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Sensor-based Traffic Control Network with Neural Network Based Control System

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ABSTRACT

Vehicle traffic congestion is one of the major problems in today's society. It produces negative effects such as pollution and disorganized management of traffic flow. This paper provides research on a traffic control system using sensors and a neural network. It utilizes vision-based sensors to monitor intersection congestion data and sends this data to the surrounding stoplights to optimize traffic flow. The neural network will be trained to intercept the data collected in each stoplight and control the stoplight signals to direct the cars in the most efficient way possible. The neural net will be trained via simulation and be optimized based on the average travel time of each simulated vehicle tor rate its performance.

Key words: sensors, neural network, digital communications, vision-based sensors.

1. INTRODUCTION

Traffic congestion is widely considered as one of the major issues. Excessive traffic volume is costly to the economy and society because it tends to result in unpredictable travel time, unnecessary fuel consumption, increase in travel time and stress. There are two types of traffic congestion: recurrent and non-recurrent. Recurrent congestion is traffic congestion which occurs on a regular basis. For example, the flow of traffic during rush hours is expected to be heavy because those are the times of the day wherein the majority start or end their work or classes. Meanwhile, non-recurrent congestion is pertaining to the heavy flow of traffic due to unexpected events such as accidents or cars breaking down. Traffic congestion has become more problematic due to factors such as the increasing number of vehicles and obsolete management of traffic.

A sensor also termed as "transducer", is an electronic device which provides an output in response to a physical quality, quantity, property or condition which is being measured [1]. The output of a sensor is observed as an electrical signal A sensor responds to a stimulus and produces an electrical signal. Stimuli include acoustic, electric, magnetic, optical, mechanical, thermal, and radiation Sensors vary with respect to what quantity it can sense. A sensor such as the Hall Effect Magnetic Sensor is an example of a motion sensor Other quantities that can be sensed are displacement, velocity, acceleration, force, strain, pressure, fluid flow, sound, moisture, light, radiation, and temperature.

Artificial Neural Network is defined as a computing system, consisting of several interconnected subsystems/elements which process received data from external inputs [2,3,4]. The concept of an artificial neural network is highly influenced by the neuronal structure of mammals. Artificial neural networks are structured in organized layers. Elements are interconnected using nodes [5]. There are three main sections of the artificial neural network: an input layer, hidden layer, and output layer. Data is presented on the input layer which is then transferred to the hidden layer where the processing of data occurs.

2. BACKGROUND OF THE STUDY

The traffic management system is one of the major key components in modern society since automobiles are in demand today. Traffic management is important because it provides organizing the flow of traffic. It prevents chaotic mobility in urban and rural communities. Technological development is important in traffic management system as it can provide benefits to the environment and society.

Internet of Things (IoT) is a concept that involves devices that provides a switch connecting through the internet. One of the examples of IoT is cellular phones, computers, tablets, and home appliances. Digital communications have a key role in this concept as about 20 billion devices around the world are connected to the internet. It is projected that the IoT network must be able to handle 25 billion things by 2020 which requires different methods of data analysis, one such example would be CoAp.

A neural network is an algorithm that involves storing and managing data that was gathered. It helps the researcher to classify information. The neural network is based loosely on the human brain which it is designed for pattern recognition.

These patterns are usually numerical or vectors which can be translated through images or audio.

3. STATEMENT OF THE PROBLEM

The traffic management system is one of the major problems in today's society. Traffic congestion increases rapidly in all urban cities [6]. With this problem, air pollution and the production level of carbon dioxide increases. Psychological factors can also be affected such as the increase of stress and anxiety.

The traffic system in Metro Manila has numerous effects. Almost 10 million Filipinos were affected. The major problem in this predicament is traffic management facilities. Most traffic lights in the Philippines are under-maintained. Most of them do not work properly or do not work at all. Some major intersections and streets in Metro Manila do not provide traffic assistance which it increases the traffic congestion. Another problem is people spend more time commuting than being in their destination due to traffic congestion. Public spaces are also affected since roads are free to access.

