

Development and Experimental Investigations of Motion Detection Module for Smart Lighting System

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Abstract. This work considers motion sensors as parts of the smart lighting system on basis of Beaglebone microcomputer. Detection system is designed for the smart lighting system. Experimental investigations of the detection system were made with different motion sensors. Based on the results comparative analysis was performed and optimal conditions for the detection system operation were found.

1. Introduction

Modern city lightning systems have raised requirements to energy conservation and resource efficiency due to growing power consumption for city lightening. Smart lightening systems meet such requirements.

Advantages of the smart lightening system over ordinary one:

- standard lightning systems have preset lightning time which does not depend on actual daylight hours and weather conditions that is solved by the smart lightning system that uses this dependence and assumes necessary measures;

- switching universally used lightning systems on and off do not depend on the presence of pedestrians and moving vehicles resulting in pointless energy consumption during long period of time [1–5];

- smart lightning control systems in contrast with ordinary ones monitor current status of each LED lamp and transfer information to the server that provides more efficient operation and timely failure removal;

- hardware could be easily updated in accordance with installation location of the smart lightning system — busy highways, quiet suburban streets or city part alleys;

- as smart lightning systems presuppose continuous monitoring and prompt troubleshooting that provides constant streets lighting and consequently influences on road safety [6].

To control smart lightning systems there are integrated systems that control lightning level, process sensor data signals and control communication with each other. Type of used sensors determines composition and functioning of the whole system as a sensor data signal ultimately indicates about the need to adjust lightning that is performed by the feedback of the majority of system units.

2. Smart lightning system structure

Lightning system is a combination of a central device and connected to it street LED lamps (figure 1).



Beaglebone microcomputer acts as a central control device. Each lamp applies to communication and detection system. First one serves to connect a lamp with Beaglebone, the second – to detect a monitored object (a pedestrian/moving vehicle passing by). When a pedestrian enters the monitored area and consequently when the sensor detects him/her a signal comes to Beaglebone that in turn switches the most neighbouring to the pedestrian LED lamps.

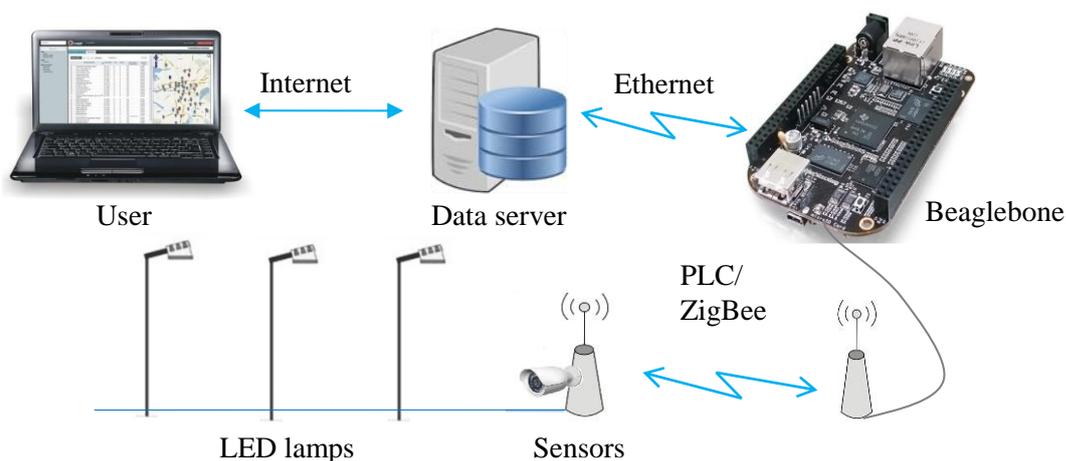


Figure 1. Smart lightning system structure.

