

Review of Computational Based Algorithms for Avoiding Congestion in Intelligence Traffic Management

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ABSTRACT

Roadways remain a primary mode of commuting, and increasing population has led to escalating traffic congestion. In our era of rapid technological advancements, traffic signals require continual improvement as they are central to the traffic system. Efficiency and optimization are crucial for modern cities, making Intelligent Transportation Systems (ITS) vital in addressing traffic challenges. Technological advancements now allow for the storage and processing of vast amounts of data, facilitating effective and efficient traffic management. This paper reviews various algorithms that have been tested and evaluated to ensure optimal traffic management.

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INTRODUCTION

Congestion and long hours of traffic on a daily basis remain a challenge in modern cities. This can test the patience of citizens and subsequently leads to traffic rules violation and subsequent fatal accidents as witnessed in many of our cosmopolitan cities. Even on Highways where the roads are not congested drivers are enticed to risky driving experience thus putting them and other road users at great risk. Occurrence of accidents everyday where lives are lost and people get injured is very worrisome. Governments all over the world imposed regulations to reduce the chances of an accident by implementing rules and levying fines on traffic violators.

Traditional traffic signals is known for its inefficient time management on road intersections where vehicle commuters often wait unnecessarily as each road is assigned a constant fraction of time for green sign move irrespective of the number of vehicles or flow density. Also they are not insulated to some inclemently weather such as like rain, fog, and the likes as the technology may not work correctly in these conditions or be visible. Also, it does not have the ability of giving priority to emergency vehicles such as Ambulances, Firemen, Police, and others as the system is not

adaptive. Such vehicles require intelligent traffic signals to open the road for them even before arriving at the intersection.

These challenges associated with traffic congestion attracted the attention of researchers and numerous techniques for managing traffic and solving the congestion issue proposed. Advent solution relies solely on counting the vehicles on each road segment at the intersection. These approaches are named sensor-based technologies that include inductive loops, magnetometer, microwave radar, laser radar, ultrasonic, acoustics, video cameras and counting cables. However, these techniques cannot be deployed largely because of the complexity and the very high manufacturing cost. In addition, they are not scalable or reliable. Damage of the counting cable and even the video cameras can limit the reliability of the whole system. There are many other setbacks of the traditional traffic management systems due to the inability of the traditional traffic signals to help provide dynamic and adaptive services. Smarter solutions that use sophisticated technologies to adopt a smart traffic management system became inevitable.

Traffic Management System (TMS) entails seamless arrangement and controlling of traffic for moving and stationary vehicles, cyclists,

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and pedestrians using technologies. One of such technology is the Internet of Vehicles (IoV), a recent research that allows the development of many promising applications in Smart Cities based on the Intelligent Transportation Systems (ITS). Modern cities are equipped with Closed-circuit television (CCTV) cameras for surveillance and other beneficial use. CCTV cameras captured a lot of data and analysis of these data can provide a solution to the traffic issue that plagues many large cities. Edge detection techniques have been used for analyzing image data in a real-time setting.

This paper presents an overview of basic algorithms adopted by researchers toward solving traffic management problems in modern cities across the globe.

COMPUTATIONAL BASED ALGORITHMS METHODS

CmapGen Algorithm

S. Rakesh et al [1] proposed CmapGen algorithm, an adapted form of edge detection technique's. In determining the traffic density of vehicles near the traffic light, many researchers developed canny edge detection methodology.

The suggested CmapGen has a higher average traffic density when compared to the traditional canny approaches that determine when to change traffic lights by computing the area-based traffic density in real time.

The CmapGen uses a picture-processing-based estimate location algorithm to calculate the website traffic density. They measure the density of web traffic in the region swamped by the vehicle borders. The CmapGen algorithm suggested increasing edge areas to determine the location of the vehicles in the collected live traffic image.

The canny technique will detect only the edges of the vehicles in the input traffic image. CmapGen algorithm processes the result of canny images using various image processing algorithms like thresholding, blur, and generating capacity maps using the features of programming language. Frames generated from the input traffic video are processed through CmapGen algorithm steps to obtain the density of traffic present in all the frames. [1]

Figure 2.1 represents the data flow of the implementation process of the CmapGen algorithm.

