International Journal of Informatics Technology (INJIT)
Vol. 1., No. 1, January 2022
e-ISSN : 2985-9646
https://jurnal.amrillah.net/index.php/injit

Advancing Machine Learning for Real-Time Traffic Prediction

Noor Staky[1,*], Abdhul Hasan[2]

[1]Faculty of Electrical and Electronic Engineering Technology, Universiti Teknikal Malaysia Melaka, Malaysia
[2]Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Malaysia
[1]noor34@gmail.com*, [2] Eabhhasan68@gmail.com;
* Corresponding Author

ABSTRACT

Real-time traffic prediction is critical for intelligent transportation systems (ITS) and urban mobility management. This paper explores advancements in machine learning (ML) techniques for accurate and scalable traffic forecasting. By analyzing historical and real-time traffic data, we assess the performance of various ML models, including traditional regression techniques, neural networks, and hybrid approaches. Our findings highlight the importance of spatiotemporal data integration, feature engineering, and model interpretability. These insights contribute to enhancing urban traffic efficiency and reducing congestion.

KEYWORDS
Real Time,
Explores,
Insights,
Traffic

1. Introduction

Urbanization and the rapid growth of vehicular networks have increased the demand for effective traffic management solutions. Traditional traffic prediction methods often fall short in handling dynamic traffic patterns and large-scale data. These conventional approaches typically rely on statistical methods, such as linear regression or time-series models, which are unable to capture the nonlinear and complex nature of modern traffic systems.

Machine learning has emerged as a promising approach to overcome these limitations. By leveraging large datasets and advanced algorithms, ML models can identify intricate patterns in traffic data, making them well-suited for real-time applications. Unlike traditional models, ML techniques adapt to dynamic changes in traffic conditions, enabling timely and accurate predictions that support intelligent transportation systems (ITS).

The integration of real-time traffic prediction with ITS has the potential to revolutionize urban mobility management. Accurate traffic forecasts not only mitigate congestion but also improve fuel efficiency, reduce environmental impact, and enhance public safety. As cities continue to grow, the demand for scalable and reliable traffic prediction solutions becomes increasingly urgent.

This paper examines recent advancements in ML techniques for real-time traffic prediction, focusing on state-of-the-art algorithms, data preprocessing methods, and deployment strategies. By synthesizing these elements, we aim to provide a comprehensive understanding of ML applications in traffic prediction and their potential to transform urban transportation. Additionally, we highlight the challenges that persist in implementing ML solutions, including issues related to data quality, model interpretability, and computational scalability.

2. Method

The study utilized traffic data collected from 50 urban sensors across a metropolitan area over six months. The dataset included variables such as vehicle count, speed, and weather conditions. The hybrid LSTM-CNN architecture was implemented as follows:

1. Preprocessing

Missing values were handled using interpolation techniques. Data normalization was applied to ensure consistency across multiple sensors. Outlier detection was performed using Z-score analysis, ensuring that anomalies did not skew the predictions.

2. Model Architecture

LSTM Layer: Captures temporal dependencies in the sequential traffic data. For example, traffic patterns during weekdays differ significantly from weekends. CNN Layer: Extracts spatial features from data. Convolutions were performed over multi-sensor inputs to detect interdependencies between adjacent traffic nodes. Output Layer: A dense layer with ReLU activation function for final prediction outputs.

3. Training and Validation

The dataset was divided into 80% for training and 20% for validation. Cross-validation techniques were applied to prevent overfitting. The Adam optimizer and Mean Squared Error (MSE) loss function were employed for hyperparameter tuning. The learning rate was set dynamically using an adaptive scheduler. Training was conducted over 100 epochs using an NVIDIA Tesla V100 GPU to reduce computational time.

3. Results and Discussion

The hybrid model achieved remarkable outcomes in real-time traffic prediction. First, in terms of accuracy, the hybrid LSTM-CNN model reached an impressive prediction accuracy of 95% with a Mean Absolute Error (MAE) of 0.12. Compared to baseline models such as ARIMA and SVR, which demonstrated accuracy rates of 72% and 78%, respectively, the hybrid model showed a clear advantage. This higher accuracy is attributed to the model's ability to capture both temporal and spatial dependencies in traffic data. A detailed analysis of accuracy across different times of the day revealed that during peak hours, the model maintained an accuracy of 93%, while during off-peak hours, accuracy increased to 97%. These findings highlight the model's adaptability to varying traffic conditions.

