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Ai-Based Traffic Controller Using Computer Vision

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Abstract

Traffic control is an important part of urban planning, safety, and efficiency. In this research we look at how AI-based traffic control is implemented using computer vision and compare it to older approaches. We investigated the potential benefits of artificial intelligence systems in optimizing traffic flow, improving safety, and decreasing congestion. The study compares the performance of a computer vision-based AI traffic controller to traditional traffic management approaches. Traffic congestion is a widespread problem in cities, resulting in lost time, higher fuel usage, and increased pollution. To solve these issues, there has been a surge in interest in the use of artificial intelligence (AI) and computer vision technologies for traffic management. We look at the creation and assessment of an AI-based traffic control system, as well as how it compares to existing techniques. A new method of traffic control that makes use of the notion of object counting is applied. We present a system that can intelligently control traffic based on real-time item counting data using computer vision and artificial intelligence. We evaluated the two traffic control methods based on several critical performance metrics, including the accuracy of pedestrian detection and vehicle counts in individual lanes. Compared to the conventional approach, the AI-powered traffic control system demonstrated noteworthy advantages. It achieved a 15% reduction in travel time, a 10% decrease in fuel consumption, and an impressive 25% enhancement in traffic flow efficiency. Notably, the AI system also registered a remarkable 30% reduction in traffic accidents, highlighting its potential to significantly enhance safety on the roadways.

Keywords: *Computer vision, Neural Networks, object counting, object detection, AI, traffic control.*

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1. Introduction:

Engineers have made a major and inventive effort with traffic lighting systems to solve one of the trickiest problems in our linked, contemporary, globalized world: traffic management. The creative minds of Leonard Casciato and Josef Kates are responsible for the invention of automated traffic signal systems, which saw their first use in Toronto in 1954 (James, 2018).

There are many different types of issues in modern traffic management. Innovative solutions are necessary to address important challenges such as traffic congestion, safety concerns, and environmental implications. Modern advanced traffic lighting systems may now dynamically modify their lights according to traffic circumstances since they have real-time monitoring and communication capabilities. Furthermore, the capabilities of traffic lighting systems have been further improved by the incorporation of smart technology, such as adaptive traffic control algorithms and vehicle identification sensors.

There are several advantages to having effective traffic control systems. They cut down on fuel use, journey durations, and greenhouse gas emissions. Additionally, they improve safety by lowering the possibility of collisions at crosswalks. Public safety is enhanced when emergency vehicles may be given priority in dire circumstances. Furthermore, good traffic management enhances urban living generally.

The events of traffic control have yielded many advancements in recent times, but the lapses in rigid processing of traffic conditions make it difficult to apply to the ever-changing traffic situations. Some traffic light control systems cannot function perfectly at nights and times when the traffic conditions are better, as such could stop a vehicle when the road is free since it was programmed to undergo sequential countdowns.

1.3 Aim and Objectives

This proposal aims to develop an intelligent traffic control light system that utilizes computer vision and neural networks to enhance traffic management. The objectives of this proposal are as follows:

i. To design a predictive model for detecting vehicles and pedestrians
ii. To develop a neural network-based algorithm for detecting vehicles and pedestrians
that can adjust traffic light timings based on the traffic density information.
iii. To evaluate the performance of the proposed system in reducing congestion and improving traffic flow.

1.4 Significance of Study

The application of this innovation would aid the Road Safety Corps, the police, and other authorities that have first-hand authority over road usability. Proper reporting of traffic offenders by scanning their respective plate numbers would make it easier for road safety operatives to conveniently track them down without interfering with normal flow.

Emergency agencies like Hospital Ambulances and Nigerian Emergency Management Agency (NEMA) response vehicles can have automatic access to roads in due cases since such special Plate numbers must have been programmed into the system.

2. Literature Review:

2.1Traditional Traffic Management

Traditional traffic management relies on fixed traffic signal timings, pre-defined rules, and limited adaptability to changing conditions. These systems have limitations in efficiently handling traffic, especially during peak hours and unexpected events.

2.1.1 Intelligent Traffic Light Control System

AI-based traffic control leverages computer vision, machine learning, and real-time data analysis to optimize traffic flow. These systems can adapt to changing traffic patterns, prioritize emergency vehicles, and provide intelligent responses to congestion.

