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Vigilance monitoring for operator safety: A simulation study on highway driving

A.V. Desai, M.A. Haque *

Department of Mechanical and Nuclear Engineering, the Pennsylvania State University, University Park, PA 16802, USA

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Abstract

Introduction: Alertness of individuals operating vehicles, aircrafts, and machinery is a pre-requisite for safety of the individual and for avoiding economic losses. In this paper, we present a new technique for determining the alertness level of the operator and elaborate the methodology for the specific case of highway driving. *Method:* Our hypothesis is that the time derivative of force exerted by the driver at the vehicle-human interfaces can be used to construct a signature of individual driving styles and to discern different levels of alertness. *Results:* In this study, we present experimental results corroborating this hypothesis and introduce a parameter, 'spikiness index,' for the time series data of the force derivative to quantify driver alertness. *Impact on Industry:* The low cost, ruggedness, and low-volume data processing requirements of the proposed technique give it a competitive edge over existing predominantly image processing based vigilance monitoring systems.

Keywords: Drowsiness detection; Driving simulation; Vehicle-human interface; Accident prevention; Spikiness index

1. Introduction

Impairment of alertness in vehicle and machinery operators poses a danger not only to themselves but also often to the public at large (Faber, 2004). For example, the National Highway Traffic Safety Administration (NHTSA) estimate that 1,200 deaths and 76,000 injuries (Rau, 1996) can be attributed to fatigue-related crashed annually, resulting in a loss of about 12.4 billion dollars in the United States alone (Wang, Knipling, & Blincco, 1996). Operator vigilance monitoring is an active safety research area and significant efforts, mainly in the automotive sector, have been devoted to detect the decrease in attention of the operator and to alert her/him. As described in the next section, various methodologies and techniques for vigilance monitoring are present in the literature. The motivation for this study comes from the observation that none of the existing techniques fulfill all of the following requirements of a driver vigilance monitoring system:

1. A non-intrusive monitoring system that will not distract the driver or compromise privacy.
2. A real-time monitoring system, to ensure accuracy in detecting lowered levels of driver alertness.
3. The system performance should not be significantly influenced by environmental conditions (traffic, landscape, weather, and darkness).
4. The system must have low unit and operation (including data processing) cost, since automotive buyers may not be willing to pay high prices for an alertness monitoring system.

As an alternative to costly and computationally extensive existing image processing based techniques, we focus on the vehicle-driver interfaces, which are the accelerator and brake pedals and the steering wheel. Taking the accelerator pedal as an example case, we observe that the direct

* Corresponding author. 317A Leonhard Building, The Pennsylvania State University, University Park, PA, 16802, USA. Tel.: +814 865 4248; fax: +814 865 9693.

E-mail address: mah37@psu.edu (M.A. Haque).

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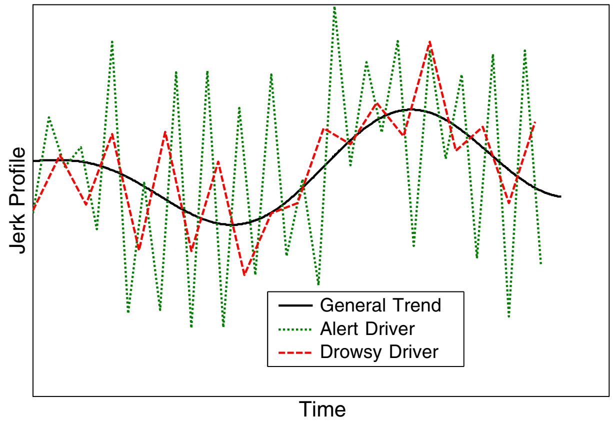

Fig. 1. Jerk Profile for Varying Alertness of Driver.

magnitude and frequency of the force that the driver exerts on this pedal is significantly influenced by the traffic and landscape and cannot be used to measure the driver alertness. However, the time derivative of the exerted force gives the jerk (time derivative of acceleration) applied on the pedal since the pedal mass is constant. It is our hypothesis that *jerk profiles for the machine-human interfaces are distinctive in different levels of alertness*. This is because an alert driver responds/interacts quicker and more frequently to changes in road patterns as compared to a less responsive driver. We discuss and validate the hypothesis by considering a specific case study of vigilance monitoring for automobile driver safety on highways. The driver-accelerator pedal contact will be used to characterize the alertness state, which can be implemented for brake pedal or steering wheel.

To illustrate the proposed driver vigilance monitoring concept, a hypothesized plot of the jerk profile (time derivative of force) of driver contact with gas pedal is shown in Fig. 1. The general trend in the plot indicates the variation due to changes in road and external conditions. Over this trend the derivative of the force, exerted by an alert and a drowsy driver, on the gas pedal is superimposed. According to the proposed hypothesis, the jerk profile for an alert driver should have higher amplitudes and also frequency as compared to a drowsy driver; this fact is depicted in Fig. 1. It should be noted that the absolute amplitudes of the jerk profile are still influenced by external and uncontrollable variables. We therefore construct a general trend in the jerk data and assign it to the uncontrollable variables. The absolute deviation of the instantaneous jerk from the general trend and its frequency is then predominantly due to the alertness or responsiveness of the driver. The advantage of using the deviation from the general trend will make the detection algorithm independent of the driving conditions since the general trend basically encapsulates and represents the external environmental conditions.

In the next section, the existing technologies for operator and driver vigilance will be reviewed. After the literature review, the proposed hypothesis for vigilance monitoring will be discussed. This will be followed by a description of the experimental set-up and the data processing unit. The results of the driving simulations and the algorithms used to estimate the spikiness index will be explained, and finally the paper concludes with the summary and future work.

2. Literature review

Impairment of alertness in vehicle and machinery operation may be due to prolonged (sleepiness, fatigue, monotony) or short term inattention. Fig. 2 shows the predominant risk factors in driving. Of all these factors,

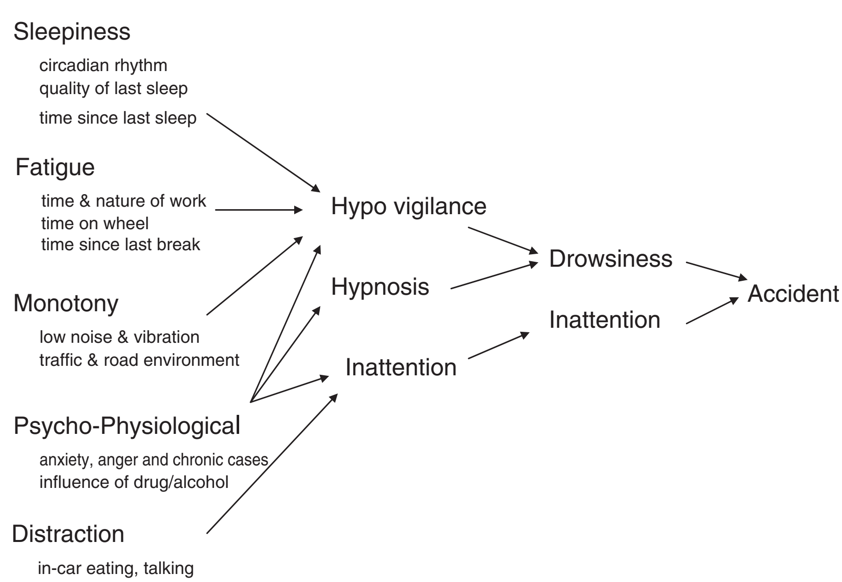

Fig. 2. Factors impairing judgement and driving performance.