

Ergonomic Data Measuring System for Driver-Pedals Interaction

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ABSTRACT

This paper presents the design and development of an ergonomic data measurement system for driver-pedals interaction. The work focuses in particular on the actuation of the acceleration and brake pedals, and aims to support the development of a deeper understanding of the factors influencing the driving comfort associated with the right leg. The ergonomic data measurement system integrates five subsystems: an electrogoniometry system and a pressure-pads system to monitor driver's positioning and movements, an electromiography system to observe the muscular activity of the lower leg, the vehicle on-board diagnostic system, a GPS system and an audio-visual system for providing environment and driving situation information. A validation exercise involving a series of test drive events confirmed the system capability to record meaningful objective comfort data which can differentiate between driving postures and styles.

INTRODUCTION

The interest for driver comfort is primarily motivated by the practical concern for the safety and wellbeing of the driver, and also by the view that with rising customer expectations comfort has become an important product differentiator. This presents vehicle design engineers with a significant challenge, as both comfort and customer satisfaction are notoriously difficult to measure and predict at the design stage.

Given the relative lack of proven and universally accepted objective metrics for comfort, vehicle

manufacturers often rely on subjective evaluations of comfort. Beyond the inherent intricacy associated with ensuring robustness of subjective evaluations this approach has a further shortcoming arising from the difficulty of establishing a functional relationship between the response (customers' subjective feeling of comfort) and the relevant engineering design attributes. This is due to the very complex nature of the interaction between the driver anthropometrics (highly variable with demographics, gender, culture, posture), vehicle packaging attributes (primarily seat / pedals / steering wheel position, but also headroom, interior styling, and environmental inputs such as wind / road noise and vibration) and the sensitivity of the subjective comfort assessment to social factors such as vehicle nameplate or purchase price of the vehicle. This complexity is further compounded by the need to assess the dynamics of this relationship in terms of short term and long term driving, which are associated with different mechanisms triggering discomfort.

Much of the work on driver comfort concentrated on seating [1, 2], including both static and dynamic evaluations [3], leading to significant achievements in terms of predicting seating comfort [4, 5]. Comparatively less work has been spent on assessment and prediction of comfort of the lower leg [6], associated with operation of the pedals [7, 8, 9, 10].

The work described in this paper focuses in particular on factors affecting the driving comfort of the lower part of the body, with the ultimate aim of understanding the relationship between the driver's perception of comfort and the engineering design attributes associated with

the pedal box design. It is recognized that in order to achieve this aim attention needs to focus on 2 aspects:

- We need to understand the relationship between the driver's actual response, i.e. what the *driver actually does* in terms of positioning, posture and adjustments to posture, pattern and amplitude of movements required to complete the driving task, and the driver's perception of comfort, i.e. the subjective response;
- We need to assess the relationship between the pedal design and other relevant engineering attributes (as inputs) and the driver's actual and perceived response.

This analysis clearly suggests that the ability to objectively measure what the driver actually does is key to achieving the ultimate aim of correlating pedal design attributes with driver's perceived comfort. The work described in this paper aimed to design and develop an ergonomic data measurement system for driver-pedals interaction that would support both of the tasks outlined above.

A design requirement set for the system was to be able to collect ergonomic data both statically and dynamically, i.e. during actual journeys. The system must be therefore portable and minimally intrusive to the driver's personal comfort and the driving task.

An initial assessment of the system requirements pointed to the following factors that need to be measured and monitored during a test:

Ergonomic factors:

- Subject anthropometrics (Leg Segments, Foot Length, Stature, Soft Tissue);
- Driver positioning (Seat Position Fore/Aft, Seat Recline Angle);
- Driver movements (Hip, Knee and Ankle Joint Angles);
- Contact surface interaction (Buttocks on Seat, Heel Contact Location on Floor, Contact Between the Foot and Pedals);
- Longer term (i.e. over an extended drive task) physiological effects (e.g. muscle fatigue in the lower leg).

Vehicle and Environmental factors:

- Vehicle controls (acceleration and brake pedal positions, vehicle speed and gear position);
- Driving situation (road type, traffic & weather conditions).

