Functional safety: on-board computing of risk of accident

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Introduction

Safety estimation is of utmost importance for in the perspective of fully automated vehicles. In particular, recent progress on accident estimation measurement made by insurance companies has revealed that correlation-based considerations do not give satisfaction. Indeed, there is no correlation between accident data bases and data collected by accelerometers such as the so-called “severe braking” that was supposed to estimate anticipation of the driver and thus a “risk of accident”. More recently, it has been demonstrated that accidents are rare events being the consequence of the repetition of “near-misses” accidents (e.g. a Quasi-Accident). It has also been shown that there exists a causality relationship which fully explains “near-misses” accidents.

A New Solution for measuring the On-Board Risk of Accident

In 2004, the French department responsible for road safety initiated a comprehensive research operation called an “Observatory of trajectories”. The goal of the programm was to observe, record, and count the “near-misses” accidents, by assuming that an accident cannot be predicted. An accident is rare: the reflexes of the driver and the other road users, the circumstances, the luck, etc… usually allow to avoid the accident to happen. A near-miss accident is the expression of a high risk, statistically speaking, and the probability for an accident to happen increases with the repetition of near-miss accidents. However, the question under which circumstances a near miss accident turns into an accident cannot be answered by causality relationships. It is only statistical: On average, an accident is the consequence of the accumulation of 100-1000 near miss accidents [1]. Fig. 1 depicts an illustration of this fact.

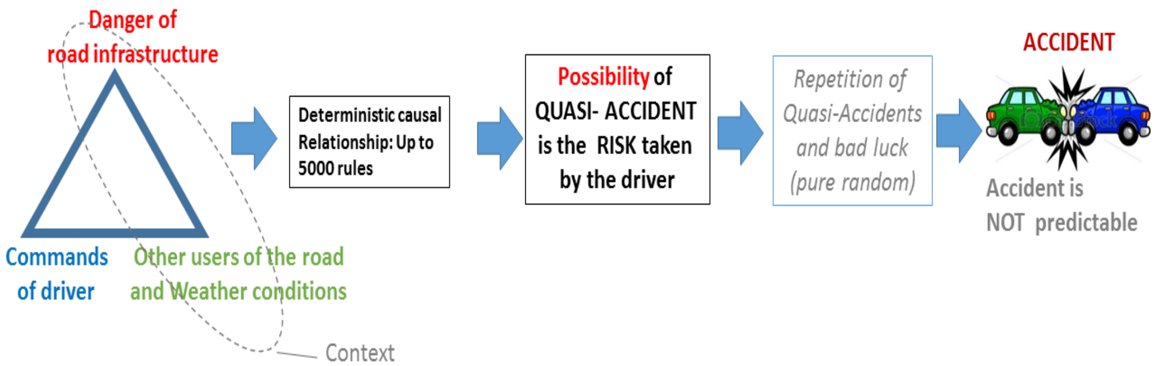

Fig. 1: Scheme explaining how a quasi accident and eventually an accident may happen.

The notion of near miss accident is very interesting. Indeed, if one can compute a real time risk function, then one can assess the risk taken by the driver at all time. If the considered car happens to be in risk too often, there is a high probability it will end up having an accident. Hence, having an indication of the risk at real time can be used to control the car.

Based upon results discussed above, NEXYAD has been designing and developing a software module named SafetyNex which allows to estimate the driving style and its relevance regarding the road environment, in real time, and assigns a risk score (score usually presented in reverse: Safety) correlated by construction to accident. This solution is the result of over 15 years of R & D, particularly in the context of four French national collaborative research programs [1-2]. This allowed NEXYAD to extract causal rules of accidents. Those rules have been validated by experts of accidents of the French Road Safety Administration [6]. SafetyNex is a knowledge-based engine, with more than 5000 rules, using "possibility theory" [3] and its implementation into fuzzy sets theory [4]. In the current state, this engine takes the dynamics of the vehicle (acceleration and speed) and an Electronic Horizon (HE) as Inputs. The EH is obtained from map matching algorithms, and it corresponds to the most probable driving path in front of the vehicle. A dimensionless quantity $r \in \{0; 1\}$ is the output. It gives an estimation of the risk at real time: if $r = 0$, the risk does not exist, if $r = 1$, the risk is high and a "near miss" accident is detected. Thanks to the Electronic Horizon, this solution is also able to obtain a "risk profile" as a function of the distance along the most probable driving path in front of the vehicle. It is thus possible to fully anticipate the risk in the future considering the current behavior of the vehicle.

