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Research paper

Hand Gesture Interface for Smart Operation Theatre Lighting

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Abstract

Operation theatre lighting system is a critical component in the operation theatre. Focusing the light to the area of surgery and varying the light intensity is manually done in currently available systems. Disruption of surgeon's attention and possibility of infection due to non sterilized hands is a major setback of the manual controlling method. This usually requires assistants to adjust the position and intensity of the light system by commands from the surgeon. So, designing an intelligent lighting system for operating theatre which can maintain the intensity values to the required level without shadow effect to the operation area is an important requirement. Proposed system makes use of accelerators in the gloves worn by surgeon so as to track hand movements. Pre defined hand movements can be configured to move the lighting system up, down, left or right. Accelerator input is interpreted for its corresponding movement by controller at transmitter side and it is wirelessly given to the receiver side using an nRF module. At the receiver side the incoming command from the nRF is taken and suitable response generated at the motor driver by the controller to move the lighting device. In the same way predefined hand signal can be used to vary the intensity of the light by using microcontroller to drive an LED driver.

***Keywords**: Accelerometer; hand gesture; nRF module; Operation Theatre*

1. Introduction

Surgery is a critical procedure done in operation theatres and it is a stringent requirement that surgical equipments should be accurate and precise. One of the key components of the operation theatre is the lighting system. It helps in providing proper illumination of the site of surgery for viewing the incisions and body cavities at varying depths and clarity. Typical surgical light system consists of a light assembly attached to a suspended robotic arm. Localizing the light above the surgical site can be done by moving the movable platform on which the light assembly is fixed giving both linear and angular movement. Operation theatre light system is maintained by biomedical engineers to check for its proper working before a surgery. It is at this point the illumination of light, colour rendition and temperature settings are properly adjusted. During the surgery operation light adjustment can be done by the surgeon or nurses. This creates an infection hazard if he/she tries to do the adjustments as sterile environment is important in such times. So this task is usually done by an assistant or a nurse based on instructions from the surgeon. But this is not very accurate in comparison to the surgeon himself adjusting it to his requirements. Proposed system enables him to do just that using hand gestures. The hand gloves worn by the surgeon is equipped with hand motion sensor that can understand the gesture and suitably move the lighting system up, down, left or right. It also has a provision to vary the intensity of the light so as to minimize the shadow effects using hand gestures. Advanced medical technology like minimally invasive surgery and robotic assisted surgeries are gaining momentum in the present decade. They require remote control of devices in the operating theatre. Such a control on the operation theatre light should ensure that cameras placed in the operation theatre rooms will capture the pictures in correct lighting which can then be sent to a remote control site. Long duration of operation may strain the eyes of the doctor under the glare of the light hence the light intensity has to be reduced accordingly.
The paper is organized as follows: section 2 presents review of related works, section 3 involves methodology for gesture detection, section 4 involves lighting structure details and section 5 includes System Requirement. Details of System Design are given in 6 followed by Results and discussion in 7 and Conclusion in 8.

2. Related Works

Gesture can be defined as a non verbal cue for communicating using movement of body usually hand or head. This natural form of communication can be used to interact with electronic devices enabling it to respond to gestures intelligently instead of pressing buttons or using touch screens. Touchless interaction with computers can be camera based, voice based, eye tracking or inertial sensors [7].
Inertial sensors are used to detect inertia and include accelerometers and gyroscope [10],[11]. The system proposed in [1] makes uses of three mpu 9255 sensor that consist of accelerometer and gyroscope to determine the 3D position of the robotic arm based on the position of hand. Flex sensor is used in finger to adjust the robotic arm griper according to movement of fingers. Such a system gives accurate results but is very bulky to be worn by a surgeon and positioning his hands in the 3D position needed for the light is a tiresome task. Automatic position adjustment of the light structure by detecting the position of the doctors head is given in [2] is a good option as the doctor need not move the light structure when he/she changes position however good visibility of the surgical site also needs light intensity adjustment.

LEAP motion controller based gesture detection is given in [3], [8] is an attractive solution in terms of simplicity of design and accurate identification of hand gestures as all ten fingers can be viewed. It has 3 IR transmitters and 2 cameras with a 140-150 degree of field of view. This controller has to be connected to a computer and cannot be used as a standalone device in an already crowded operation theatre.

Camera based systems used in "Gestix" [4] allows doctors to simply show hand gestures to browse, rotate or move MRI images. Another method involves the use of Kinect sensor that has depth sensor and RGB camera to detect gestures was used in "Gestonurse"[5] to provide tools to the surgeon based on detecting the fingers in hand to identify the tool and in [12] for 3D heart visualisation. Image processing techniques for detecting gesture demands good ambient lighting system to capture good images which is limited in operation theatres.

