Development and implementation of a neural network model for speed prediction and fuel optimization in truck tractors, using the Raspberry Pi

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Abstract

In Mexico and in many parts of the world, land cargo transport units (UTTC) operate at high speeds, causing accidents, high fuel costs, and high levels of polluting emissions into the atmosphere. The speed in road driving, by the carriers, has been a factor little studied, however, the severe damage it causes. This problem is reflected in accidents, road damage, low efficiency in the life of the engine, the life of the tires, low fuel efficiency, and high polluting emissions, among others. This project proposes the design and implementation of a neural network prototype trained to predict the optimal driving speed and optimize the fuel consumption of the UTTC. The network will be fed with the variables of a mathematical algorithm created to calculate the maximum speed at which a transport unit must be operated and the optimization of fuel consumption. The mathematical model considers the available forces of the transport unit and the forces that are required to travel the road.

Keywords: *Neural network, speed, fuel, emissions, transport*

I. INTRODUCTION

In Mexico and many parts of the world, Cargo Transport Units (CTU) operate at high speeds, causing accidents, increased fuel costs, and high levels of pollutant emissions into the atmosphere [1]. The speed in road driving, by the carriers, has been a factor little studied, however, the damage it causes is severe. This problem is reflected in accidents, road damage, low efficiency in the life of the engine, decrease in the life expectancy of tires, low fuel efficiency, and high polluting emissions, among others. The official Mexican standard NOM-012-SCT-2-2017 [2] regarding weight and maximum dimensions in which motorized transport vehicles can circulate, which travel through the general communication routes of the federal jurisdiction, establishes the limit of the speed at which an operator will drive it.

This project proposes the design of a prototype, the implementation, and training of an artificial neural network, to predict the most effective driving speed to optimize the fuel consumption of the CTU.

The network will be fed with the variables of a mathematical algorithm created to calculate the maximum speed at which a transport unit must operate to optimize fuel consumption. The mathematical model considers the available forces of the transport unit and the required forces to travel the road. The mathematical method was registered in 2016 as Simulator 2020 [3].

The methodology consists of considering the variables of SIMULATOR 2020: engine torque, gearbox axle ratio, weight, terrain type and road type on which the truck travels, engine performance, differential, frontal area, power (hp) available to the transport unit, specific engine consumption, engine performance, diesel density, distance, among others. With these variables, the Raspberry pi will be programmed, and then the prototype will then be designed and assembled to carry out the pertinent tests by UTTC and according to the route.

Different travels will be carried out at the national level to implement the speed obtained by the network, and the observed fuel consumption will be recorded. The mathematical algorithm was validated at the national level [4], operating the UTTCs at the maximum speeds calculated, yielding significant fuel savings of up to 23 percent for transport companies.

II. Background

The main problems that affect a land cargo transport unit (TU) today are, among others: high fuel prices, urgent deliveries, traffic jams in cities, road safety, and an increased number of accidents [2].
Slowing down leads to significant savings when driving at the corresponding speeds, according to the UTTC nature and road characteristics. This project applies when driving is on the road and at speed has minor variations.
Today, more recent advancements in fuel-saving technology integrally utilize aerodynamics, powertrain, and electronics to create a highly efficient trailer/tractor [5].
The new 2016 Kenworth T680 controls regulate fuel usage with an electronic speed limiter and software to shut off the engine when idling [5].
Kenworth proposes a fuel-saving system by idling; however, its areas of opportunity are:
A) Little assistance and security systems. With the engine stopped - in many cases - the power steering and the brake booster [3] do not work. A power steering gets tougher than one without assistance.
B) Slowness of reaction to use the engine again, both as an engine brake and to accelerate. If you are in neutral, you must put the proper gear back into gear. With the clutch depressed, it is considerably faster, and the engine starts immediately. This could be automated in a vehicle with an automatic gearbox.
1 Idle: The engine of the load unit (truck) is programmed to turn off automatically when it is stopped for a certain time.
C) Mexican transportation companies, which could acquire a Kenworth unit with the characteristics described above, would amount to at most 10% [5]. A deficient percentage due to high financing costs and little government support for the renewal of vehicle units is mostly seven years or more.
In countries such as China, Canada, and Ireland, the software is being designed to drive a land cargo unit, known as intelligent transport. The advantages of these systems are that they operate in countries with road safety education and awareness of the urgent need to mitigate climate change and the reduction of road accidents due to the speed of trucks [6], [7], [8], [9].
In terms of road transport, current advances in information technology are meaningless in countries like Mexico, with little to no road and environmental culture.

III. General objective

Propose as a prototype an intelligent system based on Raspberry pi and neural networks for estimating the maximum driving speed of the cargo land transport unit to optimize fuel.

A. *Specific objective*

A) Design and programming of the neural network.

B) Design and construction of the prototype in Raspberry pi.

C) Carry out the tests of the embedded system in the laboratory, with hypothetical data.

D) Run the system tests.

IV. Hypothesis

By adequately building and implementing the network, you will get an adaptive embedded system for fuel savings.

V. Scientific goals and training of human resources

The prototype of an intelligent system based on neural networks will be designed and assembled, and compared with the truck model from which it is based.
The training of human resources considers disciplines of artificial intelligence through the use of neural networks and programming logic and the skills of teamwork, discipline, responsibility, and work under pressure.

