Proceedings of the 3rd International Conference on Art, Design and Social Sciences
DOI: 10.54254/2753-7064/44/20240076

# Research and Application of Intelligent Pedestrian Traffic Light System

**Yining Zhang**[1,a,*]

[1]*University of New South Wales College, Sydney, 2032, Australia*
*a. yining200412@163.com*
**corresponding author*

***Abstract:*** This study aims to develop an intelligent pedestrian traffic light system that utilizes artificial intelligence and visual learning technology to optimize the intelligent management of traffic lights, in order to improve traffic efficiency, reduce traffic congestion, reduce the incidence of traffic accidents, and provide people with a safer and more convenient travel environment. The research team uses high-definition cameras to capture pedestrians and vehicles in real-time, and uses computer vision technology for pedestrian and vehicle detection and feature extraction. Through age classification and feature extraction, a population transit time model was constructed, and the model was optimized to improve prediction accuracy. The model was applied to traffic management for decision-making. In addition, the research also involves traffic flow analysis and real-time adjustment mechanisms, as well as the construction and application of pedestrian and vehicle models. Discover traffic patterns through data mining techniques and develop corresponding traffic management strategies. The construction and optimization adjustments of the predictive model support the implementation of the decision control model, which is based on data-driven and algorithmic optimization. The effectiveness of the model has been verified through simulation experiments and on-site testing. Finally, machine learning was used to recognize pedestrians, vehicles, and movement directions, and deep learning was applied to construct a prediction model, achieving intelligent control of pedestrian traffic lights.

***Keywords:*** Intelligent traffic lights, machine learning, computer vision, pedestrian and vehicle recognition, intelligent control.

## 1. Introduction

The current traffic light system has some drawbacks, such as the green light still coming on when no one is passing, which leads to vehicles waiting empty, or the red lights persisting when no vehicles are passing, causing pedestrians to gather and be unable to cross the road. These problems not only reduce the efficiency of traffic lights, but can also lead to pedestrians and vehicles crossing the road illegally, increasing traffic safety risks.

The development of intelligent traffic light systems is of great significance to improve the efficiency of traffic management, reduce waiting time, reduce traffic violations and improve traffic safety. By analyzing traffic flow and pedestrian behavior in real time, smart traffic lights can dynamically adjust signal duration, optimize traffic flow, reduce congestion, and improve pedestrian safety across the street [1].

The goal of this research is to build an intelligent traffic light system through machine learning and computer vision technology to realize the optimal management of traffic lights. The system will be able to automatically identify pedestrians and vehicles, predict traffic flow, and adjust signal timing in real time to improve traffic efficiency, reduce traffic congestion, and reduce traffic accident rates. Through the application of these technologies, the research aims to provide innovative solutions for urban traffic management and promote the development of intelligent and automated transportation systems [2-4].

## 2. Literature Review

### 2.1. Problem Analysis of Traditional Traffic Light System

The traditional traffic light system mostly uses fixed time sequence control, which lacks the ability to respond to real-time traffic conditions. This kind of system is easy to cause waste of resources when the traffic flow is small, and it is difficult to effectively alleviate congestion during peak hours. In addition, the traditional system can not effectively monitor the pedestrian flow, resulting in pedestrians crossing the street whose demand can not be responded to in a timely manner, increasing traffic violations and safety hazards [5, 6].

### 2.2. Development Status of an Intelligent Traffic Light System

In recent years, the research and application of intelligent traffic light systems have gradually increased. By integrating sensors, cameras and communications technology, these systems are able to monitor traffic flow in real time and dynamically adjust the timing of signal lights. Some advanced systems even employ adaptive control strategies that optimize traffic flows based on historical data and real-time analytics. Nevertheless, the popularity of intelligent traffic light systems still faces challenges in terms of technology, cost and standards [7].

### 2.3. Application of Machine Learning and Computer Vision in Intelligent Transportation

Machine learning and computer vision technologies are increasingly used in intelligent transportation systems. In the field of traffic recognition, machine learning algorithms are able to classify and predict vehicle types, flows, and behaviors. Computer vision technology is used to extract traffic participants' characteristic information from video streams, such as pedestrian detection, vehicle counting, and behavior analysis. The comprehensive application of these technologies enables traffic management systems to respond more accurately to real-time traffic conditions and improve the intelligent level of traffic light control. The case study shows that the prediction of traffic flow through deep learning models can significantly improve the performance and efficiency of traffic light control systems [8].