4. SIGNIFICANCE OF THE STUDY

The findings in this study provide research on how to improve the traffic management system. It also provides a further understanding of the neural network and the digital communications system. This study can be applied to the traffic management system in the Philippines. Benefits in this study can improve traffic efficiency as well as other psychological and economic factors. The implementation of IG or intelligent guardrails will create vast improvements in traffic control. The study also focuses on the technological improvement of today's technology since applications of vision-based sensors and neural networks are rarely developed in the traffic management system [7,8]. Journal articles involving the improvement of the traffic management system are provided in order to improve this study.

5. DESCRIPTION OF THE SYSTEM

The system is comprised of individual stoplight-sensor modules that can transmit data over wifi. This data is sent to a central processing unit that handles the decision making for the stoplight. the central processing unit is comprised of a neural net-based algorithm that is trained to handle the data and make optimal traffic flow decisions. Assigns priority to the traffic flow for further optimization. This method is also implemented by S. Sukode and S. Gite wherein their system comprised of the hardware and software, where hardware comprises of Bluetooth receivers, microcontrollers, and smart devices, and the software is composed of servers and cloud computers [9]. The system proposed is a one-way system where the Traffic lights do not communicate with the cars such as the system proposed by L. Foschini [10].

For the traffic light module itself, the unit will be composed of a traffic light module for the actual traffic direction, a computer vision-based sensor on each lane to provide the data, which is in terms of car congestion, for each known direction [11]. the last part is the digital communications module that will encrypt the data and send it to the central computing unit.

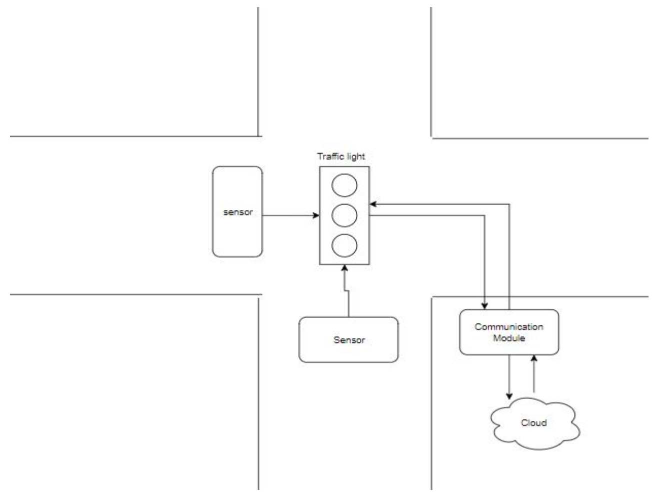

Figure 1: Traffic Light

The central processing unit will be able to intercept the incoming data transmissions, preferably over wifi, and use the data to make traffic flow decisions using a Neural Network type of algorithm. The decisions are then transmitted to be received by the individual traffic control units for execution. A similar method is used by P. Rizwan and N. Parrado where they use big data analytics and real-time streaming to handle the data input of each controller [12,13]. The neural network approach will be similar to that utilized a neural net to provide fast data processing. [14,15]

