New Approach for Intelligent Street Lights Using Computer Vision and Wireless Sensor Networks

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***Abstract*—Smart city is expressed in many different ways by people today. In recent years, smart cities and green technology have become one of the most important and promising items on the world agenda to prepare a better future. The concept of smart city has received great interest in the context of urban development policies. The goal of a smart city is to better use public resources while improving the quality of services provided to citizens while reducing the operational costs of public administration. In this study, wireless sensor networks for smart cities are developed based on smart street light applications. The street lights are equipped with wireless sensor kits to monitor the temperature, humidity and carbon dioxide information of the environment and to monitor the changes in the regions. In addition, the mobility of the environment is analyzed with the camera attached to each sensor kit. The sensor kit was developed using Raspberry pi programming card. A sensor kit for this card has been developed. A wireless sensor network has been created by adding Xbee wireless modules on the sensor kit. The obtained data is collected in a database. The collected data is displayed to the user through an interface.**

***Index Terms*-- Computer vision, Embedded software, Sensors, Smart devices, Wireless sensor networks.**

I. INTRODUCTION

The concept of smart city is a popular concept in many areas in recent years. With the development of smart homes concept of the Internet of objects, smart bus stops, street smart and intelligent system has been introduced in many of our lives. In the literature, the components of smart cities are given in Table 1 [1]. Smart cities increase people's quality of life and enable people to use technology more efficiently. Floating street lights are part of smart cities. Energy savings can be achieved with sensors integrated into the street lights [2]-[5]. Currently available street lights use only light sensor. In the event of air pollution, the light sensor activates the street light actively. In recent years, many sensors have been added, such as a motion sensor, as well as a light sensor in the street lights. If there is no movement on the street using the motion sensor, it is planned to save energy by reducing the light intensity of the lamp. In addition, wireless sensor nodes are placed on the street lights and the street lights are communicated with each other. This method allows multiple street lights to work synchronously with each other. There are many studies in the literature about smart street lights [5]-[12]. Pilar and dig. [5] offers an intelligent street lighting management system based on LED lamps. The approach based on wireless communication technologies minimizes the investment cost of traditional wired systems. He planned to reduce energy consumption by controlling the lighting system on the street. The architecture of the proposed system in the literature is given in Figure 1.

TABLE I. SOFT AND HARD COMPONENTS OF SMART CITIES IN LITERATURE [1].

Smart City Soft and Hard Components					
Soft Components				**Hard Components**	
Governace	**Economy**	**People**	**Environment**	**Mobility**	**Built Environment**
• Smart City Dashboard • Smart City Operations Center • City Maintenance • Participation in decision making • Public and social services • Transparent governance • Political strategies & perspectives • Environmental protection • Sustainable resource management	• NFC Services • Digital Signage • E-tourism • Connected Retailer • Innovative spirit • Entrepreneurs hip • Economic image & trademarks • Productivity • Flexibility of labour market • International embeddedness • Ability to transform	• Public Safety • Healthcare • Education • Social Activities • Quality of life	• Attractivity of natural conditions • Pollutions	• Smart Parking • Fleet Management • Intelligent Transport System • Traffic Management • Community Biking • Electric Vehicles Infrastructure • Smart Taxi	• Smart Building • Smart Grids and Smart Meters • Smart Lighting • Waste Management • Water Management • Noise Detection

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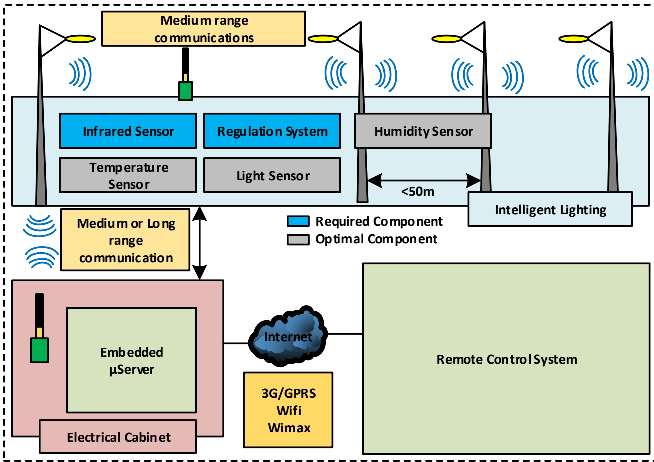

Figure 1. The architecture of the proposed system in the literature [5].

