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FULL LENGTH ARTICLE

Application of artificial neural networks for the prediction of traction performance parameters

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Abstract This study handles artificial neural networks (ANN) modeling to predict tire contact area and rolling resistance due to the complex and nonlinear interactions between soil and wheel that mathematical, numerical and conventional models fail to investigate multivariate input and output relationships with nonlinear and complex characteristics. Experimental data acquisitioning was carried out using a soil bin facility with single-wheel tester at seven inflation pressures of tire (i.e. 100–700 kPa) and seven different wheel loads (1–7 KN) with two soil textures and two tire types. The experimental datasets were used to develop a feed-forward with back propagation ANN model. Four criteria (i.e. *R*-value, *T* value, mean squared error, and model simplicity) were used to evaluate model's performance. A well-trained optimum 4-6-2 ANN provided the best accuracy in modeling contact area and rolling resistance with regression coefficients of 0.998 and 0.999 and *T* value and MSE of 0.996 and 2.55×10^{-12}, respectively. It was found that ANNs due to faster, more precise, and considerably reliable computation of multivariable, nonlinear, and complex computations are highly appropriate for soil–wheel interaction modeling.

1. Introduction

Soil–tool interactions have been discussed and investigated by many researchers due to highly complex behavior of soil that inhibits to obtain generalized yet highly valid models. Wheel as an imperative part of off-road vehicles portends sophisticated relations with soil. The significance of contact area in the domain of soil–wheel interactions is considerable (Taghavifar and Mardani, 2012). Contact area of tire, in addition to major parameters affecting contact area (i.e. tire inflation pressure and wheel load), is reliant on mutual and multiple actions between variables. These actions complicate to distinguish that contact area is chiefly impressed by which of variables. Furthermore, rolling resistance (RR) of wheel is a major production of soil–wheel interactions. RR in essence is the required energy to compact the soil beneath the wheel while traversing a definite distance. Consequently it is a resistive force against movement multiplied by the distance obtained as following.

$$R = b_w \int_0^{Z_{\max}} \left(\frac{K_C}{b} K_\varphi \right) Z^n dZ \quad (1)$$

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where n is sinkage exponent, b_w is tire width, b is the smaller dimension of the rectangular contact area, Z is the sinkage, and K_C and $K\varphi$ are the soil condition parameters, respectively. It should be noted that validity of equation above in order to predict rolling resistance based on soil deformation was offered by Wong (1984) that for wheel diameters more than 50 cm and sinkage levels less than 15% of wheel diameter. Additionally, RR relies on contact area since contact area defines the area of soil to be compacted. Contact area and RR interactions are influential on their determinations.

Artificial neural networks (ANN) are widely used to facilitate answering complicated problems in variety of science and engineering domains chiefly wherever conventional and mathematical modeling fail to succeed. Artificial neural networks have been carried out in an effectively manner in the fields of pattern recognition, modeling, and control (Haykin, 1999). A well-trained ANN, which is fundamentally inspired by human being neural system, is applicable to be utilized as a predictive model for a specific application in science. ANN models and their performance are relying on training experimental data followed by validating and testing the model by independent datasets. Accommodating multiple input variables, while it has the ability to improve its performance with new sets of data, multiple output variables can be efficiently predicted. Conventional models as well as mathematical ones are usually incapable of predicting complex nonlinear phenomena exempt from simplifying the models by neglecting interactions between parameters. This brings about rising inaccuracy. Furthermore, ANN advantages of much faster and more accurate calculations compared with mathematical or conventional methods as no prolonged repetitive calculations are needed. However, appropriate ANN topology is significant to attain simple models with lower mean squared error (MSE) and higher accuracy. Each input to the artificial neural network is multiplied by the synaptic weight, added together and dealt with an activation function. ANNs are trained by frequently exploring the best relationship between the input and output values creating a model after a sufficient number of learning repetitions, or training known as epochs (Jaiswal et al., 2005). After training, the model can be generalized with new input values to predict, simulate and re-establish the condition identified as testing procedure.

