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Intelligent Traffic Lights Control Using Q-learning

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Abstract: ***Despite the benefits of traffic lights in managing the intersection that gives safety to road users, they became disturbing for lots of people because of increasing congestion in modern city. This makes it necessary to design an intelligent traffic lights system. In this paper, we present design an intelligent traffic lights system to reduce the congestion using Q-learning that learn how to make optimal decisions through the trial and error and discuss how the intelligent system decreases the congestion and how it became important to smart cities.***

Keywords: congestion, intelligent traffic, Q-learning, smart cities

1. Introduction

Transportation is an important routine in humans' life, cars are the most popular transportation types. A big problem in car transportation is traffic congestion. Unfortunately, building new roads and bridges need high cost and free space. Reducing congestion can be done by other methods, (e.g. smart traffic lights) [1]. The presence of new technologies (e.g. Artificial Intelligence, computers and mobiles, advanced communications techniques, and sensors networks), encouraged researchers to try to enhance the traffic system. in the past, the traditional traffic lights were used to show red, yellow, and green for fixed time intervals without monitoring the number of waiting vehicles, it may show a green light to a side that is empty [2], while other sides' vehicles are waiting, this will increase congestion that leads to many problems, including wasting people's time, accidents, fuel consumption, and increasing pollution [3]. Nowadays, we have intelligent techniques and advanced systems with sensors, computers and other components [4]. In this paper, Q-learning is used that one of types reinforcement learning where the last one of types machine learning. Q-learning consist of environment send state to agent and the agent choose action according to policy then observe the reward from environment to achieve the goal.

Many simulations like SUMO used to evaluate the work that explains later. Many researchers are worked on traffic lights system using many ways, such as green wave, genetic algorithm, reinforcement learning, fuzzy logic, and wireless sensor networks such as M. Bram Bakker et al; introduced artificial intelligent reinforcement learning algorithm that computes optimal solution through multiple controllers (agents) responsible for the traffic light in each intersection [5]. Changxi Ma • Ruichun He; explained green wave traffic control where series of traffic lights turn green with some time different that allows vehicles to move through all of them without stopping traveling like a green wave (at an approximate speed decided by traffic engineering). Matt Stevens and Christopher Yeh, [6] use techniques of reinforcement learning called Q-learning. The parameters (s, a, r, ś) used to obtain optimal policy where used the equation Qs,a)= R()+γ max Q(ś,á), Q-learning learns to choose better actions. The reward is the numbers of cars that pass through the intersection per unit time. And introduce a comparison between fixed cycles and longest queue first. It uses SGD (stochastic gradient descent) to obtain the minimum or maximum by iteration. Elise Van, [7] designed and implemented Deep Q learning algorithm where an agent is trained using this algorithm. Vehicle position is represented in a binary matrix. An agent can learn. Q value functions of two neighboring agents these functions used in max- plus to make chain where two agents make decisions in three agents and four agent cycle. Rok Marsetic et al., [8]; an introduced heuristic method for traffic light optimization in real time using Q-learning algorithm and compared with actuated traffic light control.

In section 2 are explain agent, section 3 contains a description of the simulation, in section 4 method and experiment are presented, section 5 analysis and results, and conclusion in section 6.

2. Agent

The agent is a computer program uses artificial intelligence techniques to solve specific problems. This program is usually installed on a machine. Both the machine and the program are assigned to the agent [9]. Agent interactive with environment where it take state from environment and record reward to decide the action on the environment then observe new state and update policy (training to learn optimal policy depending on reward and repeat interactive with the environment) show figure 1[10].

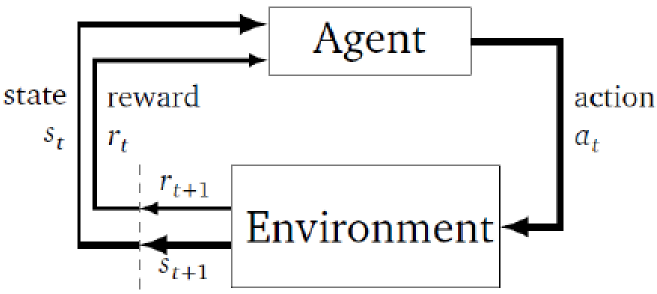

Figure 1: Reinforcement learning [11]

Q-learning is the type of RL, Q-learning is off-policy, Q-learning is updated the Q-function as shown in equations below:

