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Intelligent Connectivity in Cyber-Physical and Social Networks for Optimizing Smart Mobility and Traffic Management

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Abstract

With the rapid development of urban populations and growing traffic congestion, intelligent connectivity in cyber-physical and social networks is essential for improving smart mobility and traffic management. This research establishes an advanced approach to optimizing smart mobility and traffic management systems by incorporating intelligent connectivity within cyber-physical and social networks. The research proposes a novel method calledAquila optimizer tuned deep residual network (AO-DeepResNet), which associates the Aquila optimizer (AO) with deep residual neural networks (DeepResNet) for optimizing smart mobility and traffic management. AO is used to enhance the parameters of DeepResNet, extensively improving the traffic prediction accuracy and mobility management. The dataset comprises real-time traffic patterns, vehicle telemetry, ride-sharing demand, public transport efficiency, social media sentiment, and environmental features. The findings demonstrate that the proposed method AO-DeepResNet outperforms existing methods in terms of F1 score (97.21%), and accuracy (98.5%). Therefore, the proposed AO-DeepResNet method significantly enhanced the smart mobility and traffic management.

Keywords: Traffic Management, Cyber-Physical, Smart Mobility, Social Networks, Traffic Prediction, Aquila Optimizer Tuned Deep Residual Network (AO-DeepResNet).

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1 Introduction

The multifaceted cyber-physical-social system (CPSS) organization, social, physical, and cyber elements must be seamlessly combined, enabling enhanced interaction, data exchange, and decision making across these interconnected domains. Through the procedure of big data and cutting-edge technology, CPSS develops real-time decision-making and telecom services (Amin et al., 2024). Cyber-physical-social networks (CPSN) advance smart movement and traffic association by amalgamation big data, artificial intelligence (AI), and the Internet of Vehicles (IoV) (Kumar & Yadav, 2024). The real-time data and observant aptitude are used in CPSN-IoV to optimize traffic flow, collision detection, and navigation. The networks make it possible to afford human-centered, adjustable services for effective urban mobility (Arooj et al., 2020). To progress data directing and task extension in CPS-ITS, this investigate aims to expand an effective strategy that enhances system performance, ensures dependable communication, and expands reserve allocation. Support Learning improves decision-making and give by combination it with Gated Linear Units (GLUs). The methodology operates superior than current methods, guaranteeing safer and more effective transportation (Srinivasa Gowda et al., 2025; Udayakumar et al., 2023). To more successfully recognize false information, the approach makes use of text and image modalities. To enhance detection accuracy, it presents a cross-moral ambiguity learning technique. The model improves current detection techniques by dynamically modifying feature weights according to modality contributions (Byeon et al., 2025; Iyer & Deshpande, 2024). Connected and Autonomous Vehicles (CAVs) operating at unsignalized crossings, an Independent Connectivity Management (AIM) system with priority sharing was recommended. For cooperative trajectory planning, it presents a lane-free method and a behavior assessment method for fair priority trading (Topalova et al., 2024). By enhancing traffic flow and fairness, it increases the effectiveness of intersection management (Li et al., 2022). To maximize smart mobility and traffic management, the suggests a unique technique known as AO-DeepResNet, which combined the AO with DeepResNet (Sen & Malhotra, 2025).

System overview: Part 2 clearly explains the existing research about smart mobility and traffic management. Part 3 explains the research methodology. Part 4 demonstrates the outcome of proposed and existing methods with their discussion. Finally, Part 5 concludes with the conclusion.

2 Related Works

Anoptimizable Cyber-physical-social Awareness (CPSA) platform that leverages social media and IoV data to improve situational awareness was created (Mirza et al., 2023). Using cloud-based machine learning (ML) models, the approach combined and semantically characterizes diverse data from social media and sensors. The outcomes demonstrated that CPSA successfully crosses vast data volumes, offering more thorough and precise awareness. During real-world tests, limitations include throughput and processing time restrictions (Bhatia & Ramesh Iyer, 2025). The Cyber-Physical-Social Systems (CPSS) that develop Cyber-Physical-Social Intelligence (CPSI) were used to examine algorithmic theories (Wang et al., 2023). To create convergent and agile systems, human intelligence, computational intelligence, and physical space were united. The findings highlight the innovations for a maintainable future, such as digital twins and the metaverse. However, handling intricate relationships inside CPSI for entire system management yet presented difficulties. The proposed technique optimized the edge service deployment in CPSI for IoV by incorporating communication, computation, and cost models with the Analytic hierarchy process-based Heterogeneous edge Service deployment (AHSP) algorithm (Meng et al., 2023). To improve deployment effectiveness and minimize latency, optimized resource allocation and streamlined communication protocols are necessary (Sharmila et al., 2025). However, achieving an optimal cost-latency trade-off remains challenging due to dynamic network conditions. Experimental results demonstrated enhanced efficiency and reduced latency compared to existing approaches (Hassooni, 2024).

