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# A MULTI-AGENT SYSTEM MODEL FOR CONTROLLING TRAFFIC CONGESTIONS

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Abstract. *Traffic congestions in urban cities occur due to the massively increasing number of automobiles, the inadequate mass transit and road systems, and other reasons that are all the results of overdevelopment. Accordingly, the necessity to solve such an issue arises. One of the suggested solutions to solve such a problem is to use traffic management systems in order to control the congestions and improve the road traffic flow. Therefore, this paper proposes the state-of-the-art of a centralized traffic agent-model control system with an algorithm that aims to improve the traffic flow. The proposed model is a multi-agent model which consists of the Controller Agent, Global Positioning System (GPS) Agent, Sensors Agent, and Traffic Light Agent. The agents will work together as one system to assist the Controller Agent to adjust the time period of the traffic lights to reduce the traffic congestion as much as possible.*

**Keywords:** Multi-agent systems, Controller, Traffic congestions, Sensors, Global Positioning System (GPS)

1. **Introduction.** The industrial revolution has enhanced the quality of our lives in terms of health, education, wealth, and increasing job opportunities. On the other hand, a major drawback of such revolution is the overcrowded cities and industrial towns [1]. High population rates in such areas are causing many problems such as pollution, the increase demand on natural resources, and the increasing rate of vehicles. An example of this increasing rate can be shown in Table 1 where it presents the increase in vehicles ownership for the years 1999, 2006, and 2016 in some selected countries and regions [2].

The increasing number of vehicles and the unorganized and inefficient traffic management control systems will lead to traffic congestions, especially in the rush hours of the day. Traffic congestions have many drawbacks such as fuel consuming. Additionally, the driver may be late for work which causes a loss in productivity, and the stress that affects the driver may impact driving manners, such as aggressive driving [3]. Another serious problem that can be caused by traffic congestions is the increasing in the response time for emergency vehicles, which is considered life threatening [4]. Therefore, such a problem must be solved by taking into consideration that the roads of the city cannot always be maintained due to the lack of funding and space [5]. Consequently, finding alternative methods to solve the traffic congestion is vital. A good solution is to use traffic management system in large cities.

Several traffic management systems have been presented in the literature. For example, Al-Ani and Alheeti [6] proposed an intelligent traffic light control system, where cameras are connected to the traffic lights in order to capture the real-time traffic flow images for each direction. Based on the analyzed images, and by taking into consideration that the emergency vehicles must take the highest priority, the intelligent control system would

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Table 1. Vehicles ownership rates by region and selected countries [2]

| **Country/Region** | **Year/(vehicles per 1000 people)** | | |
|---|---|---|---|
| | **1999** | **2006** | **2016** |
| Africa | 20.9 | 25.2 | 38.9 |
| Asia, Far East | 39.1 | 49.7 | 105.6 |
| Asia, Middle East | 66.2 | 99.8 | 147.4 |
| Brazil | 107.5 | 129 | 209.3 |
| Canada | 560 | 599.6 | 686.3 |
| Central and South America | 133.6 | 102.4 | 174.7 |
| China | 10.2 | 26.6 | 141.2 |
| Eastern Europe | 370 | 254.4 | 362.1 |
| Western Europe | 528.8 | 593.7 | 606 |
| India | 8.3 | 11.6 | 36.3 |
| United States | 790.1 | 840.7 | 831.9 |

automatically adjust the traffic light control. However, the authors mentioned that their work needs an extended study of the traffic control over a long time in order to investigate all the factors that may affect their proposed system.

Rezzai et al. [7] proposed an intelligent system to solve traffic congestion at Casablanca. The proposed system is based on a multi-agent system with decentralized manner, and it uses reinforcement learning to reduce traffic congestions. The proposed system consists of two layers: the environment's perception layer and the traffic management layer. The first layer collects the information of the road's state via detection sensors, and the traffic management layer is responsible for the decisions and actions to estimate the time for the red or green phase based on the collected information. The authors did not apply their system, so no results were mentioned.

Recently, Alkhatib et al. [8] presented a low cost system for road traffic counting. Number of vehicles, vehicle's volume, and vehicle's length are considered as the main data that should be measured and known for any traffic management system. Additionally, detection infrared sensors are used with timers to count the traffic on each lane based on "1-meter check" rule and finding the k value which represents the length of the vehicle.

Biswas et al. [9] presented an intelligent traffic monitoring system that used four infrared proximity sensors (AT Mega 2560) at each road and a centrally placed microcontroller. The detecting sensors were used to collect data and fetch it to the microcontroller to develop a priority-based signaling which will help to give the priority to the emergency vehicles.

