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Development of an Automated Lighting Control System Based on Machine Vision and Wireless Communication Channels

[1]Dmitry Alekseevich Ivanov, [1]Marat Ferdinantovich Sadykov, [1]Ibragim Amirovich Murataev, [1]Danil Aleksandrovich Yaroslavsky, [1]Mikhail Petrovich Goryachev, [1]Azat Robertovich Gainutdinov, [1]Anatoly Alekseevich Naumov and [2]Rustam Shaukatovich Misbakhov
[1]Federal State Educational Institution of Higher Education, "Kazan State Power Engineering University", Krasnoselskaya St. 51, Kazan, Russian Federation
[2]KNRTU-KAI, 10, K.Marx St., Republic of Tatarstan, 420111 Kazan, Russia

Abstract: The study describes operation of the test site control system designed to create a comfortable light environment and monitor lighting characteristics of an artificial lighting system with power supply from renewable energy sources in order to ensure a high level of energy efficiency. The test site is intended for testing and debugging software for Wireless Industrial Automation Network (WIAN) modules, debugging and adjustment of functions of local and remote site control using the wireless industrial automation network modules, debugging and adjustment of self-diagnostic functions for wireless industrial automation network modules and their communication channels. Wireless industrial automation network modules having a possibility to interact with Bluetooth, Wi-Fi, PLC, Ethernet , USB, RS- 485, IrDA communication protocols are designed to monitor conditions of objects, enterprise and public buildings automation by means of information gathering and transmission from external sensors, automatic data broadcasting, etc.

Key words: Wireless interface module, module line, wireless network, automation system, set of parameters, data transmitting method, test site

INTRODUCTION

Provision of high light quality and comfort as well as energy efficiency by reducing energy consumption, in comparison with analogues, are the main objectives in the design of lighting control systems (Ivanova and Sadykov, 2014; Ivanova *et al*., 2014).

Lighting fixtures suitable for regulation can be directly controlled or equipped with auxiliary sensors or devices (Kopylov *et al*., 2015). By the method of obtaining and reaction to information from auxiliary sensors, lighting systems are divided into:

- Lighting control system based on the use of light and presence sensors
- Local lighting systems which do not have a function of integrating into the organization management system
- Control system which enables to receive information from motion and light sensors automatically

The disadvantage of the first two systems is that they work in the form of additions to a traditional lighting, i.e., they control and set lighting in fixed predetermined points where sensors are positioned that gives a small efficiency gain. The latter are more sophisticated; they will not only react to external events, but are also characterized by a certain "awareness" of their user, lighting conditions and the type of lamp (Kopylov *et al*., 2015).

Currently existing artificial lighting systems are not economically effective. As a rule, they are controlled manually. Continuous rise in energy prices generate a need for finding another sources of energy or to develop new approaches to control and optimization of energy consumption.

MATERIALS AND METHODS

Method of the control system operation: The novelty of the proposed project is in the fundamental structural and conceptual differences from existing analogues. The energy-efficient LED lighting fixtures are selected in the capacity of light sources here. Lighting control system constantly monitors the light environment and makes its own decisions working with embedded algorithms (Kopylov *et al*., 2015; Reshetnikov *et al*., 2015).

Corresponding Author: Dmitry Alekseevich Ivanov, Federal State Educational Institution of Higher Education, "Kazan State Power Engineering University", Krasnoselskaya St. 51, Kazan, Russian Federation

The test site consists of a control system, lighting fixtures and wireless industrial automation network modules. Each lighting fixture shall be equipped with a controllable power unit, be connected with the wireless industrial automation network module and is the terminal device of the test site (Safin *et al*., 2015).