To increase efficiency, the research (Xiong et al., 2023) aims to optimize CPSS operations in transportation through the use of control theories, stochastic modeling, and real-time monitoring. The strategy used cutting-edge analytical methods to enhance decision-making and traffic management. Important performance improvements were demonstrated by the results; resource constraints, security threats, and data integration issues continue to be major roadblocks. To implement CPSS in a secure and seamless manner, several restrictions must be addressed (Hu & Sinniah, 2024). A modified deferred acceptance algorithm for many-to-many matching in a bipartite network was proposed to maximize P2P (Peer-to-Peer) energy sharing in CPSS (Tan et al., 2023). The method maximized energy allocation among peers while improving efficiency and welfare. Findings support its efficacy, although issues with scalability, computing complexity, and integration with current grids yet exist. Resolving the problems was crucial for sustainability and wider acceptance (Khyade, 2019).

3 Materials and Method

The AO-DeepResNet architecture improved traffic flow and mobility prediction by combining DeepResNet and AO. For data-driven insights, it makes use of social media sentiment analysis, real-time traffic analytics, ride-sharing demand, and vehicle telemetry. The system aims to increase the effectiveness of traffic management and congestion control by dynamically improving features and predictions.

3.1 Data Collection

Smart mobility traffic dataset was collected from Kaggle (https://www.kaggle.com/datasets/ziya07/smart-mobility-traffic-dataset/data). The dataset enhanced the intelligent traffic management and smart mobility solutions by combining data from social networks (SNs) and cyber-physical networks (CPNs). The dataset encompasses social media sentiment, ride-sharing demand, vehicle telemetry, real-time traffic patterns, and environmental elements. The dataset analyzes important variables such as vehicle density, road occupancy, weather, social media feedback, and emissions data to help ML models for mobile optimization, smart city planning, and traffic congestion prediction. The social media posts were observed to identify anomalous traffic patterns, offering real-time information for wise traffic control. Cyber-physical systems (CPS) combine the basics of computers and the physical world, using real-time data and algorithms to monitor traffic flow.

4 Optimizing Smart Mobility and Traffic Management by Aquila Optimizer Tuned Deep Residual Network (AO-DeepResNet)

The Aquila Optimizer (AO) and Deep Residual Neural Networks (DeepResNet) are combined in the suggested AO-DeepResNet technique to optimize parameters for improved intelligent mobility and traffic control. AO-DeepResNet greatly enhances the precision of traffic forecasts and mobility optimization by incorporating intelligent connectivity into cyber-physical and social networks.

4.1 Deep Residual Network (DeepResNet)

ResNet was a deep learning network composed of residual learning modules, where input x was weighted by the first layer, followed by a non-linear transformation using the ReLU function and a second layer weighting, resulting in F(x) + x. In deeper architectures, skipping connections prevents disappearing gradients and network degradation by enabling information to move smoothly between leftover blocks. However, ReLU can cause permanent neuron inactivation, limiting feature extraction efficiency. To address this, the Mish activation function was introduced as a replacement, enhancing the model's ability to extract complex image features while maintaining computational efficiency in optimizing smart mobility and traffic management through deep residual network training, as illustratedin Figure 1.

