Intelligent Driving Diagnosis Based on a Fuzzy Logic Approach in a Real Environment Implementation

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Abstract—This paper considers the problem of diagnosing people’s driving skills under real driving conditions using GPS data and video records. For this real environment implementation, a brand new intelligent driving diagnosis system based on fuzzy logic was developed. This system seeks to propose an abstraction of expert driving criteria for driving assessment. The analysis takes into account GPS signals such as: position, velocity, accelerations and vehicle yaw angle; because of its relation with drivers’ maneuvers.

In that sense, this work presents in the first place, the proposed scheme for the intelligent driving diagnosis agent in terms of its own characteristics properties, which explain important considerations about how an intelligent agent must be conceived. Secondly, it attempts to explain the scheme for the implementation of the intelligent driving diagnosis agent based on its fuzzy logic algorithm, which takes into account the analysis of real-time telemetry signals and proposed set of driving diagnosis rules for the intelligent driving diagnosis, based on a quantitative abstraction of some traffic laws and some secure driving techniques.

Experimental testing has been performed in driving conditions. All tested drivers performed the driving task on real streets. The testing results show that our intelligent driving diagnosis system allows qualitative qualifications of driving performance with a high degree of reliability.

I. INTRODUCTION

According to the World Health Organization (WHO), one of the most important causes of mortality is traffic accidents, claiming more than 1.3 million annual victims around the world. Therefore, the scientific community has taken the initiative to develop vehicular measurement systems, as well as tools that seek to evaluate the performance of the driver, with the aim of establishing: a) the causes that may lead to an accident and b) drivers’ security while driving [1][2].

The main causes involving traffic accidents are: driving under the influence of alcohol or psychoactive substances, lack of driving skills, speeding, reckless drives, among others. It is important to propose solutions in order to reduce the high rate of accidents and promote prudent and responsible behavior while driving. Those solutions will certainly lead to a significant decrease in the number of fatalities.

The main dangerous maneuvers performed by drivers can be identified specifically as: speeding, inadequate wheel performance, sudden acceleration or deceleration maneuvers among others. At the present time, acquire any kind of signal that comes from the vehicle is possible. Also is possible to record video and audio of what is happening outside and inside the vehicle. This record could reconstruct any catastrophic event. For this reason, a quantitative analysis of the driving process can be performed.

Nowadays, the scientific community has taken the initiative to establish vehicular measurement parameters, as well as tools that seek to evaluate the performance of the driver, with the aim of establishing the causes that may lead to an accident. However, there are no studies that integrate an intelligent driving diagnosis system allowing online monitoring of the vehicle status.

The proposed system at its early stage [3][4], achieved the goal of intelligent driving diagnostic and drivers classification based on a neural network approach in a simulated environment. The results of this research imply that it is possible to perform a driving analysis based on telemetry data by implementing a soft computing technique using a simulated platform [5]. These positive results allow us to propose a new scheme of online intelligent driving diagnosis, where both telemetry data and soft computing technique can be used in order to make the driving assessment possible in a real environment.

In this work, the problem of performing intelligent driving diagnosis is solved by implementing an integration of vehicular signal acquisition tool and “driving diagnostic expert agent”. This proposed method evaluates vehicular telemetry signals leading to issue a quantitative judgment of driver performance; through an intelligent-diagnostic-agent implemented with a fuzzy logic (FIS) approximation based on a proposed set of rules which permits approach “driving expert knowledge” based on some traffic rules and secure driving technics related to the inputs nature. This FIS system has been designed to quantify information that is considered subjective in the state of the art [6], since there is a metrics that qualifies a proper driving process. Seeking an abstraction of expert knowledge for driving diagnosis process, a quantification of qualitative process based on logical rules that evaluate the integration of such variables – speed, horizontal acceleration and yaw rate angle- is proposed.

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II. RELATED WORKS

The design of an intelligent driving diagnosis agent, and also the proposed approach for the entire system includes a research in several areas since it combines many aspects such as: vehicle telemetry systems, driver behaviors models and intelligent techniques for drivers' analysis.

A. Telemetry data management and data analysis

Based on what was explained above, some of these studies have focused on the measurement of the variables that can be acquired directly from vehicles, such as steering, clutch, speed, acceleration, engine conditions, among others. Cambourakis, G. et al. presented the development of a system with "black box" capabilities that can take vehicle on road registration. This system has four (4) specific features: a) measurement, assistance and representation of the vehicle mechanical parameters, b) vehicle-driver control system that allows simple-driving-troubleshoot, cooperation with other electronic devices inside the vehicle, c) black box function, responsible for taking measurements and checking vehicle parameters d) travel data record that can be exported or stored in a magnetic media [7]. Researchers used the vehicle mechanical performance as a reference to assess safe driving conditions (through traffic rules established by Regulation Authorities) in order to prevent possible failure of a person while driving. But beyond establishing accurate analysis about the performance of the vehicle, the researchers also took into account possible actions in which drivers could lead into an accident, moreover there are devices designed for enabling controlling speed for report when limits are exceeded [8].

