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Fuzzy Logic Based Controller For Automated Gear Control in Vehicles

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ABSTRACT

The paper discusses a Fuzzy Logic based controller for controlling an vehicle's gears in an automated transmission system. The System takes human like decisions based on actual real time road conditions, unlike the fixed rule-set of traditional control systems. The controller model selected for the work was the Mamdani model. Fuzzy logic emulates human reasoning process and decides for all conditions unlike the traditional classical If Then rules.

Keywords: Fuzzy control, Automatic vehicle, Gear control, Mamdani Model.

1. INTRODUCTION

Traditional driving involves the vehicles to be put into various gears depending on the driving conditions. The driver would take decisions based on human reasoning depending on parameters like the slope of the road (flat or steep road), the quality of the ground surface (Bumpy or smooth path), and the traffic in the path (dense or scarce). The present speed at which the vehicle is moving has got to be taken into consideration. If the speed is too high (say 80kmph) and the vehicle shifts into first gear on seeing a bumpy or traffic road. The gear system is likely to go into breakdown. The gear shift job has been slowly but steadily shifted from the driver's control to the automated variety in the past few years. The gear shifting is done with analogue mechanical sensors and there is not much "thinking" involved. But as we move to fully automated (even driverless) vehicles, the control part of all operations is shifting to microcontrollers. Microcontrollers get inputs from various sensors and take decisions from the data. They use pre-written programs for this job and use classical rules. Using classical rules has a limitation that they have sharp boundaries. For example, a rule may say that IF slope is less than (say) ten degrees, use gear number four, while if slope is greater than ten then use gear three. Now this has a basic flaw that the gear changes at a sharp value; i.e. if the slope is measured as 9.9999999 (the sensors have their own limitations of precision) or just above this value by a mere 0.0000001 degrees, the rule ends up in different gears being chosen, which by itself sounds absurd. This is not how we humans take our decisions. Fuzzy logic takes into account sloping borders at the rule edges and decisions are gradual rather than abrupt. The basic reasoning behind fuzzy-sets is the absence of sharp boundaries in human reasoning. A number of standard fuzzy inference methods have been developed over the years. One of these is the Mamdani inference system. This paper discusses a technique based on the Mamdani model.

2. The Inference Engine

The Fuzzy system works on three inputs. *In actual practice these will be sensed by sensors fitted into the vehicle.* But for this work, which is just the software simulation, they are interactively entered by the user through the command widow. The program asks the user to enter the values of the slope, road quality and traffic conditions on the command prompt and works using the inputs provided by the user to simulate the decision process. The rule set has 27 fuzzy rules, in addition to traditional classical logic rules. The rules use linguistic variables. One example rule is:

R1
If
((The slope of road is flat)&&(The quality of road is good in terms of bumps per unit length)&& (The traffic is clear))
Then
(Selected Gear is "High")
Another rule could be
R2
If
((The slope of road is steep)&&(The quality of road is poor in terms of bumps per unit length)&& (The traffic is dense))
Then
(Selected Gear is "Low")

Each input variable (slope, road quality, and traffic) has been divided into three fuzzy sets and 27 fuzzy rules have been formulated. Realistic situations on the sloping boundaries of the fuzzy sets trigger more than one rule simultaneously. Later the consequents from all the triggered rules are aggregated together and the result is defuzzified to compute the suitable gear for the situation at hand.

3.THE ALGORITHM

The algorithm is explained with the help of the flowchart in figure 1. Initially the program executes a loop asking the user if the car is stationary or moving. If the vehicle is stationary, the Fuzzy engine is not initiated. The system goes into action, only after the vehicle starts moving. Initially, when the vehicle has to just start moving, the gear is initialized to “1”. After the initial setting to the lowest gear “ONE”, The system will ask if the user wants to move the vehicle backwards. If the user wants to go backwards, the vehicle is put into reverse gear. Since there is NO other option in backward direction regardless of slope etc; the fuzzy control system still does not statrt working at this stage. The system stays in reverse gear waiting in a enquiry loop, till the user says the vehicle should move forward again. It is only after this that the fuzzy inference system starts working. Once the vehicle settles into forward motion after being initialized to first gear, the system asks the user about the slope, road quality and the traffic condition on the interactive command window.

