SIT215-Artificial and Computational Intelligence
PBL task 1 documentation

FUZZY CAR

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Introduction

In this project, we are going to define an intelligent control system for vehicles (cars) using the fuzzy rule based expert system model. There are many intelligent control systems for vehicle such as radar-based vehicle separation, collision avoidance, lane following, cruise control etc.

The vehicle technology has grown exponentially in the recent years. The introduction of anti-lock braking system (ABS) has led the foundation for a variety of braking control systems such as brake assist, electronic stability control and much more. Along with the development of braking systems, the sensing technologies of the vehicles have also grown rapidly, such as the adaptive cruise control(ACC) system, which is the most common technology in vehicles at the moment.

Similarly, an automated braking system and a Lane Keeping Assistant system is possible in parallel to ABS and ACC, in the modern vehicles, which will be helpful in avoiding possible collisions. In practical, more strong and capable sensors would be required to implement the full use of the collision avoidance systems in the vehicles. In this article, we are going to demonstrate both of the system, in depth , using the fuzzy expert system.

The fuzzy logic based braking system uses sensors such as laser, radar or even video data to take distance and speed inputs and pressure on the brake as output. To avoid tire lock up and losing stability of the car, the fuzzy controller constantly monitors the deceleration rate of the vehicle the system using an anti-lock braking system. A minimum distance is configured in the system to ensure that a safe distance is maintained between two cars or from a car to an object before starting deceleration.

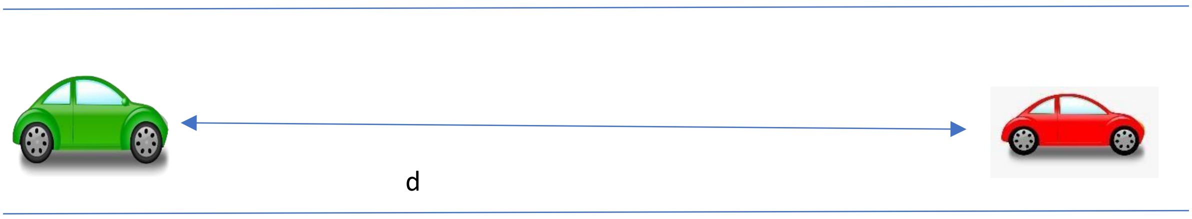
Lane Keeping Assistant System (LKAS) is a system designed to keep track of the lane in which the vehicle is driving and to also direct the car back to the center of the lane if it is deviating when we do not want it to. This can be achieved either by a camera attached on a car or by infrared sensors which detect road lane markings. The mixture of using the fuzzy logic with this system can produce a effective version of LKAS in the modern vehicles.

Problem Recognition

For the problem recognition of the Automated Braking System, let us look at 3 cases in which we can understand the problems that we need to address while designing the controller for the system.

Automated Brake System (Collision Avoidance)

Case 1: **Car1 is accelerating whereas Car2 moves at constant speed, as the Car1 accelerates, the distance between cars decreases as the relative speed increases such that first car approaches in Average Distance zone and then in Danger Zone.**



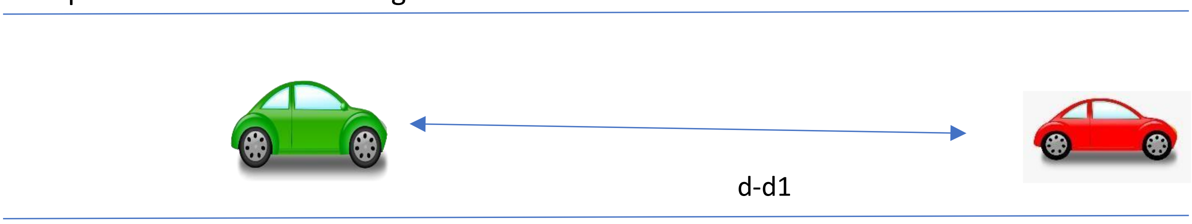
Car1 Car 2

Speed=x1 d=Safe Distance Speed=x2

Relative Velocity, v=x1-x2.

