Vehicle Fault Memory Data Extraction and Interpretation

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Résumé

In the past few years both the Rotterdam Police and the NFI have been following developments in vehicle design, turning focus towards electronic systems in vehicles. Data from these systems can be helpful for accident reconstruction. Extraction results and validation efforts are presented here. We also present a new data extraction tool, specifically designed by the Rotterdam Police for the goal of extraction freeze frame data after an accident. A distinction is made between diagnostic freeze frame data and data from an Event Data Recorder (EDR). We conclude that the latter, EDR data, is more desirable than the former. The former, however, is available in a much larger percentage of vehicles. An appeal is made for the introduction of EDR legislation in the European Union.

Introduction

In the Netherlands, specialized police units perform collision scene investigation. These units also reconstruct collisions in cases liable for prosecution. The Netherlands Forensic Institute (NFI) assists the Police at an engineering level. In the past few years both the Rotterdam Police and the NFI have been following developments in vehicle design, turning focus towards electronic systems in vehicles. Recently the Rotterdam Police was awarded funding for a specialized Government project aimed at the development of a data retrieval tool called The CrashCube. The NFI is a partner in this project and takes the role to ascertain the interpretation of extracted data.

This presentation covers both data from vehicle diagnostic as well as from event data recorders. We´ll show how the Rotterdam police has been successful in extracting these data and we´ll give an insight in our validation efforts.

Data extraction results

Relevant data is found in two levels. The highest level is pre-crash data captured by the airbag control module at the time of an accident. This function of the airbag control unit is generally called the Event Data Recorder (EDR). An overview of EDR technology was given in a recent article in Verkehrsunfall- und Fahrzeugtechnik (Steiner, 2010). Interpretation of EDR-data is relatively easy and data is of good quality. Pre-crash data may include vehicle speed as broadcasted over the vehicle data network (CAN) during the last 5 seconds before the accident. Specifically, EDR's are found in USA vehicles. EDR data from the three major American brands can be extracted using the Bosch CDR-tool. The Rotterdam Police has this tool available and used it since September 2008 successfully in 7 cases.

From contacts at several car manufacturers we learned that cars for the European market may also have an EDR installed. In two cases the Rotterdam Police successfully obtained EDR data after sending an airbag control unit to Renault. In three ongoing cases, two Renaults and one Peugeot, the units have been send and results are awaited.

The lower level is freeze frame data. A freeze frame is a set of values saved by an electronic module at the time it suspects a fault and sets a fault code (also called a Diagnostic Trouble Code, or DTC). For some specific fault codes in some specific modules, relevant values as speed or brake pedal status may be included in the freeze frame. To date, freeze frame data is best extracted using brand specific diagnostic scanners, as used by dealers. Generic scanners, including OBD-scanners, may provide a small subset of the freeze frame. The Rotterdam Police has a number of brand specific diagnostic scanners available, and may contact dealers for any other case. Table 1, below, sums all actual case vehicles for which the Rotterdam Police tried to extract freeze frame data in the first six month of the year 2010. We must stress that the table overestimates the rate of success. Firstly, officers select cases for data extraction as they have reason to suspect success. Secondly, some extractions that did not yield relevant information were not registered. However, the table shows a vast number of instances where relevant information was found.

Tool	Times used	Speed found	Speed>0 found
VCDS (VAG group)	18	11	9
STAR (Mercedes)	3	2	2
DIS (BMW)	2	2	2
Peugeot Planet Office (Peugeot)	6	6	6
LEXIA (Citroen)	1	1	1
CLIP (Renault)	9	5	4
Total	40	27	24

Table 1: List of freeze frame extractions by the Rotterdam police, 2010 January to June

Freeze Frame validation

Till now (July, 2010) the Netherlands Forensic Institute has applied validation in two cases. In addition, NFI performed three crash tests that were not case related. One case as well as the crash tests has been described by Spek et al. in an article in "Verkehrsunfall und Fahrzeugtechnik", January 2010. A very short summary of the results is listed below, starting with the crash tests.

