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Optimal Gear Indication for Green Environment

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Abstract : A method for determining the optimal gear, in terms of fuel consumption, of a vehicle drive is proposed. This method for efficient gear indication uses the speed and load of a vehicle for optimizing the fuel consumption of the engine and henceforth reducing air pollution and saving precious fossil fuels. The optimum gear is determined by rules of fuzzy logic, mechanics and geometry. The demonstration of gear shifting is presented with tools of MATLAB Fuzzy Inference System. The further implementation and usage of this technology in traffic control and global positioning system management is presented. This system needs a special type of sensing device to determine the actual load on a vehicle and a sensor is needed to record the speed instantaneously. A sensor is attached to the wheels of the vehicle to predict the quality of road (uniform or non-uniform) and according to the intensity of the vibration and other factors, the road quality is predicted. This is very beneficial for the new learner who does not know about optimal gear transmission. This system will thereby also increase the efficiency and lifespan of the vehicle's engine.

Keywords : Gear indication system, fuzzy inference system (FIS), MATLAB, optimization, green environment, fuel saving

I. Introduction

Some of the critical issues that today's world is facing are environmental degradation and depletion of fossil fuels. This has led to inflation in fossil fuel prices. It directly affects the automobile industry. As production of automobiles increase, fossil fuel requirements also increase. The amount of fuel consumed by a vehicle and its carbon emission depends on the vehicle gearbox. That is, on the type of the transmission used by the vehicle. Firstly, the difference between a multi gear vehicle and a single gear vehicle is ascertained. Then, the functioning of the gear transmission system of a vehicle is described using a graphical explanation. The mechanical and thermo-dynamical processes of generation of power, torque and speed are also discussed.

A multi gear vehicle has many gears that can be selected according to the speed and torque requirement, while in a single gear vehicle there is only one gear. Suppose, there are two motorbikes. One moving on a plane road and the other one moving up on an inclined road. Now, due to the gravitational force, the bike moving on the inclined road needs more torque than the other bike. To meet this requirement, different types of gears are required in a vehicle that can change the value of speed and torque. When an input gear has a lesser value than the output gear, the speed will be high and torque will be low and vice-versa. Therefore, when a vehicle with only one gear moves on an inclined road or a plane road, its torque and speed requirements are different from a multi-gear vehicle. A single gear vehicle cannot meet these requirements. In this case, the rings of the gear start slipping on the shaft of the engine and useful energy is dissipated in the process. However, in the case of a multi-gear vehicle, the torque and speed requirements can be achieved by changing the gear. In this paper, the approach of efficient gear determination will be discussed with the help of fuzzy logic.

II. Related Work

In [*i*], the authors proposed another invention for determining the optimum gear of a vehicle that adapts itself as it learns how the vehicle responds to the particular driver, road conditions, and engine condition encountered during a drive. The invention also related to a circuit for performing the method. The authors of [*ii*] have proposed some proficient gear shifting strategies for green driving policies. They have derived effectual automatic gear shifting policies in cars equipped with AMT (Automated Manual Transmission) with the aim at reducing fuel consumption. Two different online gear shifting approaches have been fully examined by them and described in the paper: a) E.G.A. (Efficient Gear Actuator), based on the choice at each time instant of the most efficient gear according to efficiency maps, and b) G.F.A. (Genetic and Fuzzy Algorithm), achieved from the synergic use of Genetic Algorithms and Fuzzy Logic. Comparative tests carried out on the New European Driving Cycle (NEDC) have also been presented for both approaches in order to show their efficiency and to allow comparisons.