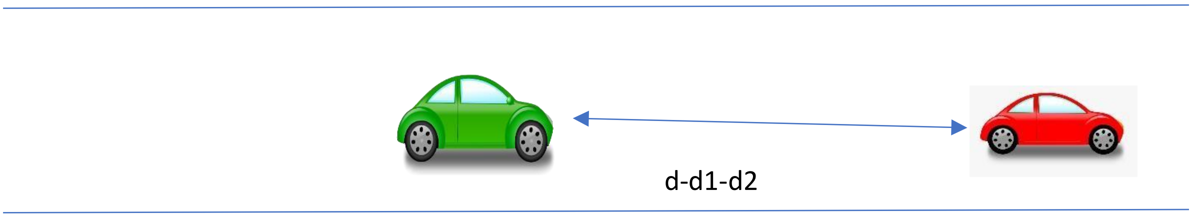
Force on Brake: Represented by f.

Let's assume increase in speed of Car1 is 'm' km/h. So, it is now x1+m. The driver is maintaining this speed and not accelerating further.



d=Average Distance Zone, v=x1+m-x2.

The system would become aware of the situation and start applying a small bit of force on brake say f= N newton such that it decreases the speed of the car1 by some factor say 'n' km/h. Still this force is not good enough to improve the distance between cars and increase the distance, and the distance decreases further as shown in figure.

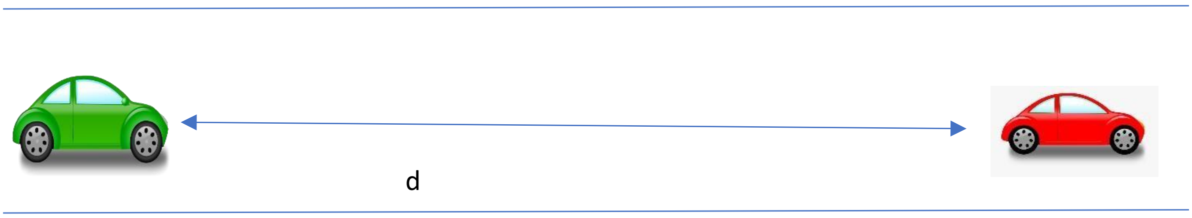


d=Danger Zone, v=x1+m-x2-n.

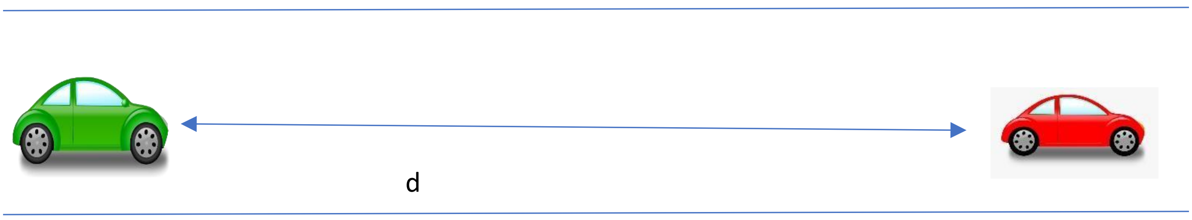
Our system would now apply high intensity brake such that the distance between cars start increasing and it is restored to safe distance. Let the force applied at this situation by brake is f=M newton such that it reduces the speed of the car by ‘s’ km/h such that the distance between car gradually increases and at last approaches safe distance.

Our aim was to make d= Safe Distance. After our system applies force, v=x1+m-x2-n-s, such that m=(n+s), therefore the speed of car1 becomes x1 again and relative speed is v=x1x2.After few seconds the distance would become Safe Distance and no further brake would be applied on the brake by the control system.

After say ‘t’ seconds, the Safe Distance is approached.



Case 2: Car2 is static and Car1 is approaching from behind at a constant speed. Since, Car2 is static as the time passes the distance between two cars is reduced, thus prompting the control system to apply force on the brake.