Speech based systems does not give good results in a noisy environment and in operation theatre there is noise due to surrounding machines as well as from doctors or nurses talking. Voice based systems [13] do not give good analog control which is needed for light intensity variation. Voice based activation of gesture module to be used for viewing radiological images [9] faced problems in voice command recognition due to difference in accent.

3. Gesture Detection

One of the major problems of implementing the system with image processing technique is the line of sight requirement demanding fixed area of user interaction and can be overcome by using a sensor based system [7]. Hand gesture is used as a communication aid to interact with devices in the operation theatre for a simple , low cost, and quicker response .Hand gesture is detected by using accelerometer ADXL335 is a capacitive accelerometer Capacitive accelerometer has a movable proof mass that is interspaced between fixed parallel plates acting as a capacitor. When the proof mass undergoes displacement, the capacitance between the plates varies and produces analog voltage which is a function of the displacement. Figure 3.1 shows the gestures that were detected using accelerometer.

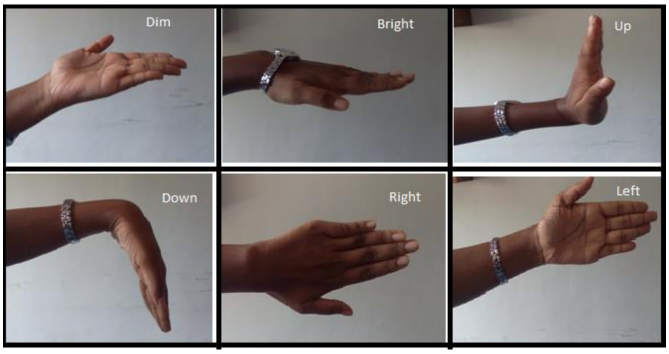

Fig 1: Gestures used.

4. Lighting Structure

Most commonly used light setup consists of a single- or multiple-light head assembly attached to a suspension arm. The surgical lighting fixture can be either mounted at a fixed point on a ceiling or on a stand. Types of lamps that is used include tungsten, quartz, and/or xenon halogens and light-emitting diodes (LEDs) most popular being LED type due to its low heating feature. The proposed system adopts a robotic arm which as its light structure for maneuverability of the light structure and to hold the lamp. Movement of the robotic arm relies on gesture commands from the hand of the doctor. The base consist of stepper motor that can be rotated up to 270 degrees to move the light structure right or left. One stepper motor placed at the elbow of the robotic arm is used to move the structure up or down and has a vertical reach of 15 inches.

5. System Requirement

An intelligent operation theatre light controlled is proposed here and can be used to aid the surgeon in his surgery by allowing him to automatically adjust the position of the lighting structure The intensity of the light can be varied to view the incisions with clarity.

Hand gloves worn by the surgeon can be equipped with small embedded system that will detect the hand gesture required to control the light structure. Lighting structure in an operation theatre is mimicked using a robotic arm with DC lamp mounted on it. The hand gloves consist of a MEMS accelerometer (ADXL 335) for gesture detection. ATMEGA328 within the ARDUINO NANO board to check for the predefined gestures and decide what action to be performed by the light system. This information is send to the receiver side wirelessly using the NRF module At the receiver side, the NRF module connected to ARDUINO UNO controller board receives the command and if the light structure has to be moved up, down, left or right, it sends suitable command to the motor driver (L293D) Similarly commands can be sent to adjust the intensity of the light which is a 12V 5W DC lamp by sending control signal to led driver (L293D).

1. Microcontroller: Arduino UNO microcontroller is used at the receiver side and Arduino nano at the transmitter side owing to its small form factor.

2. ADXL 335- The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. It contains a poly silicon surface-micro machined sensor and produce voltage proportional to acceleration.

Fig 2: ADXL335

3. NRF24L01- The nRF24L01 is a single chip 2.4GHz transceiver with an embedded baseband protocol engine designed for ultra low power wireless applications. The nRF24L01 is designed for operation in the world wide ISM frequency band at 2.400 - 2.4835GHz.

Fig 3: NRF Module

4. L293D is designed to drive a wide array of inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current and high-voltage loads. All inputs are TTL compatible and tolerant up to 7 V. L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It works on the concept of H-bridge.

6. System Design

The transmitter section given in Fig 4 is placed within the gloves used by the doctor. It consists of a MEMS accelerometer that is used to detect the hand gesture by detecting movement in the x, y and z axes. Suitable gestures are predefined for moving the robotic arm up, down, left or right and to change the lamp to suitable intensity level. When the gesture matches with the x, y, z values for the predefined gesture the microcontroller sends suitable command say “up” to the receiver side wirelessly using NRF module.