Sumi and Ranga [10] presented an intelligent traffic system that prioritizes emergency vehicles even when the traffic system is hacked. Their system consists of Road Side Units (RSUs), Traffic Management Server (TMS), vehicles and sensors that are all connected together in a Vehicular Ad-Hoc Network (VANET) system and exchange data. The authors simulated their system and compared it with two systems: EPCS and Green Wave. The comparison was done with and without hacking scenarios and showed 12% improvement over EPCS system and 17% over Green Wave system.

This paper will present a proposed model for reducing the congestion that may occur in the roads and intersections based on the multi-agent system approach, where every component in the road environment is considered as an agent. Each agent in our model will work independently, where the results will be combined to let the Controller Agent to take actions based on the data and information that are received from all agents. The proposed model utilizes the city's infrastructure by adding low cost detection sensors that will specify the traffic density. Therefore, there is no need to add cameras and analyze the received images which will reduce the time needed to take action. Additionally, this model uses Global Positioning System (GPS) receivers to determine the congestion time precisely, and presents the roads' priorities that are determined by their average daily usages. As a result, the controller agent will be able to adjust the time of the traffic light to reduce the congestion efficiently in less time than other models.

The rest of this paper is organized as follows. Section 2 presents our proposed traffic agent control system model. The proposed model's algorithm is presented in Section 3. Finally, the drawn conclusions and the planned future works are discussed in Section 4.

2. **The Traffic Agent Control System Model.** A multi-agent system is a computational model that allows many experiments to run in identical settings with many agents that interact together in a long time period. Therefore, it is perfect for studying the behavior in a complex setting within certain given information [11]. In order to build a multi-agent model that simulates a solution for a system, both the components of the system (agents) and the environment must be presented and then the interaction between these agents and the reaction between the agents and their environment are studied [12].

Our proposed model is a multi-agent system that is based on a centralized traffic system which consists of the Controller Agent, GPS Agent, Sensors Agent, and Traffic Light Agent.

The roads' statuses are obtained from the data agents which consist of the detection sensors that are attached to the road's sides and the GPS satellite. They provide the Control Management System Agent (CMSA) (the controller of the system) with the roads' traffic density in the area.

The detection sensors are used to detect the automobiles density by finding the queue's length to indicate the road current status. Furthermore, we propose a priority indicator for the roads to reflect the importance of the road based on the average daily usage, where the road with the higher average daily usage has a higher priority. On the other hand, the data that are received from the GPS satellite to the receiver that is connected to the controller agent are processed to obtain the information about the traffic density, so the starting time of the congestion can be determined by the controller for each road in the area. A queue structure is used in the controller to save the road's number and the time at which the congestion occurred. Moreover, the traffic light agent will provide its current color (red or green) to the controller.

The controller is supplied with the data needed from all agents in order to take the action to regulate the congestion by updating the time period for the traffic light. Figure 1 illustrates the agents in our model and the interaction between them.

Our proposed model's specifications are as follows.

1) The environment in our model is the road, where each road has a priority that is denoted by ($priority_n$).
2) The control management system agent is responsible for managing the traffic system by receiving the roads' statuses and controlling the congestion when it occurs. It receives the data via the data agents (GPS satellite and detection sensors).
3) The detection sensors are attached to the roads' sides to specify the traffic density by measuring the queue's length of the automobiles ($l_n$), where $l$ represents the queue's length and $n$ represents the road's number. In this paper, we considered the threshold to be the half of the road's length. Therefore, if ($l_n$) is greater than or equal to the half of the road's length, then the road reached congestion.
4) The number of automobiles ($Ano_n$) is taken into consideration in order to determine the amount of the increasing in the time period of the traffic light, and it is calculated based on ($l_n$) and the average length of the automobiles as presented in Equation (1). The average of the automobiles is used because the cars' lengths vary based on the

