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Reducing stress on habitual journeys

Víctor Corcoba Magaña Mario Muñoz-Organero

Abstract **Stress is the cause of a large number of traffic accidents. The driver increases driving mistakes when he or she is in this mental state. Furthermore, the fuel consumption gets worse. In this paper, we propose an algorithm to estimate the optimum speed from the point of view of the stress level for each road section. When the driver completes a road section, the solution provides him or her with feedback. This feedback consists of recommendations such as: "You have driven too fast". The aim is that the driver adjusts speed when he or she repeats the trip. Optimization of the speed reduces stress and improves the driving from the point of view of energy saving. The optimal average speed is estimated using Particle Swarm Optimization (PSO) and MultiLayer Perceptron (MLP). The solution was deployed on Android mobile devices. The results show that the drivers drive smoother and reduce stress when they use the proposal.**

Index Terms **Driving Assistant, Smart Driving, Stress Driver, PSO, MLP.**

I. Introduction

According to several studies, the consequence of driving at inappropriate speeds is an increase in the likelihood of traffic accidents. Report [1] points out that exceeding the speed limit is the cause in 5 per cent of accidents in London, but these accidents involved 17 per cent of fatalities. The relation between vehicle speed and accident occurrence and severity has been demonstrated on many research works [2] [3].

On the other hand, there are a large number of drivers who exceed the speed limit usually. Some authors claim that driving at high speed is not seen as a wrong doing by society [4]. Other authors argue that drivers do not appreciate the speed correctly due to factors such as noise or the surface quality [5]. Driver features such as age, gender and personality are other variables that influence the speeding [6].

Speed is a factor that is closely related to demand attention from the driver. When the speed is high, the driver has less time to make decisions. This is important when speed is not suitable for the road type (urban, rural) or road state (weather, traffic). On roads where the speed is high (motorways), safety is good. However, if the driver exceeds the speed limit, the probability of an accident is increased especially in urban road. Authors in [7] observed that the risk of a pedestrian dies in an accident at impact speed of 50 km/h is 10 times higher than at impact speed of 30 km/h. In addition, the critical point to survival is between 50 km/h and 60 km/h.

Reference [2] highlights the strong relationship between average speed and traffic accidents. They concluded that a 10% increase in mean speed results in 26% increase in the frequency of all injury accidents. On the other hand, they noted that the number of crossroads and curves also influence the likelihood of traffic accidents. They increased between 13% and 33% per additional bend/crossroad per kilometer. Sharp bends significantly increase the single vehicle accidents (34% increase in accident frequency per additional sharp bend per kilometer. In the literature there are many assistants that help to adapt the speed in order to maximize safety and reduce fuel consumption. These systems are called "Intelligent Speed adaptation" (ISA) and can be classified as follows:

- Advisory: Warn the driver when he or she exceeds the speed limit.
- Voluntary: Driver can enable and disable the speed limiter.
- Mandatory: The system adjusts the vehicle speed all the time.

On the other hand, these solutions may indicate the recommended speed based on the traffic signs (Fixed ISA). Also, they can report certain locations where a lower speed limit is required such as pedestrian crossings or sharp curves. Finally, there are more advanced systems (Dynamic ISA) which take into account the road state (weather, traffic, and incidents) to estimate the optimum speed.

It has been demonstrated that ISA improves safety. Reference [8] estimates which a simple mandatory system, with which it would be impossible for vehicles to exceed the speed limit, would save 20% of injury accidents and 37% of fatal accidents. If the solution takes into account the environment state, the authors predict a reduction of 36% in injury accidents and 59% in fatal accidents. Other authors have shown that accidents are minimized by 48.5%, while not increasing travel time more than 2.5%. [9], the authors conducted a study in the Netherlands and estimated a reduction of the accidents between 25% and 30% if all vehicles use ISA system. In [10], the authors made a large scale tests in Borlänge, Lidköping, Lund and Umeå during the period 1999 2002. They found that the average speed on stretches road and intersections was reduced with ISA. Travelling times in urban areas remain unchanged because there is less stopping and fewer braking situations. They estimate that road injuries could be reduce by 20% in urban areas.

