CONNECTING BLACK BOX DATA AND DRIVING BEHAVIOUR OBSERVATION FOR BETTER UNDERSTANDING OF DRIVING BEHAVIOUR

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ABSTRACT: This paper presents two studies where the observation method "Viennese Driving Test" (Wiener Fahrprobe) was connected to the data of a Black Box (BB). The "Wiener Fahrprobe" was used to decode these BB data in order to identify special driving behaviour like hard braking, fast acceleration, sharp turning, etc.. Data from observation rides with novice drivers and self reporting test rides on standardised test routes in Brno and Vienna were analysed in this respect. With the help of the results gathered from the evaluation recommendations for future research and future application were established.

1 Introduction

Within two projects “Black Box – Novice Drivers” and “Black Box – Introspection” the observation method “Wiener Fahrprobe” was connected to the data of a Black Box (BB). Nowadays BB are used mainly for crash investigations but not for studying driving behaviour, although it might be a quite easy and cheap way to collect information about the driving style of individuals. The Wiener Fahrprobe should help to decode these BB data in order to define special driving behaviour like hard braking, fast acceleration, sharp turning, etc.. The future goal is to analyse driving behaviour by collecting BB data, understanding those data, and additionally give feedback to the driver or maybe the driving instructor based on the data, to make suggestions about improvements or information and/or training needs. The advantages could be that novice drivers could get a quick check on their driving behaviour by looking at the data of the BB. But not only for novice drivers improvements could be seen. Also while training or testing ITS applications the concrete interpretation of driving behaviour will help to assess the effects on the driving behaviour of such applications.

Several aims were defined at the beginning of the project:

1. Connecting both methods – BB & Wiener Fahrprobe
2. Find out what driving aspects BB data do reflect compared to data of the driving behaviour observation done by human observers
3. Identify special driving behaviour with the help of BB data (for instance fast acceleration, hard braking, fast turning)
4. Give recommendations for future research

5. Future goal: Improve driver education based on BB data that are easy to collect, given that thorough interpretation is possible
6. Future goal: Evaluate differences in the driving style with or without using ITS

To find an answer to all these questions a basic BB was used within the cars which were used for the observation of novice drives and the introspection rides. The BB registered accelerations in three dimensions. In parallel, either the driver should be observed (novice drivers) or he/she should observe himself/herself and note whether he/she remembered significant situations (introspection).

This paper is based on an internal HUMANIST paper [1].

2 Methodology

2.1 Viennese Driving Test (Wiener Fahrprobe)

The Viennese Driving Test [2, 3, 4] is an instrument for behaviour observation of drivers. This method gives researchers the possibility to get a structured impression of the driving behaviour of a person. The observation was done by one observer inside the car, sitting in the back of the vehicle. The observed person was asked to drive along a standardised route of between 17 to 20 km in length which included densely inhabited areas, and to a lesser degree rural roads and motorways. The test route was divided into sections such as intersections, motorway entrances or exits, sections of road between intersections, roundabouts, etc. in order to make the evaluation of the behaviour observation easier.

The behaviour variables were observed both in a **standardised** and in a **non-standardised** way: The observer used an observation sheet where erroneous types of behaviour were listed. One sheet per section had to be filled in. But also non-standardised variables like errors, explicit interaction/communication processes and traffic conflicts were noted. For each event a note had to be taken and the number of the sections where the event happened was added.

2.2 Black Box (three axes acceleration recorder)

Acceleration is one of the most accurate indicators for critical driver behavior. Based upon this awareness, CDV (Centrum dopravního výzkumu – Brno, Czech Republic) developed a very basic Black Box (BB) which saves data of acceleration on three axes {x, y and z} in relation to the time line.

The heart of the recording device (Black Box) is the Micro Electro Mechanical System (MEMS sensor) that works as a tri-axes digital output linear accelerometer. It includes a sensing element, and an IC interface element able to take the information from the sensing element and to provide the measured acceleration signals to the external world through an I2C/SPI serial interface. The sensing element capable of detecting acceleration is manufactured using a dedicated process called Thick Epi-Poly Layer for Microactuators and Accelerometers (THELMA) to produce inertial sensors and actuators in silicon.

The Integrated Circuit (IC) interface is instead manufactured using a Complementary Metal Oxide Semiconductor (CMOS) process that allows a high level of integration to design, and a dedicated circuit which is factory trimmed to better match the sensing element characteristics.