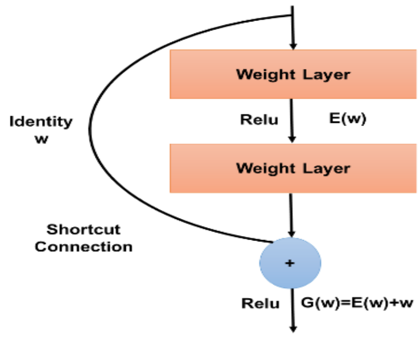

Figure 1: Residual Block Enabling Deep Residual Network Training

4.2 Aquila Optimizer (AO)

For intelligent mobility and traffic organization to be optimized, intelligent connectivity crosswise social and cyber-physical networks was essential. Moved by eagle hunting strategies, the AO provides a useful method for improving these kinds of systems. Initialization, narrow exploration, extended corruption, and expanded exploitation were the primary processes that AO takes. Depending on the number of iterations, the algorithm switches between exploration and exploitation, guaranteeing a dynamic and flexible optimization procedure. Exploration takes precedence over overexploitation when the current iteration was less than or equal to two-thirds of the maximum, improving the efficiency of smart mobility and traffic management.

The equation calculates the weight Wji by adjusting the difference between the actual value VAi and the target value KAi, scaled by$q1$, for each parameter j. given by equation (1).

$$Wji = q1 \times (VAi - KAi) + KAi, j = 1,2, \dots \dots, Mi = 1,2, \dots, Dim \quad (1)$$

The random value $q1$was a member of the interval [0,1].

The equation updates the weight $W1(s+1)$by combining the best weight $Wbest(s)$ a scaling factor based on iteration, and the difference between model output $wM(t)$ and the best solution optimizing traffic prediction to given by equation (2).

$$W1(s+1) = Wbest(s) \times ((1-s)/S) + (wM(t) - Xbest(t) * rand) \quad (2)$$

The equation updates the weight $W2(s+1)$ by combining the best solution $Sbest(s)$, distribution factor $Levy(C)$, a scaling term $Sq(s)$and randomness, optimizing smart mobility as given by equation (3).

$$W2(s+1) = Sbest(s) \times Levy(C) + Sq(s) + (z-w) * rand \quad (3)$$

During the search process, two techniques were employed to mimic people's capacity for exploitation. The first approach relies on utilizing the optimal solution ($Wbest$) and the average of each person's location (WN), optimizing traffic prediction to given by equation (4).

$$W3(s+1) = (Wbest(s) - WN(s)) \times \alpha - rand + ((VA - KA) \times rand + KA) \times \delta \tag{4}$$

The random number was denoted by $rand \in [0,1]$, the exploitation adjustment parameters were denoted by α and δ, and the second exploitation method was dependent on $Wbest$, $Levy$, and the quality function RE the traffic prediction was showed by equation (5).

$$W4(s+1) = RE \times Wbest(s) - (H1 \times W(s) \times rand) - H2 \times Levy(C) + rand \times H1 \tag{5}$$

The main objective of using RE, which is represented by equation (6), for traffic forecast was to balance the search methods.

$$RE(s) = t^{\frac{2wrand-1}{(1-s)^2}} \tag{6}$$

$H1$was a representation of various motions used to monitor the optimal traffic solution and was described to given by equation (7).

$$H1 = 2 \times rand\ - 1 \tag{7}$$

$H2$ reduced from 2 to 0, which was expressed as showing the equation (8).

$$H2 = 2 \times (1 - sS) \tag{8}$$

By combining DeepResNet and the Enhanced AO, the AO-DeepResNet hybrid model improved categorization accuracy. By optimizing hyperparameters, AO increased the efficiency of the model. Effective feature extraction and classification were guaranteed by DeepResNet. The combination enhanced the traffic management and smart mobility decision-making.

5 Experimental Result

The AO-DeepResNet approach was practiced using real-world data, counting vehicle telemetry, ride-sharing demand, and social media sentimentality. The model was trained with DeepResNet construction and AO to calculate traffic flow and movement patterns. Performance was assessed using metrics like accuracy and traffic flow optimization. Results confirmed that it outpaced existing systems in traffic change and mobility prediction.

5.1 Experimental Setup

The computer runs on an Intel CPU with an i8 core running Windows 11, is planned using Python and has 16 GB of RAM.

5.2 Evaluation Criteria

Accuracy: The presentation metric that measures the proportion of correct predictions made by a model out of all predictions. It is calculated as the ratio of the number of correct forecasts to the total number of predictions. In the context of the AO-DeepResNet model, accuracy estimates how well the model predicts traffic flow and mobility patterns, providing insights into its efficiency in traffic control and smart mobility prediction.