All terminal devices of the test site for debugging a software of wireless industrial automation network modules are made being capable for operating in production networks and public building networks under standard conditions of background radio emission and a relative humidity <80%; providing current consumption of wireless industrial automation network modules in the receive mode not >200 mA, in transmission mode no more than 300 mA and in the sleep mode 10 mA and radio channel rate up to 40 kbit/sec for data transmission from the object of control/regulation. The control system includes the fundamental blocks of the program:

- Sensor data reading block
- Fast information processing and displaying block
    - Sensor data viewing and analyzing
    - Various information and artistic items animation
    - User requests
    - Lighting calibration
    - Setting a particular lighting fixture brightness
    - Setting brightness for a group of fixtures
- Slow communication unit with parallel ports
    - Network inverter data reading
    - Illumination feedback
    - Sending commands on fixtures brightness to the wireless industrial automation network module (Misbakhov *et al*., 2015a, b)

After activation, the control system scans a working surface. Scanning is carried out with the sensors: motion and light sensors, digital tracking video cameras and other. The controlled parameter is the floor surface illumination. Information on ambient light enters the computer where it is processed and saved in memory. According to the algorithm embedded in the computer, the system makes a decision and provides control signals to the respective peripheral devices, thereby controlling the power mode of selected lighting fixtures. The complex constantly monitors the illumination level of the working floor surface. Ongoing changes in the light environment caused by movement of people and various objects in the surveillance area cause the appropriate response of the automatic control system. Information about the current status of lighting fixtures and light environment is supplied to a monitor in the form of characters and graphics (Misbakhov and Moskalenko, 2015).

Analysis of the sensor data passes individually from each lighting fixture in turn. A user can perform their calibration and at this point current illumination value for the lighting fixture becomes a mid-point toward which the system tends. That is, if the current luminance would change, a lighting fixture brightness will change too, as long as the illumination is not within the mid-point. Thus, negative feedback is carried out.

RESULTS AND DISCUSSION

As a result, we have developed a software shell for the test site control system. The control system is a software and hardware system which provides receiving and processing serial data packets from experimental wireless industrial automation network modules compatible with the hardware protocol of universal asynchronous receiving and transmission.

The blocks for data reading from the sensors, sensor data viewing and analysis, illumination feedback and sending commands depending on brightness of lighting fixtures to wireless industrial automation network modules operate for lighting control. The blocks for data reading from the inverter through the network are necessary to display information about operation of the test site electrical grid.

A smart camera can be used in the capacity of a sensor in the system. Cameras record the image data in two types of variables. The first type is the image diminished according to the principle of averaging nearby pixels of a certain radius; they are called IMAQ in the program. The second type of variables is the coordinates of the area in which there was a movement; they are called Objects in the program. The block for data reading from a smart camera uses a communication function with the network variables (Fig. 1). Block's operation can be divided into the following steps: collection of variables' addresses, opening the variables, reading the variables, closing the variables. Collecting addresses and opening the variables are carried out once at the start of the program. Reading the variables is carried out within the WhileLoop along with the rest of the blocks and when the program is stopped, the closing of the variables would be activated. WhileLoop runs at a speed which was set by WaitUntilNextmsMultiple subroutine.

Iterations within the fast data processing and display unit occur once every 200 msec as opposed to the slow data processing and display unit that runs once a second.

The block WhileLoop operates in a cycle where EventStructure is available in turn. Input to the cycle is an array with references to indicators of video cameras and function IMAQ Create which initializes an image which

