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Remote Safety Distance Control for Motor Vehicles

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Abstract: ***We define a method for monitoring and controlling the Safety Distance between motor vehicles. Failure to respect the safety distance between cars on roads and especially on motorways (where speeds are high) is among the leading causes of accidents. This fact generates serious inconveniences, such as roadblocks, resulting in enormous delays for car drivers reaching their destinations, as well as possible deaths and injuries. At the current state of the art, in this regard, steps have only been taken to define auxiliary systems on vehicles that signal when this distance has been reached, advising the driver to reduce speed to restore the minimum safety distance. However, such systems are often viewed negatively by motorists in practice and do not yield positive results. The Method and System defined in this work instead involve the use of a Remote System for controlling the Safety Distance, of the same type as those applied for speed control on roads and motorways. These systems are disliked by car drivers, precisely because of their effectiveness and deterrent effect. In this work, the state of the art regarding Safety Distance control systems, which have been present on cars up to now, is analysed. The different methods of calculating the Safety Distance between vehicles are subsequently described. The method defined in this work is then presented, based on the remote detection of the Safety Distance on roads, especially at high speeds, accompanied by some figures. Here, we highlight the innovation of the system presented in this work, where, for the first time, a System for remotely controlling the Safety Distance is considered.***

Keywords: ***Safety Distance, Remote Control, Infringement Detection.***

I. INTRODUCTION

The problem of failing to respect safety distances arises from the numerous accidents that occur on roads, especially on motorways, due to a failure to maintain these distances. The consequence of this is the long queues on highways, which often do not allow for rapid connections between the various industrial parts of a country. For the vast majority, these are due to accidents caused by failure to comply with this rule. This generates severe economic damage in the countries where it occurs, due to the delays that accumulate in motorway queues. Without forgetting the inconvenience and problems for individuals in the queue, as well as the possible physical consequences of accidents. Two main objections are made to the use of a Safety Distance Control.

The first objection is based on the fact that the population views traffic control systems (such as speed cameras) as essentially methods used by state or Local Authorities to tax the population indirectly, and therefore, as a limitation of freedom. To this objection, we must reply that this control is specifically implemented to reduce accidents among the population drastically. Even because its maximum usefulness and, therefore, its maximum use should be implemented on motorways, and not on internal roads within city municipalities.

The second objection lies in the fact that the Safety Distance is the consequence of a mathematical expression, and, in any case, is not a predefined value. It, as will be seen in this paper, can be calculated in different ways, therefore without uniqueness. This lack of unambiguity could generate protests from the population affected by the controls. However, if we consider only the cases where the speed of the cars reaches high values (let's assume higher than 80-100 km/h), the corresponding Safety Distance, regardless of the calculation method used, is higher than a few tens of meters. Therefore, when distances between two successive vehicles are detected that are less than, for example, five meters (which happens very often on the motorway due to the incorrect behaviour of many car drivers), no one could object to the danger and therefore the punishability of a situation thus generated.

In recent years, some works have been conducted regarding the possibility of calculating the Safety Distance on a computer present in the vehicle, using sensors as input to send the driver a suitable speed reduction input, thereby reducing the distance to the car in front. For this purpose, we can cite the papers [1]-[2]-[3]-[4]-[5]-[6]-[7]-[8]-[9]-[10]-[11] -[12-[13], as well as the recent Patents [14]-[15]. In particular, papers [1]-[2]-[3]-[4]-[5]-[6] concern new calculation methods to define the Safety distance. However, all these systems focus on either determining the optimal method for calculating the safety distance or explaining the most effective system for receiving input data and transmitting it to the vehicle's sensors. In our opinion, the fundamental flaw of this approach is that it completely ignores the unwillingness of vehicle drivers to maintain the required safety distance. Believing that a driver, who on the motorway approaches the rear of the previous car at high speed to "push" it into moving lanes, will follow this type of input is, to say the least, naive. Unfortunately, a high percentage of car drivers have this habit, especially on European roads and motorways.

