Street illuminance level analysis towards responsive headlight automation

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Abstract

The vehicles' illuminations level in the road in the night is uncontrolled and beyond the bearable level these days. There are two different beam modes in vehicles, such as dim and high. The high beam mode makes additional illuminance to see through the road far distances in remote areas where the least traffic and pedestrians. The additional horizontal light beams of an approaching vehicle in an urban area with high traffic may cause temporary blindness of drivers and pedestrians. Therefore, the higher beams must be switched to dim mode within a certain distance of a pedestrian or an approaching vehicle. Usually, it is difficult to switch time to time manually in between those modes in reality. Therefore, this study investigates horizontal light illuminance and analyses to make an automated beam control module to be incorporated in the vehicle.

Keywords: illumination, remote areas and urban areas

Introduction

Recent improvements in passenger vehicles' facilities and features become crucial in manufacturing vehicles as they determine demand and marketing. These days, vehicle manufacturing companies are comparatively adopting many IoT based technologies in vehicles for convenient driving. The technological momentum of vehicles from fossil fuel to fully electric force more features to be embedded with smart technologies in vehicles. In the night, driving vehicles is a challenging task for drivers and passengers in a heavy traffic area due to visibility, drowsiness, and light luminance. Typically, modern vehicles' headlights come up with three different light sources such as halogen, xenon, and LED (*The 3 Different Types of Headlights: Which Is Best? - The Vehicle Lab*, n.d.). Further, the driver controls headlights in two different adjustment modes: low beam and high beam modes. The low beam mode provides low light illumination and is highly recommended by the motor traffic department, Sri Lanka, while driving vehicles in night. But high beams mode significantly increases the light illuminance level and makes temporary blindness to the driver who comes in the opposite direction, leading to unforeseen road accidents at nights.

Further, the vision of a human eye can be categorized into three ambient light conditions: photopic, mesopic, and scotopic visions (*Molecular Expressions: Science, Optics, and You: Light and Color - Human Vision and Color*, n.d.). This research study mainly considers the scotopic condition to analyze the human vision under low light level (night). Scotopic vision uses the human eyes' rod cells to perceive the low light surroundings and make them appear in black and white. Also, the rod cells are most sensitive to wavelengths of around 498 nm (green-blue) and are insensitive to wavelengths longer than about 640 nm (reddish-orange).

The highest sensitivity of scotopic vision is found at a wavelength of about 507 nm and is shown in Fig. 1. Besides, a thorough analysis of human eye perception and street illuminance levels may improve convenient features on vehicle headlights illuminance control. This study analyses the street light illuminance and human eye response level to make automated responsive technology reduce light pollution in highly traffic urban areas. The investigation is planned in Vavuniya urban areas for horizontal illuminance level analysis to determine the street illuminance level towards responsive automation of vehicle headlights.

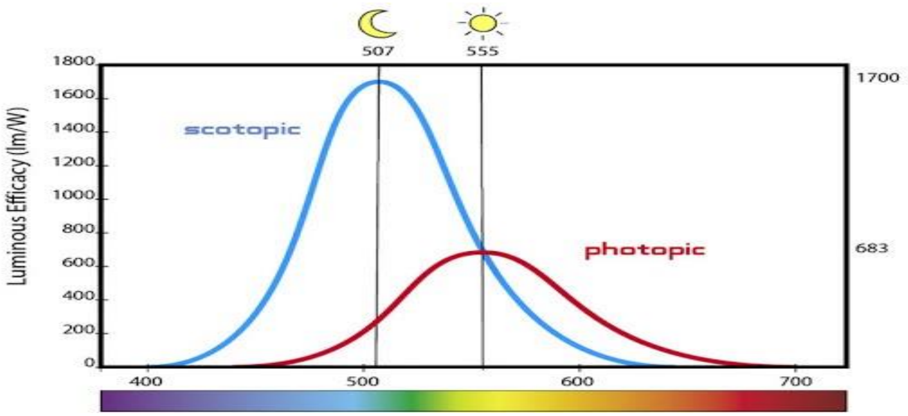

Fig 1. Luminous efficacy Vs Wavelength

Literature Review

A comparative study on the three generations of headlights (LED, xenon, and halogen) was performed by group of researchers with the help of Lux meter (Vrábel et al., 2018). The light intensity falling into the driver's vehicle's eyes in the opposite direction is measured with different headlight modes (Automatic, Dipped-beam headlights, and Long-distance headlights) for various distances (10 to 100m). Furthermore, they prefer the dipped-beam headlights mode for all three generations of headlights as the best choice. Anyhow they failed to measure the light intensity level for moving vehicles in their study.

