Research of smart lighting system for energy efficient office using image processing

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ABSTRACT

Smart grid technology uses for all levels of energy sector, its including energy production, energy distribution, energy transmission and energy users. Specially, research of smart technology usage for energy saving issue is one of the important things in this sector. In addition, researches appeared about Smart Lighting Control system for office and house building using IoT (Internet of Things). In this paper, approach of lighting control system for office building by using human detection algorithm with image processing from camera system's data is presented. In the experiment, "Raspberry Pi4 Model B", microcomputer and "Maix Dock" are used for embedded development system. In image processing algorithms, blurred images are used to ensure the privacy of the individual.

Keywords: *Camera, Machine Learning, OpenCV, Embedded System, Power Supply*

1. INTRODUCTION

Energy efficiency technology, and its smart control solutions have become one of the most interesting topic in current research. In particular, it is important to manage lighting of offices and apartments in an energy efficient manner. According to the study, 19% of energy consumption is spent on lighting [1]. For example, 11% of energy consumptions for residential buildings spends lighting system, and in the UK, about 21% of office space is spent on lighting [2, 3].

Control of unnecessary lighting in office buildings, and the efficient usage of energy have become part of the research work on the development of a new intelligent lighting management system. The development of smart technology brings a new stage to the development of this research. Compared to traditional lighting systems based on manual on / off modes, intelligent lighting systems provide efficient and healthy lighting using information and communication technology (ICT) advances such as wireless networks, sensors [4, 5].

In previous studies, the lighting control input information was obtained from sensors such as PIR sensors, microwave Doppler sensors, ultrasound sensors, WIFI sensors, motion sensors, light sensors, heat sensors, piezoelectric sensors, and infrared sensors [6-12]. The disadvantage of those research is that they sense the movement of objects other than humans.

In addition, camera has been used as acting sensor of the human sensing for smart lighting research. However, those methods process on saved images or videos and cannot be used in real time [13-16]. In another study, lighting control was performed using a stereo camera to determine the position of a person [17].

Nowadays, researchers consider research work for using smart technology, machine learning, and IoT (Internet of Things) technology to control for all types of systems. However, most research on intelligent lighting systems has been considered on outdoor lighting, such as street lighting control. Intelligent lighting control systems have also been used in the production of indoor plants for greenhouse cultivation [18].

Researches mentioned above are being studied to make building lighting systems smarter, which have a few common weaknesses. The weaknesses are the researches are not very effective and does not work in

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real time process. Therefore, this study introduces a controlling method for a lighting system in an office building by recognizing a human using real-time image processing.

2. RESEARCH METHOD

The research introduces a simple and smart control system for regular and open-plan office rooms. The advantages of this work are energy saving and reducing useless energy consumption. The presented method controls the lighting depending on the existence of human in the environment, and the camera is used for human recognition. Nowadays, there are a lot of methods such as recognition of things, objects, people, and their movements using camera systems [19]. These methods are usually divided into two types, the first is based on traditional image processing. The second one uses various artificial intelligence algorithms and machine learning methods [20]. In this research, machine learning methods were used, such as supervised learning methods and Deep Neural Network. The Python programming language, TensorFlow Lite, HaarCascade, OpenCV, numpy, imutils, and argparse libraries were used in the training process.

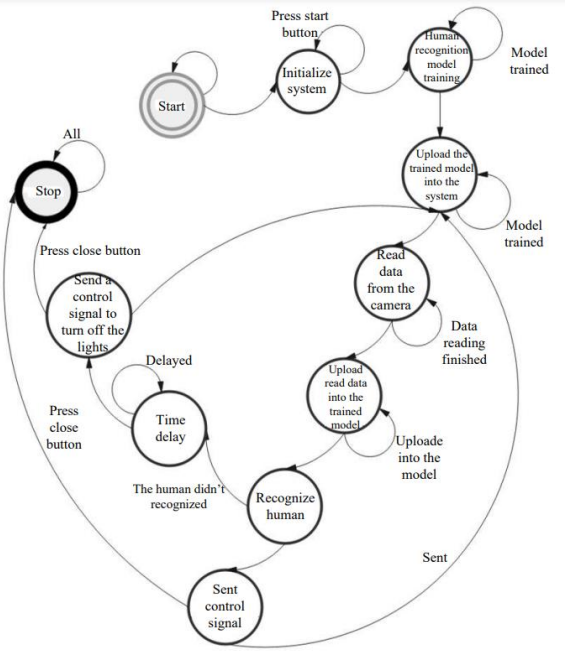


Figure 1 Main control algorithm

The working algorithm of the lighting control system is shown in Fig. 1. The control a machine learning method to train a human recognition model, compares real-time camera data with the trained model, and sends a signal to turn on the lighting if there has a person in the environment. A signal will be sent to turn off the lighting if a certain period of time passes without a person noticing. In this way, it will be possible to control and manage inefficient lighting.

