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Vehicle Navigation System based on Pollution Metric Analysis with Q-Learning Algorithm

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Abstract

The navigation systems available in the present scenario takes into account the path distance for their estimations. In some advanced navigation systems, the road traffic analysis is also considered in the algorithm for their predictions. The proposed work estimates a navigation path with respect to the present pollution level on the roadways. The work suggests an alternate path to avoid additional vehicles to enter the same road which is already impacted by air pollution. A Q-learning (Quality learning) prediction algorithm is trained in the proposed work with a self-made dataset for the estimations. The experimental work presented in the paper explores the accuracy and computational speed of the developed algorithm in comparison to the traditional algorithms.

Keywords: Q-learning, SARSA, DQN, navigation system, GPS, route selection

1. Introduction

The navigation systems have become a mandatory feature to be enabled in most of the recent year vehicles. Therefore all the vehicles are manufactured with an inbuilt Global Positioning System (GPS) for making a communication between the vehicle and the satellites [1]. The GPS modules available so far are connected with at least 3 satellites to estimate their 2D position on a road. The GPS module requires communication of 4 satellites to enable the 3D position of a vehicle. Therefore the GPS servers are equipped with 24 satellites to circulate the orbit of earth to cover-up the location of the whole world. The GPS modules can predict the speed and tracking of a vehicle when a communication is successfully enabled between the transmitter and receiver. The system can also predict the route distance and time for travel with respect to the traffic data analysis and positioning systems [2, 3].

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The autonomous vehicles work with the help of navigation system to analyse their paths. The autonomous vehicles are also employed with different type of sensors to predict the nature of their surroundings. Figure 1 explores the list of peripheral modules employed in an autonomous vehicle system. The ultrasound sensor module is employed in the autonomous vehicle for measuring and maintaining a safe distance with the vehicle travelling in-front of it [4, 5]. The adaptive cruise control systems are employed with the help of ultrasound sensors. The LIDAR (Light Detection and Ranging) sensors are also employed in the autonomous vehicle along with the ultra sound sensors for making quick decisions on pedestrian crossing and other detections. The main difference among the LIDAR and ultrasound sensors are their frequency of operation. The LIDAR utilizes a laser beam for their operation instead of the sound waves used in ultrasound sensor [6-8].

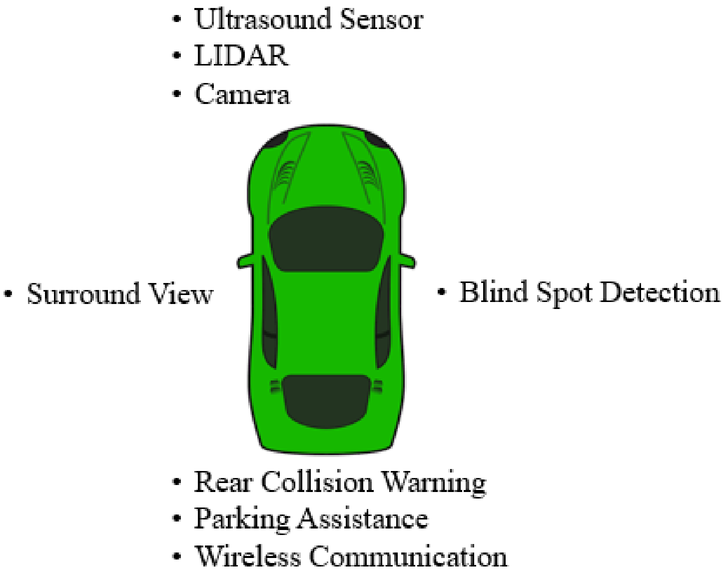

Figure 1. Autonomous vehicle connected systems

A high resolution camera is placed at the front of the autonomous vehicle for traffic sign detection and object detection. In some cases the cameras are utilized to enable lane departure warning. Similarly, a short range radar is employed in the vehicle for ensuring a clear surrounding at both sides of the car [9, 10]. A secondary radar and camera system are also employed in some models for observing the changes at the blind spot areas. The ultrasound and LIDAR sensors are also placed at the rear side of the vehicles for collision warning and parking assistance. A reliable wireless communication system is employed in the vehicle for making connection between the owner of the vehicle to the passengers and the automation system [11, 12].