The authors in [*iii*] address the indication of haptic gear shifting which consequently assesses acceptance and reduces potential fuel intake. Drivers can be assisted finding the best gear and shifting time using an algorithm taking into account different parameters like rpm value. This study uses a Continental Automotive GmbH Accelerator Force Feedback Pedal (AFFP). The stimulus for the gear up is presented as haptic double tick. This study also shows the efficiency of the AFFP concept and the haptic double tick in helping drivers to gear up earlier during a typical acceleration procedure. A possible reduction of fuel consumption was probably hindered by the low power and torque output of the engine, impairing the drivers' capability to accelerate swiftly after upshifting earlier. Additional studies using a haptic double tick to indicate an upshift could use turbocharged engines, providing for high numbers of torque in low rpm ranges, confirming the justification offered in this work. Blee and Deane in [*iv*] have similarly proposed a gearshift indicator for an automobile. A display panel has an array of LEDs to provide an indication to the driver of an automobile, mainly a diesel-powered truck, when he should change to the next top gear during acceleration from rest or low speed. The change-up speeds to which the system retorts are pre-set to be the optimum speeds for increased fuel efficiency.

Kazyaka in [*v*] has put forward a gear selection indicator for manual transmissions that delivers a positive visual indication of the currently selected gear. Similarly, the author of [*vi*] discussed a method of averting erroneous gear selection in a vehicle transmission. He endorsed a method for averting a vehicle gearbox selection of an operationally erroneous gear in the absence of a gear change regulating speed indication. The authors of [*vii*] have projected an innovative technique for indicating the optimized gearshift. They discuss a method that indicates the gear shifting process that has to be executed and encompasses the stages of computing present engine load from the intake airflow and the amount of engine gyrations. It is therefore the objective of the current invention to deliver a technique for carrying out gear changing task and indication by showing to a driver the desirable shift positions to be implemented for the best possible fuel intake rate. The limitations of this invention is that a memory with huge capacity for storing a big amount of data has to be used which would not be possible in the present scenario with reduced costs. Manual gearshift and clutch training device including a sensory display is set to be the future of this invention.

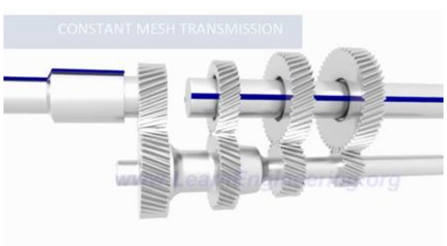

Fig. 1: *Constant Mesh Transmission*

III. Proposed Work

The proposed method to determine the preferred gear is fuzzy logic. The fuzzy inference system (FIS) is simulated in MATLAB by using the Mamdani rule. This rule has been used to determine the gear output for the gear indication system. The speed, load and gear input is taken from the user to derive the results and to plot the graphs. Sensor perceives the speed and the load of the given input and gives a fuzzy output. The fuzzy algorithm is applied to give the final output. The MATLAB software uses a FIS file to perform the computations. Real time data values are used for the dataset.

For any vehicle, at the point of contact of the tires with the road, the value of speed with respect to the road changes. Torque is the product of the force applied by the vehicle on the point of contact of the road and the radius of the tire.

Torque = Force × Radius (1)

This force value is determined by the capacity of the engine and the internal gear size. Power is defined as the no. of times the piston in the cylinder oscillates up and down multiplied by the cylinder capacity.

(Volume of Cylinder) × (No. of Rotations) = Power (2)

There is also a third relation, a general rule of mechanics,

Speed × Force = Power (3)

In circular motion, this force is actually torque,

Speed × Torque = Power (4)

From (2) and (4)

(Volume of Cylinder)×(No. of Rotations)=Speed×Torque (5)

The volume of the cylinder is generally constant because it depends on the construction of the cylinder and its size, implying that,

Speed × Torque = k × n (6)

where k is a constant and n is the no. of rotations.

It means that the product of speed and torque is directly proportional to the no. of rotations of the piston in unit time. The no. of rotations always depend on the amount of acceleration provided by the accelerator of the vehicle.

If the acceleration is constant, then,

Speed × Torque = constant (7)

which means that if speed increases, torque decreases.

Speed = c/torque (for particular value of acceleration)

Hence, speed is inversely proportional to torque for this case.

Now the gear of the vehicle comes into action.

Fig. 2: *No. of teeth T is inversely proportional to the speed N*

The equation of motion of a vehicle can be written as:

$F - mg\sin(\theta) - \mu mg\cos(\theta) = ma$ (8)

where F is the force applied by the vehicle to move up the incline, m is the mass of the vehicle, g is the acceleration due to gravity, θ is the angle of inclination of the inclined road, μ is the coefficient of friction and a is the acceleration of the vehicle moving up the incline.

