MONITORING AND REMOTE SENSING OF THE STREET LIGHTING SYSTEM USING COMPUTER VISION AND IMAGE PROCESSING TECHNIQUES FOR THE PURPOSE OF MECHANIZED BLACKOUTS (DEVELOPMENT PHASE)

Pooya Najafi Zanjani
TEDC – IRAN
pooya_najafi_tech@yahoo.com

Morteza Bahadori
Tehran Electrical Distribution Co – IRAN
bahadori@tbtb.ir

Mohammad Hashemi
TEDC – IRAN
hashemi@tbtb.ir

ABSTRACT

Street lighting system as one of the foremost facilities used in the cities plays a pivotal role in reducing nocturnal car accidents and enhancing individual and social security. Therefore, one of the main priorities in Electrical Distribution Companies is the timely repair and maintenance of the street lightening which should be regularly checked. The common mechanized monitoring of the street lighting is based on measuring the consumed current of each lamp and comparing it with the lamp nominal current. In this way, the error in network is identified. Monitoring street lighting in Iran is presently conducted by traditional inspection and check-out method. This paper suggests a new method for monitoring and remote sensing of the street lighting system, which is completely isolated from electricity network and applies picture shooting of the street lighting network, image processing, and computer vision techniques and separating the light source method in the picture and report development phase. The system performance was simulated and verified by MATLAB software. The results indicate the ability and effectiveness of this method and led to closing a research contract with Tehran Electrical Distribution Company for pilot implementation of the plan in one of the passageways in Tehran.

INTRODUCTION

Street lighting is advantageous to the society in a variety of ways such as reducing night time car accidents and injuries, decreasing street crimes and vandalism, increasing the fear to commit a crime, popularizing public transportation, providing the possibility for nocturnal economic, educational and entertainment activities, facilitating rescue missions and enhancing closed-circuit television (CCTV) effectiveness [1]. Owing to the mentioned reasons, the timely repair and maintenance of the street lighting network is one of the major duties of the electrical distribution companies. Applying network connection abilities and automation to street lighting network and relying on weather condition data, traffic volume and other external parameters, we can control the brightness intensity of the lamps to decrease energy consumption. In addition, since the monitoring and tele-management systems constantly reports the system defaults, we will benefit from time-saving, less maintenance costs and higher system reliability. Monitoring of street lighting network is based on measuring the amperage of each lamp and comparing it with the pre-determined reference values. The data collected through power line communication are sent to the local controller and enables identification of the default in lighting network[2]. The figure 1 shows the components of a smart street lighting network.

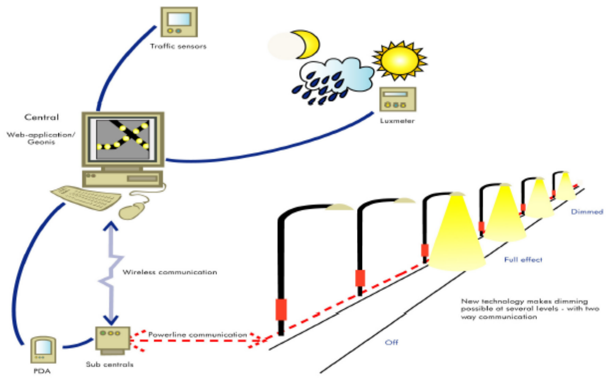

Figure 1 Components of a street lighting network monitoring and controlling system

The system described in figure 1, is completely operational and benefits from satisfactory flexibility. It can bring about considerable energy-saving by monitoring the defaults in street lighting network and controlling the lamp brightness intensity. However, since the major part of the current street lighting network is old and time-worn which belongs to 20 to 30 years ago, implementing the mentioned plan entails renewing most of the facilities and incurring high costs. Moreover, due to the complexity of the single line map of the low voltage lines and street lighting and feeding the lamps by different feeders and the necessity to install electronic ballasts with the ability to decrease brightness (dimming) and network ,controlling and measurement devices on each lamp post as well as the necessity to install current measurement instruments (Shunt Resistor, CT, Hall Effect Sensor) directly on the power distribution lines and the possibility of measurement instruments damages due to 2-phase power line, installing these facilities in some cases and is problematic and uneconomical. for monitoring of street lighting network and eradicating the defects has been already named, Also, decreasing installation and maintenance costs and providing a satisfactory economic justification, the plan of monitoring and remote sensing of street lighting network of Tehran Electrical Distribution Company using computer vision and image processing techniques for mechanized blackouts have been discussed. This method as no executive record. The schematic plan and main idea of the method is depicted in figure 2. To monitor the street lighting network for remote sensing and monitoring street lighting system, a network camera will be installed on an appropriate height from the related street lighting network area.