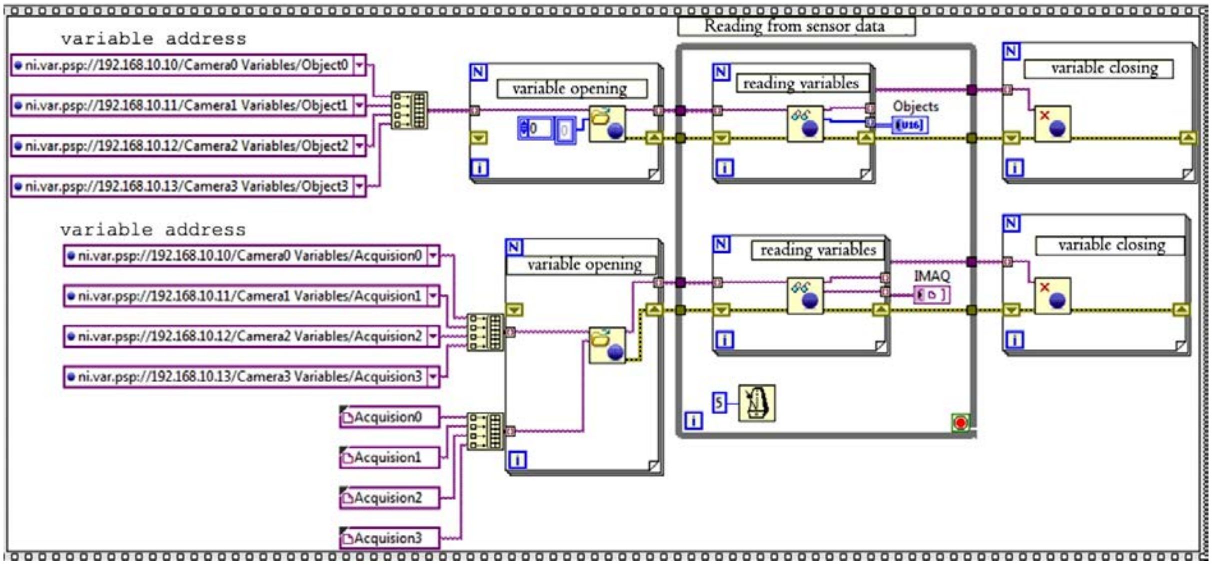

Fig. 1: Sensor data acquisition diagram

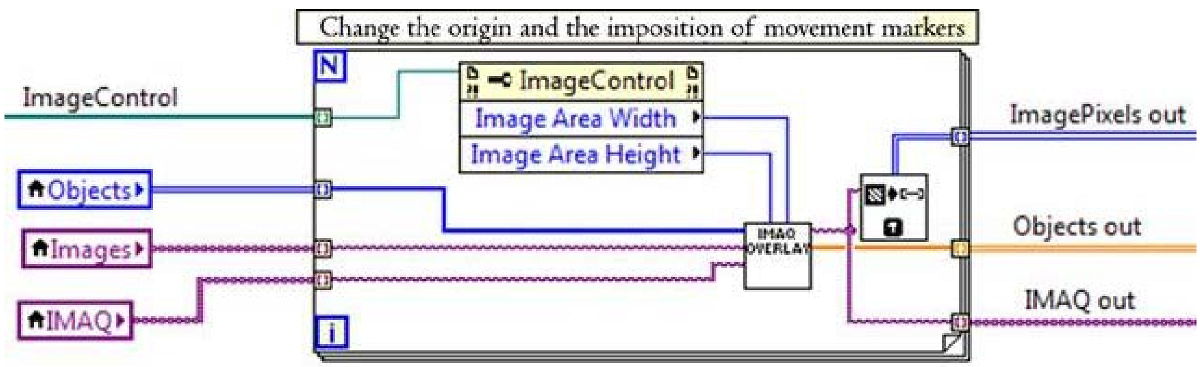

Fig. 2: Change the origin and the imposition of movement markers

will then be used as a scheme of the entire hall. EventStructure was chosen because the block under consideration processes user requests and EventStructure is well suited for this purpose. The Event Structure has four tabs: Timeout, Calibrate, One lighter and Group light mode. In the timeout window there are carried out such functions as viewing and analysis of images from cameras and animation of various information and artistic items. Timeout tab is activated regularly with some periodicity. In the other tabs the following functions are performed on the user's request:

- Calibrate: Calibration of lighting
- Onelighter: Setting a specific lighting fixture brightness
- Grouplightmode: Setting brightness for a group of lighting fixtures

Let's consider events in the Timeout tab, in the block for viewing and analysis of images from the cameras; they occur at intervals of 200 msec. Firstly, it displays the areas of movement, changes of coordinates and overlaying markers.