2. Literature Survey

An audio navigation system was developed to assist the driver in a five exist expressway. A driver behaviour data was obtained in the system by analysing the speed standard deviation and absolute acceleration. An experiment based on the developed model was conducted in a simulation tool to verify its efficiency and was found satisfactory [13]. An eye tracking control design was performed to move the wheelchairs on their desire path. The system was developed to make an add-on facility in the self-motor wheelchairs. A canny edge detection based algorithm was implemented in the work for segmenting the eye from human face and a Hough transform algorithm was added to it for observing the pupil movement [14]. A tightly coupled inertial navigation system was proposed by combining the values received from global satellite navigation system and Signals of Opportunity (SOP). The SOP systems are developed with electronic circuits and sensors to observe the changes in the surroundings of an autonomous vehicle when the navigation system signals are weak [15]. An improved safety algorithm was designed with an image classification algorithm for estimating the roadside obstacles as well as the traffic signal status. To achieve this, a hybrid algorithm was developed with the help of conjugate nonlinear optimization and the linear–quadratic Gaussian propagation [16].

A 3D scanning technique was implemented to observe the location and presence of an object in a closed environment. A simulation model was developed with the help of Microsoft Kinect and Skanect to verify the attainments of the detection process [17]. A computer vision based robotic arm movement system was developed for the application of object movement. An experiment was performed in the work with different number of motors to prove its accuracy. The validation result indicates that the accuracy values ranges from 75.2% to 89% for DC motors and stepper motors [18]. A traffic load detection system was proposed to find the vehicle movement on a poor condition bridge. The strain, deflection and vibrations are observed from the bridge at various conditions. The observed values are gathered and operated with a data mining algorithm to predict the bridge strength [19].

An inertial measurement unit was merged with GPS system to estimate the misalignment of a navigation system. A non-holonomic constraint was generated between the roadside sensors and the vehicle sensors to indicate the misalignment. The system was employed with a linear error state Kalman filter to smoothen the generated values [20]. A vehicle to vehicle communication system was designed with a Li-Fi network to make a trusty connection between the vehicles. The system is also enabled with a RFID sensor for making a short range communication between the regular vehicles and the emergency vehicles. A VANET based communication system is also employed for transferring the observed data to the cloud network [21]. An adaptive zero velocity correction algorithm was implemented in a laser gyroscope strapdown inertial navigation system to improve its accuracy. The algorithm also operates the state measurement matrix equation of the system with a Kalman filter block to regulate its accuracy. The experimental work explores a better accuracy rate at the time of parking with narrow changes [22].

An A* algorithm was designed to predict the shortest path for an industrial robotic hardware. The algorithm measures the shortest path between the source and destination along with the obstacle presence in their way. The shortest path calculation was estimated by the developed algorithm by analysing the virtual grid lines count between the source and destination [23]. An autonomous underwater tracking system was developed with a multi-sensor fusion technique to improve the accuracy of the prediction. The system has inertial navigation system along with GPS. The experimental work indicates a better prediction accuracy along with an improved robustness among the traditional systems [24]. A neural network algorithm of 53 convolution layers was designed in a darknet framework for estimating the pedestrian and vehicle count on a road. The system was employed with a YOLOv3 algorithm for object detection. The developed model was verified with a video sequence dataset with acceptable accuracy [25].

An automated headlight dipping system was proposed by making an RFID communication between the opposite vehicles at night time [26]. A hybrid technique based on unscented Kalman filter and nonlinear autoregressive neural network was designed to improve the accuracy of an inertial navigation system combined with global navigation satellite system. The experimental work performed with a real time dataset shows an acceptable accuracy among the traditional unscented Kalman filter algorithm [27]. A deep reinforcement learning technique was designed to make a real-time navigation system and routing system. The developed model was verified with nine types of realistic traffic scenarios and was found satisfied with the obtained accuracy [28].

3. Proposed Methodology

The architectural view of the proposed navigation model is shown in Figure 2. The prediction work starts from collecting information from GPS servers on route selection and traffic data. The information collected from the GPS servers contains the distance analysis data between the source and destination given by the user. Similarly, the GPS server will also forward the real-time traffic data of the respective route to the cloud data server. In the existing system GPS servers are designed to communicate with the local GPS devices connected in a vehicle for route suggestion.

