STUDY OF IN-TRAFFIC VEHICLE BEHAVIOUR, BASED ON GPS AND RADAR DEVICES

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ABSTRACT

RADAR devices are commonly used for on-board or fixed point speed measurements. GPS devices, now more affordable and precise, can be also successfully used for the vehicle behaviour study. Algorithms and computer programs were designed for GPS data real-time- and post processing.
This paper shows some possibilities to collect and process road traffic data using that type of devices. The presented results – as velocities, accelerations, road congestion or other traffic characteristics – are obtained by original methods, using CAD programming. The CAD software helps to easily store, process and graphically present all the input and output information.
The methods described in this paper can be used to analyse and manage the traffic flows.

Keywords: RADAR, GPS, data processing, statistics, road traffic

1. INTRODUCTION

The motor vehicles represent today the main mean of transportation in the world. Ensuring efficient road traffic is an important issue of present life. The management of the road traffic suppose the knowledge of its properties, which are statistical characteristics often combined with deterministic influences. To study the road traffic properties, its main features, the needed data about vehicles movement can be gathered from external or on-board sources. More than often, by the acquisition process, this data arrive into computers, devices with impressive possibilities to store, process and communicate information. The vehicle dynamics- or road traffic data provided from sensors are normally subjected to real-time primary processing followed by supplementary post processing performed in laboratory.

The road traffic is influenced from one side by the each vehicle-driver pair characteristics (dynamic and other performances, driving abilities, etc.) and by other side by the vehicle-vehicle- and vehicle-road interactions.

In this paper are presented some methods designed and used by the authors to collect and process road traffic data using RADAR and GPS devices for fixed-point and mobile acquisition.

2. RADAR MEASURING DEVICES

To obtain the traits of traffic flows, mainly as statistical characteristics, the data must be obtained for many places and many vehicles for long periods of time. To realise that, it is necessary to use different devices and to combine the different kind of the gathered data. The radar devices ensure obtaining data for many vehicles, but in one place (or some places, if more radars are used), while GPS devices permits collecting data for one vehicle (or some vehicles), but in many places (diff. routes).

2.1 Short presentation of the radar devices

The instruments used in the presented fixed-point measurements are unmodulated continuous-wave radar-devices [8]. To measure vehicle speeds, in contradiction with their name, these devices aren't using the radar principle (measurement of the time needed by an electromagnetic wave to reach an object and come back after reflection), but the Doppler effect (the change in frequency of a wave transmitted to- and reflected by an object moving relatively to the source of the waves). After calibration, these equipments are also able to estimate the dimensions of the passing vehicles.

Figure 1: DataCollect SDR radar traffic classifier

Mounted in fixed position in the proximity of the road (figure 1), and using electric batteries, the devices can work long periods of time. The measured values are stored in internal memory and then can be transmitted by a communication interface as files in text- or proprietary data formats. Another feature of these radar devices gives the possibility to realise in-place some statistical calculations.

Here are some characteristics of the radar devices used in this study:

- Type: DataCollect SDR traffic classifier
- Sensor: 24.125 GHz, 5 mW output
- Speed range: 3-250 km/h
- Length resolution: 0.1 m
- Memory: 128 MB

In a non intrusive and discrete way, the SDR gets and stores data for all passing vehicles in two directions (max. 1.6 million vehicles in up to 21 days of operation with intelligent power management).

The device setup and monitoring and the data retrieval can be done easily either with a PDA or via wireless connection (GPRS or Bluetooth), without disturbing the traffic flow and ensuring by that more realistic speed information [7].

2.2 Primary processing of radar traffic data

More radar-devices were used for long-time traffic measurements in four Romanian county-capital cities. The input data obtained this way was used in studies regarding the optimisation of the traffic flows or the evaluation of the global noise level in these cities [6], [7], [11], [13], [14].

Each record of the radar-device text-files contains the next data:

- The vehicle speed, in km/h.