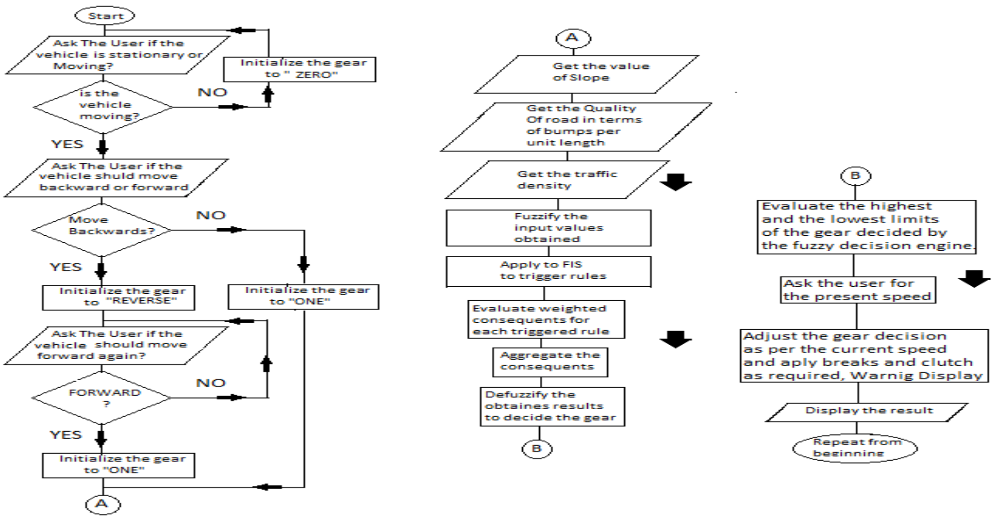

Figure 1. The Flowchart describing the algorithm for the FIS

4.THE IMPLEMENTATION

The Algorithm described above was implemented using the Fuzzy Logic toolbox of MATLAB. The program works interactively in absence of actual sensors, but can easily take inputs from sensors in real situations. First stage is confirming the vehicle is supposed to move or stay stationary. The vehicle continued in a loop at neutral gear till the user said that it is now not stationary – which is till all the passengers get in even after the ignition key is turned on and other similar situations. Figure 2 illustrates the interaction. Until the vehicle is ready to move, the gear selected continues to be neutral. Once the user says that the vehicle should move, the system asks whether the vehicle should move forward or backward. If backward, the system selects the reverse gear. This is displayed in Figure 3. If forward motion is required, the system asks if the terrain is sloping downwards in the forward direction. If so, the system moves to neutral gear. Once the downslope is over, the system goes into the first gear irrespective of conditions as the vehicle is starting from rest. This is displayed in Figure 4.

