DESIGN OF DENSITY-BASED SPEED MAPPING FOR AUTOMOTIVE SYSTEMS

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Abstract - *The following research paper focuses on the design of a system capable to reduce the number of accidents in automobiles, solely due to over speeding. It withholds the criteria and processes implicated in solving the problem. It is observed that drivers and riders are given complete autonomy in the activity, and this tends to create maximum chaos due to minimum human-to-human interaction. To reduce this sole-discretion, we have ideated such a prototype that uses automation in limiting the speed of the automobile based upon traffic density in the particular area. The system uses Image processing for Density calculations and this information is transmitted to individual automotive, thereby signaling the Automated Limiter and mapping its speed via acceleration reduction. Further implied it can be used in the research of Autonomous Driven System Designs, for vehicle-to-vehicle interaction and communication.*

Key Words: Density calculation, Speed-Limiting, Automated Systems, Automotive Automation, Speed mapping.

1.INTRODUCTION

In our day to day activities, travelling holds the center of mode to reach our destination. Although in today's scenario, with the increase in the population around us, the vehicular traffic along with pedestrian traffic gradually increase by the day. This huge number eventually results in heavy traffic blockages and rush during peak times, which in-turn affects the behavioral patterns of drivers and riders, tending to over-speeding and thereby greater number of accidents. To tackle this cause of accidents, mainly by over-speeding, we need to act upon the speeding element itself. And with the rise in electrical systems in automobiles, it is easier to actuate the speed. *But how would it know what speed?*

To objectify the right speed, we use an Image Processing System, which gives us the amount of traffic in terms of density percentage, which is then communicated to all the vehicles in the vicinity. Thus, altering their speeds if exceeded above a limit mapped by the density. The following system helps in maintaining a balance and reducing the number of mishappenings due to over-speeding.

2. IDENTIFY, RESEARCH AND COLLECT DATA

REV-LIMITERS:

Current situations hold the need for hard and soft speed limiters, which are mechanical based. This is mainly for protecting the running condition of the engine. A limiter prevents a vehicle's engine from being pushed beyond the manufacturer's limit known as the red line (literally the red line marked on the tachometer). At some point beyond the red line, engine damage will occur. Limiters usually work by shutting off a component necessary for the combustion processes to occur. Compression ignition engine use mechanical governors or limiters to shut off electronic fuel injectors. A spark-ignition engine may also shut off fuel or stop the spark ignition and some just reduce the engines power by changing the spark timing.

These Rev Limiters are classified on basis of types of control (fuel or spark) and type of limiter (hard or soft).

TYPES OF CONTROL:

Fuel control

Fuel-cutting rev limiters are the most common because they wear less on exhaust components. These systems usually lean out the engine's over speed by shutting off the fuel injectors. This is less popular in high performance engines due to high temperatures in lean operation.

Spark control

Ignition control rev limiting systems work by shutting off the spark plugs once the engine overspeed. This is less common in production vehicles because the system still injects fuel into the cylinder and consequently releases unburned fuel which may ignite at a turbo charger or in the exhaust pipe. This can affect the temperatures in the exhaust, causing premature wear on the catalytic converter.

HARD AND SOFT LIMITERS:

Hard-cut limiters:

Hard-cut limiters completely cut fuel or spark to the engine. These types of limiters activate at the set RPM and "bounce" off of it if throttle is applied. The "bouncing" occurs because the limiter will cut off fuel or spark at the set RPM, which causes the RPM to drop. If the engine is in a state of open throttle when the RPM drops, the RPM will then raise back to the limit. This causes the engine to cycle its power on and off.

Soft-cut limiters:

Soft-cut limiters are a type of rev limiter that partially cuts off fuel to the engine. These limiters may also retard the ignition timing. If using a soft-cut rev limiter, the engine will start to cut fuel or retard ignition timing before the set RPM until it slowly reaches it and remains there.

Physical Limiters:

The maximum RPM of an engine is limited to the airflow through the engine, the displacement of the engine, the mass and balance of the rotating parts, along with the bore and stroke of the pistons. Formula One engines can rev up to 15,000 rpm as per Formula One rules because of their smaller displacement, low mass, and short stroke.

Engines with hydraulic tappets (such as the Buick/Rover V8) often have in effect a rev limiter by virtue of their design. The tappet clearances are maintained by the flow of the engine's lubricating oil. At high engine speeds, the oil pressure rises to such an extent that the tappets 'pump up', causing valve float. This sharply reduces engine power, causing speed to drop.