All three crash tests involved an oblique front to front collision between a BMW 318 Compact (E46) and a Volvo V70. The brand specific diagnostic scanners Volvo Vida and BMW DIS were used to extract freeze frame data. Vehicles had been installed with a switch, simulating a disconnected ABS-sensor wire, to ascertain at least one fault. The switch was set to be triggered by the impact. For three of the six vehicles involved, one Volvo (52 km/h) and two BMW's (55 and 112 km/h), freeze frame speed values were found at or just below the crash speed. In these three vehicles comparable speed values were found with the simulated fault as well as with other spontaneously occurring faults. For the other three vehicles extracted speeds were much less than the impact speed. One Volvo showed a speed of 8 kph and another Volvo showed a zero speed, whereas actual crash speeds were 18 kph and 22 kph, respectively. We did not find a specific reason for these results, although it may have to do with the relatively low crash speeds. One BMW showed zero speed for an actual speed of 73 kph. We found out that in the presence of one specific fault, an ABS pressure sensor wiring fault, any newer freeze frame only shows zero speeds.

The two validation cases involved a BMW, one M6 (E63) and one 328i (early E46). In both cases a moped crossing the road had collided against the front of the vehicle, respectively the right front corner and the left front corner. In both cases the BMW DIS system came up with specific fault codes, DSC h5DA1 for the M6 and ASC h12 for the 328i (hexadecimal fault codes). These fault codes indicate a suspected faulty signal from the respective front wheel ABS sensors. The freeze frame of this fault includes a speed and brake status. Speeds found after the accidents were 133 for the M6 and 120 for the 328i. We were able to introduce the same fault code by switching wiring, while driving, from the sensor mounted at the wheel towards a loose sensor. For the M6 at constant speed, freeze frame speed turned out to be quite exact. Under conditions of braking we found M6 freeze frame speeds to be about 10 percent too low, which we regard as the influence of wheel slip. The 328i was tested under constant speed conditions only, as that was the case during the accident. We noticed that freeze frame speed was reliable under these conditions, although truncated to the lower tenfold. The 328i validation case was finished with a court ordered crash test, similar to the accident situation. The crash test resulted in the spontaneous occurrence of the same fault code as in the accident (ASC h12), a freeze frame speed of 110 kph where actual crash speed was 119 kph, and a dummy throw distance similar to the accident situation.

The accuracy and reliability of the freeze frame speed is one issue, the other is linking the fault code to the accident. In both cases the specific faults were at least understandable in the circumstances of the accident. A first look at the freeze frame, however, would suggest that these faults had occurred not during the accident, but before that. The M6 stated an odometer value of six kilometers below the dashboard indicated odometer value. A second look would show identical odometer values in all freeze frames, including freeze frames related to air bag deployment. During our tests we learned the cause of the difference. It appeared that the odometer value as saved with freeze frames is updated once every eight kilometers. Thus, when the accident occurred, the odometer value update occurred six kilometers earlier. Additionally, we were able to prove from physical evidence that the left front wheel suddenly stopped rotating when a piece of metal from the moped penetrated the tire. We replicated this event electronically, by supplying a similar sensor signal to the ABS-module, and learned that it produced the same fault code (h5DA1). In addition we learned that this event would switch off ABS control of the single wheel involved, with control at the other wheels remaining active, explaining a single skid mark from the collision site to the rest position. The court and successively the appeal court were convinced that the freeze frame speed related to the actual driving speed.

The 328i freeze frame does not include an odometer value, but it includes a counter value, which showed a value of six for the accident case. We consulted the Dutch BMW distributor, who explained that the value indicates the number of key cycles (ignition on) since the fault. The freeze frame was extracted within the first key cycle after the accident, which would suggest that the fault was stored in the fifth key cycle before the accident. During our tests we learned, however, that not only turning on the ignition would increase the counter value, but also every communication request from the diagnostic device to the ABS module. The protocol as used in the original data extraction implied a total of five communication requests. Thus, the fault code must have been stored within the same key cycle as the accident after all. This, combined to the fact that the same fault code (h12) was found after the crash test, did convince us of the relation between the fault code and the accident.

EDR Validation

Rotterdam police encountered a Dodge Ram 1500 vehicle with an EDR installed, that was involved in a Fatal Collision. The EDR was extracted using the Bosch CDR tool. The EDR set includes a total of 50 speed samples over the 5 seconds before the accident, i.e. 10 samples per second. The first sample, five seconds before the accidents, showed a speed of 147 km/h. With the last sample, just before impact and under full braking, a speed of 86 km/h was registered. The Rotterdam court ordered the NFI to perform a validation for the case. Validation was performed in a joint cooperation with the NFI and the Rotterdam Police. The actual accident vehicle was

FIGURE 1: Dodge Ram 1500 accident vehicle used for validation testing

used for the tests, after some emergency repairs ; (figure 1). With the help of the ACM manufacturer, TRW Automotive GmbH, we were able to reconstruct and introduce an airbag deployment event (EDR trigger) while driving at high speed, without actually deploying any airbag.