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Therefore, only an external detection system, connected to a traffic control and police station, could be an effective deterrent to such hazardous habits. This will significantly reduce the percentage of accidents that occur.

To reduce accidents, past works and patents related to the detection of excessive speed, commonly referred to as "speed cameras", have been developed. In particular, we refer to the Patents [16]-[17]-[18]-[19], which concern methods and systems for monitoring and controlling the speed or the average speed of vehicles in transit. Instead, the work presented in this paper aims to address the issue of the numerous accidents caused by excessive car proximity, especially at high speeds. This work is based on the definition of an innovative safety distance detection system.

In this paper, we propose a different and practical approach. We develop a system and method for remotely detecting safety distance. Building on the experiences we have gained in work related to the so-called "speed cameras", we have developed a system using sensors to detect the passage of vehicles and, therefore, calculate the distance between two successive vehicles.

The advantageous novelty of this method lies in the fact that, for the first time, it is considered a System for remotely controlling the Safety Distance, thus allowing for the effective detection of infringements.

We organised this work as follows. In Section II, the Methods for calculating the Safety Distance are presented. In particular, possible variations due to the weather are highlighted. In Section III, a description and an implementation of the method are presented using some significant figures. We highlight, in particular, the uniqueness of the solution offered. At the end, in Section IV, concluding remarks and developments are defined.

II. SAFETY DISTANCE: CALCULATION METHODS

The safety distance is the distance a vehicle must maintain compared to the one in front of it to be able to stop in time, when and where necessary, without hitting the car in front of it if the latter stops abruptly. What must be taken into consideration to calculate the minimum safety distance between two cars? Various factors, including the physical state, quick reflexes, and age of the driver; physical characteristics of the vehicle; road section you are traveling on; weather conditions; visibility; road slope; traffic; condition of the tires and the car in general (brakes, suspensions, etc.); conditions of the road surface. The calculation of the minimum safety distance should take into consideration the distance travelled by the vehicle in front of us in one second. This is to determine how much time and distance are required between the possible activation of the stop sign and the braking of your vehicle, assuming the car in front has the same braking distance as yours. In any case, it is clear that the minimum safety distance increases as the speed increases.

But that's not enough: the parameters we listed above must be taken into consideration. In fact, as the speed increases, a quadruple braking distance will be needed. A straightforward calculation method, used in the past, provides $D = (V/10)*2$, where "D" represents the safety distance, and "V" is the speed at which you are travelling. However, even this empirical method does not account for all the variables listed above. Another empirical method, which can be performed without distractions and in conditions of total safety, is to take a reference and start counting from when the vehicle in front passes it to when we catch up with it. This time should be at least 3 seconds, but may increase under certain conditions. Another practical calculation concerns the speed at which we are travelling. If we travel at a speed of 130 km/h, for example, it means we are travelling at 36 m/s. If we recall the 3-second method, it means that the minimum distance must be at least 108 meters; however, we also stated that in certain conditions, this space must be increased. On average, the reaction time of an individual in good psychophysical conditions is approximately 1 second, or half of a range that varies between half a second and 1.5 seconds. In this situation, the action of moving the foot from the accelerator to the brake takes approximately 0.8-1 second, a time interval during which we will have travelled about twenty meters (if we travel between 50 and 80 kilometres per hour, at a higher speed, this distance also increases). The reaction time and the distance covered during this period must always be related to the vehicle's speed.

It is obvious that a car with worn tires, a braking system that has not been recently inspected, or one carrying a specific type of load, will require larger stopping distances. Therefore, the answers given by the reaction time can change, because in the case above, we considered not only a person in good physical and psychological condition but also a vehicle that has always enjoyed good maintenance and does not present any particular problems.