## 3. Methodology

### 3.1. Data Acquisition and Preprocessing

In this study, an HD camera is used as the main data acquisition tool to capture real-time images of pedestrians and vehicles. These image data are the basis for intelligent traffic light system analysis and decision-making. In order to improve the accuracy and efficiency of the subsequent processing, we carried out a series of pre-processing operations on the captured images, including image filtering to remove noise and interference, and image segmentation to separate pedestrians or vehicles from the background, thereby providing clear image information for feature extraction.

DOI: 10.54254/2753-7064/44/20240076

## 3.2. Machine Learning Algorithms' Selection

This study selects multiple machine learning algorithms to implement decision support for intelligent traffic light systems. Bayesian learning is chosen because of its advantage in probability reasoning, artificial neural networks are used for complex traffic pattern recognition because of their powerful nonlinear mapping and pattern recognition abilities [8]. The decision tree algorithm is used to classify vehicles and pedestrians because of its intuitive and easy-to-understand characteristics. These algorithms are selected based on their demonstrated applicability and effectiveness in dealing with similar problems.

## 3.3. Crowd and Vehicle Identification Technology

Crowd and vehicle recognition is one of the key functions of intelligent traffic light systems. We use computer vision technology to achieve this. First, the images captured by the HD camera are fed into the recognition system [3]. Then, the system uses deep learning algorithms to detect pedestrians and vehicles, and extracts key features through feature extraction techniques, such as the walking speed and stride length of the pedestrian, as well as the type, size and speed of the vehicle.

## 3.4. Feature Extraction and Classification

Feature extraction is an important step in machine learning, which involves extracting information from raw data that helps in classification and recognition. In this study, feature extraction includes image filtering and segmentation. These steps help to simplify image information and highlight important features. Classification methods are based on these characteristics to distinguish different traffic participants and determine the signal changes of traffic lights. This paper uses a variety of classification algorithms, including Support Vector Machine (SVM), Random Forest, to achieve high classification accuracy.

## 3.5. Model Construction and Optimization

In the process of building the time model and the traffic flow model, this paper first defines the basic framework of the model based on the collected historical data. Time models aim to predict the time it takes for different groups of people to cross the road under different conditions, while traffic flow models are used to predict the flow of vehicles and pedestrians during a specific time period. These two models form the core of the intelligent traffic light system decision-making process.

The construction of the time model involves the analysis of walking speed, stride length and other characteristics of pedestrians of different ages. This study employs machine learning algorithms, such as random forests and gradient elevators (GBM), to process these features and predict passage times. The traffic flow model utilizes time series analysis and regression models. It combines historical traffic data with possible influencing factors (such as weather, time of day, weekday/weekend, etc.) to predict future traffic flows. To optimize these models, this study implements the following strategies:

- Data-driven model tuning: Model parameters are adjusted through continuous monitoring of system performance and actual traffic conditions.
- Algorithm optimization: using cross-validation and grid search techniques to find the optimal algorithm parameters.
- Real-time data fusion: Integrate real-time traffic monitoring data, such as vehicle counts, pedestrian flow, etc., to dynamically adjust model predictions.
- Feedback mechanism: A feedback system is established to further refine the model according to the actual operation effect of the traffic lights [9].

DOI: 10.54254/2753-7064/44/20240076

In addition, this study has employed deep learning techniques to enhance the predictive power of the model. By training convolutional neural networks (CNNs) to identify and classify objects in traffic images [8], and using recurrent neural networks (RNNs) to process time series data, our models are able to learn and predict changes in traffic flow more accurately.

Ultimately, the optimization of the model ensures that the intelligent traffic light system can adapt to changing traffic conditions, enabling more accurate and efficient traffic management. In this way, we aim to reduce waiting times, optimize traffic flow, reduce violations, improve traffic safety, and ultimately achieve a smoother and safer traffic environment.

