DESIGN OF FUZZY EXPERT SYSTEM FOR VEHICLE AUTOMATION

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***Abstract* - In the present scenario, numbers of vehicles are increasing day by day. People tend to apply brakes even in cases where it can be avoided. In highly congested roads, cases of drivers applying brake for every few metres of travel are no longer few and far between. With drivers competing for each and every inch of space available, accidents on the roads are also on the increase. Safety norms have been comfortably flouted.**

The need of the hour hence is to design an efficient vehicle manipulation system that could safely and efficiently negotiate the traffic and also other hindrances. This has propelled in design of a fuzzy control system. The speed of computation and the manner in which uncertainties could be handled in an ontological system makes it an ideal choice.

Keywords – Fuzzy Logic Controller, Vehicle Automation, Mamdani Model, Fuzzy Expert System, Rule Formulation

I. INTRODUCTION

Soft computing techniques have been in existence for quite a large period of time. However, their usage in ontological applications has come to effect only from the late 1990s. With design of tools using modern technology, the need arises to put its usage to optimum effect. In this connection, a number of real world applications have been designed using these tools to a varying degree of success. It has been proposed to explore its usage in a vehicle automation system. Although systems have been in vogue that monitors traffic, not much importance has been given to the manner in which vehicles can be maneuvered. This work focuses on improving the efficiency of vehicles by proper maneuvering of vehicles considering the necessary set of parameters.

As a large number of parameters in the real world are fuzzy in nature, a normal rule based system may not fit the needs of the situation. Hence it is proposed to design a Fuzzy Logic controller to cater to the needs of the problem at hand.

II. FUZZY LOGIC

Fuzzy Logic is basically a multi valued logic that allows intermediate values to be defined between conventional evaluations like Yes/No, True/False or On / Off. Fuzzy Logic has emerged as a concise tool for the controlling of ontological systems and complex industrial processes, as well as for household and entertainment, electronic, diagnosis systems and expert systems.

Fuzzy Logic analysis and control methods process all inputs according to human based fuzzy If – Then rules and then averages and weights the resulting outputs from all individual rules into one single output decision which defines the work of a controlled system. The output is defuzzified to get a crisp value.

A fuzzy perception is an assessment of a physical condition that is assigned an intuitive value but may not be precise. Fuzzy logic propositions deal with truthfulness and falsehood. It does not deal with definite values. Fuzzy Logic has found wide acceptance in the real world and is being increasingly used in day to day activities.