Furthermore, when considering the stopping distance, we must also take into account the vehicle in front of us, which implies considering additional factors. For example, if, for the reasons just mentioned, our stopping distance is quantified as 40 meters and the stopping distance of the previous vehicle is 30 meters, this imbalance will inevitably lead to a different braking time. Moreover, if the minimum safety distance is not respected or is in any case lower than expected, the risk of a rear-end collision will be significantly increased. Therefore, it can be said that the safety distance is the result of the sum of the distance travelled in the reaction time and the braking distance based on the speed at which you are travelling and other factors. The formula to calculate the braking distance is as follows: $V2/(2a\cdot\mu)$ where "V" is the velocity (expressed in m/s), "a" represents the average deceleration of 9.8 m/s^2 (i.e. the gravitational acceleration term) and "μ" the coefficient of dynamic friction between tires and road surface. The latter varies according to the conditions of the asphalt, ranging from 0.8 in the case of dry asphalt to 0.05 in the case of an icy road, and 0.4 in the case of a wet road.

In the event of rain, the safety distance values can increase by 20-30%, depending on the amount of rainfall. When it rains, you should moderate your speed, lowering the expected limit by at least 20 km/h. If it rains, you must carefully consider the variable factors that affect the vehicle's braking distance.

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In recent years, several works have highlighted innovative methods for calculating the Safety Distance. In particular, the work of Lian et al. [2] presents a new safety distance model that enables vehicles to adapt to different driving roads, taking into account the adhesive coefficient between the tire and road, and to conform to drivers' characteristics through a driving intention parameter. The work of Chen et al. [1] derives a new safety distance model. The system detects the distance between the car and the vehicles in front of it (obstacles). It uses the vehicle's speed and other parameters to calculate the braking safety distance of the moving car. The system compares the obstacle distance and braking safety distance to determine whether the moving vehicle's safety distance is sufficient.

In our work, however, the method of calculating the safety distance is not fundamental, as our approach focuses on reducing law violations by recording instances of vehicles being too close to each other. Therefore, our method does not require a formula for defining the Safety Distance. Simply, a "Small" Distance is assumed, certainly lower, once the speed is fixed, then the Safety Distance, however it is calculated. For example, at 100 km/h, a distance of 6 m is certainly and significantly less than any logically calculated Safety Distance. However, as proof that this detection could serve as a useful deterrent, many cars can be seen on the motorways travelling at high speed very close ("glued") to the car in front, with enormous risks of a possible accident.

III. METHOD AND SYSTEM FOR EXTERNAL CONTROLLING OF THE SAFETY DISTANCE

The primary objective of this work is to develop a system for detecting the distance between two successive cars. Another aim of the present work is to develop a system for detecting the speed of motor vehicles and a method that enables sending the detected data directly to the authorities responsible for enforcing highway code regulations.

The system developed to control the Safety Distance of vehicles on motorways comprises at least one infrared ray or equivalent electronic system designed to illuminate cars in transit, and at least one camera (black and white or colour) capable of detecting the rear image. Photocell speed detection systems are the most widespread. They usually have two laser photocells. The passage of a vehicle's head through the beam of the first photocell interrupts it, initiating detection by starting a timer. Meanwhile, the passage through the second beam blocks the timer. Once the distance between the two cells is known, the speed is calculated as a function of the time taken to cross the two beams. If the detected speed exceeds the set value, the device takes a photograph of the vehicle, which, in the models currently on the market, is in digital format.

The system also provides a photoelectric sensor capable of detecting the moment when a first vehicle passes under the sensor itself. Subsequently, it also determines the moment at which the next car passes. Together with the speed data obtained with the camera and with the sensors for detecting speed, this overall system can provide the necessary data to a local computer for calculating the distance between the two subsequent cars. Therefore, if the distance itself is less than the distance established by the relevant Authority as the Safety Distance, an infringement will be detected. A large but reasonable margin of error will be taken into account for the measurements themselves, to avoid any potential complaints. If the distance detected is, for example, 5 m, a measurement error of 50% can easily be added; however, the distance between the cars will always be significantly lower (at high speeds, let's say above 100 km/h). At any Safety Distance, however, it is calculated. Therefore, it will be a distance with a "high risk of accidents".

