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Expert-Driving-Criteria Based on Fuzzy Logic Approach for Intelligent Driving Diagnosis

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***Abstract*—**This paper considers people's driving skills diagnosis under real driving conditions. In that sense, this research presents an approach that uses GPS signals which have a direct correlation with driving maneuvers. Besides, it is presented a novel expert-driving-criteria approximation using fuzzy logic which seeks to analyze GPS signals in order to issue an intelligent driving diagnosis.

Based on above, this works presents in the first section the intelligent driving diagnosis system approach in terms of its own characteristics properties, explaining in detail significant considerations about how an expert-driving-criteria approximation must be developed. In the next section, the implementation of our developed system based on the proposed fuzzy logic approach is explained. Here, a proposed set of rules which corresponds to a quantitative abstraction of some traffics laws and driving secure techniques seeking to approach an expert-driving- criteria approximation is presented.

Experimental testing has been performed in real driving conditions. The testing results show that the intelligent driving diagnosis system qualifies driver's performance quantitatively with a high degree of reliability.

***Keywords*—**Driver support systems, intelligent transportation systems, fuzzy logic, real time data processing.

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, scientific community has taken the initiative to develop vehicular measurement systems, as well as tools that seek to evaluate the performance of the driver, seeking of establishing: a) the causes that may lead to an accident and b) drivers' security while driving [1], [2].

The main causes involving this kind of accidents are: driving under influence of alcohol or psychoactive substances, lack of driving skills, speeding, reckless drives, among others. With these, 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.

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 main dangerous maneuvers performed by drivers can be identified specifically such: speeding, inadequate wheel performance, suddenly 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.

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 that research, allows establishing that it is possible to perform a driving analysis based on telemetry data by implementing a soft computing technique using our simulated platform [5].

In this work, the problem of 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 diagnostic agent of intelligent 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 techniques related to the inputs nature. This FIS system has been designed to quantify information being considered subjective in the state of the art [6], since there is a metric 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.

II. Related Works

The design of an intelligent driving diagnosis agent, and also the proposed approach for the entire system includes a

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research in several areas since it combines many aspects such: vehicle telemetry systems, driver behaviors models and intelligent techniques for drivers' analysis.

A. Telemetry Data Management and Data Analysis

Based on that was explain 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 as a reference the vehicle mechanical performance 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 [10] has 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 the 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, it is made a general diagnosis of the route, 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 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 presenting in the following sections.

III. Proposed Approach

The proposed intelligent system use vehicle motion information referred directly to the maneuvers that the driver performance during this process, characterized by speed, acceleration, yaw angle rate, and satellite position, allowing making 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, 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.

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A. *Proposed Intelligent Driving Diagnosis Agent*

The implementation in a real environment of driving intelligent diagnosis seeks to achieve a drive diagnosis based on the intelligent agent approach that attempts to approximate the expert knowledge of driving laws and criteria of secure driving techniques (some of those).

In Fig. 1, the formal design of the proposed approach is shown. In this figure, it is possible to distinguish the different sections that make up and generally summarize the solution to the problem of study.

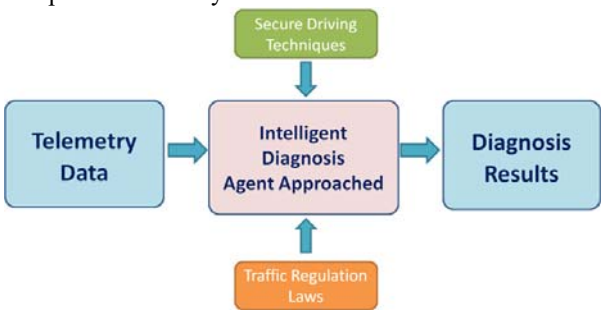


Fig. 1 Formal Presentation of Intelligent Driving Diagnostic Scheme

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

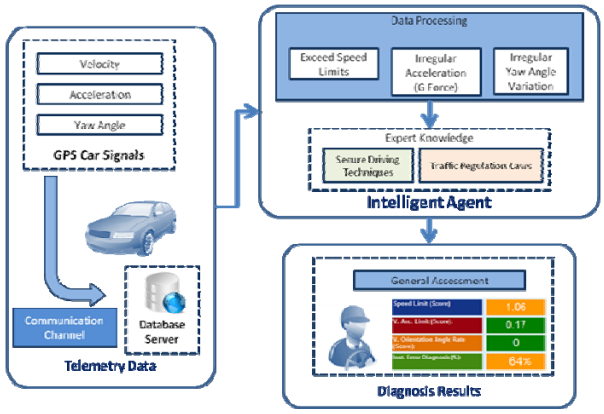


Fig. 2 Intelligent Driving Diagnosis System – Block Diagram

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

1. Data Acquisition by Vehicular Telemetry

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

Speed: understood by the speed limits that can reach a vehicle on public roads, whether in urban or 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.