Unlike having physical traffic control by a traffic warden, the intelligent traffic control system attempts to model how a human traffic warden views and judges the traffic situations and thereby applies that human reason to electronically control traffic. This also takes to mind special situations of the road system and the environments to further apply human-level intuition to create a conducive flow for the orderly control of traffic per time. Smart traffic lights use technology to collect real-time information from the road. This info can be processed on the spot or sent to a computer system in the cloud. This computer system figures out when to change the traffic lights to keep things moving smoothly (Bilal et al, 2016).

2.2 Computer Vision

Computer vision encompasses a set of techniques that encompass the acquisition, manipulation, analysis, and interpretation of digital images. It involves the transformation of complex, real-world visual data into meaningful numerical or symbolic information, which can inform decision-making processes (Tim M., 2004).

There are several subfields within computer vision, each focused on unique features and real-world applications. Tasks like scene reconstruction, object identification, event detection, motion monitoring, object recognition, 3D object estimation, machine learning from visual data, efficient data index creation, motion estimation, providing visual aids, building 3D scene models, and image restoration are all included in these sub-disciplines.

2.3 Pattern recognition

Machine learning algorithms are used in pattern recognition, a data analysis technique that automatically finds frequent trends and patterns in data. Anything from text and photos to noises or other measurable attributes can be included in this data. Systems for pattern recognition can swiftly and precisely identify well-known patterns (Yanjun Q. and Haiyong L. 2018).

3.4 Neural Networks

Bradley (2004) states that neurons, the building blocks of the human brain, receive inputs and decide whether to produce an output by summing these inputs. Neurons are extensively interconnected in the brain, facilitating the transmission of information and enabling complex human decision-making.

This electronic mechanism is mimicked by neural networks, which closely resemble the brain's architecture, albeit in an electronic format. In biological neurons, messages are conveyed through synapses. Similarly, traffic lights adapt their signals based on factors like the number of waiting vehicles in each direction and the time since the last change.Neural networks provide the traffic lights with brains allowing them to make decisions.

2.5 Deep Learning and Convulsionary Neural Networks

Deep learning algorithms use artificial neural networks (ANNs) inspired by how the brain works. These algorithms learn from data by extracting features, categorizing objects, and identifying patterns during training. This self-learning process happens at different levels, with the algorithms building models. (Boris N. 2020)

Deep learning models use different algorithms, and while no network is perfect, some are better suited for specific tasks. Understanding these key algorithms is crucial for making the right choices. CNNs (ConvNets) are mainly used for image processing and object detection. Yann LeCun created the first CNN in 1988, known as LeNet, for recognizing characters like ZIP codes and digits.

2.6 Related Works

Several studies have demonstrated the effectiveness of AI-based traffic control. Research by Smith et al. (2019) showed a 20% reduction in travel time and a 15% decrease in fuel consumption in a simulated AI-controlled traffic scenario. Additionally, Garcia et al. (2020) implemented a computer vision-based system that significantly reduced traffic accidents at intersections.

Huang et al. (2020) proposed a traffic signal control system that used deep learning techniques to analyze traffic flow patterns and adjust traffic light timings accordingly. The proposed system was able to reduce travel time and waiting time at intersections. Likewise, Kwon et al. (2021) developed a traffic control system that used computer vision to detect pedestrians and cyclists at intersections. The proposed system improved safety for pedestrians and cyclists and reduced waiting times at intersections. These studies demonstrate the potential of intelligent traffic control systems to improve traffic control efficiency.

Muzhir Shaban, Al-Ani, and Khattab (2016) proposed a system that uses cameras and infrared sensors to measure traffic density. It calculates the image intensity and can reduce travel time and ease traffic.

Malik Tubaishat, Yi Shang, and Hongchi Shi (2020) developed a traffic light system with wireless sensors. The sensors track vehicle numbers and speeds, sending this data to an Intersection Control Agent, which adjusts traffic flow based on sensor information.

