INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Cloud-based energy efficient smart street lighting system

Muhammad Umar[1], Sajid Habib Gill[1]*, Riaz Ahmad Shaikh[2], Muhammad Rizwan[3]

1 Ph.D. Scholar, Department of Computer Science, Shah Abdul Latif University, Khairpur, 66020, Sindh, Pakistan. Tel.: +92-313-6789357
2 Associate Professor, Department of Computer Science, Shah Abdul Latif University, Khairpur, 66020, Sindh, Pakistan
3 Department of Computer Science, MTB College, Sadiqabad, 64350, Punjab, Pakistan

Abstract

Background/Objectives: Pakistan is experiencing significant energy crises for the last two decades. The increasing power demand cannot be controlled with traditional energy techniques. The conventional street lighting system remains ON all over the night. Consequently, a huge amount of energy is wasted. To overcome the shortage of energy, an efficient smart lighting system is proposed. **Methods:** The prime thought to accomplish is ``Energy on-demand'' i.e. handed-in wherever, whenever required. To achieve this goal, the cloud-based smart street lighting system provides a feasible solution. The proposed system uses an Arduino and its various shields based on a movement-based actuation system like Light Detection and Ranging (LiDAR), automate the street lighting system. This design is executed and implemented on a one-way road and its results are carried out at three different scenario cases. The analysis is done by a decision-making module that obtains results from the sensor (LiDAR). **Findings:** The availability of low cost advanced devices like LiDAR, Arduino, cloud storage, and the accessibility of wired and wireless connection, smart street lighting system becomes a reality. The proposed system is beneficial to overcome the CO_2 emission. Further, it will also be helpful to avoid the unnecessary consumption of streetlight as well as to reduce power utilization and save energy up to 99%. **Applications:** This proposed framework has an immense potential to revolutionize street lighting and to achieve the demand for a smart street lighting system that is easy to maintain, durable, and reliable.

Keywords: IoT; cloud; LiDAR; street lighting system; Arduino

1 Introduction

Street lighting is one of the key facilities that are given in any smart city. The unnecessary consumption of street lighting directly influences the economic standard of the developing country. The major problem of street lighting is power consumption. The reduction of this energy utilization is not easy. Along with the help of different computing mechanisms, this power utilization could be lessened [1]. In any country, street lighting plays a significant role in the contribution of pedestrian and traffic safety. The current lighting system uses traditional techniques and requires manual intervention. Due to less efficiency, it leads to the wastage of electricity as well as manpower [2].

One of the basic adverts is to enhance the performance of the common street lighting system. Another major and significant resource of Pakistan is power [3,4]. In Pakistan, a lot of power is used because of the continuous activity of road lighting everywhere throughout the night. The streetlights remain ON for over 10 hours. In June 2017: The data of streetlight was collected at 484.000 Giga Watt-hours (GWh) that is an increased figure from previous statistics reported as 459 (GWh) in June 2016. The data updated by the Ministry of Finance about street light yearly was updated from June 1992 to 2017 as 382.500 (GWh) [as shown in Figure 1] [5].
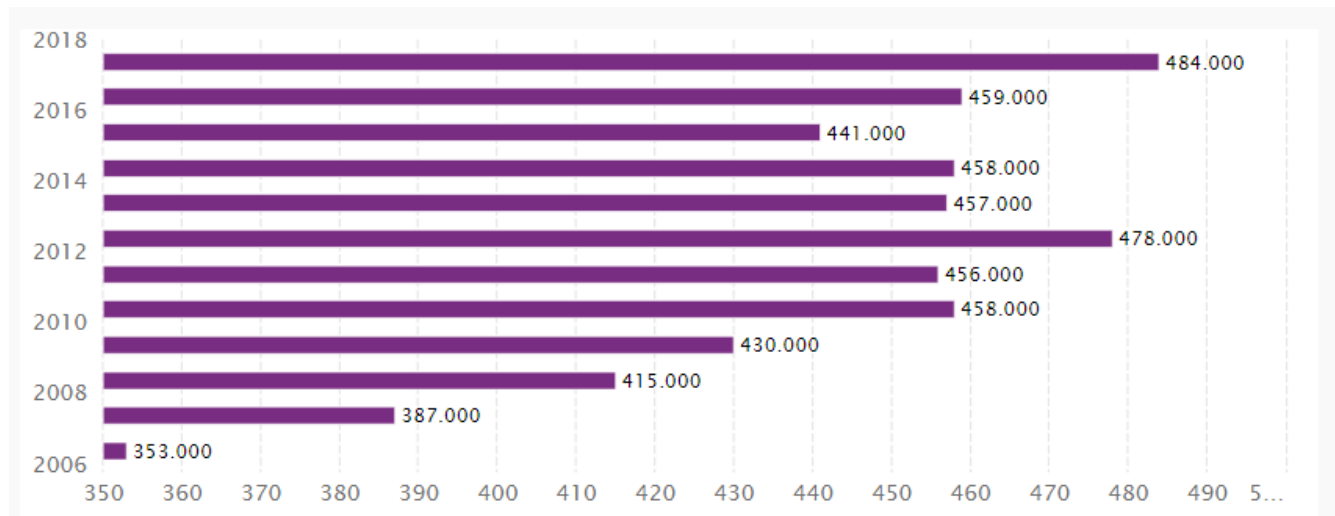