Results and discussion of validation tests

Safety measurements have only been made by analyzing data collected from accelerometers so far, by assuming that a "severe breaking" (important acceleration variation) reflects a lack of anticipation, and thus, an unsafe behavior. The variation of acceleration is also assimilated to the Eco driving attitude (Fuel consumption is related to acceleration variations). Hence in the severe breaking assumption, the safety is directly correlated to the Ecological driving attitude.

We have imagined four different scenarios to highlight the most common driving behaviors:

1. The "Good" driver
2. The "Quiet – dangerous" driver
3. The "Bad" driver
4. The "Expert Sportive" driver

Driver profiles for those four scenarios are the following:

The "Good" driver does not accelerate much and has a good anticipation when approaching a Dangerous Point Of Interest (DPOI) [5]. The "Quiet – Dangerous" driver does not accelerate much, but does not stop at all when approaching a DPOI. The "Bad" driver accelerates very often and strongly, and does not slow when approaching a DPOI. The "Expert Sportive" driver accelerates very often and strongly, but slows down when approaching a DPOI.

Each scenario has a duration of about 90s, following the same journey of 1,5 km. The Journey, driven by a professional driver, was mostly composed of traffic lights, pedestrian crossings and intersections, representing a typical journey in an urban environment.

To measure the impact of the individual driving attitude regarding the vehicular energy efficiency ("eco attitude") when executing those scenarios, an extra module called EcoGyser, developed by the Nomadic Solution Company, has been integrated to SafetyNex. The EcoGyser modules takes the acceleration and standard NMEA/GPRMC GPS frames as inputs. Then the EcoGyser engine analyses acceleration signals following ten different rules and it outputs a dimensionless quantity varying from 0 to 100% which quantifies the eco driving style ("eco attitude"). The combination of the two modules allows obtaining point clouds in the Safety - Eco Space by collecting data at every second. Point clouds in the Safety - Eco space (scale in percent) for those fours scenarios are given in Figure 2. On can see that for the "Good" driver case (2.A), points are only confined in the green area, with Safety values varying between 100% and 50%, and the Eco values are always around 70% and 75%, which corresponds to a good Eco attitude: the driver has a global safe and an eco attitude at the same time. In the "Quiet Dangerous" driver case (2.B), safety values vary between 100% and 0% and Eco values are around 70% and 75%. In the "Bad" driver case (2.C), points spread all over Safety and Eco range, with a rather important number of points confined in the red area: the driver has a global unsafe and wasting attitude Finally, in the Expert Sportive case (2.D), most of safety values are found between 100% and 50%, with a few of them below 50% though. Eco values otherwise vary between 70% and 0%.