Q (s, a) = R (s, a) + γ * Max[Q(s̀, à)]….. 1

Where
Q, R matrix
s = state
a = action
γ = gamma
s̀ = new state
à = new action

3. SUMO Description

SUMO is an open source software that simulates traffic system containing cars, intersections, traffic lights. SUMO uses TraCI (traffic control interface) commands that provide functions, such as traci.trafficlights.get phase to get the side(north, south, west or east), traci.trafficlights.setphase (x,y) sets the phase, where x represents the traffic lights and y represents the side north, south, west or east, and stepvehiclenumber() function counts the number of vehicles that crossed over the sensor. These functions may be called from python or Java …etc. SUMO allowed us to simulate any place on earth by downloading the map file from OpenStreetMap, adding the highways, traffic lights, primary ways, and type of vehicles. The map file should be converted to an XML file which is needed by SUMO [12]. TraCI is able to retrieve information in the simulation e.g. the vehicles and the network. Also, we can create any network manually. For example, to make one intersection, we need two lines and four points. Simulation can compare the efficiency of different schemes [3], it reduces the cost, time, data required to test different schemes additionally, it make it easy to add or delete objects, and it shows complete description to the state that we need. Here, it was used to create the traffic light that it gives the number of vehicles, speed, type of vehicles, delay, and the capacity of the street [13]. The benefit of using a simulation system to evaluate the performance of the proposed approach. The majority of the information we get from traffic detectors. They are sensors put on the traffic network that provide statistics about the traffic passing through them. There are many types of traffic detectors, The most common are induction loops [14].

4. Method & Experiment

The first proposed system is shown in Figure 2, depicting the main system parts which are: Traffic environment has (a stream of cars for certain intersection, a traffic signal and sensors) and the agent has (number and speed of cars, pool of actions, reward function, and Q-algorithm).

- The traffic signal is as we know a set of coloured lights, typically red, yellow, and green, used to control traffic at road intersections.
- Sensors (The sensors put on the traffic network that provides statistics about the traffic passing through them.
- The number of the car represents the cars wait in the one side of intersections, the speed of it represent the velocity in that side.

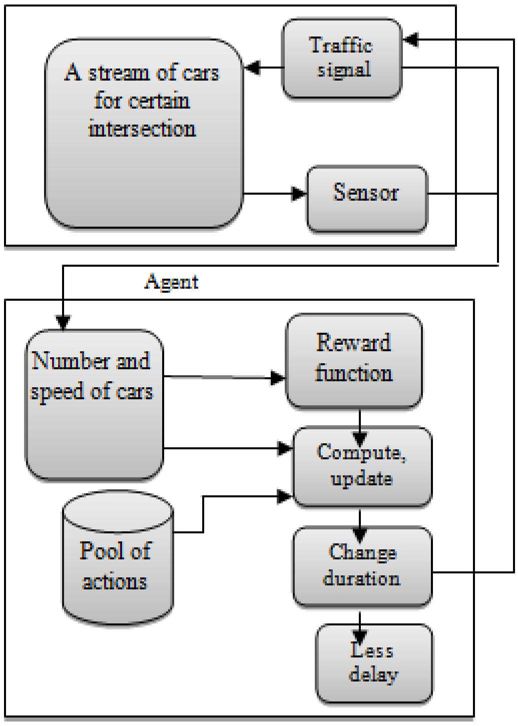

Figure 2: Block Diagram for the proposed system.

The algorithm is used to learn the agent from experience and trial. The agent training to explore the reward (represent matrix R) in the environment, each episode in the simulation is equivalent to one training session. The agent receives the reward and observes if it reaches the goal state. The benefit of the training is to enhance the 'brain' of the agent, represented by matrix Q. the flow chart of Q-learning is shown in figure 3.

