A HEAVILY INSTRUMENTED CAR FOR NATURALISTIC DRIVING RESEARCH

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Abstract: Heavily Instrumented Cars (HICs) are vehicles equipped to record a large number of data from a car, the driver of this car and the environment around the car while it is being driven around. Altogether, the data collected aim to provide a complete picture of the system composed by the three sources aforementioned so that hopefully most of specific questions, that a researcher might be interested in, could be answered. In a Greek small scale field trial conducted within the framework of the European project PROLOGUE, a HIC has been used. The car is equipped with an electronic unit (gateway) that receives information from the vehicle (CAN bus) and the information is stored to the data logger. CAN bus data include gas/brake pedals position, longitudinal speed/acceleration, yaw rate, steering angle, lights/wiper status, external temperature. The same logger stores GPS data. A frontal ACC radar enables recording distance and relative speed of the leading vehicle. Three synchronised cameras are mounted on the vehicle depending on the study requirements (e.g. frontal, face and rear view).

Keywords: HEAVILY INSTRUMENTED CAR, NATURALISTIC DRIVING, CAN BUS DATA, DRIVER BEHAVIOUR, WARNING

1. Introduction

Heavily Instrumented Cars (HICs) are research vehicles that record a large number of data from the driver, the car, and the surroundings in a continuous way. HICs provide different sources of data: numerical driving parameters, video data from the driver and the surroundings, eye movements from the driver and geographical data, etc. In summary, HICs record as much information as possible about what happens inside and outside the car when it is driven by participants of a naturalistic driving (ND) study. This aim contrasts with the approach of using low instrumented cars (LICs) for naturalistic driving studies where typically a smaller number of measures are taken and the equipment used can be installed in the cars of participants.

The aim of naturalistic driving studies is to observe unobtrusively the behaviour of drivers (Backer-Grøndahl, et al., 2009). However, notice that “observation” and “unobtrusive” are two words with somewhat conflicting meanings. Once a driver is being observed, this potentially interferes with his normal behaviour since he/she is aware of being observed. The extent of such interference is, however, a matter of debate, as it has been claimed that drivers seem to forget very quickly that their actions are being recorded and often exhibit behaviours that seem to be “natural”. Nevertheless, it still seems intuitive that drivers will exhibit at least some level of behavioural modification when they know they are under observation and that this may result in an absence of extreme behaviour such as risky or aggressive driving that may otherwise have been present.

A goal of naturalistic driving studies is to reduce the interference making the observations as inconspicuous as possible. Thus, researchers equip the participant’s own cars with devices hidden from the participant`s view (Backer-Grøndahl, et al., 2009). When cameras are used to observe the driver and his surroundings, they are installed as unobtrusively as possible so that the participants effectively forget about their presence. Other more sophisticated instruments, such as eye movement recorders, often require a significant amount of adjustment and set up for each participant. However this is a one off activity and once undertaken does not need to be repeated during the course of the study. It is however not possible to discreetly install this equipment since it is necessarily dashboard mounted in the driver’s field of view. Hence the naturalistic aspect of the study may suffer as a consequence. Finally, other provisions may be undertaken such as the identification of the driver before each journey, subjective measures such as questionnaire or travel diaries, and specific instructions given by the experimenter, etc. that may lead the studies still further away from the naturalistic grounds that may be required for the specific research question.

HICs as a research instrument for ND studies impose a number of specific restrictions that may jeopardise the spirit of such studies. Thus, letting participants of a study drive an HIC car may conflict so strongly with the goal of unobtrusiveness that it may be argued that any study carried out with an HIC will hardly meet the requirements of naturalistic driving. The idea of “naturalistic” and “unobtrusive” driving studies might indeed be unreachable. However, any naturalistic study should be analysed individually in order to understand which aspects of it are actually natural and which are not in order to carry out the right generalizations from the data recorded to real life.

The goal of this paper is to provide a description of Hellenic Institute of Transport HICs with the purpose of providing an overview of the different capabilities, solutions, and technology used in European research studies

2. The Instrumented Vehicle

HICs are vehicles equipped with a variety of systems in order to record a large amount of data from a car, the driver and the environment around the car while it is being driven around. The data collected aim to provide a complete picture of the system composed by the three sources aforementioned so that hopefully most of specific questions that a researcher might be interested in could be answered.

The vehicle CERTH/HIT is using is a Lancia Thesis 2.4 Emblema. This test vehicle and its recording systems have been an internal project of CERTH/HIT with Centro Ricerche FIAT S.C.p.A. (CRF) in Italy.