F1-core: The metric of F1-score associations precision and recall into one amount, offering a balance between the two. The f1-score is especially useful in circumstances with imbalanced class accumulations, as it offers a full assessment of model performance by considering both false positives and false negatives. This makes it well-suited for scenarios where one class leads the dataset. In the context of the AO-DeepResNet model, the F1-score, which symbolizes the harmonic mean of precision and recall, serves to assess how effectively the model stabilities traffic flow prediction with mobility management, ensuring both precise prediction and efficient traffic control.

5.3 Comparison Phase

The recommended method was compared to the existing process, Enhanced Weight Elman Neural System (OWENN) (Neelakandan et al., 2021), in terms of accuracy and F1 score. Table 1 expresses the numerical standards of all metrics amongst OWENN and AO-DeepResNet.

Table 1: Comparison of Numerical Values of OWENN vs AO-DeepResNet

Parameter	OWENN (Neelakandan et al., 2021)	AO-DeepResNet [Proposed]
Accuracy (%)	98.23	98.5
F1-Score (%)	96.69	97.21

The suggested AO-DeepResNet model performs marginally better than the OWENN model, indicating its efficacy in reaching higher accuracy (98.5%) and F1-score (97.21%). The graph also compared the performance of the conventional strategy such as OWENN model and the proposed AO-DeepResNet model with respect to accuracy and F1-score, both of which were shown in Figure 2.

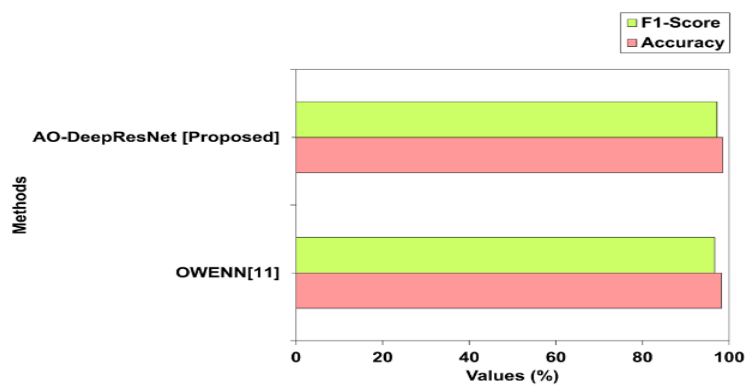

Figure 2: Comparison of F1-Score and Accuracy

The main drawback of the OWENN is the susceptibility to overfitting in complex datasets, requiring extensive training data and computational resources for optimal performance.AO-DeepResNet provides high accuracy in traffic prediction, improved mobility management, optimal model performance via AO, and effective integration of several real-time data sources.

6 Conclusion

The suggested AO-DeepResNet approach combines AO and DeepResNet to greatly enhance mobility management and traffic prediction accuracy by taking into account real-time traffic data, vehicle telemetry, ride-sharing demand, public transportation efficiency, social media sentiment, and environmental factors. The proposed model outperforms current techniques with an F1 score of 97.21%, and an accuracy of 98.5%, advancing intelligent mobility solutions and transportation systems. However, its effectiveness could be impacted by constraints including computing complexity, scalability issues, and reliance on high-quality real-time data. To improve traffic optimization and mobility management, future research should concentrate on increasing computational efficiency, incorporating cutting-edge deep learning methods like transformers and graph neural networks (GNNs), and extending applications to driverless cars and smart city infrastructure.

