Intelligent Speed Adaptation System with Hybrid Algorithm

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Summary
Millions of road users and pedestrians are killed in traffic accidents each year. The need to increase road safety is one of the major concerns, and the better way to increase safety is to develop systems which are able to automatically drive. The authors have tried to extract the information of sharpness of curves on the road and have presented the system which will provide the Intelligent Speed Adaptation. The data thus acquired is fed into the network, which controls steering, brake and throttle of the vehicle. Experimental results have shown that the proposed system is able to correctly adapt its speed according to the curvature of the road, in the same way that human do. The paper is concluded with exploring the processing of data on suitable image processing tool/platform as future scope.

Key words:
ANFIS: Adaptive Neuro-Fuzzy Inference Systems, ITS: Intelligent Transportation System.

1. Introduction

A world report on road traffic injury prevention has been published by the World Health Organization, estimating 1.2 million people are killed in road crashes each year, and as many as 50 millions are injured [1]. Projections indicate that these figures will increase about 65% over the next 20 years. The global cost of road crashed and injuries are estimated to be US$ 518 billion per year. The causes of these accidents are attributed to human error, alcohol, bad weather, heavy traffic or bad infrastructures. Some of these causes can be managed by measures, but the primary cause is human error, and improving the security won't help with this kind of error. Autonomous driving system is the only solution which can decrease the risk of human error. The Intelligent Autonomous Vehicle focuses on modeling the human driver in aspects of perception of the environment, learning and reasoning. While several researches have been made and proved effective on highways, with simple scenarios like lane marking, slow changes in curvature, no crossing [2, 3, 4], automated driving in more diverse and complex environment is still far away from being implemented. An average person can easily drive in a city with stops, pedestrian crossings, lane changing, accelerating or slowing down according to the environment changes, but these tasks are hard to reproduce on a computer.

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Intelligent Speed Adaptation is a system which can regulate the vehicle speed on roads [5, 6 and 7]. The system has been tested and proved efficient in several countries, but these systems only react to the speed limit of the road, and for the more complex systems, they can also adapt their speed to the road and weather conditions. But none of them can slow down when the car reaches a curve dangerously, which can cause the vehicle to go off the road and create an accident. Driving can be modeled as a continuous decision-making process involving a set of rules that relate sensory inputs to control output. But designing all these rules is quite difficult, so the simplest way is to learn from human expertise for extracting the rules. After considering advantages and disadvantages of various soft computing tools, author has carried out research with ANFIS, Adaptive Neuro-Fuzzy Inference System.

2. Methodology

A) Fuzzy Systems
Fuzzy logic is considered today to be one of many tools, necessarily to build system solutions in a fast, cost effective, and transparent fashion. Fuzzy systems use a series of simple rules, based upon Fuzzy set theory. It reduces the design development cycle, simplifies design complexity, improves time to market, provides better alternative solution to non-linear control, improves control performance, simplifies implementation, and reduces hardware costs[8]. Fuzzy systems use a series of simple rules, based upon Fuzzy set theory. This theory had been used to exploring various decision handling situations in the Intelligent Transportation field. Rule based fuzzy systems, with expert knowledge represented explicitly using a set of if-then rules offer a high degree of transparency into the system being modeled. The fuzzy systems can be designed Mamdani or Sugeno Inference systems.
The Sugeno system is computationally efficient, works well with linear techniques (e.g., PID control), well with optimization and adaptive techniques, has guaranteed continuity of the output surface, well suited to mathematical analysis. The Mamdani Inference systems is intuitive, has widespread acceptance, well suited to human input.

B) Neural Networks

Artificial neural networks are systems constructed to make use of some organizational principles resembling those of the human brain [9]. They are good at tasks such as pattern classification, function approximation, optimization, vector quantization and data clustering. Neural networks have a large number of highly interconnected nodes (called neurons), that operate in parallel [10].

C) Hybrid Approach

Neural networks are low-level computational structures, while fuzzy systems can reason on higher level. However, since fuzzy systems don't have learning capability, it is difficult to tune the fuzzy rules and membership functions from the training data set. Also, because the internal layers of a neural network are very opaque for the user, the mapping rules in the network are not visible and are difficult to understand. Thus, the neuro-fuzzy integration reaps the benefits of both neural networks and fuzzy logic systems [11]. The neural networks provide connectionist structure and learning abilities to the fuzzy logic systems, and the fuzzy logic systems provide the neural networks with a structural framework with high-level fuzzy IF-THEN rule thinking and reasoning. We can characterize the fusion of these two systems in three categories:

