Presentation of modern accident reconstruction procedures - case study

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Abstract. Nowadays, the reconstruction of traffic accidents utilizing current vehicle technology presents new challenges for professional accident analysis. The downloading and reading of data stored in vehicles and the professional interpretation of these data is becoming important for full interpretation of the accident reconstruction. But this data cannot be interpreted without the use of separate mathematical analysis and comparison to the physical scene data for the analysis of traffic accidents.

In this paper, the process is discussed of an accident resulted by a Toyota Yaris passenger car's stability loss of control that resulted in a traffic accident.

During the analysis, we will use data from the electronic EDR (Event Data Recorder) placed in the vehicle, as well as data recorded by in the auxiliary equipment (on-board camera).

In determining the most likely accident process, account should be taken of the data obtained from other accident related devices as well as the GIS data for the environment. The paper details how data from different sources can be evaluated, how conflicting data can be reconciled and, how to resolve contradictions.

Keywords: Accident Reconstruction, Event Data Recorder, Vehicle Movement Simulation, On-board Camera.

1. Introduction

In the analysis of traffic accidents, an increasing emphasis is being placed on the data stored in the vehicle. The reasons for this are as follows:

- EDR (Event Data Recorder) systems collect data from a vehicle's CAN (Control Area Network) bus system that needed to evaluate an accident during an accident process [1], [2];
- the data stored in the vehicle can be classified as objective data [3], [4];
- with the existence of on-board vehicle recording capabilities, the vehicle controls executed by the driver and autonomous vehicle motion control systems can be separated and analysed [5], [8].

Downloading and reading data alone is not enough to reconcile the accident process and reveal cause of the accident. Additional mathematical analysis is also essential for the professional interpretation of stored data.

In this paper, an accident involving a Toyota Yaris car is presented, which losts stability and lefts the roadway. The data stored in the vehicle's EDR system was read with a Bosch CDR 500 unit. The vehicle had been also equipped with a video camera that recorded the crash. The location of the accident was determined using Google Earth and Google Street Map applications.

2. Short description of the accident process

The Toyota Yaris was travelling on a slightly off-camber road near a residential area. Prior to losing control, the Toyota passed over a nearly 1 m wide asphalt pavement repair. When the rear axle has passed over the uneven surface, the vehicle loses its stability causing it to initiate an approx. 180 degrees yaw to the left whereupon the Toyota slid into the ditch where it came to rest.

3. The accident site

There was no data recorded at the site of the accident, therefore it was possible to examine determine the Toyota trajectory at the accident location. There was no measurement of the radius of the road, the width of the roadway, the profile of the ditch, and no data on the road defect that caused the accident. No photographs were made about damage to the Toyota.

But in a review of the accident with the assistance of the driver, using the Google Earth program, it was possible to identify the accident site. With this information, the vehicle's trajectory from loss of control to point of rest could be determined.

Location of loss of stability occurred near Esztergom, 47.715874; 18.867048 at GPS coordinates. Figure 1 shows this location.

Fig. 1. Accident Location (Satellite Recording)

Fig. 1. Road fault causing a loss of stability

Figure 2 shows the road fault causing a loss of stability in accordance with Toyota's trajectory.

Fig. 1. Approaching the Toyota car from the road

Figure 3 shows Toyota's arriving point after crashing. The location could be identified on the basis of vegetation from Google Street photos and comparison with video capture from the vehicle.

4. Data downloading from the EDR

Using the Bosch CDR 500 Interface Adapter Kit [6], the Toyota Data Vehicle Recorder (EDR) unit was downloaded to examine the recorded data. These readings are produced in a multi-page report. Table 1 shows data for 5 seconds prior to the accident.

Table 1. Bosch CDR data.