- The time moment of the vehicle arrival, including year, month, day, hour, minute and second.
- The apparent vehicle length, that, by a calibration process, can by corrected to indicate the approximated vehicle length.
- An index with two possible values (1 or 2) to indicate the vehicle is approaching to- or is moving away from the radar device. On two-ways two-lane roads, this index was used to separate the traffic flows on the lanes.

The text-files were imported in Microsoft Excel for primary and statistical processing. Firstly, using the corrected lengths, the vehicles were conventionally divided in three classes: B – bikes (small vehicles), C – cars (medium vehicles) and T – trucks (long vehicles). Also, for each vehicle the arrival moment was included in a time interval (a quarter hour or an hour).

3. GPS MEASURING DEVICES

2.1 Short presentation of the GPS devices

The GPS technology becomes more spread on the commercial market. Different applications are already offered, mostly used to guide and track vehicles or pedestrians, [9]. Beside the existent applications, mainly for on-board navigation systems, new others start emerging. This tendency is favoured by the down scaling of the electronic devices, price decrease and performance augmentation of GPS receivers, [2]. But using GPS devices for road traffic study presents other two big advantages:

- the existence of a very precise and universal time information;
- the existence of tree-dimensional position data, that can be derived to obtain other useful information as height, slope or, combining with time data, velocity and acceleration.

The GPS system consists ([2], [3]) of:

- a network of convenient placed satellites on the Earth ionosphere, that, by high-frequency radio waves, transmit, all simultaneously, a very precise time signal and, individually, their position and correction information (the both parts of the signal forming the so-called Coordinated Universal Time);
- the ground stations, that are used to control the satellites and update the information;
- the receiver, that based on the Coordinated Universal Time signals transmitted by at least four satellites is able to compute its (receiver's) longitude, latitude and altitude anywhere in the world and associate these with the Universal Time; the location coordinates and the time can be used further by the receiver to compute its velocity; all or part of these primary processed information are normally sent to a computer or other device for further processing.

For the traffic studies were used four different GPS devices with tracking possibilities, three of them being presented in figure 2:

- Garmin GPSMap 60CSx, a handy and light-weight commercial device (1 sample per second recording rate, able to compute speed);
- Garmin GPS 18x-5Hz, a precise very small device (5 sample per second recording rate); connecting this to a notebook (figure 2) and realising an original software for real-time communication, data storing and primary processing (speed

calculation, data filtering and trajectory graphical representation), the authors realised a valuable, affordable and easy to use GPS data logger;

- Racelogic VBox 100, a professional device (with the recording rate up to 100 sample per second, able to compute speed and acceleration and graphical represent the gathered data in real-time).

Figure 2: Three GPS devices used in measurements: left – Garmin GPSMap 60CSx; middle – GPS 18x-5Hz; right – Racelogic VBox (the blue case) and the first two devices

2.2 Primary processing of GPS traffic data

The first type of GPS data processing consists in the computation of all useful geometric and kinematic information, as trajectory, height, road slope, velocity (with magnitude and orientation), turning radius, acceleration (with magnitude and orientation). Using some assumptions, it can be also estimated the vehicle heading and the longitudinal and centripetal components of the acceleration, [3]. To do that, the programming possibilities of the Autodesk Autocad software were chosen, mainly for two reasons:

- the abilities of its Autolisp programming language to handle and process lists;
- the large freedom and possibilities to work with three-dimensional graphic objects.

The useful geometric and kinematic information are stored in two types of lists, as track point properties and track line properties, [2], [3]. For example, the speed can by an instantaneous-value stored as point property or a mean-value of a trajectory-segment stored as line property.

Depending on the processing stage, the geometric and kinematic values may exist or not, that increasing the computation rapidity and reducing the amount of memory space need for data storing (it is possible to treat millions of GPS records). Another advantage is the freedom to add new information as properties in the lists, if new ideas or needs of processing may appear.