The MEMS has a full user selectable scale of 2g, 6g and it is capable of measuring accelerations over a maximum bandwidth of 2.0 KHz for the X, Y and Z axis. The device bandwidth may be selected accordingly to the application requirements.

The BB was located below the driver seat. The data were transferred and logged on a Laptop after the rides.

There were different reasons for using "only" a basic BB within the project:

- The project was designed as a pilot study to see if the connection between the two data gathering methods is worthwhile
- The costs of project has to be as low as possible
- The BB has to be easily transferred to different cars which were used in Vienna and Brno

2.3 Procedure of both projects

Both methods which are described here were connected to two projects.

Project Black Box – Novice Drivers:

This project was part of a dissertation carried out in the framework of the NoE HUMANIST [5]. In the frame of the dissertation several novice drivers were observed with the method of the Wiener Fahrprobe while driving a BB equipped car on four different test routes in Brno, Czech Republic and in Vienna, Austria. During these test rides data were registered with help of the BB.

The sample included 24 novice drivers in Brno (43 rides) and 7 novice drivers in Vienna (14 rides). All test rides were done during August and September 2006.

Project Black Box – Introspection:

Additional to the test rides with novice drivers, introspection rides were done in Brno as well as in Vienna. Employees of CDV and FACTUM drove on two of the test routes with a car which was equipped with the BB. The drivers were also observed and after each test ride the drivers recorded all noticeable situations themselves. The aim was, on the one hand, to compare the observations of the observers with the notices of the drivers and, on the other hand, to compare both notices with the data from the BB. This procedure should help to get more knowledge of the character of the BB data and what they mean in terms of actual behaviour in traffic.

Two test rides were carried out in Brno in October 2006 and January 2007 and two test rides were carried out in Vienna in February 2007.

The results and recommendations derived from both projects are reported in the following chapters.

3 Results and achievements

According to the aims defined at the beginning of the project, the following results can be reported so far.

3.1 Connecting both methods

To start with, it can be stated, that both methods could easily be connected. The BB only has to be implemented in the car before starting the observation rides. There is no further need for handling the BB since the data are recorded automatically, then. The use of the BB while observing driving behaviour is totally unobtrusive, it does not interfere with the behaviour of the driver, nor the one of the observer. Just the time of the beginning and the time of the entrance in a new section have to be noted by the observer on the observation sheet. This extra effort is necessary in order to make the connection of the BB data with the behaviour observation data possible.

During the project it turned out, that many "manually" registered behaviour aspects could also be identified with the help of the BB data. Types of behaviour recorded with both methods reflect acceleration, braking and turning performances. Additionally, with the BB data the observer receives a simplified impression of the overall driving style. As the observer never notices acceleration, braking and turning behaviour in a such a continuous and differentiated way as the BB can do, the BB reflect more thoroughly whether a person drives smoothly or more in a staccato style. Because of this extra information a more quantitative assessment of the driver is possible.

On the other hand, it is not possible to interpret the BB data without any additional information. E.g., the amplitudes in the graphs (see in next chapter) do not tell whether a person just drove into a curve very fast, or if he/she approached an unexpected object and had to swerve rather quickly.

Thus braking and turning performances that can be observed (Wiener Fahrprobe), can also be identified in the BB data, but BB data do not give any information about circumstances.

3.2 Driving behaviour reflected by the BB data

In relation to what was said above, the first step was to find out the meaning of the BB data, i.e., in which way do the data reflect observable driving behaviour. Graphs of about 15 test drives were produced which display the acceleration in the longitudinal axis (x-values) and lateral acceleration (y-values). The reason for using the data from only 15 test rides was that within the financial and schedule frame of this pilot study only a small sample of the test rides could be evaluated. Furthermore we did not deal with z-values (vertical accelerations, e.g., when driving over a hump) at this stage because of the same reason stated above. The data used for evaluation within the novice driver project was gathered from test rides with only one car.

If the amplitude on the **longitudinal axis** of the values goes up this reflects acceleration, and if goes down this means braking. Of course, also stand-stills can be identified, for instance because of a red traffic light.

With the help of those graphs the first statements about the driving behaviour can be made, for instance whether the acceleration behaviour of a driver is steady or not. If the amplitude goes rather steeply up and down all the time this means that a rather strong acceleration is always followed by a rather sharp braking manoeuvre and vice versa. Behaviour observation can give the additional information that, for instance, a hard braking of the driver occurred due to a red traffic light.