The load can be written as,

$$\text{Load} = mg\sin(\theta) + \mu mg\cos(\theta) \qquad (9)$$

This load can be calculated by a special type of sensor that requires the actual value of the mass of the vehicle and the angle of inclination of the inclined road. Once the value of the load is calculated, there is no need to calculate it again. If the angle of inclination changes again, it can then be calculated with the help of a GPS device.

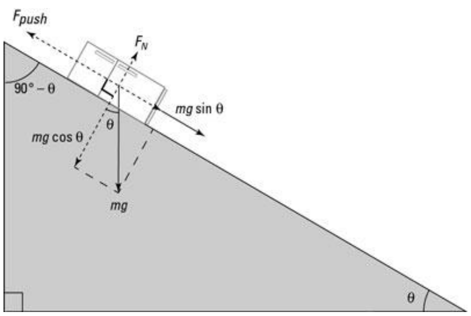

Fig. 3: *Free body diagram of a vehicle moving up on an inclined road*

IV. Results and Tables

The FIS input variable 'speed' is classified in four ranges (in kmph) as shown in the graph in Fig. 4, i.e., 0-30, 30-60, 60-90, 90-120. Both FIS input variables 'speed' and 'load' together determine the FIS output variable 'gear', i.e., the optimal gear of the system.

The load of the vehicle is classified in three categories as shown in the graph in Fig. 5, i.e., normal, heavy and very heavy. The load is a typical thing to understand as it depends on the actual mass of the vehicle and on the load that it carries.

