Traffic Jam Minimization and Accident Avoidance System Using IoT

Mohsin Khan and Bhavna Arora

Abstract Traffic jam is one of the biggest challenges of twenty-first century, and hence, there is an urgent need to combat the issue of vehicular congestion. Traffic congestion can be classified by the Department of Transportation as 'recurring' which occurs on regular basis due to bottlenecks, narrow roads, etc. and 'non-recurring' which consists of temporary disruptions like accidents, bad weather, etc. With the emergence of 4G/5G technology, the Internet of Things (IoT) has grown exponentially, thus facilitating real-time transfer of data bits. The indulgence of the IoT for the vehicular movement can be used to minimize the traffic congestions. A two-way communication is established between the vehicles in its local vicinity or zone and the critical information flows between them, in real time. In this paper, a concept has been proposed that will attempt to minimize the traffic congestion by using IoT. The proposed concept will handle the safety of the vehicles, thus reducing the probability of accidents and will minimize the traffic jam especially 'phantom jams or jamitons.' To elucidate the proposed concept, algorithms and flowcharts for maintaining a minimum or safe distance between vehicles, overtaking and lane changing are presented in this paper.

Keywords Internet of Things (IoT) · Traffic jam · Vehicular congestion

1 Introduction

According to the statistics, 78.6 million automobiles have been sold in 2018 worldwide [1]. A mathematical explanation for the occurrence of traffic congestion was proposed by Boris Kerner. The proposed traffic theory comprises three phases, namely free flow, synchronized flow and wide-moving jams [2]. During the transition from the free flow to the synchronized flow as the density of the vehicles increases, the speed of the vehicles drops considerably, but there is no noticeable change in

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flow rate. Hence, there is a synchronized flow of automobiles present in different lanes. While the traffic moves through the bottleneck, transition to wide-moving jam emerges through synchronized flow when both flow rate and velocity drop significantly as the density of the vehicles per unit area increases. The widening of the roads has been established in order to minimize traffic jams, but recent studies have shown that after the widening of the roads, the density of the vehicles or automobiles increases, thus grasping a threshold point where the jams are again meant to happen [3]. Sometimes there are no causes such as closed lanes, accidents or bad weather; still there are congestions on the roads; this phenomenon is called 'phantom jams' [4] which was coined by the researchers at Massachusetts Institute of Technology (MIT). It is caused due to hard hitting of brakes when two or more vehicles progress too much close to each other maintaining a small space in between. According to the Department of Transportation, traffic jams are classified as 'recurring' and 'non-recurring.' Recurring traffic congestion is caused due to high density of vehicles than the roads can accommodate. Non-recurring traffic congestion is triggered due to environment, mechanical issues and humans [5]. The environmental issues incorporate rain, fog, snowstorm, etc. The mechanical issues involve breaking down of car or accidents, and the humans are the main reason as there are many cases of drunk driving or emotional driving according to the National Highway Traffic Safety Administration [6]. With the emergence of Internet of Things (IoT), it is possible to minimize the congestion as the vehicles will be connected to each other in its local zone sharing critical information and calculating some predefined variables [7]. Those variables include the limit of speed up to which the driver must drive the automobile at specific situations so that a safe distance is maintained between the vehicles, the current speed of the vehicle, distance covered from a reference point [8]. The transfer of that critical information or data bits needs to be real time, i.e., the transference of data prerequisites to be fast enough with minimal transmission delay which can be attained by 4G/5G network communication [9].

1.1 Background and Research Motivation

The automated vehicles use mechatronics, artificial intelligence and multiagent system, and its autonomy levels are from 0 to 5, where level 0 means no automation, level 1 means driver assisted, level 2 means partial automation, level 3 means conditional automation, level 4 means high automation and level 5 means full autonomy [10]. Levels 0, 1 and 2 are more prone to accidents and jams as the vehicle is under the direct control of the driver, and most of the decisions are taken by the driver, while as the levels 3, 4 and 5 are less prone to accidents and jams because the vehicles are programmed and not under the direct influence of the driver. This means that the decisions taken in those levels are executed by the system. Levels 3, 4 and 5 vehicle automation cannot be completely applied in the urban and rural areas of developing countries like Brazil, India, Pakistan, South Africa, [11] etc. The main cause of accidents is risky overtaking manoeuvre. According to Brake and Direct line's survey [12],

1. 80% drivers have felt threatened by an overtaking manoeuvre.
2. 94% drivers have observed a risky overtaking manoeuvre, and more than half, i.e., 53% have spotted those manoeuvre on the monthly basis.
3. 18% drivers have acknowledged that they have overtaken without making sure if there are other vehicles that could have smashed.

