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Estimating risk effects of driving distraction: A dynamic errorable car-following model

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ABSTRACT

This paper aims to estimate the risk effects of distracted driving, by incorporating a dynamic, data-driven car-following model in an algorithmic framework. The model was developed to predict the situational risk associated with distracted driving. To obtain longitudinal driving patterns, this paper analyzed and synthesized the NGSIM naturalistic driver and traffic database, through a dynamic time warping algorithm, to identify essential driver behavior and characteristics. Cognitive psychology concepts, distracted driving simulator, and experimental data were adapted to examine the probabilistic nature of distracted driving due to internal vehicle distractions. An extended microscopic car-following model was developed and validated, which can be fully integrated with the naturalistic data and incorporate the probabilities of driver distraction.

1. Introduction

Motor vehicle crashes are the leading cause of death in the United States for persons aged 3 to 34 and crashes are among the top three causes of death throughout a person's lifetime (National Safety Council (a), 2010). Each year since 1994, between 39,000 and 46,000 people have been killed in motor vehicle crashes each year (National Safety Council (b), 2010). In addition to the fatalities, there are many more people who suffer serious life threatening and/or life-changing injuries in motor vehicle crashes. More than 2.3 million injuries occurred as a result of crashes in 2009. Over 2.5 million rear end collisions are reported every year, making them the most common type of automobile crash (42%) (Center for Disease Control, 2009). Given that the vast majority of collision types are rear end, we will be focusing on this type of collision in this paper.

Driver distractions have become as dangerous as alcohol and speeding as factors that cause serious injury crashes. Estimates of the amount of crashes caused by distracted driving range from 10% to 80% (McEvoy and Stevenson, 2007; Sutts et al., 2005; Neale et al., 2009). Despite the wide range in the estimated number, the general consensus is that human factors play a great role in today's crashes. Studies have shown that "multitasking" while driving impairs our driving performance, including reaction time, lateral lane position, and vision. A complete review of the literature involving studies regarding crash risk and distracted driving is beyond the scope of this paper; interested readers are referred to references (McCartt et al., 2006; Wickens and Horrey, 2004; Caird et al. 2008; Brace et al., 2007).

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As we are focusing on rear end collisions in this paper, our research is concerned with the link between distracted driving and an increase in perception-reaction time in car-following situations. We looked to utilize sufficient statistic samples to characterize stochastic distributions of increased reaction time which were fed into the microscopic-level car-following model for crash prediction. A meta-analysis by Caird et al. (2008) examined 33 studies collected through 2007 that had a total sample size of 2000 participants. The studies investigated the results of cell phone use while driving on reaction time, lateral vehicle control, headway, and speed. It specifically identified 7 studies that looked at events where the stimulus was lead vehicles braking and measured the mean increase in reaction time of distracted drivers. This condition is most similar to what a driver would respond to in a car-following situation, which leads to rear end collisions, and was therefore used as the basis for quantifying the effects of distraction for this study. The driver's reported mean increase in reaction time for a lead vehicle braking was 0.36 s with a standard deviation of 0.42 s.

It has been increasingly evident that continuing advances in crash predictions and evaluation of safety enhancing strategies intrinsically depends on advances in driving behavior modeling. Driver behaviors are often intertwined with traffic, infrastructure, and environmental factors, and jointly lead to congestion, incidents, and collisions that impose significant pressure on the transportation system. Transportation planning and operational applications therefore need to rely on realistic representations of complex situation-dependent driving behaviors and heterogeneous driving perception and preferences. This paper proposes extending the (Newell, 2002) car following model by incorporating results from naturalistic and experimental studies with naturalistic data to derive the safety risks associated with distracted driving. (Przybyla et al., 2012) presented a simplified conceptual car following model to capture the probabilistic effects of distracted driving. This paper aims to systematically consider the dynamic effects in an errorable car following model, through a tight integration with an advanced data mining approach, namely dynamic time warping. The car-following parameters, estimated from the NGSIM data set, are further used to predict the risk effect of distracted driving, which is equivalent to a probabilistic extended reaction time in the dynamic Newell's car following model.

We anticipate that the extended driver performance model will be able to accurately predict situation dependent crash risk. Currently, the model can provide deterministic and probabilistic crash risk results and situation dependent crash risk and rates. We anticipate the model will be used within an ITS infrastructure as it can provide an estimate of real-time crash risk. This real time crash risk has the potential to be used as a catalyst for the proactive deployment of countermeasures such as warning signs, cell phone deactivation, vehicle to vehicle communications, collision avoidance in self-driving cars, active safety features, adaptive cruise control, and others.

This paper is organized as the following: Session 2 first reviews the NGSIM vehicle trajectory database and car following models. In session 3, the proposed model begins with naturalistic data obtained from NGSIM naturalistic driver and traffic database and extract correlated leader–follower vehicle trajectories. Through the method of dynamic time warping, we use apply cognitive psychology principles to study data about situation dependent distraction which are deterministically and probabilistically incorporated into the naturalistic driving profiles. In session 5, the modified driving profiles are then examined to determine if the imposed distractions resulted in a collision. A flow chart depicting the general process of the proposed extended car-following model is shown in Fig. 1.

2. Literature review

2.1. Newell's simplified car-following model

Car-following models, and, in general, driver-behavior models have over time become more complicated with the infusion of driver behavior terms. In contrast to the more complicated models (Newell, 2002), introduced a simplified model in 2002. Newell built off of Chandlers' model (Chandler et al., 1958) with the removal of the drivers' "reaction time"

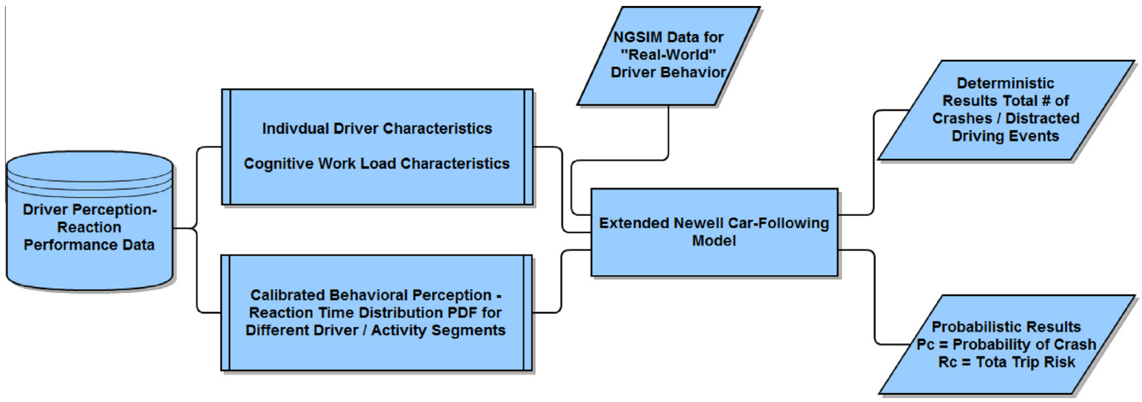

Fig. 1. Extended car-following framework.