C.1) **Neural Fuzzy Systems** the use of neural networks as tools in fuzzy systems

C.2) **Fuzzy Neural Networks** fuzzification of conventional neural networks models

C.3) **Fuzzy-Neural Hybrid Systems** incorporating fuzzy technologies and neural networks into hybrid systems

D) **ANFIS: Adaptive Neuro-Fuzzy Inference System**

The Sugeno fuzzy model was proposed for a systematic approach to generating fuzzy rules from a given input-output data set. A typical Sugeno fuzzy rule can be expressed in the following form:

IF x_1 is A_1
AND x_2 is A_2
. . . . .
AND x_m is A_m
THEN $y = f(x_1, x_2, \ldots x_m)$

where $x_1, x_2, \ldots, x_m$ are input variables, $A_1, A_2, \ldots, A_m$ are fuzzy sets; and y is either a constant or a linear function of the input variables. When y is a constant, we obtain a zero-order Sugeno fuzzy model in which the consequent of a rule is specified by a singleton. When y is a first-order polynomial, i.e.

$y= k_0+k_1x_1+k_2x_2+\ldots+k_mx_m$ We obtain a first-order Sugeno fuzzy model.

Jang's ANFIS is normally represented by a six-layer feed forward neural network. Figure 1 shows the ANFIS architecture that corresponds to the first order Sugeno fuzzy model. For simplicity, we assume that the ANFIS has two inputs – x1 and x2 – and one output – y. Each input is represented by two fuzzy sets and the output by a first-order polynomial. The ANFIS implements four rules:

Rule 1: IF x1 is A1, AND x2 is B1, THEN $y= f_1 = k_{10} + k_{11}x1 + k_{12}x2$
Rule 2: IF x1 is A2, AND x2 is B2, THEN $y = f_2 = k_{20} + k_{21}x1 + k_{22}x2$
Rule 3: IF x1 is A2, AND x2 is B1, THEN y = f3 = k30 + k31x1 + k32x2
Rule 4: IF x1 is A1, AND x2 is B2, THEN y =f4 = k40 + k41x1 + k42x2

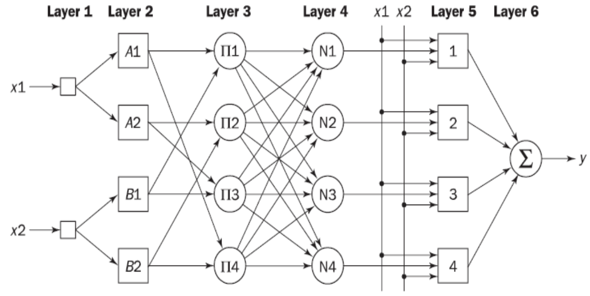

Figure1. Adaptive Neuro-Fuzzy Inference System (ANFIS)

where x1, x2 are input variables; A1 and A2 are fuzzy sets on the universe of discourse X1; B1 and B2 are fuzzy sets on the universe of discourse X2; and k_{i0}, k_{i1} and k_{i2} is a set of parameters specified for rule i.

The **ANFIS** shown in Figure 2 is functionally equivalent to a **first** order **Sugeno** fuzzy model. Specifically, **ANFIS** only supports **Sugeno**-type systems.

- Design **first** order **Sugeno** type of **Fuzzy inference Systems.**
- Train system with **ANFIS** to it with the training data set which is based on the experiments made on human drivers, in order to understand what processed information is acquired while they are driving.

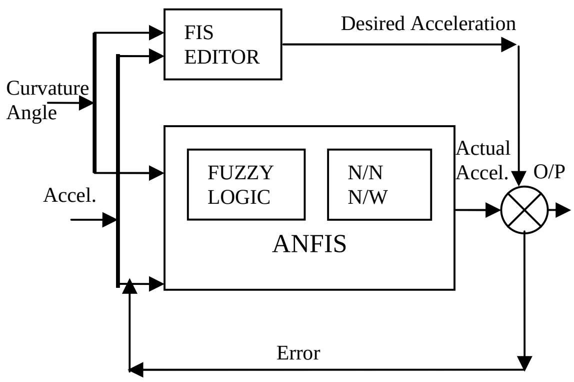

Figure 2 Basic Block Diagram

Anticipation of curves can be achieved using soft computing technique and among these techniques, fuzzy logic control appears to be the most promising, due to its lower computational burden and robustness. Also, a mathematical model is not required to describe the system in fuzzy logic based design. But, the main problem with the conventional fuzzy controllers is that the parameters associated with the membership functions and the rules depend broadly on the intuition of the engineers. If it is required to change the parameters, it is to be done by trial and error only. There is no scientific optimization methodology inbuilt in the general fuzzy inference system. To overcome this, Adaptive Neuro-Fuzzy Inference System (ANFIS) is used. In ANFIS, the parameters associated with a given membership function are chosen so as to tailor the input/output data set.