A dynamic system needs to be fabricated in order to minimize those fatal situations regarding overtaking manoeuvre. Thus, an innovative touch needs to be integrated in the level 2 automation where the vehicle is under the direct control of the driver. The proposed model adds an innovative touch to the level 2 automation which is vastly used in the developing countries, consisting of algorithms and flowcharts. Those algorithms and flowcharts are explained in the later section of this paper, which when implemented will reduce the probability of traffic jams especially phantom jams or jamitons and will also minimize the probability of accidents caused due to overtaking and lane shifting on a one-way road structure with many lanes, as the driver has to take only action based on the decisions which are taken by the collaboration of the vehicles using IoT, sharing data and calculating the results.

2 Related Work

If every vehicle is replaced with the automated vehicle, the traffic jam will be completely eradicated, but this scenario is not possible. The automated vehicle is programmed according to the rules and regulations of the Department of Transportation. Rules are transformed into equations which are later imposed via any programming language. On the basis of levels 3, 4 and 5, self-driving car or robotic cars are capable of sensing its environment with little or no human input [13]. In self-driving cars, common positioning system is based on the satellite technologies, such as GPS, Galileo, GLONASS [14]. The technology proposed as connected vehicle technology is advantageous for the movement of traffic at the intersections [15], which provides an efficient signal control strategy. The authors have also proposed a fast branch and bound algorithm for the improvement of the computational efficiency leading to reduction in delays and stops [16].

Fuzzy logic can be used to control the trajectory of automated vehicles with a centralized controller. Alternative track prediction, keeping a safe distance between vehicles and integrating night vision using infrared cameras can be achieved using fuzzy logic [17]. The author has developed ethical crashing algorithms using guided track systems for avoiding collisions. The rational approach is integrated with artificial intelligence approach and a natural language requirement. The algorithms related to automated automobile predict various alternative crash paths, and a path is selected on the basis of lowest damage or likelihood of collision [18].

Waymo [19] was set in motion as a project of Google self-driving technology development company. The technology is in testing phase; it has passed the tests and has been employed in certain environments, yet it has to pass the tests in harsh environments.

3 Proposed Model

The proposed model can be implemented via MATLAB and its components related to the driving scenario simulation. The MATLAB code created during the implementation of the proposed algorithms presented in this paper needs to be tested. The first testing phase can be conducted using MATLAB performance testing framework which includes performance measurement-oriented structures [20], and the second testing phase can be conducted by integrating Google Map API. The infrastructure of roads based on the Google Maps will be used to simulate the scenario, and the road structures are selected in the series of distinct stages. First those structures are selected which will be easy to simulate the scenario, and after passing the previous structure, more difficult environment will be selected on the Google Maps. The efficiency of the algorithm is developed and enriched after deep deliberation and analysis of scientific research studies regarding to this field. Thus, a model is proposed that is going to work on the following algorithms and flowcharts.

3.1 Proposed Algorithm and Flowchart for Maintaining a Threshold Distance Between Two Vehicles

Algorithm 1. Maintaining a minimum and a safe distance between the vehicles not only maintains a free flow but also reduces the probability of phantom jams or jamitons. The algorithm regarding to the maintenance of a minimum distance is given as follows:

Vehicle at front = v_1
Vehicle at back = v_2

Speed of v_1= Sp_{v1}
Speed of v_2= Sp_{v2}

Velocity of v_1= vel_1
Velocity of v_2= vel_2

Distance between v_2 and v_1 = $dist$

A point p is selected by $v_1$as reference point
While, Time t_n where $n \geq 0$
Distance, $d_{v1}$from point p = $d_{v1} + \int_{tn}^{tn+5} vel_1 dt$
Distance, $d_{v2}$from point p = $d_{v2} + \int_{tn}^{tn+5} vel_2 dt$
$dist = d_{v2} - d_{v1}$