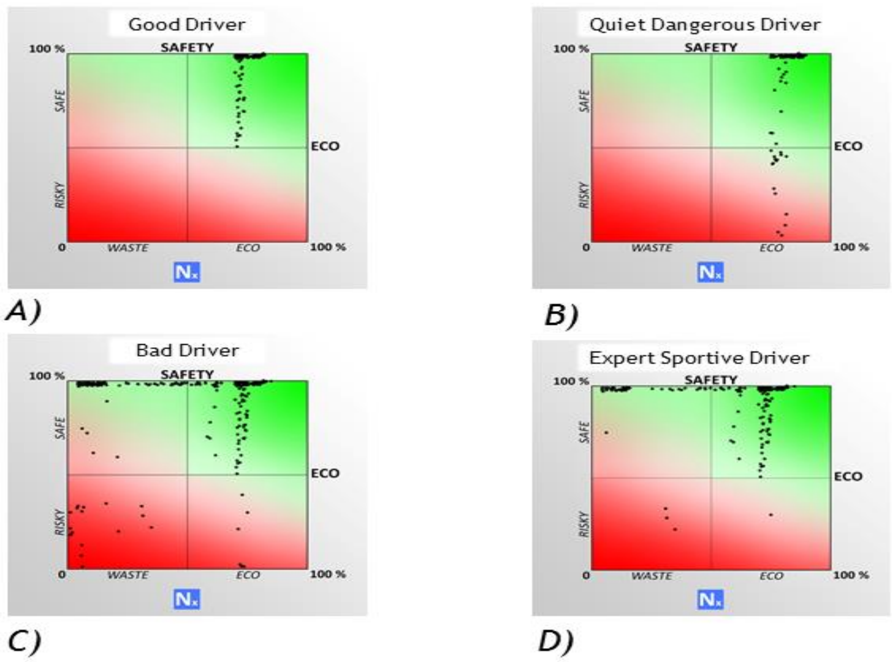

Fig. 2: Point clouds in a Safety - Eco Space for four different scenarios. Each point has been recorded every second with our solution SafetyNex for the Safety, and EcoGyser (from our partner Nomadic Solution Company) for the quantification of the energy efficiency ("eco attitude").

Let us discuss the "Quiet and dangerous" and the "Expert Sportive" driver cases. For the first case, the driver generates dangerous situations because he never slows down when approaching a DPOI, but has a good Eco driving attitude (the driver does not accelerate much, and keeps a relatively constant speed). Hence, as an example, if the driver approaches a pedestrian crossing, he does not slow down to anticipate the presence of a pedestrian who would suddenly appear. So even though it has a good Eco driving signature, the driver is dangerous, which contradicts the idea that a good Eco driving attitude is necessarily safe. Hence, there are in general no correlations between safe and ecological driving styles. This is visible from a formal point of view when observing the cloud point in the Safety - Eco space: one cannot fit the cloud point with a linear curve passing at the origin and having a slope “one half”. The Expert Sportive driver case, in the opposite, does not generate dangerous situations most of the time, even if his Eco driving attitude is very bad (the driver accelerates and breaks very often and rather strongly).

Conclusion

We show that our approach is more appropriate to estimate the real safety level than accelerometers and the so called “severe breaking” assumption. SafetyNex is a module based on causality relationships, which integrates 5000 rules, all validated by Road Safety Experts, which take into account the road infrastructure. In particular, by studying four different driver profiles, the “Good”, the “Bad”, the “Quiet Dangerous” and the “Expert Sportive”, we show that safe and ecological driving styles (measurement of acceleration variation) are not correlated. Hence, the “severe breaking” assumption falls down. This is particularly visible for the case of the “Quiet Dangerous” driver. Indeed, the driver does not accelerate (Good Eco score), however he does not slow down when approaching a dangerous area (Bad Safety Score) but passes through it at constant speed. Upon the “severe breaking” assumption, the diver would be given a good score, whilst he is clearly dangerous. This is a clear illustration of the fact that the “severe breaking” assumption is not appropriate to measure real safety level.

However, since the EH is obtained from map matching, the map resolution clearly limits the efficiency of SafetyNex. As a further extension of our solution, weather conditions and the grip of the road could be added to inputs. The risk estimation could be also improved by adding a camera in order to merge signals obtained from the road/obstacles detection in front of the vehicle. Finally, in addition to an autonomous car, this solution can be used either for making data-based services richer or for a more relevant estimation of safety level and a better accident anticipation, e.g. by the insurance sector.

References

[1] Final document of the SARI program by the French research institut IFSTTAR *http://sari.ifsttar.fr*

[2] Final document of the SARI program by the French research institut CEREMA *http://normandie-centre.cerema.fr*

[3] « Théorie des possibilités », D. Dubois, H. Prade ; 2006, REE, 8, 42

[4] « Fuzzy Sets as a Basis For Theory of Possibility », A. Zadeh; 1978, Fuzzy Sets and Systems, 1, 3-28

[5] A Dangerous Point Of Interest (DPOI) is a road location where a near miss accident has a high probability to happen

[6] « Evaluation du risque de sortie de route pour l’aide à la conduite ou le diagnostic d’infrastructure », J. Brunet, P. Da Silva Dias, G. Yahiaoui, Session « caractérisation du risque routier », conférence PRAC 2010, 3-4 Mai 2010.