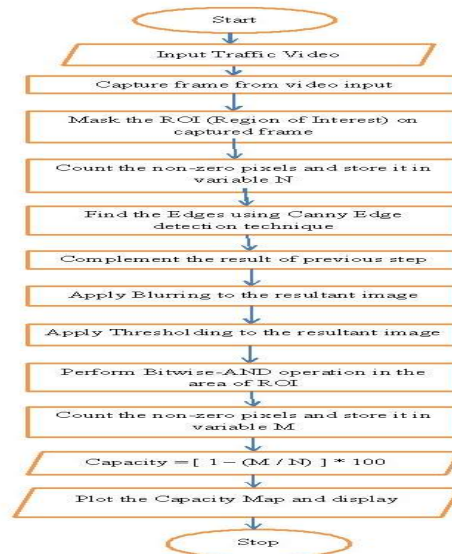


Figure 2.1: Flow chart of CmapGen Algorithm

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This method is only compatible with static images. A further improvement is required to determine the density of moving cars at the intersection of traffic lights, allowing for the calculation of real traffic density and the use of that information to operate smart traffic systems.

Adaptive Traffic Management Algorithm

The Adaptive Traffic Management Algorithm (ATMA) is the heartbeat of ITMS. ATMA's main aim is to adaptively optimize the traffic signal according to the traffic density, to reduce the waiting time (delay) to the barest minimum, and to maximize the flow rate at the intersection. Using the proposed architecture and the features of IoV, all the relevant data such as the number of waiting vehicles in the intersection, the waiting time of each vehicle, the vehicle type (normal, truck, or emergency), the flow rate of the open road, and the state of each road segment can be collated in real time by the STS without any extra hardware (only IoV components and the STS). This information, if harnessed and used properly by an ATMA, can result in optimal traffic management.

Samir A et al [2] propose the deployment of the existing VANET and IoV infrastructure to provide an efficient and intelligent

traffic management system without any need for special deployment through an adaptive algorithm. The proposed architecture supports any adaptive algorithm without having the need to change the architecture. Most of the existing model uses sensor-based technologies that rely mainly on counting the vehicles on each road segment at the intersection. These include inductive loops, magnetometer, microwave radar, laser radar, ultrasonic, acoustics, video cameras and counting cables.

In the proposed system, there will be no need for color lights. Vehicles will be able to communicate with the Intelligent Signals wirelessly to achieve their services and provide the following features: the ideal traffic flow as the opening (green light) for any road will be based on a dynamic priority; the opening time will be based on the number of waiting vehicles. This can optimize the waiting time (reduce the delay time, reduce traffic congestion, give priority to crowded roads, and eliminate useless openings, thus facilitating adequate traffic flow.

The Flowchart of the overall proposed adaptive traffic management algorithm is shown in Figure 2.2.

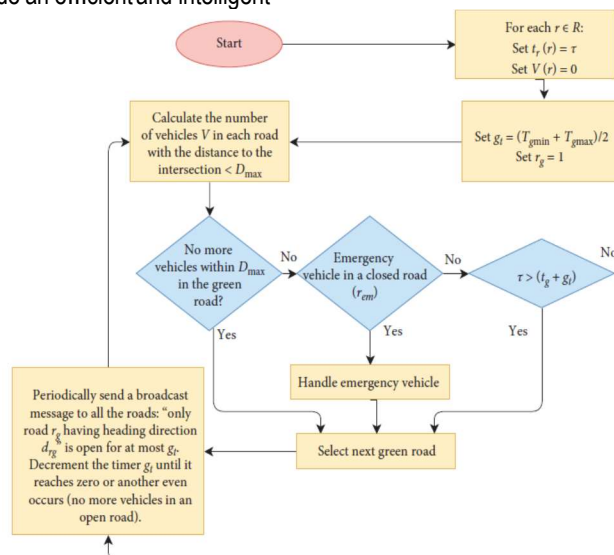


Figure 2.2: Flowchart of the overall proposed adaptive traffic management algorithm.