If $dist \leq length\ of\ v_2$
Then "v_2 has to decrease the speed"
Else
"Depends upon the driver of v_2"

Time is incremented, $t_n = t_{n+5}$
End While

Flowchart 1. The flowchart regarding to the algorithm for maintaining a threshold distance between vehicles is given as (Fig. 1):

3.2 Proposed Algorithm and Flowchart for Overtaking

Algorithm 2. Controlling overtaking will reduce the probability of fatal accidents, thus an algorithm has been fabricated which is as follows:

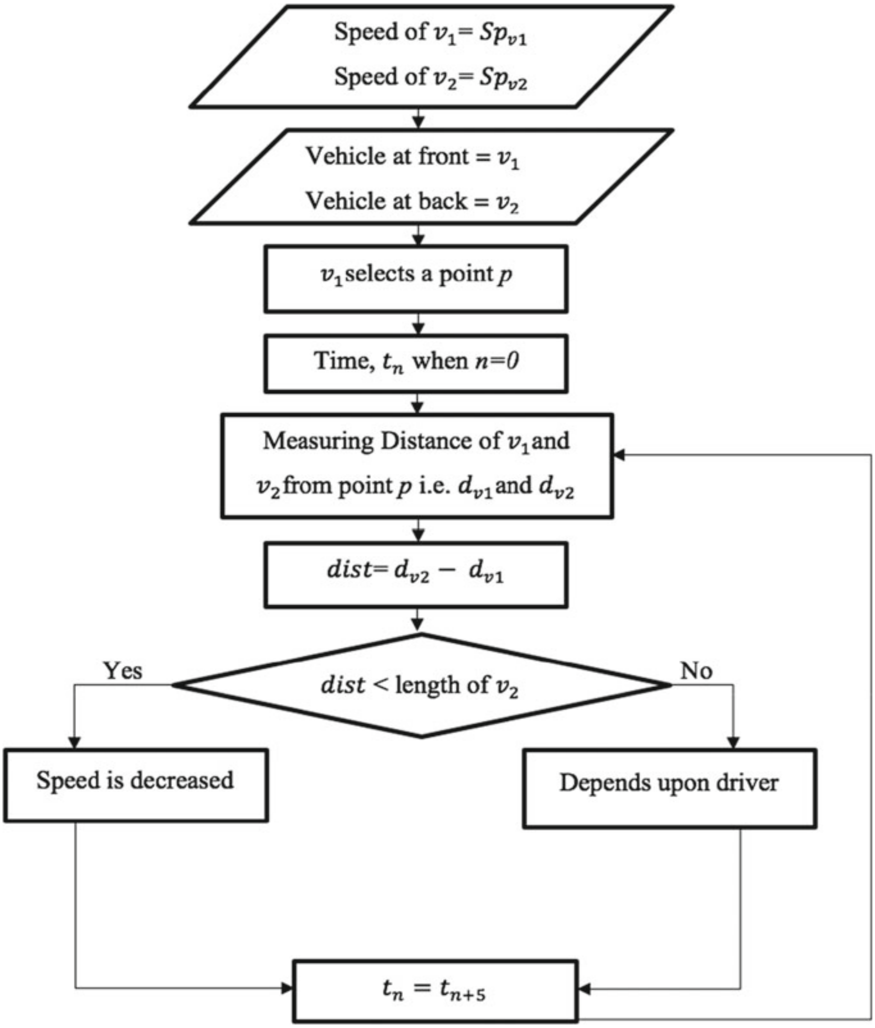

Fig. 1 Maintaining a threshold distance between two vehicles

```
Vehicle that wants to overtake= v_0
Vehicles in other lane= v_l
Number of vehicles, v_0 has to overtake= n
Vehicle in the front-end of v_0= v_n
Distance of v_0= d_vo
Distance travelled by vehicles present at the front-end
of v_0 = d_vn

Initial value, n = 1
While n ≤ 3
Algorithm 1 between v_n and v_n+1
If
dist > (length of v_0 + (length of v_0)/2 ) = δ
Overtaking is initiated at time T
Else n++
End While

If n > 3
"overtaking not possible"
Else
"overtaking is possible"

In other lane at time T,
Applying algorithm 1 to v_0 , v_1 and v_l
Distance covered by any vehicle in other lane= d_vl

For
d_vn + length of v_n < d_vl
Or
d_v0 − length of v_0 > d_vl
"Permission for overtaking is granted to v_0"
Else
"Permission for overtaking isn't granted to v_0"
End For

If d_v0 > d_vn
"overtake successful"
```

Flowchart 2. The flowchart considering the algorithm for overtaking is given as follows (Fig. 2):