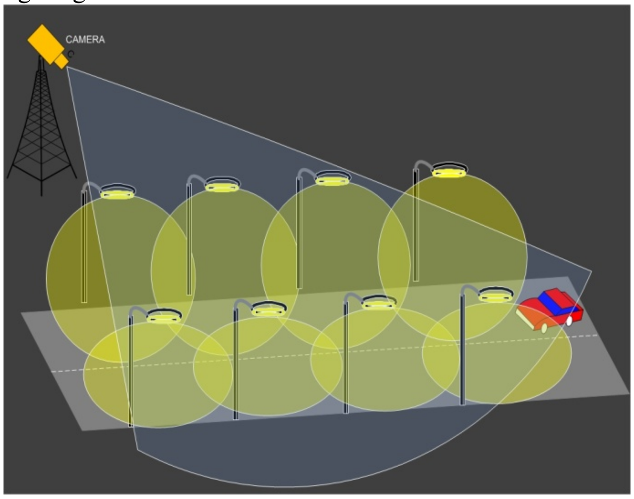

Figure 2 The main idea of monitoring and remote sensing of street lighting network using computer vision and image processing techniques

In this case, with selecting the location and using a lens with an appropriate focal length, the camera is able to imaging several kilometers of the depth and range of the street lighting network area. On November 30, 2012, in order to validate the algorithm in real conditions, the street lighting network of Hakim Highway-West was imaged by the low cost digital camera (Samsung ES30), from top of the Milad Tower, Tehran, in sever air pollution (while imaging from top of the Milad Tower with a height of about 380 meters, the temperature inversion and air stagnation phenomenon was felt and the temperature at the top of the tower was unexpectedly higher than its bottom). Irrespective of other lights in the image, remote sensing capability is provided for more than eighty one, 400-watt high pressure sodium vapor double-lights. The amateur camera equipped with a CMOS imaging sensor with high level of noise, temperature inversion conditions and air pollutant particles, all made the test conditions pessimistic with a high noise. Figure 3 shows the mentioned photo. The data obtained from imaging is given to computer and the matrix for the picture is formed. Intelligent software uses computer vision and image processing techniques as well as the geographical databases related to the street lighting posts, filters the other light sources present in the picture and recognized the location of the street lamp posts belonging to Electrical Distribution Company in the picture and examines them being on or off. Afterwards, a mechanized report about the blackouts of the street lighting network is issued. In the following parts of the article, the executive methods, image processing and

Figure 3 Imaging of the Hakim Highway-West at the top of the Milad Tower, Tehran, on November 30, 2012

Computer vision techniques as well as the related results will be discussed in detail. Moreover, the mentioned plan has been registered in Iran`s Organization of Inventions and Industrial Properties on July 8th, 2012 with the registration number 1404132.

THE PROPOSED METHOD

For picture shooting of street lighting network a network camera is used. This camera can be described as a combination of a camera and a computer in an integrated unit. The internal components of the camera include optical devices, image sensor, compression unit, operating system with the ability to connect to network, server, Web and FTP and other required facilities. Also, this camera does not need to be installed on a computer and can be connected to the network through IP independently and send the data to the target computer. Therefore, this camera is able to send pictures wherever there is a network based on IP whether wired, wireless or fiber optics. The visual data are digitally sent to the central processing unit through the telecom platform Point To Point Radio Link in an IP based network to transfer the picture of street lighting network, conduct the essential processes and recognize the blackouts. Block diagram of the executive method and the facilities used for transferring the picture by the above-mentioned method are depicted in the figure 4.

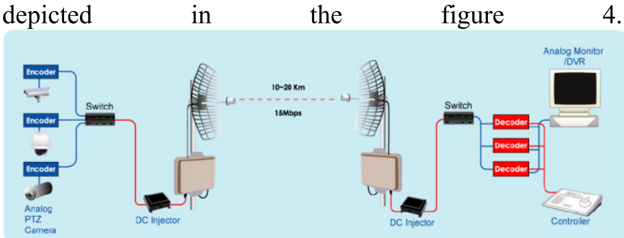

Figure 4 Picture transfer from camera to the central computer Point To Point Radio Link telecom platform

After picture shooting of the street lighting network, the data enter the central computer through telecom platform and will be analyzed by intelligent software using image processing techniques. The necessary reports are issued in a mechanized manner after information extraction. The figure 5 shows the general block diagram of the system. After the

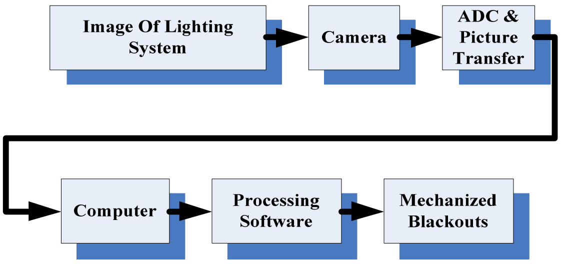

Figure 5 The general block diagram of the system

picture was received and entered into the memory of the central computer in form of RGB matrix, the phases below were designed and simulated in MATLAB software to detect the blackouts of the street lamps in the picture. Block diagram of the software components is depicted in figure 6.