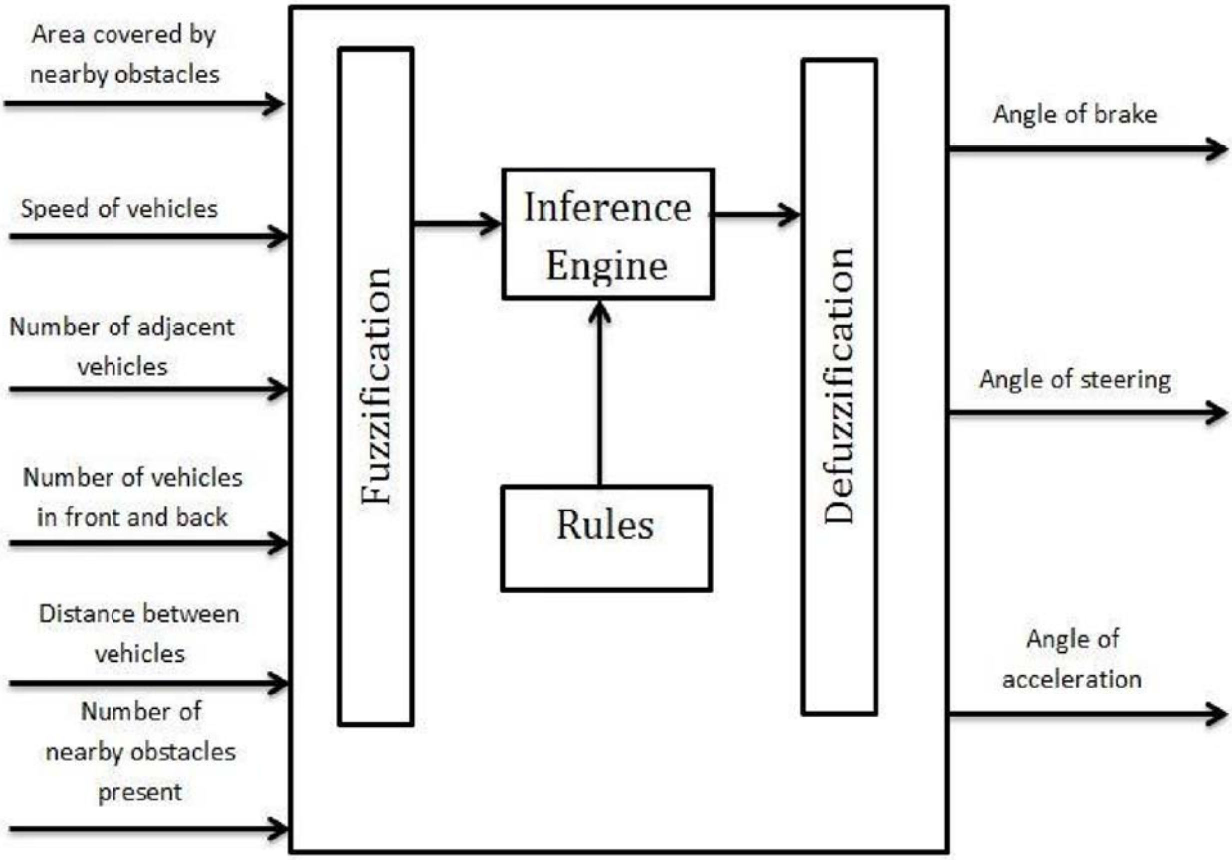

Fig. 1. Fuzzy Logic Controller

Fuzzy Logic Systems (FLS) have been credited with providing an adequate methodology to design robust systems that are able to deliver satisfactory performance when contending with the uncertainty, noise and imprecision attributed to real-world environments and applications.

III. FUZZY EXPERT SYSTEM

Fuzzy expert systems deal with fuzzy logic and reasoning of data. The system is designed with the help of rules and membership functions. The collection of rules is referred to as a rulebase.

Here, a number of rules have been framed based on the road conditions and the actions of driver during adverse situations. A sample rule deals with an action of applying brake performed whenever the vehicle in front is too close for comfort.

IV. DESIGN OF FUZZY LOGIC CONTROLLER

A fuzzy logic controller has been designed to incorporate effective management of traffic. A schematic of the same has been shown in Fig. 1.

Percepts such as area covered by obstacles, speed of vehicle, number of vehicles and distance between vehicles have been obtained based on the road conditions. Sensors are used to determine the necessary values for each percept. These sensors in turn are used to activate the provided actuators.

Fuzzy Controllers work rather different than conventional controllers; expert knowledge is used instead of differential equations to describe a system. This knowledge can be expressed in a very natural way using linguistic variables, which are described by fuzzy sets.

The rules such as “If distance between vehicles is close or number of nearby obstacles present is high then apply brake” framed are applied on the fuzzified inputs and the consequents have been drawn. Based on the consequents, inferences, the decision to apply brake (in this case) are obtained. These inferences are used to draw conclusions (which is applying the brake in this case) are then defuzzified to obtain the necessary outputs. The outputs have been framed based on the behaviour of the driver.

No mathematical model exists as of date to determine the exact amount (angle) of brake or accelerator or steering to be applied at a particular time period. With growing number of accidents, it is felt necessary to design a suitable model that can take into account a significant number of factors and model the same. As almost all the factors taken into consideration deal with vague values, a fuzzy controller has been deemed necessary.

A. FUZZIFICATION

The existing literature available for such systems dealt with handling crisp values. However, in ontological systems, most of the parameters do not deal with crisp values. Hence, the need for fuzzification arises. One of the sample cases considered deals with assigning values of speed as slow, medium, fast and very fast instead of an exact value.

If the speed of the vehicle is between 0 km/hr and 30 km/hr then it is said that the speed of vehicle is low. If the speed of vehicle is between 25 km/hr and 60 km/hr then the vehicle is said to have medium speed.

