Transportation Research Part F 22 (2014) 86–95

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Detecting Powered-Two-Wheeler incidents from high resolution naturalistic data

Eleni I. Vlahogianni *, George Yannis, John C. Golias

National Technical University of Athens, 5 Iroon Polytechniou Str, Zografou Campus, 15773 Athens, Greece

ARTICLE INFO

Article history:
Received 29 October 2012
Received in revised form 9 October 2013
Accepted 7 November 2013

Keywords:
Powered Two Wheelers
Driving behavior
Naturalistic experiments
Microscopic incident analysis
Outlier detection

ABSTRACT

During risky conditions, Powered-Two-Wheeler (PTW) drivers often alter their behavior from a regular driving pattern to an irregular chain of driving actions by braking, changing the throttle pressure, maneuvering and so on, or combinations of the above. However, both the actual and perceived thresholds of regular and irregular driving behavior differ among PTW drivers. A simple and flexible methodology is proposed in order to define PTW driving profiles by distinguishing between regular and irregular PTW driving behaviors using high resolution naturalistic data. "Irregularities" in driving behavior are consistently expressed as outlying values in the dataset of driving parameters. The detected irregularities are those that diverge from the centroid of the jointly considered driving parameters. These irregularities may be considered to define critical driving situations (incidents) that are further associated to typical driving events. Results indicate that the joint consideration of variables which are directly connected to the mechanical characteristics of PTW, such as front and rear brake activation, wheel speed, throttle and steering, are adequate to distinguish the regular from irregular PTW driving behavior.

1. Introduction

Understanding Powered-Two-Wheelers (PTWs) driving behavior and interactions with the rest of the traffic is critical to the design of efficient accident countermeasures and is, hence, essential (Yannis, Golias, & Papadimitriou, 2005). An efficient manner to understand PTW driving behavior – given the improvements and innovations of modern technology – is through constant monitoring and analysis of PTW driver's actions during driving. Until recently, PTW accident risk has been largely studied through macroscopic and in-depth data analyses (Dupont et al., 2009; Thomas et al., 2005; Yannis, Papadimitriou, Dupont, & Martensen, 2010), as well as through behavior analyses such as questionnaire based surveys, guided discussions, video-based methods or simulators (Engstrom, Johansson, & Ostlund, 2005; Haque, Chin, & Huang, 2010; Huang & Abdel-Aty, 2010; Savolainen & Mannering, 2007). These analyses are inherently destined to qualitatively assess on the factors that increase accident risk mainly from a social point of view, without being able to extract accurate and detailed information on the manner PTW drivers behave on the road and especially before, during and after critical driving situations (incidents).

A new and efficient way to understand PTW driving behavior is by creating a least intrusive–restrictive (naturalistic) – environment to monitor and record drivers' actions on the road by employing advanced sensor technologies. Recently, a number of such attempts have been conducted in Europe, the US and Australia to understand driver's behavior. Some prevailing efforts are described in large scale projects such as the 100-Car study (NHTSA, 2006), SHRP 2 Naturalistic Driving Study (SHRP2 2011) and Euro-FOT (Csepinszky & Benmimoun, 2010). Several findings on commercial vehicle driver's

* Corresponding author. Tel.: +30 2107721369; fax: +30 2107721454.
E-mail addresses: elenivl@central.ntua.gr (E.I. Vlahogianni), geyannis@central.ntua.gr (G. Yannis), igolias@central.ntua.gr (J.C. Golias).

1369-8478/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.trf.2013.11.002

behavior and inattention are summarized in Olson, Hanowski, Hickman, and Bocanegra (2009) and Klauer, Guo, Sudweeks, and Dingus (2010). However, so far no results are publicly available concerning PTW driver's behavior (Regan et al., 2006; Baldanzini et al., 2009; FESTA, 2008; NHTSA, 2006).

A key problem in naturalistic PTW driving studies is to define which driving situation may be considered as critical or risky. Interestingly, in all relevant approaches documented so far, such as the 100-Car study (NHTSA, 2006) and SEMiFOT project (SEMiFOT, 2010), typical driving parameters' (speed, acceleration, etc.) thresholds (triggers) are empirically established uniquely for each driving parameter; based on those values, criticalities are extracted and further analyzed (a review of such approaches may be found in Baldanzini et al. (2009)). This technique is univariate, since it detects incidents from changes in a single driving parameter. But maneuvering on roads may be reflected on changes to more than one parameter.