This paper presents the development work for the ergonomic data measurement system for driver pedal interactions, and covers a description of the system architecture and a validation exercise to demonstrate the capability and performance of the system.

SYSTEM ARCHITECTURE

The measurement system integrates the electro-goniometry, electromyography, pressure pads, audio-video (AV), GPS and on-board diagnostics (OBD) subsystems, and facilitates the monitoring of all required factors, while allowing time synchronization of the output provided by each subsystem.

Ergonomic factors such as driver's positioning, contact surface interactions and lower body kinematics are monitored by the combined functions of the electro-goniometry and pressure pads subsystems, while muscular activity in the lower leg is monitored via electromyography.

The OBD, GPS and AV subsystems supply vehicle and environmental data; the OBD and AV data also is used to support the interpretation of the electro-goniometry data regarding driver's lower body kinematics.

The basic architecture of the system and the distribution of system's components between the vehicle and the driver are shown in Figure 1.

The Joint Event Marker (Figure 2) is used to identify specific events during the driving tests by simultaneously recording marks in all subsystem data logs; these marks are used to align the data, collected from each subsystem, for post-processing and analysis.

The system requires three laptop computers: first laptop drives the electro-goniometry, electromyography and the pressure pad subsystems via three USB links, second laptop records audio-video and GPS data via two USB and one serial link, while third laptop drives the OBD data acquisition.

The laptops are located in the rear seats area of the vehicle, which allows the observing engineer to monitor the equipment and conduct the tests without distracting the driver (Figure 3).

All equipment is powered from the vehicle's 12V battery via appropriate DC/DC convertors.

ELECTRO-GONIOMETRY - The electro-goniometry subsystem, tasked with monitoring the motion of driver's right leg, is assembled from readily available components supplied by Biometrics Ltd. It includes three electro-goniometry sensors, a portable signal amplifier, a base unit and the associated data logging and post-processing software installed on a laptop computer. The twin-axis electro-goniometers can simultaneously measure angles in two planes on two independent data channels and are used to monitor the movement in the hip, knee and ankle joints (Table 1).

The sensors are attached directly to driver's skin using double-sided adhesive tape. A pair of test-trousers has been developed to allow easy access down the side of the right leg, and secure the amplifier and the sensor cables.

The amplifier, worn by the driver, is a tiny microprocessor controlled signal conditioning unit with 8 analogue and five digital input channels, which communicates with the base unit via a RS422 data link; newer versions of this device are now offered with wireless communication [Biometrics Ltd., UK].

PRESSURE PADS - A customized pressure pad subsystem has been developed with Sensor Products Inc., based on their Tactilus® piezoresistive array technology, to monitor contact interactions between the driver and the vehicle. The subsystem consists of five separate pressure arrays (technical specification Table

2), two signal processing base-units linked with a laptop computer via a USB link, and the associated monitoring and post-processing software.

The pads are used to monitor the pressure between the driver and the seat (Figure 5), between driver's right foot and shoe's insole, and the shoe-car floor, shoe-accelerator pedal and shoe-brake pedal pressure (Figure 6). By providing information about the distribution and the magnitude of the contact pressure, the pressure pad subsystem assists the dynamic tracking of driver's positioning and movements.