B. Digital image processing analysis in driving scenarios

Some studies focused on the design of devices that take a record of all events that occur within the same vehicle and are related particularly to the attitudes that both passengers and driver can take in risky driving situations, providing a visual record of what may happen before and during a car accident. Thus, Hickman S et al. [9] implemented a video monitoring system to assess risk behaviors when they are driving commercial vehicles. They studied, through a video recording, how to recognize dangerous behaviors and maneuvers performed by drivers who developed deliveries and shipping services tasks, in order to reduce them. These studies showed the implementation of a visual recording low-cost system allowed to highly reducing the probability of a risk event. Similarly, the audio and video recordings have also been used for registration and control vehicle purposes during a route, allowing sending real-time data or at the end of the tour. In their studies, Chien-Chuan et al. [10] have developed a device that can record tracks in a vehicle, which also performs real-time transmission of the recording video signals. Finally, the design presented by Chien-Chuan also allows vehicle satellite location, either in real-time tracking or once the tour is over.

C. Towards an intelligent driving diagnosis

Motivation for Intelligent systems applied in real vehicles has been desirable since the positive results in the simulators. For this reason Michler T. et al., [11] implemented a diagnostic system in a test vehicle in order to replace human faculties of a driver for an electromechanical system that takes into account all the variables acquired from the vehicle to assess its operation. The results in this system proved to be quite relevant, because the system is easy to install and also adaptable, allowing it to be implemented in different test vehicles.

Other studies use soft computing to determine variables taken from vehicle –as known driving erroneous rates and vehicle satellite positioning-. One of them, conducted by Quintero [5], implemented artificial neural networks, in order to find wrong driving patterns in a driver when driving in a simulated system. At the same time, the vehicle makes a reference satellite marking pointing places where driving patterns were detected as inappropriate or risky. Finally, a general diagnosis of the route is made, including driving performance in situations such as: excess speed limit, sudden and rudder movement of pedals, among others.

As its early stage, this research is based in a first approach based in a simulation environment; Quintero M, et al [4] proposed a first approach of a driving intelligent diagnosis based on neural network implementation, aiming this proposal which is going to be presented in the following sections.

III. PROPOSED APPROACH

The proposed intelligent system uses vehicle motion information referred directly to the maneuvers that the driver performs during this process, characterized by speed, acceleration, yaw angle rate, and satellite position, allowing a diagnosis to assess potentially erroneous cases while evaluating driver performance through the driving activity. The design and implementation of a computational intelligence system based on an intelligent agent and dedicated to the task of evaluating the driving process under real conditions, is an important tool for generating new research proposals related to this issue. This research could allow different entities such as transit authorities, insurance companies, car rental houses, transport companies, driving schools, among others, to be aware of how drivers performed the driving task under different contexts and how this may prevent any kind of unwanted event on the tracks.

This work, regarding an analysis tool for intelligent driving diagnosis, presents the basis for carrying out the construction of an integrated driving diagnosis system based on an intelligent agent. Specifically, this paper presents a system that uses computational intelligence to perform a driving diagnosis under real conditions based on the driver actions (maneuvers) while someone is driving in real time and driving conditions.

A. Proposed intelligent driving diagnosis agent

The implementation of driving intelligent diagnosis in a real environment aims to achieve a drive diagnosis based on the intelligent agent approach that attempts to approximate the expert knowledge of some driving laws and criteria of secure driving techniques.
As a result of the above, Figure 1 shows the formal design of the proposed approach. In this figure, it is possible to distinguish the different sections that make up and generally summarize the solution to the problem of study.

Figure 1. Formal Presentation of Intelligent Driving Diagnostic Scheme

Based on Figure 1, it is possible to reach a more specific methodology used to solve this problem. Figure 2 shows a detailed scheme in terms of achieved implementation. Each of the blocks shown will be explained in detail below.

Figure 2. Intelligent Driving Diagnosis System – Block Diagram

It is possible to note that the approach rigorously conserved the characteristic properties of the system for intelligent driving diagnosis. The three sections that constitute the system are presented: telemetry vehicle data acquisition, intelligent diagnostic agent and driving diagnosis results.