This open data structure facilitates the improvement and development of the procedures used to manage GPS data, for example to study road traffic characteristics. Compared with the state from references, new elements were added:

- a graphical user interface (GUI);
- new software procedures, which permit to select only part of the GPS data or to retrieve and further process geometric and kinematic information directly accessing graphical objects, as plots, lines or points, already existent;
- different possibilities to filter the numerical data.

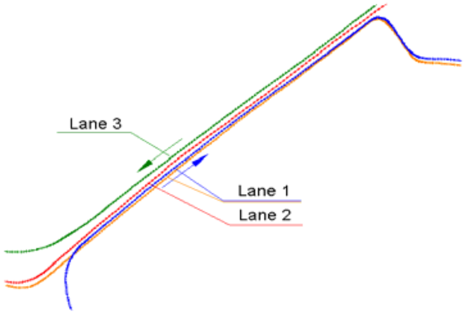

Figure 3: Graphical representation of four vehicle-passages trough a same road sector on three different lanes

The accuracy, repeatability and precision were also verified for GPS receivers and the conclusion was that, by this point of view, this kind of devices is suitable for traffic studies. For example, figure 3 shows vehicle trajectories recorded four times, in different days, on the same 200 m long straight-line road-sector. As can be seen, the repeatability and the parallelism of the trajectories are good enough. The estimated maximum error for the sector is of about 2 m.

4. RESULTS OF TRAFFIC STUDY

4.1 Results obtained with radar devices

In order to suggest modalities to manage the increased road traffic, the specialists must to know the main characteristics of the traffic flows, for long periods of time and in many points of the road network. One very important factor needed for good road management decisions is the rate of the traffic flows, i.e. the number of different vehicle types passing in a certain place in a considered time interval.

Figure 4 presents the temporal evolutions of the flow rates corresponding to an entering into a county-capital intersection. The intersection, located in the city centre, was monitored in a summer day for 6 h 45 min long. On a single line it were recorded 1396 vehicles, from which 82 categorised as bikes, 1214 as cars and 100 as trucks. The proportion of bikes, cars and trucks can be easily observed from the figure.

As expected, the rates change with respect to the day moment, the maximum variation (about 60%) being observed in only 1 hour, in the interval 14:30 – 15:30 PM. It can be also noted that more small vehicles (from which most are bicycles) are observed in the morning, before 11:15 AM, when the heat it is not yet installed.

