Smart Street Light Control for Power Saving

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Contents

Motivation

- Conventional street light system demand for a high amount of energy consumption.
- In certain places there are lesser amount of vehicle movement, or no movement at all on a particular day.
- Even then all the street lights are turned on during the night in conventional street lighting systems.
- To overcome this issue, proper energy saving methods and lighting control is to be implemented.
- Motion-based object detection can easily determine the presence or absence of an object, but has a disadvantage in that the detection accuracy is inferior and the object cannot be classified.

Motivation

- Conventional street light system consumes unnecessary energy.
- In certain places there are few to none vehicle movement, yet all the street lights are turned on all night.
- To overcome this issue, proper energy saving methods and lighting control is to be implemented.
- Motion sensor based detection is limited to just detecting movement and is subject to fail under environmental factors.
- A better and more accurate system is necessary.

Objectives

- Controlling street lights in such a way that they turn ON only when a vehicle or a person appears and stays in dim state otherwise.
- Developing an object detection model to detect vehicle and human presence.
- Creating a smart street lighting system that does not compromise public needs or safety.

Introduction

- There is high consumption of power in the recent days and management of power is very crucial.
- In some area or lane the number of vehicles passing is very low and still there is overwhelming electrical power. It is possible to automatically slash the electricity in the area where there are no vehicles and resume the electricity for these parts once there are some vehicles in the scene.
- Intelligent lighting control and energy management system is a perfect solution for energy saving especially in public lighting management.
- The smart street light controls the power consumption effectively , the lights turn ON when pedestrians and vehicles come and turn off or reduce its intensity when there is no movement of vehicle or pedestrian.

Introduction

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- Intelligent lighting control and energy management system is a perfect solution for energy saving.
- The smart street light controls the power consumption effectively , the lights turn ON when pedestrians and vehicles enter and turn OFF otherwise.

Literature Review

Author	Title of the paper	Contribution	Journal/ Conference
S. S. Kalyan, V. Pratyusha, N. Nishitha and T. K. Ramesh	Vehicle Detection Using Image Processing	• Front view of vehicles are acquired. • Vehicle is identified based on its size. • Edge detection and Morphological processing is used.	INOCON - International Conference for Innovation in Technology, 2020.
P. C. Veena, P. Tharakan, H. Haridas, K. Ramya, R. Joju and T. S. Jyothis	Smart street light system based on image processing	• Raspberry Pi is used as control unit. • Object-Level Frame Comparison (OLFC) method is used detect the different objects in a frame. • GSM module is used for detect the failed street light.	ICCPCT - International Conference on Circuit, Power and Computing Technologies, 2016.

Literature Review(contd..)

Author	Title of the paper	Contribution	Journal/ Conference
T. Novak, K. Pollhammer, H. Zeilinger and S. Schaat	Intelligent streetlight management in a smart city	• Raspberry Pi is used as control unit. • The camera is used to identify the vehicle or pedestrian. • All lights have Zigbee communication modules.	ETFA - Emerging Technology and Factory Automation, 2014.
S. Kamoji, D. Koshti, J. Noronha, E. Arulraj and E. Clement	Deep Learning-based Smart Street Lamps – A Solution to Urban Pollution	• The number plate identification has been done using RCNN. • Camera feed is captured and sent to the MQTT server for processing.	ICIRCA - International Conference on Inventive Research in Computing Applications, 2020.

Literature Review(contd..)

Author	Title of the paper	Contribution	Journal/ Conference
J. W. Baek, Y. W. Choi, J. Lee and K. T. Lim	Edge Camera based Dynamic Lighting Control System for Smart Streetlights	• An edge camera which detects objects for itself using a light weight deep neural network. • Tiny-YOLO is used	ICAIIC - International Conference on Artificial Intelligence in Information and Communication, 2020.
M. Mahoor, F. R. Salmasi and T. A. Najafabadi	A Hierarchical Smart Street Lighting System With Brute-Force Energy Optimization	• Paper presents a smart street lighting (SmSL) system in which energy consumption by street lighting poles is reduced based on Brute-Force search algorithm	IEEE Sensors Journal, 2017.

Literature Review(contd..)

Author	Title of the paper	Contribution	Journal/ Conference
G. Prabhakar, B. Kailath, S. Natarajan and R. Kumar	Obstacle detection and classification using deep learning for tracking in high-speed autonomous driving	• Vehicles and pedestrians are classified using CNN and SVM deep learning • To optimize the detection time modified version of CNN called R-CNN is used	TENSYMP - IEEE Region 10 Symposium, 2017.
H. S. DIKBAYIR and H. İbrahim BÜLBÜL	Deep Learning Based Vehicle Detection From Aerial Images	• Aerial view of images are considered, due to small dimension of vehicles to improve the performance rate of YOLOv3 algorithm faster R-CNN is used.	ICMLA - International Conference on Machine Learning and Applications, 2020.

