

Novel Routing Algorithm for Autonomous Vehicles in Smart Transportation System

Haoxiang Wang

Director and Lead Executive Faculty Member, GoPerception Laboratory, Cornell University, Ithaca, USA

E-mail: wanghaoxiang1102@hotmail.com

Abstract

In recent times Automation is emerging every day and bloomed in every sector. Intelligent Transportation System (ITS) is one of the important branches of Automation. The major constrain in the transportation system is traffic congestion. This slurps the individual's time and consequently pollutes the environment. A centralized management is required for optimizing the transportation system. The current traffic condition is predicted by evaluating the historical data and thereby it reduces the traffic congestion. The periodic update of traffic condition in each and every street of the city is obtained and the data is transferred to the autonomous vehicle. These data are obtained from the simulation results of transportation prediction tool SUMO. It is proved that our proposed work reduces the traffic congestion and maintains ease traffic flow and preserves the fleet management.

Keywords: Intelligent Transportation System (ITS), Traffic Congestion, Environmental Pollution, Autonomous Vehicle, SUMO and Fleet Management.

1. Introduction

Due to the population growth and modernisation the demand for transport vehicle has increased in recent decades. Most of the people are attracted towards individual vehicle and this reduces the usage of public transportation [1]. Though it develops the economy of a country it also pollutes the environment by many factors such as emission of carbon dioxide, noise,

greenhouse effect and so on. It also causes unnecessary accidents. To overcome these issues the researches has come up with a successful traffic management system called Intelligent Transportation System (ITS) and it is a centralized management system which helps the administrators to reduce congestion [2]. Traffic congestion at peak hours is a big headache to deal with. Autonomous vehicle is an unmanned vehicle which can drive on its own and it has full control of the vehicle. Most of the autonomous vehicles are non-fuel vehicles i.e. electric vehicles [3]. These get energized using electrical energy which preserves the environment by omitting the carbon dioxide emission. This also avoids man power and this is cost effective. It is completely connected to the server and these are designed with numerous sensory units. This helps to reduce accidents [4]. When we update the periodic traffic condition of the entire city to the autonomous vehicle it observes the flow of traffic in each streets of the city and chooses the appropriate way. This reduces the man power and optimizes the entire transportation system. The general overview of the Intelligent Transportation System is shown in Figure 1.

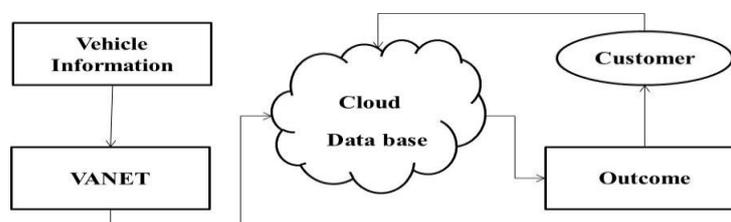


Figure 1. General Block Diagram of Intelligent Transportation System

The traffic prediction is obtained by evaluating the historical data of traffic. The flow of traffic does not remain constant [5]. The density of the traffic will be very high during peak hours in a day and it will be normalized during the rest of the time. So based on this our proposed system predicts the congestion. By using SUMO the traffic condition is predicted [6]. The proposed system has attached to the smart phone and these acts as a server for the autonomous vehicle. Periodic update about the traffic condition is stored in its corresponding server. The previous methods require huge man power and there were lot of human errors [7]. The main objective of our proposed work is to establish an optimized transport system with

future prediction abilities in terms of traffic flow and duration of traffic [8]. This is highly depended on the density of the traffic. Further the related works of our paper are discussed in section 2, an overview of the SUMO tool and our proposed mechanism are elaborately discussed in section 3, the experimental results are briefed in section 4 and the section 5 covers the conclusion part.