3. EXPIREMENTAL RESULTS

The main part of the research work is the experiment of the human recognition algorithm using several types of devices. It includes:

- Raspberry Pi 4 Model BMaix Dock (SiPEED
- M1W, AIoT Module, K210 AI INSIDE)
- Personal Computer

Devices used for experiment are shown in the Fig. 2 – 5.

Figure 2 Raspberry Pi 4 Model B

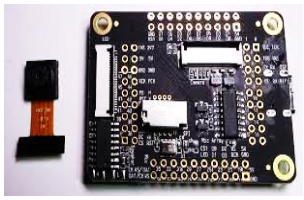


Figure 3 Maix Dock

Figure 4 Personal computer

Figure 5 Web camera

3.1. Human detectection algorithm using Maix Dock microcontroller

First, a human recognition model by learn various human images was generated on the TensorFlow Lite platform. Then, the generated model was uploaded to the Maix Dock microcontroller, and the software processing was performed to test the algorithm for displaying the face when a human image enters the camera. Correct face detection will be indicated by LED light, and information will be sent to the lighting control system. The expirement results are shown in Fig. 6 and 7.

Figure 6 Detection result on Maix Dock microcontroller (first scene)

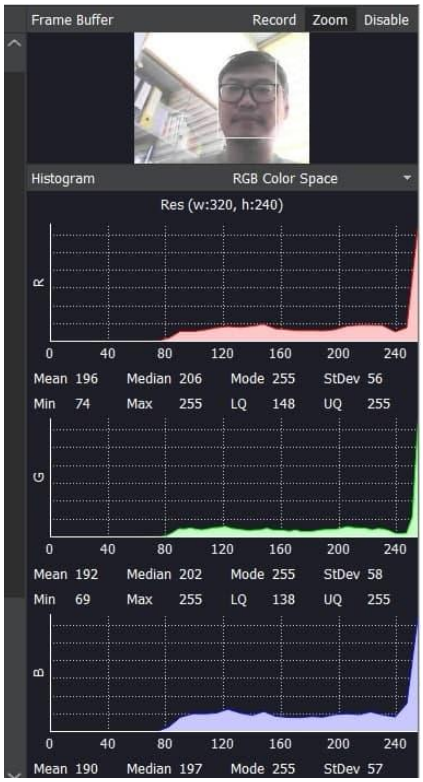


Figure 7 Detection result on Maix Dock microcontroller (other version of detection)

3.2. A Human recognition method using Raspberry Pi 4 Model B

The general methodology of the human recognition process from the model created by the deep learning method using the Raspberry Pi controller is shown in the Fig. 8 below.

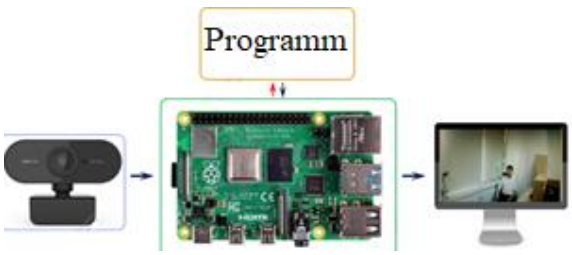


Figure 8 The hardware for human recognition method

Deep learning methods on the Teachable Machine platform is used for the generated a human recognition model and tested the algorithm. The Python programming language was used to perform the experiment on a Raspberry Pi microcomputer. The generated model was uploaded to a microcomputer and used in the test code. An algorithm of the program developed in Python language will execute following steps:

The data taken from the camera will be compared with the input of the model generated by deep learning.

- If a person enters the camera, the "Person" variable will be equal to one, and the signal to turn on the light will be sent to the control device.
- Else, if the image of a person does not enter the camera, the "Person" variable will be equal to zero, and a command will be sent to the light control system to turn off it.

Fig. 9 and 10 show the algorithm and expirement results of the human recognition system.