Yusoff and dig [6] developed a wireless sensor network-based method to save energy from street lights in Malaysia. In the developed method, nodes were created using wireless sensor networks. These nodes are mounted on every street light and street lights are communicated with each other. Using the information from the motion sensors in the street lights, the light intensity of the street light is adjusted by the PWM method. Thus, it is aimed to consume less energy. Labu and dig [7] are doing street light control for intelligent cities using autonomous network sensors. The sensors installed on the street lights enable the street lights to operate according to the traffic intensity on the streets. Mohapatra and dig [8] used solar systems for street lights. The solar module for street lights was developed to illuminate the street lights with solar energy. Yoshira and Dig [9] proposed a sensor network-based method for smart street lights. The proposed method uses Zigbee wireless communication modules to communicate between street lights. It uses motion sensor and light sensor on street lights. Lukkien and Dig [10] have developed a long-term data collection system for dynamic street lighting.

In this study, a wireless sensor network based method was developed for smart street lights. Temperature sensor, moisture, carbon dioxide sensors are used in the sensor node designed for street lights. In addition, camera movements are analyzed by placing a camera at the sensor node. In the node structure developed using the Raspberry pi programming card, the data from the sensors and the camera are processed and transferred to the next node. The information from the nodes is stored in a common database via the coordinator node. As a result of this process an interface is created and the data taken from street lights are analyzed and shown on a map.

II. PROPOSED METHOD FOR SMART STREET LIGHT

In this study, a sensor network is created and the data from the sensors are collected in a database. The sensor kits are used with the Raspberry pi programming card. The sensor module is added to the Raspberry pi programming card to receive data from the sensors. Accepted data are collected at a center via Xbee module. There is also a camera in each sensor node. Real-time images are taken from the cameras to determine the motion in the image. The motion intensity in the environment is calculated and transmitted to the database via Xbee modules. The database contains node information, sensors connected to each node, and camera information. Numerical data received from the sensors and camera at specified intervals are written in the database. Users can observe the sensor nodes on the map and the data from these sensors. In the proposed method, the architecture of the system is given in Figure 2.

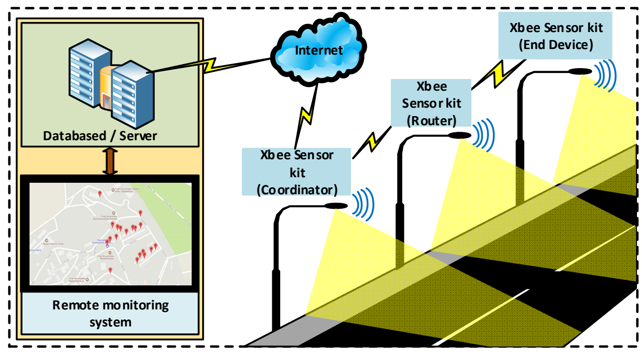

Figure 2. Architecture of the proposed system

In the architecture of the proposed method shown in Figure 2, there are three different sensor kits. The "End Device" module allows the transmission of data from the sensors to the "Router" mode. The "Router" module transmits the data received from the sensors on its own and the data received from the "End Device" modules to the "Coordinator" module. The "Coordinator" module transmits both the data from the sensors on its own and the data from the "Router" modules to the database on the server via the internet. The structure of each sensor module used in the proposed method is shown in Figure 3. The proposed method uses a humidity sensor, temperature sensor, carbon dioxide sensor and usb camera.

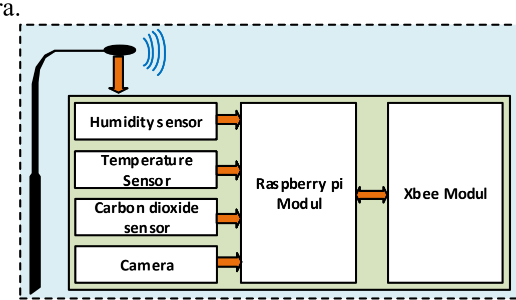

Figure 3. Structure of each sensor module used in the proposed method

A. Wireless Sensor Networks

In this work, wireless Xbee modules are used to create sensor nodes. Wireless sensor networks are one of the most impressive technologies in the industry [13]-[15]. Wireless technologies such as "Bluethooth" and "WiFi" operate at low bandwidth. Such technologies do not fully meet the demands of industry applications. For this reason, ZigBee technology has emerged in recent years. Zigbee technology is used as one of PAN (Personal Area Networks) networks using IEEE 802.15.4. ZigBee technology uses four basic topologies: Peer-to-Peer (P2P), Star, Mesh, and Cluster Tree. Because the ZigBee Alliance follows a configuration based on IEEE 802.15.4, the first two layers have not changed much. ZigBee uses the beacon technique of the IEEE 802.15.4 standard, which means that a node always sends small packets to its neighbors stating that it exists on the network. If two or more nodes are connected in a network form, then they can be interleaved by other nodes. ZigBee runs over the "routing discovery" protocol. The node in the ZigBee network is designed to be a battery-powered or sleep-worn structure capable of saving energy, searching for existing networks, transferring data as needed, defining data availability, requesting data from the network coordinator. An exemplary ZigBee network model is shown in Figure 4.