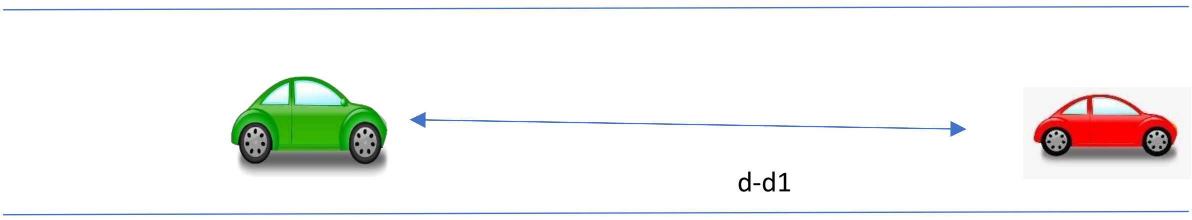
Car1 Car 2

Speed=x1 d=Safe Distance Speed=0

Relative Velocity, v=x1.

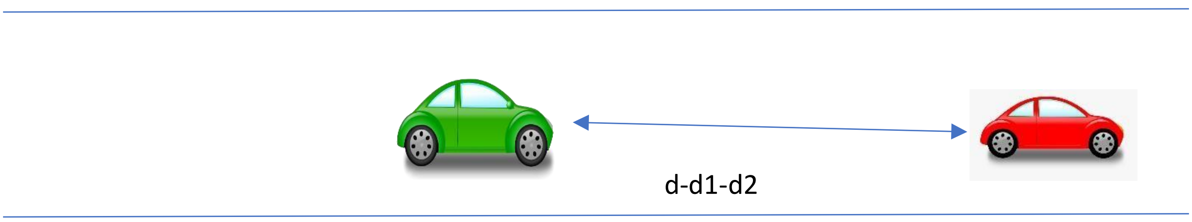
Force on Brake: Represented by f.

Let’s assume that in ‘t’ seconds the distance travelled by Car1 is d1 and the car enters Average distance zone which would look like as demonstrated below.



As Car1 approaches Average distance zone, the control system is prompted to apply force of low intensity is applied say force of f=M newton is applied on the brake reducing the speed of the Car1 by some factor say ‘c’ km/h.

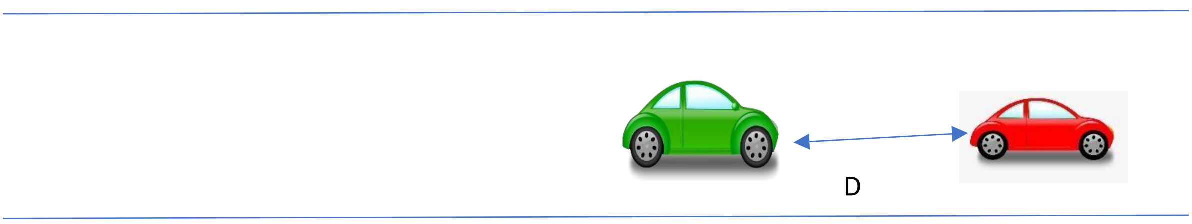
After the action of control system speed of **Car1=x1-c** but Car1 is still on the move and would cover some further distance in next few seconds and this would make Car1 approach Danger Zone, thus the system has to apply larger force on the brake system so that Car1’s speed becomes 0 and collision is avoided.



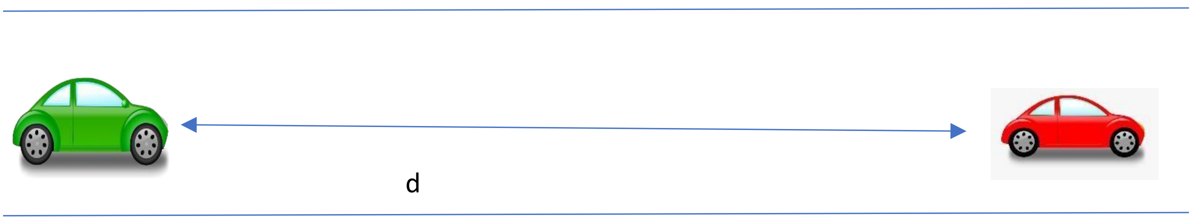
Let’s assume the force of N newton is applied on the brake by control system reducing the speed of the car further by ‘c1’ km/h such that (c+c1=x1), which would mean that Car1 comes it a standstill at certain distance say ‘D’ metres away from Car2, avoiding collision as demonstrated in figure below.

Final state of both cars would look like this:

x1=0km/h, x2=0 km/h with distance of D metres between both cars.