System Overview

- The block diagram of the smart street light system is as shown in Figure 1.

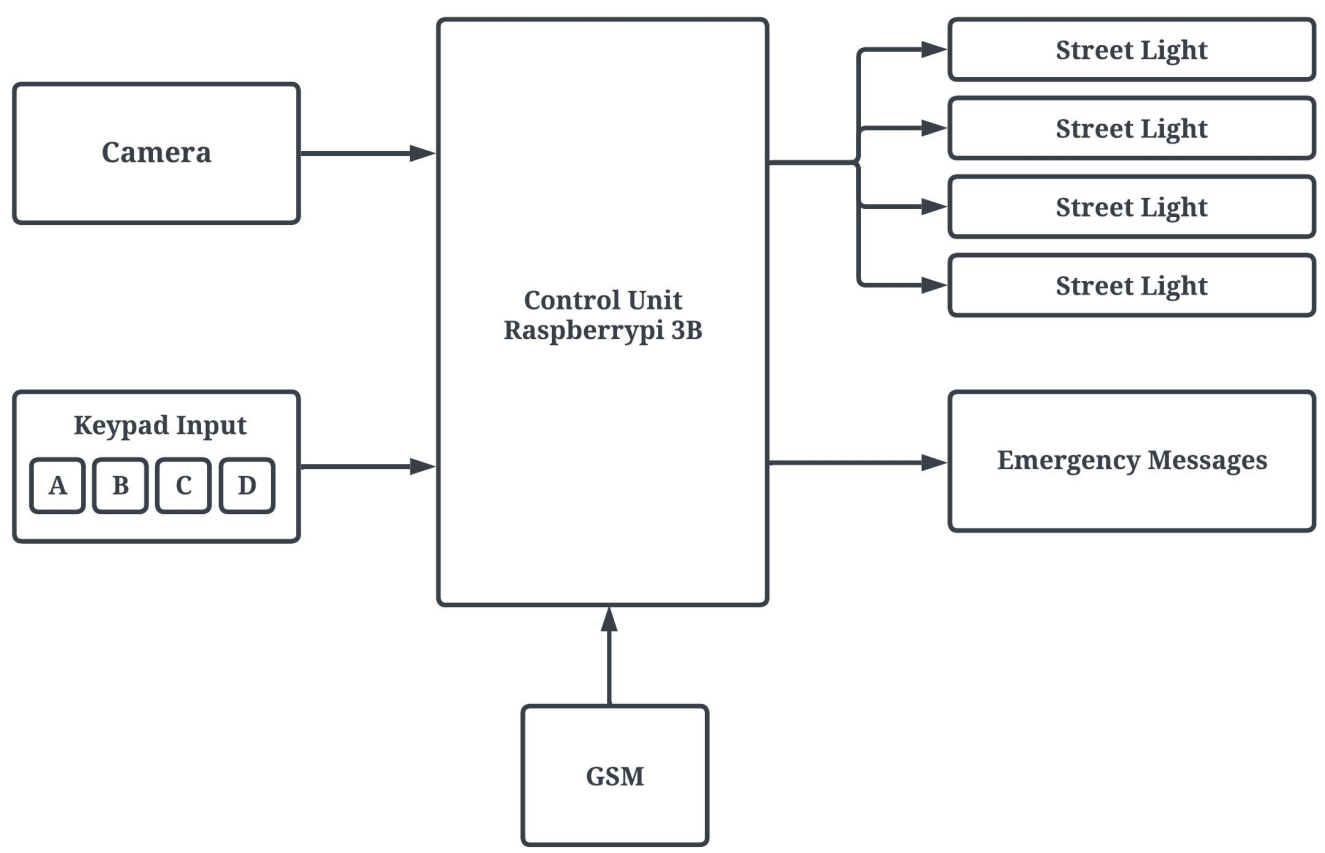


Figure 1: System block diagram

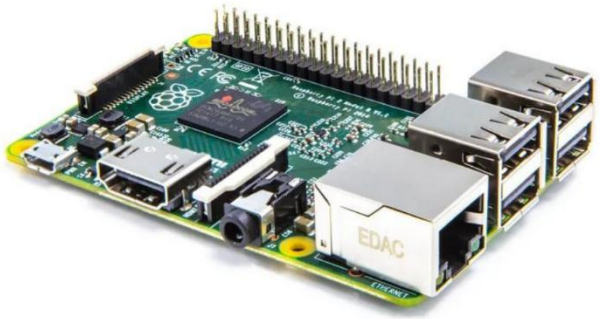
Methodology

- Cameras are installed at every segment.
- Live feed is fed to the control unit where detection of vehicle, human and animal is done.
- Object detection models are used to identify and differentiate between a vehicle, human and an animal.
- If a vehicle or pedestrian is detected – lights are turned ON.
- There will be no detection for any other movement.
- The buttons on the keypad function as follows:
  - The buttons send an alert message to the nearest ambulance, police, malfunction services along with the landmark as and when needed.
  - A button is dedicated for manual control of lights of that segment.