2. Related Work

The traffic density is predicted by using deep learning methods. Convolution neural network and triple loss are combined to extract the features and the traffic congestion states are predicted by using deep clustering technique [9]. The extended offline services are managed by multitask learning modules (OT-PHRM and OA-PHRM) and dataset of GPS trajectory. The prediction accuracy is enhanced by increasing the prediction layers [10]. The traffic signs are segmented using CNN and the features are extracted by FNN. The localization and characteristic estimation of the autonomous vehicle are predicted by using deep learning method. Single shot detector and faster convolution neural network are employed for object detection [11]. The traffic at intersection is controlled by using deep reinforcement learning. By combining CNN and reinforcement learning methods the delay in traffic can be controlled. The data labelling is done by cycle-GAN network [12]. The vehicle categorization is done by CNN and reinforcement learning and further this methodology is used to short the multiclass problems. A logistic system is constructed using scheduling algorithm to allocate route to the autonomous vehicle. Smart phones are used to store the information [13]. The combined system of autonomous and electrical vehicle is built to enhance the transportation system using logistic system. Balancing algorithm is utilized to determine the best route to the costumer [14]. This is specialized algorithm to determine the shortest path based on the traffic condition at the intersection and edges of each street in a city. The traditional methods such as man power and traffic light control system are less accurate and needs huge resources and expensive. The duration of travel are predicted by using time dependent algorithm [15]. The congestion is avoided by pre-determination of flow of traffic and makes a dynamic transport network. Our

proposed work smoothen the traffic flow by reducing the congestion and the working procedure is briefed in upcoming sections.

3. Proposed Work

This section includes the working procedure of our proposed work along with a general overview about the three main tools involved in our proposed work namely

- a. Simulation of Urban Mobility (SUMO)
- b. DFROUTER
- c. ABATIS Route Server

Figure 2 represents the architecture of the proposed centralized transportation management model.

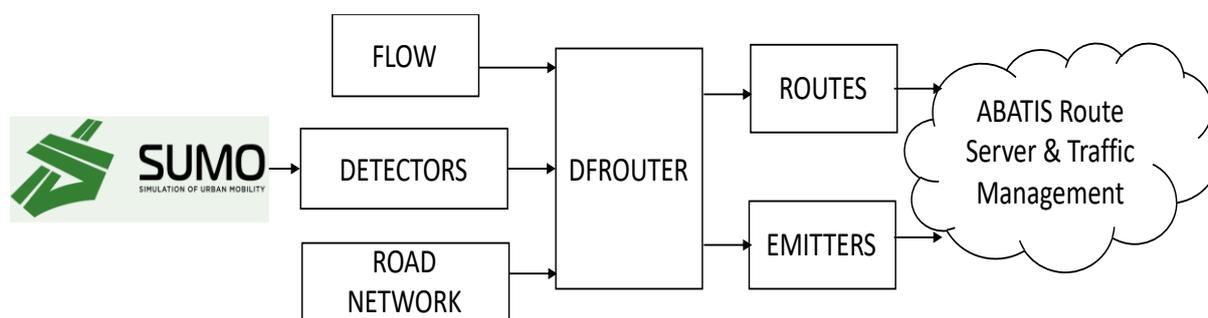


Figure 2. Proposed centralized transportation management architecture

3.1 Simulation of Urban Mobility (SUMO)

This simulation tool is specially designed for managing transportation system. The main features of SUMO are open source, traffic control interface, open street map and so on. The traffic condition of an area is predicted by using basic details about the vehicles passing through that region [16]. Vehicle type, duration of travel, speed, arrival and departure time are

some of the basic details required for better understanding. We can feed all these data in SUMO to determine the congestion state. SUMO can be used to evaluate the density in all categories of transportation from pedestrian course to railways. It can also be used to divert a vehicle to different lane of same road [17]. This helps the autonomous vehicle to enhance its mobility performance.

3.2 DFROUTER

It comes along with SUMO package and used to determine O-D matrix. This tool is used to count the number of vehicles enters and leaves a road in a city. Each and every street in a city is taken into account [18]. With this data the average traffic flow is determined and with additional data such as speed and type of vehicle passing through each lane a précised congestion state is predicted. It is used to form O-D matrix along the intersections by using induction loops. Real time error occurs while separately computing the induction loop data [19]. To overcome this issue DFROUTER is introduced where the module is trained and tested multiple times and produces O-D matrix which is similar to realistic traffic flow. The comparative result shows that this tool reduces the error and increases the accuracy level.