Pre-Crash Data, -5 to 0 seconds (Most Recent Frontal/Rear Event, TRG 1)

Time (sec)	-4.813	-3.789	-2.765	-1.741	-0.717	0 (TRG)
Vehicle Speed (MPH [km/h])	33.6 [54]	36 [58]	38.5 [62]	39.8 [64]	42.3 [68]	42.3 [68]
Brake Switch	OFF	OFF	OFF	OFF	OFF	OFF
Accelerator Rate (V)	1.99	1.99	1.99	2.03	2.03	0.78
Engine RPM (RPM)	2.800	2.800	3.200	3.200	3.200	3.600

4.1 Evaluation of EDR data

Based upon a review of the EDR data, the Toyota was travelling 54 $^{km}/_{h}$ at 4.8 seconds prior to the time the event was triggered (abrupt stopping in the ditch). The Toyota's speed is shown in Table 1 to be approximately was 68 $^{km}/_{h}$ when stopped in the ditch. According to the examination of the data, the driver did not brake during the

trajectory but increased the engine speed from 2800 to 3600 RPM during the approx. 5 second period.

4.2 Analysis of vehicle recording

The vehicle was mounted on an on-board camera that recorded the entire accident process. The video was separated into individual frames for analysis. By knowing the image capture frequency it was possible to estimate the time of the car's loss of stability:

$$T = -3.545 \text{ s}$$

At which at the moment Toyota's speed was:

$$V = 59 \, {}^{km}/_{h}$$

A Fig. 4 - Fig. 8 are displayed video clips. The timing of camera images is the same as the EDR data (Table 1).

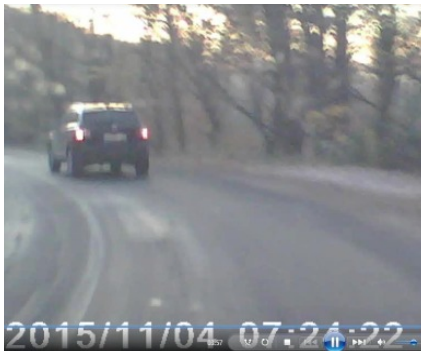

Fig. 1. T = -3.545 s

Fig. 1. T = -2.765 s

Fig. 1. T = -1.741 s

Fig. 1. T = -0.717 s

Fig. 1. T = 0 s

5. Simulation of the movement of a car

Based on satellite recordings, we initially estimated the trajectory prior to loss of stability and the trajectory after loss of stability.

Then, the simulation calculation was conducted using Virtual Crash 2.2 software [7]. This application is intended for forensic experts working in the field of traffic, who specialise in elaborating technical expert reports about causes of road traffic accidents.

We set the parameters of the car, and the speed (59 $^{km}/_{h}$ based on EDR) before the loss of stability.

During the simulation calculation, the time from the loss of stability and the trajectory leaving the road was approx. 3.5 seconds by comparing the results of this analysis to previously verified data. The sequential positions in time illustrating the trajectory are shown in Figure 9, and the speed time diagram is shown in Figure 10.