Hardware Description

Raspberry Pi 3B

- Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz 1GB LPDDR2 SDRAM
- Extended 40-pin GPIO header
- Full-size HDMI
- 4 USB 2.0 ports
- Micro SD port for loading your operating system and storing data
- 5V/2.5A DC power input



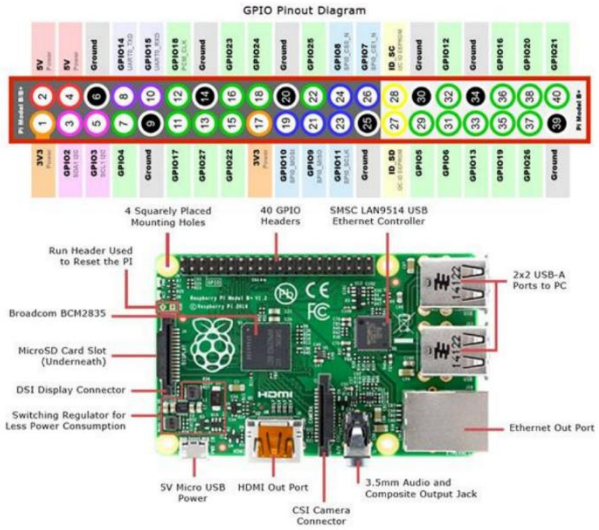


Figure 2: Raspberry Pi

Hardware Description (Contd..)

Camera

- Description: Plug-and-play HD 720p calling.
- Resolution/fps: HD 720p/30fps
- Diagonal Field of View: 60°

Figure 3: Camera

Hardware Description (Contd..)

GSM

(Global System for Mobile communication)

- Dual-Band 900/ 1800 MHz
- Supply voltage range : 3.2 … 4.8V
- Low power consumption: 1.0mA(sleep mode)
- Operation temperature: -40°C to +85 °C

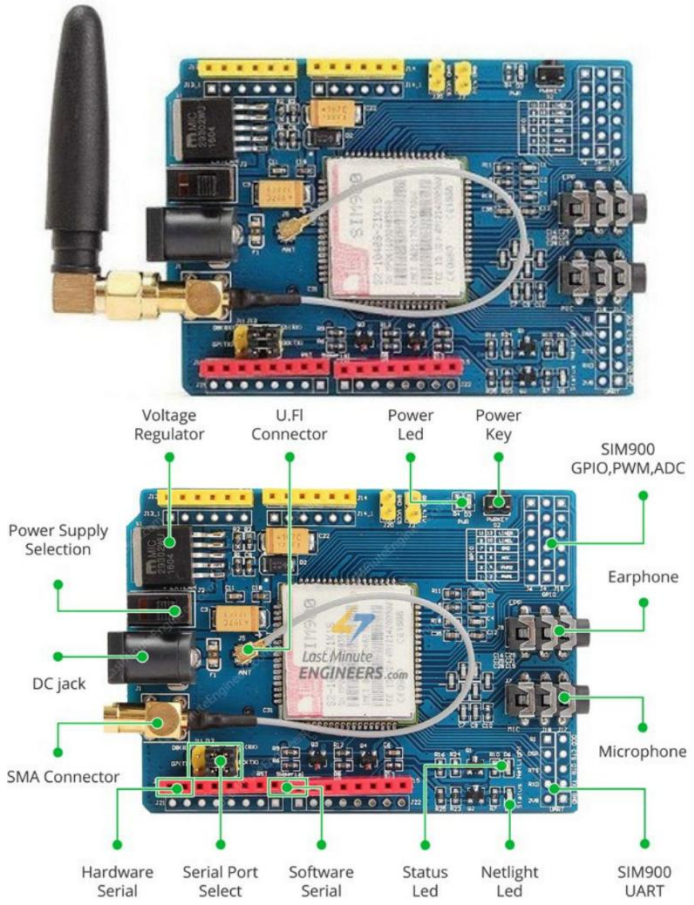


Figure 4: GSM

Hardware Description (Contd..)