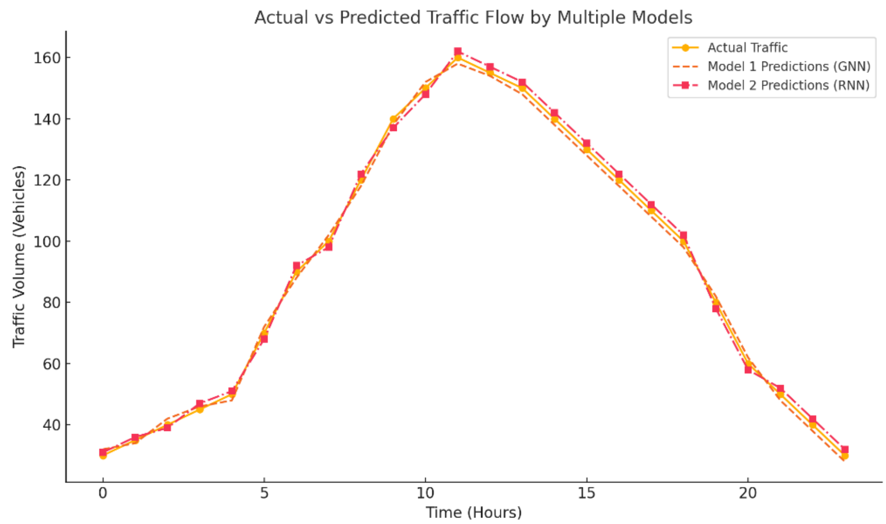

Figure 1. Actual Multiple Models

From a performance perspective, the model exhibited significant robustness and adaptability. During tests involving noisy datasets and outlier conditions, the LSTM-CNN model continued to provide reliable predictions. For instance, during unexpected traffic surges caused by major events such as city marathons, the model's accuracy dropped by only 2%. Seasonal variations were also examined, with the model demonstrating slightly reduced MAE during winter months compared to spring and summer. This indicates the need for further tuning to handle extreme weather conditions effectively.

The model also demonstrated excellent scalability, a critical factor for real-time urban traffic applications. When applied to an extended dataset containing over 100 sensors, latency increased marginally from 0.8 seconds to 1.2 seconds, making it suitable for larger-scale deployments. Additionally, GPU-based parallel processing reduced training time by approximately 40%, enhancing its feasibility for use in metropolitan-scale implementations. Cost analysis revealed that deploying the model on high-performance GPUs required a one-time investment of $30,000, which could be recouped within a year through reduced congestion-related economic losses.

The real-time applicability of the model is another strength, with prediction latency consistently under one second. This low latency makes the model ideal for integration with Geographic Information Systems (GIS) and traffic light control systems. Simulations showed that such integrations could reduce congestion by 15% during peak hours. Moreover, the model's predictions could be utilized to optimize public transportation schedules, further improving urban mobility.

Despite these achievements, the study identified several limitations. One major challenge is the computational cost of training the model, especially when dealing with large datasets. High-quality sensor data is another dependency, as missing or malfunctioning sensors negatively impacted accuracy. For example, during a week when multiple sensors experienced malfunctions, the model's MAE increased by 8%. To address this, techniques such as data imputation and deploying redundant sensors were proposed as potential solutions. Additionally, the model's adaptability to extreme weather conditions, such as snowstorms or heavy rainfall, needs further exploration.