3. Simulation

In this paper, a two-input Sugeno fuzzy model is used to adapt the speed of the vehicle depending upon the curve on the road. It can be observed that the input membership functions of a Sugeno model are non-linear (Triangular membership functions), whereas the output membership functions are linear. So, while tuning the parameters from a given input-output data set, it is most effective to use hybrid learning *algorithm* method. Since the input side functions are non-linear, error back propagation method is a suitable optimization routine, and since the output side functions are linear.

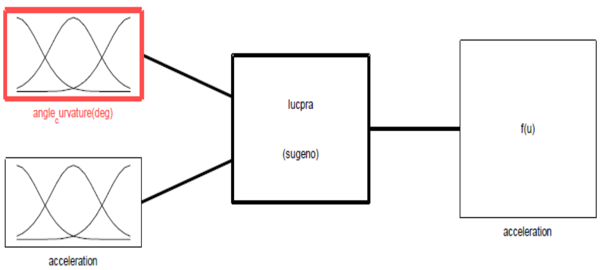

Figure 3 Sugeno type controllers with two inputs and one output.

The inputs to the system are Angle curvature and Acceleration and the output is Acceleration. Range of Angle curvature is $0\text{-}90^0$ and it is divided into six membership functions as straight, soft, normal, sharp, hard and extreme

Range of Acceleration is divided into three membership functions as slow, medium and fast. The output is Acceleration and according to the rule base classified into 18 membership functions as negative extreme, negative hardest, negative harder, negative hard, negative normal, negative ok, negative soft, negative softer, no change, const., positive softer, positive soft, positive ok, positive normal, positive hard, positive harder, positive hardest, positive extreme.

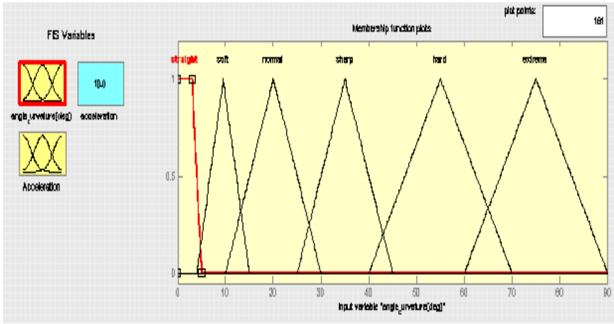

Figure 4 Membership functions for angle curvature

According to the constraints of ANFIS number of output membership functions must be equal to the number of rules i.e. 18 rules. Authors have used 18 pairs of data for training the ANFIS model and chosen Back Propagation method for training the Neuro-Fuzzy Network.

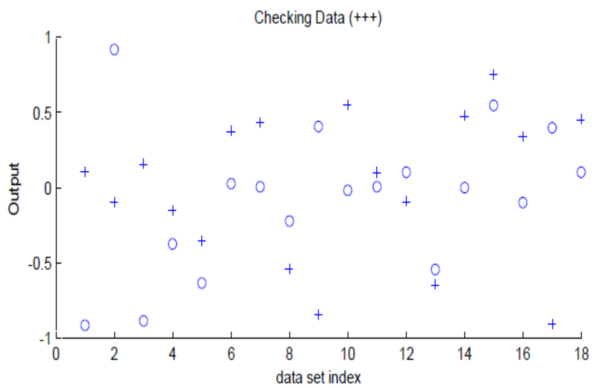

Figure 5 ANFIS editor showing training and checking data.

4. Results:

The Intelligent Speed Adaptation system has been designed and simulated .The simulation has been run with the sample data number of times up to 1000 samples and it was found that after 20 epochs the system get minimum error in optimum time interval and it is checked with appropriate data within the specified range.

A. For 20 epochs:

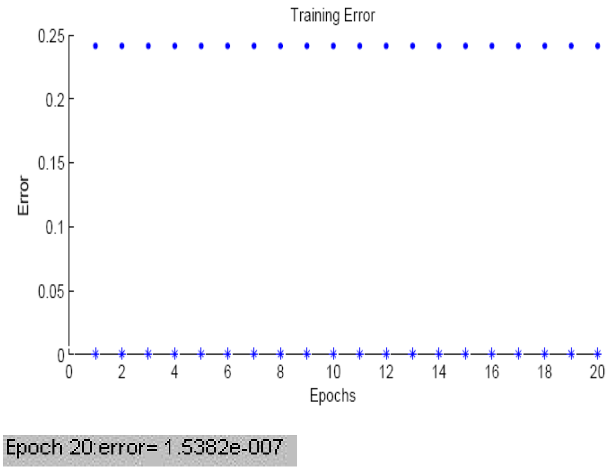

Figure 6 Training for 20 epochs showing training error is 1.5382 x 10 $^{-7}$.