3.3 ABATIS Route Server

Some commercial and free service providers such as Tom-Tom and Google map can be utilized to predict the traffic flow in a specific region for short period of time. These applications are user friendly but it requires continuous update from multiple users and historical data for prediction. There is some privacy issues associated with these applications [20]. To overcome this, the researchers have designed a centralized control system named ABATIS route server with artificial intelligence and prolonged usage to predict medium to long term traffic prediction and decision making capability. It is associated with HTTP to provide service based on request [21, 22]. It has separate port to listen and respond to a request along with the geographical interface. The working procedure of ABATIS is stated below

1. Normalization of the graph which is extracted from the Open street map application
2. Adding route to the normalized graph
3. Enhancing the route estimation by partitioning the obtained graph into cell
4. Coordinating the cells to predict all possible routes
5. The results are stored in a shared memory for better usage
6. The request is processed through known IP

Load balancing can be achieved by providing proper update to the module. From the available resources the routes are allocated to the vehicles. The entire process is repeated until we get best results with minimal error.

3.4 Methodology

The working procedure of the proposed work is briefed in this section. The load matching is extracted from the pre-segmented unit of traffic congestion and it is given by equation (1)

$$f(x) = \frac{i}{1+e^{j-\frac{x}{k}}} - \frac{i}{1+e^j} + t_{ff} \quad (1)$$

From the above equation x denotes total count of vehicle, t_{ff} denotes free-flow time, j denotes curve, i denotes maximum time, k denotes displacement. Our main objective is to predict the traffic congestion and provide the best route to the user. For this purpose we have used SUMO and OMNET++ simulators along with ABATIS which acts as routing server. All these are independent simulators which have distinct properties, format and functionality. To communication interface is used to bridge these simulators.

3.4.1 ABATIS Interface Link

Previously, Traffic control interface is used to connect SUMO and OMNET++ simulator. Where TraCI is an open source and uses real time data to understand the pattern of traffic, mobility are few more attributed of vehicles in a city. This technique is added on with few more functionalities to enhance the predicting ability [23]. Here the assumption is taken on each segmented cell i.e. every street in a city. To reduce the congestion we need best alternate route. To achieve this we need a pool of data of each street. A brief analysis is carried out on the basis of how many vehicles pass through each segment, how long it takes to cross each segment, at what speed the vehicle passes in each segment and so on. Collectively all such data is transferred from this interface to the ABATIS route server.

After the completion of traffic update the ABATIS link interface move on to the route allocation to the vehicle. For this it needs some basic information about the vehicle's initial and destination position, departure time, speed etc. This information is collectively transferred to route server. Then based on this data the router server will assign an appropriate route to the vehicle [24]. As discussed earlier the simulator and the route server follows different format. So to bridge a communication interface between these applications we require a translator which can be able to translate both formats. For future reference we store the information.

SUMO processes all the contextual information about the vehicle such as ID, topographical harmonises, edge details and speed of the vehicle. This is evaluated for the entire segment of each street in a city. This process enhances the speed and accuracy of the system [25]. The route obtained from ABATIS will be insufficient in some cases such as long road which does have any detail about the mid portion of the route. To overcome this issue we utilize the edge information. The edge information gives further deep knowledge about the traffic condition of the corresponding route. When a new request is received the simulator evaluates all the needed data and provides a best rout with short distance along with less traffic. Our proposed method reduces the traffic and thereby circuitously reduces the fuel consumption and avoids carbon-dioxide emission.