1) Data acquisition by vehicular telemetry

Acquired signals for the intelligent driving diagnosis through an adapted telemetry-data-prototype in this paper are presented below:

Speed: understood by the speed limits that can reach a vehicle on public roads, whether in an urban or a rural way. Around the world, the speed that a vehicle can reach is a factor of diagnostic performance in terms of safety drivers [2]. For this reason, traffic regulators rely on electronic devices that can determine the speed of vehicles and thus have control over driving practices. Speed is evaluated according traffic regulation. In that sense, speed value is the normalized magnitude between acquired signal and the allowed speed limit.

Horizontal acceleration: physiological tests allowed the establishment of the limits of human tolerance to horizontal acceleration. It is known that the human body is capable of being exposed to 2G for at least five (5) seconds before getting physically unconscious. On issues related to driving, horizontal acceleration is strongly related to driving behaviors in terms of breaking and acceleration process, i.e., best practices to drive establish that the acceleration or deceleration process should be progressive over time. This represents horizontal acceleration values between 0.1, and 0.23 G, which are considered low. High values of acceleration can be reached in abrupt, sudden, and irregular and/or hard acceleration or deceleration events (e.g. events that go over 20 km/h to 0 km/h in 1 second) represent a strong horizontal deceleration 0.57 G of magnitude, which is a dangerous abnormal conduction process. Based on what was say above, an acceleration limit is established. Then the normalized value between acquired signal and the established threshold is processed.

Yaw Angle Rate: maneuvers carried out on the wheel are related to the orientation of the vehicle. A low angle yaw rate magnitude represents normal use and not dangerous driving, therefore, one can register a secure driving behavior in terms of taking the turns, junctions, lane changes and overtaking. According to previous measurements of yaw angle values and its rate of change, it is possible to propose a secure yaw angle rate in which the normalized magnitude between acquired signal and proposed limit is presented.

Figure 3 shows our adapted prototype for vehicular telemetry acquisition and driving diagnosis.

Figure 3. Adapted Driving Diagnosis Prototype

2) Intelligent driving diagnosis agent

This research focuses on the presentation of the characteristic properties of intelligent agent responsible of the task to evaluate a driver. This driver diagnosis system aims to identify dangerous maneuvers in an instant of time.
Thus, it is possible to see that a direct engagement exists between two factors: the first is given by monitoring vehicle signs that have a direct correlation with the driver actions executed when driving, and the second is based on how achievable it is to apply expert knowledge focused on driving diagnosis in terms of safety or risk behavior that an action can represent. So, the three (3) main blocks proposed for this diagnosis are:

Data processing: This block makes acquisition signals processing. The processing of these signals takes into account the evaluation criteria, allowing the system to be adapted to different scenarios.

Expert knowledge: This block contains an abstraction of some of the most relevant information (driving laws and driving techniques) in which it is possible to propose an intelligent driving diagnosis. Here, a quantitative approach of driving notions, assumptions and subjective definitions are contained. Thus, this research proposes a set of rules based on subjective evaluation notions for the driving diagnosis process.

Integration of expert knowledge and data processing: The main objective of the Intelligent Agent is to identify possible dangerous events in a given time while someone is driving. For variables analysis, the agent is based on three input signals: speed (V), horizontal acceleration (HA) and yaw angle rate (YAR).

3) Driving diagnosis results

The analysis of driver diagnosis results provides the opportunity to perform the examination of driver’s driving awareness given by the intelligent agent. The diagnosis result will be validated using the video records of the driver. This analysis will help to identify whether an erroneous behavior occurred and whether it was well diagnosed or not.

IV. INTELLIGENT DRIVING DIAGNOSIS AGENT IMPLEMENTATION

As the proposed approach for the intelligent driving diagnosis has already been presented, the detailed implementation is here explained in terms of the algorithm.

A. Driving diagnosis algorithm

The intelligent agent approach in this research was implemented in Fuzzy Logic. In terms of its fuzzy inference engine, each block diagram shown in figure 4 can be explained based on the proposed membership functions for each input and output.

In that sense, for each input (meaning each variable selected for analysis) the proposed membership functions are as shown in figure 5 (a, b and c). It is important to mention that each proposed membership function has low, mid and high levels in terms of how risky the level is. Consequently, the proposed rules for the abstraction of some of the traffic laws and driving techniques were explained as shown in Table 1. Notice, that all parameters are normalized in terms of a maximum value for each variable. For inputs and output, the membership functions’ shape and slope are proposed based on the acquired and processed signals. A progressive change in the membership value permits more fuzzy values between each level.