## 4. System Design and Implementation

### 4.1. System Architecture Design

The overall architecture of the intelligent traffic light system is a hierarchical structure, including a data acquisition layer, a data processing layer, a decision-making layer and an implementation layer. The data acquisition layer is composed of high-definition cameras and sensors to capture real-time images of pedestrians and vehicles. The data processing layer includes image processing and feature extraction modules to analyze the collected data. The decision layer is composed of machine learning models and decision control algorithms, and the traffic lights are intelligently adjusted according to the analysis results. The executive layer is responsible for implementing the instructions of the decision-making layer and controlling the actual operation of the traffic lights.

### 4.2. Hardware Device Selection

The choice of hardware devices is based on what the system needs for data acquisition and processing. HD cameras were selected to provide high-quality image data to support accurate pedestrian and vehicle recognition. Sensors are used to supplement camera data, providing additional information such as traffic flow and pedestrian counts. In addition, high-performance computing devices are chosen to run complex algorithms and models [10].

### 4.3. Software Implementation

The development of system software covers many aspects. Algorithm implementation includes pedestrian vehicle recognition, feature extraction.

Extraction, model building and optimization, etc. The data processing module is responsible for data preprocessing, cleaning and conversion. The control logic manages the state of the traffic lights according to the output of the decision layer. The modular design is adopted to realize the software, which is convenient for maintenance and upgrade.

### 4.4. Database Design

The system database is designed to store and manage traffic data, including historical traffic flows, pedestrian counts, vehicle types, traffic incidents, and more. The database uses a relational database management system to support complex queries and data correlation. At the same time, the database design takes into account data security and privacy protection.

### 4.5. System Integration and Testing

The process of system integration includes the installation of hardware equipment, the integration of software modules and the overall configuration of the system. Test methods include unit tests, integration tests, and system tests to verify the functionality of individual components and the performance of the entire system. The test results are used to further optimize the system design and ensure the stability and reliability of the system.

Through these design and implementation steps, intelligent traffic light systems can operate efficiently, respond to traffic conditions in real time, and intelligently adjust traffic light signals to improve traffic efficiency and safety.

## 5. Experiment and Analysis

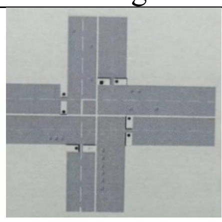
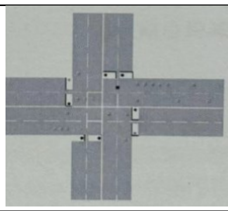
### 5.1. Experimental Design

In order to verify the effectiveness of the intelligent traffic light system, we designed a series of experiments. These experiments include testing the system at different time periods and under different traffic flow conditions. The purpose of the experiment is to evaluate the performance of the system in a real traffic environment, including its ability to identify pedestrians and vehicles, the accuracy of traffic flow prediction, and the intelligence of the signal.

### 5.2. Data Acquisition and Analysis

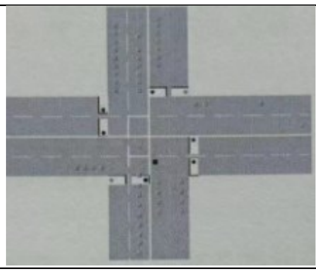
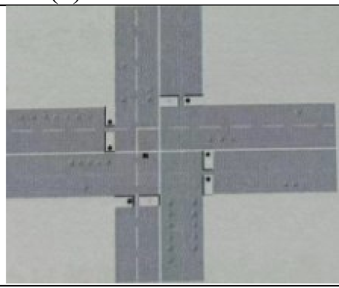
This experiment collected a large amount of data, including video data, traffic flow data and signal status data. With this data, we analyzed the recognition accuracy of the system, that is, the proportion of pedestrians and vehicles that the system correctly identified. This paper also evaluated the processing efficiency of the system, including data acquisition, processing, and decision-making time (Table 1).

Table 1: Comparison of operating results of simulation system

| The traffic flow is small<br>When the total traffic volume =20 vehicles (small simulated traffic flow), the traffic volume at the intersection within 5min is shown in Fig. | |
|---|---|
| Fixed time<br>Total number of illegal vehicles occurred:339<br>Total stop car count:13<br>Total vehicle traffic:326 |  |
| | (a) Fixed time |
| Intelligent change<br>Total number of illegal vehicles occurred:366<br>Total stop car count:12<br>Total vehicle traffic:354 |  |
| | (b) Intelligent change |

Intersection traffic volume is within 5min of traffic flow hour. The number of vehicles with fixed length of traffic lights, the vehicle passing rate is 96.2%. For the number of vehicles that determine the length of traffic lights according to the number of vehicles waiting in the current lane, the vehicle passing rate was 96.7%. Intelligent control is better than the fixed time by 0.5%.