Fig 1. Streetlight: Electricity consumption (Source: www.ceicdata.com | Ministry of Finance)

This research study presents the estimation to possibly lessen the power utilization and consumption of energy in Pakistan. It provides an idea to make streetlights to be on by monitoring ongoing traffic and vary the light (On/Off) accordingly. The following advantages could be attained [6,7].

1. CO2 pollutants and light discharge will be reduced
2. Everyday living standards will be improved
3. The saving of electricity

Publicly, the lighting systems that are framed and implemented are right now working on old technical grounds [8]. Numerous systems had suggested containing landline sources and wireless access points to control the street lighting system. Out of which the wireless channel got recognition [9]. In recent years, because of ecological issues like an unnatural weather change and environmental variations, energy-securing

solutions became the norm[10]. Thousands of probers are pondering over the smart street lighting system. Their basic concern is to switch on the light automatically at nightfall and some persist on the detection of the object such as pedestrians and traffic. In traditional street light systems, automatic switches used transistors to switch the state of light "On and Off". The light will switch off as the sunlight is sensed and automatically switch on as no sunlight is found. This mechanism is done by the sensor called LDR (Light Dependent Resistor) that works like human eyes. As a motor and walker is detected in an area the Motion Sensor will automatically switch on the light and if nothing is detected in an area the light will automatically switch off. The design and idea presented in the paper will not only hedge these shortcomings but will also be able to save energy in real sense for street lighting[11]. In the current situation, the streetlamps of the cities are being manually controlled. This method is not efficient as well as causes wastage of manpower[12]. Vehicle detection is also an important aspect. LiDAR and camera could be used for this purpose. The traffic will be detected with the help of the grid projection method using the LiDAR point cloud information. LiDAR is most effective and efficient as it can detect objects at a long distance[13]. The most used sensors for the detection of pedestrian, or traffic is LiDARs as compared to the camera's[14]. Another study proposed by[15] presents that vehicle will be detected by using the IR transmitter. After sensing the vehicle, the data is sent to the microcontroller to switch ON the light. As the vehicle moves away from the light, they will be switched OFF again. This mechanism is implemented by embedded systems to handle the streetlight according to the movements of objects and vehicles. The proposed system[16] consists of user application, edge computing (a sensor, IP address, and microcontroller) and a cloud server. Real-time data is collected by the system that enables live streaming of different images captured by the camera. This also offers an API for data queries. In[17] author discussed the streetlight concepts by network topologies and communication considering all the aspects of its ups and downs and utilize the IoT and 5G technologies for the implementation of smart public lighting applications. Reference[18] explains about dynamic street lighting concept. The lighting effects are being controlled by traffic intensity and weather conditions. The intensity of light will be adjusted accordingly by sensors and microcontrollers. This concept gives the real-time feature, likewise if there is a full moon day then the intensity of light will be reduced to half of its glow.

This design of a cloud-based smart street lighting system will overcome the consumption of electricity and reduce energy use by up to 99% with connected lighting. This smart and versatile system is cost effective and supportable choice for smart cities as it can connect the existing streetlights with new connection rapidly and easily. This system also has a great potential to reduce the maintenance and operating expenses. Thus, the saved energy by using our proposed system could be utilized or invested in another industrial sector of Pakistan.