Choudhary et al. (2014) proposed an automatic headlight management system using the LDR sensor. The opposite vehicle's headlight intensity is measured and based on the threshold value, the system automatically tackles the vehicle's headlight modes. Asaduzzaman et al. (2013) also proposed the same system, including the IR sensors, to take advantage of the fail-safe strategy. Another group of research people proposed an Adaptive Headlight System for accident prevention using Atmel AT89S52 microcontroller and stepper motors. The headlights are connected to the stepper motor and controlled based on the illuminance level received by the photodiode fixed in the vehicle (Shreyas et al., 2014). Although these systems are inexpensive the authors failed to analyse the light intensity level correlated with human eyes' visual perception.

Improvement of driver visibility at night by Ego Vehicle Headlight Control was developed by Sarathchandra et al., (2020) using image processing techniques. The author introduced a 3 x 8 LED array of the headlamp to control the light intensity. Images of the opposite vehicles' headlights are captured and processed using the Raspberry Pi camera. Further, the system automatically switches on and off the LED array based on the program's condition. But the authors missed considering the visibility factors of a human eye during the night journey.

A group of researchers proposed an anti-glare headlight system using an LED projector instead of traditional headlight systems. The illumination emitted by the projector can be divided into multiple tiny powerful beams and controlled separately by the programmable processor in their project. Further, they have used a camera to identify the oncoming vehicles and adjust the projector's beams without affecting the opposite driver even in high beam mode. Even though this is a novel approach, the ethical issues of using projectors in vehicles and the heat produced by them are not taken into consideration (Balasubramanian et al., 2011). This work aims to overcome the excessive horizontal illumination issues in the street in urban areas during night driving and provide a convenient solution to drivers and pedestrians by adopting medical and traffic ethics.

Methodology

The implementations run across various phases to provide a feasible solution to vehicle drivers and pedestrians. The strategy diagram of this work is clearly illustrated in Fig. 2.

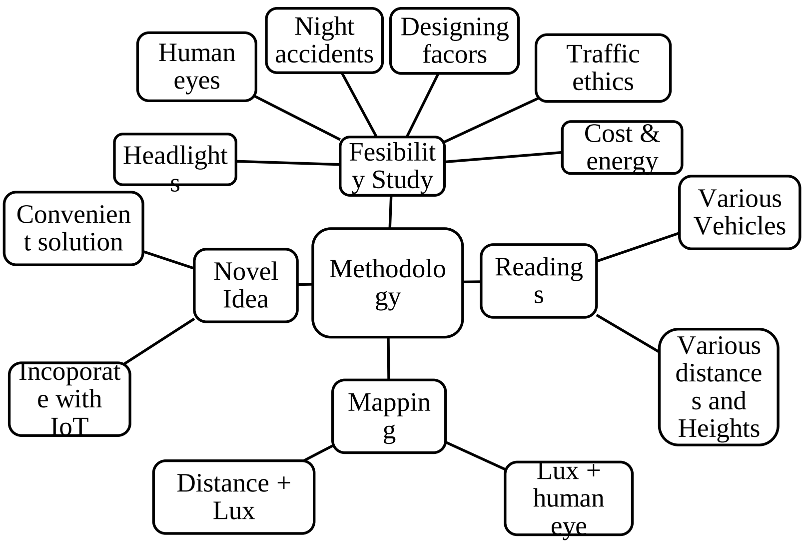

Fig 2. Strategy diagram

The research study has been initiated with collecting the existing technologies adopted in the headlights and the statistics of night accidents that are occurring due to the high beam mode of the headlights. The analysis is planned with the measurement of horizontal illuminance level using a lux meter. The lux meter has been placed around 5 – 25 m away from the moving light source and around 1.2m height in an A grade road of Sri Lanka near

Vavuniya town. The measurement has been taken for different kinds of vehicles with the same distance and lux reading has been recorded. The Fig. 3 describes the reading of lux meter for various vehicle types with distances.