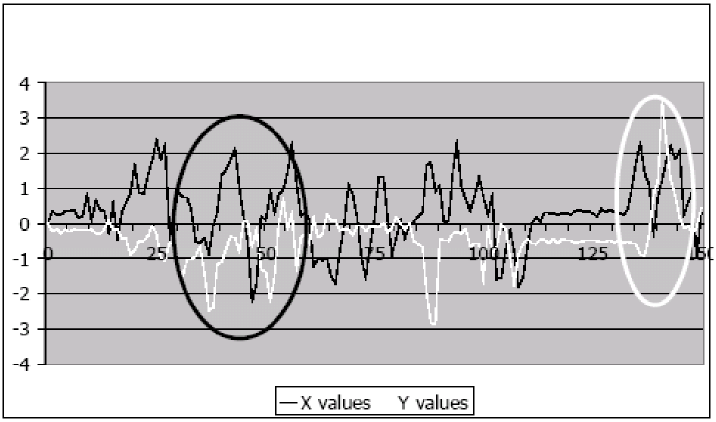
If the amplitude on the **lateral axis** of the values goes up it shows a left turn of the car, if it goes down it reflects a right turn.

The combined graph below shows the x- and y- values and displays the driving behaviour with respect to acceleration and turning.

Two situations could be described with the help of this chart. The **black circle** shows the acceleration and braking behaviour before and after two right turns. First, the driver slows down before the right turn (seconds 33 till 35 – black line) → turns right (seconds 35 till 37 – white line) → accelerates after the turning manoeuvre (seconds 37 till 42) → brakes again for the next turn (seconds 43 till 46) → turns again right and accelerates during the turn (seconds 50 till 55).

The second situation describes the behaviour of the driver after a red traffic light, marked with the **white circle**. The driver waits at the traffic light for about 20 seconds (seconds 112 till 132) → after the traffic light has turned green the driver starts to accelerate and drives into the intersection (seconds 133 till 136 – blue line) → slows down as a preparation for the turn, turns left and accelerates during the turn (seconds 136 till 140).

Graph 1: Acceleration to the front (x-values) and acceleration to the side (y-values) for 150 seconds

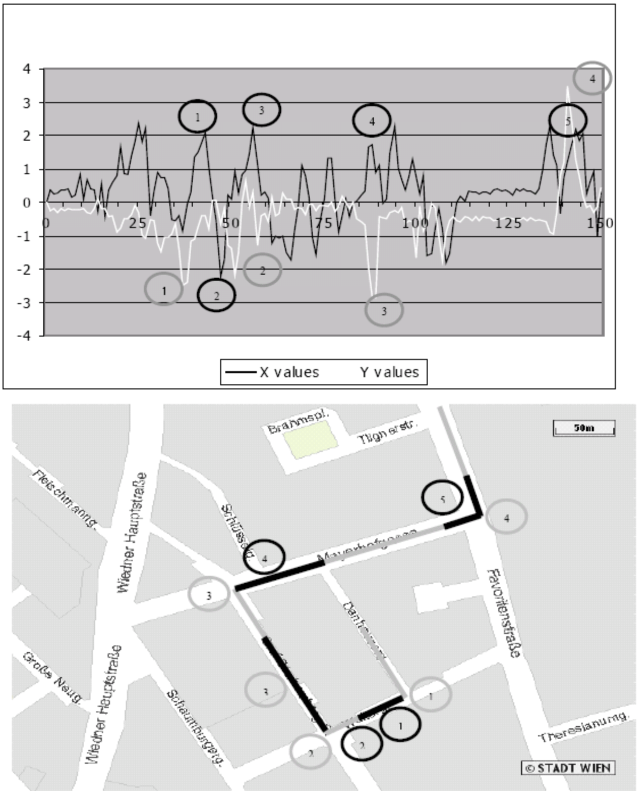


By looking only at the graphs it is of course not clear where on the test route these situations occur. Therefore several self-introspection rides were carried out with employees of the two institutions working within the project. The aim of these rides was to describe the test routes according to turns, intersections, etc., and the driven time between those sites. Also some hard braking and fast acceleration manoeuvres were carried out on purpose in order to identify how such behaviour is displayed by the BB data. This is necessary in order to be able to interpret the graphs, because it makes clear what the amplitudes mean in reality. With the help of these descriptions the sites that test persons have to drive through can be identified. In this way special events like hard braking or fast acceleration because of, e.g., an error of the driver become better identifiable, by amplitudes on the x- or the y- axes in sections where there should not be any deflections.

