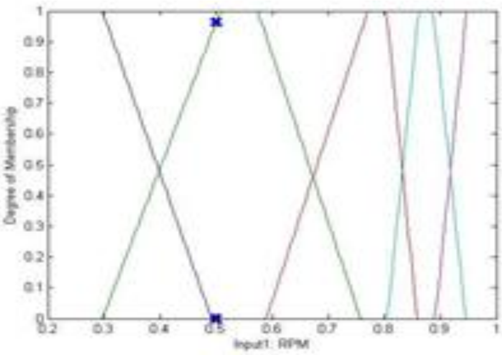


Fig.2 Input Membership functions for Engine rpm

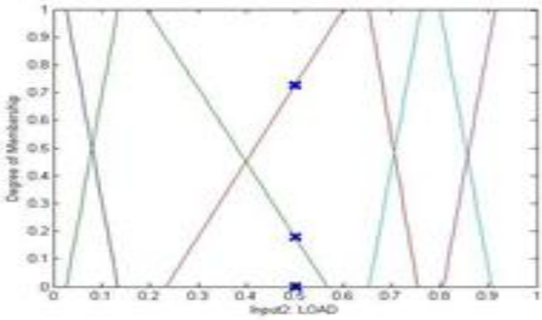
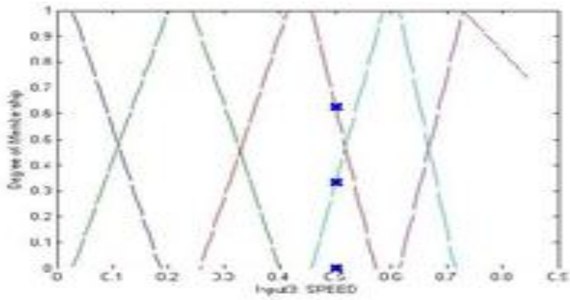


Fig.3. Input Membership functions for Engine load



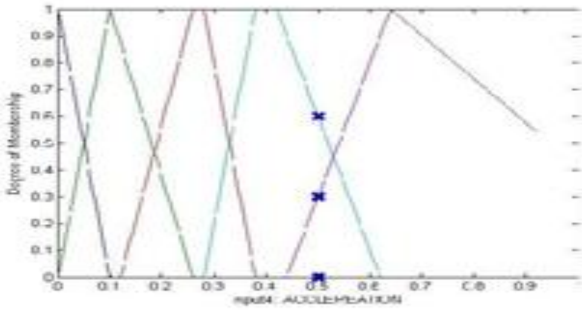


Fig.4. Input Membership functions for Vehicle speed
Fig.5. Input Membership functions for Acceleration

Fig.6. Output Membership Functions

Where, μ_c represents the degree of membership for data point z in output membership function. The crisp output for degree of correctness is obtained for each reading after this step. This process is carried out for a couple of readings. According to the threshold set, these values can be classified as good or bad. The numbers of good and bad points are recorded. The driver is considered as good if good points exceed bad points and otherwise as bad driver. Degree of correctness of driver is calculated using number of good points and total number of readings.

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VII. RESULTS

The results obtained for the test readings of size 1386 x 4 are shown in Fig.7.

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Total readings = 1386
Good readings = 847
Error readings = 539
Driving skills in percent = 61.1111
DRIVER HAS AVERAGE DRIVING SKILLS
DRIVER NEEDS MORE PRACTICE
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Fig.7. Output given by fuzzy system

Sample readings for four inputs are given in the first four columns of table I followed by the output (degree of correctness of each reading) in the fifth column.

The threshold is set as 0.5. The number of readings giving output less than 0.5 are considered as bad and the rest as good. We got 12 points as good and 5 as bad suggesting he is a good driver and driving skills of driver in percentage is 70.5882.

TABLE I
SAMPLE READINGS WITH OUTPUT

Engine rpm	Engine Load	Vehicle speed	Acceleration	Output
0.600	0.160	0.240	0.210	0.6938
0.500	0.150	0.219	0.208	0.7277
0.549	0.150	0.214	0.200	0.7251
0.590	0.170	0.270	0.215	0.7271
0.650	0.190	0.300	0.230	0.5669
0.800	0.800	0.800	0.800	0.2672
0.600	0.160	0.240	0.210	0.6938
0.500	0.150	0.219	0.208	0.7277
0.549	0.150	0.214	0.200	0.7251
0.590	0.170	0.270	0.215	0.7271
0.650	0.190	0.300	0.230	0.5669
0.124	0.160	0.800	0.700	0.5000
0.450	0.560	0.500	0.020	0.3220
0.500	0.500	0.014	0.400	0.2559
0.800	0.700	0.010	0.100	0.7441
0.800	0.700	0.010	0.400	0.2559
0.9491	0.173	0.5857	0.100	0.2559

VIII. CONCLUSIONS

In this article, we have addressed a solution to an issue of unorganized driver licensing system for Light Motor Vehicles. After implementation of the system, the driving skills in percentage and number of good and error (bad) readings according to the degree of correctness are obtained as a result. This may help the licensing authorities to make a better decision about the skills of the driver. This may reduce the increasing rate of accidents happening because of unskilled drivers.

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