Software components are used in accordance with hardware. Developed program runs on Beaglebone that sends appropriate control signals to lamps. The complexity of it consists in creation of a reliable method of this or that object sensing. Such challenge is caused by the level of the design of motion sensors used in lightning systems. Currently they are often activated falsely or are not activated wrongly and also go off when the monitored object stops. Solution for this problem may be found with combined sensors and perfect algorithms for processing data.

Communication between LED lamps and microcomputer is provided by the power line communication (PLC) technology or ZigBee wireless technology.

PLC communication center should be capable to transfer data on LED condition, voltage, current strength, consumed power, capacity with transmission facilities using protocol ANSI/EIA 709.1 [7 – 8].

In comparison with PLC ZigBee protocol allows to avoid pauses in operation and fails caused by noise and signal attenuation using wireless signal transmission. This protocol is based on standard IEEE 802.15.4 and has following features: low price, low power consumption, high reliability [9].

All data on events taking place in the lightning system after processing come to the database server and are delivered to a dispatcher.

3. Experimental unit

The most widespread motion sensors used in smart lightning systems are radio-wave, infrared, ultrasonic and combined.

An experimental unit was assembled. It included detection system of the smart lightning system (figure 2). Its main components are BeagleBone Black microcomputer, infrared sensor DP104, ultrasonic sensor SRF08, combined sensor Sockol-3, power supply unit with outputs 5V, 12V.

Microcomputer BeagleBone Black. Microcomputer BeagleBone Black is used as a control unit that performs a program of information readout from sensors. BeagleBone Black specifications are presented in table 1 [10].

Infrared sensor DP104. Specifications of DP104 infrared sensor are presented in table 2.

Ultrasonic sensor SRF08. SRF08 Ultrasonic sensor connects BeagleBone Black microcomputer with a serial data bus I²C.

In the beginning microcomputer initializes address of the sensor connected through the protocol I²C [10]. To scan the monitored area with the sensor requires a command that sends certain value to the command register SRF08. The next step is reading out data from sensor registers. Data are received in hexadecimal format and carry information about distance to the object in cm. Features of SRF08 ultrasonic sensor are presented in table 2.

