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Embedded system to evaluate the passenger comfort in public transportation based on dynamical vehicle behavior with user's feedback

Juan C. Castellanos *, Fabiano Fruett

School of Electrical Engineering, University of Campinas, Av. Albert Einstein 400, CEP: 13083-852 Campinas, SP, Brazil

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ABSTRACT

This paper shows the development of a system (Hardware, Firmware and Software) focused to assess the dynamic motion factors that affect the comfort in public transportation systems. The data is collected, on-board processed and transported using the public transportation system vehicles as mobile smart sensors. Therefore, the acceleration measurement using a tri-axial accelerometer, the position detection using Global Positioning System (GPS) and the appropriate algorithms allow the system to detect rude driver styles and defects on the pavement. The firmware is composed by two algorithms. The first one is based on the detection of acceleration and Jerk magnitudes out of the comfort range, which is called Jerk-Acceleration Threshold Detection (JATD). An algorithm to compute the Jerk with comparable results to prior researches is proposed in this paper. The second algorithm, called Comfort Index with Acceleration Threshold Detection (CI-ATD), is based on the detection of acceleration values out of comfort range and the average ride comfort. The average ride comfort is supported by the recommendation of the international standard ISO2631-1. The comfort range or threshold values can be set using the user's perception. A software developed in LabVIEW™ interface, visualizes discomfort event in online maps for geographic location of each event. Also, the software implements road unevenness detection, which is based on the collected data analysis. The system was successful tested in a conventional bus line on its daily ride, the results reveals that most of the events are due to vertical acceleration disturbances. Also, a preliminary test indicates higher sensibility for vertical than longitudinal or transversal accelerations.

1. Introduction

Transport policies are important for society, because efficiency in the transportation system have a positive economic and social impact as better accessibility to markets, employment and additional investments [15]. Nowadays, one of the principal problems in big cities is the large fleet of vehicles [5,21]. Some policies such as improving the quality of public transportation would collaborate to turn car's users into public service users; this change of roles will have a positive impact in decreasing traffic jams, atmospheric and noise pollution [5,11,18]. However, the efficiency of policies depends on the service quality. According to the Highway Capacity Manual 2010 [19], the quality of service can be influence from several factors as speed, travel time, reliability, convenience, maneuverability, cost, accessibility, safety, comfort, etc.

Statistics from vehicles fails, accidents, number of complaints and specific surveys are used to assess the quality of the transportation service [16]. However, performing comfort statistics is an expensive task in terms of human resources and time, because of surveys and personal

* Corresponding author. Tel.: +55 (19)88410241.
E-mail addresses: juancast@dsif.fee.unicamp.br (J.C. Castellanos), fabiano@dsif.fee.unicamp.br (F. Fruett).

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interviews [12]. Hence, systems to collect objective data in aim of guarantee or assess safety and comfort are being proposed.

Several applications have emerged to improve the quality of transportation system; those could be classified in four topics: mobility, information, security, and comfort. In the first topic, mobility solutions as Bus Rapid Transit (BRT) and subways use fleet management system, as the ITS4mobility [20], to improve the impact in urban mobility. Nowadays, information about buses routes, station localization, arrival and departure times can be accessed through web sites or phone applications, e.g. the Bus Catcher is an application developed to assists mobile users to plan their travels using a PDA, resulting in saving time [3]. Since the last decade, Global Positioning Systems (GPS) are most widely used; this technological advance became the Vehicle Tracking System in one of the most successful solution in the security field. The comfort measurement may be the most challenge topic to be measure, because it depends on the human perception and it is affected by several factors.

Förstberg [6] specifies some types of human-vehicle interaction variables that influence the user's comfort: Human Factors (as age and gender), environmental factors (as temperature, noise, and pressure), spatial factors (as workspace, leg room, seat shape, etc.) and dynamic motion factors. The ISO 5805 [9,17] defines comfort just as "subjective state of well-being or absence of mechanical disturbance in relation to the induced environment". In this paper, the comfort scopes will be limited to mechanical disturbances or dynamic motion factors.