We introduced a deployment and we did this while braking for a few seconds. EDR speeds were compared to both a wheel slip independent speed measurement (Correvit S350) and against CAN BUS speed. A result is shown in the graph below ; the test was reproduced four times with similar results. We found that EDR speed closely followed Can bus speed. Can bus speed appeared to be quite exact apart from the effect of wheel slip during braking. Tests revealed an anomaly, namely that the first EDR sample, stamped −5,0 seconds, may belong to the time of the crash. This anomaly was encountered in two out of four tests and was not found in the EDR data from the accident. (We consider the possibility that the anomaly was created by the test arrangement.)

EOBD fault codes

We did some directive tests involving the introduction of regulated emission related faults (EOBD). This was done by interrupting electrical wires to lambda sensors and fuel injectors for various vehicles. For faults introduced during a long enough period of constant speed, freeze frame speed matched driving speed. Tests under braking and acceleration suggest that these faults may be recognized with a delay by certain vehicles. The duration of this delay seems to depend on the nature of the fault code and the mode of driving. If the vehicle is accelerating, thus as the engine is producing high power, fault recognition seems much faster then while coasting or braking. Especially in the case of braking this phenomenon may cause the freeze frame speed to be lower or even zero. While accelerating after a crash, for instance in the case of a hit-and-run accident, freeze frame speed may be too high.

Developments

At this moment, the Rotterdam police and Launch Tech China are in the process of developing the “CrashCube”. This device will extract freeze frames from regulated emission related faults (EOBD) as well as brand specific freeze frame data from several vehicle manufacturers. The ambition is that all important modules, including the ABS/ESP module, the engine control unit, the airbag control unit and the instrument panel and the drive train control module can be scanned for all vehicles from model year 2006 and beyond. As the tool is designed as a forensic tool it will not delete fault codes or change module parameters, it will store its communication with the vehicle and it will output extracted data in a form that can not be tampered with. Data relevant for linking freeze frames to the accident, like the current odometer value and current internal clock time, are gathered as part of the standard protocol. At the time of writing this paper, we have a prototype available that can (only) scan EOBD freeze frames. This prototype has been succesfull, in the sense of finding a speed value, in 7 instances during the first 6 month of 2010.

In the course of the project, NFI and Rotterdam Police will co-operate in several freeze frame data validation excersises, similar to those discussed in this presentation. In this way we intent to gain a growing insight into the proper inter-