Horizontal acceleration: physiological tests allowed establishing 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, the 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 the 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 acceleration or deceleration events abrupt, sudden, and irregular and/or hard (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.

Yaw Angle Rate: maneuvers carried out on the wheel are related to the orientation of the vehicle. A low angle yaw rate magnitude represent 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.

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

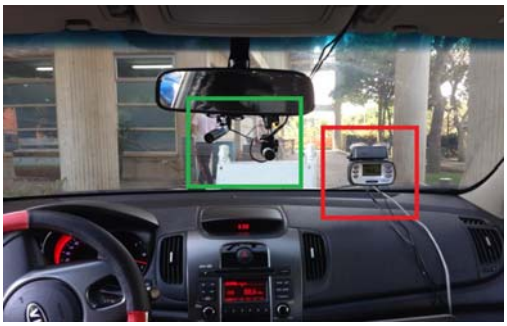


Fig. 3 Adapted Driving Diagnosis Prototype

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 seeks 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 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

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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 diagnostic process.

Integration 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 Diagnostic Results

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 at first instance will be matter of study through results itself and video recording supports. It would allow identifying whether an erroneous behavior had occurred and whether was well diagnoses or not.

IV. Intelligent Driving Diagnosis Agent Implementation

Once the proposed method for intelligent driving diagnosis was presented, the detailed implementation can be presented. Here, detailed explanation of the driving diagnosis algorithm.

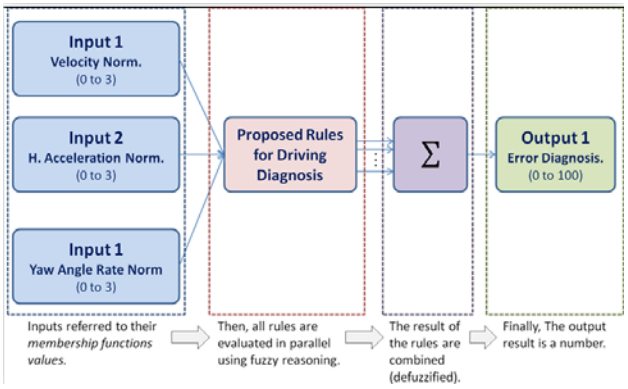
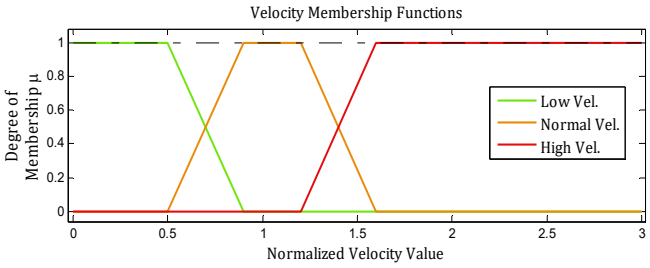


Fig. 4 Fuzzy Inference Engine Design

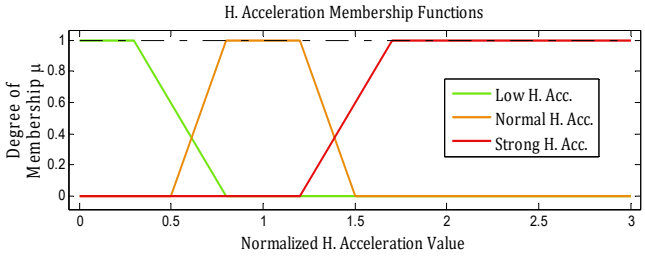
A. Driving Diagnosis Algorithm

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

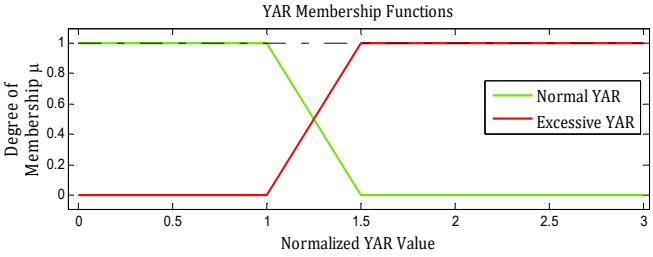
In that sense, for each input (meaning each variable selected for analysis) the proposed membership functions are as shown in Figs. 5 (a), (b), and (c). It is worth to mention, each proposed membership functions has low, mid and high in terms of how risky the level is. As well as inputs levels for membership functions were explained, proposed rules for the abstraction of some of the traffic laws and driving techniques were proposed as shows Table I. Notice, that all parameters are normalized in terms of a maximum value for each variable.