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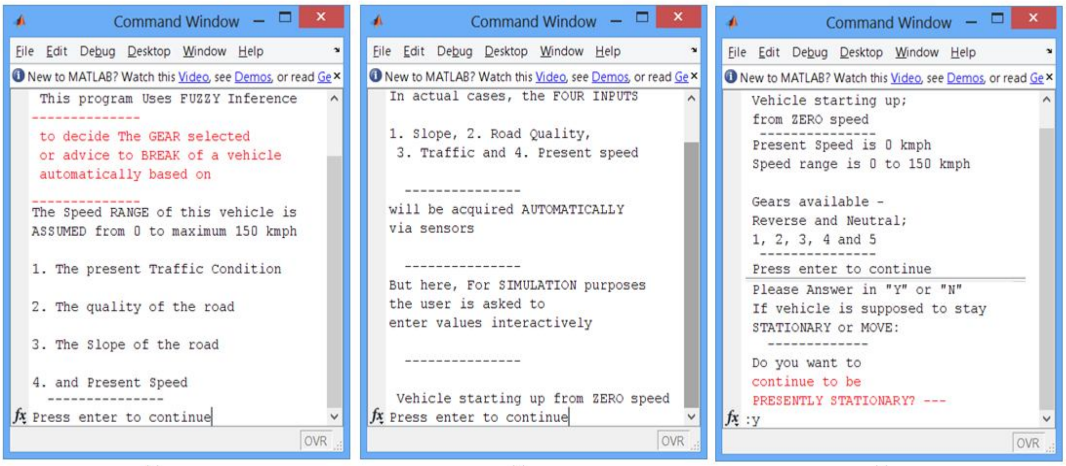
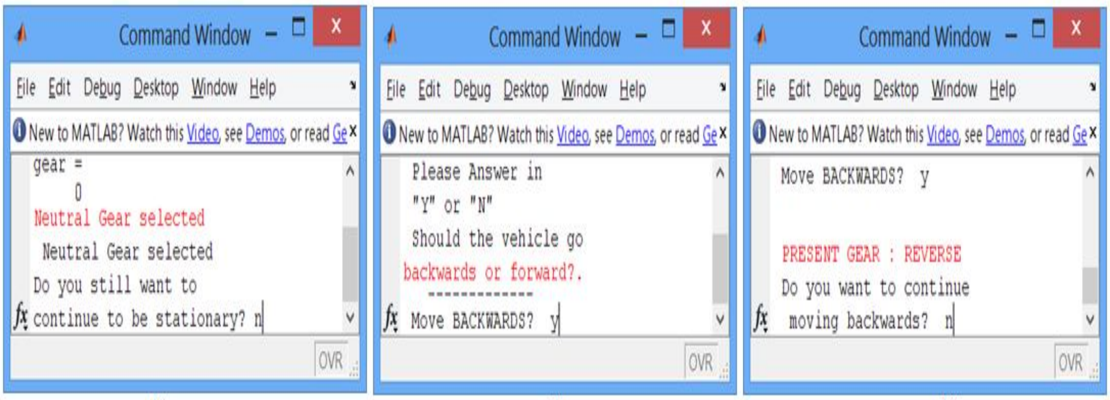


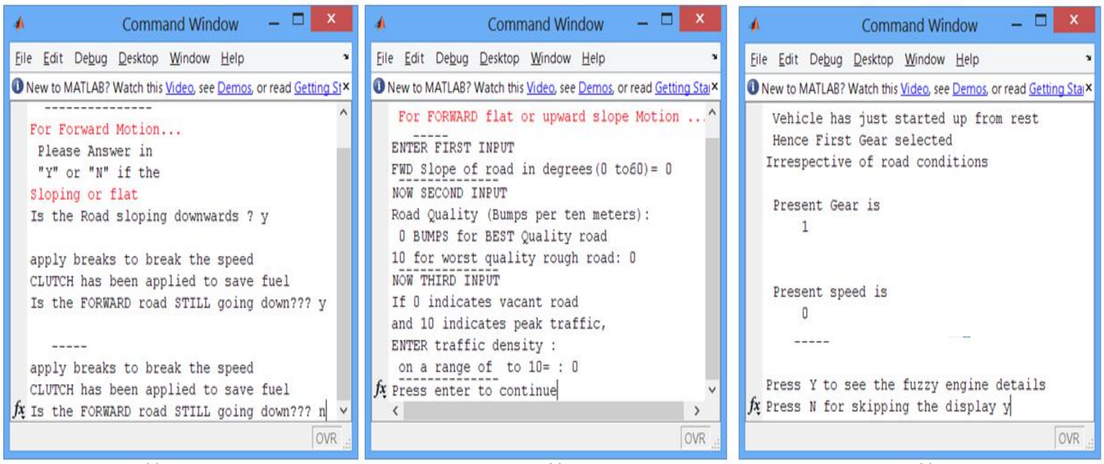
(A) (B) (C)

Figure 2: The command prompt displays for the initialization. The system asks the user whether the vehicle should be stationary or move.



(A) (B) (C)

Figure 3: The command window. (A) Till the user wants the vehicle stationary, it stays in neutral gear in a loop. (B) Once the user says the vehicle should move, the system asks to move forward or backward, and applies reverse gear if commanded to move backwards.



(A) (B) (C)

Figure 4: (A) Commanded to move forward, the system enquires about the path sloping downwards in forward direction. If so, neutral is applied. (B) For flat or upward motion forward, the system enquires about the slope, road quality and traffic condition, but regardless of the actual situations, the first gear is selected for starting from rest.

