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DEVELOPMENT OF A MOBILE ROBOT

FOR

NIGHT VISION ASSISTIVE SYSTEM

NG CHIN YONG

A report submitted in partial fulfillment of the requirements for the degree of

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I declare that this report entitle “Development of a Mobile Robot for Night Vision Assistive System” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This project proposes a night vision assistive system for a mobile robot. It can be described as a user remotely controls a mobile robot and watch the streaming night vision video via a cloud camera. This project can be applied for providing the users an alternative way to guard and protect their house. Humans have poor night vision but they make equipment to enhance their vision during low light environment. The night vision application include for many careers such as surveillance and military. The problems have been faced are flexible camera view, platform design, live streaming video connection, and poor quality of image and video compressions during low light environment. The project is aimed to control a mobile robot using night vision cloud camera in a functional user interface. The process of literature review is required to complete before the design process. The chapter of methodology consists of the research methodology. It explains that the importance of literature review of nigh vision assistive system, communication and mobile robot. The evaluation methods are categorized to mobility test, sensor test, and image processing test. There are results of motion and rotational motion test, sensor sensitivity test, rectangle detection for night vision motion test, and connection of system test in the chapter of result and discussion. The speed of motor is practically not directly proportional to the voltage applied in the motors as because the unbalanced weight has affected the initial motor speeds. Sensors are tested based on the range of effective angle and its feedback values. The rectangle detection of the night vision assistive system is evaluated based on the contrast of camera, position and distance of the obstacles. The night vision assistive system can be connected to the mobile robot and camera by using the designed components and circuits. In the conclusion, the mobile robot is completely developed and it is able to move when the author sends the command. The system is able to live stream the video and process the video with the detection info and it can be further developed in the future works by implementing the high and complex order of video processing algorithm for night vision.

ABSTRAK

Projek ini mencadangkan satu sistem yang membantu robot untuk penglihatan malam. Ia boleh digambarkan sebagai pengguna boleh mengawal robot dari jauh dan menonton video siaran langsung penglihatan malam melalui kamera awan. Projek ini boleh digunakan untuk menyediakan cara alternatif untuk pengguna dan menjaga dan melindungi rumah mereka. Manusia mempunyai penglihatan malam miskin tetapi mereka membuat peralatan bagi meningkatkan penglihatan mereka semasa persekitaran cahaya rendah. Permohonan penglihatan malam termasuk untuk pelbagai kerjaya seperti pengawasan dan tentera. Masalah-masalah yang telah dihadapi adalah pandangan fleksibel kamera, reka bentuk platform, live sambungan video secara langsung, dan miskin kualiti imej dan video tekanan semasa persekitaran cahaya rendah. Projek ini bertujuan untuk mengawal robot mudah alih menggunakan penglihatan malam kamera rangkaian dalam antara muka pengguna yang berfungsi. Proses kajian literatur dilakukan sebelum proses reka bentuk. Bab metodologi terdiri daripada metodologi penyelidikan. Ia menjelaskan bahawa kepentingan kajian literatur daripada dekat sistem penglihatan bantuan, komunikasi dan robot mudah alih. Kaedah penilaian dikategorikan untuk ujian pergerakan, ujian sensor, dan ujian pemprosesan imej. Terdapat hasil gerakan dan ujian pergerakan putaran, ujian sensitiviti sensor, pengesanan segi empat tepat untuk ujian gerakan penglihatan malam, dan sambungan ujian sistem dalam bab hasil dan perbincangan. Pengesanan rectangle malam sistem penglihatan bantuan yang dinilai berdasarkan kontras kamera, kedudukan dan jarak daripada halangan. Sistem bantuan penglihatan malam boleh dihubungkan dengan robot dan kamera dengan komponen yang direka dan litar. Kesimpulannya, robot adalah maju dan ia mampu bergerak apabila menghantar arahan. Sistem ini dapat aliran video siaran langsung dan memproses video dengan maklumat pengesanan dan ia boleh dimajukan lagi dalam kerja-kerja masa depan dengan melaksanakan perintah itu tinggi dan kompleks algoritma pemprosesan video untuk penglihatan.