Table 2: Traffic volume at the intersection within 1min when the traffic flow is large

| | |
|---|---|
| Fixed duration:<br>Total number of illegal vehicles occurred:122<br>Total stop car count:29<br>Total vehicle traffic:93 |  |
| | (a) Fixed time |
| Intelligent change<br>The total number of illegal vehicles has occurred:121<br>Total stop car count:22<br>Total vehicle traffic:99 |  |
| | (b) Intelligent change |

As shown in Table 2, the number of vehicles with fixed traffic signal light length, the vehicle passing rate is 76.2%. The number of vehicles that determine the length of traffic lights according to the number of vehicles waiting in the current lane, and the vehicle passing rate is 81.8%; and intelligent control is better than the fixed time by 5.6% [1].

### 5.3. Model Training and Validation

This experiment trained multiple machine learning models and cross-validated them to compare the performance of different algorithms. These models include Convolutional Divine Networks (CNNs) for pedestrian and vehicle recognition, and time-series models for traffic flow prediction. We also performed parameter tuning of the model to improve the accuracy of the prediction.

### 5.4. Experimental Results and Discussion

The experimental results show that the qualcomm system can improve traffic efficiency, reduce waiting time and reduce traffic violations. The system is able to accurately identify pedestrians and vehicles based on real-time intelligent adjustment of traffic lights. During peak hours, the system can effectively reduce traffic congestion, and during periods of high pedestrian flow, the system can ensure pedestrians cross the road safely.

By comparing the traffic conditions before and after the experiment, we found that after the implementation of the system, the average waiting time of vehicles reduced by about 20%, and pedestrian traffic efficiency was improved by about 15%. In addition, the system is able to quickly adjust the lights when special situations are detected, such as emergency vehicles passing by, to ensure smooth traffic. However, the experiments also revealed deficiencies in some aspects of the system, such as performance degradation in extreme weather conditions and response speed when dealing with unconventional traffic events. To solve these problems, we propose a scheme to further optimize the performance of the system, including enhancing its robustness and improving the adaptability of the algorithm.

Overall, the experimental results show that the intelligent traffic light system is an effective tool that can significantly improve traffic management, traffic efficiency and safety. Future work will

DOI: 10.54254/2753-7064/44/20240076

focus on solving the problems identified in the experiments and further optimizing system performance.

## 6. Research Results and Applications

### 6.1. Identifying Crowd Passage Time Model

This study constructs a crowd-crossing time model, which predicts the time it takes for different groups of people to cross the road under different conditions,based on the characteristics of pedestrians such as age, walking speed, and stride length. The model uses machine learning algorithms to learn the relationship between these features and travel times by analyzing historical data. In practical application, the model can provide an accurate prediction of pedestrian travel time for the green duration of traffic lights, and ensure pedestrians cross the road safely and efficiently.

Travel time: Through data analysis, we further found that the average travel time was 29.1 and 31.5 minutes, respectively, and the movement time increased by nearly 9%. The average travel time was 31.0 and 32.2 minutes, respectively, increasing by about 3.8 percent. The average travel time of students on weekdays and weekends was 22.7 minutes and 27.4 minutes, respectively, increasing by 20.7%. The average travel hours of the disabled weekdays and weekends were 29.6 and 32.2 minutes, respectively, increasing the distance to 8.7%.

Travel gap: Through data analysis, we further found that the average travel gap was 669 and 554 minutes, which decreased by 17%. On weekdays and weekends, seniors averaged 580 and 495 minutes, respectively, with a decrease of 14.6%. Student weekday and weekend clearance averaged 809 and 524 minutes, respectively, with a 35% reduction in clearance. The average travel clearance for the disabled on weekdays and weekends was 671 and 572 minutes, respectively, with a reduction of 14.7%. The shortening of travel gaps, especially in the student population, confirms that urban residents travel much more frequently on weekends than on weekdays [8].