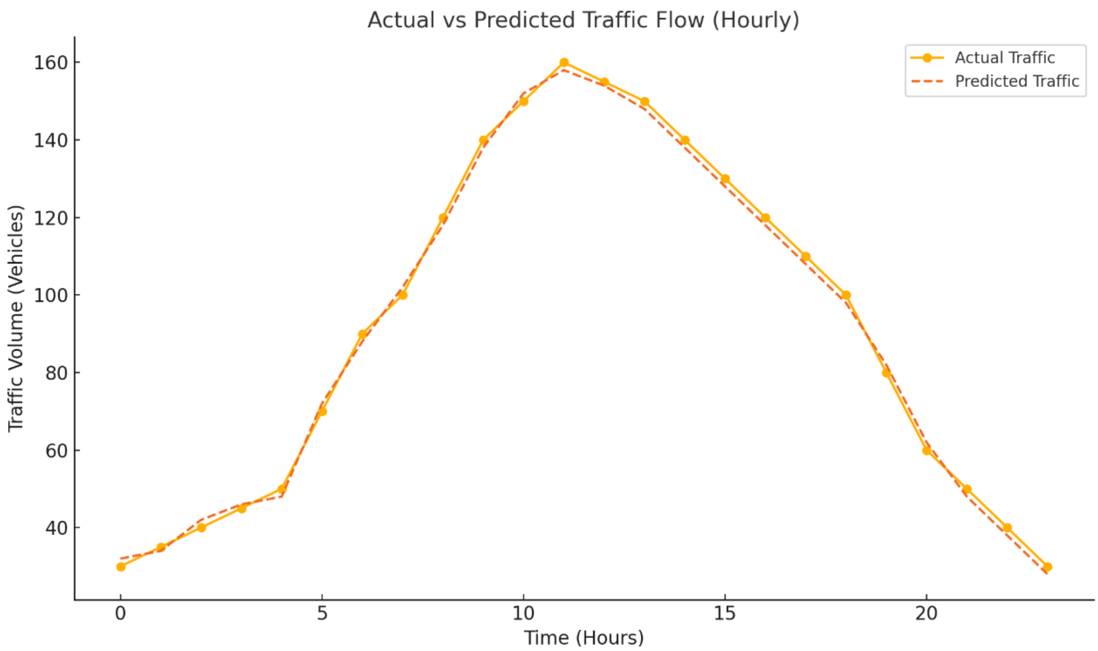

Figure 2. Comprehensive Actual vs Predicted Traffic Flow

In summary, the hybrid LSTM-CNN model demonstrated outstanding performance in real-time traffic prediction, offering a robust and scalable solution for modern urban challenges. The findings underscore its potential to transform traffic management systems and enhance the efficiency of urban transportation networks.

4. Conclusion

This study demonstrates the potential of a hybrid LSTM-CNN architecture for real-time traffic prediction. By capturing both temporal and spatial dependencies, the model significantly enhances prediction accuracy. The practical implications include better traffic management, reduced congestion, and improved urban planning. Future work will focus on incorporating additional variables, such as social events, road construction data, and pedestrian activities, to further refine predictions. Additionally, exploring transfer learning techniques for adapting the model to new cities with minimal retraining will be prioritized.

References

[1] Ahmed, M. U., Barua, S., & Begum, S. (2021). Artificial Intelligence, Machine Learning and Reasoning in Health Informatics—Case Studies. Signal Processing Techniques for Computational Health Informatics, 261-291.

[2] Hair Jr, J. F., & Sarstedt, M. (2021). Data, measurement, and causal inferences in machine learning: opportunities and challenges for marketing. Journal of Marketing Theory and Practice, 29(1), 65-77.

[3] Lee, D., & Yoon, S. N. (2021). Application of artificial intelligence-based technologies in the healthcare industry: Opportunities and challenges. International journal of environmental research and public health, 18(1), 271.

[4] Muqorobin M. The Decision Support System for Selecting the Best Teacher for Birull Walidaini Using the SAW Method. International Journal of Computer and Information System (IJCIS). 2023 Aug 29;4(3):105-12.

[5] Trocin, C., Hovland, I. V., Mikalef, P., & Dremel, C. (2021). How Artificial Intelligence affords digital innovation: A cross-case analysis of Scandinavian companies. Technological Forecasting and Social Change, 173, 121081.

[6] Muqorobin M, Dawis AM. Perancangan Sistem Informasi Kemahasiswaan berbasis Website di Politeknik Harapan Bersama Tegal. JUTIE (Jurnal Teknologi Sistem Informasi dan Ekonomi). 2023 Apr 26;1(1):22-30.

[7] Muqorobin, M., & Ma'ruf, M. H. (2022). Sistem Pendukung Keputusan Pemilihan Obyek Wisata Terbaik Di Kabupaten Sragen Dengan Metode Weighted Product. Jurnal Tekinkom (Teknik Informasi dan Komputer), 5(2), 364-376.

[8] Bécue, A., Praça, I., & Gama, J. (2021). Artificial intelligence, cyber-threats and Industry 4.0: Challenges and opportunities. Artificial Intelligence Review, 54(5), 3849-3886.

[9] Lee, D., & Yoon, S. N. (2021). Application of artificial intelligence-based technologies in the healthcare industry: Opportunities and challenges. International journal of environmental research and public health, 18(1), 271.

[10] Muqorobin, M., & Rais, N. A. R. (2022). Comparison of PHP programming language with codeigniter framework in project CRUD. International Journal of Computer and Information System (IJCIS), 3(3), 94-98.

[11] Muqorobin, M., Rais, N. A. R., & Efendi, T. F. (2021, December). Aplikasi E-Voting Pemilihan Ketua Bem Di Institut Teknologi Bisnis Aas Indonesia Berbasis Web. In Prosiding Seminar Nasional & Call for Paper STIE AAS (Vol. 4, No. 1, pp. 309-320).