VI. Scientific methodology

Table 1. NOMENCLATURE

$V : speed$	T : differential gear ratio´s
N: newton	C_8: rolling static coefficient
g: gravity acceleration	C_v: rolling dynamic coefficient
$a = acceleration$	p: rolling friction coefficient
A: front area of the truck	r : engine performance
C_6: aerodynamic coefficient	P_a: available power
$m =$ mass	P_e: fuel efficiency
T: gear transmission ratio	P_r: required power
S_P: speed per power	SC: specific fuel consumption
R_c: fuel efficiency	F_t: tractive force
ρ: fuel efficiency	F_a: air resistance force
F_p: slope resistance force	F_r: rolling resistance force
θ: inclination angle	d: air density

The procedure consisted of the unit would operate according to the speed calculated by the Neural Network trained offline whit a database obtained from a mathematical model described in [3]. This ensures that the Raspberry processes only process a Back-Propagation Neural Network and not the complete mathematical model. At the end of the tour, the performance will be observed by the operator.
The average fuel efficiency (km/l) will be estimated for different scenarios and routes. Using the theoretical model and generalized by a trained Neural Network.
The previous paragraph tries to explain to the reader the three points proposed by the reviewer. The first and second points clarify that it is an offline-trained network that starts from a database obtained through a proven mathematical model. Therefore, the network will only extrapolate the results of this model with a fast calculation and without processing problems for a raspberry. This will allow to implementation of a low-cost embedded system.

A. *Truck model.*

Forces involved in the unit are broken down below.
The truck uses the available force given by the engine and the force required according to the road characteristics.

1) *Force required by the drive unit.*

The vehicle's powertrain (engine, transmission, differential, axles, and wheels) converts engine torque into useful tractive force from tires to pavement [2]. When this force is greater than the sum of its forces acting against the movement of the vehicle, it accelerates in the direction of the road. The tractive force greater than the forces that oppose resistance to the vehicle, accelerating it, can be expressed as follows:

$$F_t = F_p + F_a + F_r + ma \quad (1)$$

$$F_p = gmsen\theta \quad (2)$$

$$F_a = \frac{d}{2} C_d A_f V^2 \quad (3)$$

$$F_r = (C_8 m + C_v mV)r \quad (4)$$

Considering the international units, to express all the forces in Newton, the available traction force is obtained by multiplying the speed of the truck by the factor 0.0003714 [1] to get the required engine power in horsepower (hp). The following expression is used to obtain the fuel efficiency (km / l).

$$R_c = \frac{V}{P_r + SC\frac{1}{\rho}} \quad (5)$$

See Table 1.

B. Methodology

1. Generation of the database for the training of a back propagation neural network.
2. Back propagation neural network architecture tests: selection of number of layers and neurons, as well as transfer functions.
3. Installation and startup of the Raspbian operating system and the Tensor Flow package on the Raspberry Pi (Figure 1).

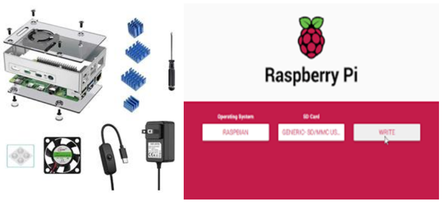

Figure 1. Raspberry PI Configuration

4. Connection of the MPU 6050 sensor with the Raspberry PI and communication between both devices (Figure 2).

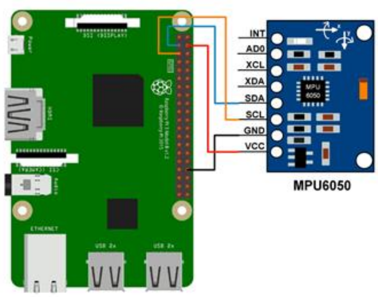

Figure 2. Raspberry Pi connection with

5. Connection of the Raspberry Pi with the MQ7 sensor as shown in Figure 3.

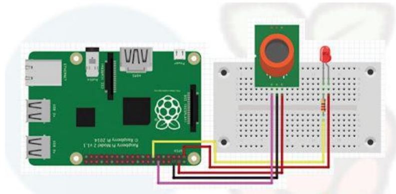

Figure 3.

6. Prototype assembly with protection casing. Once the cables are soldered, and the required connections are made between the sensors and the Raspberry PI, they are placed in the housing designed to protect the electronic elements.

VII. Deliverable Results

An embedded system will be delivered ready to carry out the laboratory's corresponding tests and truck tractors. A prototype was developed that can reduce emissions and save energy with digital and minimal power consumption, which means that as engineers in training, we can conceive the real scope that an engineer can have when developing a digital project like this. Design and construct an electronic device to calculate the optimum speed at which a freight trucking operator should drive.
Once the prototype is functional, it will be able to estimate the optimal speed based on the mathematical model. This allows expecting a saving similar to that shown by the model of up to 23%. This saving will be achieved by calculating the optimum speed for the road in cargo vehicles.

VIII. Institutional Benefits

The prototype will set the standard in the educational program of Engineering in Manufacturing Technologies and the Educational Program of Automotive due to its scope for practices in electronics and automation.

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