Case 3: Car1 is moving at constant speed whereas Car2 reduces its speed which would decrease the distance between the cars and if control system does not reduce speed of Car1 it could result in collision.



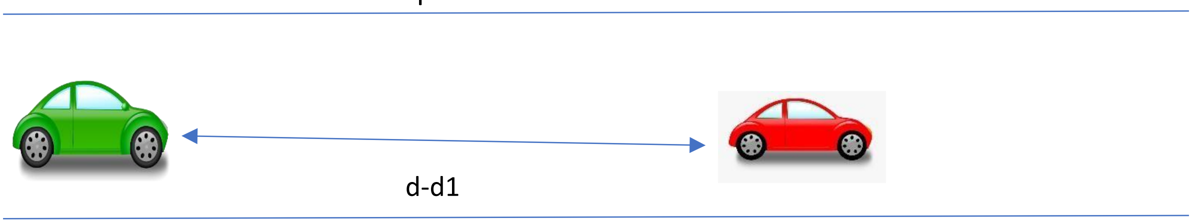
Car1 Car 2

Speed=x1 d=Safe Distance Speed=x2

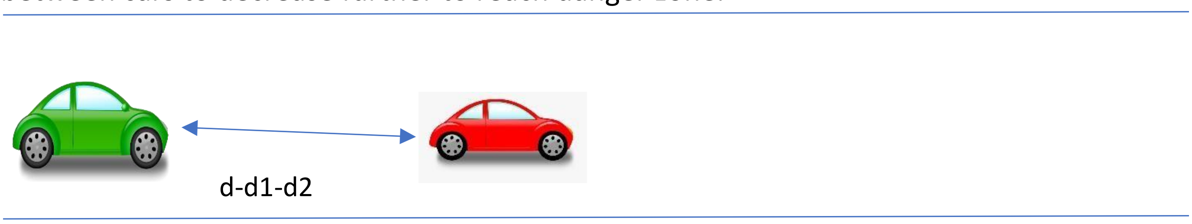
Relative Velocity, v=x1-x2.

Force on Brake: Represented by f.

Let's assume that in 't' seconds the velocity of Car2 decreases by 's' km/h, increasing the relative velocity which decreases the distance 'd' by say factor of 'd1' metres. The demonstration below is based upon these facts.

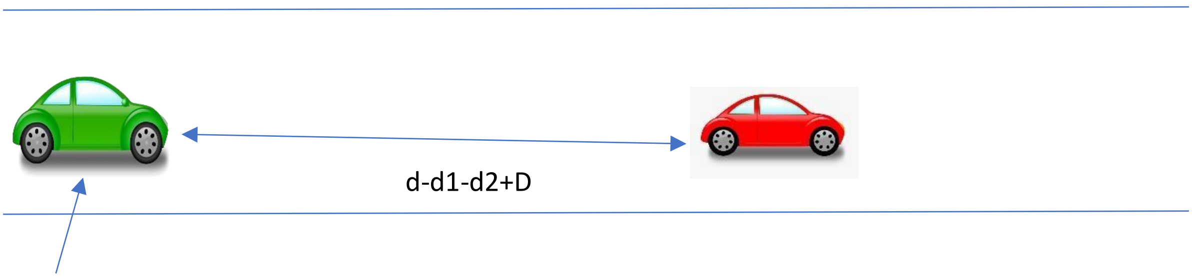


The distance d-d1 lies in Average Safe Zone, so the control system would apply low intensity force on the brake let's say f=N newton, this decreases the speed of Car1 by 'c' km/h but is still not enough as compared to decrease in speed of car2 which decreases by further 's1' km/h making x1=x1-s-s1 km/h, this results in further increase increases in distance between cars and thus reducing the distance further say by a factor of 'd2'. This result the distance between cars to decrease further to reach danger zone.