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Authors Biography

Dr.M. Raja, Head Global Affairs, Professor and Head, Department of Artificial Intelligence and Data Science. His Vision is to focus Academic Excellence through Student Centric Learning, High Ethical Standards, Creative Research, Continuous Improvement, Fostering Creativity & Innovation to produce Globally Competent Skill Based Professionals, Computer Scientists, Software Engineers for Leadership and Professional Careers, Advanced Research Study with Social Justice and Intrinsic Values to Build Vibrant Nation for Holistic development to respond Swiftly to Challenges to match Global Benchmarks to become Institution of Global Eminence. He has obtained B.E degree from University of Madras, M.E degree in Anna University Chennai and was awarded Ph.D., from Anna University, Chennai, Tamil Nadu. He has around 24 years of Academics, Administration, Industry and R&D experience. He has worked as a Director, Principal, Dean, and HOD in various reputed colleges and Universities, A certified Professional in Data Science from Dell EMC, Coursera, Elsevier and NPTEL. He has established Incubation Centre, Research Labs and guided students to develop interdisciplinary projects as a Research Coordinator. He has association with Web of Science as a Researcher. He has worked for NBA Accreditation, NAAC Accreditation, Autonomous status, ABET. He has published 16 Patents, 2 Patents Applied for Grants in 2024 under Examination, published 35 Research Papers and Book Chapters in SCOPUS Indexed Journals, UGC Recognized Journals and in Conferences. He has life membership in various professional bodies Indian Society for Technical Education (ISTE), Soft Computing and Research Society (SCRS), International Association of Engineers, International Association Innovation Professionals, EDEN, FISITA. He has delivered many Invited Talks, guest lectures, attended Industry Conclaves, workshops, FDPs, seminars and national and international conferences, worked for collaborating with leading industries and foreign Universities etc.,

Dr.P. Sundara Bala Murugan holds a Ph.D. in Management and MBA from CEG, Anna University, Chennai and Engineering from Annamalai University. He has over twelve years of academic experience and nearly five years of industrial exposure, he brings a balanced blend of theoretical knowledge and practical insight into business education. His teaching interests include FinTech, Data Analysis, Investment Management, Risk Management, and Personal Finance, where he emphasizes analytical thinking and real-world applications. His research interests lie in the domains of Investment Management and Behavioural Finance, with a particular focus on individual investor behaviour, risk perception, and decision-making under uncertainty.

Dr.M. Rajapriya is currently serving as an Assistant Professor in the Department of Management Studies at Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai. With over 16.5 years of academic experience, she specializes in Human Resources (HR) and Marketing. She holds multiple qualifications, including an MBA, M.Sc. in Psychology, M.Phil., and a Ph.D. Driven by her deep interest in HR and psychology, she pursued research on the intersection of both fields. Her doctoral thesis, titled "Disability of Women Working in the Garment Industry at Chennai," explores the mental and physical health challenges faced by women in this sector. Her research has been internationally recognized and was awarded Best Thesis by the University of Massachusetts Dartmouth, Charlton College of Business, USA. In addition, she has received the Global Excellence Award for Accomplishments in Human Resources Development and Research, jointly presented by Special Minds, India, and UNIFACVEST University, Brazil, South America. As a recognized research supervisor, Her mentors the Research scholars in the areas of HR and Marketing. She also teaches various HR and marketing subjects and actively conducts personality development training to help students evolve into successful managers.

Komiljon Aynaqulov is a Doctoral Researcher in the Department of Agricultural Product Processing Technologies at Gulistan State University, Uzbekistan. His research interests span the interdisciplinary domains of intelligent systems, cyber-physical infrastructure, and smart mobility solutions. With a particular focus on optimizing traffic management through the integration of cyber-physical and social networks, his work aims to contribute toward the development of sustainable and intelligent transportation systems. He is actively involved in research that leverages connectivity and data-driven technologies to enhance mobility efficiency and urban planning strategies in emerging smart cities.

Mushtariy Akhmedova is a PhD student at Jizzakh State Pedagogical University, Uzbekistan. Her research focuses on the convergence of cyber-physical systems and social networks to enhance smart mobility and traffic management. She is particularly interested in the role of intelligent connectivity and real-time data integration in developing efficient, adaptive transportation infrastructures. Through her interdisciplinary work, her aims to contribute to the advancement of smart city technologies and sustainable urban mobility solutions.

Dr.R. Udaya Kumar completed his M. S (Information Technology and Management) from A.V.C. College of Engineering and Awarded Ph.D. in the year 2011. He is serving in Teaching & Research community for more than two decades, he successfully produced 5 Doctoral candidates, he is a researcher, contribute the Research work in inter disciplinary areas. He is having h-index of 27, citation 2949(Scopus). He is associated as Dean – Department of computer science and Information Technology and also Director IPR, Kalinga University, Raipur, Chhattisgarh.