There is a total of four segments of this paper, first being the introduction, the second part explains the methodology of the proposed system. The third part concludes the results and argumentation. And the fourth segment presents the judgment of the paper.

2 Proposed Methodology

The main idea was to build a cloud-based smart lighting system prototype (as shown in Figure 2) to overcome the usage of energy for streetlights after providing the utmost light intensity for specific situations. This proposed mechanism will trace human beings and traffic including, light traffic vehicle, heavy traffic vehicle, further it will switch on the lights accordingly. The proposed mechanism will not judge daylight or night because such a system will drain the electricity for the complete day. For the betterment of the system, we use LiDAR, Arduino, cloud server, and internet card.

The major attributes of this proposed prototype are mentioned below:

1. Individuals or groups of streetlights control.
2. Control unit relates to four streetlights to build up one set and they do not require any intercommunication.
3. Each set contains its control unit.
4. The control unit will monitor the consumption of electricity to reduce it.
5. Remote communication is being held between local electronic devices and cloud servers, based on a 3G/4G connection.
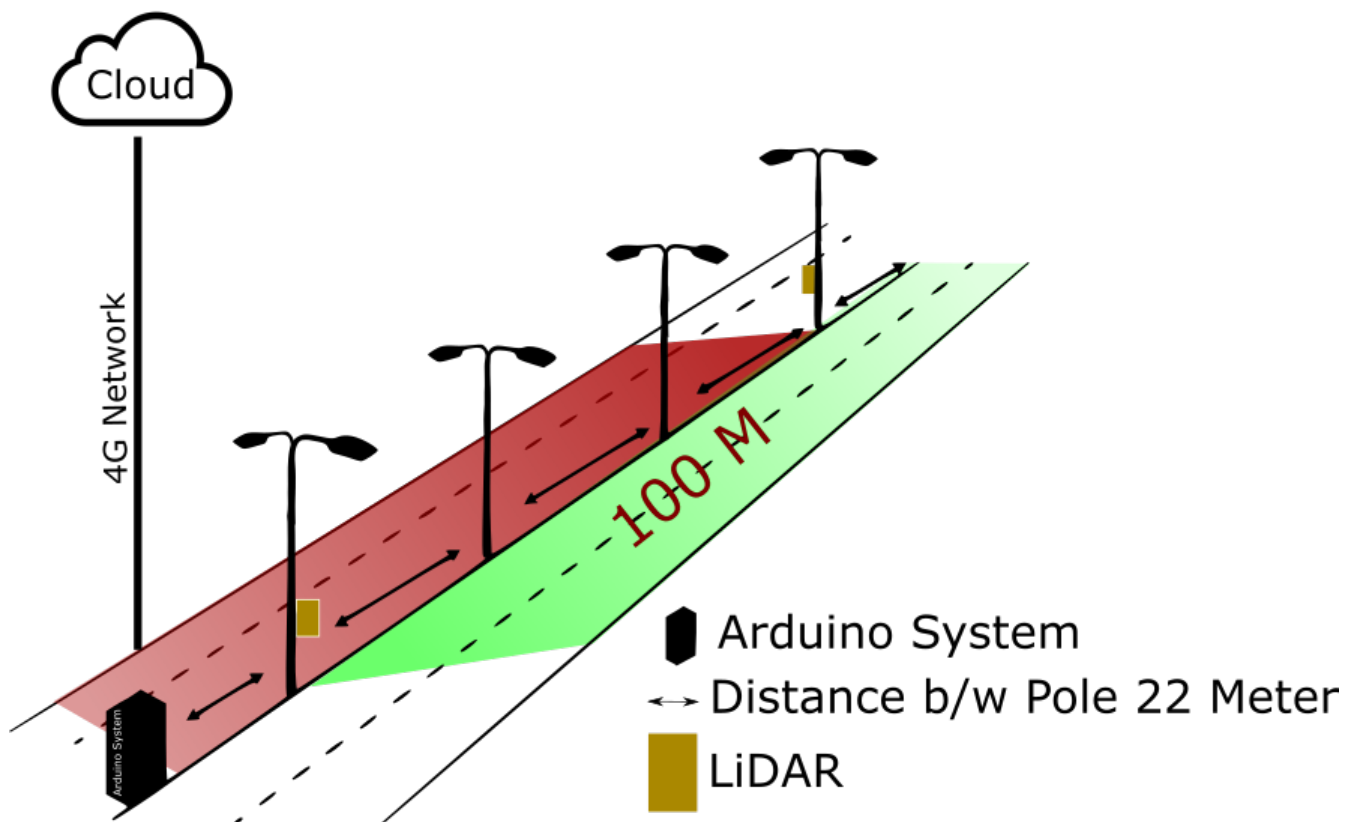