B. DEFUZZIFICATION:

The parameters dealt with are essentially fuzzy. However for performing the actual computation, crisp values are necessary. As the name suggests, the approximate values are converted back to the definite numbers (inverse process). For a real world application to function properly, a definite input is needed which is obtained through defuzzification of the fuzzy input. In output, if the acceleration angle is “low” then the acceleration applied is in the range from 0˚ to 7˚.

C. RULES AND INFERENCE ENGINE:

The inference rules are derived based on the objective to reduce the application of brakes by the driver (by controlling the vehicle by acceleration and steering) to increase fuel efficiency. A substantial number of inputs like area covered by obstacle, speed of vehicles, number of adjacent vehicles, number of vehicles in front and back, distance between vehicles and the number of obstacles present have been taken into consideration. Depending on the need and situation, the controller decides whether to apply brake, accelerate or steer the vehicle.

Acceleration is preferred when the distance between the vehicles is not less and number of obstacles surrounding the vehicle is a bare minimum. The system has been designed to manipulate movements of the steering when the number of vehicles in the surrounding environment is not too high. The application of brake is felt necessary during unexpected conditions that may lead to collision.

V. CHOICE OF MODEL

A vehicle automation system has been set up which takes into consideration a wide range of parameters and performs the necessary actions. As the characteristics taken into consideration are fuzzy, a suitable model needs to be incorporated to achieve the desired results. A wide range of choices are available. However, since research on the various models is few and far between, an appropriate model has been taken into consideration keeping the salient features in perspective.

Two chief models namely Mamdani and Takagi Sugeno are found to have a wide range of applications. However, Mamdani method is found to synchronize with the need of the problem. The intuitive nature of Mamdani models helps in exploration problems specifically dealing with uncertainties. Besides, the output membership functions need not be constant. Research studies used in the design of systems capturing information from the environment through percepts have tended to favour usage of this model.

VI. CHOICE OF MEMBERSHIP FUNCTIONS

A number of membership functions are available. Here, trapezoidal membership function is used for easier implementation. The trapezoidal membership function has an advantage of depicting a range of values which is significant in representing the driver behaviour.

Using this membership function, the driver’s decision is obtained with less number of rules which results in an optimized rulebase.

A range of values is taken into consideration for representing real world parameters. Membership functions are framed based on the range of values. Example, distance between vehicles can be classified into very close, close, medium and far. When the distance is between 0 and 30 cm then it is very close. If it is between 25 and 60 cm then it is close. If it is between 55 and 100 cm then it is medium. If it is between 95 cm and above then it is termed as far.

One of the advantages of fuzzy logic is that overlapping of membership functions is possible. Real world entities do not have a precise range. Uncertainty always exists. Overlapping is used to aid this. The values of speed of vehicle overlap as the range between 25 km/hr and 30 km/hr cannot be categorized definitely as low or medium speed because they fit into both the membership functions.

A. AREA COVERED BY NEARBY OBSTACLES:

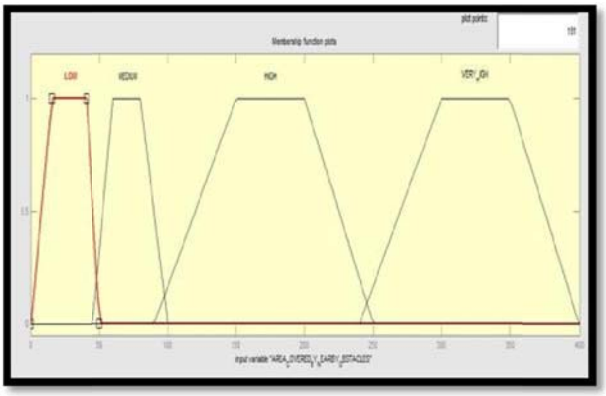

Fig. 2. Membership function for area covered by nearby obstacles

When a vehicle is on move, many obstacles are on its way. But only the ones that are near to the vehicle have some impact on the vehicle. Here, the areas covered by such nearby obstacles include people, animals, traffic signals, sign boards, pits, etc. As shown in Fig. 2, the membership function for the same is categorized as low, medium, high and very high based on the area occupied by the obstacle.