![Figure 4. Fuzzy Inference Engine Design](image)

![Figure 5. Proposed membership functions for the inputs](image)

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<td>1</td>
<td>High Vel.</td>
<td>None</td>
<td>Excessive YAR</td>
<td>Highly Risky</td>
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<tr>
<td>2</td>
<td>High Vel.</td>
<td>Strong H. Acc</td>
<td>None</td>
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</tr>
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<tr>
<td>6</td>
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<td>Low H. Acc.</td>
<td>Normal YAR</td>
<td>Without Error</td>
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<tr>
<td>7</td>
<td>Low Vel.</td>
<td>Low H. Acc.</td>
<td>Excessive YAR</td>
<td>Without Error</td>
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TABLE I. PROPOSED RULES FOR INTELLIGENT DIAGNOSIS APPROACH
According to expected driving scenarios, it is possible to propose some rules in which expert-knowledge is approached. Based on input and output levels, it is established a set of 7 rules for categorizing driving performance. Figure 6 shows how the proposed set of rules combines both input levels and output levels. Note that the proposed levels for driving diagnosis are: highly risky, risky, moderate, low and without error according to our proposed qualification method.

Figure 6. Output Membership Function

V. RESULTS AND DISCUSSION

The results of the experiments performed are now described in detail. The results will be shown according to the different routes. On each of these, there will be particular emphasis on the diagnostic performance of the intelligent agent. Based on the video records, the final diagnosis made by the intelligent system will be verified.

A. Intelligent driving diagnosis verification

Once the experiments are performed, it is quite important to verify the intelligent diagnosis. Below, a sample of one route is presented. The scored signals and the intelligent diagnoses number would be presented. In this run, each of the signals monitored in terms of the degree of membership (score) for diagnosis process as well diagnosis issued by the intelligent agent are presented.

Figure 7. Interface Diagnosis Results during a run

In this case, figure 7 shows the diagnosis issued by the intelligent system during the route for one driver. The system identifies anomalies in the variable “horizontal acceleration” in a section of the route with “straight line” shape. The video record indicates a slightly irregular acceleration at which the system decides it is not a risky maneuver and calls “Without Error” with 13.8%.

B. Driver diagnosis analysis

The driver analysis that takes into account proposed categories is presented. The following data represents the average of total scores per variable (Velocity score, H. Acceleration score and YAR score) and also the total error diagnosis result per category as well on each signal here 0% represents no error detected and 100% the maximum error in terms of the intelligent driving diagnosis score. Figure 8 shows another faculty of the system, showing the time-series analysis of the three (3) inputs.

Figure 8. Data Analysis and Interpretation

1) Analysis by categories and route characteristics

Table 2 shows the means analysis of each of the evaluated drivers on each route. All categories maintain secure levels while driving, it means that the intelligent agent establish that low levels in terms of erroneous maneuvers were diagnosis.

However, analyzing the percentage of erroneous behaviors issued by our intelligent driving diagnosis agent, it is possible to notice that drivers would perform a slightly increasing on irregular maneuvers in straight-line route shape specifically committing speeding and abrupt breaking process. Meanwhile, the other routes present lower values than the first route. This proposed means analysis focused the fact that the proposed intelligent diagnosis system correctly evaluates drivers as well allows to analyzed the driving diagnosis issued.

| TABLE II. AVERAGE SCORES AND AVERAGE TOTAL INTELLIGENT DIAGNOSIS FOR EACH ROUTE |
|-------------------------------------------------------------|-------------------------------------------------------------|
| 1. Route 1: Average Score | 2. Route 2: Average Score |
| Velocity: | 3. Route 3: Average Score |
| H. Acceleration: | 4. Route 4: Average Score |
| YAR: | 5. Route 5: Average Score |
| 0% | 100% |

106
The horizontal acceleration variable has a high impact on the physiology of the driver. This variable was not exceeded in any of the tests since an excessively high acceleration or deceleration could be achieved only in collision events. However, slight increases in this variable were noted during acceleration or abrupt deceleration in cases where high speed levels were reached.

VI. CONCLUSION

This paper and the results presented above shows it is possible to present the proposal of an intelligent driving diagnosis system applied in real driving conditions based on the presentation of the characteristic properties of an intelligent diagnosis agent, getting accurate results from the intelligent driving diagnosis according to proposed quantitative assessment levels. These results show the relevance and importance of the implementation of vehicle safety systems, contributing to the research of ITSS in Safety Systems.

The proposed intelligent diagnosis agent allows diagnosing different types of drivers in different kinds of routes, based on the records of vehicular telemetry data and the adapted telemetry-data-prototype.

This new proposal contributes to the presentation of the characteristic properties for the intelligent diagnosis agent. It aims to present a structured approach to make the driving diagnosis task possible.

REFERENCES