4. Result and Discussion

As we discussed earlier we have used traffic control interface to connect SUMO and OMNET++ and with the help of ABATIS link interface and a translator, the ABATIS route server is connected to these two simulators. We obtain load balance from equation (1) and further our proposed work is test on two circumstances namely

- a. Load Balancing based on Uniform Region
- b. Load Balancing based on Hotspot Region

These two circumstances are evaluated based on the following metrics

- a. Typical vehicle speed
- b. Typical mobile time
- c. Advent time

4.1 Load Balancing based on Uniform Region

In our proposed work we have considered a uniform region of 77.40 km² with 34060 vehicles for duration of 15 min during peak hour to evaluate the efficiency of the system in terms of congestion reduction and load balancing. The typical mobile time of the vehicle and the overview of the prediction efficiency can be understood visually from the figure.3. It shows that the vehicle's waiting time is reduced thereby it reduces the overall travel time. Figure.4 presents the advent time of the vehicle and it is observed that it has higher efficiency than the locus value. Figure.5 defines the typical vehicle speed and it is observed that the vehicle can move faster while we apply load balancing stratagem and it works better than the actual traffic condition. The gauss bell value is approximately 4.9%.

While evaluating the performance metrics it is observed that we can restrict the traffic congestion by providing numerous alternative routes to the vehicle. This is achieved by

applying load balancing stratagem. Our algorithm reduces the congestion and thereby safes the customer time by reducing the overall travel time. This also cost effective because to limits the usage of fuel consumption and protects the environment from pollution.