This is the first block where data received from smart cameras are processed. First of all places should be marked where a motion has occurred, but the coordinates of moving objects do not match the coordinate system, so the data pass through the change of origin and the subsequent imposition (Fig. 2).

The block input data are the previously obtained IMAQ and objects as well as collected initialized Images. The input data are arrays and each array consists of four elements from the four cameras, so the further cycle For Loop is performed 4 times.

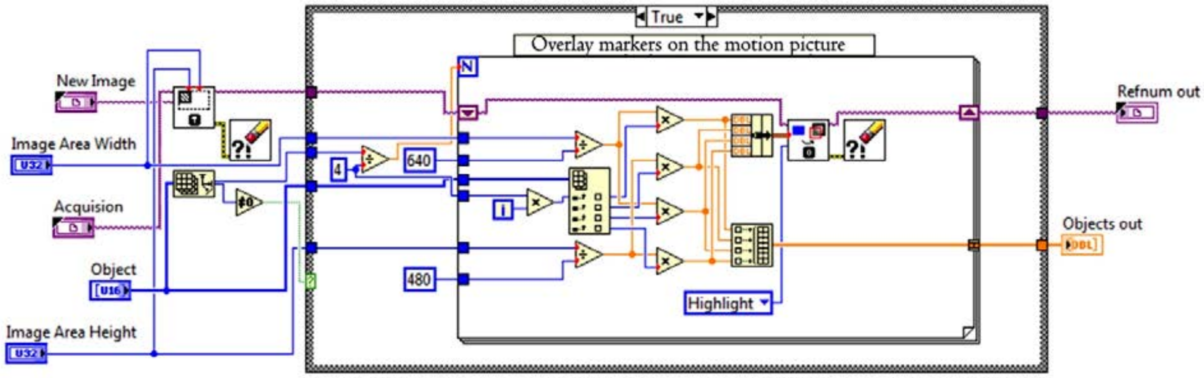

Fig. 3: Block diagram for overlay.vi. the subroutine performs a change of coordinates of moing objects and overlaying appropriate markers in the new coordinates

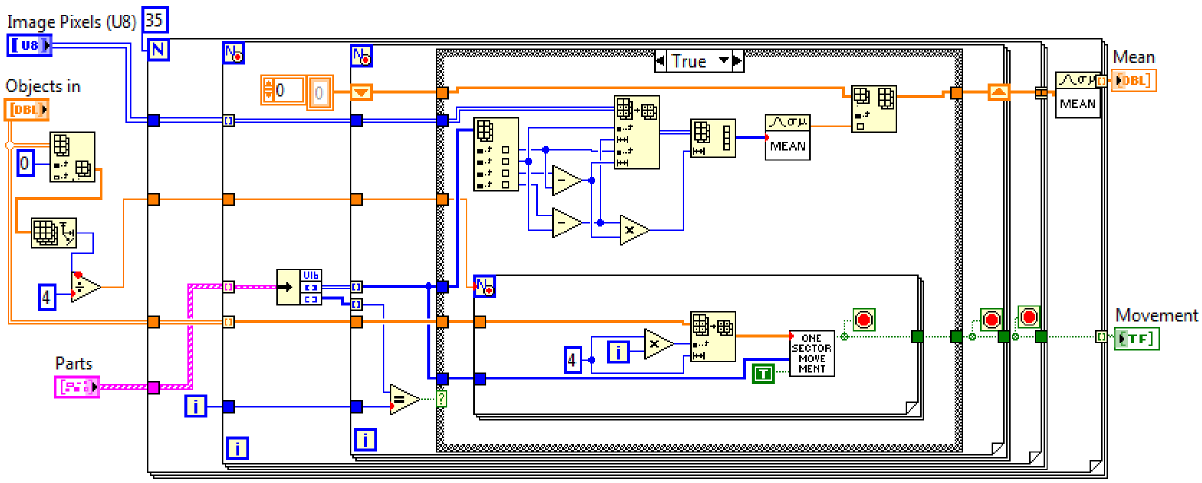

Fig. 4: Mean move.vi for calculation of mean luminance and availability of motions within the area under the lighting fixture

In the cycle, the following actions are performed. Property Node sends the height and width values from the four indicators which display video from the cameras. These values continue to be needed in a subroutine overlay.vi (Fig. 2 and 3). Overlay.vi is a subroutine which itself performs a change of coordinates and overlaying a marker to a particular image.