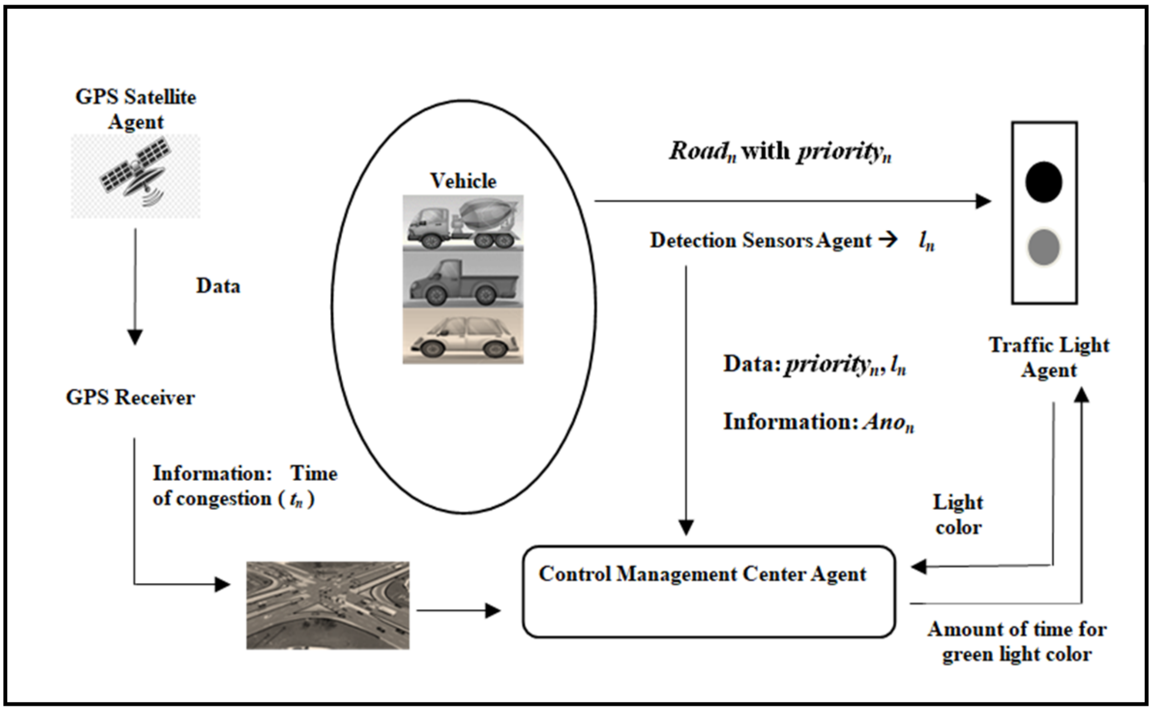


FIGURE 1. The traffic agent-model control system

class of the car.

$$Ano_n = l_n / average\ of\ automobiles\ length \tag{1}$$

5) A timer is used to register the time ($t_n$) for each road at which the congestion occurred based on the data that is received from the GPS agent. The GPS agent will send the information about the congestions at the roads to the GPS receiver that is used to detect the GPS signals and then send the required information to the controller. Then, the timer will record the time of the congestion occurrence. The values $n$ (the road number) and $t_n$ are stored into the queue structure in the controller agent. Therefore, the road with the first congestion that occurred, its number ($n$) and its congestion time ($t_n$) are stored first in the queue using the queue concept "*First In First Out*".
6) The traffic light color will be sent to the controller by the traffic light agent in order to update the time period of the colors based on the road's density.
7) We suggest that the increasing amount of the time period in seconds will be 1/2 second for each automobile as presented in Equation (2).

$$amount = (1/2 * Ano_n) \text{ seconds} \tag{2}$$

3. **The Traffic Agent Control System Algorithm.** In any algorithm the efficiency is determined by its execution time and its memory allocation which are the main factors that make an algorithm better than another. In some cases, the algorithm of our model depends on the road's priority and the number of intersections in the area, and these constant data are available at the control management center agent. Additionally, the queue's length which is determined directly by the sensors that are attached to the road will inform the control management center agent about the congestion occurrence. The data (queue's length, roads' priority and the number of intersections) assist the control management center agent to manage the congestion with less time than other algorithms. In another case, our algorithm may depend on the time of the congestion which is determined by the GPS receivers; however, the execution time will remain better than other algorithms. In terms of memory allocation, our algorithm applies the queue structure which is an advantage since it does not require a large memory space.

The algorithm of our model is presented as a pseudo code and as a flowchart which is illustrated in Figure 2 as the following.

**Input:**

- Traffic's light color.
- The value of $l_n$ that is sent by the detection sensors.
- The value of $t_n$ that is determined by the timer based on the GPS data.

**Process:**

- The controller checks the received value of $l_n$ and store $t_n$ for each road ($n$) (road ($n$) is the intersection ($n$)).
- Calculate the number of automobiles ($Ano_n$) at road ($n$), where:
  $\boldsymbol{Ano_n = l_n / average\ of\ automobiles\ length}$
- if ($l_n < road_n\, length$)

```
        - No changes will be applied to the time period of the traffic light.
  else
   {
        if (l_n >= 1/2 road_n length)
        {
            - enqueue (n, t_n)
            - if (number of intersections > 2)
            {
               - Check the priority for each intersection.
               - if (number of intersections with the same priority > 1)
                  {
                     - dequeue (n, t_n)
                     - Increase the green light time period for this intersection by
                       amount = (1/2 * Ano_n) seconds
                  }
                  else
                     - Increase the green light time period for the intersection
                       with the highest priority by amount = (1/2 * Ano_n) seconds
            }
        }
        else
                  Increase the green light time period for the next traffic light by
                  amount = (1/2 * Ano_n) seconds
   }
```

**Output:** Decrease the congestion as much as possible in the roads

4. **Conclusions and Future Works.** This paper presented the state-of-the-art of a centralized traffic agent-model system to detect and provide a solution for traffic congestions. The proposed model uses different data that are provided by the agents of the system to make the decision by the controller of the system of whether to update the time of the traffic light period or not. The time period will be updated in case the automobile's density reached 1/2 of the roads length. The priority of the roads, the congestions occurrence time and the number of the automobiles are taken into consideration as well to calculate the increasing amount time for the traffic lights.