In a next step the charts we had received were analysed accordingly. The following graph 3 shows 150 seconds of the test route. Graph 2 below displays acceleration and braking behaviour, and right or left turns. The **black circles** in both graphs show accelerations and brakings for "special" occasions, while the **grey circles** show the turning behaviour.

By comparing the graphs derived from the BB data (graph 3), the notes of the driving behaviour observation (table 1), and the map showing the test route (graph 2), turning behaviour at intersections, accelerations and brakings before and after these intersections, and also standstills at traffic lights, can be identified.

Graph 2 & 3: Map of the first part of the test route in Vienna, acceleration in the longitudinal axis (x-values) and lateral acceleration (y-values) for 150 seconds



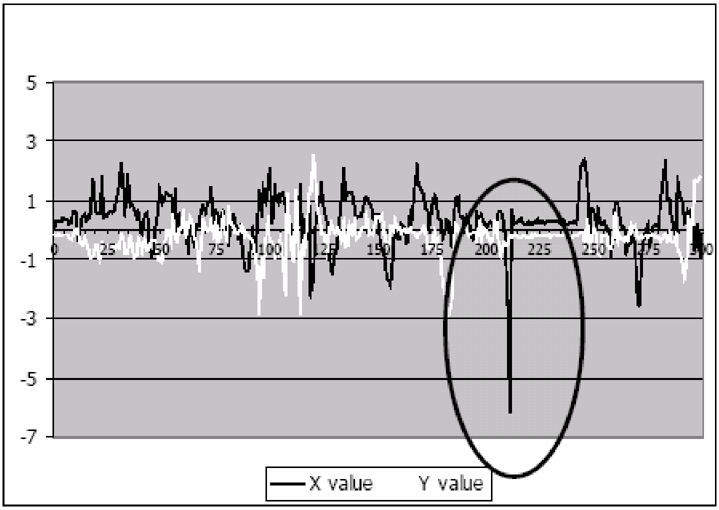
Source: www.wien.gv.at [6]

1	First right turn	1	Acceleration after first right turn
2	Second right turn	2	Braking before second right turn
3	Third right turn	3	Acceleration after second right turn
4	First left turn	4	Acceleration after third right turn
		5	Acceleration during first left turn

3.3 Identification of "special" driving behaviour within the BB data

As said, not only the behaviour before and after turns can be identified, also special situations can be identified when comparing BB data and behaviour observation. For a demonstration, a hard braking manoeuvre was selected. The following graph shows a cut-out of the data from a novice driver and describes a hard braking manoeuvre before a traffic light (**black circle**). The observer marked this behaviour in her notes as "maladjusted speed before traffic light". Several other situations like the above described were found in the BB data as well as in the observation notes.

Graph 4: Acceleration on the longitudinal axis (x-values) and lateral acceleration (y-values) for 300 seconds



3.4 Problems

Unfortunately, not all graphs can be interpreted that easily, and the comparison with the behaviour observation notes and the street map did not work for all drivers. Also the comparison of different charts of drivers displaying the same section of the route was hard to interpret. The main problem was that the BB used at this moment is only saving acceleration data on three axes and the corresponding time (seconds), but cannot take up and reflect the exact position of the driver. Therefore, from the data it is sometimes not clear where exactly on the route the driver is located, and what the circumstances there are. Thus, the comparison with other drivers becomes complicated because test persons drove with different speeds and therefore arrived at sites at different times. Also the fact that the test persons have to wait at a different number of traffic lights makes comparisons of the graphs difficult. For example, some drivers were at the first left turn within two minutes, while others needed two and a half minutes to get there. The longer the test persons had been driving, the larger the bias became. Without information about the driven meters, or GPS data, this problem cannot be solved.