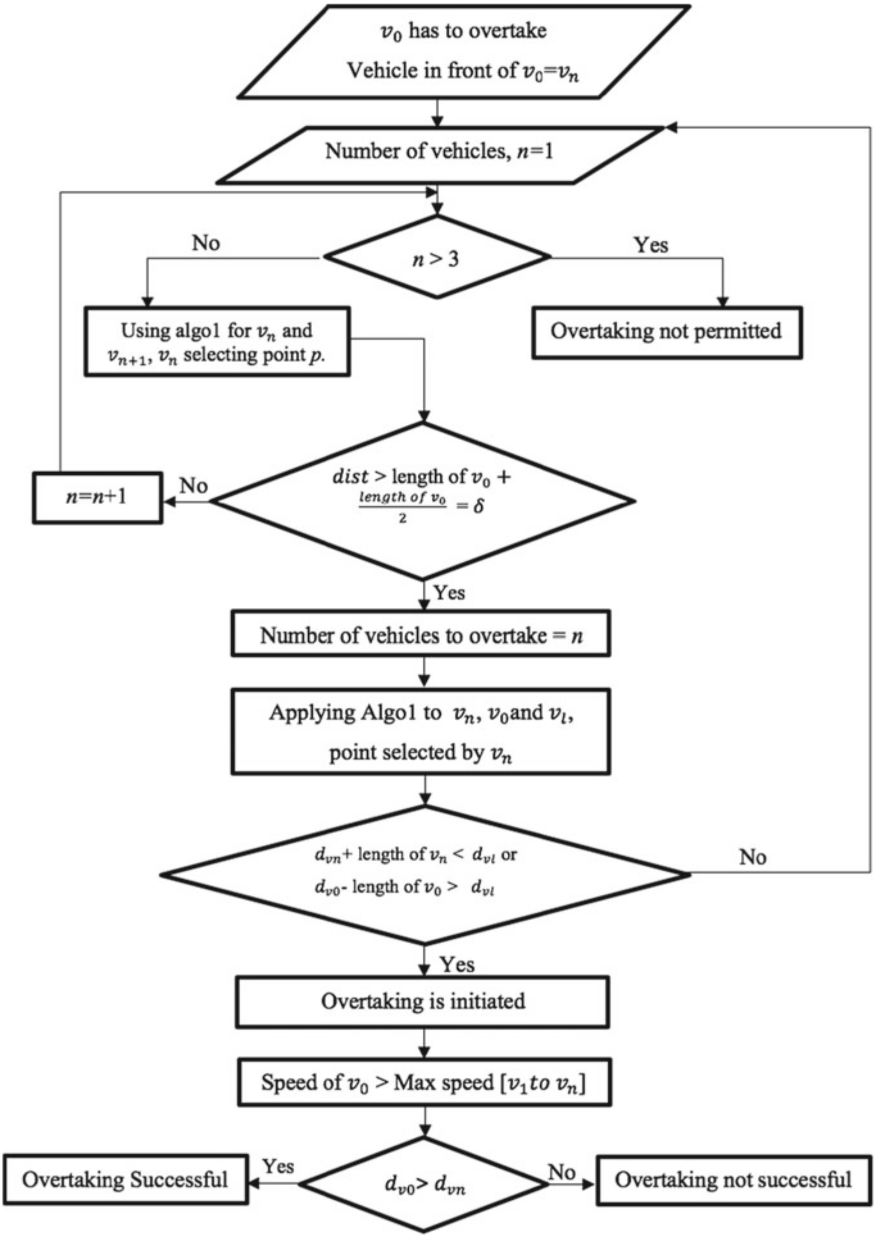

Fig. 2 Overtaking on a one-way road with more than one lane

3.3 *Proposed Algorithm and Flowchart for Lane Shifting*

Algorithm 3. Controlling the changing of the lanes can further help in minimizing traffic jams and accidents. The algorithm for lane shifting is as follows:

```
Vehicle that wants to change lane= v_0
Vehicles in other lane in the zone of v_0= v_l
In other lane
Applying algorithm 1 to v_0 and v_l;reference point selected
by v_0
Distance travelled by v_0 = d_vo
Distance travelled by v_l = d_vl

While
d_vo+ length of  v_0 < d_vl or
d_vo- length of  v_0 > d_vl
"Lane changing is permitted to v_0"
End While
```

Flowchart 3. The process flow for shifting the lane is given in following flowchart (Fig. 3):

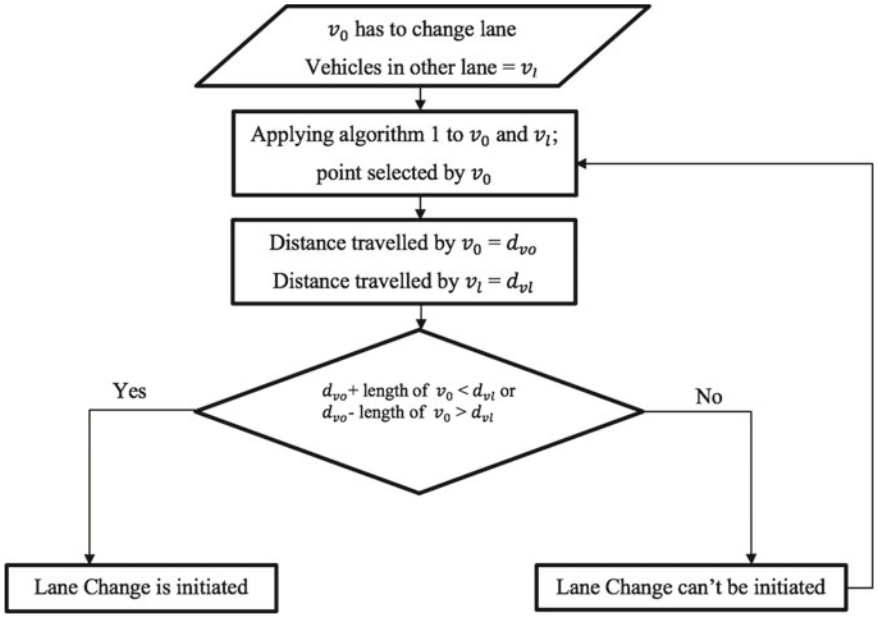

Fig. 3 Lane shifting on a one-way road

4 Discussion

The main reason for traffic jams is overtaking and lane changing which can be avoided by the communication of vehicles in their vicinity using IoT, sharing the real-time value of variables for individual calculation in each component or vehicle [21]. Hard hitting of brakes arises jamitons which can be avoided by keeping a safe distance between the vehicles. The further explanation on the basis of previous algorithms for the maintenance of threshold distance between vehicles, overtaking and lane changing in this paper is as follows:

4.1 Maintaining a Threshold Distance Between Two Vehicles

The vehicle at the front is denoted by v_1, and the vehicle at the back is denoted by v_2. The speed of both vehicles will be given as Sp_{v1} and Sp_{v2}, respectively. Similarly, vel_1 and vel_2 are velocities of vehicles v_1 and v_2, respectively. v_1 select a reference point p as a starting point, and this point will be the latitude and longitude in real world which is selected on the GPS connected to the system at a specific time t_n, where initial value of n is equal to zero. The loop starts at this point applying the increment after obtaining the distance first time. The distance d_{v1} of the vehicle v_1 is measured from that point using equation.