ISA also has a positive impact on the environment. Regan *et al.* [11] shows an improvement on fuel consumption and the emission of gaseous pollutants in the zones limited to 80 km/h (both 4%). The authors in [12] found that the percentage of improvement was closely related to the percentage of penetration of ISA. They estimated that if all vehicles using the solution, fuel economy would be 8% on urban road, 3% on rural road, and 1% on highway.

Acceptability is very important and depends heavily on the feedback provided to the driver. Reference [13] found that drivers who drive at high speed are less encouraged to use this type of solutions. On the other hand, drivers with a smooth driving profile are motivated to use speed limiters, but the effect is lower because they drive at a speed close to the recommended speed [14]. In the majority of cases, the results indicate that using the system increases its acceptance compared with the first opinion [8] [15].

However, these driving assistants have several problems. Reference [16] showed less safe car following behavior in the speed interval 70±90 km/h when drivers used the ISA system. In addition, they cause frustration and its level depends on the frequency of the speed limitations.

In this paper we propose an algorithm to estimate the optimal speed for each road section in order to improve the safety and the fuel consumption. The main difference between our solution and other proposals is that the optimum speed is estimated taking into account driver's profile, his or her level of fatigue and the road conditions. This method allows us to obtain an optimal speed more realistic than other solutions. The aim is to avoid the frustration of the user, which is one of the most important problems. On the other hand, the proposal is implemented on Android mobile device (it could be easily ported to other operating systems like IOS). This reduces costs and driver has not to make modifications in the vehicle.

II. SPEED ASSISTANT FOR REDUCING STRESS AND IMPROVING FUEL CONSUMPTION

Particle Swarm Optimization (PSO) [17] and Multilayer Perceptron (MLP) [18] are used to estimate the average speed for each section of the road. Figure 1 shows the flowchart to estimate the optimum speed. The main advantage of PSO algorithm is that it maintains multiple potential solutions at one time. Each solution is represented by a particle in the search space. It has the following elements:

- Position: In our case is the recommended speed for reducing the stress level and improving the fuel consumption.
- Pbest: This is the best position on the current particle (speed that minimizes the heart rate and improves the driving style).
- Gbest: It is the best position among all particles.
- Speed: Is calculated using equation 1. It determines which will be the next speed of the particle.

$$v_i(t+1) = wv_i(t) + c1r1 * (Pbest(t) - x_i) + c2r2 * (Gbest(t) - x_i(t)) \quad (1)$$

where $v_i(t)$ is the particle's velocity at time t, w is the inertia weight, $x_i(t)$ is the particle's position at time t, Pbest is the particle's individual best solution as of time t, and gBest(t) is the swarm's best solution as of time t, $c1$ and $c2$ are two positive constants, and rl and r2 are random values in the range [0 1]

The particles "fly" or "swarm" through the search space to find the minimum value. During each iteration of the algorithm, they are evaluated by an objective function to determine its fitness. Next position is calculated by equation 2:

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad (2)$$

where $x_i(t)$ is the current particle's position and $v_i(t+1)$ is the new velocity.