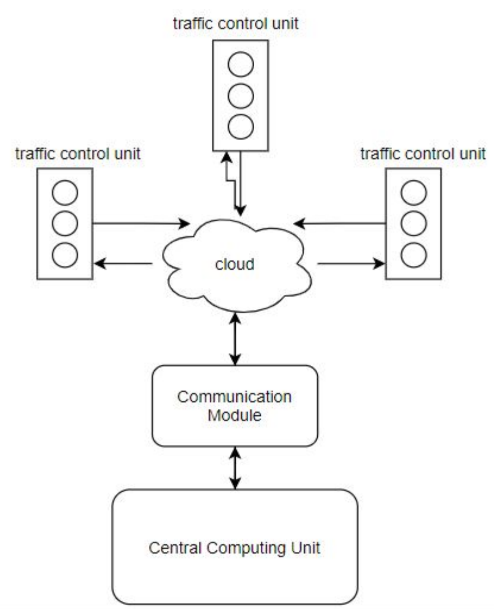

Figure 2: Traffic Light system

6. METHODOLOGY

The system will theoretically be set up first using SUMO or Simulation for Urban Mobility. Here a small group of city blocks with 6-8 two-way intersections. This will serve as the base for training the neural network to optimize traffic flow. Data will also be taken to see the progress of the neural nets progress rate such as the average time stopped on each vehicle, flow consistency, and compare them to the traditional timer-based traffic control system. The neural network itself will be made using the multilayer perceptron model to take in the various outputs and correlate them to specific input with each generation of the neural network, the fitness of each child will be taken and the process will be repeated with the fittest child as the parent. This is similar to the work which attempted to create an Ai that could model the traffic flow of an area [16].

The next logical step is to create a prototype stoplight-sensor module. here a powerful microcontroller module must be used say Raspberry Pi 3. The board can be integrated easily with computer vision and can readily access the internet. The traffic light itself will be composed of a 4-face case with 3 colors LED arrays on each face for low power but high visibility. These lights will be controlled by the controller. The Digital Communications aspect will be handled by taking in the data from the computer vision sensors and send them to a database, preferably AWS for easy access and management. Each stoplight data feed will have an identification tag for the central computer, which houses the neural net, for easy identification and processing.

With the whole system into place, all that is left is the actual implementation with the existing stoplight network in the city of question. The prototype must be easily integrated into the already existing traffic light. This can be done by packing the controller into a compact RSU or Roadside Unit that will be in a small vicinity to the stoplight, and a few cables to connect to the individual lights on the Traffic light module. Once this is achieved The Traffic network will be able to provide a dynamic approach to manning traffic flow, which will effectively reduce stagnant traffic especially in congested areas such as Taft Ave [17].

7. REVIEW OF RELATED LITERATURE

Neural Works for Real-Time Traffic Signal Control is a journal article on the research conducted by Dipti Srinivasan, Min Chee Choy, and Ruey Long Cheu in 2006. This group of researchers aimed to provide an effective real-time traffic signal control designed for complex traffic network. Their research suggests a multiagent system approach by planting responsive traffic control models which can communicate with each other and with the main controller. One multiagent system is a hybrid computational system whose main function is decision-making. The other multiagent system is developed integrating an approximation theorem on fuzzy neural networks, NN. The simulation conducted that hybrid multi-agent systems improve traffic situations. The results of this study demonstrate the positive effect of hybrid NN-based multi-agents systems in improving the problems of large traffic problems. [18]

Network-based strategies for signalized traffic intersections is a journal article of the study of Magdi S. Mahmoud, Faisal A. Al-Nasser and Fouad M. Al-Sunni in 2013. The researchers considered various traffic light control structures over communication links. The objectives of the study include minimizing the time of “red light”, maximize the flow of traffic in intersections while reducing the time of the stoppage and reduce the waiting time on while stopped. The researchers conducted a simulation in MATLAB to compare the different types of networked control systems. [19]

One such network proposes the use of ad hoc networks and RFID tracking to locate and identify vehicles as objects and map them in real-time. This type of traffic control system requires much more computing power and a more expensive application. RFID tracking technology may also be used to identify traffic law offenders for effective apprehension [20].

Real-Time Traffic Control for Sustainable Urban Living is a research article conducted by Xiao-Feng Xie, Stephen F. Smith, Ting-Wei-Chen, and Gregory J. Barlow in 2014. This research provides a simulation of decentralized traffic control. They were aiming to provide techniques for approaching traffic control and optimizing vehicle and pedestrian delay tradeoff [21].

An IoT Based Traffic Signal Monitoring and Controlling System Using Density Measure of Vehicles is a journal article by B. Prakash, M.Naga Sai Roopa, B. Sowjanya, and A. Pradyumma Kumar in 2018. The research provides the application of automated traffic monitoring and IoT. It also contains IR sensors in a traffic control system that can measure vehicle movement. Internet of Things (IoT) is applied in this study as it is based on the activity of emergency vehicles. The researcher aimed to decrease clog issue in traffic flow in urban communities by using automated concepts [22].