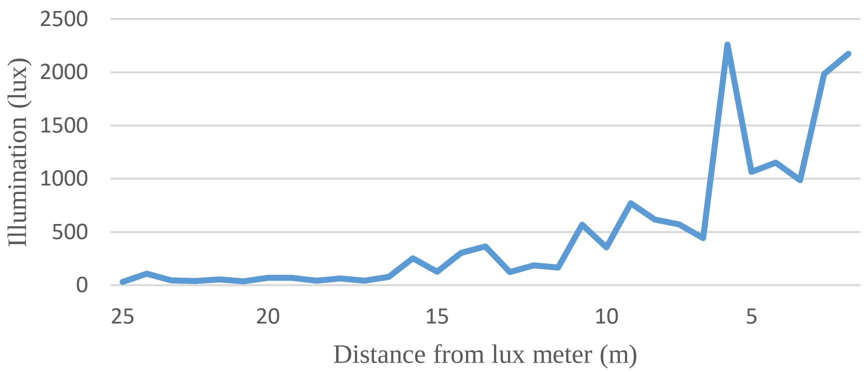

Fig 3. Distance Vs Illumination

Further, the human eye's visual perception level has been studied for comparison and assesses the impact of human visual perception in the street at night. Tables 1 and 2 describe the recommended vertical illumination levels for various types of streets and details of the human eye's visual perception levels in lux, respectively.

Table 1. Recommended vertical illumination levels for

Type of street/ road	**Recommended illuminance (lux)**
Walkways exclusively for pedestrians	5
Residential traffic areas for slowly moving vehicles (<=10 km/h)	10
Regular vehicle traffic (<=40 km/h)	10-20
Main urban streets	20
Urban roads	10-20

Rural paths and roads	2-5
Pedestrians passages, vehicle turning, loading and unloading points	50

Table 2. Human eye's visual perception levels

Illuminance (lux)	Activity
100	Casual seeing
150	Some perception of detail
200	Continuously occupied
300	Visual task moderately easy
500	Visual task moderately difficult
750	Visual task difficult
1000	Visual task very difficult
1500	Visual task extremely difficult
2000	Visual task exceptionally difficult

In the end, the headlight illumination level readings have been mapped with the human visual perception level and suggest convenient illumination levels for vehicles in high traffic areas to avoid night accidents. However, the horizontal readings are mapped by assuming those standard measurement levels given in the existing studies, even though it is measured vertically and in the surrounding. However, in reality, the horizontal standard measurements must be less than those valued referred to in Tables 1 and 2 as it is directly hitting the human eyes. Hence, a more in-depth detailed analysis can be done for further studies.

Results and Discussions

According to the night accidents that have been reported in Sri Lankan local news channels, most of the vehicles involved are dual-purpose motor vehicles and motor coaches (*Road Accident Archives | Sri Lanka News - Newsfirst*, n.d.). Therefore, this research study predominantly examines certain classes of vehicles such as B, C1, C, CE, D1, and D classified by the department of motor traffic, Sri Lanka (*Vehicle Classes*, n.d.). Further, A9 road is selected because it has been used by several passengers regularly, even at nights.

As shown in Fig. 3, when the approaching vehicle is between 10 to 25 meters away from the lux meter, the illumination results obtained have fluctuated from 30 to 500 lux. Further, it can be derived that the visibility in these distance ranges can be convenient for human eyes to observe the surroundings even at high beam headlight mode of approaching vehicles. Nevertheless, the illumination value reaches 2000 lux when the vehicle comes within 10 meters and this observation reveals the difficulty in vision based on the recommended values given in Table 2. Therefore, this sudden boost in the illumination level leads to temporary blindness to the drivers or pedestrians and contributes to unexpected accidents.

Conclusions and Recommendations

Even though the night journeys are insecure, they are inevitable in some circumstances. Sri Lankan government takes several safety precautions to avoid night accidents in many ways, such as assigning traffic police, road signs, real-time monitoring through the camera, etc. But these efforts are insufficient to monitor all the main roads in Sri Lanka. Further, the vehicle with high beam headlight mode, which comes within 10 meters, may cause dangerous impacts to drivers and pedestrians, as illustrated in Fig. 3. Therefore, this research study proposes an automated headlight controlling system for the vehicles to control the modes of headlights based on the distances between approaching vehicles or pedestrians. An IoT based model can solve this problem easily.

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