As future work, this system will be simulated in order to check its efficiency, and it could be improved by using machine learning methods to assist the controller to make better decisions.

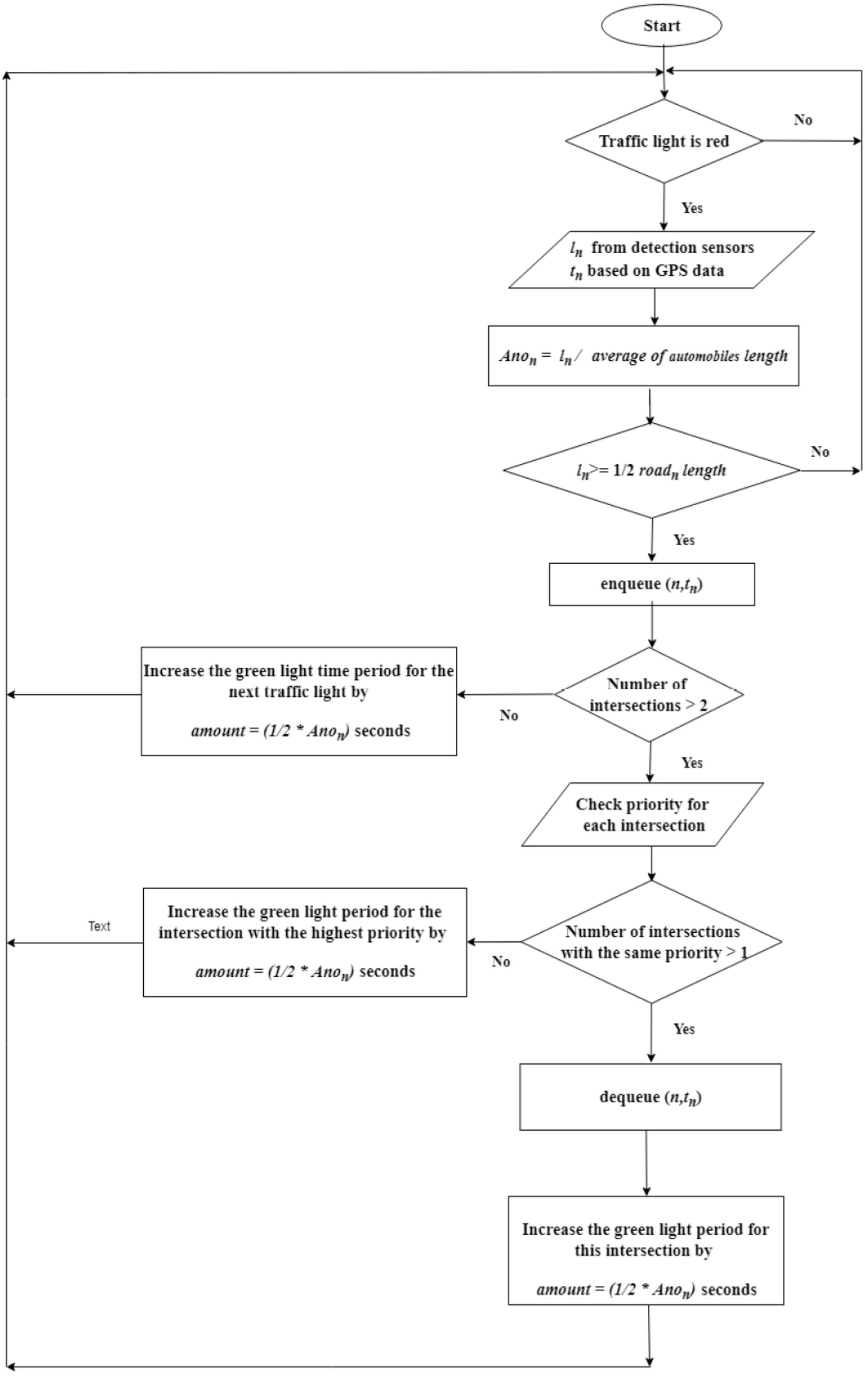


FIGURE 2. The flow chart of the algorithm

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