Reinforcement Learning for True Adaptive Traffic Signal Control is a journal article conducted by Baher Abdulhai, Rob Pringle, and Grigoris J. Karakoulas in 2003. This article provides research about adaptive control and exertion of real-time in the transportation system. It involves Q-learning and reinforcement algorithm that can be applied to the traffic control system. The article provides research that involves optimal control of traffic congestion [23].

IoT Based Smart Traffic Signal Monitoring System Using Vehicles Counts is a journal article by Jonathan, Veeramanickam, Arun, Narayanan, Anandan, and Javed. This article was published in 2018. It involves the Internet of Things (IoT) in the traffic control system. This article is different from other IoT related article as it involves vehicle count. The case studies of this research are the traffic control network and organized traffic management [24].

Real-Time Highway Traffic Condition Assessment Framework Using Vehicle–Infrastructure Integration (VII)

With Artificial Intelligence (AI) is a journal article by Ma, Chowdhury, Sadek, and Jeihani in 2009. This journal provides information on artificial intelligence application in highway traffic. AI paradigms such as Support vector machines and artificial neural network are involved in this journal as it provides information on multiple vehicles that travels within the highway area. This journal developed a model of support vector machine framework that can be used in evaluating the simulation of the traffic environment. The case study for this journal article involves incident locations and blockade of lanes that can be used in emergency response strategy [25].

CoAP Congestion Control for the Internet of Things is a journal article by Betzler, Gomez, Demirkol, and Paradells. It involves the handling of traffic congestion using the Constrained Application Protocol (CoAP). This protocol is one of an application in IoT. The article involves a case study of advanced congestion control mechanism called CoCoA. This mechanism introduces the estimating technique of the round-tripping time. With this factor, it would provide controlled retransmission adaptation that is suitable to the IoT communications. This article shows the simulation of CoCoA. It shows that the CoCoA can outperform the basic CoAP congestion mechanism [26].

Intelligent Traffic Information System Based on Integration of Internet of Things and Agent Technology is a research article by Hasan Omar Al-Sakran. This article involves an integrated traffic administration system using IoT. It features the benefits of improvising traffic control systems such as cost and efficiency. IoT is involved in this article as it applies to sensor recognition and technological detection The architecture of the information system involves radio frequency identification also known as RFID. It also involves wireless sensors and ad-hoc networking [27].

8. THEORETICAL CONSIDERATIONS

For the traffic control network to be implemented properly, the most efficient way is to integrate it with the cities already existing traffic management system. This implies that the system to be developed must be easily installable, and maintainable in already existing traffic infrastructure [28].

To be able to create the Module to interact with the individual stoplights, a microcontroller that can be integrated with a wifi module can be implemented. The Raspberry Pi is favored for its powerful microcontroller functions and its compatibility with Wifi technology. The sensors will be camera-based which when partnered with computer vision, will serve as the sensors. This can also be integrated with the roadside CCTV system. the data gathered will then be sent via the controller's wifi module and will be stored as data in the database. The database to be used will be AWS database to store the data. This database allows for easy storage management and analytics in the cloud [29].

The central processing unit will serve as a cloud computer that the traffic lights can access to make optimal decisions. It must have access to the database and the data pertaining to each stoplights location and traffic conditions. It will then utilize a neural network that was trained with a simulation of traffic in the area, and optimized with respect to the average trip time, and traffic flow consistency. With these systems in place, traffic flow will be more consistent and dynamic with the varying traffic conditions. Aside from this, the continuous data stream will train the neural network to further optimize the traffic direction systems [30,31,32].