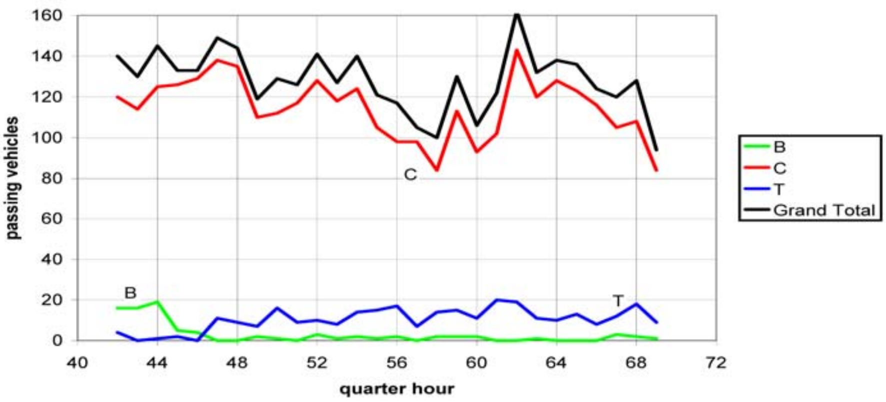

Figure 4: Measured one-lane traffic-flow rate

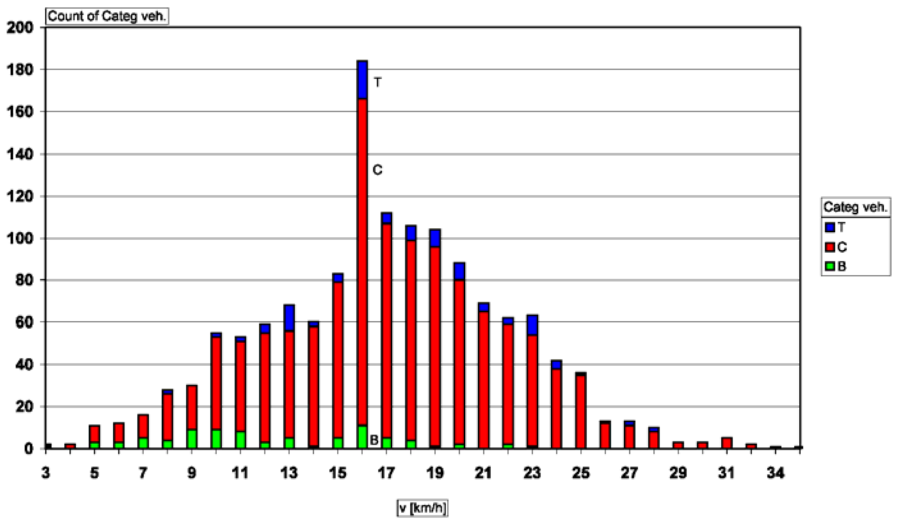

Figure 5: Statistics of passing vehicle speeds

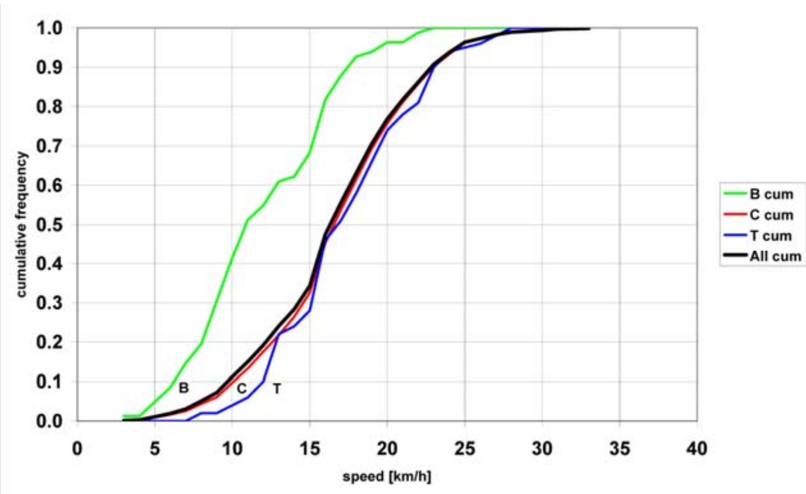

Figure 6: Experimental repartition functions (cumulative frequencies) of vehicle speeds

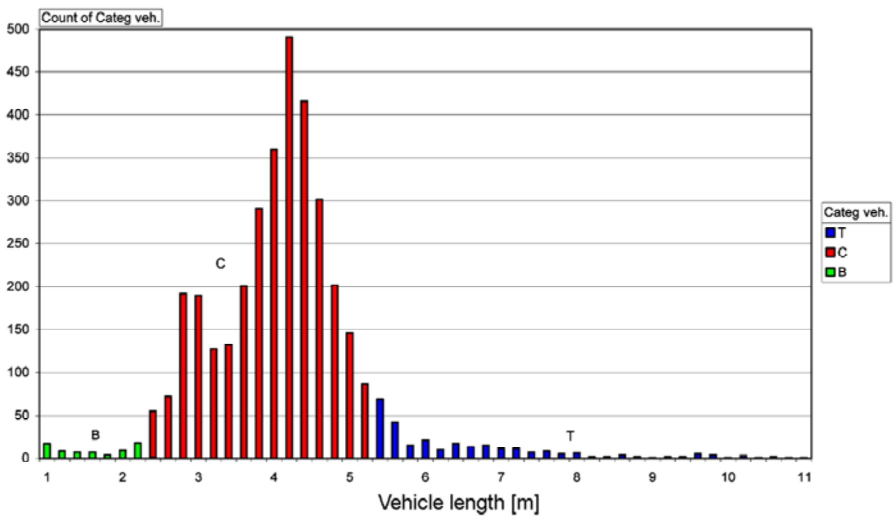

Figure 7: Statistics of passing vehicle lengths

In figure 5 it is showed the spectrum of the vehicles' speed when these enter in the same intersection. This almost respects a normal (Gaussian) distribution, with a evident maximum at 16 km/h.

