International Journal of Automotive Technology, Vol. 24, No. 3, pp. 811–828 (2023)
DOI 10.1007/s12239–023–0067–9

pISSN 1229–9138/ eISSN 1976–3832

UNTRIPPED AND TRIPPED ROLLOVERS WITH A NEURAL NETWORK

Gridsada Phanomchoeng[1,2)*], Kailerk Treetipsounthorn[3)],
Sunhapos Chantranuwathana[1,2)] and Lunchakorn Wuttisittikulkij[4)]

[1)]Department of Mechanical Engineering, Chulalongkorn University, Bangkok 10330, Thailand
[2)]Smart Mobility Research Unit, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand
[3)]Department of Computer Engineering, Chulalongkorn University, Bangkok 10330, Thailand
[4)]Department of Electrical Engineering, Chulalongkorn University, Bangkok 10330, Thailand

(Received 23 March 2022; Revised 11 November 2022; Accepted 26 December 2022)

ABSTRACT–To improve rollover prevention and rollover warning systems, indicators for detecting rollover risks are extremely important. Vehicle rollover accidents occur in one of two ways: tripped and untripped rollovers. For detecting tripped rollovers, the traditional rollover index is ineffective; most precise rollover indicators depend on dynamic models that must identify all the parameters for computations. In this study, we focused on exploring a new index for detecting tripped and untripped rollovers using a neural network (NN). Four types of NNs, i.e., FNN, Tanh, long short-term memory, and gated recurrent unit (GRU), were examined to develop models for estimating rollover indices. The results demonstrated that the GRU and large Tanh network are the most suitable NNs for untripped and tripped rollover prediction, respectively. Moreover, the untripped rollover prediction model having a small GRU network could precisely anticipate the trend of the untripped rollover indicators for up to 0.2 s in advance. Moreover, the created tripped rollover anticipation model with a large Tanh network could precisely forecast the trend of the tripped rollover index up to 0.5 s in advance. Based on these results, rollover prediction in future can be advantageous for rollover prevention and warning systems.

KEY WORDS : Rollover index, Tripped rollover, Untripped rollover, Feedforward neural network, Recurrent neural network, LSTM, gated recurrent unit (GRU), *Tanh*

1. INTRODUCTION

In the last decade, because vehicles have changed in various ways, e.g., shapes, size, and weight, there has been an increase in rollover accidents. Dangerous as it sounds, rollover accidents also have a higher casualty rate than other accidents. As per the records of the National Highway Traffic Safety Administration (NHTSA) (http://www.safercar.gov), there were ~ 9.1 million passenger car, SUV, pickup, and van accidents in 2010, 2.1 % of them involving rollovers (US Department of Transportation, 2017). The proportion of the rollovers was considered relatively small compared to total accidents, yet, there were over 7,600 casualties, accountable for almost 35 % of all fatalities, in rollover accidents in the said year (US Department of Transportation, 2017). Moreover, in Europe, more than 20 % of casualties are caused by vehicle rollover accidents (Wu *et al*., 2010). In particular, in Germany in 2005, 2 ~ 5 % of all vehicle accidents included rollovers, whereas rollover accidents caused ~ 90 % of deaths in that year (Licea and Cervantes, 2017).

**Corresponding author*. e-mail: gridsada.p@chula.ac.th

Vehicle rollover accidents are categorized in two types based on the cause of the incident: tripped and untripped rollovers. A tripped rollover occurs when a vehicle collides with an outside obstacle, e.g., a curb, pothole, or guardrail, and leads to a rollover. Conversely, an untripped rollover usually occurs when there is a high lateral acceleration with a sharp turn and not from external factors (Rath *et al*., 2016; Phanomchoeng and Rajamani, 2013). NHTSA data show that 95 % of single-vehicle rollovers are tripped, whereas untripped rollovers are less than 5 % (US Department of Transportation, 2017). Because rollover accidents are high in number and casualties, they must be studied to improve vehicle safety.

Many car manufacturers, such as Ford and Volvo, have been improving active rollover prevention systems to prevent untripped rollover accidents (Rajamani and Piyabongkarn, 2013). Several types of actuation systems can be used in rollover prevention. Differential braking systems, such as anti-lock braking systems, electronic braking systems, and electronic stability programs, have received considerable attention from researchers (Wu *et al*., 2010; Rajamani and Piyabongkarn, 2013; Warwas and Augustynek, 2016; Zhu *et al*., 2016; Solmaz *et al*., 2008; Lee *et al*., 2013; Yu *et al*., 2016). These systems employ