Relay Module

- Supply voltage – 3.75V to 6V
- Trigger current – 5mA
- Current when relay is active – 70mA (single), 140mA (both)
- Relay maximum contact voltage – 250VAC, 30VDC
- Relay maximum current – 10A

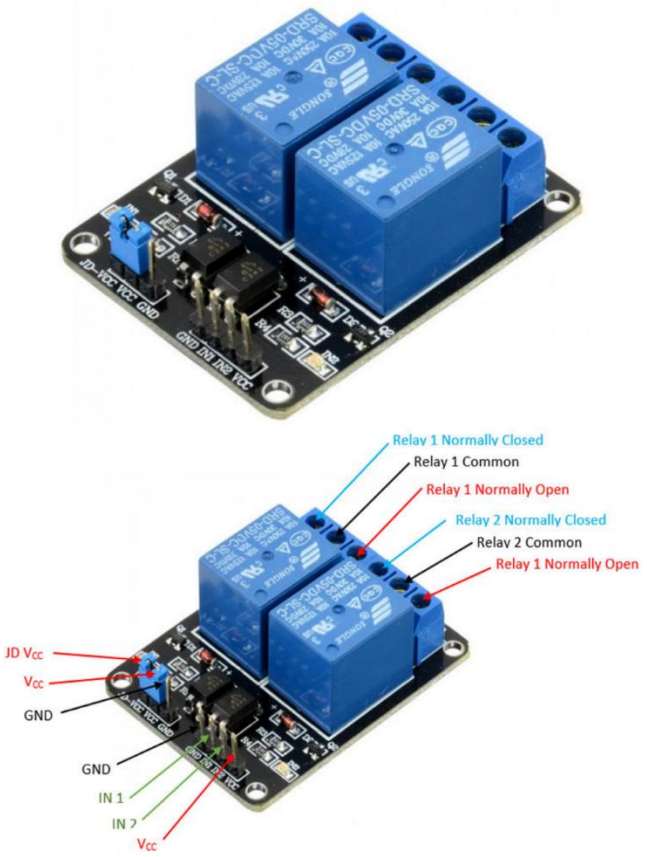


Figure 5: Relay Module

Software Description

- Raspberry pi OS (raspbian) is used as the operating system for the control unit. Raspbian is a debian-based operating system for raspberry pi.
- Python version 3.9 programming language is used to perform the coding.
- YOLO v4 algorithm is used for real time object detection.
- OpenCV is used as a tool for image processing and performing computer vision tasks. It is an open-source library that can be used to perform tasks like face detection, objection tracking, landmark detection, and much more.

Algorithm

1. Turn ON the system during dark hours (time varies from season to season).
2. Camera live input is fed to the control unit.
3. Video feed is processed using YOLO v4 Tiny algorithm.
4. The lights of that particular segment are turned ON if the control unit detects car, truck, bicycle or a person.
5. The lights are kept ON until the object is in the line of sight and are switched OFF later.
6. Repeat above process for the consecutive road segments.
7. The buttons on the keypad function as follows:
   - The buttons send an alert message to the nearest ambulance, police, malfunction services along with the landmark as and when needed.
   - A button is dedicated for manual control of lights of that segment.

YOLO: ‘You Only Look Once’

- YOLO algorithm employs convolutional neural networks (CNN) to detect objects in real-time.
- Requires only a single forward propagation through a neural network to detect objects.
- YOLO v4-tiny is a compressed version of YOLO v4.
- It has only two heads while there are three in YOLO v4 and it is modeled using 29 pre-trained convolutional layers in comparison to 137 pre-trained layers in YOLO v4.
- Quicker response time is crucial than accuracy when working with a real time object detection environment.