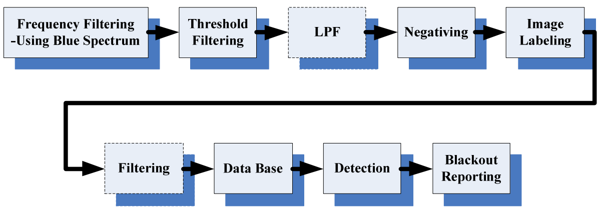

Figure 6 Block diagram of blackout recognition software in street lighting

According to proof of performance of image processing technique in the initial phase[3], in the development phase, to verify the suggested method, an example of an urban model, which includes streets and buildings and cars and lighting networks are designed in accordance with figure 7.

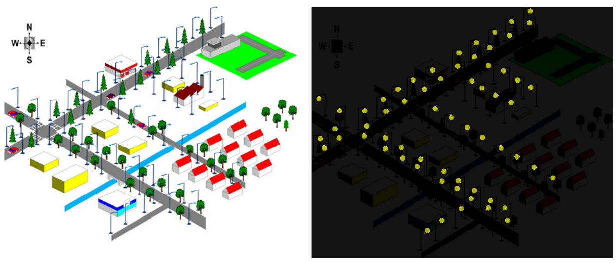

Figure 7 Urban simulation during the day and night.

Regarding the light emission curve of the street lights, if the camera is installed lower than the light fixture, it can film a wide area of the street lighting network of a highway. Also, with regard to the NON CUT-OFF luminaire caused by reflector design of the light fixture, some parts of the light produced by the lamp are emitted to the upper space of the luminaire. This phenomenon contributes to the monitoring and remote sensing techniques of street lighting network and enables imaging a wider area of street lighting network including several highways and streets by installing the camera higher than the light fixture. After image processing and detection of light spots in the image, 5 parameters (namely, starting coordinates X0, starting coordinates Y0, finishing coordinates X1, finishing coordinates Y1, and the number of pixels corresponding to each spot) are extracted by image processing techniques. Firstly, the algorithm performance is analyzed in laboratory conditions to prove its philosophy and efficiency. The algorithm is composed of two parts: 1-database preparation and 2-image analysis using the database. At the first stage after imaging the street lighting network and transferring images to a computer in order to prepare the database, given the light spectrum of high-pressure sodium lamps, which are widely used by power distribution companies to provide street lighting, and the tests made in this research project, the use of blue light spectrum eliminates most unwanted light sources and also make obvious light sources associated with high-pressure sodium lights in the image. The use of this frequency filter initially optimizes the algorithm and improves processing speed. Image processing is then performed on the lighting network image. After filtering out noise and improving conditions, the data for light spots is extracted from the image. Then, with approval of a system expert, the extracted data related to light spots of street lights for power distribution companies is stored in the database. The operation of storing information in the database is performed only once for each landscape of the street lighting network for calibration. Next, only the data of the database is read. In the second stage, the system continues imaging the street in specified time periods. In each cycle, the data of light spots in the image is extracted by image processing techniques and forms a special matrix. The matrix consists of 5 columns and some rows equal to the light sources detected in the image. Then, the first array stored in the database (which is related to one of street lights of the power distribution company in the image) is called and the Mean Square Error (MSE) is calculated for that array and all extracted arrays related to light spots. Finally, the Minimum of Mean Squared Error (Min (MSE)) is calculated for the first array in the database. This error measurement cycle is done for all arrays in the database and the error vector is formed. In ideal conditions, after imaging the street lighting network, if all the street lights whose characteristics are stored in the database, are normal and on, the resulting error vector must have an error of zero. In real conditions, the error value is practically zero for normal and on lights in the image. Then, using an adaptive threshold limit whose stimulation threshold level is set by a coefficient of the average error in the error vector or a coefficient of the standard deviation, it is possible to declare normal and defective lights in the image. Finally, a report is issued about off lights. Considering that this algorithm relatively evaluates the error of the data extracted from the image and the data stored in the database, and then uses the adaptive threshold limit to detect normal and blackout lights, it has a high stability against all types of noise, shake in the image, environmental pollution, weather conditions, and other factors causing damage to the image.

VALIDATION AND SENSITIVITY MEASUREMENT IN LABORATORY CONDITIONS

In order to validate the relative comparison algorithm against the database, Figure 7 (where all the lights are normal and on) is given to the algorithm. Then, Diagram 1 is produced as the software output.