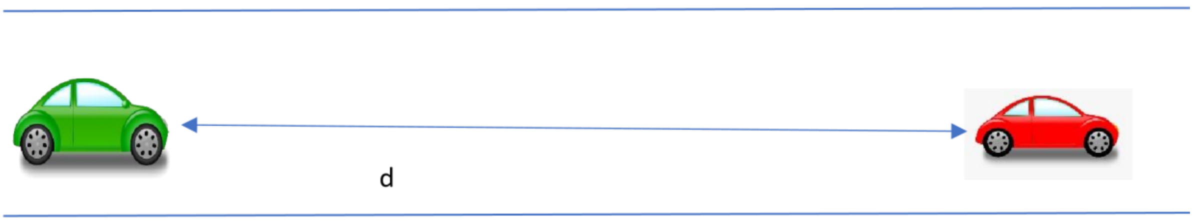
In such scenario control system would apply larger intensity force of M newton further decreasing the speed of Car1 by a factor such that the speed of the Car1 becomes less than Car2 for few seconds so that the distance between cars increases to being Safe distance.

Final state of the both cars would mean that speed of both car is reduced by certain factor and distance is maintained for avoiding the collision between cars as showing in the demonstration.



Speed x1-c

Distance becomes: d-d1-d2+D+D1 such that it is equal to ‘d’ metres.



Speed x1-c-C

Lane Keeping Assistant System (LKAS)

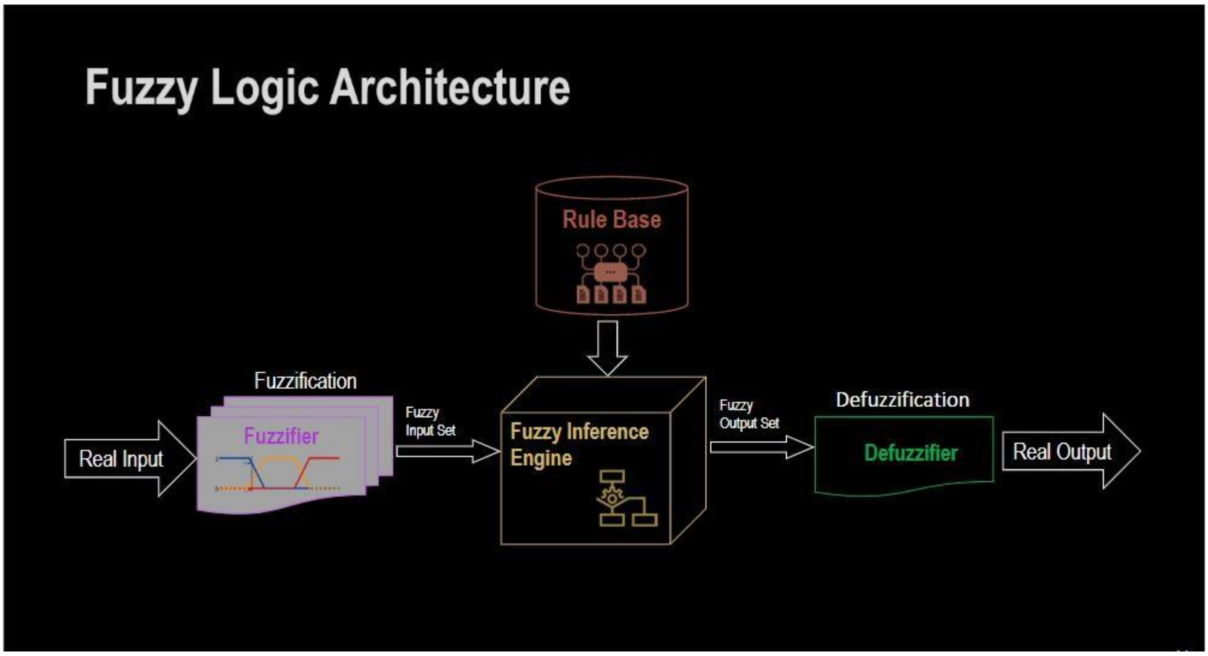
A significant proportion of accidents happen due to lane departure crash. For examining the problem for the Lane keeping assistant system, we can inspect some of the scenarios. These scenarios usually arise when the driver is out of concentration or he is dozing behind the wheel. These accidents can be prevented if we use a system (LKAS) which will tell the driver when the car is going off lane and direct car automatically back to its lane.

Solution Design and Exposition

The fuzzy model mainly composed of 4 components- Fuzzifer, Defuzzifier, Rule Base and Fuzzy inference engine.

Below is the basic diagram for the fuzzy rule based expert system model.