YOLO algorithm works using the following three techniques:

- Residual blocks
- Bounding box regression
- Intersection Over Union (IOU)

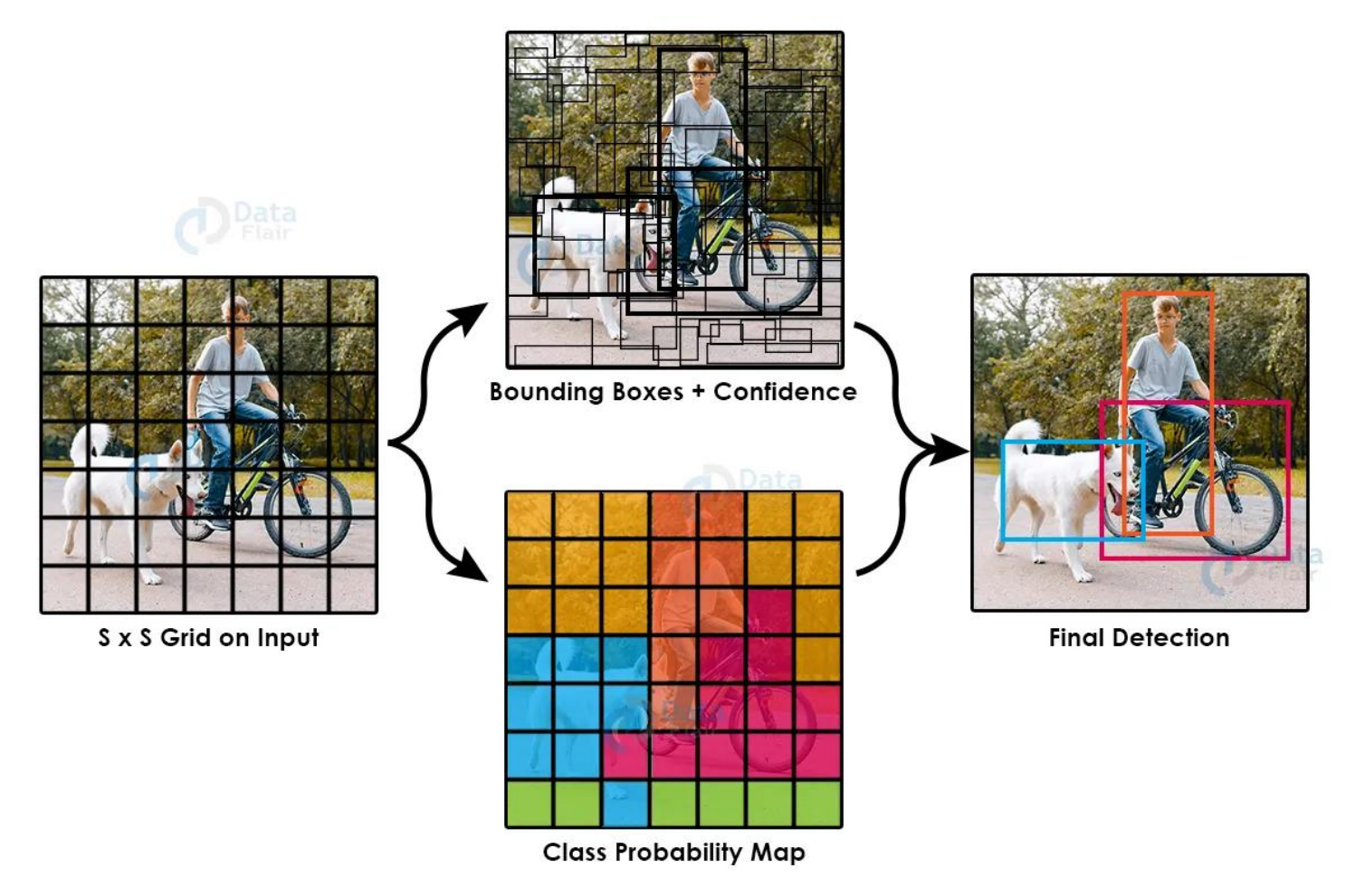


Figure 6: YOLO object detection algorithm Image Source: DataFlair

Flowchart

Figure 7 illustrates the structural flow of the smart street light system.