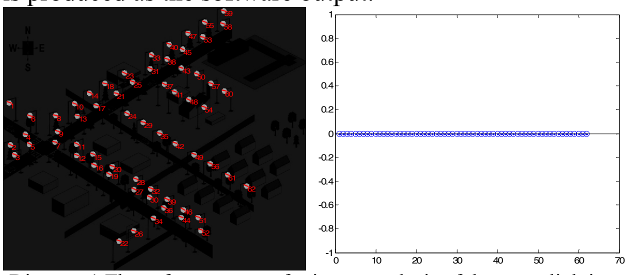

Diagram 1 The software output for image analysis of the street lighting network in ideal conditions

Given that the measured error is zero for all 62 street lights whose characteristics are stored in the database, according to the algorithm, it is inferred all the desired street lights are on, and referring to Figure 7, the algorithm and software efficiency and the report accuracy are confirmed. Diagram 1 shows that all the street lights stored in the database are reported in the output with an error of zero. But according to the algorithm, zero or small error for any light means the presence of that light in the image and also means it is normal. The Confusion Matrix method is used to evaluate efficiency, sensitivity and accuracy of the proposed algorithm. Table 1 shows the confusion matrix for the software performance, using Figure 7. Then, using the accuracy equation 1, the system's correct diagnosis was calculated 100%. 100% sensitivity means absolutely correct diagnosis of light sources, and perfect accuracy of the software failure report in laboratory conditions.

Table1 Formation of the confusion matrix in order to analyze the algorithm accuracy using the database in laboratory conditions

	-	+
False	FN=0	FP=0
True	TN=0	TP=62

$$Accuracy = \frac{FN+TP}{FN+FP+TN+TP} \times 100 = \frac{62}{62} \times 100 = 100\% \quad (1)$$

Next, to retest the software performance, two street lights in Figure 7 are turned off and the resulting image is applied to the software as input. By applying the image to the software, detection and extraction of the characteristics of light sources in the image is started and 60 light sources are detected in accordance with Diagram 2. Then, based on the proposed algorithm for relative comparison with the database, the software output is obtained, as shown in Diagram 2. Next, four street lights are turned off, and the software output is obtained, as shown in Diagram 3.

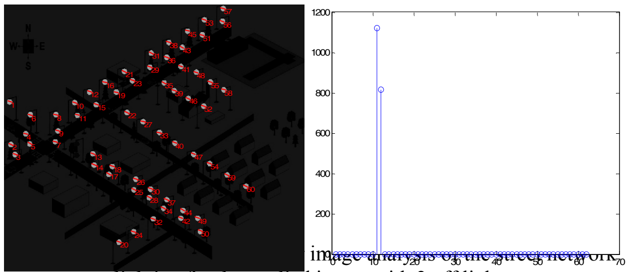

image analysis of the street network lighting for the applied image with 2 off lights

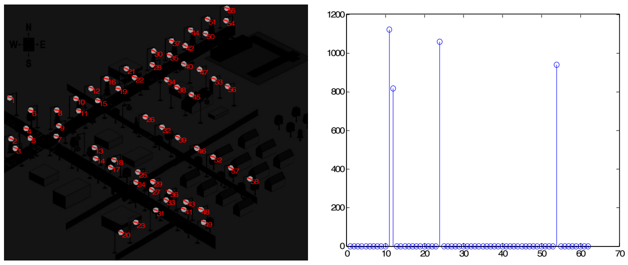

Diagram 3 The software output for image analysis of the street network lighting for the applied image with 4 off lights

Then, by applying the adaptive threshold limit, the maximum error points are detected in the output error vector. According to Diagram 2, Points 11 and 12 have the greatest error compared with other points and the average error. Based on the algorithm, Lights 11 and 12 are absent in the image, so they are defective.

CONCLUSION

This plan can be completely isolated from the street lighting power network and conduct monitoring and remote sensing of a large number of street lamps which are fed by different branches using camera and transfer data and image processing systems. Given that the performance of computer software and video camera is known as a Linear Time-Invariant Systems, decision-making based on relative comparisons with database in laboratory conditions will followed by a desirable result, it will have 100% sensitivity and accuracy in other conditions, and the result will be generalizable to other conditions. In the next phases of the project, other techniques will be examined for extracting data with high accuracy and increasing the reliability of remote sensing technique.

REFERENCES

[1] N. Smith, 2009, "Investing in street lighting; Investing in community infrastructure," Institution of Lighting Engineers (Midlands Region), UK.

[2] H. Walraven and E. As, 2006, "Market Assessment and Review of Energy Savings," e-street light, Norway.

[3] P. Najafi, 2012, "Monitoring And Remote Sensing Of The Street Lighting System Using Computer Vision And Image Processing Techniques" In IEEE 19th International Conference On Mechatronics And Machine Vision In Practice, Auckland, New Zealand.