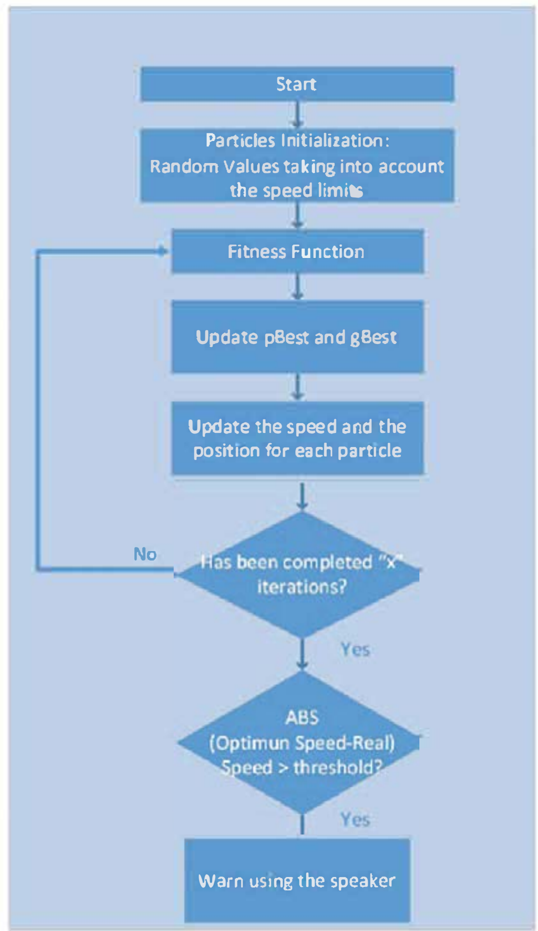

Fig 1. Flowchart to estimate the optimum speed

A multi layer perceptron (MLP) is employed as fitness function. Figure 2 shows the fitness function. It is trained using the driving samples obtained by the own driver and other drivers. This algorithm is an artificial neural network that has multiple layers and whose main advantage is to allow non linearly separable problems. The input variables are:

- Average Speed: Its value is provided by the PSO algorithm. The optimal value depends on multiple parameters such as the driving style, the road state, and the level of fatigue. For example: If the driver has not rested, the system should recommend a low speed that prevents the lane departures.

- Standard Deviation of Vehicle Speed: This variable allows us to categorize drivers. Aggressive drivers change the vehicle speed frequently. On the other hand, normal and efficient drivers make a smooth driving, maximizing the time at constant speed. This causes a positive effect on fuel consumption and safety. If the driver has to be varying the speed constantly, the probability of making driving mistakes increases as well as the stress level. Furthermore, the driver could cause an accident chain. The fuel consumption is reduced because there is no acceleration resistance force if the driver is only keeping the vehicle speed. Therefore, the tractive force required to move the vehicle will be less.
- Average Acceleration: The acceleration (positive and negative) may indicate the presence of stress or fatigue. These actions increase the likelihood of a traffic accident and fuel consumption. The driver from behind might not have enough time to brake.
- Positive Kinetic Energy: It measures the aggressiveness of driving and depends on the frequency and intensity of positive accelerations. A low value means that the driver is not stressed and drives smoothly. An unusual high value may indicate that driver are driving at an inappropriate average speed. The driver is forced to accelerate frequently and sharply to achieve the desired speed.
- Weather State: The number of vehicles on the road grows when the weather conditions are bad, increasing the likelihood of traffic incidents. Moreover, the roll coefficient changes. Therefore, the advice have to take into account that factor. In addition, many studies highlight that when it is hot, the fatigue appears be fore. On the other hand, cognitive capacity of the driver worsens when it is cold.
- Traffic State: When traffic is heavy, the stress level increases. In these cases, the vehicle speed must be adjusted in order to avoid accelerations and decelerations.
- Time: Fuel consumption is increased at rush hours. The driver has to accelerate and slow down more frequently. In addition, the engine is switched on during more time. This situation causes stress, increasing the accidents risk. On the other hand, night driving maximizes the likelihoods of sleep despite he or she has previously slept. This is due to the sleep cycle. Therefore, we have to take into account the time when we estimate the optimum speed.
- Weekday: The rush hour depends on the day. For instance, it is common that the average speed is higher on weekend because there is less traffic. If the road conditions are good, the system should recommend an average speed high enough to avoid the frustration of the driver.

We highlight that the variables related to the vehicle's telemetry are calculated based on a historical database of previous drives. The idea is that the multi layer perceptron estimates the heart rate given the average speed provided by the PSO algorithm and taking into account the results obtained by other drivers with similar driving behaviors.

Finally, when the driver completes a road section, the solution compares the average speed obtained by the user with the best average speed. In the case in which the difference exceeds a limit, the assistant notifies the driver about if he or she has driven too slow or too fast using the speaker from a smartphone.