4 Recommendations for future research

Because of the results of these two projects and with the knowledge gained about how to interpret the BB data with the help of the Wiener Fahrprobe, it became clear that further research is needed. Especially, the preconditions for comparison of the data of different test rides should be improved in the future. The reason for problems there was that no continuous variable which would make the data comparable, such as meters or other positioning parameters, could be included in the BB measurements. Furthermore, there are still some more questions about the correct meaning of the data to be answered. For example: What does the difference between an amplitude which goes up to the value of 2g and an amplitude which goes up to the value of 3g mean? Would only a value of 5g mean that the behaviour was "really" inappropriate? Where does the boarder go?

Because of these questions several recommendations for further research were formulated. The aim of these recommendations is to make the data collection more precise and better comparable in order to be able to interpret the outcome of the data more thoroughly:

<u>Recommendations concerning Data collection</u>

The knowledge of the actual **speed** will help to interpret the data. Speed is one criterion for the classification into appropriate and inappropriate behaviour.

Similar to speed, also a **distance measurement** will be needed. As already said comparisons of the graphs were sometimes difficult because some of the test persons drove faster or were waiting at red traffic lights more often than other test drivers. With the knowledge of the driven meters the data of all test rides could be compared more thoroughly and easily. The most efficient, but also the most costly solution would be to include GPS and/or XL-meter data in the data collection of the BB.

- During the analyses it also become obvious that the measuring of data was not well **calibrated**, also depending on where the BB was put into the car or which car was used. Especially a comparison between the data from the novice driver project and the introspection project, were different cars where used, showed quite different values on the x- and y-axis while driving on the same route. Within the novice driver project it was also tried to put the BB in the trunk which had also an effect on the data collection. A calibrated data collection will also make the resulting data better comparable.

<u>Recommendations concerning interpretation of the data</u>

- More test- and introspection rides have to be carried out in order to gain **more knowledge about the meaning of the data** – i.e., what different types of behaviour and interaction are reflected in the graphs produced by the BB. And what are the critical values where one can say that they reflect erroneous or dangerous behaviour. This applies for acceleration as well as for the driven speed in curves.
- The behaviour **observation has to be better adapted** to the content of the test rides with the BB, as well. Many of the behaviour variables which are observed and noted with the help of the Wiener Fahrprobe do not necessarily have to be taken care of at this point of the project. Especially, behaviour which has nothing to do with longitudinal and lateral acceleration can be eliminated from the observation sheet. This means that for instance the use of the indicator does not have to be recorded by the observers, in this phase. On the other hand, better specified notes about speed behaviour in relation to circumstances (acceleration, speed in curves) need to be included.

5 Conclusion

In general it can be said that the behaviour observation and the data collection method with a BB can easily be connected, and that they in principle can be seen as complements of each others. The data of the acceleration on the three axes have been visualised with the help of graphs and compared with the notes of the behaviour observation. With the combined methods it was possible to assess special types of behaviour like full braking at curves as well as other sites could be identified and better explained and described.

Some difficulties occur when one only relies on BB-data and if one wants to exactly determine the changes in the stimuli for the drivers, and to transform such aspects into readable data that represent realistic conditions. No criteria could be introduced that allowed to interpret exactly when a certain type of acceleration on one of the axes is critical, meaning that an error or dangerous behaviour occurred, like "really" driving too fast through curves or braking too hard. So it was not possible at this stage of the project to say that one full braking was more dangerous than another one. Only the statement that it was a full braking could be made. To describe such mistakes no secure statements can be given by only looking at the graphs. The connection with the behaviour observation is needed to finally describe, and to understand, the behaviour of the driver.

However, one of the future goals is that the graphs which display the BB data should be used as a stand-alone in order to describe driving behaviour. The aim could be to give driving instructors additional, concrete and demonstrative material in order to assess and explain the driving style of a learner. On the other hand it could be possible to assess the driving style of novice drivers and give further recommendation about his/her driving style. Another possibility for the use of such stand-alone graphs could be to assess the driving style of drivers while driving with and without ITS in the car. As it was shown in the results of this feasibility study two graphs could easily be compared and different behaviour could be evaluated. This would also include the effects on the driving style while using ITS.

To conclude, it has to be stated that the results of these two (pilot) projects are very promising concerning the future goal of improving driver education by "proving" with the help of BB data that erroneous or dangerous driving behaviour really has occurred. However, to achieve this it will be necessary to complete the BB data registration with other measurements, like, e.g. GPS and XL-meter, and to add site descriptions to the acceleration data graphs. This will help to give more detailed, more thorough, and better comparable descriptions of the test rides.

6 References

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