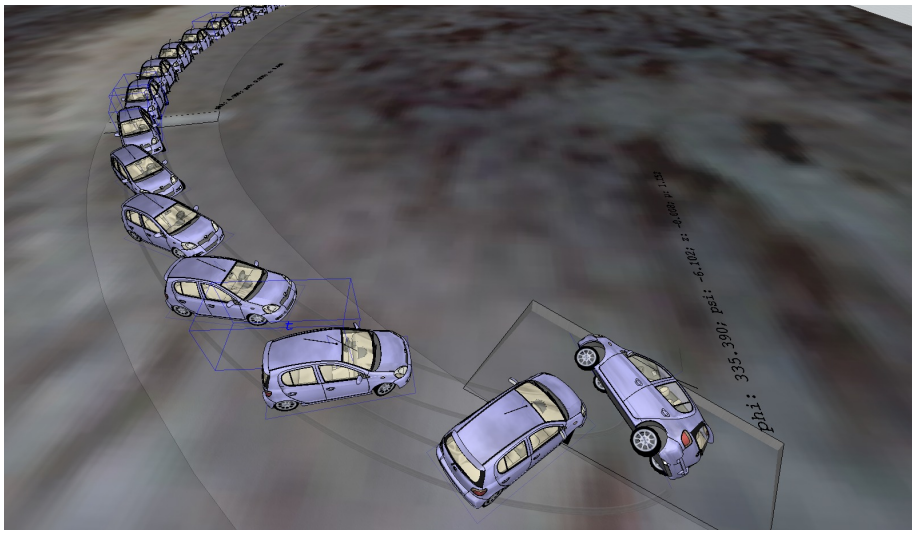

Fig. 9. The Toyota trajectory with time-separated positions (Virtual Crash 2.2)

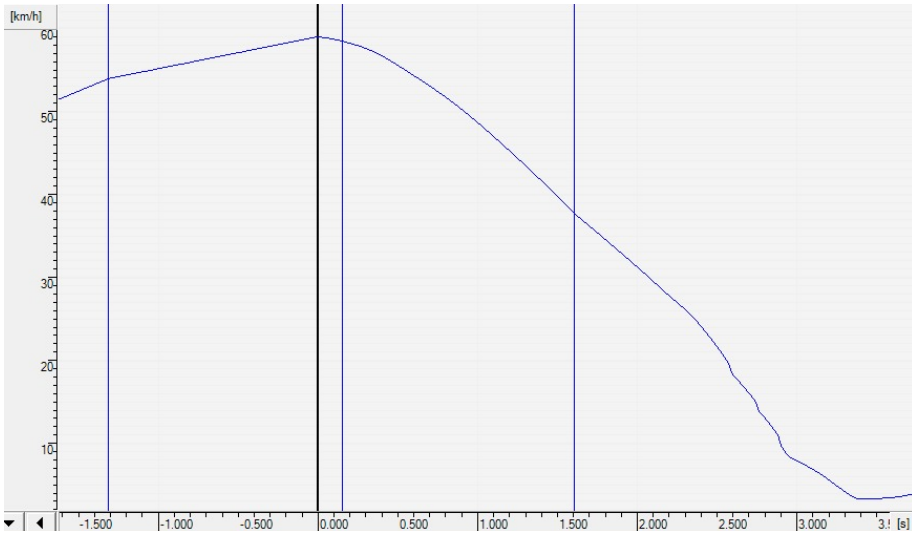

Fig. 10. Speed-time diagram

As a result of the simulation calculation, the initial estimate of the speed of the car when the loss of stability occurred was decreased. This was apparently contradicted by EDR data stored in a car, as the data showed an increase in vehicle speed.

The reason for the controversy is that EDR records the velocity based on the ABS sensor data that are related to wheel speed. Thus, the recorded data does not refer to

the speed of the centre of gravity of the vehicle on the road but rather the speed of the angular velocity of that wheel. This discrepancy was evaluated and compared to the results of the simulation software.

Based on the EDR data it appears that the driver has operated the accelerator during the stability loss, as a result of which the engine speed has increased and the angular speed of the wheels has increased. At the same time, in the course of the real trajectory during the stability loss, the wheels slipped indicating a higher speed, but in actuality, the drifting vehicle slowed down and its speed decreased.

6. Conclusions

During the accident analysis, electronic data stored in the vehicle will be given more and more emphasis in the future. However, in analysing accidents, these data must be interpreted in an appropriate way, and it is not sufficient to simply use the data without utilizing additional accident reconstruction analysis to provide an accurate reconstruction scenario. It is necessary to understand what the information is in relation to the data content and how the operation of the electronic equipment that generates the data presents it in the final report. An investigation of an accident is a complex process, in addition to the knowledge of the data stored in the vehicle, the use and proper interpretation of all available data is also required. In the absence of these, the analyses may prove to be inaccurate and may lead to erroneous decisions.

List of Abbreviations

ABS – Anti-lock Braking System
EDR – Event Data Recorder
CAN – Control Area Network

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