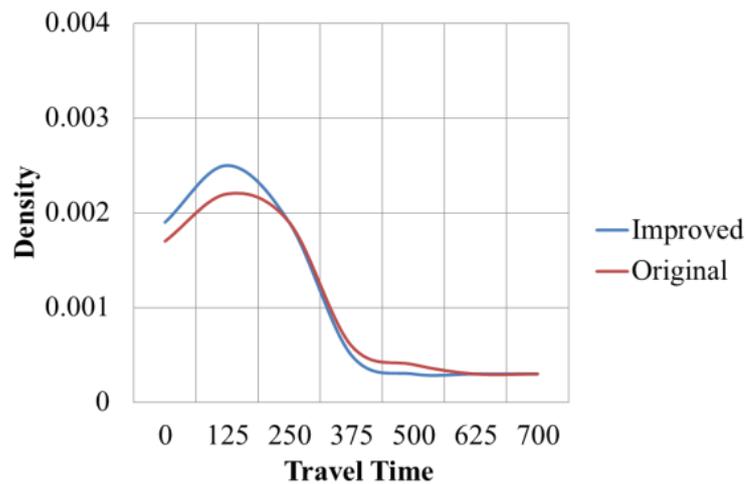


Figure 3. Graphical representation of Typical Travel Time of Vehicle

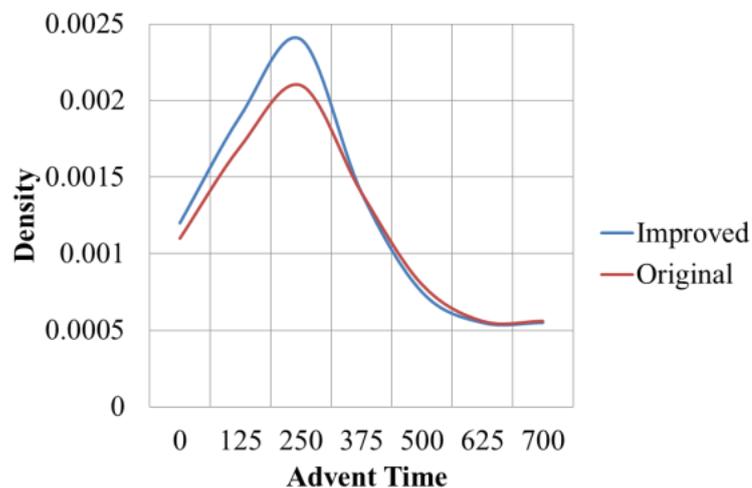


Figure 4. Graphical representation of Advent Time of Vehicle

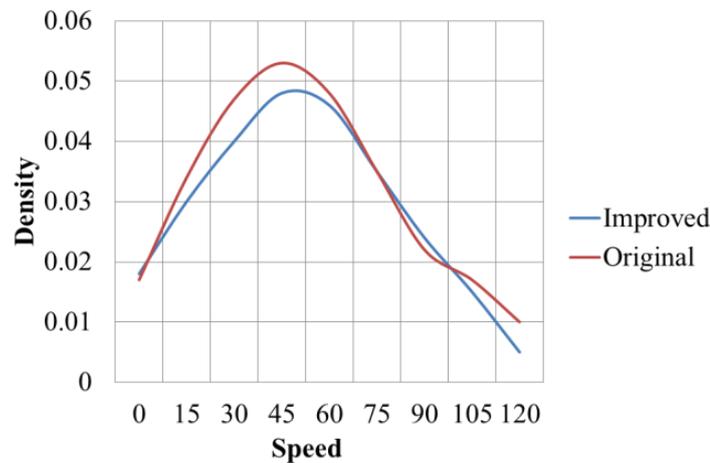


Figure 5. Graphical representation of Typical Speed of Vehicle

4.2 Load Balancing based on Hotspot Region

In this circumstance we have choose a busy road during peak hour with a coverage of 2155×550 m with 350 vehicles for a duration of 15 min. The O-D matrix is limited to its specified region and the load is balanced as per the equation (1). In this section we have increased the number vehicles to check the efficiency of the system and behavioural changes of the system.

$$t, m = \frac{\alpha}{\gamma} \beta + \delta \quad (2)$$

Where α denotes the minimum number of vehicle on a street, γ denotes the total segment of a street, β denotes the traffic flow, m denotes number of iteration and δ denotes the count of newly added vehicles. The gauss bell value is approximately 7.9%. Under non-balanced condition it is observed to be 15% fluid compared to the normal condition. The figure 6 represents the visual understanding from the graph of typical travel time before and after adding vehicles to normal traffic. The figure 7 represents the visual understanding from the graph of advent time before and after adding vehicles to normal traffic. The figure 8 represents the visual understanding from the graph of typical speed before and after adding vehicles to

normal traffic. It is observed that the tool effectively predicts traffic over the specified range and it reduces the congestion by providing numerous alternative routes. This reduces the accumulation of vehicle on same region and safes the passenger's time and energy. It is observed that the efficiency of our proposed algorithm remains high even after increasing the number of vehicle in the same region.

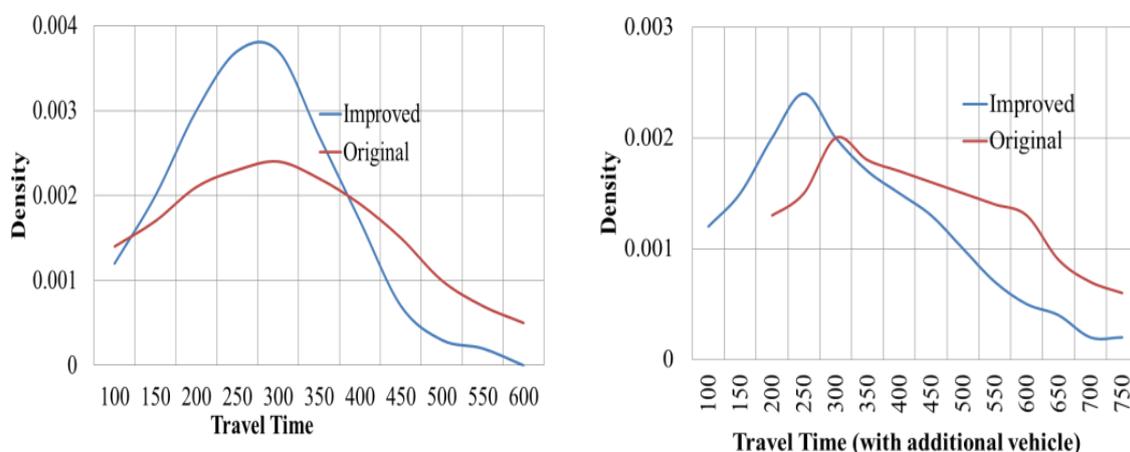


Figure 6. Graphical representation of Travel Time (with and without additional vehicles)