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After initializing the variables, the system repeats the following steps; It calculates the number of vehicles in each road with the distance to the intersection $<D_{max}$. In a situation where there are no more vehicles within D_{max} in the open road, that road is closed after waiting for the transition period. Then, select the next open road. At any time if an emergency or priority vehicle arrives on any closed road, a warning message will be sent to all vehicles on the open road (rg) that the road will be closed now due to the existence of an emergency or priority vehicle on another road. Then, wait for the transition time, T_y , and after that close the open road, rg , and open the road (rem) having the emergency vehicle and keep it open until the emergency vehicle sends a message that it has crossed the intersection (overriding the T_r max threshold). On the expiration of the green timer, the system will decide dynamically which road should be open. A dynamic algorithm called "Select Next Open Road" is devised to estimate the best road to open in order to optimize the traffic flow, minimize the average waiting time, and increase the number of serviced vehicles (crossing the intersection):

- i. To prevent starvation (few vehicles waiting too long on a road while there are many vehicles on the other roads), find the road with the largest close time with the condition that it has vehicles, excluding those having no vehicles. If this road is closed more than T_r max, then this road will be the next one to open.
- ii. Otherwise, the road having the largest number of vehicles will be the next one to open.
- iii. The green time (the open time) will be set dynamically as the ratio of the number of vehicles of the selected road and the total number of waiting vehicles on all the roads multiplied by the cycle time
- iv. $T_{turnover}$.
- v. Adjust the calculated green timer to be within the maximum and minimum allowed values for the

- vi. Open timer.

Distributed Decision Traffic Management Algorithm

Nikolaev A.B et al [3] proposed a distributed form of central adaptive system. The ITS consist of set of roadside controllers where each controller is responsible for roadside vehicles management and congestion detection within the range of its coverage area. The congestion control mechanism periodically performs routing of all vehicles to avoid congested areas. The system comprises of four components, the distribution of the roadside unit RSU, collection and transmission of data, congestion detection and congestion control. The algorithm for each of these components is elucidated below:

Placing of roadside controllers (RSU)

Allocation of road side controller (RSU) is uniform depending on their radius and size of the map. Thus, the larger the range, the smaller the number of roadside controllers is used to cover the map. The algorithm of placing RSU on the map:

Input: Width // Total width of the map

1 Length // Total length of the map

2 Radius // Operating range of RSU

Output: Coordinates of the points of each RSU

// returns the amount of RSUs to cover the entire map

3 $rsus \leftarrow \text{getNumberOfRSUs}(\text{Width}; \text{Length}; \text{Radius});$

4 foreach $\gamma \in rsus$ do// returns the coordinates (x; y) for each RSU

5

$R_{sus_coordinates.add}(\text{getCoordinate } s(r));$

6 end [3]

Collecting and transmitting data in the RSU

This algorithm provides data collection from RSU to obtain information about the events taking place within their communication range, as well as information about the behavior of the vehicle in their coverage area. Vehicles within the coverage area periodically send information about

the position, speed, distance covered, time and direction of travel movement in the near RSU. This information is transmitted via the long-range communication (LTE or 3G).

The algorithm of Collecting and sending data to the nearest RSU

```

Input: N // Set of vehicles on the network
      1 RSUs_Coordinates // Set with the
        coordinates of each RSU
      2 foreach  $u \in N$  do // returns
        information about vehicle V
      3 status v.getInfo(); // returns
        the nearest RSU to vehicleV
      4 nearestRsu
        RSUs_Coordinates.getNearestRSU(v.ge
        tPosition());
        // creates a message with the
information of vehicle v and sends it to the
nearest RSU
      5 message ←
        CreateMessage(status);
      6 message.sendTo(nearestRsu);
      7 end [3]
  
```

The algorithm of alternative routing of vehicle

The change of route of vehicle movement occurs periodically depending on the current traffic. Each roadside controller is responsible for the selection of a new route within its range. The distortion depends on the intensity of vehicle movement and the weight of the road. An overload vehicle may be forwarded to another route to avoid congested areas. The base routing algorithm is used to find the shortest route in time, wherein the set of K shortest paths is calculated as alternative ways in which K can be easily adjusted to adapt better to the behavior in the network. Of these alternative routes, the only way is selected by using the probability distribution of Boltzmann.