Using the same data, the experimental repartition functions (cumulative frequencies) of vehicle speeds were also computed, as are presented in figure 6. In the analysis of the intersection flows, big importance presents the value of the speed that is not exceeded by 85% of the vehicles passing through that intersection, [1]. It considers that this value must never exceed the legal speed. The mean speed for all the vehicles, which is 16.9 km/h in this case, is another important characteristic of the pair intersection-type of traffic flow.

The spectrum of the vehicle lengths, for a more congested intersection (also in the city centre), can be seen in the figure 7. It was realised counting a total of 3639 vehicles in 7 hours, from which 88 bikes, 3261 cars and 290 trucks. The spectrum maximum was at 4.4 m length, while the mean length was 4.2 m.

The mean speed for this intersection was 33.1 km/h, twice times bigger as for the first intersection.

Such presented data can be used for different calculations and decision regarding intersection geometry, traffic lights cycles, speed limitations, road durability, chemical or noise pollution and others.

4.1 Results obtained with GPS devices

In the last years, the authors of this paper have imagined and putted in practice new applications for GPS devices, in fields as:

- evaluation of vehicle dynamics (based on measurements), [2], [3], [5];
- evaluation of vehicle fuel consumption (based on measurements and some parameter estimation), [3], [5];
- estimation (based on repeated measurements) of road traffic parameters as congestion ([2], [6], [7], [11], [14]), chemical pollution ([6], [11]) and noise ([4], [6], [13]).

Detailed presentation of the primary data processing algorithms was indicated in [3]. Particular procedures were also presented in [3] and [5] for the estimation of vehicle dynamic behaviour and in [2] and [4] for the traffic congestion and noise.

The processing of the data recorded by on-vehicle GPS devices starts normally with the graphical representation. Figure 8 presents, as functions of time and distance, the evolutions of driving speed and acceleration when vehicle travel in a congested big city. The left side of the figure shows the probability distribution functions for these two parameters, able to statistically characterise the vehicle kinematics in city traffic (small slope assumed). If the route length is long enough, the probabilistic functions maintain almost the same aspect, as figure 9 demonstrates.

If a more detailed statistics is intended, the bi-parametric probability distribution function can be used, that indicates the probability for the vehicle to be driven at certain values for speed and acceleration. Examples of such bi-parametric probabilities are presented in figures 10…13, for all being used the same acquisition frequency of 5 samples per second. Figures 11…13 show GPS-based data obtained recording the vehicle behaviour in different real and representative traffic conditions, respectively: urban route (fig. 11), combined urban- and sub-urban route (fig. 12) and mountain twisted route (fig. 13). The first two figures correspond to congested big-city traffic, while the third to mean-congestion traffic.

The left side of these three graphics present the shape of each recorded route. This is possible due to the GPS information. More than that, the presented software maintains, if is needed, the full connection between the function on time, the function on distance, the route shape and the representation on a geographical map.

