Generating Artificial Driving Patterns by Using Generative Adversarial Networks

Fannia Pacheco
Department of Mechanical and Electrical Engineering
University of Southern Denmark, SDU
Sonderborg, 6400, Denmark
fpacheco@sdu.dk

Mariela Cerrada
Research and Development Group on Industrial Technologies (GIDTEC)
Universidad Politécnica Salesiana
Cuenca, 010105, Ecuador
mcerrada@ups.edu.ec

José Ignacio Huertas
Energy and Climate Change Research Group
School of Engineering and Science, Tecnológico de Monterrey
Monterrey, 64849, Mexico
jhuertas@tec.mx

Abstract

A Driving Pattern (DP) describes how drivers drive in a given region. The DPs are obtained by monitoring a representative sample of vehicles traveling on roads of different characteristics and under normal conditions. A Driving Cycle (DC), on the other hand, is a speed time series that represent the DP, and it is used to assess the performance in energy consumption and tailpipe emissions of the vehicles. The construction of a DC consists in obtaining a speed time series whose characteristic parameters (CP*s) are similar to the characteristic parameters of the driving pattern (CPs). The CPs are variables derived from speed and time, such as the mean speed and mean acceleration. The methods to construct DC (Micro-Trips, Markov chains, and MWD-CP) are well-known and established. However, challenges remain with respect to the repeatability of their results, the need for a large number of measured trips, which is highly expensive and time-consuming. This work presents an alternative and novel approach to construct artificial DC representing DPs using a few measured trips and a Deep Learning (DL) model called Generative Adversarial Networks (GAN). A GAN combines two DL architectures: the generator and the discriminator. The generator creates candidate artificial DC as similar as possible to the real trips, while the discriminator distinguishes between real and artificial DC. Therefore, a competition is triggered between the generator and discriminator, resulting in a generator capable of creating representative candidate artificial DC. For instance, the generator looks after: i) to minimize loss functions which are the relative differences between CPs of the artificial DC and of the driving patterns, and ii) to maximize the failure of the discriminator. In addition, the resulting model can be used to obtain DCs from other cities using transfer learning techniques. Transfer learning consists of reusing a well-trained and validated model in a similar application by adjusting only the model parameters. As a case example, we collected second by second data of speed, fuel consumption, and tailpipe pollutants, obtained monitoring for two months, a sample of 16 vehicles operating in Mexico City. A GAN was trained for constructing artificial but representative DC of 20 minutes duration with a resolution of 1 Hz. We used that GAN to construct 10000 representative DC and found that in all cases, the DCs exhibit CP*s within the 10% of the relative difference with respect to the corresponding 19 CPs that describe the DP, fuel consumption, and tailpipe emissions. According to the literature, 10% of the relative difference is an acceptable criterion for this purpose. Similar results were observed applying transfer learning to data from Bogota, Colombia.

The proposed artificial trip generator aims to alleviate the data collection costs to obtain DC, fuel consumption, and tailpipe emissions. Ultimately, we introduced new emerging technologies based on artificial intelligence to tackle an existing challenge in the field of intelligent transportation and smart mobility.

Keywords
Driving patterns, Driving cycles, Generative Adversarial Networks, Deep learning, Transfer learning.

Acknowledgements
This work has been supported by the GIDTEC research group at the Universidad Politécnica Salesiana, Ecuador, and the Energy and Climate Change research group at the Tecnológico de Monterrey, México.

Biographies
Fannia Pacheco received her M.Sc. Degree in Computer Science from the Universidad de Los Andes, Venezuela, 2015. Between 2015 and 2016, she joined the "GIDTEC" research team at the Universidad Politécnica Salesiana (UPS), Ecuador. At GIDTEC, she worked as a researcher in topics related to Machine Learning, Signal Processing, and fault diagnosis in rotating machinery. She earned a PhD in computer science at the "Université de Pau et des Pays de l'Adour" jointly with the telecommunication company "Thales Alenias Space" in 2019. Her research topic was focused on the characterization and identification of Internet traffic for improving the QoS in Satellite networks. She will join the department of Mechanical and Electrical Engineering as a postdoctoral fellow at the University of Southern Denmark. Her main interests cover novelty detection, data analysis, and intelligent systems.

Mariela Cerrada is a full professor with the Mechatronics career and researcher with the development and research group on industrial technologies (GIDTEC) at the Salesian Polytechnique University in Cuenca, Ecuador, and was with the Control Systems Department at Universidad de Los Andes (ULA), Venezuela. She earned her B.Sc. in System Engineering and the M.Sc. in Control Engineering from ULA. She received her Ph.D. from the National Institute of Applied Sciences, Toulouse, France. She is IEEE senior member, she has published journal and conference papers, and completed research and industrial projects. Her main research interests include fault diagnosis and prognostics in industrial processes, intelligent industrial supervision and control, and machine learning applied on different knowledge domains.

Jose Ignacio Huertas Cardozo is a Professor of the Mechanical Engineering Department at Tecnológico de Monterrey, México. Researcher of the Energy and Climate Change Research Group. Member of the Mexican Academy of Science and of the National System of Researchers. Research areas: Energy, Combustion, Vehicular Emissions, Air Pollution and Smart mobility.