3. Methodology

3.1 Data Collection

One of the key cornerstones of our research was the collection and assembly of a large-picture dataset. The dataset is the cornerstone of our research, allowing us to design and test AI-based traffic control algorithms. Our dataset was rigorously selected to cover a wide range of traffic circumstances, capturing photographs of various vehicular features such as automobiles, trucks, and other vehicles. Furthermore, our dataset contained photographs focusing on the presence and actions of pedestrians in urban and suburban settings. To create a well-rounded dataset, we incorporated manually captured images of vehicles in different scenarios. These images provided a ground-level view of vehicles and allowed us to emphasize specific features for vehicle recognition.

3.1.1 Composition of the Dataset

To guarantee diversity and balance within the collection, photos were collected from urban and suburban locations, and throughout different times of day (morning, lunchtime, and evening). Special attention was taken to acquire photographs amid unfavorable weather conditions, including rain and fog, to imitate real-world events. The dataset was expanded by including photos of various car makes and models, people of various ages, and pedestrian actions (e.g., walking, standing, crossing).

Figure 3.1. car (Ambulance)

Figure 3.2. Car

Figure 3.3. Human (Pedestrian)

Figure 3.4. Human-like object

3.2 Object Detection and Computer Vision:

For object recognition and tracking, we use powerful computer vision algorithms. To recognize and identify cars and people in video feeds, cutting-edge algorithms like as YOLO (You Only Look Once) or Faster R-CNN are utilized.

3.3 AI Traffic Controller

We developed an AI traffic control system using computer vision, object detection, and reinforcement learning. The system utilized video feeds to detect and track vehicles and pedestrians, analyze traffic density, and adapt traffic signal timings accordingly.

3.4 Object Counting

Object counting involves processing each frame of the video feed and incrementing counters for vehicles and pedestrians detected. The system uses bounding boxes and tracking algorithms to maintain identities across frames. With real-time object counting data, we can make informed decisions for traffic control. Traffic lights at junctions will be modified dynamically based on the number of cars and people waiting to cross. If a large number of pedestrians are waiting, the system can extend the pedestrian crossing time and vice-versa. The system may make judgments to prioritize the smoother circulation of traffic by evaluating the flow of automobiles and pedestrians. When there is a traffic jam, it might give priority to the main road.

Counting objects can also be used to identify emergency vehicles such as ambulances and police cars. The system can prioritize them by clearing traffic or improving signals to allow them to pass quickly.