Fig 2. Smart street lighting concept

2.1 Why Arduino and LiDAR

Arduino is a microcontroller that is best for an implementation point of view as it meets all the requirements of the user. As compared to other similar boards Arduino is open-source, easy to program, erasable, and much faster. By using actuator and sensor, Arduino can send and receive data on the internet. Due to the availability of different sheaths like Motor Driver Shield, Wireless Shield, and Ethernet shield[19], LiDAR is the most prominent and effective technology to collect data from the surrounding objects. This sensor permits you to build up a 2-D or 3-D space map[20]. The LiDAR technology automatically routes the track and enables to move to a point on the map[21]. LiDAR sensor works on the principle action of radar i.e. the light beam return to the receiver as it gets reflected from the objects.
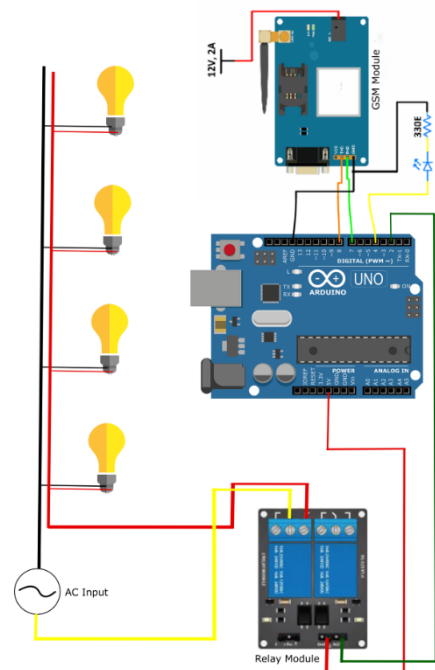
Fig 3. Schematic circuit diagram

Block Diagram

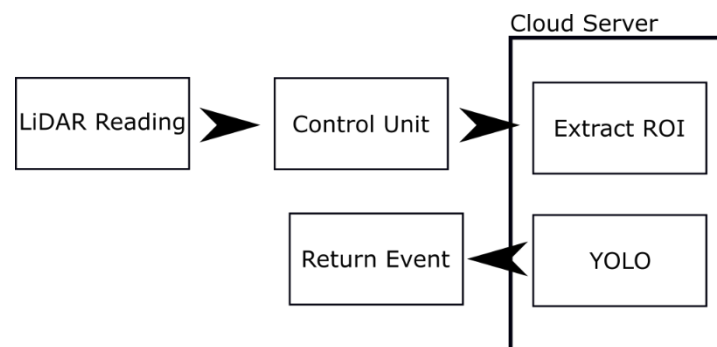**Fig 4.** Block diagram

1. LiDAR will get the origin point and sends this to the cloud server via the control unit.
2. After that region of interest is extracted at the cloud server.
3. Run the state-of-the-art YOLO[22] object detector to find a region of interest (ROI).
4. The state of lights will be changed accordingly after fetching the result.
5. Repeat the above steps for the whole night.

2.3 Scenario Cases

The model that is put forwarded in the paper is that every pole has dual bulbs, equally for the left and right. A bulb takes aW (Watt) and a single pole consumes $2 * aW$ (Watt). This very system utilizes bW, the whole consumption of one unit of the system is granted by $10 * (\text{energy consumed by light}) + \text{energy consumed by the system}$. The energy used by the cloud server is excluded. Here are three possible cases that could happen throughout the night that are discussed (see Table 1).

i. Best Case

No movement of pedestrians or traffic is observed by the system throughout the night. In the results, the gross energy consumed through light is $0W$ and the whole usage is $10 * 0 + bW = bW$ and $10 * aW - bW$ was saved by us but it will be $10 * aW$ without system.

ii. Average Case

The bulbs will remain ON for half time over the night due to the average movement of pedestrians and traffic. Thus the total energy consumed by the bulbs are $\frac{a}{2}W$ and gross utilization is $10 * (a/2) + bW = (5 * a + b)W$ and total energy save by us is $(5 * a + b)W - bW$ but it will be $(5 * a + b)W$ without system.

iii. Worst Case

The bulbs will remain ON for the whole night due to the continuous movement of pedestrians and traffic. Thus, the total energy consumed by the bulbs is xW and total consumption is $10 * aW + bW$ and the system will be unable to save energy, but the system consumed yW.