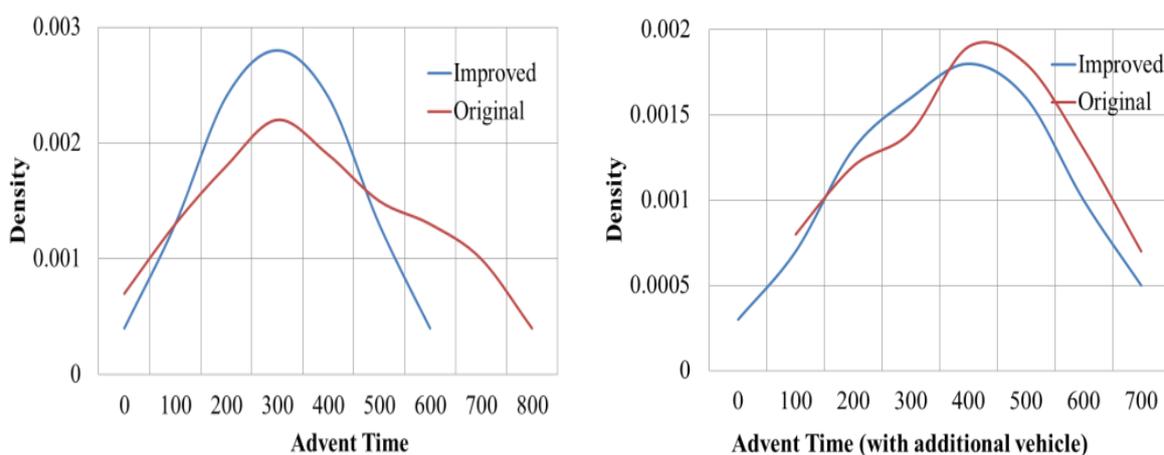


Figure 7. Graphical representation of Advent Time (with and without additional vehicles)

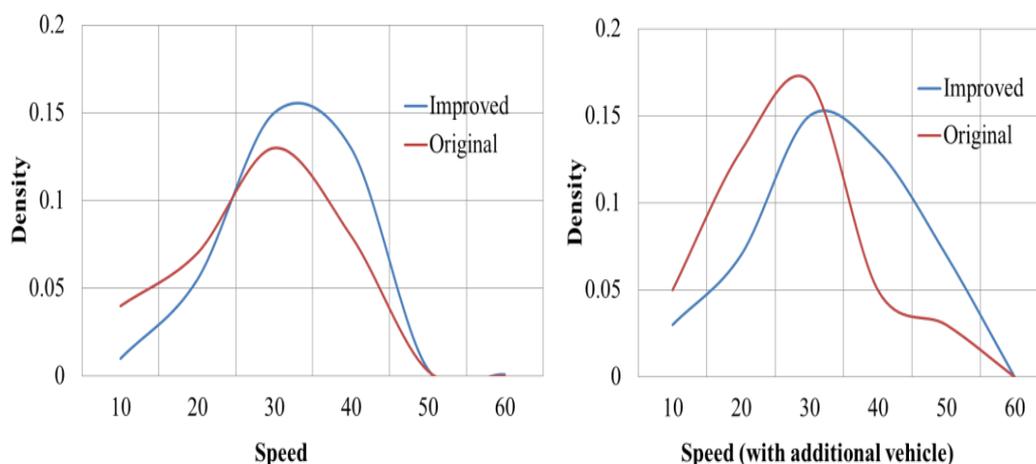


Figure 8. Graphical representation of Typical Speed (with and without additional vehicles)