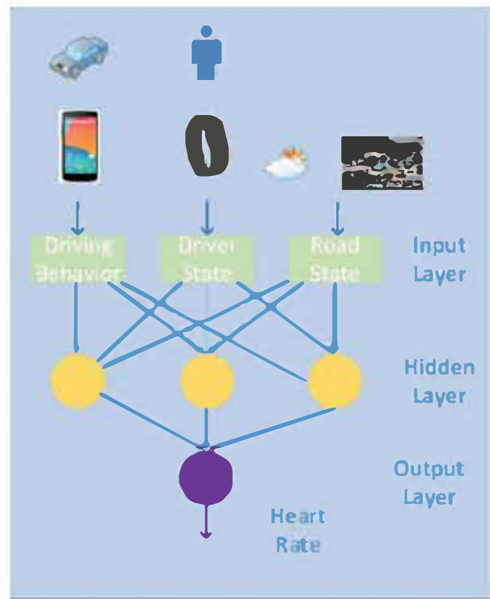

Fig 2. Fitness Function to estimate the heart rate

A. Devices

We employ the following devices to monitor the driver and the vehicle:

- *Mobile Device:* Current mobile devices have a large number of sensors that allow us to obtain information about the user and the environment. In this work, we use GPS in order to obtain the vehicle location and the vehicle telemetry: speed, acceleration, deceleration, standard deviation of vehicle speed, etc. The Internet connection is employed to obtain information about the road state and weather conditions. These data are obtained from webservices (AEMET and DGT).
- *Heart rate chest strap:* Stress, fatigue and sleepiness has a great impact on the automatic nervous system. Heart Rate Variability signals are employed as an indicator of ANS neuropathy for normal, fatigued and drowsy states because the ANS is influenced by the sympathetic nervous system and parasympathetic nervous system. This indicator is not intrusive. A high variability means the driver has stress. In opposition, a low variability could be since the driver is tired or asleep.
- *Fitbit Charge HR:* This wearable is cross platform and provides a REST API [19]. It allows us to estimate the

stress level and measure the sleep quality using their multiple sensors:

- Optical heart rate monitor
- 3 axis accelerometer
- Altimeter

III. SYSTEM EVALUATION

A. Experimental Design

The eco driving assistant was deployed on Android mobile devices: Nexus 6 and Nexus 7. Both devices support Bluetooth Low Energy. Heart Rate was monitored using Fitbit Charge HR [19].

In order to evaluate the improvement on safety and driving style using the proposal, 240 driving tests have been performed with 4 different drivers. The tests were performed in Madrid between the months of March to May 2015. We have chosen three different road section. The distance was 2.5 km in all cases and the vehicles employed were Citroen Xsara Picasso 2.0 HDI. Each driver completed 20 times each road section. The first 10 times without using the solution, and then using the proposal. All driving tests were performed under good weather and traffic conditions.

B. Results

Figure 3 captures the average speed for road section 1, 2, and 3, respectively. It decreases by 9.90% on road section 1, 12.55% on road section 2, and 12.10% on road section 3 when the solution is activated.

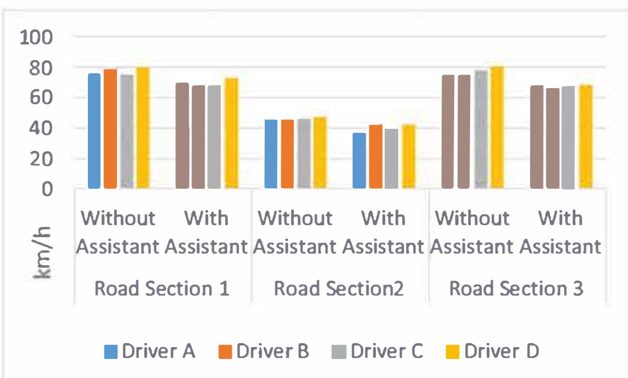

Fig 3. Average speed (km/h) for the roads sections

Figure 4 captures the average heart rate for road section 1, 2, and 3, respectively. The heart rate decreases by 9.75% on road section 1, 7.24% on road section 2, and 7.64% on road section 3 when the solution is activated. The heart rate value is influenced by the sympathetic nervous system and parasympathetic nervous system. A low value means that the driver is not stressed. On the other hand, stress depends on many independents factors of the driving such as the physical activity, the fatigue, working time, etc. In order to avoid inaccurate results, all driving tests have been made in the morning before work and when the driver was relaxed and he or she had slept 8 hours.