The second step is the calculation of mean luminance and presence within the movement area under the lighting fixture in the subroutine "mean move.vi" (Fig. 4).

Video streams IMAQout are separated for each camera. Subroutine "showmovement.vi" on the hall scheme "Hall" shows the deviation from the mid-point and the sector in which there was a movement (Fig. 5).

The input data for the subroutine: ZigBee modem the port number to which the wireless industrial automation network module is connected:

- Lamps: the number of the selected lighting fixture
- Brightness: the brightness level in percent
- Errorin sends error information

The output parameters of the subroutine are:

- ZigBee modem out repeats ZigBee modem
- Connectionerror: announces that there are problems with the connection
- Errorout: reports the error number

Slow block is executed in parallel with the fast block, but with a rate of once per second. The block consists of a "While Loop" cycle in which there are two main processes: collection of data on the power supply of the inverter and issuing commands to lighting fixtures according to the current brightness level.

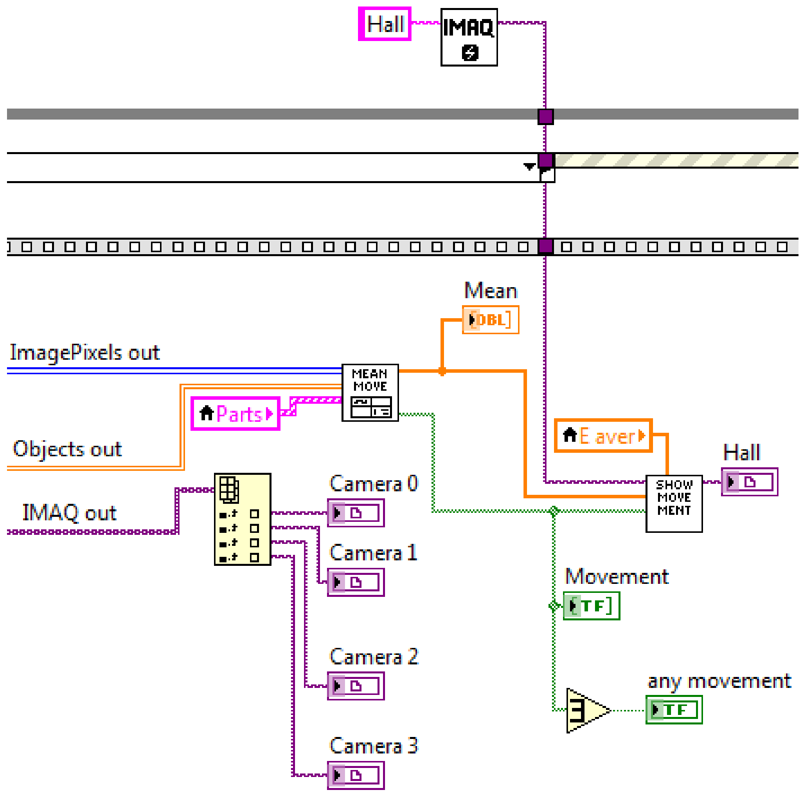

Fig. 5: Analysis results displaying

CONCLUSION

The algorithms described along with the hardware platform were implemented as an automated system for test site lighting on the basis of Kazan State Power Engineering University (Kazan, Russia). It is designed for testing and debugging software for wireless industrial automation network modules, debugging and adjustment functions of local and remote site control using the wireless industrial automation network modules, debugging and adjustment of self-diagnostics feature of wireless industrial automation network modules and their communication channels.

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