Fig. 1 *CERTH/HIT instrumented vehicle.*

The vehicle has been equipped with the following devices:

- Basic electrical equipment to manage the power to all additional equipment described hereafter; in particular this point cover auxiliary battery, fuses, relays, switches and lamps to configure and monitor the system.
- An additional electronic unit (gateway) that retrieves

information from the vehicle (CAN bus).

- Availability on the CAN bus of data regarding the vehicle (gas, brake pedals position, longitudinal speed/acceleration, yaw rate, steering angle, lights status, wiper status, external temperature).
- A frontal ACC radar to acquire information about the leading vehicle (distance, relative speed); these data will be available on the CAN bus network.
- An industrial PC for data acquisition and real-time data processing; the PC includes:
    - Main unit (case main-board, video card, LAN and CAN card)
    - LCD Monitor, keyboard and mouse installed in the rear seat for the operator
    - Windows Operative System and Basic Software Licenses (CAN included)
    - Application software for sensor data acquisition, recoding, display and processing
    - A small (7”) LCD VGA screen installed over the vehicle dashboard to display data to the driver.
- A Lane Departure Warning System based on image processing which exports lane data on the CAN bus.

2.1. Prototype Architecture

The architecture of the prototype has been designed taking in account the possibility to expand the actual system with additional subsystems. A first block diagram of the architecture is shown in Figure 2. The basic communication network between subsystems is based on automotive standard CAN bus.

An ECU (Electronic Control Unit), named VIDAC (Vehicle Integrated Data Acquisition and Communication) developed by CRF, interfaces the system with all vehicle signals; the VIDAC is also in charged of managing power for other subsystems. The main sensors of the system, the Frontal Radar and the video based Lane Detection system, are connected to the CAN bus. All the information (vehicle data, obstacles data, lane data are collected by an industrial PC named “PC_LOG”. The PC by means of a serial interface (RS-232) acquires data also from the GPS localization system (E-Where). The visual output of the system can be shown, for the system operator, in the PC console and, for the vehicle driver, in an additional display integrated in the dashboard. Audio output is possible by means of an additional amplifier and stereo speakers.

Inputs to the system are possible both by the operator (keyboard and touch-pad) and the driver (touch-screen integrated in the display). A control panel, integrated in the glove compartment is mainly dedicated to the control of the system (switch on/off, debug).

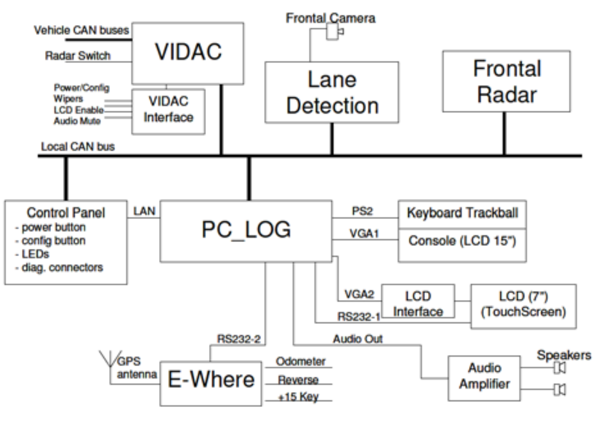

Fig. 2 *Architecture design.*

The research vehicle collects data from the CAN bus network. These signals are divided into the following three categories:

- The vehicle related signals
- The Lane Departure signals
- The RADAR signals (Obstacle related)

The CAN bus transfer rate is 500m/sec. These signals described in Table 1.

Table 1: *Vehicle Related signals*

Abbreviation	Description	Measurement unit
System Time	System Time	System time in milliseconds 1
VS	Vehicle speed	Km/h
Ax	Lateral Acceleration	m/sec^2
Ay	Longitude Acceleration	m/sec^2
YR	YawRate	Rad/sec
Cu	Curvature	1/m
RC	Curvature radius of vehicle	m
GPP	Gas pedal pos	
MCP	Master Cylinder Pressure	
StA	Steering Angle	
Br	Brake	
RPM	RPM	
GE	Gear level	Not used
(ExTe)	External Temperature	Celcius
Wi	Wiper Status	% -Possible values: 7 (low), 1 (medium), 2 (fastest)

The data are stored in .txt format. Each column contains tha data for each parameter. The log files are compatible to be viewed by many word processing applications and Microsoft excel or Open Office-Libre Spreadsheet for post analysis.