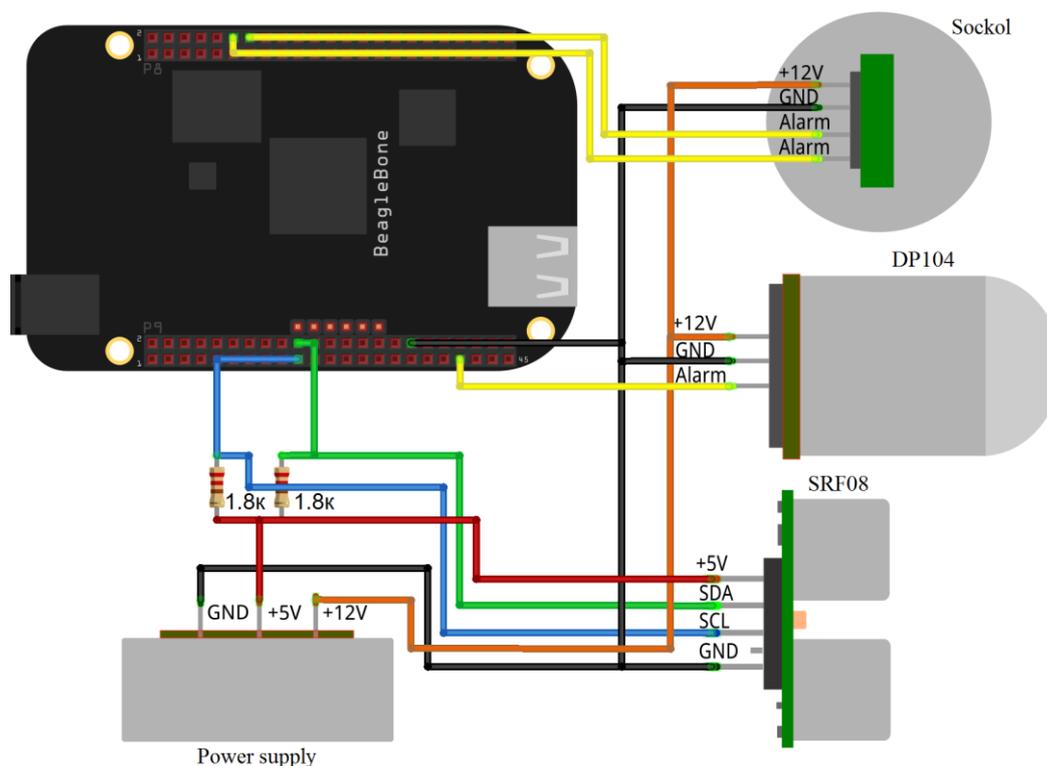


Figure 2. Experimental mock-up.

Table 1. Specifications of BeagleBone Black.

| | |
|----------------------|---|
| Processor | 1 GHz AM335x |
| Memory | 512 Mb DDR3 (faster 1.6 Gb/s and lower power) |
| Storage | On-board 2 Gb eMMC (4 Gb eMMC on the Revision C board) and micro-SD card slot |
| Video | On-board HDMI |
| Debugging | JTAG header present but not populated |
| Serial Connection | TTL header present but separate cable needed |
| Input/Output Headers | GPIO, analog outputs/inputs, 5 V, 3.3 V, 1.8 V power supply, timers, buses: I ² C, UART, CAN, SPI, GPMC, MMC, LCD, McASP |

Combined sensor Sockol-3. When a person enters the detection area both detection channels go off (in any consequence). At the same time an alert is produced by breaking output relay contact.

Table 2. Specifications of sensors.

| | | | |
|---------------------------|---|--|--|
| Type of sensor used | DP104 | SRF08 | Sockol-3 |
| Voltage | DC 12 V | 5V | 10..15V |
| Current | - | 15mA Typ. 3mA Standby | 30mA |
| Working range | 6-10 m | 3 cm..6 m | 5...10m |
| Working temperature range | - | - | -30..+50°C |
| Additional information | time setting: 5s~6min, lux setting: 2~2000 lux | connection: standard I ² C bus | Microwave, infrared types of sensors combined |

Sensor continually monitors interference signaling environment in protected room: if interference level through one of channels exceeds tolerable, sensor automatically changes the detection algorithm. The sensor operates during 2 minutes subordinate to the changed algorithm, in 2 minutes it returns to the basic detection algorithm and the cycle begins to repeat. Transfer to another algorithm is indicated by the green light. If operating sensor receives an alert by the detection algorithm in conditions of increased interference, immediately after its termination the sensor returns to the basic detection algorithm.

Specifications of Sockol-3 combined sensor are presented in table 2.

4. Experimental results and analysis

Main aim of experimental investigations of motion sensors is comparative analysis of existed sensors, determination of optimal conditions for the use in the smart lightning system on the basis of BeagleBone Black microcomputer.

C++ based program was designed. It allows receiving information about sensor actuation at a motion in the sensors' control area.

Examination of sensor sampling results in choosing typical devices from each category that were previously presented and used in the experimental unit. For motion sensors of different categories a chart is built to show areas of their coverage determined by an experiment (figure 3). An experiment was performed in the area covered by all involved sensors. Its aim is to detect response of each sensor to pedestrian's motions.