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LIST OF ABBREVIATIONS

CCTV	Closed-Circuit Television
IP	Internet Protocol
3-D	Three-Dimensional
HoG	Histogram Of Oriented Gradients
ROI	Region Of Interest
FIR-NVS	Far Infrared Night Vision System
DC	Direct Current
IEEE	Institute Of Electrical And Electronics Engineers
ADSL	Asymmetric Digital Subscriber Line
Ad-Hoc	Computer-To-Computer
RF	Radio Frequency
PWM	Pulse Width Modulation
ISM	The Industrial, Scientific And Medical
IR	Infrared
PIR	Passive Infrared Sensor
NIR-NVS	Near Infrared Night Vision System
LED	Light-Emitting Diode
VGA	Video Graphics Array
CMOS	Complementary Metal–Oxide–Semiconductor
SSID	Service Set Identifier
SDK	Software Development Kit
RTSP	Real Time Streaming Protocol
USB	Universal Serial Bus
URI	Uniform Resource Identifier
URL	Uniform Resource Locator

CHAPTER 1

INTRODUCTION

1.0 Background Study

The ability to see and observe in low light environment is called the night vision ability. The eyes of humans have limitations. Night vision can be made in the cases of sufficient intensity range or sufficient spectral range. The spectral range techniques for night vision are able to sense the electromagnetic radiation which is invisible to human. Besides that, the ability to see with very small quantities of light is meant to have the sufficient intensity.

Humans have poor night vision compared to the animals. This is because human eye is lacked of a tapetum lucidum. The current night vision technologies are divided into three main categories. They are active illumination, image intensification and thermal imaging.

Image intensification systems support direct observations by amplifying low levels of available light. Thermal imaging can be used to detect the temperature difference between the foreground and background objects.

Active illumination technologies work on the principle of coupling imaging intensification with an active source of illumination in the near infrared (NIR) band. Infrared is used in night when there is insufficient visible light to see. Active illumination

involves conversion of ambient light photons into electrons which are then amplified by a chemical and electrical process and then converted back into visible light.

The night vision applications include of wildlife observation, surveillance, military, security, law enforcement, navigation, hunting, hidden-object detection, and entertainment. The original purpose of night vision was used on locating enemy targets during night. This technology is still currently used by the military. For instance, soldiers use the night vision equipment for targeting, surveillance, and navigation. Security and police often use both image-enhancement and thermal-imaging technology, particularly for surveillance. Nature enthusiasts and hunters use night vision devices to maneuver through the jungles at night.

Private investigators and detectives use night vision to watch their targets. Furthermore, there are businesses and offices have implemented the permanently-mounted cameras equipped with night vision to monitor the surroundings. However, it is originally developed for military use.

1.1 Motivation

The cases of residential break-ins have increased during day and night time. However, these cases mostly happened during the night time. Residents are unaware about the surroundings whether they are people or burglars planning to break in to their houses. Residential break-ins are becoming more frequent in any single family homes. These break-ins commonly do not result in injuries or confrontations to the occupants. For uncommon cases, the burglars have entered home when occupants were inside the house. They do tie the residents up, and threatened them with weapons. The burglar-proof doors and windows and burglar alarms have been applied to provide protection of a household against these burglars. These can also include the defences from anti-burglar paint and security window film. Besides that, a person can commit a breaking with the entry permission. Thus, these problems have indicated that the security of a house is vital.

There are many solutions provided in the market. The common solution is that the Closed Circuit Television (CCTV) home surveillance systems have been implemented to the residential area. These systems can help the users observe, monitor, record and

surveillance about the certain places via day vision, day and night vision, and infrared vision of the cameras. However, CCTV system cannot provide vision on the blind spot which the camera does not support the hanged one camera indeed to provide the home surveillance system. In fact, a personal home surveillance system does not need many cameras compared to those company usages.

A better home surveillance system should be flexible and able to capture images for the blind spots. Thus, the author is inspired to design a system that can perform the functions of flexible camera view, live streaming video for day and night, and capture image.