(a) Velocity Membership Functions



(b) Horizontal Acceleration Membership Function



(c) Yaw Angle Rate Membership Functions

Fig. 5 Proposed membership functions for the inputs

TABLE I
Proposed Rules for Intelligent Diagnosis Approach

Rules	Input			Output
	Norm. Velocity	Norm H. Acce.	Norm. Yaw Angle Rate	Erroneous Diagnosis
1	High Vel.	None	Excessive YAR	Highly Risky
2	High Vel.	Strong H. Acc.	None	Highly Risky
3	Normal Vel.	Strong H. Acc.	Excessive YAR	Risky
4	Normal Vel.	Normal H. Acc.	Normal YAR	Moderate
5	Low Vel.	Normal H. Acc.	Normal YAR	Low
6	Low Vel.	Low H. Acc.	Normal YAR	Without Error
7	Low Vel.	Low H. Acc.	Excessive YAR	Without Error

Based on proposed rules, it was established for categorizing driving performance as well as the inputs were defined. For that reason, the output levels the driving

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diagnostic are show in Fig. 6. Note that the proposed levels for driving diagnosis are: highly risky, risky, moderate, low and without error.

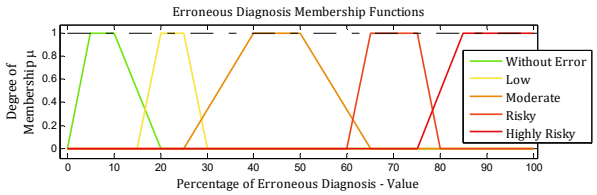


Fig. 6 Output Membership Function

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 were performed, it is quite important to verify the intelligent diagnosis. Below, it is presented a sample of one route. 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 issue by the intelligent agent are presented.

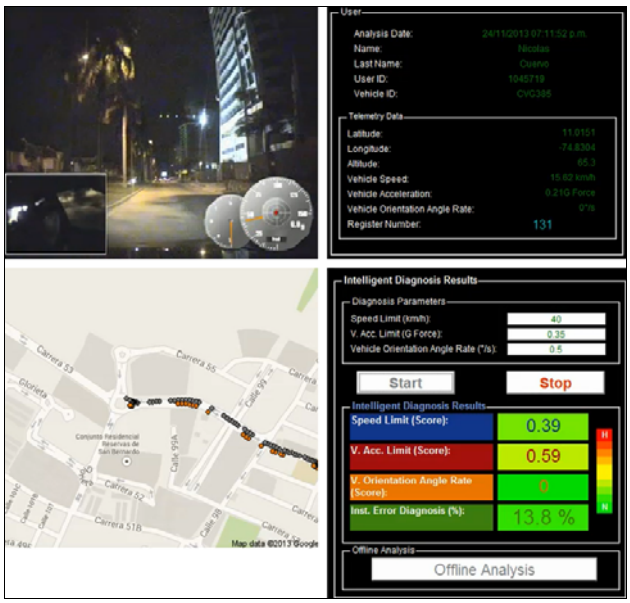


Fig. 7 Interface Diagnosis Results during a run

In this case, Fig. 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. Fig. 8 shows another faculty of the system, showing the time-series analysis of the three (3) inputs.



Fig. 8 Data Analysis and Interpretation

1. Analysis by Categories and Route Characteristics

Table II 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.

2. Route Analysis and Hazardous Areas

By grouping all analysis issued per route, our proposed intelligent agent shows that every route presents secure levels of driving diagnosis establishing that low levels in terms of erroneous maneuvers were diagnosis. However, means

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analysis in this cases suggest that in route two (2) a higher values of erroneous driving maneuvers were issued. Based on the results of horizontal acceleration and yaw angle rate variables, it is possible to confirm that the intelligent agent diagnoses a slightly increase in the total score, suggesting that evaluated drivers would tend to commit some risky maneuvers in this kind of route because of the turns, and also the straight line shapes.