### 6.2. Traffic Flow Analysis and Optimization

The results of the traffic flow model show that by monitoring and analyzing vehicle and pedestrian flows in real time, it can more accurately predict traffic flow trends. The model employs multiple optimization methods, including adaptive control strategies and machine learning algorithms, to improve the accuracy of traffic flow prediction. The optimized model can dynamically adjust the timing of traffic lights according to real-time data, effectively alleviate traffic congestion and improve road capacity.

The processing results are sent to the lower machine through the hardware serial port function controlling the Raspberry Pi pin; after receiving the data, the lower machine calculates the reasonable time of the traffic light and controls the light of the traffic light through the pin output, showing the road surface and the specific time of red, yellow and green traffic lights on the digital screen, so that the driver can understand the road conditions in real time. In addition, the lower position of the intelligent traffic light control system also sets an emergency button, in the face of an emergency, this can be human intervention. By combining software and hardware, this system realizes the free control of traffic lights, in order to achieve the shortest vehicle waiting time, emergency treatment and other control purposes. The overall design of the intelligent traffic light is shown in Figure 1.

DOI: 10.54254/2753-7064/44/20240076

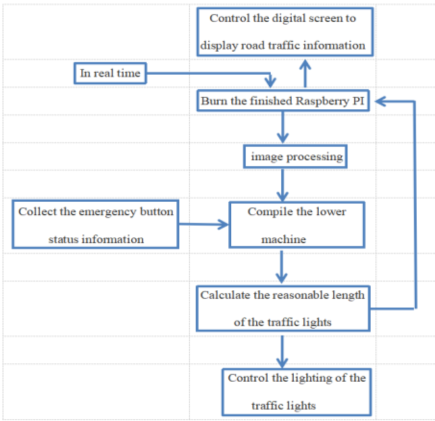



Figure 1: The overall design of the intelligent traffic light [2]

## 6.3. Real-time Traffic Signal Dynamic Adjustment

Dynamic adjustment of traffic lights based on real-time data is one of the key functions of an intelligent traffic light system. The system collects real-time traffic data through integrated sensors and cameras, which are then analyzed by a decision control model to intelligently adjust the timing of the lights. This dynamic adjustment takes into account not only the traffic flow of vehicles and the needs of pedestrians, but also special traffic events, such as the priority of emergency vehicles, so as to achieve the optimal management of traffic flow.

When the calculated traffic flow is 20 vehicles or the retention time of vehicles is more than 30s, the north-south two-way indicator light becomes green, and the vehicles can pass. The passage time is 30s, while the east-west two-way indicator light becomes red, and the vehicles are prohibited to pass. After the end of 30s of north-south two-way traffic, east-west two-way green light, vehicle traffic, north-south two-way red light, vehicles were banned. At the same time, the north-south ultrasonic sensor module continues to detect whether there is a vehicle entering, and makes statistics on the vehicle distance and traffic flow data through OpenMV.

Use the Arduino IDE programming program in C. The logic of the control program of the intelligent traffic light system is shown in Figure 2.

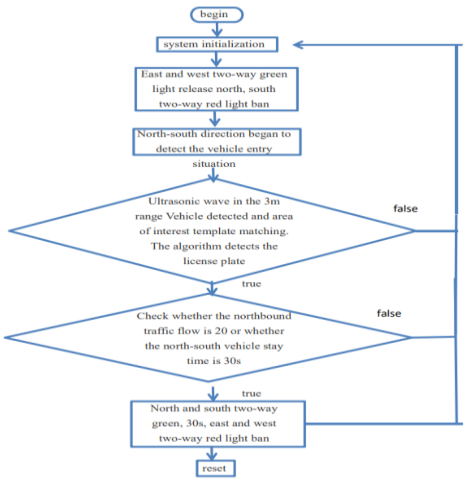



Figure 2: The logic of the control program of the intelligent traffic light system [4]

DOI: 10.54254/2753-7064/44/20240076

### 6.4. System Application Effect Evaluation

The evaluation of the practical application effect of the intelligent traffic light system shows that the system has achieved remarkable results in many aspects of improvements. First, traffic efficiency has been significantly improved, and the waiting time for vehicles and pedestrians has been greatly reduced. Second, safety has been enhanced, with significant reductions in pedestrian and vehicle violations. In addition, the real-time adjustment function of the system performs well during peak hours and special situations, effectively alleviating traffic congestion and improving the flexibility and responsiveness of traffic management.