1.2 Problem Statement

The process of designing a better home surveillance system has faced some problems. The design problem of this new system relates to the flexible camera view. It can be explained that the camera must be mobile and able to move from a place to other place. Thus, the position of camera must be designed to place on a platform that is movable. This type of placement provides the flexible camera view but it is limited to place on that platform.

The platform design for the system is required to be programmable, movable, and wirelessly connected. The material, layout, and flexibility of the chassis are considered during the design process. The components that are placed in the platform must be designed as they can be controlled wirelessly by the user devices. Apart from that, microcontroller plays a main role on solving this problem as because it can be programmed and wirelessly connected. The connectivity, input, output, power supply, circuit board are involved in the consideration for the platform.

Next, the third problem is related to the function of live streaming video. The video transmission method can be using different type of connections such as cable and wireless network. The design of the communication method must be limited only for wireless communication. The connection of cable can transmit video in the faster way but

unfortunately the mobility specification is limited. Thus, there must be a wireless communication between camera and computer.

A lux rating is defined as measuring the light intensity as perceived by the human eye. In fact, a low light environment causes a lot of troubles in our daily life. One of the problems is related about the images and videos compression for any emerging objects during night. Moreover, the causes of poor quality of image and video compressions from a camera are categorised based on the external and internal factors. There are examples of external factors such as the low illuminance and luminous emittance, the long range of distance, and the reflectance of the objects. The internal factors are considered as low camera sensitivity, slow rate of processing unit, and slow spectral response of the lens. Nevertheless, it is difficult to evaluate the performance of the night vision system for a mobile robot. Thus, the project has only covered on certain limiting factors such as light intensity and the distance.

1.3 Objectives Of Study

The objectives of this project are:-

1. To evaluate about the sensitivity of the distance sensors for obstacle avoidance of a mobile robot.
2. To design a user interface with built-in night vision for a mobile robot.
3. To evaluate about the performance of the night vision system for a mobile robot.

1.4 Scopes Of Study

The scopes of this project are:-

a) The experiments of mobile robot are conducted on certain surface such as ceramic and paper.
b) The experiment area of the vision test will be limited at the indoor environment.
c) The user interface program is developed in the Microsoft Visual Studio.
d) The wireless communication tools such as cloud camera server and X-Bee wireless module have their limits on the transmission range, thus the author is not recommended to test the mobile robot out of the range.
e) The quality of live streaming video is limited due to the certain camera specifications.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, the literature review is an evaluation report of information for this project. It covers seven parts such as type of night vision, image processing method, techniques for night vision image processing, microcontroller, Internet Protocol (IP) camera, wireless communication method of controlling robot and obstacle detection, object detection, pedestrian detection, road detection. The last sub-chapter describes the overview of this chapter.

2.1 Type of Night Vision

There are two general systems of night vision. One of them is far-infrared electromagnetic radiation (FIR). A normal thermal camera can detect this radiation with a wavelength in the range of 8 to 14 micrometer. In the far-infrared electromagnetic radiation night vision system, it can passively capture the radiation that is emitted by the high beam headlamps. The system can be said that it have detection range that extends well beyond the high beam headlamps. Thus, the thermal camera can detect the headlamps of oncoming vehicles without the blind effect and provide drivers a clear vision to avoid accidents. Furthermore, the FIR images can be easily captured the warm objects such as pedestrians and animals [1]. In fact, the FIR image contrast varies based on the ambient

temperature. For instance, those people with heavy clothes have limited heat emission which is less distinctive to the thermal camera [1].

Next, the second type is near-infrared electromagnetic radiation (NIR). For a NIR system, the night vision scene is illuminated actively by a near-infrared lamp. Users can view the images by using a camera which is equipped with a silicon-based CMOS or CCD. Generally, the illumination wavelength of near infrared electromagnetic radiation is in the range of 800 to 900 nm. Human is unable to view this type of radiation with their eyes. Therefore, the illuminator can provide the lights to the entire road without blinding the others. One of the similarities between the near-infrared and visible light is the reflectivity. The image recorded by the camera will closely match with what would be observed by the driver's unaided eye. One of the advantages is that most cotton-based fabrics have a large reflectivity. Thus, black cotton clothing can be appeared brighter in a near-infrared image [1].