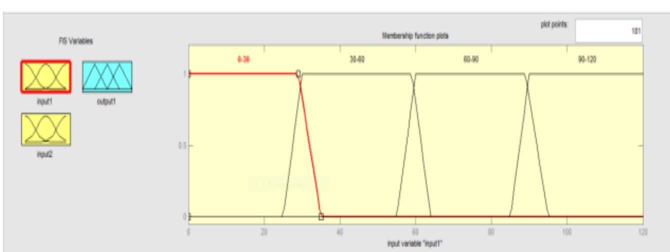

Fig. 4: *Membership function plot for the first FIS input variable 'speed'*

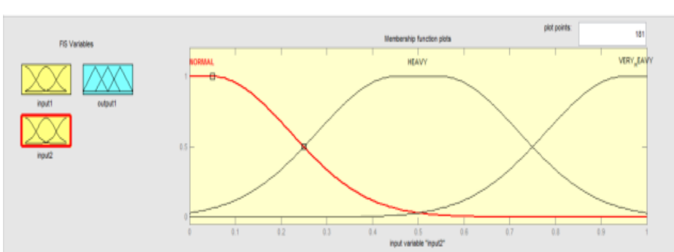

Fig. 5: *Membership function plot for the second FIS input variable 'load'*

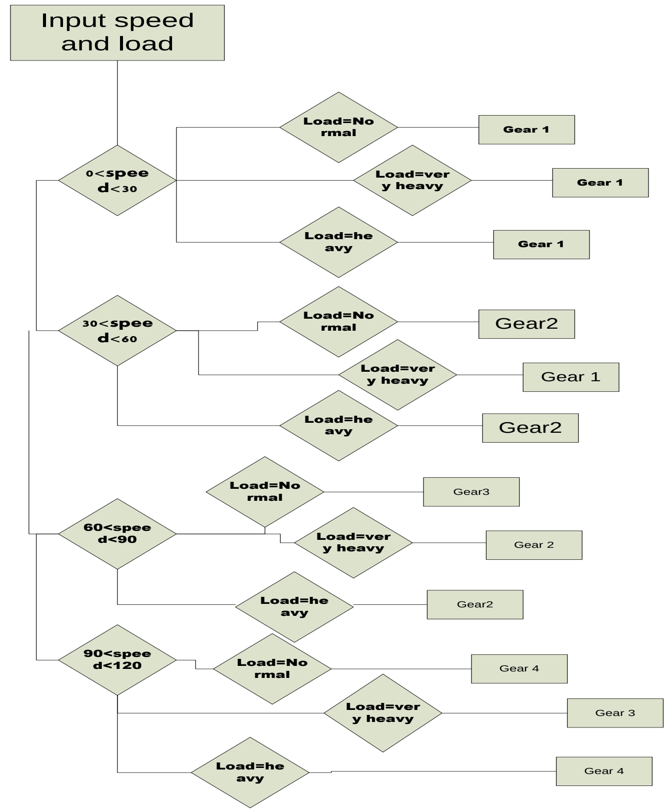

Fig. 6: *Block diagram of the gear indication system*

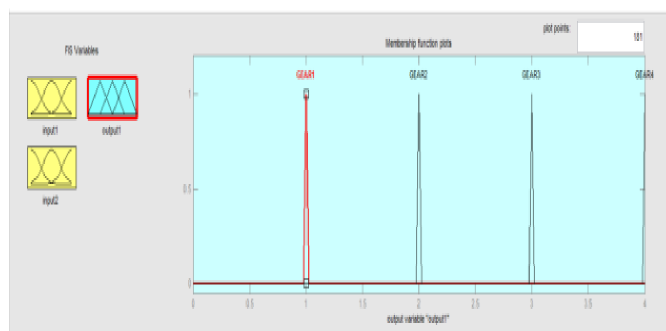

Fig. 7: *Membership function plot for the FIS output variable 'gear'*

Table 1: Optimal gear selection with respect to speed and load

SPEED (in kmph)	NORMAL	HEAVY	VERY HEAVY
0-30	GEAR 1	GEAR 1	GEAR 1
30-60	GEAR 2	GEAR 2	GEAR 1
60-90	GEAR 3	GEAR 2	GEAR 2
90-120	GEAR 4	GEAR 3	GEAR 2

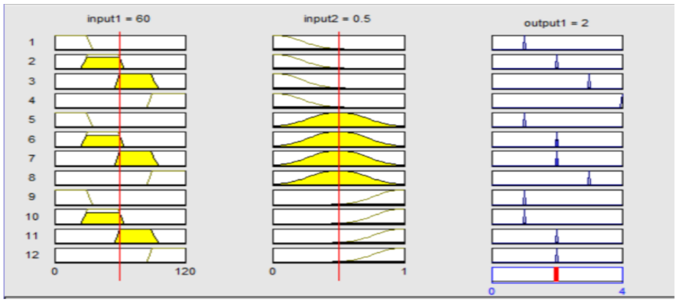

Fig. 8: *The rule view for sample FIS input values 60 and 0.5 of speed and load respectively, generating the FIS output value 2 for optimal gear selection*

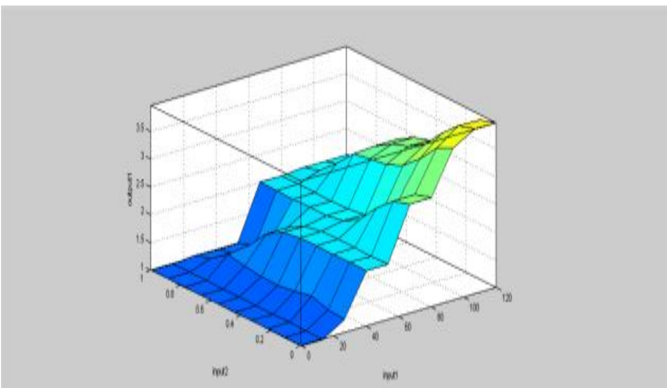

Fig. 9: *The 3D surface view for the gear indication system using the surface viewer tool. The FIS input variables 'speed' and 'load' are plotted on the x and y axes respectively and the FIS output variable 'gear' is plotted on the z axis*

V. Conclusion

In this paper, the optimal gear in terms of fuel consumption of the vehicle is determined using fuzzy logic and implemented using MATLAB. This ensures that the vehicle does not waste its fuel unnecessarily as in the case of a vehicle without a gear indication system. Hence, it results in saving precious fossil fuels for a green environment.

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