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Optimizing LSTM for Traffic Accident Prediction Using Beluga Optimization Algorithm

Rafael Mendez
University of Queensland,Brisbane, Australia
rafael93@uq.edu.au

Abstract:

Accurate prediction of traffic accidents plays a crucial role in enhancing road safety and mitigating risks. Long Short-Term Memory (LSTM) networks have demonstrated significant potential in modeling sequential data for traffic prediction tasks. Building on prior research that highlights the efficacy of Multi-LSTM models and convolutional neural networks, this study leverages the Beluga optimization algorithm to refine LSTM models for improved accuracy in predicting short-term traffic accidents. The proposed method addresses limitations related to data sources and factor analysis by enhancing parameter selection and model performance. Experimental results indicate that the optimized LSTM model surpasses conventional approaches, providing more precise predictions and contributing to advancements in traffic management and accident prevention.

Keywords:

Beluga Optimization Algorithm; LSTM; Traffic Accident Prediction.

1. Introduction

Hochreiter S. et al. [1] introduced the foundational concept of Long Short-Term Memory (LSTM), a groundbreaking neural network architecture designed to selectively process and retain relevant previous information while discarding less important data. LSTM excels in handling sequences of data, making it particularly suitable for tasks involving long- and short-term dependencies. Building upon this concept, Tang L. et al. [2] developed an advanced prediction methodology that effectively predicts lane change intention based on a multi-short-term memory (Multi-LSTM) framework. Their results demonstrated the model's ability to accurately forecast vehicle lane change intentions in highway scenarios, achieving a maximum prediction accuracy of 83.75%. This performance significantly surpasses that of traditional methods, such as Support Vector Machine (SVM), highlighting the potential of LSTM-based models in dynamic and complex driving environments.
Zhang Yankong et al. [3] expanded on the applications of LSTM and neural networks by proposing a method for predicting short-term traffic accidents in urban areas. Their approach integrates the road network structure with advanced machine learning techniques, using a combination of multilayer convolutional artificial neural networks and bidirectional LSTM to construct a robust prediction model. The study emphasized the critical influence of both spatial and temporal features on the model's prediction performance. However, the researchers noted limitations in the model, such as its reliance on multiple data sources and the absence of comprehensive factor analysis to refine the results further. Addressing these limitations, the current paper adopts an improved optimization algorithm to enhance the LSTM model, improving its accuracy and reliability in traffic accident prediction. This approach not only leverages advanced neural network architectures but also incorporates innovative optimization techniques to address existing challenges, paving the way for more effective predictive models in traffic management and safety analysis.

2. Beluga Whale Optimization Algorithm

Beluga whales are highly social animals that can cluster in groups with 2 to 25 members and an average of 10 members. In Figure 1 (b) below, in fig, the fish are omnivorous, including but not

limited to shrimp, worms, cod, trout, and salmon. When summer comes, many creatures gather in some estuaries, so beluga whales gather to eat. Because beluga whales do not have sharp teeth, they usually carry their prey into their mouths by suction. Sometimes beluga whales will coordinate teams to attack the fish, guiding the fish into shallow water. Moreover, beluga whales are threatened by killer whales, polar bears, and humans during the summer months. Some beluga whales may die during migration and fall into the deep sea, known as "beluga fall", providing ample food for a large number of organisms without sun and oxygen, as shown in Figure 1 (c) below. Inspired by the behaviors of beluwhale swimming, hunting, and whaling, Zhong C[4] A new meta-heuristic algorithm, the Beluga optimization algorithm (BWO), was developed.

3. LSTM Model

LSTM is an extended ANN structure whose hidden layer has an additional set of state modules, called cell unit states, that can be used to study a long-term dependent relationship. LSTM uses a special grid structure that allows it to store input data with a long history, with the same requirements as RNN input data, that is, the input data must be composed of coherent upstream and downstream data to better understand and analyze the complex relationships between cell states.