$$d_{v1} = d_{v1} + \int_{t_n}^{t_n+5} \mathrm{vel}_1 \mathrm{d}t \tag{1}$$

Other vehicles v_2 travel through same reference point, i.e., same latitude and longitude, and its distance d_{v2} is measured by the equation

$$d_{v2} = d_{v2} + \int_{t_n}^{t_n+5} \mathrm{vel}_2 \mathrm{d}t \tag{2}$$

Distance dist between v_1 and v_2 is measured by subtracting d_{v1} from d_{v2}.

$$\mathrm{dist} = d_{v2} - d_{v1} \tag{3}$$

The dist should always be greater than length of v_2 between v_1 and v_2. If the distance is less than the threshold value, then the driver has to apply brakes decreasing the speed and maintaining the dist of more than threshold value which is length of v_2. The time t is incremented by the value of five seconds, i.e., t_{n+5} after which the loop starts again.

4.2 Overtaking

The vehicle that wants to overtake is denoted by v_0, and the vehicles present in front are denoted by $v_{1\,\mathrm{to}\,n}$ where max value of n depends upon the vehicles, v_0 has to overtake. Let T be the time of the initiation of the process. Using algorithm 1, distance is measured between v_n and v_{n+1} where initial value of $n = 1$.

$$\delta = \left(\text{length of } v_0 + \frac{\text{length of } v_0}{2}\right) \tag{4}$$

If the dist is greater than δ, then the number of vehicles to overtake will be equal to the recent value of n and if the dist is less than δ, n is incremented by 1 which means the next vehicle is checked for δ. The loop continues until δ is found or the condition of $n \leq 3$ is met which means max number of vehicles to overtake is 3. When $n > 3$, v_0 doesn't get any acknowledgement. If the conditions are satisfied, an acknowledgement is received by v_0 and an acknowledgement is sent by the vehicle that finds the δ, i.e., v_n. The last value of n denotes the number of vehicles that will be overtaken by v_0. The vehicles in the other lane in the zone of v_0 is checked for distance, and algorithm 1 is applied, where the reference point is selected by v_n. The distance covered by v_0 is denoted by d_{v0}, and the distance covered by v_n is denoted by d_{vn}. In the other lane, if the distance covered by every vehicle in that local zone is greater than (d_{vn}+length of v_0) and less than (d_{v0}−length of v_0),, then the overtaking is possible and the driver will get the permission of overtaking else the overtaking is not possible. So, if the criteria are met, then in the other lane during the process of overtaking, the vehicles which have covered distance more than (d_{vn} + length of v_n) and less than (d_{v0} − length of v_0) have to maintain the speed that was recorded at time T, i.e., the initialization of the overtaking process. The maximum of the speed of vehicles from v_1 to v_n is taken in consideration and v_0 has to maintain the speed greater than that during overtaking. For checking the successful completion of the overtaking process, d_{v0} must be greater than d_{vn}.

4.3 Lane Changing

The vehicle that wants to change lane is denoted by v_0, and its local zone or local vicinity is selected. The distance covered by v_0 is denoted by d_{v0}, and the distance covered by vehicles in other lane, v_l is denoted by d_{vl}. In the other lane, if the distance covered by every vehicle in that zone is greater than (d_{v0} + length of v_0) and less than (d_{v0} − length of v_0), then the lane shifting is possible and the driver will get the permission for changing the lane else it is not possible. The condition is checked in a loop until the lane changing procedure is completed.

5 Conclusion and Future Scope

The changing of lanes, overtaking and upholding a safe distance between vehicles can help the transportation department to minimize the traffic congestion or 'jamitons.' If any driver of the vehicle does not follow the result of the algorithms, then an alert message will be received by Department of transportation with information about the vehicle and its owner. The system can be implemented in real life by programming Raspberry Pi in an IoT environment [22] integrating Google Map's API. In future, the algorithm can be developed for the intersection and for the turning points. The speed of the transfer of critical information which has been discussed in this paper must be in real time or with a minimal delay. This can be attained by using 5G/4G where delay is much less and transfer happens in real time [23].

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