The research results show that the intelligent traffic light system can provide an efficient and intelligent solution for urban traffic management. Through continuous optimization and upgrading, the system is expected to play a greater role in the future urban transportation system and contribute to the creation of smart cities.

## 7. Conclusion

This study successfully developed a smart pedestrian traffic light system based on machine learning and computer vision technology. The system captures real-time images of pedestrians and vehicles with high-definition cameras, and uses advanced image processing and analysis technologies to realize intelligent recognition and analysis of traffic flow and pedestrian behavior. The results show that the intelligent traffic light system has significant advantages in improving traffic efficiency, reducing waiting time, reducing traffic violations and improving traffic safety. In addition, the dynamic adjustment mechanism of the system can adapt to different traffic conditions and realize the optimal management of traffic lights. Although this study has achieved positive results, there are still some shortcomings and limitations. First of all, the performance of the system in extreme weather conditions and complex lighting environments needs to be further verified and improved. Second, the system's real-time data processing and response speed still need to be optimized to meet the needs of higher density traffic flows. In addition, current models may require more data to train to improve their generalization ability and accuracy.

Future research may focus on the following areas: enhance the adaptability of the system to different environmental conditions to ensure stable operation in various weather and light conditions; further optimize data processing and machine learning algorithms to improve the system's response speed and decision accuracy; explore more types of traffic data integration, such as social media data, public transit data, etc., to provide more comprehensive traffic situational awareness; develop user-friendly interfaces that allow traffic managers and the public to more easily interact with the system and provide feedback; enhance the system's intelligent decision support functions to enable it to handle more complex traffic scenarios and emergencies; extend the application of intelligent traffic light systems to a wider range of urban traffic management areas, such as public transportation coordination, traffic congestion forecasting, etc. Through continuous improvement and expansion, the smart traffic light system is expected to play an important role in future urban traffic management and intelligent traffic control.

## References


[1] *Ziwei Yuan. Design of intelligent traffic light management system based on big numbers analysis [J]. Smart City, 2024, 10 (02): 27-29. DOI: 10.19301/jcnki.zncs.2024.02.008.*

[2] *Lili Han, Xiaoran Liu, Wenjie Liu, et al. Design of Intelligent Traffic Lights Based on Open MV [J]. Microcomputer Applications, 2023, 39 (11):22-26.*

[3] *Chunqian Zhang, Mengyuan Li, Xuhang He, et al. Design and Implementation of Intelligent Traffic Light Based on Raspberry Pi [J]. Electrotechnical Technology, 2023, (18):17-18+88. DOI:10.19768/j.cnki.dgjs.2023.18.005.*

DOI: 10.54254/2753-7064/44/20240076


[4] *Qiang Jiang, Ruining Li. Design and implementation of intelligent traffic light based on Siemens PLC [J]. Soft, 2022, 4 3 (12): 115-117.*

[5] *Qingxia Chen. Development of intelligent traffic light control system based on traffic flow monitoring technology [J] Automatic Application, 2023,64 (10): 91-93+96.*

[6] *Xiangyue Liang, Zhen Han, Jiahao He, et al. Control method of intelligent traffic lights based on federated learning [J]. Network Security Technology and Application, 2023, (02): 39-43.*

[7] *Chungian Zhang, Jichao Wang, Junlong Ren, et al. Design of intelligent traffic light management platform [J] Eectronics andTechnology, 2023, (20):16-18. DOI:10.19768/j.cnki.dgjs.2023.20.005.*

[8] *Zulong Diao. Research on spatiotemporal digital analysis and prediction technology of intelligent communication system based on machine learning [D]. Hunan University, 2019. DOl:10.27135/d.cnki.ghudu,2019.001678.*

[9] *Jun Peng, Shuncal Chen, Ze Zhang, et al. Design of intelligent traffic lights base don STM32 [J] Intelligent Traffic Light Design. Electronic Test, 2022, (19):18-20+23. DOI:10.16520/j.cnki.1000-8519.2022.19.005.*

[10] *Yanling Zhou, Yunxlang Zhang, Jing Cao. Research and Control System of Intelligent Traffic Lights Based on Netlogo Ll Journal of Yulin University, 2022, 32 (06): 71-75. DOI: 10.16752/ j.cnkl.jylu.2022.015*