Area of nearby obstacles plays an important role even when the number of obstacles is less. A real life situation that aids this is the presence of one truck which has a greater impact than many bicycles.

VII. DIAGNOSIS OF FUZZY EXPERT SYSTEM

An efficient fuzzy expert system has been designed that takes into consideration the set of all traffic conditions taking place on the roads, simulates the same and provide the driver of the vehicle with a suitable appropriate decision. With growing rate of accidents taking place in day to day life, the exact decision to be taken has come as a blessing in disguise through this work. The amount of break / accelerator to be applied under various circumstances has been inferred. A few sample cases have been shown below.

A. DETERMINATION OF ANGLE OF STEERING

Case (i):

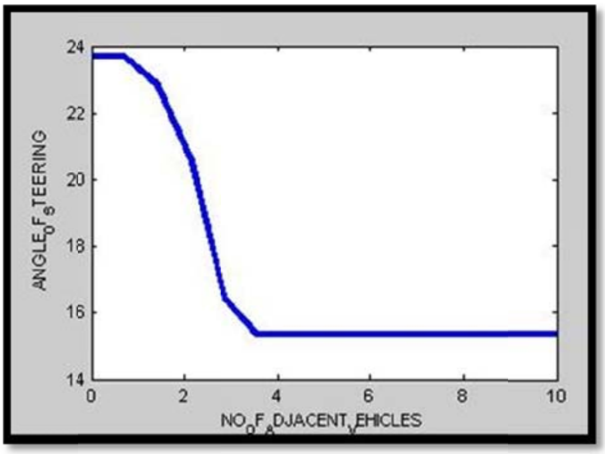

Fig. 3. Number of adjacent vehicles vs Angle of Steering

It is a known fact for any human being that the application of steering to a particular direction depends on the free space available. This in turn also depends on the number of vehicles that ply adjacent to the vehicle taken under consideration. A detailed analysis has been projected in Fig. 3 where studies clearly show the extent to which steering can be turned. Increase in number of vehicles decreases the need for steering.

Case (ii):

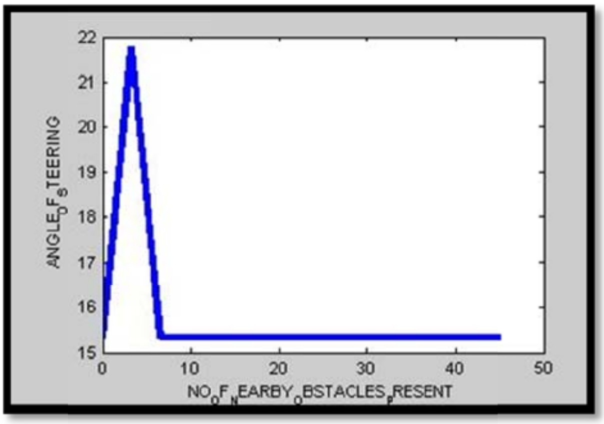

Fig. 4. Number of nearby obstacles present vs Angle of Steering

The usage of steering can be significantly enhanced when the road is relatively traffic free. It is widely known that in peak hour traffic, the extent of manipulation of steering is considerably less. The extent to which this is reduced has been projected in Fig. 4.

B. DETERMINATION OF ANGLE OF ACCELERATION

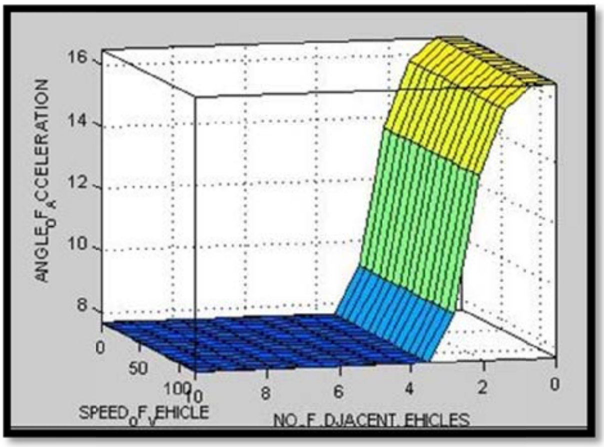

Fig. 5. Speed of vehicle vs Number of adjacent vehicles vs Angle of acceleration

As depicted in Fig. 5, the angle of acceleration does not show any change as the number of adjacent vehicles decreases. When the number of vehicles in less, then the angle of acceleration increases gradually. It can be sufficiently concluded that a larger degree of acceleration could be applied when there are less obstacles on the way of the vehicle.