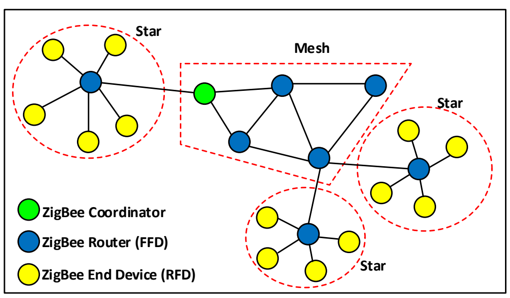

Figure 4. An example ZigBee network model

B. Vision Based Motion Analysis

In this study, there are cameras in real-time employees developed sensor node for street lights. The cameras are mounted on the Raspberry pi programming card to detect movement on real time images. Raspberry pi is a low-cost mobile computer that has an operating system on it and is used for many purposes [16],[17]. The flow chart of the method developed for motion detection is given in Figure 5.

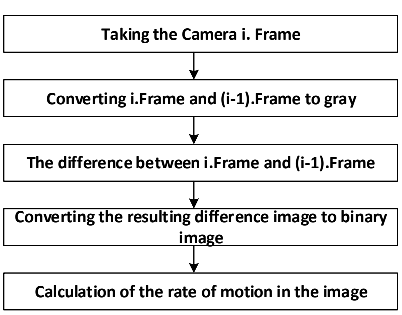

Figure 5. Proposed method for motion detection

In this study, frame difference method is used for motion detection. In this method, the previous frame is always selected as the background from the frames belonging to the image [18]. If the difference between these two frames is above a certain threshold value, it is perceived as motion. In this study, motion intensity is calculated by transforming the difference frame determined by frame difference method into binary form. The difference density is obtained by dividing the number of white pixels on the difference image by the total number of pixels. The frame difference method is tested by taking 3500 frame images on a sample video. In Figure 6, motion intensity is calculated by applying the frame difference method on the sample images.

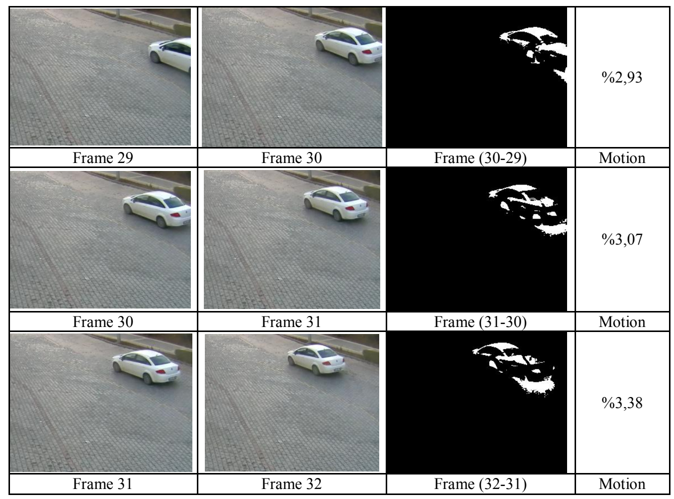

Figure 6. Application of frame difference method and calculation of motion intensity on sample images

The motion intensity graph obtained by applying the frame difference method on approximately 3500 frame images on the sample video is given in Figure 7.

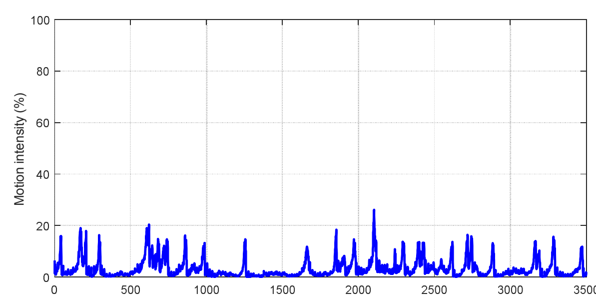

Figure 7. Calculation of motion intensity using frame difference method on sample video

In the graph shown in Figure 7, daily routines were obtained from a region used by cars and pedestrians. The graph in Figure 7 has a normal motion intensity. If the movement intensity is high, there is a lot of movement in that area. Thus, intelligent street lights provide information about the environment by calculating the intensity of the motion in the street in real time.

III. EXPERIMENTAL RESULTS

Three temperature sensors, three humidity sensors, three carbon dioxide sensors, three cameras, three wireless Xbee modules and three Raspberry pi programming cards were used in this study. The properties of the devices used are given in Table 2.