Figure 7 Plot of system output vs output required

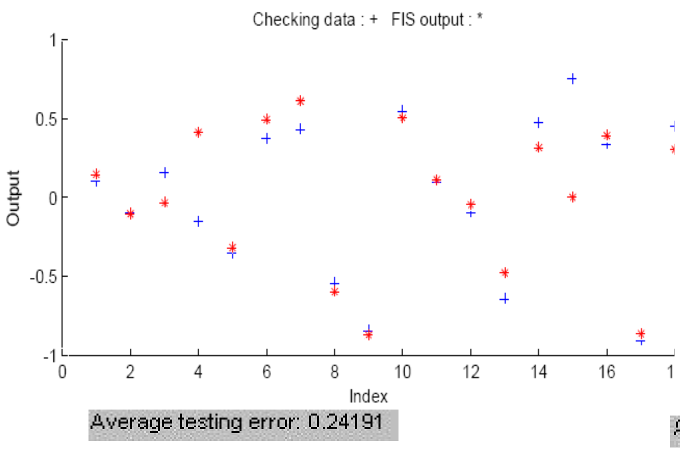

Figure 8 Plot of the system output vs. checking data

B. For 100 epochs:

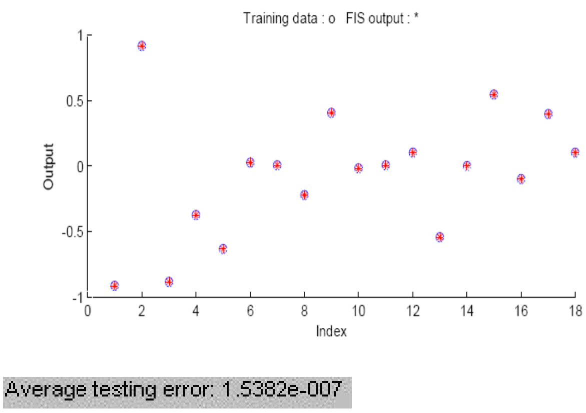

Figure 9 Plot of system output vs output required. Training error remains unchanged.

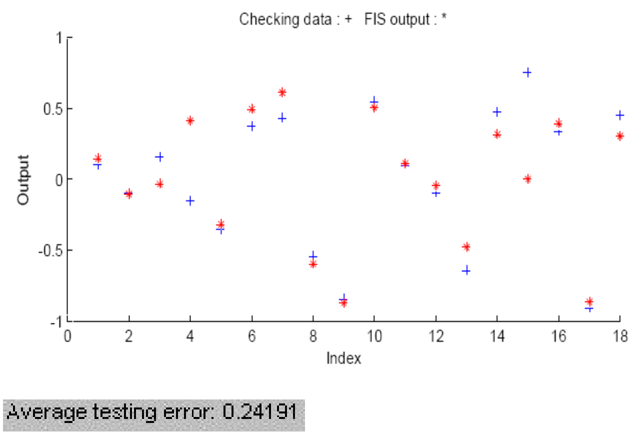

Figure 10 Plot of system output vs. checking data. Checking error remains unchanged.

C. For 1000 epochs:

Figure 11 Plot of the system output vs. checking data. Checking error remains unchanged

The results of training the system with various samples are presented above with error decreases substantially as the epochs are increased.

5. Conclusion and Future Scope

In this paper, Authors have proposed a concept to implement Intelligent Speed Adaptation in autonomous vehicles especially when vehicle system arrives at curves, with hybrid controller, which still remains under development. The fuzzy neural network possesses the learning technique of neural network to detect hidden relation in driving data, and the capabilities of fuzzy rule based to handle inherent uncertainty of the driving environment and reason approximately. The adaptive controller was able to craft a rule base of human driving expertise and perform the same driving behaviors. A simulation is carried out on random data. Result shows that by training the adaptive controller, the system was able to correctly adapt its speed according to the type of curve. The Intelligent Speed Adaptation is a quite new research area, especially for adapting speed on curves. The results are promising, and by using sophisticated image processing tools the speed adaptation can still be enhanced.

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