Recent Implementations:

In late models, speed is controlled by the Powertrain Control Module. The PCM is constantly receiving inputs pertaining to engine RPM, load, transmission range, vehicle speed and much more. When the PCM detects engine speed over a certain value in park, it will go into a limiting mode that may selectively disable fuel delivery and /or modify spark timing to prevent a further rise in RPM. This “cut off” will be at a considerably higher RPM with the transmission in drive or in gear. The cut off may be based on RPM, vehicle speed, or any other chosen parameter. It is among the many instructions programmed into the PCM during manufacture.

Basically, the car's computer sees the revs reach the prescribed limit and will intervene. These days with electronic throttle control, it can simply intervene and stop you from going beyond the prescribed limit. The computer can have different limits that are dependent on things like oil and coolant temperatures or if certain diagnostic trouble codes are currently in the system. It’s an electronic control and it’s hard coded into the ECM programming. Normally, it reads speed either off the crank or camshaft position sensor, or it may use both as a failsafe. Some vehicles - particularly heavy-duty trucks - can have a lower limit user programmed, as well. The engine control module (ECM) cuts off the pulsed electric current to the fuel injectors if the programed rev limit is reached.

Traffic Density Measurement using Image Processing System-

An SVM approach - In this system after loading the image of the road it will be converted into gray and then binary scale. Here gray and binary scale images give better result than RGB images. Because in image processing technique binary and gray scale images take less time than RGB and are also cost effective. RGB images contain more color pixels and pre-processing overhead. So, the binary and gray scale image is much efficient to use in this system.

After that Erosion and Dilation will be applied on the binary image. Erosion will decrease the size of objects and remove disturbances in the image and this technique is called Noise reduction. Dilation will increase the size of objects by filling the holes and broken areas in the image by connecting them. After completing all those processes, it will be easier to detect and count the total number of objects from the image. A threshold value will be set. If the total number of vehicles is greater than the threshold value then it should be defined as high traffic density otherwise low traffic density. This traffic detection technique will give us a proper analysis of traffic in the road.

Density Based Traffic Control –

The model works on the principle of changing delay of traffic signals based on the number of cars passing through an assigned section of the road. There are four sensors placed at four sides of a four-way road which counts the number of cars passing by the area covered by the sensors. Here we are using IR sensors replacing system to design an intelligent traffic control system. IR sensor contains IR transmitter IR receiver (photodiode) in itself.

These IR transmitter and IR receiver will be mounted on same sides of the road at a particular distance. As the vehicle passes through these IR sensors, the IR sensor will detect the vehicle & will send the information to the microcontroller.

The microcontroller will count the number of vehicles, and pro glowing time to LED according to the density of vehicles. If the density is higher, LED will glow for higher time than average or vice versa. The traffic lights are initially running at a fixed delay of 5 seconds, which in turn produces a delay of 20 seconds in the entire process. This entire embedded system is placed at that junction. Microcontroller is interfaced with LEDs and IR sensors. The total no of IR sensors required are 4 and LED's 12 Therefore these are connected to any two ports of microcontroller.

3. PROBLEM STATEMENT AND SCOPE

While learning alongside the past research done in the field, it comes to solve a few problems, but yet the accidents are not wholly prevented. Individually both the above related works have a targeted approach to the problems, split in two. Thus, combining the knowledge of work and our focused application, we can define a steady approach to tackle our undertaken problem.

Utilizing this as an opportunity we have defined our challenge to be *prevention of accidents* in the domain of ***Over-speeding.*** As stated above, with the increasing autonomy among the drivers and riders, the path of transportation is uncertain and random. Within this randomness, and the lack of communication among the drivers/riders lies the trouble. Thus, if this problem needs to have a solution, it would have to be in the initial stages, so to say, in reducing the speed of the vehicles itself.

Unlike Autonomous vehicles, the current scenario lacks mutual interactions which notifies the other of its surroundings. We need to manually feed the users, the data of the environment. So, the final problem comes down to defining a system, such, to enable users to be aware of the environment and depending on the state of this environment, tweak the parameters of the vehicle, mainly its speed.

Considering the upcoming innovations and advancements in automotive technology, the need for this system reduces. However, it is long until these technologies benefit the developing countries. It would take a few years for the establishment. Moreover, considering the rural areas of the countries and other space limitations for the setup, it adds to the restrictions.