TABLE II. GENERAL PROPERTIES OF THE DEVICES USED IN THIS STUDY

Devices	Properties
Raspberry pi	• Broadcom BCM2836 ARMv7 Quad Core SOC • 900 MHz Processor Speed, 1 GB RAM • 10/100 Ethernet RJ45 jack, 4 x USB2.0 port • Video/Audio Output: HDMI ve 4-kutup 3.5mm connektor • 40 Pin GPIO, 27 x GPIO, UART, I2C, SPI - 2 CS • 3.3V, 5V, Ground • Windows 10, Raspian, Debian, Fedora, Arch,…
Xbee	• 3.3V @ 45mA, 250kbps max data rate • 1mW RF Output power (+0dBm), 100m range • 6 10-bit ADC input pin, 13 dijital I/O pin • 128-bit encryption, AT or API support
Camera	• CCD sensor size: 1/4 inch • The camera operating voltage is 3-5V. • Focus distance: 6mm (adjustable) • Viewing angle: 75.7 degrees • Resolution: 1080p
Temperature Sensor, Humidity Sensor	• Low energy consumption: 80uW (@ 12bit, 3V, 1 measurement / sec) • RH operating range 0-100% RH • Temperature operating range -40 - +125 C, RH response time 8 sec.
Carbon Dioxide Sensor	• Operates with 5V voltage • Digital (TTL level) and analog outputs.

A PCB module has been developed to connect the sensors and Xbee module to the Raspberry pi programming board. The use of the developed PCB module with the Raspberry pi programming card is shown in Figure 8.

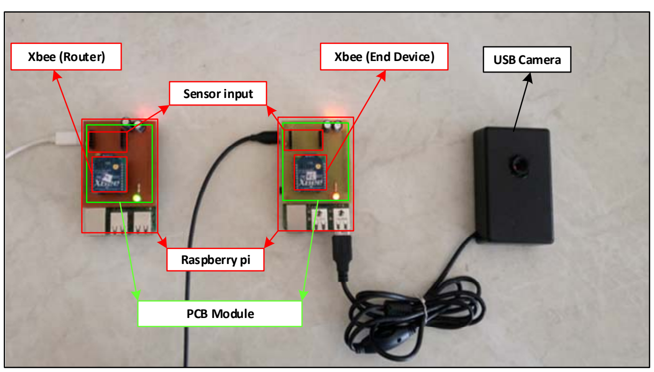

Figure 8. Use of PCB module with Raspberry pi programming card

Figure 8 shows the PCB modules developed for the experimental setup. The PCB modules connect the sensors and Xbee modules with the Raspberry pi programming card. In Figure 8, the image obtained from the USB camera is processed on the Raspberry pi module and motion detection is performed. "Python" is used for motion detection on Raspberry pi. The motion intensity information is transferred to the "Xbee (Router)" module via the "Xbee (End Device)" module. In the "Xbee (Router)" module, all data coming to it is transferred to "Xbee (Coordinator)" mode. "XBee (Coordinator)" module is connected to the Internet. All the data from the "Xbee (Coordinator)" module is transferred to the server along with the "Xbee module id" information. The data transferred to the server is stored in the database. By creating an interface on the server, the locations of the sensor modules are marked on the map. The sensor modules are shown on the map as in Figure 9.

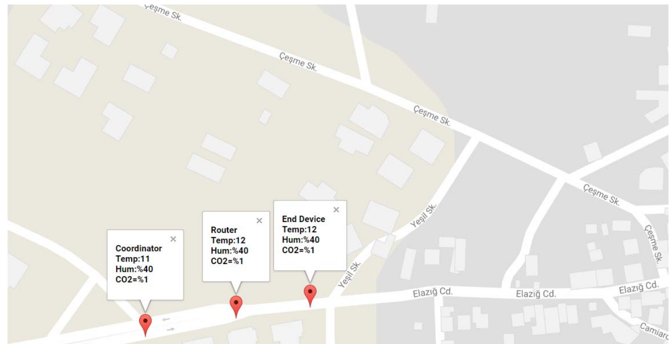

Figure 9. Display of sensor modules on the map

As seen in Figure 9, the data from the sensors is displayed on the map. The time to refresh the data on the map is 30 seconds.

IV. CONCLUSIONS

In this study, an application of wireless sensor network base for smart street light was developed. In the developed application, temperature, humidity, carbon dioxide value and motion intensity in the environment are monitored by taking images from both sensors and cameras. According to the obtained data, weather conditions and traffic density in a street or in the neighborhood can be monitored. This work is a preliminary work for using smart street lights as a sensor network. There is no cost of wiring due to the wireless operation of the developed method. Only three wireless modules have been developed and tested in the proposed method. Next time, a professional monitoring interface will be developed to monitor data from wireless sensors more appropriately. It is an advantage of this study to be used in the camera when only data from the sensors are taken in studies in the literature. The availability of cameras in wireless sensor modules further increases the importance of this work. Many different applications can be done by developing image processing algorithms on Raspberry pi programming card. Raspberry pi modules thus developed can be used for many purposes.

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