Usually, the quality of the comfort is evaluated using subjective rating tests [17], which may include several issues not coupled with the ride as mood, tiredness, etc. Also, the vocabulary used to rate may be different among individuals and changes in perception level or acceptance level may occur. Therefore, the objectivity of the evaluation of comfort is an interesting issue to be implemented, because, it also allows repeatability, comparison between competitors and creation of scales as mentioned by Strandemar [17].

Vehicles interaction with road will be reflected in terms of acceleration, Jerk (the rate of acceleration change) and angular motion, which depend on bus maintenance, driver behavior and road's state. In elevators, Jerk is used to confirm motion control settings associated to ride quality [10]. Moreover, Andersson et al. [1] demonstrated the influence of the train lateral Jerk in walking, standing and sitting passenger.

It is possible to assess the dynamic motion comfort using five methodologies: average ride comfort, estimated ride comfort, comfort disturbances, motion sickness and vibration effects in daily activities [6]. Reveriego [14] collects data using the acceleration, speed and position through a mobile telephone. Those data can be used to evaluate the fore-and-aft and lateral ride comfort using a methodology based on acceleration thresholds. In the same way, Zoysa et al. [22] proposes a system sensor network to monitor road surface condition. It can be used to detect vertical ride comfort using the comfort disturbance with a vertical acceleration threshold. However, those solutions are not designed to process the acceleration data as average ride acceleration, which make difficult the comparison, e.g. between drivers, roads, etc.

Lin et al. [12] uses average ride comfort methodology to assess the comfort. Using participatory phones to collect data, a ride index is computed in a server and matched with the transportation database. This system allowed them to compare different bus types in aim to determinate the most comfortable vehicle (bus type) and ride. However, the comfort evaluation depends on the availability voluntaries and their care for measurement, e.g. fixation technique. Also, the battery discharge and costs associated to data communication (GPRS) can discourage the voluntary users and limit the distance of the evaluation.

The main contribution of this paper is the implementation of a complete system (Hardware, Firmware and Software) specially designed to assess the dynamic motion comfort in public transportation. The data reported by the system can be highly important for transportation agencies, road state surveillance authorities and efficiency of quality transport polices.

The innovative work includes using buses as mobile sensors to collect, process and transport information related with comfort in public transportation (as driver's behavior, road state, etc.). Also, previously works often used just one measurement methodology. The proposed system uses two complementary measurement methodology (average ride comfort, comfort disturbances) for an objectively comfort assessment without need additional data processing. The average ride comfort methodology follows the entire international standard ISO 2631-1 [8] for comfort measurement. The comfort disturbances detect sudden motion, which is measured through acceleration and Jerk signals above a defined threshold. The threshold value can be determined by the own system using passengers experience feedback hardware under controlled ride conditions. Those two methodologies are complementary, the first methodology provides an average measurement, which can be used to compare tracks, vehicles or drivers and it is in accordance with the standard ISO 2631-1. On other hand, the second methodology allows the source of discomfort events to be localized, geographically and temporally. In this way, algorithms using the two methodologies were created in this paper: Jerk and Acceleration Threshold Detection (JATD) and Comfort Index with Acceleration Threshold Detection (CI-ATD). These methodologies were both embedded in the system software.

The hardware, described in Section 2, is based on tri-axial accelerometers, a Global Positioning System (GPS) module, wireless communication modules and user's feedback module. The firmware, described in Section 3, is divided in the two algorithms JATD and CI-ATD. The software, described in Section 4, is composed by three parts: event's visualization interface, set-up (configuration) interface and defects on the pavement detection interface. Also, Section 5 presents the results obtained using the system with the two algorithms, user's feedback module and analysis of data to detect defects on the pavement. Finally, section 6 presents conclusions and discussion associated to this paper.