2.2. Power Management

Normal production electronic devices are directly connected to the main battery and they are able to self-switch on and off because they are sensitive to the Key-on signal or to the door switch. Automotive general requirements related to power supply do not consider specific problems that could occur with prototypal systems based on PC platforms and high-level operating systems. In particular, it is referred to power-on and power-off phases. To guarantee optimal power management, it was used a principal schema, shown in Figure 3.

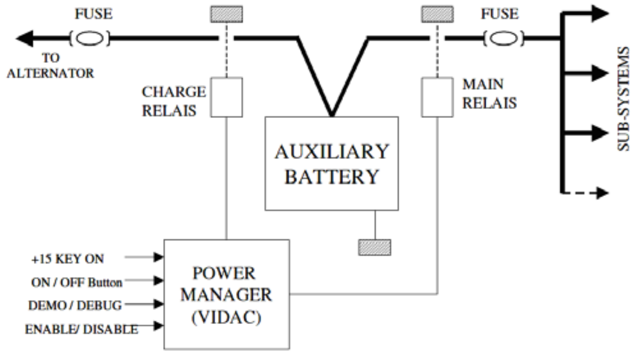

Fig. 3 *Functional schema for power supply management.*

All installed additional equipments are powered by an auxiliary battery recharged by the main circuit (main battery + alternator). An automotive ECU, by means of 2 relays, allows to the system to work in all operative conditions (engine on/off, key on/off). Main advantages of this schema are:

- The mobility of the car is in any case guarantee; the main battery can not be discharged even if subsystems fail.
- The system is more isolated by disturbance due to main electronics (i.e. injector spikes and low battery voltage during cranking phase).
- The software implemented in the ECU allows flexibility in the power management strategy.

2.3. The Video Recording Cameras

Research has been undertaken on a number of different cameras and the models with the appropriate specifications have been selected to be part of the system. The main specifications that play vital role on the selection terms are listed below:

- The camera should be able to record in low light exposure
- It should be a charge coupled device (CCD) camera
- It should provide Application Programming Interface (API).

The following cameras have been selected because their specifications answer all the requirements that have been set

- POINT GREY – Chameleon 1.3 MP CCD, USB interface, compact,
- JAI - AD-080GE Digital 2CCD Progressive Scan Multi-Spectral Camera
- Logitech Webcam Pro 9000.

The most vital of the cameras' setting was the number of frames that the cameras are set to capture. The above cameras are able to store up to 30 frames per second. The frame rate of the cameras was set to 10 frames per second. On one hand, this rate provides a secure and reliable coverage of events in the vehicle and on the other hand, it requires a lower storage need.

Another vital specification of the cameras is that they are totally autonomous and they do not interfere with the other functionalities of the vehicle's main PC. The reason is that the system only reads information and stores the values from the vehicle's CAN bus into the PC but it does not send anything back to the CAN bus. The system was able to be installed on any PC, even on a laptop, but it finally installed on the main vehicle's external PC for synchronization and storage purposes.

2.4. Instrumented car CAN bus and GPS data acquisition testing

The vehicle application collects the data that have been mentioned in section 2. It provides two main functionalities: the first one is to collect data in exact the same time interval (synchronized data) and the second one is to store the values of the data to log files. There are two different log files; one for CAN bus signals and the second one for the GPS data. It was decided to separate the data storage into two files in order to provide smaller files for the post analysis process rather than one huge file. The data are written to a file every 100 milliseconds approximately.

The instrumented vehicle has been driven on urban, rural and highway roads with different speeds and traffic density. No problem in data recordance and system reliability has been noticed. Various data files have been logged in order to check logging consistency. The log files are stored in vehicle with a different filename as "DriversLogFile_xxxxxxx.txt" where xxxxxxx is the current date-time in milliseconds.

The recording video cameras have also been tested during these trials. For each camera, a separate folder was automatically created which contains the frame recorded during the test route. After each trial, the logged files have been checked for frame disruption, proper synchronization and good quality frame capture (possible distortion due to e.g.: light & focus adjustments, camera vibration). Figure 4 is an example of synchronized video frames of the three in-vehicle cameras. The synchronization application has been developed within CERTH.