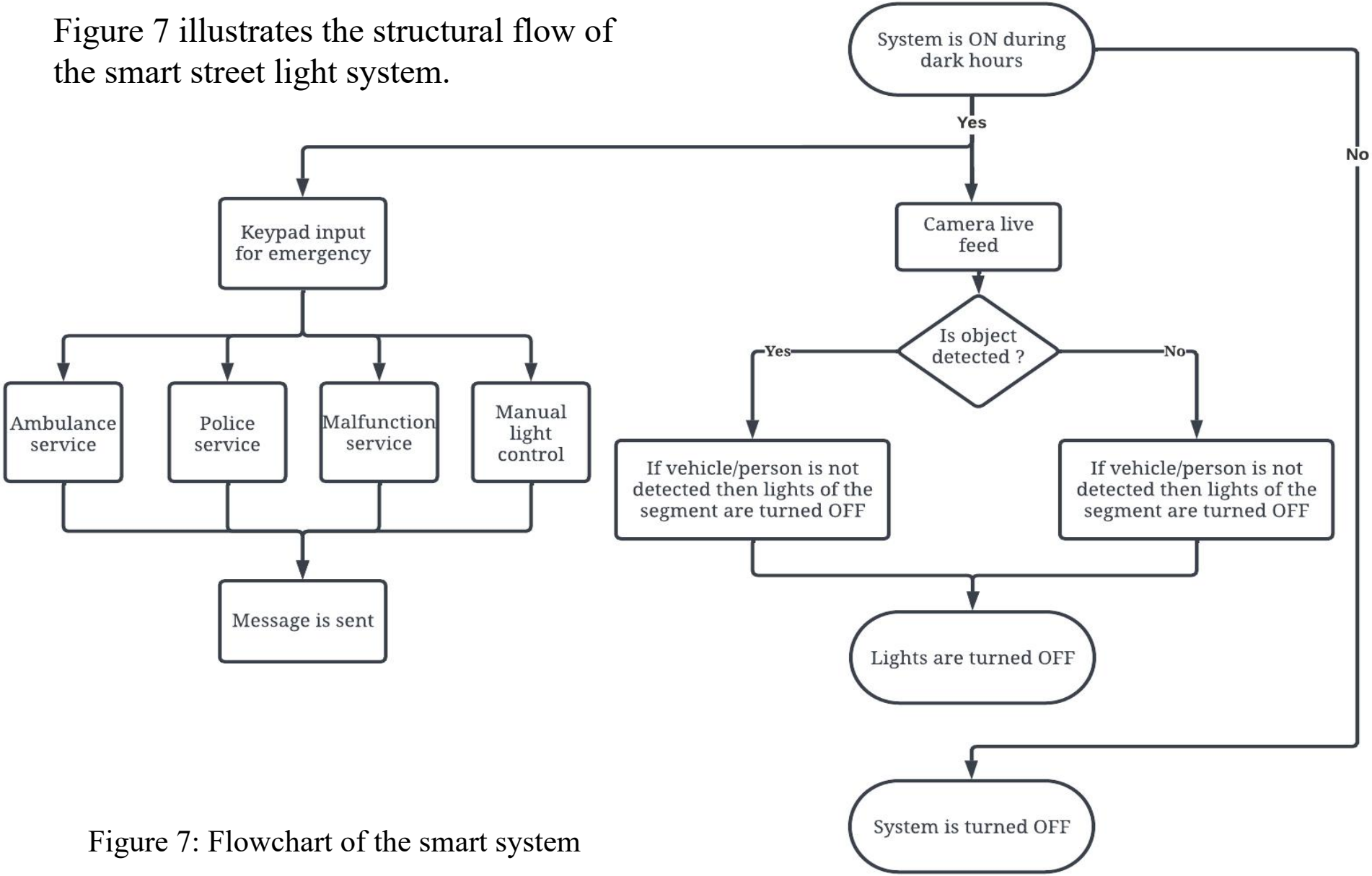


Figure 7: Flowchart of the smart system

Power Calculation

Consider a street light has a rating of 80 watts. The energy consumption in conventional system and smart street light system considering 5 street light per segment and 50 vehicles passing through that segment is as per the Table 1 below:

Table 1: Energy consumed per segment

Energy Consumed	Conventional System	Smart System
1 Hr	400	220
1 Day	4800	2640
1 Month	144000	79200
Energy consumed (in kWh)	**144**	**79.2**

Results

Street lights are controlled in such a way that they turn ON only when a vehicle or a person appears and turns OFF otherwise. The objectives of the project are satisfied as follows:

- Developed an object detection model to detect vehicle and human presence.
- Created a smart street lighting system that does not compromise public needs or safety.
- It is estimated that the smart street light system is efficient and saves up to 45% of electric energy, there by saving a huge amount of money spent on street lights.

Test Cases

Test Case 1: In this case a person is recognized by the system and the street lights are turned ON as shown in Figure 8.

Figure 8: Person is detected

Test Cases(Contd..)

Test Case 2: In this case a motorcycle is recognized by the system and the street lights are turned ON as shown in Figure 9.

Figure 9: Motorcycle is detected

Test Cases(Contd..)

Test Case 3: In this case a car is recognized by the system and the street lights are turned ON as shown in Figure 10.

Figure 10: Car is detected

Test Cases(Contd..)

Test Case 4: In this case both vehicles and people are detected by the system and the street lights are turned ON. Vehicles and pedestrians are tracked, identified and are bounded by a box as shown in Figure 11.