Modeling draught, as an index of RR, has long been discussed in the literature. Roul et al. (2009) successfully applied ANN model predicting the draught requirement of tillage implements under varying operating and soil conditions. Zhang and Kushwaha (1999) utilized RBF function in ANN to estimate draught of narrow blades in soil under multiple input variables. They stated that an appropriate neural network model could effectively predict the required draught for the blade. Literature survey further indicated that no outstanding attempt has been made to utilize ANN to predict RR and contact area simultaneously. Appropriate application of ANN in this case is highlighted when taking into account that conven-

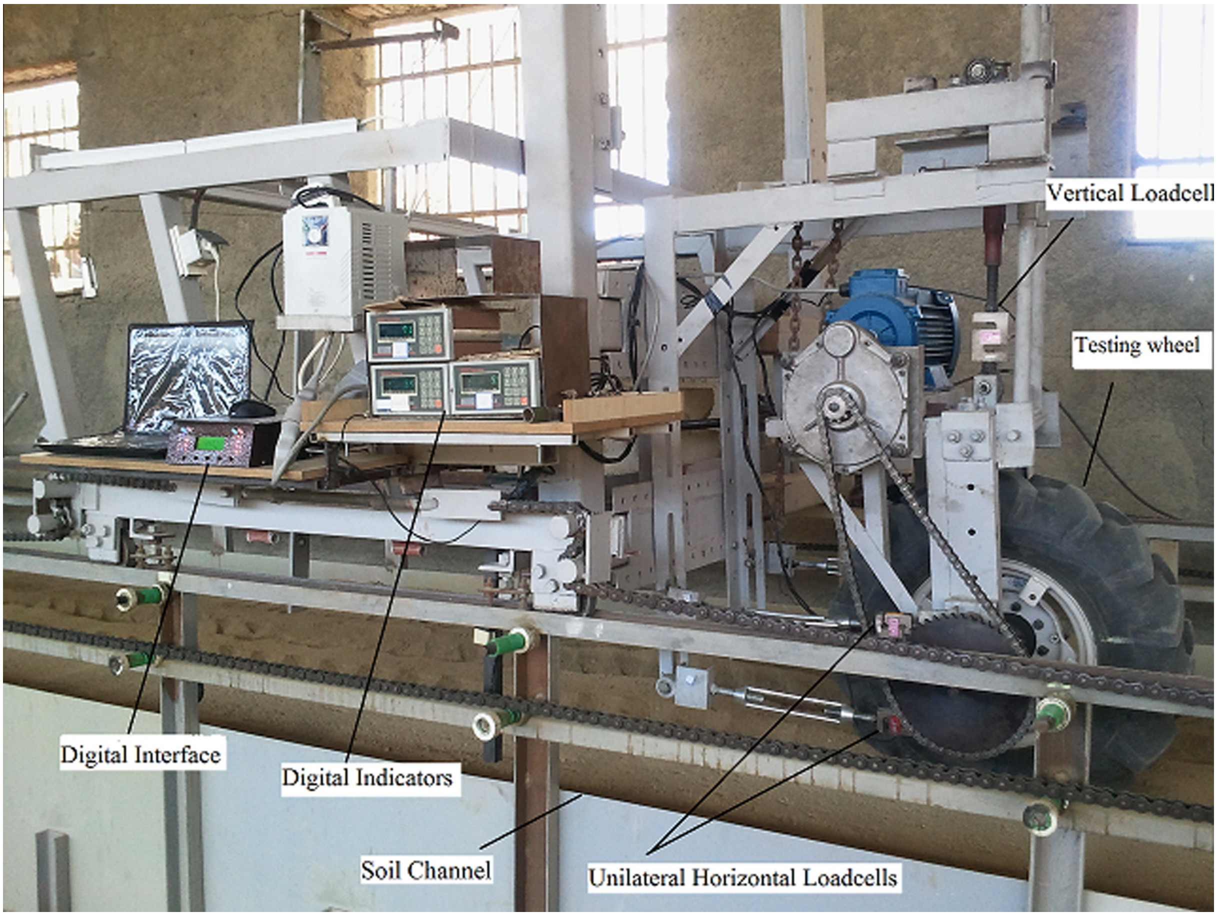

Figure 1 The picture of test soil bin facility.