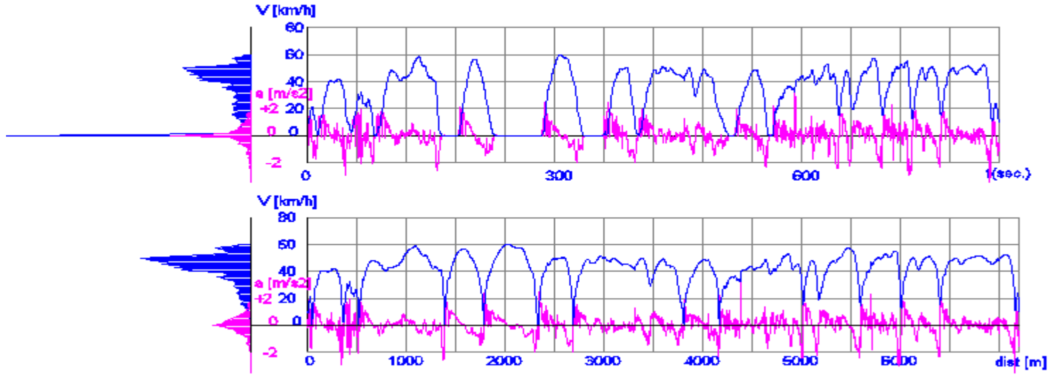

Figure 8: GPS-obtained speed and acceleration plotted as functions of time and distance

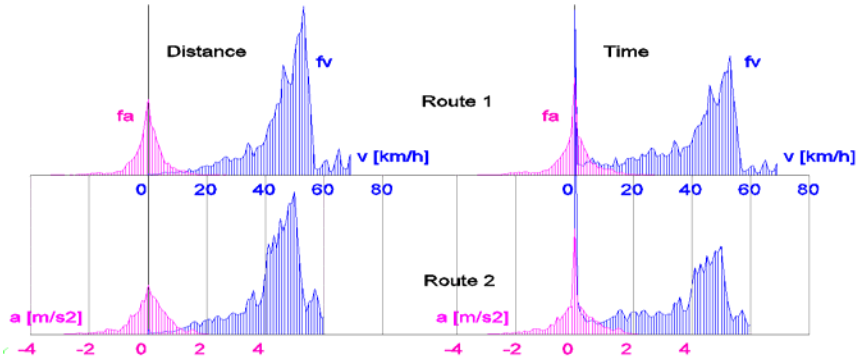

Figure 9: Two experimental mono-parametric probability density functions of vehicle speed and acceleration – same urban route, different moments

As is well known, for different world regions are some standardised driving cycles, used to compare different vehicle brands for some performances as fuel consumption, pollution, driveability or others. As figures 10…13 demonstrate, there are very significant differences between the spectrums of the bi-parametric probability distribution function for the standardised European Driving Cycle – EDC (figure 10) and the real driving conditions (figures 11…13). For that reason, the manufacturers are obliged to analyse such statistical data so that their motor vehicles to perform well in a big diversity of traffic conditions, ensuring this way the customer satisfaction.

5. CONCLUSIONS

This work presented some modalities, imagined by the authors, to combine the use of fix and mobile, RADAR and GPS devices, to obtain valuable road traffic data, absolutely necessary for the traffic engineer in order to respond to the contemporary challenges of road traffic management. Also, several results, obtained in road tests, were presented. The presented methods and results already constitute a data base to be used in future traffic studies.

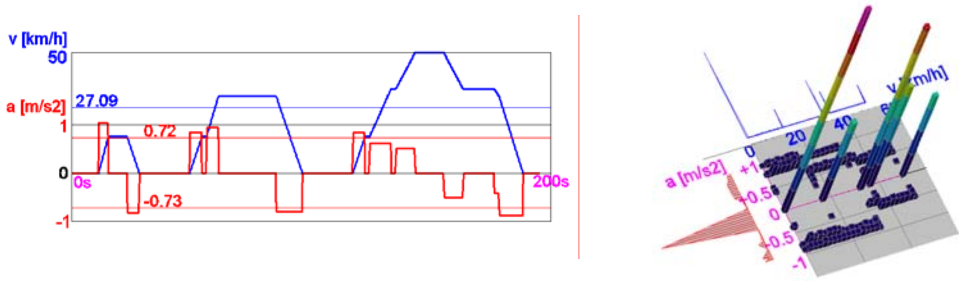

Figure 10: Mono- and bi-parametric probability density functions of vehicle speed and acceleration – EDC (European Driving Cycle)