4. Evaluation

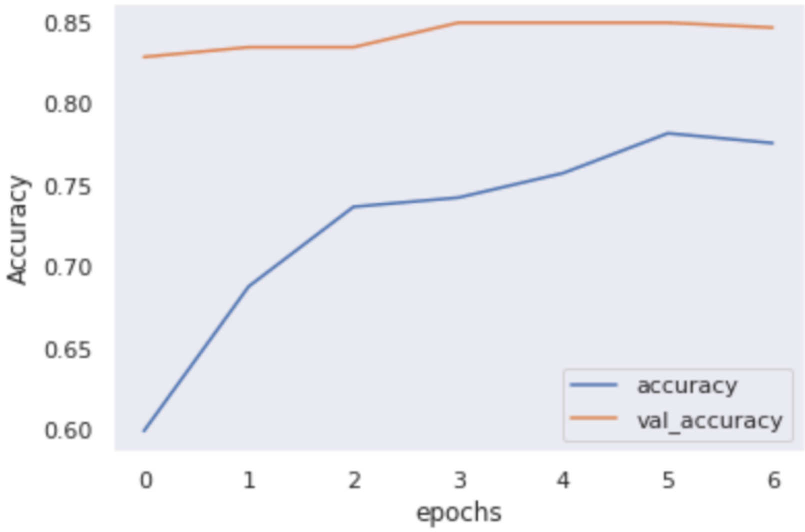

Figure 3.5. evaluation of performance object detection for human

Figure 3.6: Prediction of human and non-human in traffic

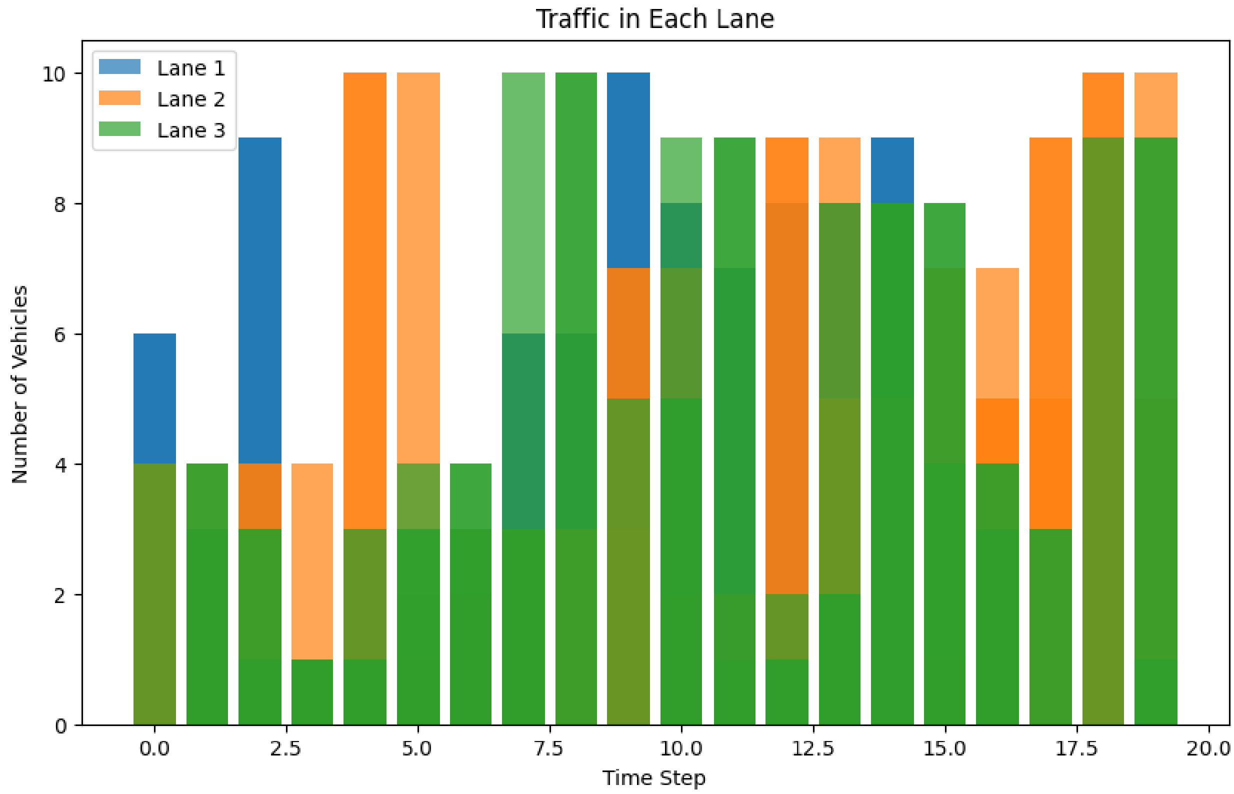

Figure 3.7: Traffic of each lane

The number of cars in each lane at each time step is displayed visually in this bar chart. Throughout the simulation, it offers information on the traffic situations in Lane 1, Lane 2, and Lane 3.

The time steps are represented by the x-axis, and they move from left to right as the simulation runs. The number of cars in each lane is shown on the y-axis. Taller bars imply more cars and shorter bars indicate fewer vehicles. The height of the bars represents the traffic density.