9. DATA AND RESULTS

The data in this paper is a metric of what the researchers define as an effective outcome. The simulations conducted by Gui-yan, Long-hui, and Jiang-Feng was used to compare three types of multiagent systems: hybrid NN, SPSA-NN, and GLIDE. The results of the simulations are given in the tables below

TOTAL MEAN DELAY FOR SHORT EXTREME SCENARIO WITH TWO PEAKS

Control technique	Total Mean Delay (sec per vehicle)		Current Vehicle Mean Speed (mph)	
	1st Peak Period	2nd Peak Period	1st Peak Period	2nd Peak Period
SPSA-NN	420	510	5	5
Hybrid NN	400	470	7	8
GLIDE	500	650	5	3

CURRENT VEHICLE MEAN SPEED FOR THE LONG EXTREME SCENARIO WITH MULTIPLE PEAKS (24 h)

Control technique	Current Vehicle Mean Speed (mph)							
	1st Peak Period	2nd Peak Period	3rd Peak Period	4th Peak Period	5th Peak Period	6th Peak Period	7th Peak Period	8th Peak Period
SPSA-NN	5	10	15	7.5	4	5	4	0
Hybrid NN	7	10	14	7.5	6	4	4	4
GLIDE	7	5	5	5	0	0	0	0

TOTAL MEAN DELAY FOR THE LONG EXTREME SCENARIO WITH MULTIPLE PEAKS (24 h)

Control technique	Total Mean Delay (sec per vehicle)							
	1st Peak Period	2nd Peak Period	3rd Peak Period	4th Peak Period	5th Peak Period	6th Peak Period	7th Peak Period	8th Peak Period
SPSA-NN	600	750	600	550	500	500	500	850
Hybrid NN	400	450	450	450	450	500	650	700
GLIDE	400	500	600	650	800	1500	2300	3200

10. ANALYSIS OF DATA

Artificial Neural Network was used in a traffic control system to provide storing and managing information or data of vehicles and the road. Internet of things is a concept that involves gadgets and devices that are connected to the internet and use them like a switch. The internet of things is used in a traffic management system to provide ease of managing the traffic. It was also used to provide spatial recognition of the environment and automobiles. Deep learning was also used in the traffic management system as the research involves spatial recognition. With this research, the traffic management system will be organized and efficient if the theoretical concepts were implemented. Consideration was given to database administration in big data [33,34,35]

11. CONCLUSION

This research paper shows real-time traffic information in the traffic control system. It can detect vehicle count using sensor recognition or Internet of Things and can compute other factors such as emergency response strategy using database monitoring. This research paper provides the application of neural network and Sensors in the traffic management system. Concepts such as Service Vector Machine, Artificial Neural Network, and Internet of Things were applied to this case study. Digital communications and systems were applied. It involves numerous features such as spatial imaging, electronic sensors, artificial neural network, database monitoring, and data or information transfer. This research can be beneficial to the environment and society as it improves economic factor, efficiency, and environmental safety.

Artificial neural network (ANN) is a concept that is loosely based on the human brain. This concept features recognizing patterns. The traffic management system needs technology that can recognize patterns which can be used for vehicles and roads. This paper applied ANN for the traffic control system to provide ease of managing the traffic flow. Electronic sensors were used in this paper as these are the technical parts that can be used to apply theoretical concepts that were mentioned in this paper. Sensors such as IR sensors were used to sense the traffic movement of vehicles. Internet of Things is a concept that involves gadgets being used as a switch when it is connected to the internet. This concept was used to provide spatial recognition of the environment and highways.

The researchers were able to provide journal articles that involve digital communication systems to provide applications of the traffic control system. The results of the simulation of journal articles in this problem were successful as it satisfies the condition to the statement of the problem.

12. RECOMMENDATION

Based on the findings in this research paper, the researchers recommend providing a precise simulation of a traffic control system using software tools as it can provide accurate results. Conduct simulations in which the researchers will be able to compare various approaches to conclude the most effective traffic control system. Technological improvement in the traffic management system is a must as it provides efficiency and safety.

The researchers recommend providing more journal articles to give more extensive knowledge and research about the traffic management system.

The researchers recommend to research on how to develop the technical advancement of the concepts as most of them are in theoretical or under developed. Technology for managing traffic should be advancing to keep up with the worsening of traffic congestion.

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