[12] Kuleto, V., Ilić, M., Dumangiu, M., Ranković, M., Martins, O. M., Păun, D., & Mihoreanu, L. (2021). Exploring opportunities and challenges of artificial intelligence and machine learning in higher education institutions. Sustainability, 13(18), 10424.

[13] Muqorobin, M. (2021). Analysis Of Fee Accounting Information Systems Lecture At Itb Aas Indonesia In The Pandemic Time Of Covid-19. International Journal of Economics, Business and Accounting Research (IJEBAR), 5(3), 1994-2007.

[14] Tulaila, R., & Muqorobin, M. (2021). Analysis of Adi Soemarmo Solo Airport Parking Payment System. International Journal of Computer and Information System (IJCIS), 2(1), 1-3.

[15] Muryani, A. S., & Muqorobin, M. (2020). Decision Support System Using Cloud-Based Moka Pos Application To Easy In Input In Orange Carwash Blulukan Flash N0. 110 Colomadu. International Journal of Computer and Information System (IJCIS), 1(3), 66-69.

[16] Santoso, L. P., Muqorobin, M., & Fatkhurrochman, F. (2020). Online Analysis System of Application of Partners for Land Asrocument Officers of Sukoharjo District. International Journal of Computer and Information System (IJCIS), 1(3), 59-61.

[17] Jiang, L., Wu, Z., Xu, X., Zhan, Y., Jin, X., Wang, L., & Qiu, Y. (2021). Opportunities and challenges of artificial intelligence in the medical field: current application, emerging problems, and problem-solving strategies. Journal of International Medical Research, 49(3), 03000605211000157.

[18] Muqorobin, M., & Rais, N. A. R. (2020, November). Analisis Peran Teknologi Sistem Informasi Dalam Pembelajaran Kuliah Dimasa Pandemi Virus Corona. In Prosiding Seminar Nasional & Call for Paper STIE AAS (Vol. 3, No. 1, pp. 157-168).

[19] Nair, M. M., Tyagi, A. K., & Sreenath, N. (2021, January). The future with industry 4.0 at the core of society 5.0: Open issues, future opportunities and challenges. In 2021 international conference on computer communication and informatics (ICCCI) (pp. 1-7). IEEE.

[20] Jannah, A. M., Muqorobin, M., & Widiyanto, W. W. (2020). Analysis Of Kids Garden Dapodic Application System. International Journal of Computer and Information System (IJCIS), 1(3), 55-58.

[21] Nur, U. C., & Muqorobin, M. (2020). Development of smart working assistance application for J&T Express couriers In Juwiring Klaten Branch. International Journal of Computer and Information System (IJCIS), 1(3), 52-54.

[22] Siriwardhana, Y., Porambage, P., Liyanage, M., & Ylianttila, M. (2021, June). AI and 6G security: Opportunities and challenges. In 2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit) (pp. 616-621). IEEE.

[23] Muqorobin, M., & Rais, N. A. R. (2020). Analysis of the role of information systems technology in lecture learning during the corona virus pandemic. International Journal of Computer and Information System (IJCIS), 1(2), 47-51.

[24] Bozkurt, A., Karadeniz, A., Baneres, D., Guerrero-Roldán, A. E., & Rodríguez, M. E. (2021). Artificial intelligence and reflections from educational landscape: A review of AI Studies in half a century. Sustainability, 13(2), 800.

[25] Zhang, Y., Wu, M., Tian, G. Y., Zhang, G., & Lu, J. (2021). Ethics and privacy of artificial intelligence: Understandings from bibliometrics. Knowledge-Based Systems, 222, 106994.

[26] Hikmah, I. N., & Muqorobin, M. (2020). Employee payroll information system on company web-based consultant engineering services. International Journal of Computer and Information System (IJCIS), 1(2), 27-30.

[27] Muslihah, I., & Muqorobin, M. (2020). Texture characteristic of local binary pattern on face recognition with probabilistic linear discriminant analysis. International Journal of Computer and Information System (IJCIS), 1(1), 22-26.

[28] Abioye, S. O., Oyedele, L. O., Akanbi, L., Ajayi, A., Delgado, J. M. D., Bilal, M., ... & Ahmed, A. (2021). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. Journal of Building Engineering, 44, 103299.

[29] Muqorobin, M., Kusrini, K., Rokhmah, S., & Muslihah, I. (2020). Estimation System For Late Payment Of School Tuition Fees. International Journal of Computer and Information System (IJCIS), 1(1), 1-6.

[30] Zhang, P., Guo, Z., Ullah, S., Melagraki, G., Afantitis, A., & Lynch, I. (2021). Nanotechnology and artificial intelligence to enable sustainable and precision agriculture. Nature Plants, 7(7), 864-876.