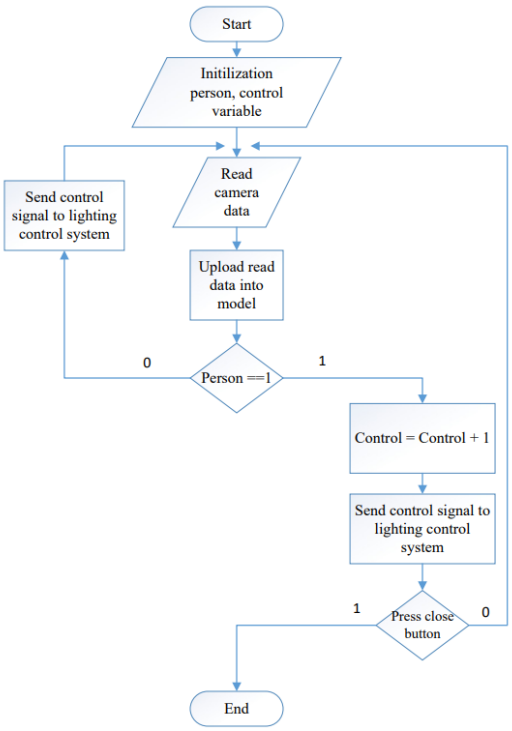
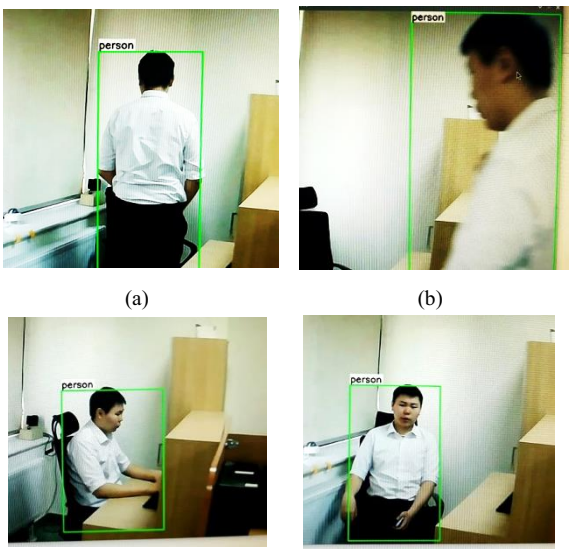


Figure 9 An algorithm for human recognition system



(a) (b)

(c) (d)

Figure 10 Image processing results: (a) back, (b) side, (c) setting position, (d) front

3.3. A Human recognition method by using personal computer

The real-time data processing from the computer camera will be identified and counted with the help of a model developed using the HaarCascade, OpenCV, numpy, imutils, and argparse libraries of the Python programming language, and the signal will be sent to the lighting system after neutralization to ensure the privacy of the person's image.

The real-time data processing from the computer camera will be used for human recognation model. The model is developed using the HaarCascade, OpenCV, numpy, imutils, and argparse libraries of the Python programming language. The recognition algorithm works following steps:

When a person enters the camera, face will be blurred and counted. And the control signal will be sent to the lighting system.

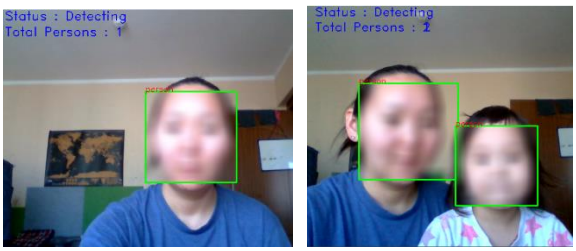


Figure 11 Image processing result of face detection and blurred image using personal computer

According to the expiremental results shown in Fig. 11, human recognition, counting and image blur are successfully carried out. Further, it is possible to read camera data and control the lighting system based on the presence of people.

4. FUTURE WORK

In the future, this research work will be expanded and tested using the Jetson Nano microcontroller.

Furthermore, human recognition algorithms will be processed on industrial computers to determine the most efficient and cost-effective methods and compared to previous methods. In this way, real results will be created, such as hardware processing and development of devices for controlling the lighting system of office buildings. In addition, expirements will be carried out on real objects.

5. CONTEXT

In the context of the efficient management of energy consumption, the control system using modern image processing and machine learning methods was discussed. In this paper, a lighting-controlling method based on AI is proposed for an open-planned office. The system could control lights depending on whether people are in the office room. For this purpose, artificial intelligence-based machine learning method was used to train the model and it is compared with the real-time camera data and recognized the person. It has also added a camera blur feature to ensure privacy. The results of the research show that artificial intelligence algorithms can be used in image processing and can be used in human recognition for lighting control systems. In addition, the feature of this study was that the embedded systems, microcomputers, and personal computers were used for expirements.

6. ACNOWLEDGMENTS

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