In the proposed work, the GPS devices are connected to the GPS servers through a cloud server. The cloud server is also designed to collect the pollution data in the respective routes with the help of an IoT server. The particle sensors which are connected on the roadside makes continuous communications regarding the pollution data to an IoT server. The algorithm behind the cloud units are framed to fetch the pollution data from the IoT server only at the required time with respect to the user intimation. This reduces the computational load on the cloud server. A preprocessing step is included in the work for removing the abnormal pollution data for consideration. The pre-processed data are forwarded to a pre-trained Q-learning algorithm for the prediction work.

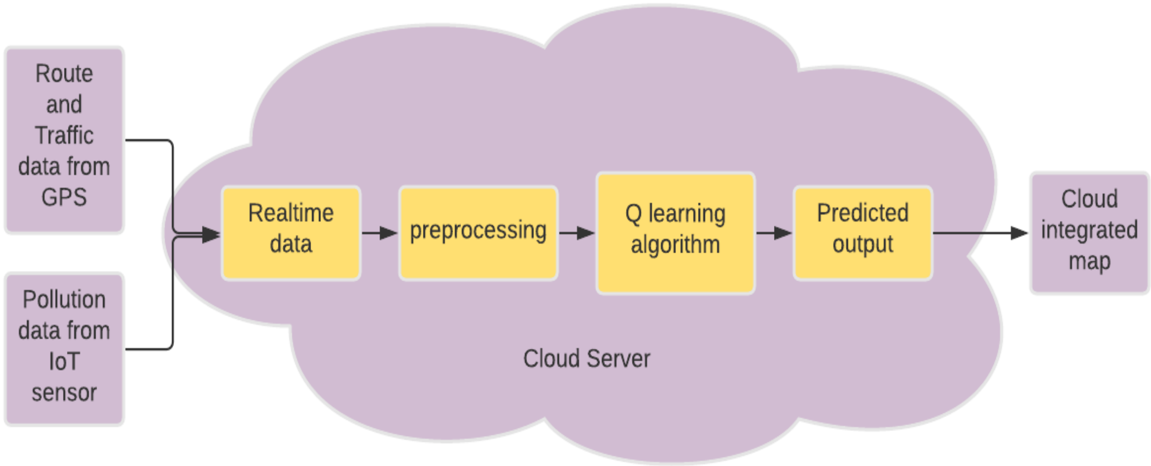

Figure 2. Architectural view of the proposed model

The algorithmic flow of a Q-learning process is shown in Figure 3. Q-learning is a type of reinforcement learning algorithm which is developed to train the neural network algorithm with only useful information. The reinforcement learning algorithms are employed in the place where the training and testing data are collected from a real-time scenario. The technique was structured as an extension of a supervised learning process, where the algorithm will be credited with positive points for every correct prediction and negative points for every wrong prediction. The Q-learning algorithm, updates its learning value information with the help of a Bellman equation. In some cases, the value functions are updated by the points earned on prediction training process.

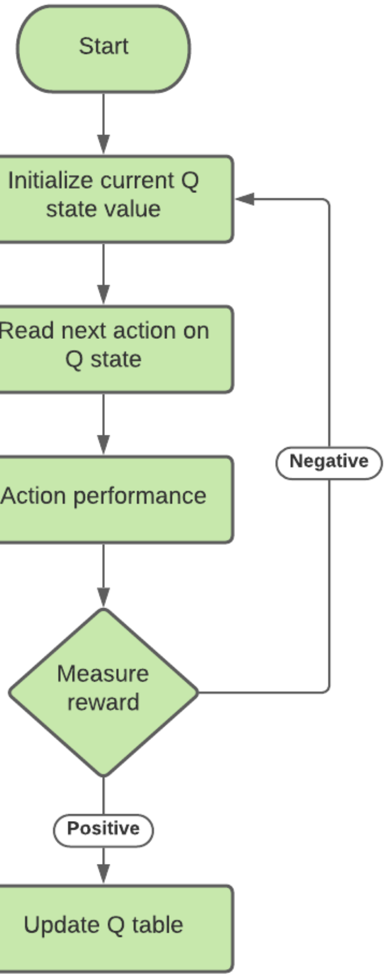

Figure 3. Algorithmic flow of a Q-learning algorithm

4. Experimental Work

An experimental work was performed to prove the efficiency of the proposed model with a self-made dataset. The dataset consists of pollution data collected from various routes on different timings. In the same way, the dataset is also engaged with the route distance matrix table along with its traffic conditions on different timings a day. A set of 75 route data are considered in the work for training process and a set of 25 route selection data are taken into account for the testing process.