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After this, the fuzzy inference engine is invoked. In the next loop, the vehicle is already in motion, and hence the actual conditions of the road and the present speed together decide the next gear to be used. This is illustrated in figure 5.Now the situation may be that the gear decided as per the road conditions, and the speed at which the vehicle is already moving are mismatched. In that case the system adjusts the selected gear and also aplies eithe brake or clutch or both to prevent engine damage. An illustration of one such situation is shown in Figure 6.

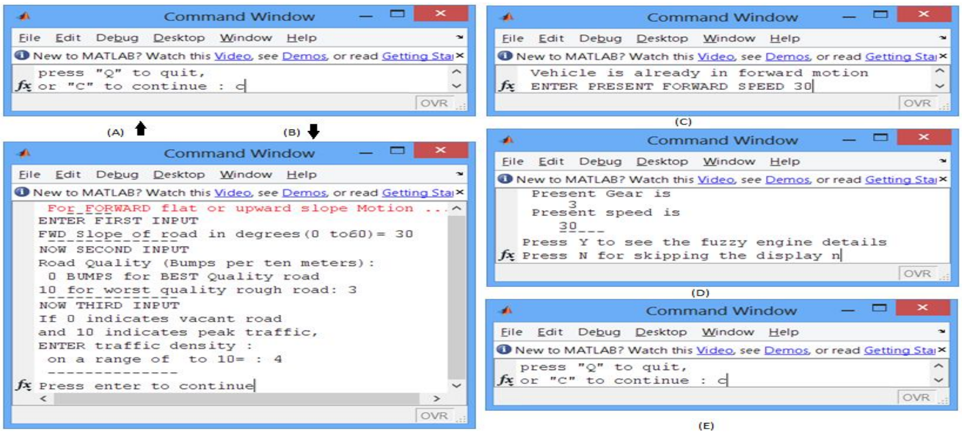

Figure 5: For the vehicle on the move, the system keeps checking conditions in loop till asked to quit. For the given conditions and known speed, the gear is decided.

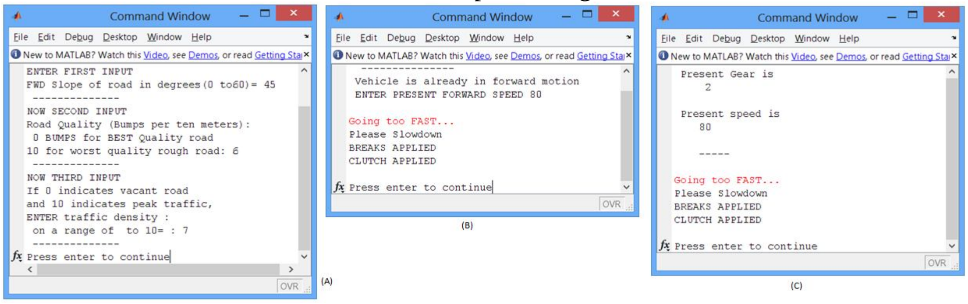

Figure 6: Vehicle is on a road condition needing First gear, but current speed is 80 KMPH. Hence the gear is stepped up to second and brakes are applied, and a warning is flashed.

5.THE APPLICATION OF THE FUZZY ENGINE AND THE RESULTS

The Fuzzy engine applied in this work has 27 rules and a Mamdani structure. The liguistic description details are shown in figure 7 below. The Graphical representation of the fuzzy engine and the rule set is shown in Figure 8. There are totally 27 rules in the fuzzy engine, extendible to include more real life road conditions in changing situations.Finally the rule application view for typical antecedent values of slope, road quality and traffic density, and the surface view of the decision edge, for a particular case is displayed in figure 9.