The system also provides a computer capable of processing, transmitting, and receiving the signals from the video camera; the computer stores, at least temporarily, images and other data of the vehicles in transit and calculates their speed. Additionally, we will have a remote station capable of receiving images and other identification data of specific cars from the local stations. We can provide various transmission systems (GSM, mobile phones in general, optical fibres, or similar) to communicate between the different local stations and the remote station. Using this arrangement, the remote station receives data relating only to the vehicles to which an infringement shall be contested. Eventually, inside the column, sensors are designed to identify and detect possible vandalism.

The Method and System defined in this work for remote safety distance control are represented, and this is made more evident through the following figures.

Regarding Fig. 1, the system comprises at least one vehicle detection unit 8, which can detect the type and speed of vehicles, in combination with one video camera 1, which can read the license plates of the cars. The vehicle detection unit 8 is conveniently constituted, for example, by an electronic detector 5, which is connected to a sensor. The camera is installed on a pylon 2. The sensor, for example, is constituted by two plates installed in the pavement of the lane to be monitored. Said unit 8, therefore, performs continuous monitoring of vehicle motion and transmits information to local or peripheral processing units. Video camera 1 allows the capture of images of the vehicle in transit to detect the license plate number.

Correspondingly, to determine the distance between the two subsequent vehicles, as shown in Fig. 2, a photoelectric sensor is used to detect the passage of the first vehicle. Concerning Fig. 3, once vehicle 2 has arrived, detection four is carried out at the moment the second vehicle passes. The distance between the two cars is then calculated based on the speed detected by sensor beams 5 and 6 in Fig.1. If the calculated distance is less than the established safety limit distance, the photograph of the license plate of vehicle 2 detected with camera 3 of Fig. 2 and Fig. 3 is sent to the judicial authority.

An infrared light source is associated with video camera 1, enabling it to detect license plates even in low-visibility conditions or at night. Video camera 1 can be installed on one of the portals commonly found on highways. Essentially, the video camera captures images of all vehicles in transit on the monitored lanes, regardless of their speed.

The system must therefore store the data of the images related to the transits, which will be deleted if no infringement has occurred.

The functions that the software of the central processing unit must process

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are a) detection of infringements by processing the data received from the peripheral units; b) verification of infringements; c) Transmission of the data related to the infringement to the information system of the highway police.

We can summarise the data flow related to Safety Distance detection, as shown in Fig. 4. This figure represents a flowchart of the method for verifying the infringement of the Safety Distance. First, the vehicle speed is acquired, as described above. At the same time, the passages under the photoelectric sensors of the first and second vehicles are acquired. In this way, using the data defined above, the distance between the two cars can be calculated. At this point, we can decide whether the calculated distance is less than the established Safety Distance. If it is less, the infringement is detected and the data is sent (as established above) to the relevant Authority.

An objection that could be made to this method is that it would detect many infringements in the event of queues forming, for example, on motorways, when the speeds of the vehicles are very low. The distances between them are minimal. However, it is clear that this method only makes sense to apply when travel speeds are high, above a certain threshold, for example, 100 km/h.

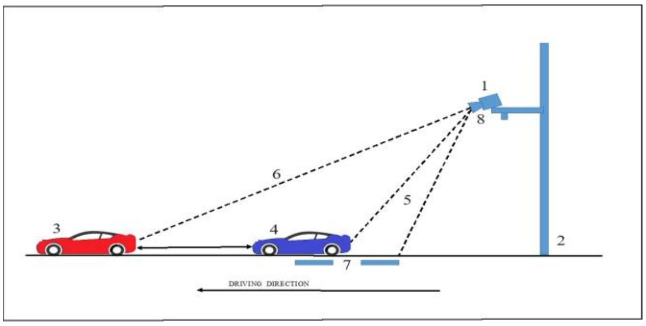

Fig. 1. Speed Control and License Plate Photography through Camera 1, Relating to the Passage of Vehicles 3 and 4