The performance of the proposed algorithm model is compared with other types of reinforcement learning processes including State-Action-Reward-State-Action (SARSA) and Deep Q Network (DQN). The SARSA differs from the Q-learning algorithm in terms of observing Q-values with respect to present policy reward instead of an average policy reward. The DQN algorithms are constructed with more than one layer of convolution blocks for the learning process. However, the complexity of DQN is comparatively high as it has change in

Q-values on the prediction policy. The experimental projections observed from the proposed work are shown in Figure 4 and Table 1.

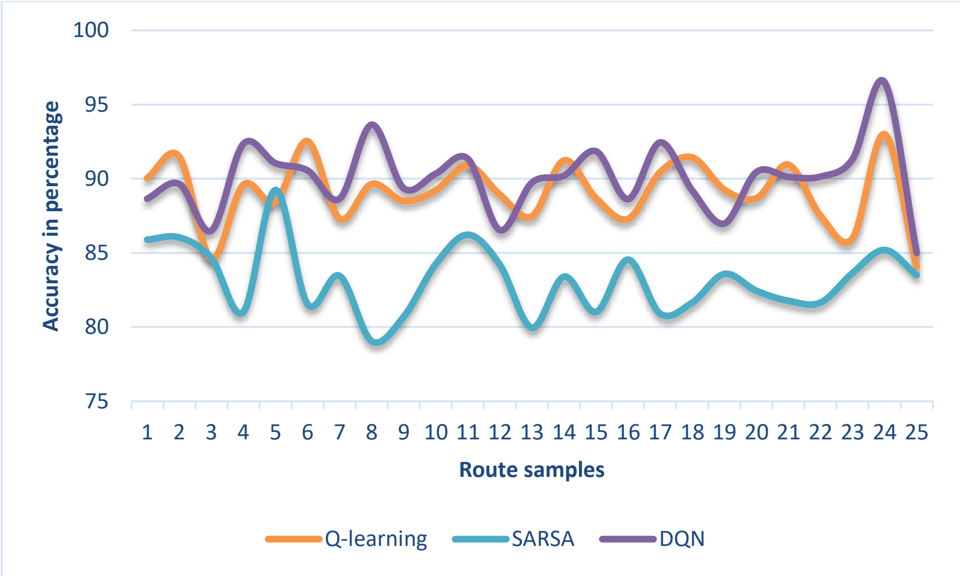

Figure 4. Comparative analysis of the proposed model with SARSA and DQN

Figure 4 indicates the change in accuracies observed among the Q-learning along with SARSA and DQN. The experimental work shows that the accuracy rate of DQN and Q-learning are comparatively better than the SARSA model. The experimental analysis explores that both Q-learning and DQN are approximately equal in performance on different sample data counts. However, the average accuracy of DQN shows a better performance with 90.04% which is comparatively better than the other two models.

Table 1. Average accuracy and computational time of the verified algorithms

Algorithm	Average Accuracy (Percentage)	Average Computational Time (Seconds)
Q-learning	89.08	2.5
SARSA	83.18	2.75
DQN	90.04	4.75

The computational time performance of the verified algorithms are shown in Table 1 along with their average accuracy. The performance of the Q-learning algorithm is satisfied in terms of computational time with 2.5seconds. Similarly the average accuracy of the Q-learning algorithm is almost closer to that of DQN where the difference is 0.96%.

5. Conclusion

Vehicle navigation systems are essential for autonomous vehicles in terms of path prediction and tracking. However, the recent year vehicles are implemented with a GPS based navigation system for assisting the drivers to reach new and unknown destinations in an efficient way. The motive of the proposed work is to develop a nature friendly model on vehicle navigation system by analysing the route pollution data in addition to the traffic and route distance attributes. The algorithmic model behind the proposed system is employed with a Q-learning algorithm and its performances are compared with other reinforcement models like SARSA and DQN. The experimental work indicates a better computational time on the Q-learning algorithm with a minor reduction rate in accuracy when compared with DQN. Despite the slight relaxation in accuracy rate, this work suggests the Q-learning process for the vehicle route selection process, as it accomplishes at a lesser processing speed, which is one of the primary requirement for any prediction algorithm.

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