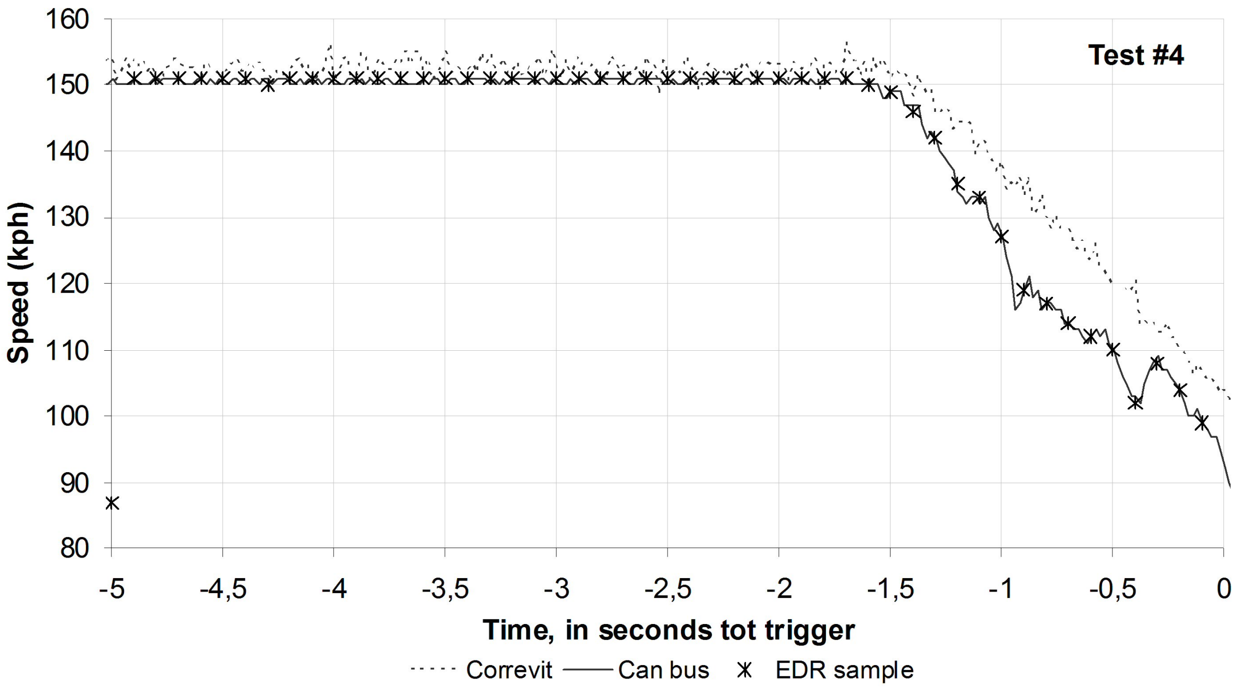

FIGURE 2: EDR validation test result

pretation of freeze frame data.

One specific type of fault code to focus on will be those related to fuel pump crash shutdown, as initiated by airbag deployment. We encountered such fault codes, with freeze frames, in a number of modern vehicles. Technically speaking these are not fault codes, but event reports packed as fault codes. The main advantage over other freeze frames is the straightforward relation to the accident.

Discussion

In the case of data extracted from an Event Data Recorder in a modern American car, the accuracy of speed information and its timing in relation to the accident are covered by USA law (49 Code of Federal Regulations part 563, paragraphs 7 and 8). Results of validation tests have been published for several vehicles and for several circumstances (e.g. Laurence et al., 2003, Niehoff et al., 2005). In the light of this, our validation exercise for the Dodge Ram Van as presented in this paper may seem unnecessary. Nevertheless a validation study for the specific vehicle model had not been published, the case was the first instance of EDR data use for a Dutch criminal court and it may be argued that American rulemaking does not apply to vehicles sold in the EU. And although not of relevance to the specific case, our tests may have exposed an anomaly.

In the case of data from fault code related freeze frames, there are no such regulations. One may expect that freeze frame speed is accurate in general, as the current technological state provides very accurate speed sensors (that is, apart from the influence of wheel slip). The main problem, however, is the relation between the accident on the one hand and the freeze frame on the other hand. Such a relation requires that some occurrence during the accident, such as wiring rupture, sudden wheel lock or engine stall, causes a module to promptly detect or assume a fault. Delayed fault detection, such as we expect for emission related faults, will cause an incorrect speed value.

We recommend that if interesting freeze frame data has been found in a case, an effort is made to assess the relation between the fault code and the accident. Freeze frame data should not be used, or at least very carefully, if such a relationship cannot be established. The latter puts the importance of data from vehicle electronics in its true perspective. In a certain fraction of cases, a freeze frame with a speed is found. In some of these instances only a “zero” is found as a value, although clear from physical evidence that the vehicle was driving. The remaining instances may be applicable for further investigation, which is costly and will not always be successful.

We may conclude that in cars, European and American alike, sensor data from the time of an accident may be captured and stored permanently. This is certainly relevant information that should be available for accident reconstruction, at least in criminal cases. The exact meaning of this information is design specific and therefore proprietary to the manufacturers of either the vehicle or the module, or both. The true meaning of such data may be exposed by means of reverse engineering, as we applied in the two validation cases involving BMW's. This is a sophisticated and costly effort that will only be successful in a certain percentage of cases. It is therefore not unimaginable that manufacturers will be compelled by court to take part in the investigation of specific accidents. A more desirable perspective, in our view, is the introduction in the EU of an Event Data Recorder (EDR) regulation. Similarly to the current US regulation, such an EU regulation should force the installation of an EDR, set a minimum standard for the data contents and its accuracy, specify the conditions that trigger the EDR and assure that a means for data extraction is available.

Keywords

Diagnostics, CAN BUS, Diagnosis, DTC, Speed, Braking , Velocity, Delta-V, CDR, EDR, Freeze frames, Modules, Electronic Control Unit, ECU, ABS, Airbag Module, OBD, DLC, DL16 connector, EOBD2, CrashCube.

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