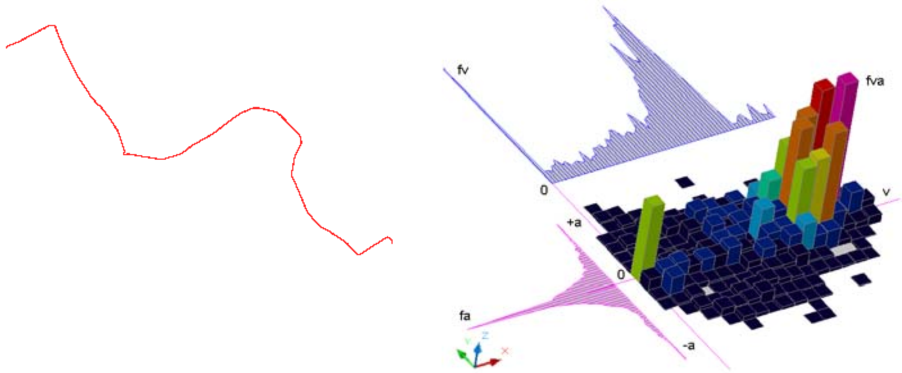

Figure 11: Experimental mono- and bi-parametric probability density functions of vehicle speed and acceleration – urban route

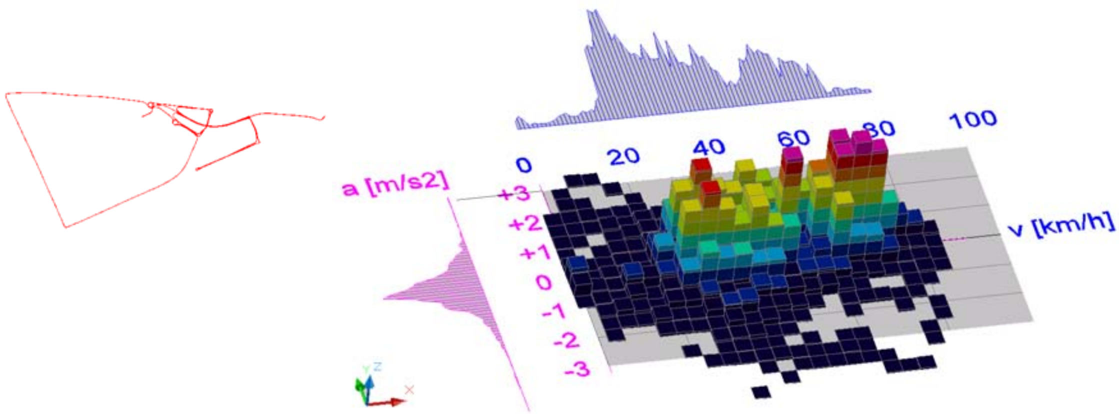

Figure 12: Experimental mono- and bi-parametric probability density functions of vehicle speed and acceleration – combined urban- and sub-urban route

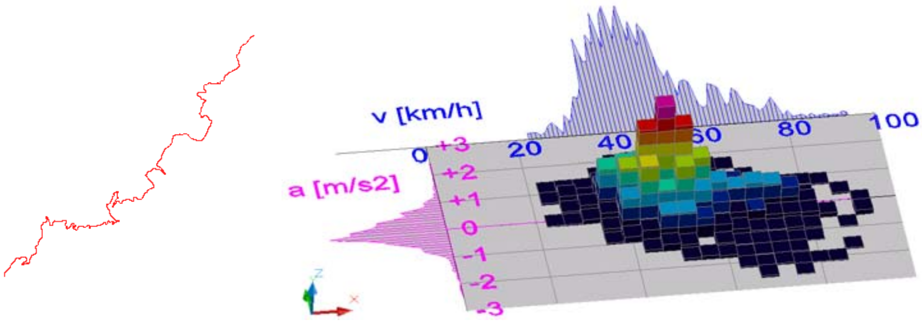

Figure 13: Experimental mono- and bi-parametric probability density functions of vehicle speed and acceleration – mountain route

6. ACKNOWLEDGEMENT

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