C. DETERMINATION OF ANGLE OF BRAKE

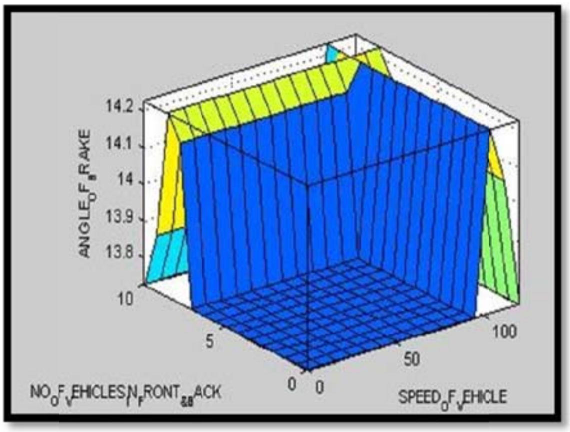

Fig. 6. Speed of vehicle vs Number of vehicles in front and back vs Angle of brake

A relationship has been obtained between speed of vehicle, number of vehicles (in front and back) and angle of brake. A scenario has been depicted in Fig. 6 where it has been observed that when the number of vehicles and speed of vehicles are constantly increasing up to a certain point (Speed of vehicle is approximately equal to 85 km/hr and number of vehicles in front and back is 7 approximately), the angle of brake is minimum. After this point, the angle of brake increases.

To summarize, when the speed of vehicles is very high and the vehicles in front and back are also more, it increases the necessity to apply brake. This is a worst case scenario where the possibility of applying brake arises.

A fuzzy supervisory scheme to provide effective learning applications with a good deal of uncertainty has been implemented earlier. Knowledge obtained from the same has been used to fine tune the current work.