Algorithm of alternative routing of vehicles

```

input: N // a Set of vehicles in range of each RSU
      1 G // the Graph is created for each RSU
      2 K // Number of alternative ways
      3 For  $u \in N$  do
  
```

```

// sets of edges that make up the route of vehicles
V
  
```

```

      4 route v.getRoute();
      // returns the current coordinates of the vehicle
      and the distance to
      the last segment of the path V, contained in the
      graph G for a given RSU
      5 source ← v.getPosition();
      6 lastEdge ← G.getLastEdge(route);
      // calculates K shortest paths from the starting
      point to the last
      point of movement of the vehicle
      7 alternativeRoutes ← G.getKShortestPaths
        (source; lastEdge;K);
      // select a path from a set of alternative paths
      8 newRoute ← boltzmann(alternativeRoutes;G);
      9 if lastEdge! = route.getDestination() then
      // returns the remaining part of the route of vehicle
      V from the
      last section
      10 remaningEdges ← route.split(lastEdge);
      11 newRoute.add(remaningEdges);
      12 v.setRoute (newRoute);
      13 end
      14 else
      15 v.setRoute(newRoute);
      16 end
      17 end
  
```

Other Computational Intelligence Based Algorithms

The Followings are some of other computational intelligence based algorithms for avoiding congestion worth mentioning.

Ant Colony Optimization (ACO)

The Ant Colony Routing method solves the dynamic traffic routing issue. This algorithm employs artificial 'ants' for searching the network, and the consequent ants assignment identifies the network's splitting rates. The algorithm functions by network pruning and forecast control. An ACO algorithm was integrated with map segmenting and the mean speed of travel forecast for deriving an enhanced congestion avoiding method. Segmenting and short-term forecast were utilized



for overcoming the dynamic nature and rapid variations of road traffic [4].

Bee-Based Optimization

The algorithm provides a solution to the ride-matching issue, and, as a result, the congestion issue using this algorithm. Ride-matching assists commuters in sharing a transport details during their travel to their destinations, and thus minimizes the number of vehicles having one occupant only.

Genetic Algorithms

Genetic algorithms are based on populations that provide possible solutions as chromosomes. All chromosomes comprise of a group of items that provide a group of solutions for optimizing variables. The evaluation of the suitability of every solution is carried out by an objective function. The three essential operations of genetic algorithms are selecting, crossing over, and mutating.

Random Forest Algorithm

Random Forest based on Near Neighbor (RFNN). RFNN calibrates and validate real-world data, such as location and time, extracted from GPS. The travel time between adjacent stations was calculated based on real-world data, which was also used to train the RFNN model. A lot of information was investigated and large features were extracted from the database. Gradient boosting as well as random forest algorithm was used to train and evaluate the performance. Data, such as taxi demand, time, trip length distribution, and most traversed areas, were the points of interest.

Deep Learning Algorithm

Artificial Neural Networks (ANN) are effective methods for modeling traffic data mathematically. They offer functionalities like learning and organizing on their own, and can recognize patterns. They carry out non-linear approximating between outputs and inputs. As they are nonparametric, no assumptions are made regarding data distribution. The ANN technique

considers real traffic data as well as aggregated past values for predicting the future traffic flow. The performance of the network is analyzed through parameters, such as accuracy and speed. The study revealed that prediction based on both real-time traffic and historical data was found to be more accurate than the prediction based on only historical data.

CONCLUSION

Today's traffic planning is focused on using the existing densely populated areas more efficiently to create better living conditions. Solutions are been designed to optimize mobility, ensure greater safety for road users, and reduce pollution resulting from vehicles. ITS gather supplementary information about the configuration of the traffic flow, which helps to reroute vehicles to avoid traffic jams. Also similar solutions are available to assist in toll collection on specific roads or stretches of roads, known as urban tolling. The whole gamut of this technology form an integral part of smart city concepts and can be enforced with modern technology.

Collection of traffic data is one of the primary and important functions in managing the traffic as all other traffic management procedures rely on the accurate prediction of traffic. The development of machine learning and artificial intelligence changed the design concepts in traffic management. These provided the tool that is use in understanding and processing of tons of data where vehicular congestion can be detected using machine-learning technology. Using state of the art deep learning algorithms and computer vision, it is now possible to detect objects, vehicles, people and their activities.

The availability of the essential infrastructure is key in determining the best option to adopt in the implementation of ITS system.

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