With these factors in mind we have defined the project to be ubiquitous, be in the rural areas or the suburbs. It is targeted mainly to the accident-prone areas, as it corresponds to heavy data cognition among drivers/riders and a high risk of accidents. These include crossroads, expressways, city centrals, and certain hotspots (airports, railway stations, etc.). The domain of the project extends to cater multiple users simultaneously, by mapping their speeds in order to reduce the over sped vehicles and to prevent fatality prior to collisions.

4. RESEARCH AND WORK

Based upon the following collective data, we have gathered the knowledge that the existing solution is neither real-time nor is it feasible in the case of recurrent data for speed. Also, it is used for mechanical systems, whereas our targeted market is the Electric Automotive Industry.

To do this, we need a system that acts before the power is transmitted across the power train. Speed limits are set with the goal of keeping everyone safe. There is an inherent risk when driving a vehicle – not just for the driver, but for others on the road (including passengers, other drivers, bicyclists, and pedestrians). 95% of the Road accidents include 2-wheeled vehicles in India. The limits are designed on what is believed to be the safest speed for the flow of traffic and the safety of drivers, passengers, bicyclists, and pedestrians. They are typically set on the basis of what 85% of drivers would comfortably drive on their own without posted limits. In order to save lives, it's really important that we must have a control over the speed of vehicles.

This project is integrated within 3 parts:

1. *Image Processing:*

In this segment, the camera placed at the potential hotspot will gather real time traffic images, which will be compared with the lowest density (global minimum) and therefore give the segmented image. This image will be based on difference between the real-time image and lowest density image. The final output in numerical form will be transmitted to the vehicles.

2. *Communication:*

This part includes the transmittivity of information in the given area, to all the incoming vehicles.

3. *Speed Control:*

This mechanism, within the power train of the automobile will use the information in numerical form and will act upon the acceleration of the vehicle.

4.1. PROGRAM WORKFLOW (PROTOTYPE)

- Using Raspberry Pi as the platform, we use the camera to take real-time periodic pictures.
- These pictures at some point will have a local minimum, which will then act as the global minimum until a lower density is obtained.
- At every iteration, the real-time images are compared with reference and the difference between them is calculated in a numerical value.
- This value (density percentage), is then using the Bluetooth module, transmitted to the vehicle.
- The electric circuit then generates a particular resistance to reduce the supply to motor and in-turn speed of the vehicle.
- This resistance is directly proportional to the speed and therefore RPM of motor.

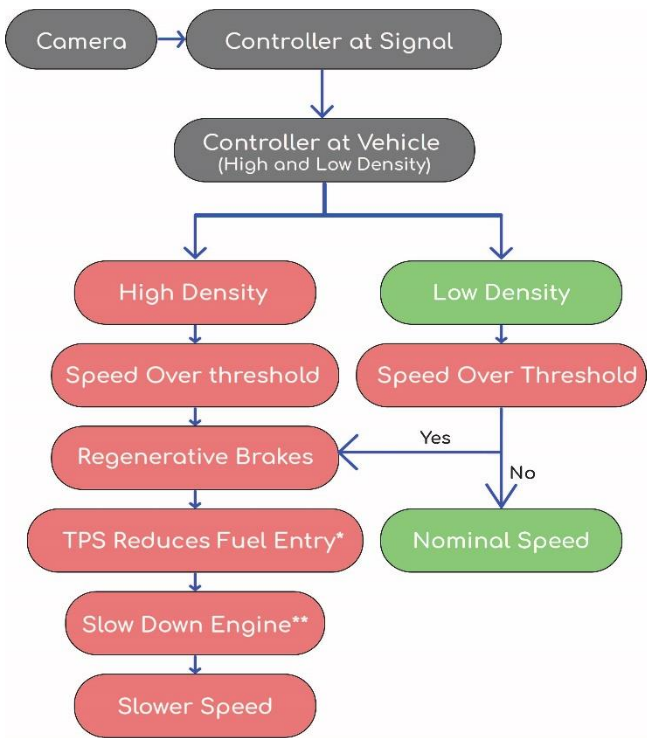

Chart 1: Process Flow

** In E-Vehicles, the regenerative breaks will in turn reduce the current to alternator, thus slowing its speed*

4.2. IMPLEMENTATION

Implementation of the device in two wheelers:

Currently two types of vehicles are available in the market: one that use engine for power generation and other that use battery for power generation. Hence, we need to select the components accordingly for the both the cases in order to implement the device.