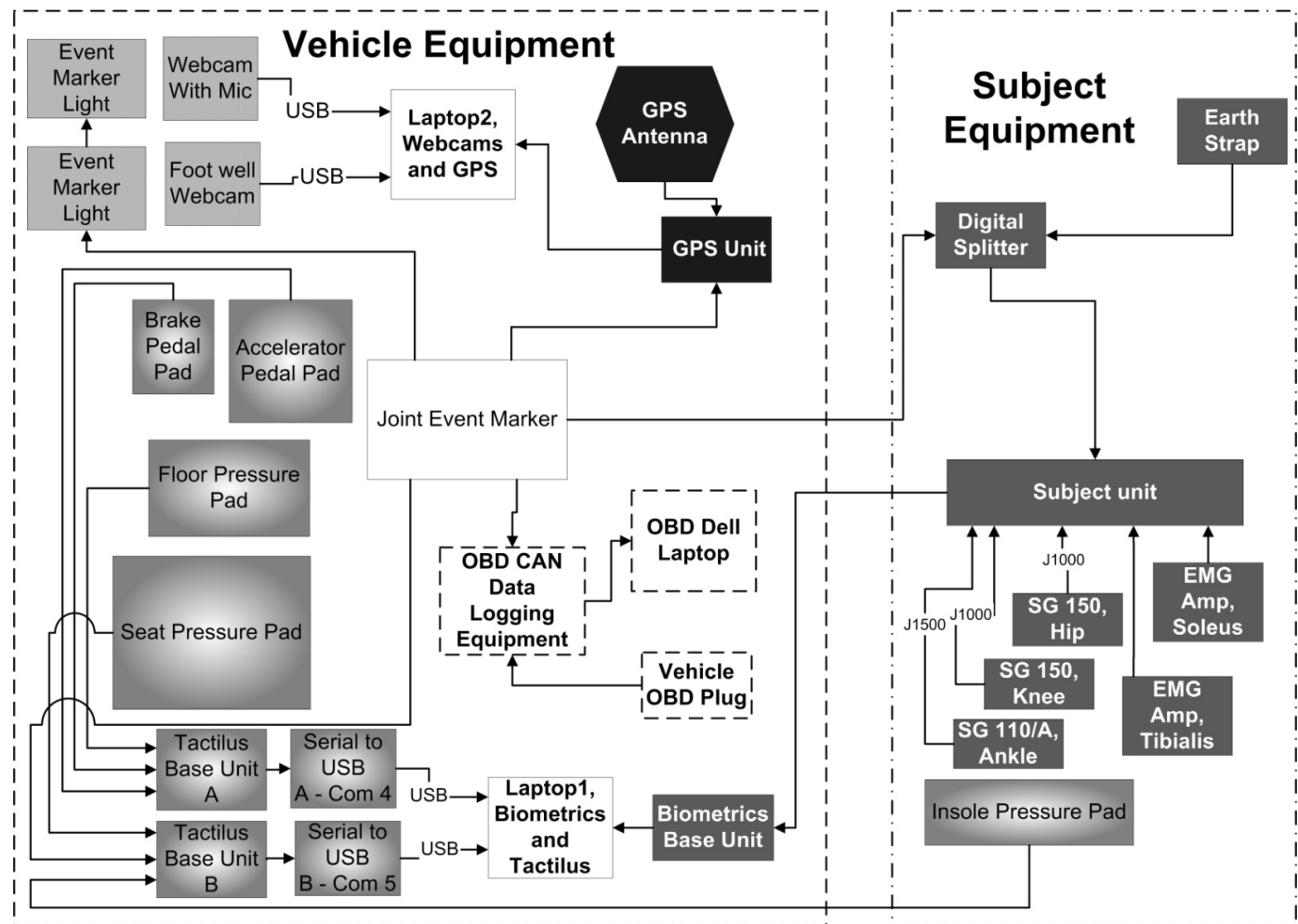


Figure 1. Ergonomic data measuring system architecture

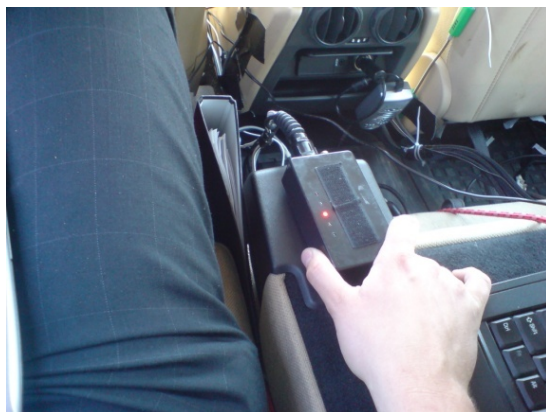


Figure 2 Joint Event Marker in situ



Figure 3 Laptops located in rear seating area of vehicle