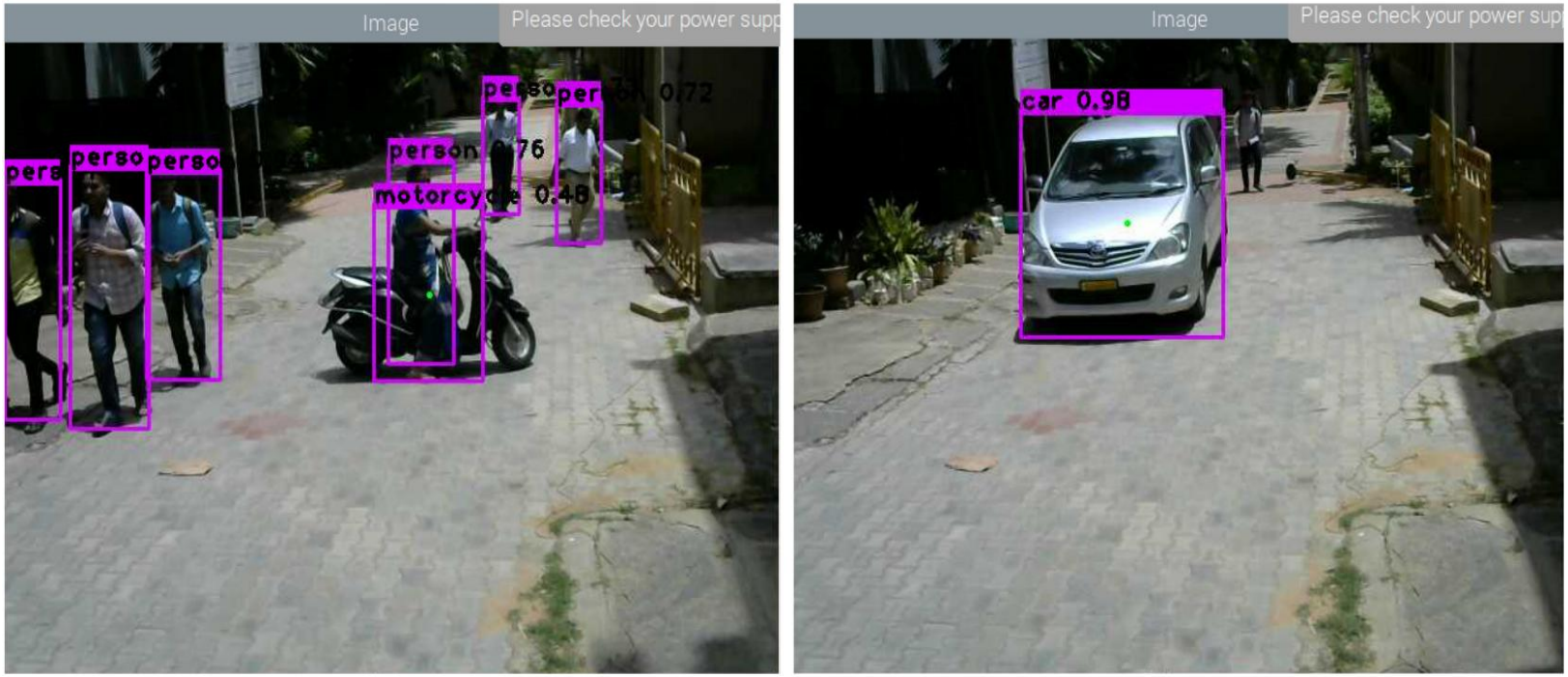


Figure 11: Vehicles and pedestrians are detected

Test Cases(Contd..)

Test Case 5: In this case a car and a person is recognised by the system, whereas the animal is not recognised as shown in Figure 12.

Figure 12: Animals are not detected

Snapshots

- Test Case 6: This case illustrates an emergency situation, an alert message is sent to the necessary emergency services such as ambulance, police and malfunction repair services, along with the landmark of the system. The messages are shown in Figure 13.
- Figure 14 is the system model of smart street light system.