Implementation on the Electric bike:

Electric bike working:

Working of the bike starts with a battery. The battery consists of two terminals one is positive and another one is the negative terminal. The positive terminal is linked to the stator body of the motor on the other hand, the negative terminal is linked to the edge of the vehicle. The battery and the motor are connected into series. At the point when the engine powers through the current, the stator field coil gets magnetized and induces the rotor shaft to rotate in the counter clockwise direction. Towards the finish of the engine shaft significant conditions are made for the seating of clutch assembly. Clutch is a power transmission gadget, which drives to the back wheel.

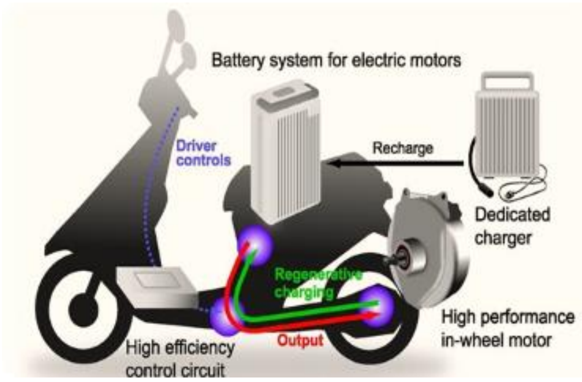

Fig-1: Electric Bike Components

Main components used in electric bikes are:

- **Battery:** Main function of the battery is to provide power to the electric components when engine is not running. Battery stores some charge as a form of energy and then utilize it for functioning. Lithium ion batteries are commonly used in the vehicles.
- **Alternator:** Alternator provide power to the components when engine is running. It generates AC current. Then by using regulator AC is converted into DC. And it drives the drive motor.
- **Drive Motors:** BLDC motors are commonly used due to high efficiency. But in some motors DC motors are used as well widely.
- **Controller:** Controllers that are used are different for BLDC motor and DC motor. Depending on the motor used controller is selected.

Methodology used: As per our solution one camera will be present at the signal. By using image processing we can measure the traffic area and then map it for speed value. Then based on the speed value rider will be able drive the vehicle in particular speed limit. Following diagram explains the methodology of the project.

Implementation in ICE bikes:

Controlling speed of ICE (Internal Combustion) engine bikes is difficult by using external mechanism. It is very complicated. Instead we can use a throttle position sensor as a speed controller.

Throttle position sensor working:

Throttle position sensor is nothing but a potentiometer. Resistance varies with the throttle. Hence, we can control the flow of the air in ICE based on the speed of the vehicle. Throttle position sensors are currently used as limiters. However, we are using Throttle position sensor as speed controller. The block diagram remains almost the same but instead of alternator we are using throttle position sensor in ICE two-wheeler vehicle.

Fig -2: Throttle position sensor

Methodology used:

In ICE vehicles, the speed of the engine can be controlled by varying the amount of fuel and air supplied to the engine. For this throttle system is used. Previously, a mechanical linkage was attached to the throttle pedal by which the butterfly valve of the throttle system was controlled. When the driver hits the accelerator cable the valve used to open wide which causes high flow of fuel or air thereby increasing the speed of the vehicle. But instead of that we can use throttle position sensor for accelerometer pedal. Here, we will be mapping the speed as a resistance value. And will vary the resistance as per the speed value mapped.

System Definition:

Our system consists of two components.

- An image processing component,
- A speed controlling component on vehicle.

To demonstrate the prototype, we are using the MATLAB software with a USB camera for image processing and an Arduino based two wheeled robot on which speed can be controlled.

1. MATLAB Implementation:

This implementation has three parts in it.

First part is finding the threshold of a given image for segmentation purposes. After fitting the camera at the required place, the first part is run on the system when the road is empty and histogram of image is observed. By observing this plot, we determine the value of the threshold for segmenting roads. This threshold value along with the image of an empty road is saved into the system for further use.

After getting the value of threshold from the first part, in the second part we first process the image of the empty road from the first part and convert it into a grayscale image. This grayscale image is then segmented using threshold value to get the area of the road. Here we convert the segmented image into a binary image of zeroes and ones.

After this we continuously capture new images in the real time system and then we also process them to get grayscale images. Old image of an empty road is then subtracted from the new image to continuously get the changes or congestion of the road. This density of changes is calculated using simple division. This value in range 0 to 1 is mapped to the value of PWM in 255 to 0 and it is sent through Bluetooth connected Arduino.