D. SENSITIVITY ANALYSIS

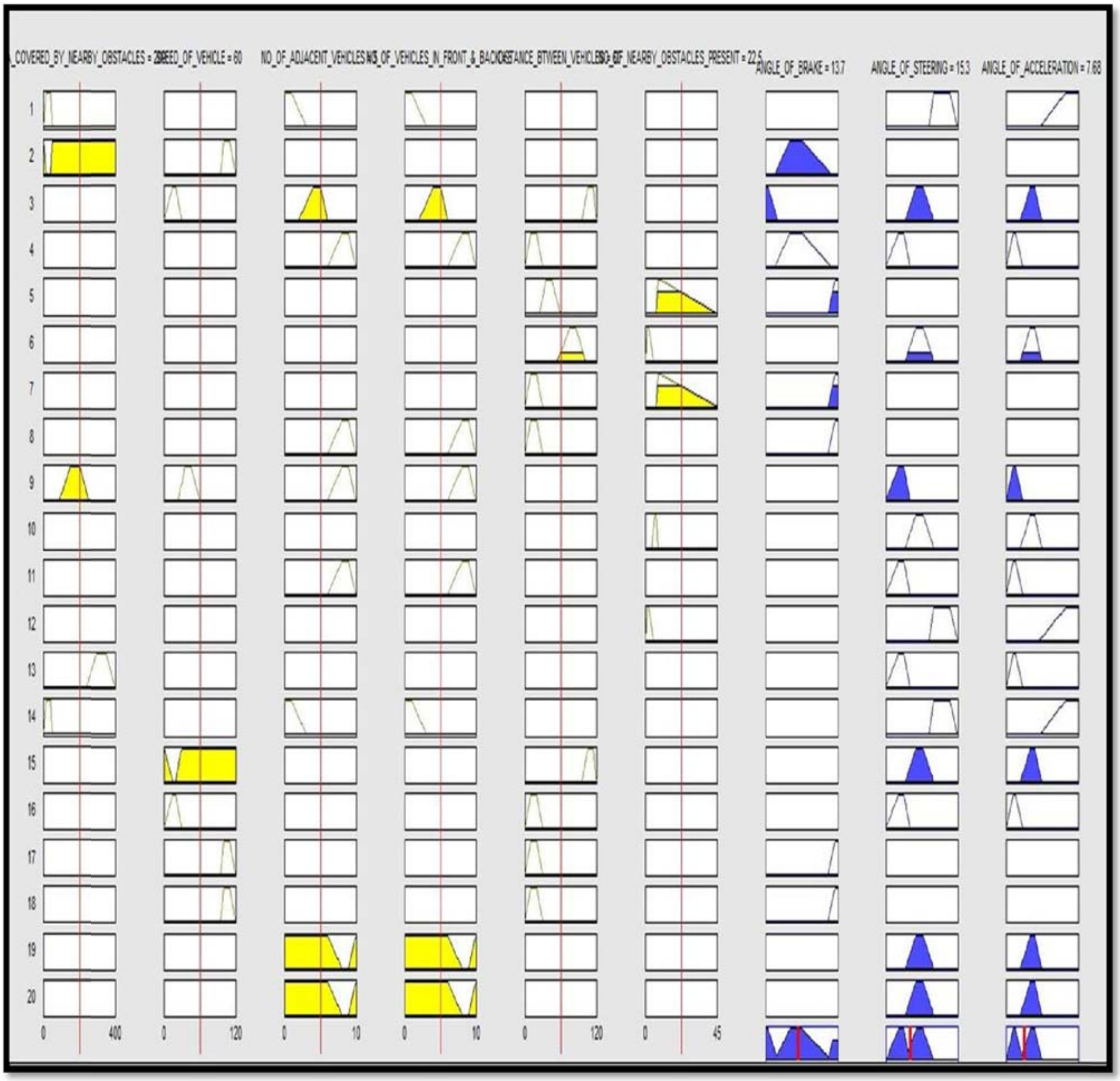

Fig. 7. Sensitivity Analysis

A detailed experimental analysis has been carried out to determine how the angle of acceleration, angle of steering and the angle of brake varies with the input parameters such as area covered by nearby obstacles, speed of vehicles, number of adjacent vehicles, number of vehicles in front and back, distance between vehicles and number of nearby obstacles. It has been observed that a large number of parameters play a role in determining the various levels. However, not all factors show similar variations.

It has been observed that a small variation in the area covered by nearby obstacle has a significant influence in the angle of steering.

In a situation where the number of nearby obstacles present is very less, even a large variation in speed of vehicle will not have an observable effect in the angle of brake.

When there is minimal number of adjacent vehicles then there is a huge increase in the angle of steering. This implies that the driver can steer the vehicle without much hindrance from other vehicles.

In order to determine the set of sensitive parameters, sensitivity analysis has been carried out. It is used to observe the effect of input parameters over the output. It helps in determining which parameter is most influential on the output. The input can have either a great influence or less influence on the output. This gives an insight into the sensitivity of the output with respect to the input.

Through this analysis it can be concluded that all the parameters have some effect on the output in one way or the other. All the parameters play a vital role in deciding the angle of brake, acceleration and steering.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A fuzzy expert system that can automatically analyze the situation based on the road conditions and take appropriate decisions has been designed. It has been observed that the performance of the system can be improved multifold when the amount of brake applied can be reduced. This work takes into account all factors playing a role in handling vehicle across roads. The major factors playing a role in the outcome have been given necessary importance and decision on application of steering instead of a brake wherever possible has been taken.

It can be concluded that usage of steering in place of brake improves the performance of the vehicle. So situations where the driver can steer instead of applying brake have been framed and detailed analysis has been carried out.

However efficient a system is, no system can be considered to be perfect. Future improvements for this vehicle automation system will witness the inclusion of a fault tolerance system that will take care of any real time failures associated with the system. The automation system can also be enhanced by using Type 2 fuzzy logic as it is more adept at handling uncertainties.

The usage of a Sugeno model instead of Mamdani may make it suitable for functional analysis. However, it is not known whether there will be a significant improvement or degradation through usage of the same. This aspect is left for future exploration.

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