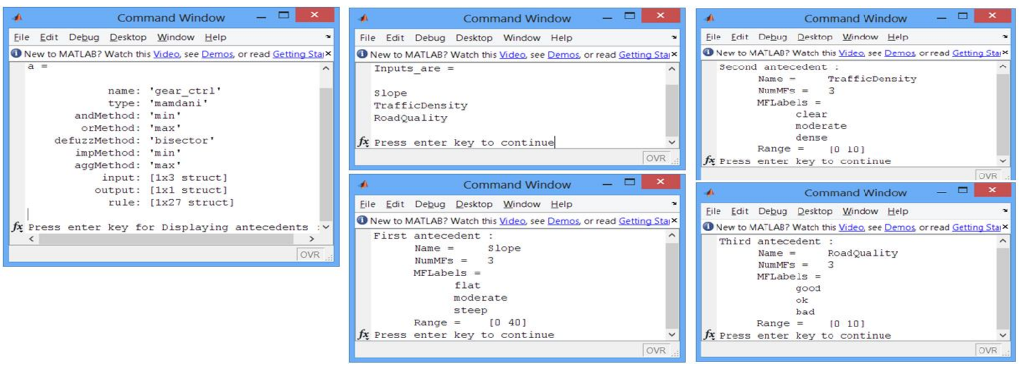

Figure 7: The Description of the fuzzy decision engine and the linguistic variables used

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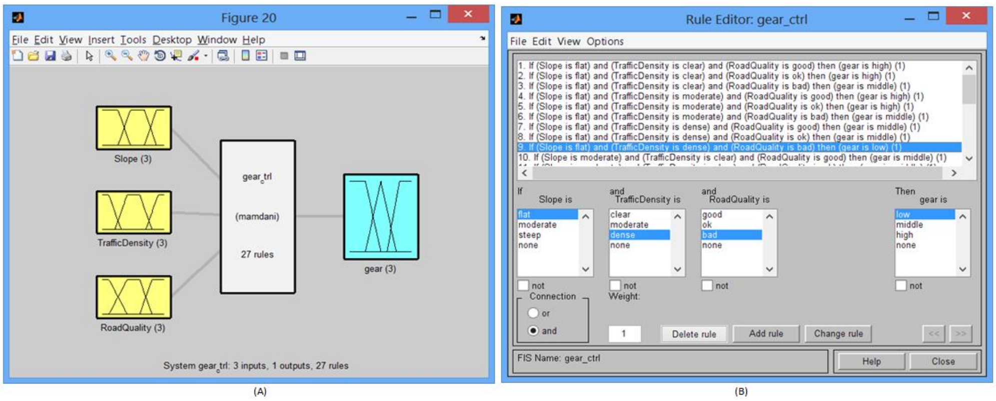

Figure 8: The graphical representation of (A) The fuzzy engine and (B) The ruleset.

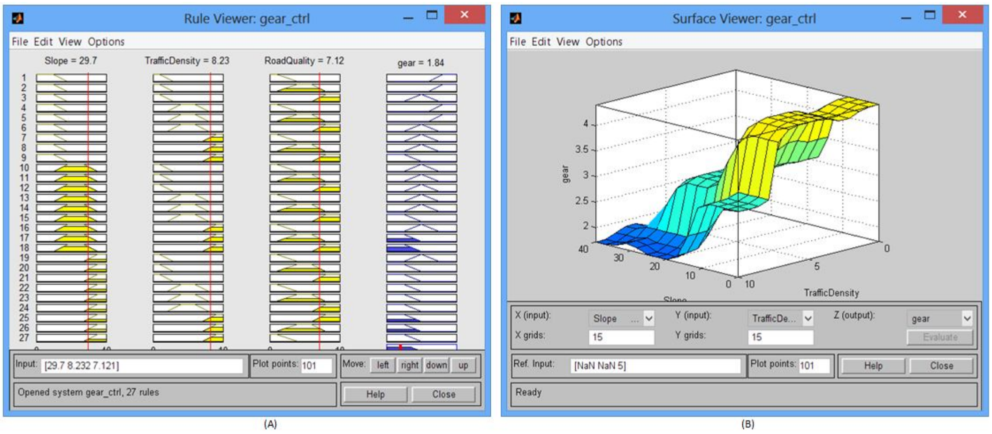

Figure 9: (A) The Rule Application view (B) The discriminating surface view.

5.CONCLUSION

The problem of automatic gear control was approached by a fuzzy logic based approach. The fuzzy engine was able to handle various conditions and abrupt changes too, and the results of various situations were illustrated. The engine was designed to flash warnings and take corrective steps in case of suddenly changed road conditions contradicting the currently chosen gear in use. The system worked acceptably in the simulated situations taken in the development of this paper.

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