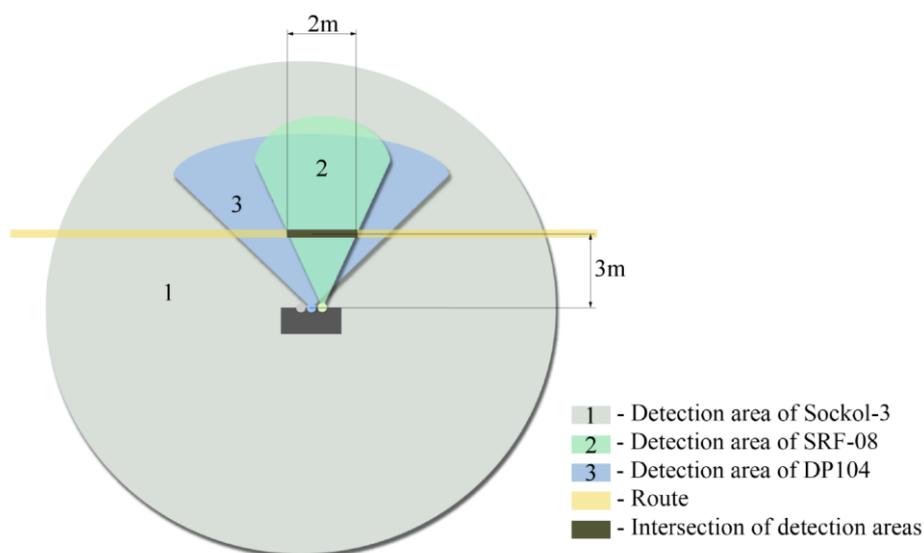


Figure 3. Detection areas of motion sensors and experimental conditions.

Detection of sensor response to pedestrian's motions was in 3 meters from sensors' location. Measurement data are presented on figure 4. Pedestrian motion distance in the area of all sensor intersection is 2 meters, at that distance for Sockol-3 and DP104 is two times longer.

In the course of measurements it was determined that the fastest response time appertains to ultrasonic sensor SRF08 that is second splits. Delay when a pedestrian enters the controlled area is typical for a infrared sensor and a combined one. It is 0.5 second. At that a delay after pedestrian leaving the controlled area is 5 seconds for DP104 and 0.5 second for Sockol-3.

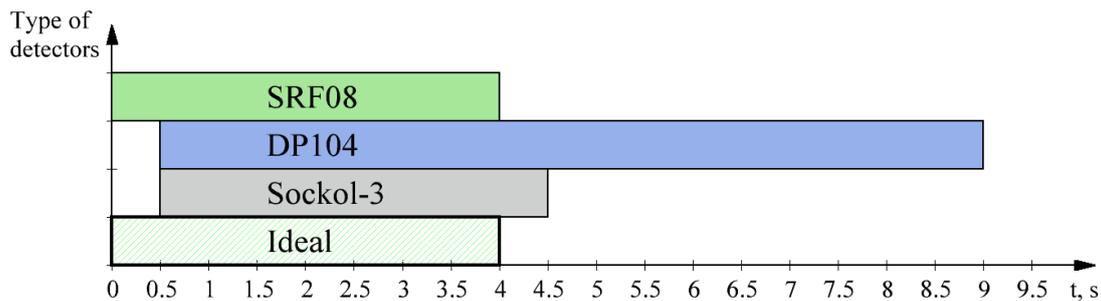


Figure 4. Detection areas of motion sensors and experimental conditions.

According to the results presented on Figures 3 and 4 we can conclude that combined type of sensors is the most optimal option for the use in smart lightning systems. The use of ultrasonic sensor in such systems is hardly possible due to the small angle of sensor action. More than that, this type of sensors has a high price in comparison with others. Also it is possible to use an infrared sensor in smart lightning systems as it has a great angle of action; however it is characterized by a bigger delay in response time.

5. Conclusion

In the course of made investigations different types of motion sensors were analyzed. The most optimal pair of sensors was determined for the use in the smart lightning system. It is realized in the examined combined sensor. The use of combination of detection methods allows increasing accuracy and sensitivity of the lightning system operation.

Diagrams and algorithms of sensor connection to the Beaglebone Black microcomputer were worked out. They have become a basis for an experimental mock-up. Investigations of different sensor types' sensitivity were made. A chart showing coverage areas of examined sensors was built.

Results of this investigation are planned to use in creation of pedestrian motion algorithms in areas of smart lightning systems installation in Tomsk. More than that, the system of communication between LED lamps and control units in the smart lightning systems will be worked out on the basis of the received data.

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