And thus often used for modeling and predicting data. The LSTM structure consists of a series of interconnected neural network nodes, also known as units, which are marked with the letter A in the horizontal direction. In the vertical direction, the flow direction of the input and output parameter interaction is unidirectional. The structure of the LSTM model is shown in Figure 1:

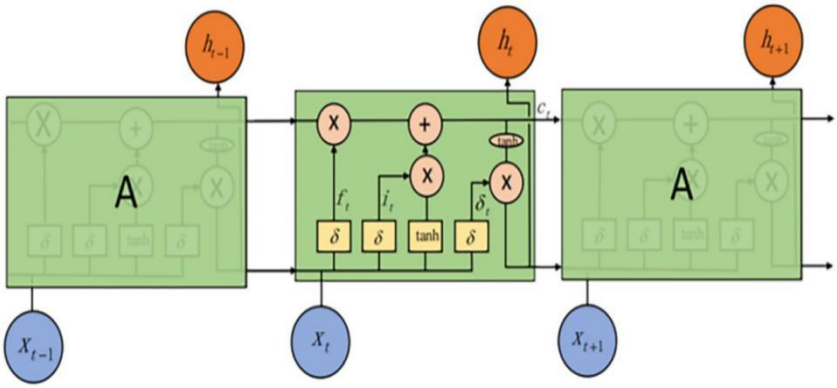

Figure 1. Structural diagram of the LSTM

4. Traffic Accident Prediction based on BWO-LSTM

The default parameters of LSTM are often based on the user's empirical preferences, and its high stochasticity will cause the prediction accuracy is not particularly high and even fall into the range of local optimal solutions. To address these problems, we used a modified Beluga algorithm to optimize the LSTM model. The main core task of the optimization using the Beluga algorithm is to optimize the number of neurons focused on the hidden layer, the learning rate, and the number of iterations. Therefore, the LSTM model optimized by beluga whale algorithm is used to predict traffic accidents. The main optimization parts include the following aspects:

(1) Initialize all the parameters contained in the network, and define the topology structure;

(2) Select the parameter search space based on the random value defined, and the parameters to be optimized;

(3) Calculate the fitness of individual beluga whale and use it to verify the model. If the calculated adaptation value is the smallest, it is defined as the best value of this time. The value is compared with the global best value. If this value is less than the global best value, a substitution will be generated;

(4) For iteration, constantly replace the hyperparameters of LSTM and repeat steps (3) and (4) until

the maximum number of iterations is completed.

In this paper, the number of traffic accidents in a city from 2016 to 2020 is used to predict, and the ratio is 8:2. The prediction results are shown in Figure 2:

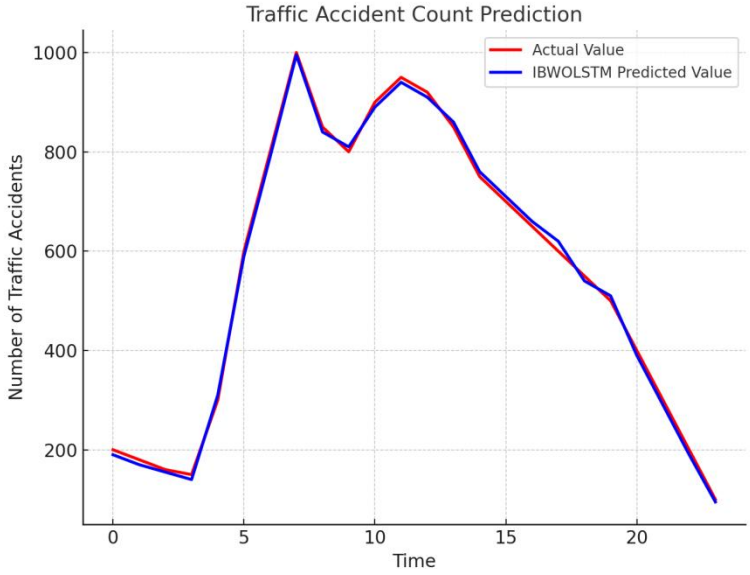

Figure 2. The BWO- -LSTM traffic accident prediction results

5. Conclusion

This paper demonstrates the significant advantages of employing the Beluga Optimization Algorithm (BOA) for enhancing the performance of the Long Short-Term Memory (LSTM) model. By leveraging the BOA, the study effectively fine-tunes the LSTM model, identifying optimal parameters that maximize its predictive accuracy and robustness. The optimized LSTM model is then applied to the critical task of traffic accident prediction, showcasing its ability to provide precise and reliable forecasting. The results achieved underscore the efficacy of this approach, as it not only enhances prediction accuracy but also highlights the potential of integrating advanced optimization techniques with deep learning models to address complex real-world problems. These findings open up new avenues for future research in predictive analytics and optimization-driven model enhancement, particularly in traffic management and accident prevention systems.

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