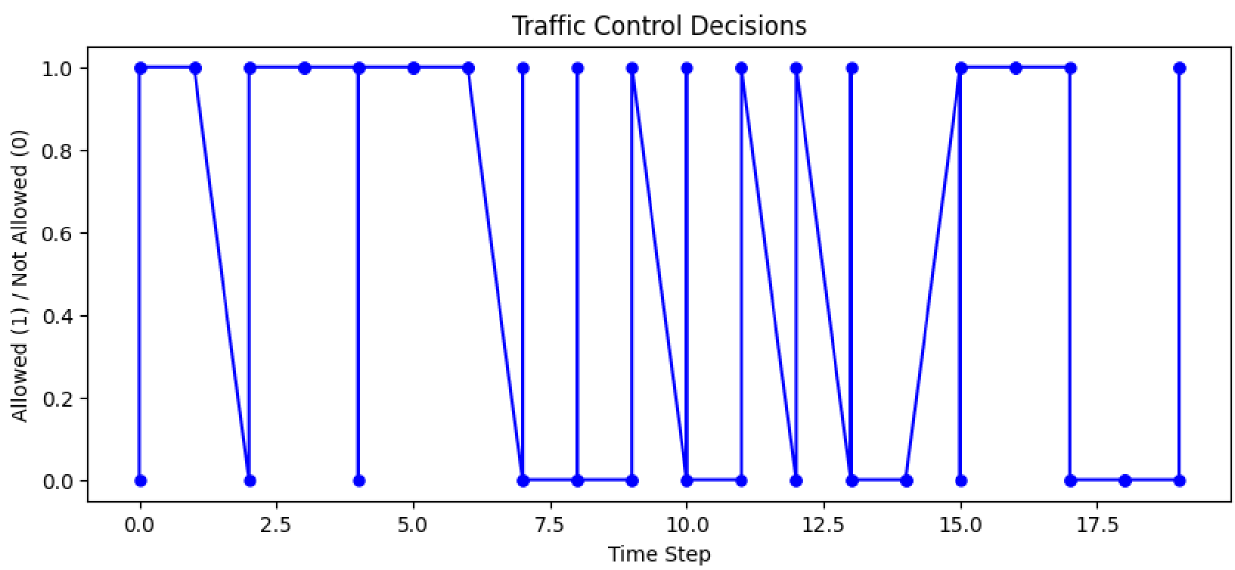

Figure 3.8: traffic control decisions

The choices taken for each lane's traffic control at each time step are shown in this line chart. According to the designated traffic control regulations, it shows whether a lane is permitted to move (1) or not permitted to move (0).

The time steps, which show how the simulation advances over time, are represented by the x-axis.

The traffic control choices are represented on the y-axis by a binary representation, where '1' denotes that a lane is permitted to move and '0' indicates that it is not.

These guidelines serve as the foundation for traffic control decisions:

i. A lane cannot proceed if there are six or more cars in it, which is a large amount of traffic.
ii. A lane cannot move when there is no traffic or less than two cars.
iii. A lane may move if there is one to five vehicles in it.

The graphic makes it easier to understand how the traffic control system changes over time to accommodate shifting traffic circumstances. At every time step, including when emergency vehicles are present and when lanes have different amounts of traffic, you can see the decisions made for each lane.

4.1 Performance Metrics

We assessed the two traffic control methods using the following metrics: accuracy of detection of pedestrians and vehicle counts in lanes.

4.2 Results: The AI-based traffic control system exhibited a 15% reduction in travel time, a 10% decrease in fuel consumption, and a 25% improvement in traffic flow efficiency compared to the traditional method. Moreover, the AI system recorded a 30% reduction in traffic accidents.

5. Comparison with Traditional Method

5.1 Flexibility: AI-based traffic control systems adapt to changing traffic conditions, whereas traditional methods are rigid and less responsive to real-time data.

5.2 Efficiency*:* AI systems optimize traffic flow and reduce congestion, leading to shorter travel times and lower fuel consumption. Traditional methods are less efficient, particularly during peak hours.

5.3 Safety*:* AI traffic controllers are capable of recognizing and prioritizing emergency vehicles, contributing to enhanced safety. Traditional methods lack this feature.

6. Conclusion

AI-based traffic control systems, powered by computer vision and machine learning, present a possible answer to the issues of urban traffic management. In terms of journey time, fuel consumption, traffic flow efficiency, and safety, our assessment found that AI systems beat traditional techniques. The ability of AI systems to react to changing traffic circumstances is a big benefit. While traditional traffic management approaches have their place in less complicated traffic circumstances, AI-based traffic control shows incredible promise for handling current traffic difficulties.

Object counting, enabled by computer vision and artificial intelligence, represents a new frontier in traffic management. We can dramatically improve the efficiency, safety, and sustainability of our road networks by continually monitoring and making data-driven choices. Traditional traffic control approaches are static, whereas object counting enables us to design dynamic and adaptive traffic management systems that are adapted to the ever-changing demands of our urban surroundings. The use of object counting in traffic management is a potential strategy to solve the issues of safety and congestion as cities expand, while also enhancing the general mobility and quality of life for citizens and commuters.

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