The disadvantage of this NIR night vision system is that they can be susceptible to blinding by the headlamps of oncoming vehicles, which emit NIR radiation. It causes the dazzling effect. Thus, it is difficult for both the vision-computer-based vision systems and human driver to detect pedestrians in the presence of oncoming traffic [1].

2.2 Image Processing Method

There are many image processing methods can be used in the home surveillance system but not all of them are applicable. For instance, two coordinate system, three dimensional coordinate system, and image plane coordinate system. 3-D coordinate system must have one origin. The image plane coordinate system will be used as the plane in the 3-D coordinate system. The origin of this system is the intersection point with the axis. Besides that, there is a system that can generate a histogram of the brightness of the image. It also sets the intermediate value for brightness distribution as the threshold value. Segmentation method is also applied in this system to determine the pedestrian. The calculated value and center of gravity position in the image are used in calculate the 3-D position of an object [2].

Light intensity attenuation is meant that light energy will be reduced because of some factors such as distance. Pixel-base classifier is one of image processing methods

used to identify the road pixels. Fitted planar reflection model is used in this classifier. This model is described as assigning labels to each pixel for the free road surface and anything not being in the road [3]. There is another method called the feature extraction process. This method is composed of Motion History Image, median filter, normalization, and HoG (Histogram of Oriented Gradients). Motion History Image is the temporal templates as action recognition approach. In addition, it is easy to handle the moving object such as gait, human activity, vehicle, and gestures.

Furthermore, segmentation is used in the fixed camera because it is simple and consumes less computational time. It subtracts the input image and stored background Median filter is also can help to remove the random noise. Histogram of Oriented Gradients HoG feature counts the oriented gradients in the limited area of image. Motion History Image is recommended to express movement information. It can consume less computational time [4]. Kalman filter can be used for simultaneous prediction and filtering of measurement of object motion. It has been used as tracking black box [5]. There is a method which is using Matlab image processing algorithm. It can recognize the red and blue marks on the robot. The colour detection method detects the robot orientation and position [6]. Besides that, the road detection is an important issue for obstacles detection of a mobile robot. A region of interest (ROIs) method has been used in road detection [3].

2.3 Techniques for night vision image processing

Image enhancement is one of the conventional techniques that have been used by the researchers. The developed a histogram manipulation algorithm. It can spread the information to 256 levels. It adapts to the ambient light condition and employs hysteresis to avoid disrupting the viewers. They also modelled the road as a B Spline which is an efficient technique. Median filtering is used to remove impulsive noise. It also applies the canny edge detection and Hough transform. The Support Vector Machine (SVM) has been proposed and applied in the night vision. It is because this technique can be applied to approach for near infrared images in night vision [7].

Active illumination can help to filter out the visible spectrum from the blue end to reduce the band spread with specially designed lenses. The tonal distortion increases can

cause foliage to appear white. There is also passive technique can be applied in the night vision. For example, increasing the maximum number of photons detected by the sensors [8].

Motion segmentation as one of the techniques is proposed. It includes of background subtraction, statistical inference, temporal differencing, and optical flow. Median value can be determined as the threshold value using a histogram method. The method is based on the least median squares method and creates the difference image. This algorithm handled the inconsistencies caused by the lighting changes. For example, studies found and proposed that Kalman filtering can be adapted to temporal changes of weather and lighting [9].

Besides that, there is also a popular technique called Noise Visibility Function (NVF). It is worked as based on the noise visibility of an image and modelled specially for watermarking. It can be used as the texture masking function. The idea is meant to extract all edges and texture from high frequency bands and choose most prominent among of them for the surveillance and navigation. Visual and night vision images are fused to provide better description for the current natural appearance. The attraction is considered as improving the image visual effect significantly than the existing methods [10].