Moreover, the specific technique addresses all drivers as being similar in their driving behavior. This lacks consistency with the fact that each driver has its personal stock of values, ideas, beliefs and practices, reflecting rigorously on its behavior on the road, such as the braking, overtaking and so on, that may not resemble to the behavior of other drivers on the road (Vlahogianni, Yannis, & Golias, 2013). Evidently, the driving conditions which are considered as critical are not the same for all drivers, but should be defined on the basis of driving parameters' values that may vary among drivers. Moreover, a critical event may be reflected on changes to a single driving parameter (e.g. braking), but also to more than one driving parameter (e.g. steering and decelerating). In this context, the question that emerges is how the high resolution naturalistic driving data which is, by nature, multivariate and noisy, can be used to define a self-contained multivariate personalized PTW driver's profile.

The objective of this paper is to propose a methodology for identifying PTW driver's profile based exclusively on high resolution naturalistic driving data without the need to observe the videos for identifying situations where the behavior of the driver may be considered as beyond normal. The data exploited concern information on wheel speed, acceleration, throttle, steering, brake activation and so on. A comprehensive methodological shell is proposed in order to distinguish between regular and irregular driving behavior. "Irregularities" in the driving behavior are consistently expressed as outlying values in a multivariate consideration of the available driving parameters. The detected irregularities are those values that diverge from the centroid of the jointly considered driving parameters and define critical driving situations that may further be associated to typical driving events.

2. Extracting powered-two wheeler irregular driving patterns

2.1. The Concept

In general, driving is a complex – often cyclic – task; at a specific instance, the driver will have to scan and recognize stimuli from the road environment and decide which action(s) to take mainly described by braking, accelerating/decelerating or steering. The above actions lead to a change of the status of the vehicle (e.g. velocity or yaw, pitch or roll rate). During the course of a trip, the driver will be forced to repeat these actions for forthcoming driving instances. Evidently, this cyclic task is strongly dependent on factors such as the level of actual knowledge and skill, the amount of experience, the individual level of development and maturity, the social situation and lifestyle (Boyce & Geller, 2002; Gregersen & Berg, 1994; Møller, 2004); thus, each vehicle's driver may act or react to stimuli in a unique manner.

Given the ability to monitor the exact actions of a PTW driver, literature has for long supported the uniqueness of driver behavior in automobiles and the possibility to use it for personal identification to achieve safer driving (Igarashi et al., 2004; Wahab, Quek, Tan, & Takeda, 2009). This uniqueness may be reflected to the variability of driving signals e.g. braking, accelerating and so on; such driving characteristics, in particular, the amount of pressure a driver applies on the accelerator pedal and/or the brake pedal have been utilized in personal identification and define personal driving profiles (Wahab et al., 2009). Although such argument may readily extend to the case of PTWs, PTW research lacks focus on defining PTW driver individual profiles. Nevertheless, the ability to define a driver-specific profile is important and may have significant implications to various Intelligent Transportation Systems (ITS) applications. A system that may recognize each driver's individual style and manner to react to different driving situations may improve the safety and mitigate the risk during driving. By implementing necessary actions, a system can control the vehicle every time a driver may deviate from its individual driving norm and engage in irregular driving.

The challenge of the proposed approach in introducing a manner to distinguish between normal and irregular driving patterns lies in two issues: first, deviation from the average "normal" PTW driving may not be uniquely defined based on one driving signal. Second, a mathematical manner to define the PTW driving vector and the emergence of irregularity should be introduced. In the present paper, a distance based metric is implemented to define the vector of driving and the concept of outlier data is used to distinguish between normal and irregular driving. Outliers form an important concept of multivariate time series. According to Barnett and Lewis (1994), an outlier is an observation (or subset of observations) which appears to be inconsistent with the remainder of that set of data. In the specific study, an outlier is defined as an observation for a specific time interval, during which the PTW driver for some reason drastically alters its driving behavior due to an external or internal stimulus. Outliers may be caused by measurement error or equipment failure (faulty values) or may depict a critical pattern in the observed data much more rich in information about the systems than the rest of the data e.g. congested patterns in traffic flow (Chen, van Wang, & Zuylen, 2010).