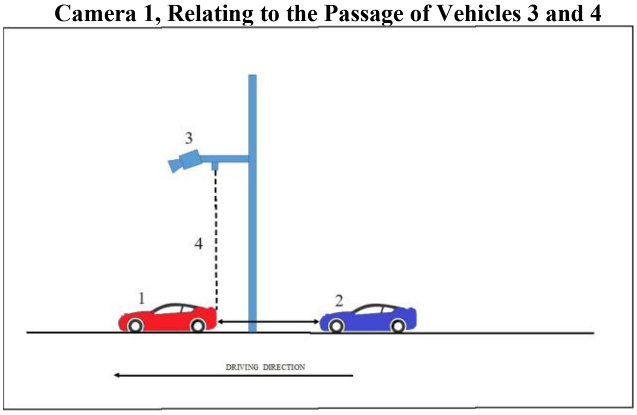

Fig. 2. Control of the Transit Position in Correspondence With Position Sensor 4, Concerning Vehicle 1, to Calculate the Distance Between the Vehicles

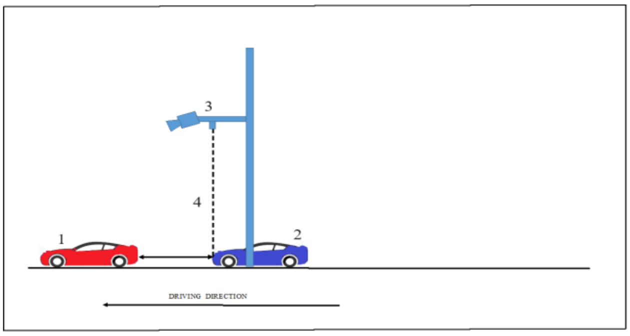

Fig. 3. Control of the Passage Position in Correspondence with the Position Sensor 4, Relative to Vehicle 2

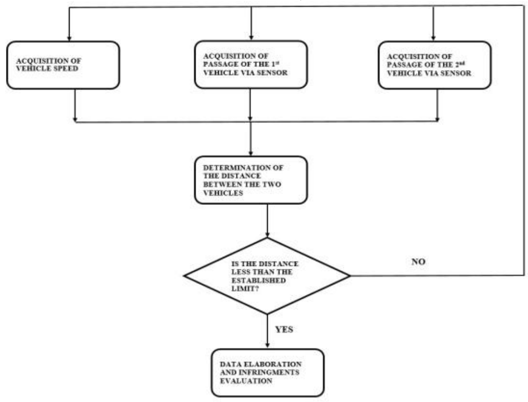

Fig. 4. A simplified Flowchart of the Method for verifying the Infringement of the Safety Distance

IV. CONCLUSION

This work describes a method for monitoring and controlling the Safety Distance between motor vehicles. The method defined in this work involves the use of a Remote System for controlling the Safety Distance, of the same type as those applied for speed control on roads and motorways. The different methods of calculating the Safety Distance between vehicles have been described. Subsequently, we presented the method developed in this work, based on the remote detection of the Safety Distance on roads, especially at high speeds, accompanied by some figures. We highlight that the innovation of the system presented in this work results in the fact that, for the first time, a System for remotely controlling the Safety Distance between motor vehicles is considered.

In the future, we could implement a method that combines the effect of the safety distance detected remotely and controlled by the Authority with direct vehicle driving control. For example, the transmitter could be composed of an interface, which in turn is connected to a transmitter that sends the signal using a suitable transducer. The receiver will inform the driver of the presence of a transmitter in the proximity (Safety Distance control) using information displayed either on the receiver or in the dashboard display. On the display, the actual Distance from the previous vehicle will be shown. The receiver could be combined with the speed regulator (Cruise control) installed on vehicles by the manufacturer.

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Authors Contributions	I am the sole author of the article.

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