- First, we enter the crisp input values into the system.
- Those values are converted into fuzzy sets, by using the fuzzifier, which is further sent to the fuzzy inference engine.
- Then the fuzzy Inference Engine, with the help of rules in the Rule Base, gives the output in fuzzy sets. The fuzzy inference engine will use those fuzzy sets and will try to match the conditions in the set with the rules which are present in the Rule Base.
- The output fuzzy sets are converted into real crisp values using the Defuzzifier. Those crisp values which is given by the model is the solution that we need. Without the de-fuzzifier, the output would be fuzzy sets which have little meaning.



For the solution implementation of the project, we have used the ‘skfuzzy’ library in python. ‘skfuzzy’ library is particularly used for the implementation of the fuzzy model.

In the python code after importing the required libraries, we firstly defined the antecedents i.e. distance and speed, and the consequent i.e. brake. The antecedents are the inputs and consequent is the result of the inputs (output).

The skfuzzy library is using **Mamdani’s** fuzzy inference technique. This technique uses the if-then approach (if values are the antecedents and then is the consequent). There are two ways of implementing this technique- forward chaining and backward chaining. Our approach was the forward chaining. This means that we give data first, then rules and finally predict an output.

There are different ways of visualising the membership functions on the graph. For example- triangular, s-shape, Gaussian, trapezoidal, etc. For our illustration, we chose trapezoidal. Then we define the fuzzy sets for different linguistic variables such as 'very_low', 'low', 'medium' and 'high' for each antecedent and the consequent. The linguistic variables are assigned to a logical range of values corresponding to our worldly knowledge. Then, to verify the sets, we visualize those using graphs.

Then we create the rules which we need for the implementation of the fuzzy inference system. In the Automated Braking System, we have created 16 different rules, with different combinations of the distance and speed giving us different linguistic values for the force used on the break, whereas for the LKAS we have created 15 different rules, with different combination of speed and deviation from the lane. After defining the rules, the rules are stored in the **Rule Base**.

Finally, we created a dictionary of different data (varying distances, speeds and brake values), to test each and every situation possible. We tested each and every case for both of the systems using the fuzzy system and gave the output with the associating graph for clarification.

The limitation of the Automated Braking System is that the system is working on the continuous basis i.e. in the starting when the distance between the car_1 and car_2 is d_1, after some time the distance between the cars is $d_2(d_2<d_1)$, then the automated braking system will work fine. But if there is a sudden obstacle of any kind, for example, a car coming out of the service road, at more than average speed, without any indication, this might lead to an error in the automated braking system causing an accident.

Whereas the limitation of the LKAS is that we have to turn off and turn on the system multiple times when we need it. And at this moment we can not anticipate the result of continuous shifting on the controller. This might cause a mechanical problem to the controller.

Conclusion

During the execution of the projects there were multiple topics and concepts which we went through.

With the problem recognition, we analysed different cases that may arise on the road while driving a car where automated driving system or Lane Keeping Assistant system can be useful.

During the solution design, we studied different possible cases and came out with the solution for each case study and assign different linguistic variable and fuzzy sets. The variables had to have their own purposeful meaning to be used effectively.

Also, during the execution of our python code, we had to thoroughly learn about the ‘skfuzzy’ library. This required us to go through the documentation of the skfuzzy library and understand each and every method, function, object etc. that we had to use to implement the fuzzy model.

To conclude, this project required us to do extensive research on the internet. We went through various documentations, journal and training videos to gain the required knowledge. Each and every member did their part of research and shared their knowledge amongst each other.

REFERENCES:

Mamat, M. & Ghani, Nor Maniha. (2010). Fuzzy Logic Controller on Automated Car Braking System. 2371 - 2375. 10.1109/ICCA.2009.5410301.

Sharma, M. and Atri, S., 2011. Fuzzy Rule based Automatic Braking System in Train using VHDL. *IJCST*, 2(2), pp.332-334.

Bennajeh, A., Bechikh, S., Ben Said, L. and Aknine, S., 2019. Anticipation model based on a modified fuzzy logic approach. *IET Intelligent Transport Systems*, 13(2), pp.330-339.

Vukadinovic, D., n.d. *Fuzzy Logic*. 3rd ed. Nova Science Publishers, pp.84-110.