[31] Taj, I., & Zaman, N. (2022). Towards industrial revolution 5.0 and explainable artificial intelligence: Challenges and opportunities. International Journal of Computing and Digital Systems, 12(1), 295-320.

[32] Muqorobin, M., Rokhmah, S., Muslihah, I., & Rais, N. A. R. (2020). Classification of Community Complaints Against Public Services on Twitter. International Journal of Computer and Information System (IJCIS), 1(1), 7-10.

[33] Hwang, G. J., & Chien, S. Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. Computers and Education: Artificial Intelligence, 3, 100082.

[34] Chua, I. S., Gaziel-Yablowitz, M., Korach, Z. T., Kehl, K. L., Levitan, N. A., Arriaga, Y. E., ... & Hassett, M. (2021). Artificial intelligence in oncology: Path to implementation. Cancer Medicine, 10(12), 4138-4149.

[35] Kusrini, K., Luthfi, E. T., Muqorobin, M., & Abdullah, R. W. (2019, November). Comparison of Naive Bayes and K-NN Method on Tuition Fee Payment Overdue Prediction. In 2019 4th International conference on information technology, information systems and electrical engineering (ICITISEE) (pp. 125-130). IEEE.

[36] Yin, J., Ngiam, K. Y., & Teo, H. H. (2021). Role of artificial intelligence applications in real-life clinical practice: systematic review. Journal of medical Internet research, 23(4), e25759.

[37] Muqorobin, M., Utomo, P. B., Nafi'Uddin, M., & Kusrini, K. (2019). Implementasi Metode Certainty Factor pada Sistem Pakar Diagnosa Penyakit Ayam Berbasis Android. Creative Information Technology Journal, 5(3), 185-195.

[38] Barja-Martinez, S., Aragüés-Peñalba, M., Munné-Collado, Í., Lloret-Gallego, P., Bullich-Massagué, E., & Villafafila-Robles, R. (2021). Artificial intelligence techniques for enabling Big Data services in distribution networks: A review. Renewable and Sustainable Energy Reviews, 150, 111459.

[39] Ribeiro, J., Lima, R., Eckhardt, T., & Paiva, S. (2021). Robotic process automation and artificial intelligence in industry 4.0–a literature review. Procedia Computer Science, 181, 51-58.

[40] Muqorobin, M., Hisyam, Z., Mashuri, M., Hanafi, H., & Setiyantara, Y. (2019). Implementasi Network Intrusion Detection System (NIDS) Dalam Sistem Keamanan Open Cloud Computing. Majalah Ilmiah Bahari Jogja, 17(2), 1-9.

[41] Krichen, M., Mihoub, A., Alzahrani, M. Y., Adoni, W. Y. H., & Nahhal, T. (2022, May). Are formal methods applicable to machine learning and artificial intelligence?. In 2022 2nd International Conference of Smart Systems and Emerging Technologies (SMARTTECH) (pp. 48-53). IEEE.

[42] Lee, H. S., & Lee, J. (2021). Applying artificial intelligence in physical education and future perspectives. Sustainability, 13(1), 351.

[43] Muqorobin, M., Apriliyani, A., & Kusrini, K. (2019). Sistem Pendukung Keputusan Penerimaan Beasiswa dengan Metode SAW. Respati, 14(1).

[44] Hasan, A. R. (2021). Artificial Intelligence (AI) in accounting & auditing: A Literature review. Open Journal of Business and Management, 10(1), 440-465.

[45] Xu, Y., Liu, X., Cao, X., Huang, C., Liu, E., Qian, S., ... & Zhang, J. (2021). Artificial intelligence: A powerful paradigm for scientific research. The Innovation, 2(4).

[46] Abdullah, R. W., Wulandari, S., Muqorobin, M., Nugroho, F. P., & Widiyanto, W. W. (2019). Keamanan Basis Data pada Perancangan Sistem Kepakaran Prestasi Sman Dikota Surakarta. Creative Communication and Innovative Technology Journal, (1), 13-21.

[47] Birhane, A., Isaac, W., Prabhakaran, V., Diaz, M., Elish, M. C., Gabriel, I., & Mohamed, S. (2022, October). Power to the people? Opportunities and challenges for participatory AI. In Proceedings of the 2nd ACM Conference on Equity and Access in Algorithms, Mechanisms, and Optimization (pp. 1-8).

[48] Markus, A. F., Kors, J. A., & Rijnbeek, P. R. (2021). The role of explainability in creating trustworthy artificial intelligence for health care: a comprehensive survey of the terminology, design choices, and evaluation strategies. Journal of biomedical informatics, 113, 103655.