5. Conclusion

In future most of the people will move towards autonomous vehicle and utilize the benefits of navigation. As the demand increases it automatically relies on the supply chain. So there will a need for proper fleet management. This paper will be an initiative to address the solution to the traffic congestion problem by providing a centralized traffic management tool. By collecting all the fundamental information about the traffic flow in each and every segment of the cell of street we predict the traffic congestion using ABATIS routing server. The server provides various routes with shortest path with reduced traffic. The experimental result proves that the proposed method is precise and highly accurate and the ultimate goal is reached by reducing the congestion. It is applicable to large area such as 77.40 km² and the mobility time is reduced by 6% and the speed is increased by 6% as compared with the normal traffic condition. The efficiency remains same even after increasing the number of vehicle. The advent time is increased to 7.9% and the efficiency is increased to 15% as compared to the normal traffic condition. Further we can develop the system by enhancing its application to predict the level of carbon-dioxide emission and limit the fuel ingestion.

Reference

- [1] S.G.Manyam. et al, "Cooperative Routing for an Air-Ground Vehicle Team-Exact Algorithm, Transformation Method and Heuristics", in IEEE Transaction on Automation Science and Engineering, vol. 17, no. 1, pp. 537-547, 2020.
- [2] Karthikeyan, M., S. Sathiamoorthy, and M. Vasudevan. "Lane Keep Assist System for an Autonomous Vehicle Using Support Vector Machine Learning Algorithm." In International Conference on Innovative Data Communication Technologies and Application, pp. 101-108. Springer, Cham, 2019.
- [3] Smys, S., Haoxiang Wang, and Abul Basar. "5G Network Simulation in Smart Cities using Neural Network Algorithm." Journal of Artificial Intelligence 3, no. 01 (2021): 43-52.
- [4] D.Liu et al., "Two-Echelon Vehicle-Routing Problem: Optimization of Autonomous Delivery Vehicle-Assisted E-Grocery Distribution", in IEEE access, vol. 8, pp. 108705-108719, 2020.
- [5] J. Mandziuk, "New Shades of the Vehicle Routing Problem: Emerging Problem Formulations and Computational Intelligence Solution Methods", in IEEE Transactions on Emerging Topics in Computational Intelligence, vol.3, no. 3, pp. 230-244, 2019.
- [6] Bestak, Robert. "Intelligent Traffic Control Device Model Using Ad Hoc Network." Journal of Information Technology 1, no. 02 (2019): 68-76.
- [7] K. Peng et al., "A Hybrid Genetic Algorithm on Routing and Scheduling for Vehicle-Assisted Multi-Drone Parcel Delivery", in IEEE Access, vol. 7, pp. 49191-49200, 2019.
- [8] Kamel, Khaled, S. Smys, and Abul Bashar. "Tenancy Status Identification of Parking Slots Using Mobile Net Binary Classifier." Journal of Artificial Intelligence 2, no. 03 (2020): 146-154.
- [9] G. Vitello et al., "A Bio-Inspired Cognitive Agent for Autonomous Urban Vehicles Routing Optimization", In IEEE Transactions on Cognitive and Developmental Systems, vol. 9, no. 1, pp. 5-15, 2017.