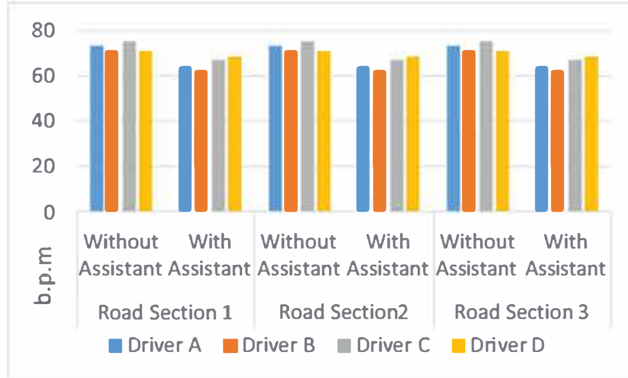

Fig 4. Average heart rate (b.p.m.) for the roads sections

Figure 5 captures the average deceleration (absolutes values) for road section 1, 2, and 3. It is reduced by 3.25% on road section 1, 8.40% on road section 2, and 29.13% on road section 3 when the drivers employed the solution. The effect that the user set the speed to the indicated by the proposal is a reduction in the number and intensity of the decelerations. Sudden decelerations have a negative effect on the fuel consumption since the energy generated by the engine is wasted as heat. They can also be a problem for safety. The car behind might not have enough time to stop because it is not aware that the car in front is going to decelerate sharply. The result could be a pileup.

Fig 5. Average decelerations (m/s^2) for the roads sections

Figure 6 captures the positive kinetic energy for road section 1, 2, and 3, respectively. This variable measures the aggressiveness of driving and depends on the frequency and intensity of positive acceleration [20]. A low value means that the driving is not aggressive. The positive kinetic energy decreases by 9.82% on road section 1, 11% on road section 2, and 46.1 % on road section 3 when the drivers use the proposal.

If the driver is speeding up and slowing down with frequency and intensity, the likelihood of traffic accidents increases. Driving at an appropriate speed (is the aim of our proposal) maximizes the time in which the driver is driving at constant speed. The consequences are that energy consumption and safety improve.

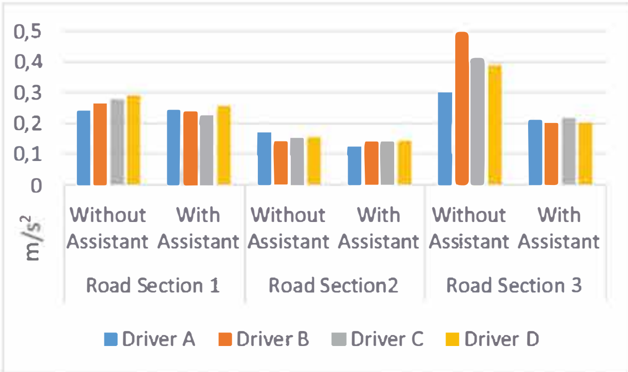

Fig 6. Positive Kinetic Energy (m/s^2) for the roads sections

IV. CONCLUSIONS

In this paper we have proposed an algorithm to estimate the optimal average speed which reduces stress. The aim is to improve safety and reduce fuel consumption. Particle Swarm Optimization (PSO) algorithm is employed to obtain the appropriate speed. This algorithm takes into accountthe driving style of the driver, his or her level of fatigue and the road state (weather and traffic). Therefore, the calculated speed is realistic and the user can get it without changing his driving style abruptly. The results of these tests indicate that the proposal achieves all drivers reduce the vehicle speed and the aggressiveness of driving.

As future work, we want to consider other variables to calculate the optimum speed such as: age, gender, and level of experience. It would also be interesting to use gamification tools to encourage the user, avoiding the high level of frustration which can generate this type of assistant. We could provide different feedback such as the amount of money that he or she have saved on the trip.

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