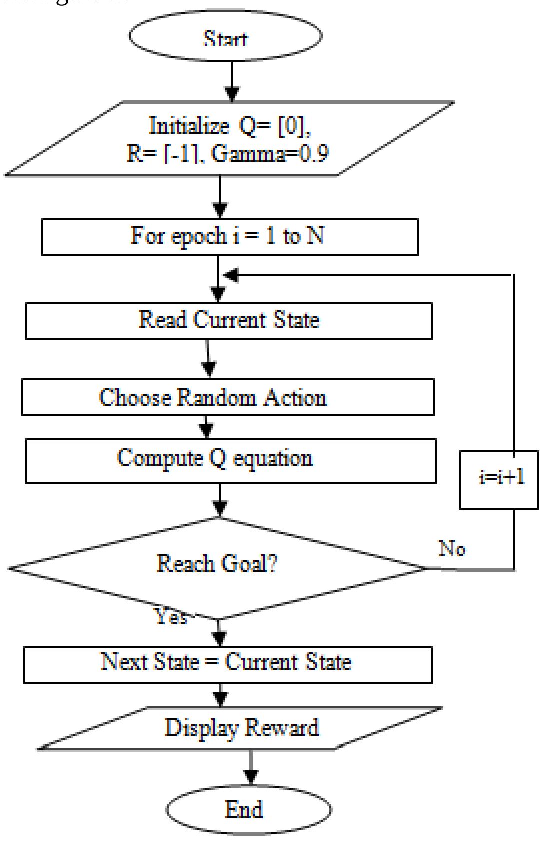

Figure 3: Q-learning Flowchart

1) Determine a value of Gamma parameter.
2) Set Q matrix initialize to zero.
3) Reward matrix initialized to one
4) For each episode:
- Get the initialize state that is vehicle number and means speed.
- Do while the goal hasn't been reached.
- Select random action among all possible actions for the current state.
- Using this action, to go to the next state.
- Compute: Q(state, action) = R(state, action) + Gamma * Reward
- Set the next state as the current state.

   End Do
   End For

5. Analysis & Results

To analysis the proposed system take scenario consist of two intersections (al-Misbah and Eqba in Baghdad city), using a proposed system was implemented and compared with the fixed time phase traffic light system to show efficiency design that suggested to reduce congestion. Notice the result for the comparison between fixed time traffic control and proposed Q-learning is illustrated in figure 4 the x-axis represents the number of cars and the y-axis represents the delay. The results show that in general, the increase in the number of vehicles will increase the delay time. Before learning the delay of fixed time equal to Q-learning for the same number of cars. While after learning after 210 sec for this scenario notice the fixed time reach 1100 sec that represent the average waiting time for 400 cars in two intersection, but the Q-learning is reaching 450 sec delay at the same Circumstances.

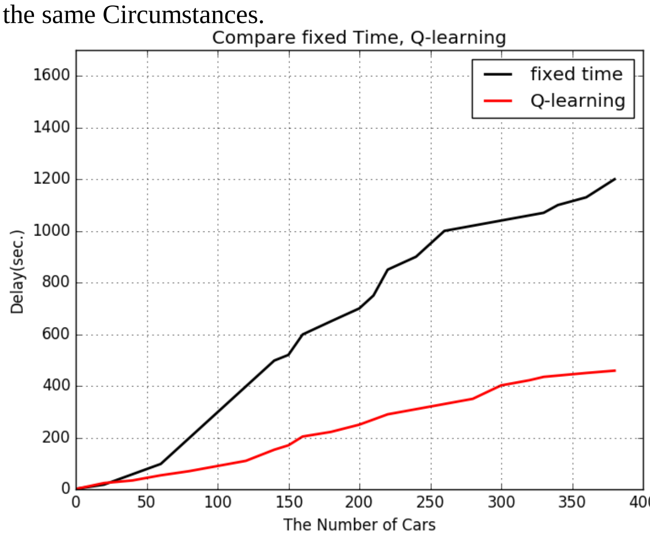

Figure 4: Comparison between fixed time traffic and Q-learning

This comparison is implemented using simulation SUMO that explained previously, and the sumo-gui of two intersections shown in figure 5.

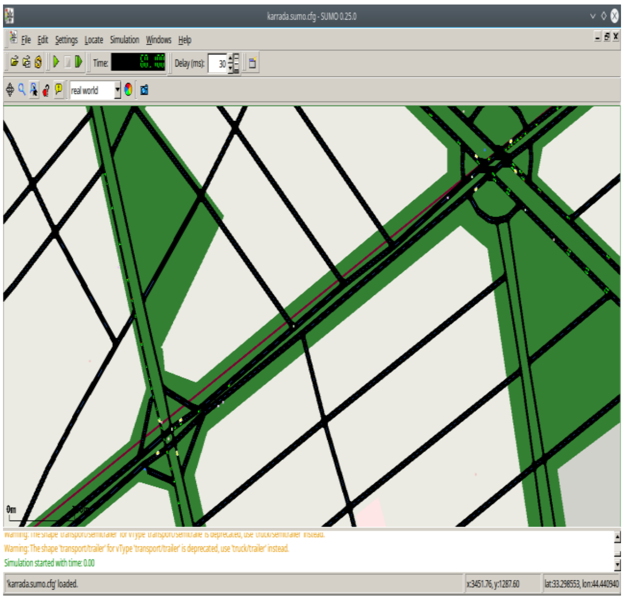

Figure 5: Sumo-gui with two intersections

6. Conclusion

The traffic lights became a problem for people especially in big cities so many researchers are trying to change the traditional traffic lights control to intelligent traffic lights control. The intelligent traffic lights control perform better than traditional traffic control with less vehicle waiting time. Thus, it will reduce the congestion, leading to less fuel consumption, and pollution. The used intelligent mechanisms include sensors, cameras, image processing, and many software programs to reduce problems in the traffic lights control system.

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