TABLE II
AVERAGE SCORES AND AVERAGE TOTAL INTELLIGENT DIAGNOSIS FOR EACH ROUTE

Route 1- Straight Line Road				
Categories	Vel. Score (%)	H. Acce. Score (%)	YAR Score (%)	Total Intelligent Diagnosis (%)
Drivers until 20 years	44,17	7,10	38,25	25,29
Drivers between 21 and 40 years	42,57	13,59	29,95	17,67
Drivers over 40 years	37,39	9,53	31,81	18,32
Route 2- Intersections, Straight Lines and Turns Road				
Categories	Vel. Score (%)	H. Acce. Score (%)	YAR Score (%)	Total Intelligent Diagnosis (%)
Drivers until 20 years	38,19	14,60	36,17	19,94
Drivers between 21 and 40 years	40,58	6,67	39,49	19,24
Drivers over 40 years	38,34	9,48	34,79	21,38
Route 3- Low Speed Limits and Intersections Road				
Categories	Vel. Score (%)	H. Acce. Score (%)	YAR Score (%)	Total Intelligent Diagnosis (%)
Drivers until 20 years	40,85	13,15	35,09	18,68
Drivers between 21 and 40 years	38,06	14,72	38,68	19,29
Drivers over 40 years	42,49	7,90	32,65	18,01

TABLE III
ROUTE ANALYSIS AND HAZARDOUS AREAS

Route	Vel. Score (%)	H. Acce. Score (%)	YAR Score (%)	Total Intelligent Diagnosis (%)
Route 1	40,93	10,24	32,91	19,96
Route 2	38,97	10,58	36,77	20,17
Route 3	40,62	11,62	35,26	18,61

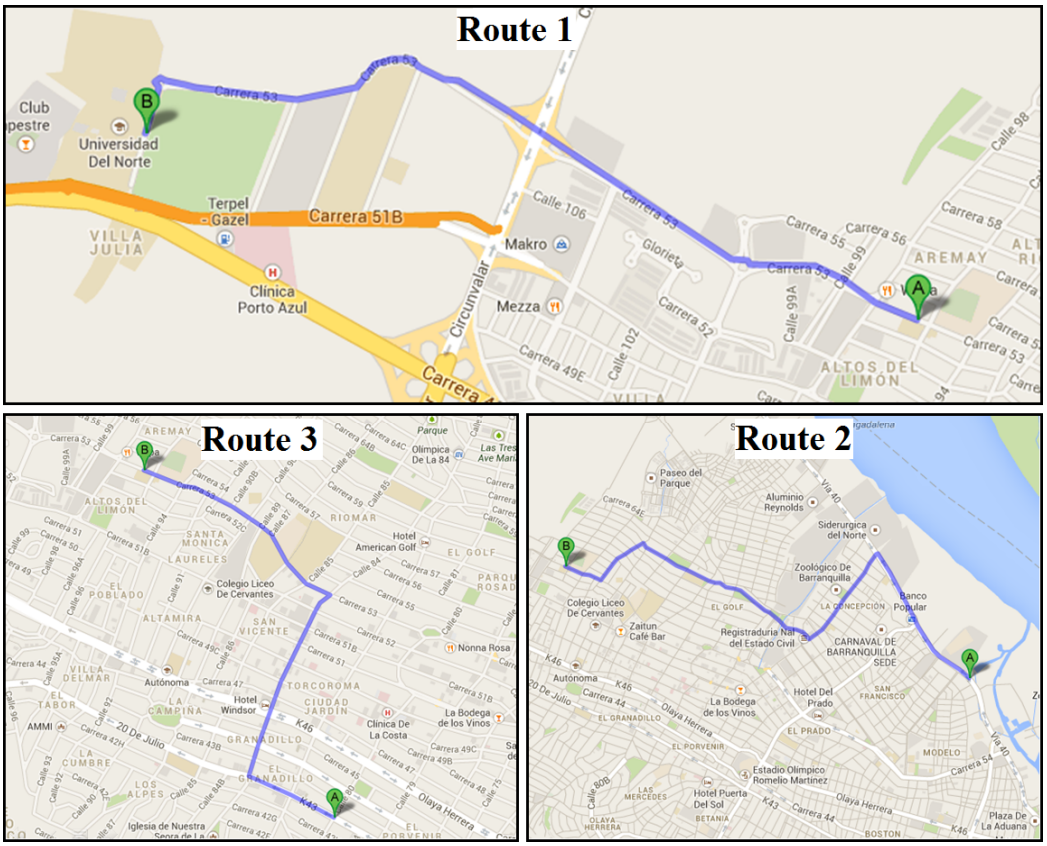


Fig. 9 Route Analysis and Hazardous Areas

C. General Analysis

Generally, the Intelligent Agent executes correctly the driving diagnose for any kind of drivers. However, in none of these cases a corrective support for the driving process of the person is provided. It can be noted that in the straight-line paths some drivers exceed or nearly exceed the speed limit. However, the intelligent diagnosis correctly interprets whether this represents a non-dangerous maneuver or do not.

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 a 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 kind 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. This seeks presents a structured approach to make possible the driving diagnosis task.

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