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Deep learning-based vehicular engine health monitoring system utilising a hybrid convolutional neural network/bidirectional gated recurrent unit

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ABSTRACT

Vehicles play a pivotal role in the current era of Industry 4.0 by providing passengers with excellent mobility, comfort, and safety while strengthening national and international economies. Unanticipated vehicular engine issues can hinder performance and lead to costly maintenance. As analytics processes become faster, more accurate, and more reliable, intelligent fault prediction and diagnosis for vehicles, particularly engines, is becoming increasingly popular. To date, hybrid deep learning approaches to vehicle engine diagnostics have been limited, and none have used engine health monitoring and categorisation based on vulnerability assessment and vehicle structural information. This paper introduces a hybrid deep learning-based vehicular engine health monitoring system (VEHMS) decision model using Deep CNN (convolutional neural network)-BiGRU (bi-directional gated recurrent unit). This model monitors a vehicle's engine health in real-time and classifies its status as good, critical, moderate, or minor condition. Several advanced and hybrid deep learning algorithms were applied to monitor engine health and categorise its status by integrating sensor data with evaluated vulnerability information from an infrastructure vulnerability assessment model. The Deep CNN-BiGRU-based VEHMS decision model outperformed other techniques with an accuracy of 0.8897, ensuring minimal decision losses while classifying engine conditions. This study aims to contribute to developing comprehensive vehicle health monitoring systems and advance the automotive industry by incorporating more intelligent features. The proposed approach can enhance vehicle performance, reliability, and efficiency in the transportation sector by improving engine health monitoring.

1. Introduction

The vehicle acts as a key factor in our society for prosperity, employment, economic exchange, and personal freedom (Göhlich, Syré, van der Schoor, Jefferies, Grahle, & Heide, 2022). The engine is the heart of the vehicle, which is made up of a variety of vital components and systems. Ensuring the desired efficiency and maintaining the performance and durability of the vehicular engine is the most challenging task. Various studies about real-time vehicle engine monitoring have been carried out over several decades to offset such challenges, including engine oil level, engine temperature (Thamaraimanalan, Mohankumar, Dhanasekaran, & Anandakumar, 2021), and engine exhaust (Sumathy et al., 2023) monitoring systems to predict its health condition. The current vehicles are equipped with OBD-II to monitor the vehicle's engine health and ensure a comfortable journey with features like navigation systems, anti-theft systems, lane detection systems, collision mitigation systems, and driving assistance systems. Typically, OBD-II is used to monitor specific characteristics of vehicle engines, such as the rotational speed, coolant temperature, exhaust gas quality, air–fuel ratio, and ignition system, in addition to these primary concerns relating to the vehicle's structure (Shafi, Safi, Shahid, Ziauddin, & Saleem, 2018). As the importance of automobiles in our everyday lives is increasing, the need to monitor the condition of a vehicle's engine in a more sophisticated manner is also becoming more crucial.

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