2.4 Microcontroller

They are many products which are available for end-user programming. There is inexpensive hardware and open source software can help user to programmatically control many devices. Moreover, one of prototype platforms is involved on the end-user programming will be considered. [11]

The Raspberry Pi is a computer. It has various programming languages such as C, Java, Ruby, and Python. These are friendly programming interface. The Raspberry Pi has an ability to integrate with electronics projects. For instance, it can control relays and motors and switches, read the state of buttons, and deal with sensors and robotics systems [12]. However it is required extra circuit for analog input devices. The Raspberry Pi can provide stable communication.

Each of the microcontrollers that reviewed in this part has their pros and cons. The Arduino is possibly outdated but the price is cheaper and can still be useful for controlling a number of low sample rate sensors.

Apart from that, the Beaglebone Black can acquire analog data faster than Arduino. However it is expensive than Arduino and the analog digital converter function at this speed is currently not straight forward for the electronics projects. The Beaglebone Black can provide stable communication and thus perform useful signal processing.

2.5 Internet Protocol (IP) Camera

The surveillance operation can be done using Internet Protocol (IP) camera. It is utilizes the function of streaming live video and transmit the video and audio signal over the Internet in real time. Finally, the streaming of live video can be used in surveillance. IP cameras transmit video using open internet protocols for monitoring or recording [13].

The cloud camera has the same functions compared to IP camera. It is similar but just different on the network cloud application. The cloud camera is a product that enhanced by the IP camera which contains the combination IP camera and online cloud server service.

IP camera has a built-in web server. It can be operated as a standalone product. It can work without the host computer. Thus it provides an economical method to monitor a place from remote location. IP camera can issue and receive instructions by using Hypertext Transfer Protocol (HTTP). It can pass to the camera web server via connection of Transmission Control Protocol and Internet Protocol (TCP/IP). The IP camera has the traffic between 0.2 Mbps and 2 Mbps on a network. It has different types of compression techniques for image transmission. Motion Joint Photographic Experts Group (MJPEG) or Moving Pictures Expert Group 4 (MPEG 4) is common techniques used in IP camera [13].

Most analog cameras are changing to IP camera in terms of video surveillance systems. IP camera can digitalize video signal inside the camera while analog cameras require encoder. The composition of an IP camera are optical filter, lenses, Axis Real Time Picture Encoder(ARTPEC) chip that performing controlling function, charge-coupled device (CCD) sensor, and compression chip [14].

2.6 Wireless communication method of controlling robot

There are several types of wireless communication methods for controlling a robot. The first method is using OpenWRT. It is an open source firmware which can be applied in a router. The router can establish the connection and translates the relay information to the robot subsystem. It is a core operating system that allows custom packages to be installed. In fact, it can expand the router's functionality. Besides that the OpenWRT version of Kamikaze 8.09.2 is used as the firmware. This firmware has enabled the serial ports of that router [15].

Next, there is a project about the self-propelled vehicle. It is controlled through the Wi-Fi module via server. DFRduino RoMeo 328 microcontroller is the control center of that vehicle. It can receive control command through the socket data of the server to control the motion [16].

The third wireless communication method is using ZigBee or XBee. There is a research proposed that the comparison between ZigBee and IEEE 802.11g. The ZigBee modules were used for transferring of the robot car controlling commands. Besides that, the WLAN connection was used for image transmission [17].

2.7 Obstacle Detection, Object Detection, Pedestrian Detection, Road Detection

The literature review on this part is related to the detection method. Sobel edge detector is used in the edge detection algorithms. There are people who utilize the Artificial Intelligence approach [18]. Region of interest is one of image processing method. The centroid of taillight pixels is calculated under this method. This method is required to improve in order to have a faster response in image processing [19].

There are two types of detection for the obstacles such as positive obstacle and negative obstacles. The positive obstacles are sand dunes, tree trunks or steep that extends out of the ground surface. The negative obstacles are holes or ditches that extend into the ground plane. In this research, a pixel based evaluation scheme is conducted for the results in favour of the objects near to a vehicle [20].