2. Arduino Implementation:

In Arduino IDE we take value from the MATLAB using Bluetooth receiver port. Functions for forward and backward are written. We use the ***if*** condition to limit the speed to the received value. Here as the robot is set to run at max possible speed, it will run at value received from the Bluetooth.

4.3. HYBRID AUTOMATA MODEL AND VALIDATION

If we consider a bike as a linear system and we can control the system with control speed let's say **u** then we can easily model a control structure for the bike with density as limiting parameter.

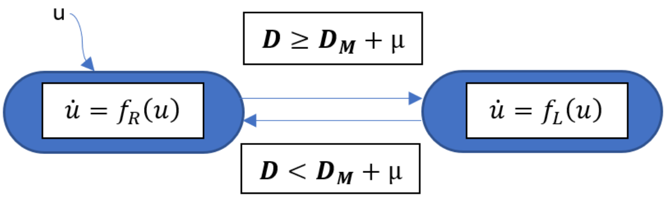

Fig-3: Hybrid Automata Model Representation

$\dot{\boldsymbol{u}} = \boldsymbol{f_R}(\boldsymbol{u})$ represents dynamic model of the system with speed as a control input. Here **R** subscript indicates function indicates the rider is in control. In other words, this represents mode 1.

$\boldsymbol{D_M}$ indicates the maximum traffic density in particular area for which switching of the modes occur, $\boldsymbol{D}$ indicates the current density mapped using camera at the signal, $\boldsymbol{\mu}$ indicates a very small value of density.

$\dot{\boldsymbol{u}} = \boldsymbol{f_L}(\boldsymbol{u})$ represents mode 2 where the rider is not in control. We limit the speed of the vehicle by limiting function which does not allow the rider to accelerate anymore.

Working- We will design a function which can take speed of the vehicle as the control input and traffic density as the limiting parameter. If the traffic density D is more in particular area then bike will go in mode 2, where we put limit on acceleration, so that bike will travel with constant speed. Now as soon as the density decreases, we will switch back to rider mode. To avoid continuous switching between two mode continuously we have added a small value of density in limiting parameter. A small value ensures that switching does not lead to any sort of jerks.

Environment without object –

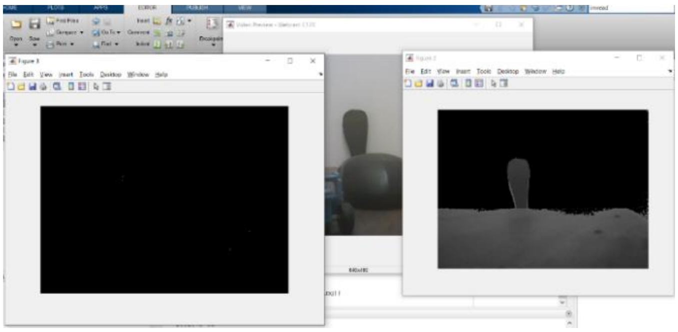

Fig-4: Segmentation Analogy of Empty Road with reference image (Density ≈ 0)

Environment with object -

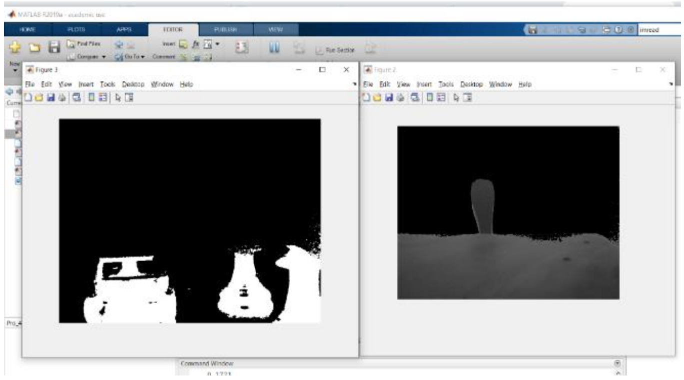

Fig-5: Segmentation Analogy of crowded road with reference image (Density >> 0)

5. CONLCUSION

With the implementation of the system, not only do we limit the autonomy of the riders and drivers in accident prone areas, but we also get a real-time information of the crowd or traffic at the particular spot which can be useful in detecting emergency attention. The system acts as a virtual speed breaker for the vehicle whose magnitude depends on the amount of traffic in the selected area.

We can there by conclude that such a system would provide a great help in development of future systems in the field of Automation for the Automobile sector and Transport Sector. Further implication over this project can lead to various other applications too, in providing hassle-free human-machine interaction.

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