3 Results & Discussion

One pole bulb will consume 400 Watts which is equivalent to 0.4 KWh. According to a reference, the distance between the two poles is measured as 22.86 meters. Here we are discussing 4 poles in a set that will cover the distance of 91.44 meters. By assuming day and night as 12 hours each.

So, the energy consumed by one pole is $0.4 * 12 = 4.8$ KWh in one night. And energy consumed by four poles in one night $4.8 * 4 = 19.2$ KWh. Arduino will consume the energy as 0.000697 Watts which is equivalent to $6.97 * 10 - 7$KWh. The consumption of LiDAR is as 0.00125 KWh. Le910 Version II consumes 0.002KWh. Thus, the total energy consumed by the proposed system is 0.003947 KWh. And in the whole night, it will consume 0.047364 kWh in 12 hours.

Let
x_k= consumed hours
C = consumption of energy per hour
E_0 = constant (0.047364) denotes the consumption of energy by the system in 12 hours
K = 1,2,3
$f(x_k)$ = total consumption of energy in 12 hours
$E(x_k)$ = energy saved (%)
Then
$f(x_k) = cx_k + E_0$
$f(x_k) = cx_k + 0.047364$
$E(x_k) = 100 - \frac{f(x_k)}{cx_i}$
where $X_i = \text{Max}(x_k)$
$k(\text{ Scenario Cases }) = 1, 2, 3$

Table 1. Results (consumption, saved Energy)

Scenario Case	Consumed Hrs. (H)	Consumption per Hrs. (KWh)	Consumption in 12 Hrs. (KWh)	Purposed System Power (KWh)	Total Consumption in 12 H (KWh)	Energy Saved (%)
1: Worst Case	12	0.4	4.8	0.047364	4.847364	-0.98675
2: Average Case	6	0.4	2.4	0.047364	2.447364	49.01325
3: Best Case	0	0.4	0	0.047364	0.047364	99.01325

A high-speed internet connection and a server to process data over the cloud is required. This system cannot work efficiently on slow speed internet. Consequently, there is no delay between any sensors is assumed by us. The efficiency of this system cannot be achieved with a low-speed internet connection. As it is assumed that during the communication of sensors there should be no delay.

4 Conclusion

This study has great potential to revolutionize the traditional street light system particularly the areas with low traffic and pedestrian frequency. Moreover, it will also be helpful to overcome the CO_2 emission. Thus, by using the concept of LiDAR and Arduino sensor this system was made with which is highly efficient and reduces power consumption. The power consumption is reduced by 99.01325 % in the best-case scenario. The best implementation of this system could be observed on the roads with no or less traffic.

In the future, implementation of this module on a commercial scale loaded with such sensors having vehicle detection to monitor the condition of the roads, air pollution, weather conditions, lamp inclination availability of natural light and more along with accident detection could become a reality.

References

1) Mohandas P, Dhanaraj JSA and Gao XZ. Artificial Neural Network based Smart and Energy Efficient Street Lighting System: A Case Study for Residential area in Hosur. *Sustainable Cities and Society*. 2019;48:101499–101499. Available from: https://dx.doi.org/10.1016/j.scs.2019.101499.

2) Sudheer K, Madhurita D, Chandana A, Thanesh M and Babu MK. Intelligent Street Light System For Smart Cities. *International Journal of Applied Science and Computations*. 2019;6(5).

3) Ali S and Shah N. Electricity Crisis in Pakistan: Reception & Adoption of Energy Saving Campaign Messages by PEPCO. *Pakistan Journal of Social Sciences*. 2012;(1):32–32.

4) Asif M. Energy Crisis in Pakistan: Origins, Challenges, and Sustainable Solutions. *OUP Catalogue*. 2012;.

5) Pakistan . 2017,. Available from: www.ceicdata.com/en/pakistan/energy-consumption-and-supplies-annual/electricity-consumption-street-light.