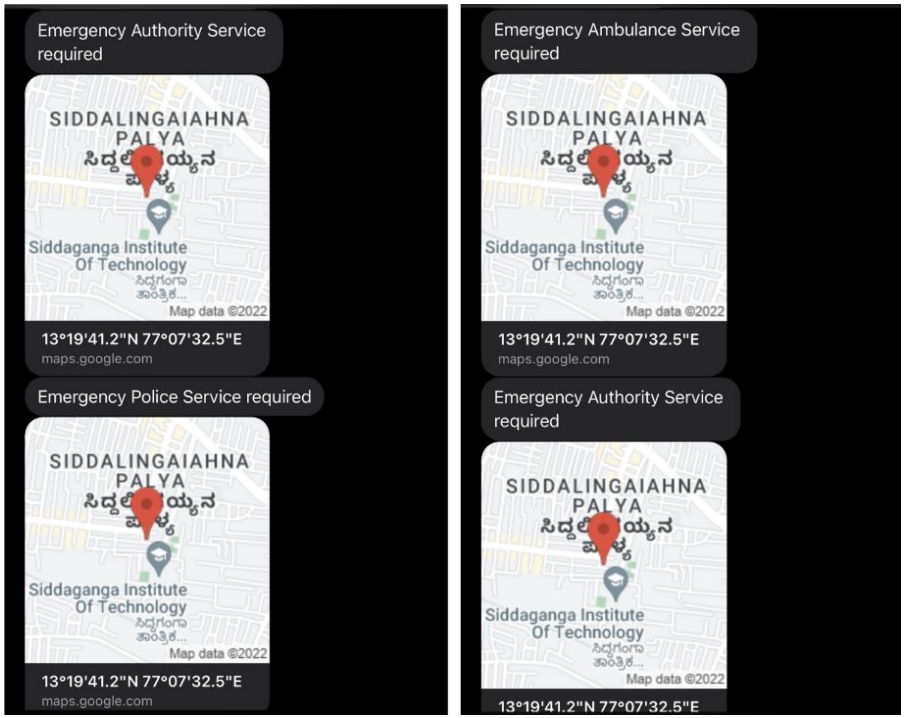


Figure 13: Emergency messages

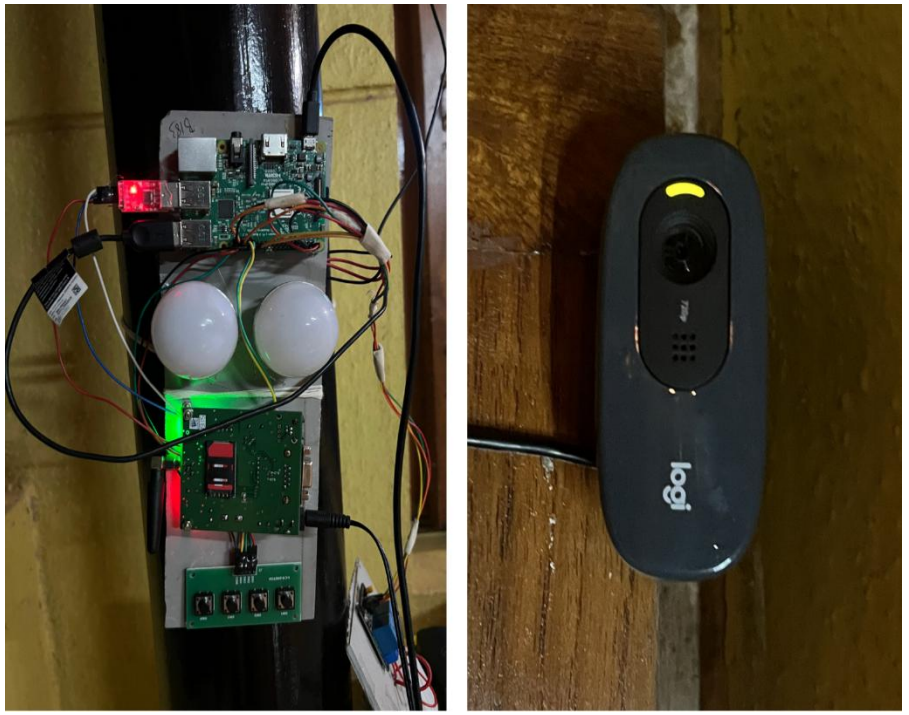


Figure 14: System model

Conclusion

- Intelligent street lighting system is one of the most important frameworks for smart cities.
- The main advantage of this system is performance, savings and effective cost management.
- Currently, we have implemented a prototype of this system in low cadence areas based on the needs applicable to each area.
- This initiative helps governments save energy while meeting national and industrial needs.
- In addition to energy consumption, maintenance costs are also reduced.

Scope for future work

- The model can be improved in terms of accuracy by integrating a better camera with higher resolution and night vision capabilities.
- The control unit can be replaced with a better one with higher processing power thereby reducing delay in processing images.
- Solar panels can be integrated in the system, making it even more efficient and self-sustaining.

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THANK YOU