- [10] Tesfamikael, Hadish Habte, Adam Fray, Israel Mengsteab, Adonay Semere, and Zebib Amanuel. "Simulation of Eye Tracking Control based Electric Wheelchair Construction by Image Segmentation Algorithm." *Journal of Innovative Image Processing (JIIP)* 3, no. 01 (2021): 21-35.
- [11] Aishwariya, K. K., Sanil K. Daniel, and K. V. Sujeesh. "Zone Safe Traffic Assist System and Automated Vehicle with Real-Time Tracking and Collision Notification." In *International Conference on Innovative Data Communication Technologies and Application*, pp. 663-669. Springer, Cham, 2019.
- [12] Sungheetha, Akey, and Rajesh Sharma. "Fuzzy Chaos Whale Optimization and BAT Integrated Algorithm for Parameter Estimation in Sewage Treatment." *Journal of Soft Computing Paradigm (JSCP)* 3, no. 01 (2021): 10-18.
- [13] K. F. Chu et al., "Dynamic Lane Reversal Routing and Scheduling for Connected and Autonomous Vehicles: Formulation and Distributed Algorithm", in *IEEE Transactions on Intelligent Transportation Systems*, vol. 21, no. 6, pp. 2557-2570, 2020.
- [14] Samantaray, Sahil, Rushikesh Deotale, and Chiranji Lal Chowdhary. "Lane Detection Using Sliding Window for Intelligent Ground Vehicle Challenge." In *Innovative Data Communication Technologies and Application*, pp. 871-881. Springer, Singapore, 2021.
- [15] Dhaya, R., and R. Kanthavel. "Bus-Based VANET using ACO Multipath Routing Algorithm." *Journal of trends in Computer Science and Smart technology (TCSST)* 3, no. 01 (2021): 40-48.
- [16] C.K. Peterson et al., "Persistent Intelligence, Surveillance and Reconnaissance using Multiple Autonomous Vehicles with Asynchronous Route Updates", in *IEEE Robotics and Automation Letters*, vol. 5, no. 4, pp. 5550-5557, 2020.
- [17] Bhalaji, N. "A Novel Hybrid Routing Algorithm with Two Fish Approach in Wireless Sensor Networks." *Journal of trends in Computer Science and Smart technology (TCSST)* 2, no. 03 (2020): 134-140.

- [18] Palwe, MeghRaj V., and Pramod Kanjalkar. "Development and Validation of Engine Start/Stop Strategy for P2 Hybrid Electric Vehicle." In International Conference on Inventive Computation Technologies, pp. 59-66. Springer, Cham, 2019.
- [19] Jacob, I. Jeena, and P. Ebby Darney. "Artificial Bee Colony Optimization Algorithm for Enhancing Routing in Wireless Networks." Journal of Artificial Intelligence 3, no. 01 (2021): 62-71.
- [20] R. Rout et al., "Design of Line-of-Sight Guidance Law and a Constrained Optimal Controller for an Autonomous Underwater Vehicle", in IEEE Transactions on Circuits and Systems " , Express briefs, vol. 68, no.1, pp. 416-420, 2021.
- [21] N. Toorchi et al., "Skeleton Based Swarm Routing (SSR): Intelligent Smooth Routing for Dynamic UAV Networks", in IEEE Access, vol. 9, pp. 1286-1303, 2021.
- [22] Mugunthan, S. R. "Wireless Rechargeable Sensor Network Fault Modeling and Stability Analysis." Journal of Soft Computing Paradigm (JSCP) 3, no. 01 (2021): 47-54.
- [23] Srinivas, Kethavath, and Mohit Dua. "Fog Computing and Deep CNN Based Efficient Approach to Early Forest Fire Detection with Unmanned Aerial Vehicles." In International Conference on Inventive Computation Technologies, pp. 646-652. Springer, Cham, 2019.
- [24] Chen, Joy Iong Zong. "Optimal Multipath Conveyance with Improved Survivability for WSN's In Challenging Location." Journal of ISMAC 2, no. 02 (2020): 73-82.
- [25] J.J.Q.Yu, "Two-State Request Scheduling for Autonomous Vehicle Logistic System", in IEEE Transactions on Intelligent Transportation System, vol. 20, no. 5, pp. 1917-1929, 2019.

Author's biography

Haoxiang Wang is currently a director and lead executive faculty member of GoPerception Laboratory, Ithaca, USA. His research interests include multimedia information processing, pattern recognition, machine learning, remote sensing image processing, and data-driven business intelligence. He has co-authored over 60 journal and conference papers in these fields

on journals such as Springer MTAP, Cluster Computing, SIVP; IEEE TII, Communications Magazine; Elsevier Computers & Electrical Engineering, Computers, Environment and Urban Systems, Optik, Sustainable Computing: Informatics and Systems, Journal of Computational Science, Pattern Recognition Letters, Information Sciences, Computers in Industry, Future Generation Computer Systems; Taylor & Francis International Journal of Computers and Applications and conference such as IEEE SMC, ICPR, ICTAI, ICICI, CCIS, and ICACI.