6) Gagliardi G, Casavola A, Lupia M, Cario G, Tedesco F, Scudo FL et al. A smart city adaptive lighting system. In: and others, editor. In 2018 Third International Conference on Fog and Mobile Edge Computing (FMEC) . 2018,. p. 258–263. Available from: https://doi.org/10.1109/FMEC.2018.8364076.

7) Leccese F and Leonowicz Z. Intelligent wireless street lighting system. *2012 11th International Conference on Environment and Electrical Engineering*. 2012;p. 958–961.

8) Leccese F. Remote-Control System of High Efficiency and Intelligent Street Lighting Using a ZigBee Network of Devices and Sensors. *IEEE Transactions on Power Delivery*. 2013;28(1):21–28. Available from: https://dx.doi.org/10.1109/tpwrd.2012.2212215.

9) Shahzad G, Yang H, Ahmad AW and Lee C. Energy-Efficient Intelligent Street Lighting System Using Traffic-Adaptive Control. *IEEE Sensors Journal*. 2016;16(13):5397–5405. Available from: https://dx.doi.org/10.1109/jsen.2016.2557345.

10) Byun J, Hong I, Lee B and Park S. Intelligent household LED lighting system considering energy efficiency and user satisfaction. *IEEE Transactions on Consumer Electronics*. 2013;59(1):70–76. Available from: https://dx.doi.org/10.1109/tce.2013.6490243.

11) Rao A and Konnur A. Street light automation system using arduino uno. *Int J Innov Res Comput Commun Eng*. 2017;5:16499–16507.

12) Wu Y, Shi C, Zhang X and Yang W. Design of new intelligent street light control system. In: and others, editor. In IEEE ICCA 2010. IEEE . 2010,. p. 1423–1427. Available from: https://doi.org/10.1109/ICCA.2010.5524348.

13) Wang H, Lou X, Cai Y, Li Y and Chen L. Real-time vehicle detection algorithm based on vision and lidar point cloud fusion. *Journal of Sensors*. 2019;.

14) Wang H, Wang B, Liu B, Meng X and Yang G. Pedestrian recognition and tracking using 3D LiDAR for autonomous vehicle. *Robotics and Autonomous Systems*. 2017;88:71–78. Available from: https://doi.org/10.1016/j.robot.2016.11.014.

15) Prakash PV and Rajendra D. Internet of things based intelligent street lighting system for smart city. *International journal of innovative research in science, engineering and technology*. 2016;5(5).

16) Yang YS, Lee SH, Chen GS, Yang CS, Huang YM and Hou TW. An Implementation of High Efficient Smart Street Light Management System for Smart City. *IEEE Access*. 2020;8:38568–38585.

17) Pasolini G, Toppan P, Zabini F, Castro CD and Andrisano O. Design, Deployment and Evolution of Heterogeneous Smart Public Lighting Systems. *Applied Sciences*. 2019;9(16):3281–3281. Available from: https://dx.doi.org/10.3390/app9163281.

18) Jagadeesh YM, Akilesh S, Karthik S and Prasanth. Intelligent Street Lights. *Procedia Technology*. 2015;21:547–551. Available from: https://dx.doi.org/10.1016/j.protcy.2015.10.050.

19) Louis L. WORKING PRINCIPLE OF ARDUINO AND USING IT. *International Journal of Control, Automation, Communication and Systems (IJCACS)*. 2016;1(2):21–29.

20) Denysyuk P, Teslyuk V and Chorna I. Development of mobile robot using LIDAR technology based on Arduino controller. In: and others, editor. In 2018 XIV-th International Conference on Perspective Technologies and Methods in MEMS Design (MEMSTECH) . 2018,. p. 240–244. Available from: https://doi.org/10.1109/MEMSTECH.2018.8365742.

21) Grisetti G, Kummerle R, Stachniss C and Burgard W. A Tutorial on Graph-Based SLAM. *IEEE Intelligent Transportation Systems Magazine*. 2010;2(4):31–43. Available from: https://dx.doi.org/10.1109/mits.2010.939925.

22) Redmon J, Divvala S, Girshick R, Farhadi A and IEEE. You only look once: Unified, real-time object detection. In: and others, editor. IEEE Conference on Computer Vision and Pattern Recognition (CVPR) . 2016,. p. 779–788.