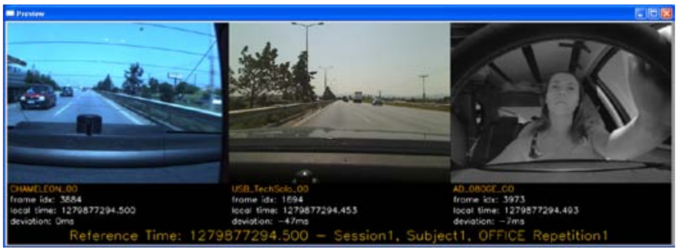

Fig. 4 *Synchronized video frames.*

3. The PROLOGUE study

The main objective of the FP7 EU co-funded project PROLOGUE (PROmoting real Life Observations for Gaining Understanding of road user behaviour in Europe) was to explore the feasibility and usefulness of a large-scale European naturalistic driving observation study. The work that HIT has been conducted focused on the feasibility of using an instrumented vehicle in order to investigate the effect of in-vehicle (Forward Collision and Lane Deviation) warnings in real life driving. The video cameras installation aimed at recording driver's activities during driving in order to gather information on the actual role of the warnings in driving experience. The trials lasted three consecutive weeks (baseline, FCW on, LDW on) and five drivers with driving experience above three years participated in the field trial.

3.1. Data Coding

Data coding taxonomy was applied resulted by the three cameras analyses. Data coding process is a time consuming and difficult procedure. In order to derive valuable and reliable data, two researchers viewed and coded the gathered data; hence lowering inter-rater variability. As distraction in relation to warnings was the investigation objective of this study, thus videos were scanned 10 seconds before and after the recording of the warning. However, not all viewings led to true activations of the warnings. According to the video material, false warnings accounted in some cases for 16. 5% of Forward Collision Warnings (FCWs) and 21.3% Lane Departure Warnings (LDWs).

4. Conclusions

The naturalistic driving methodology is the observation of driving behaviour in real context with inherent limitations in causality and the likelihood of confounding variables. Areas in driving research that have gained insight are "driver distraction and inattention", "driver drowsiness and fatigue", "heavy vehicle –light vehicle interaction", "driver characteristics and states" and "applied use of naturalistic driving observation". For this reason, instrumented vehicles have been prepared in order to log/capture the daily driving behaviour of drivers in usual traffic conditions.

Despite efforts to make HICs as inconspicuous as possible, the fact is that they incorporate a larger range of equipment than standard cars and, although technicians make every effort to hide equipment from the drivers, there are a number of clues that still make drivers aware of its presence. For example: sensors protruding from the car, camera lenses pointing at the driver, extensive eye-tracking calibration process, etc. Indeed, it seems very plausible that drivers of these cars may have a more intense feeling of being observed than if they were driving a less equipped car. As a consequence, the driver may not behave as naturally as desired for research purposes.

One of the most important lessons learned during the Greek study is the need for golden rule when instrumentation of vehicles is involved for larger scale observations. The sophistication of existing technology may be exchanged for richness of data. The data compression before downloading could be a solution for longer uninterrupted recording sessions and, thus, promoting further the realistic experience of driving an instrumented vehicle. On the other hand, the current sophistication gives in depth and reliable data, and hence more reliable inferences, whenever plausible. In order to organize a future study, the pitfalls and problems of the previous one should be resolved or at least controlled for.

The main advantage of the Greek trial was the capability of in depth gathering and, consequently, analysis of data coming from the instrumented vehicle. This process allowed for focus on potential vehicle and driver variables and isolating variables that may be of more interest in providing useful and information and/or serve as indexes in real traffic situations with private and/or leased vehicles.

The plethora of logged parameters may provide rich data but it also slows data download with a high required data download frequency. Data had to be gathered on a daily basis and checked; therefore it was decided to follow a specific driving route. In addition, false alarms had to be controlled and checked; which required extra effort by the researchers in order to eliminate artefacts in the database. In addition, false alarms with regard activation of warnings should be taken into account and fed to a future set up in order to be automatically removed from data reduction process. False alarms may be associated with increased non response to warnings behaviour (i.e. if stimulus response behaviour is dissociated or is not successful at all times).

Moreover, participants followed a pre-determined route which was though part of drivers' daily driving routine as it was selected to be near the institute to facilitate downloading of data but, also, to contain road segments with delineation that would ensure warnings' activation (the system is effective in highway road segments). The naturalistic element was present in the fact that all drivers follow this route at least twice per day (to go and return to work); hence it was part of their daily driving activity.

The data logging systems of potentially studied private vehicles could not be elaborate as the one implemented in this study because this process would hinder the procedure. Therefore a condensed and portable system should be developed based on the main findings.

References

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