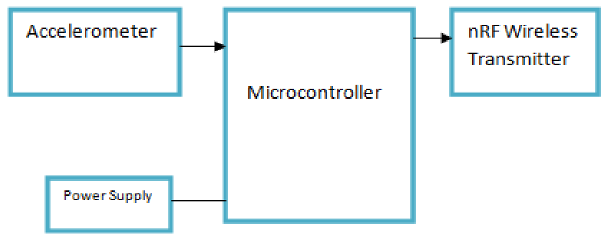

Fig 4: Transmitter Section

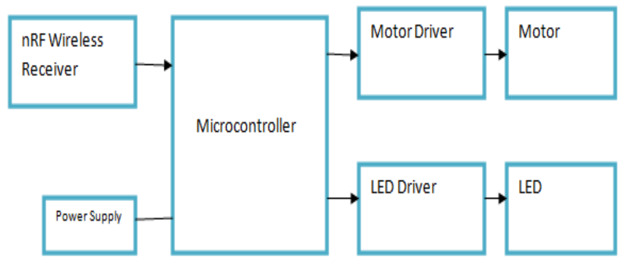

Fig 5: Receiver Section

The receiver side given in Fig 5 is placed at the surgical lighting structure to control the robotic arm which holds the lamp. The microcontroller receives the command from NRF module and decides what function to do-move the robotic arm or vary brightness. Robotic arm consist of 2 stepper motors one for base rotation to right or left and other to move the structure up or down. The 2 inputs from the stepper motor is connected to L293D motor driver. If the motor is to be moved suitable instruction is given to the motor driver to move the robotic arm in the desired direction. If intensity of the DC lamp is to be varied then PWM signal generated by microcontroller with varying length is given to the LED driver.PWM is a square pulse of varied width that can be generated at dedicated pins of arduino. 2 modes of intensity level is defined for the lamp – dim and bright. This acts as the control input to the L293D that acts as LED driver.PWM with varying duty cycle will result in different intensity for the light without manual intervention making the process automatic.

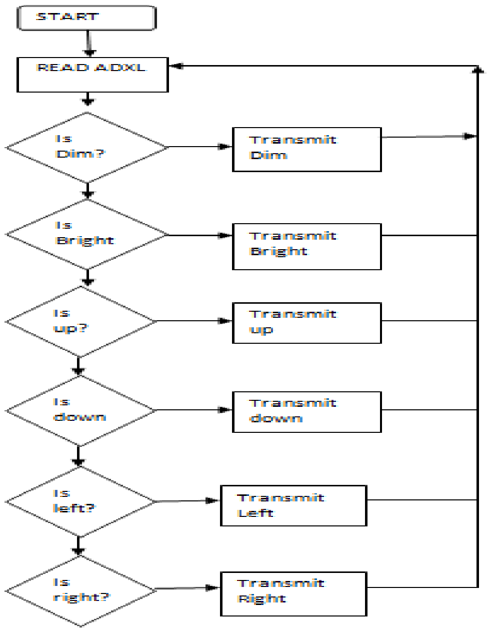

Fig 6: Transmitter section Flow chart

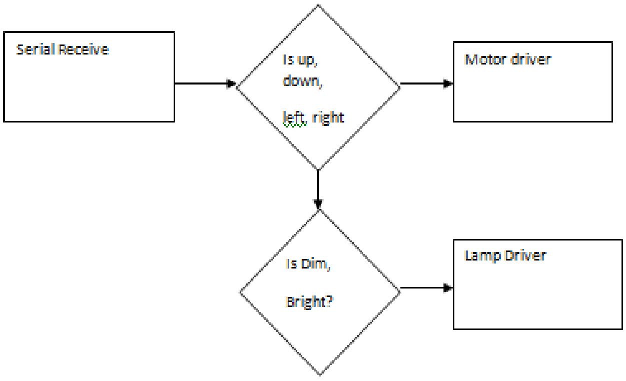

Fig 7: Receiver section flow chart

7. Results and Discussion

The proposed system was implemented in a low cost manner to move the light structure of a robotic arm to vary the intensity of the light. The project was implemented using 2 controllers Arduino nano and Arduino UNO. Arduino nano was used at the transmitter side to detect hand gestures using accelerometer. Accelerometer reading was taken for each gesture and minimum and maximum range was defined for the x, y, z values for each gesture. Given in Fig 8 is the setup at the receiver side. The detected gesture was communicated to the receiver side wirelessly using nRF module working in the SPI mode. Based on the gesture if the action is to be performed by the robotic arm structure then suitable control is given to L293D motor driver. Robotic arm consist of 2 servo motors one for movement in the vertical direction (up and down) and other in horizontal direction (left/right). If the gesture was detected to control the intensity of the lamp then Arduino UNO gave suitable control to the lamp driver L293D.A varied pulse PWM generated from arduino acts as control for the LED to vary it’s intensity The receiver side requires an adapter of 12V to drive the motor and lamp. All other devices operate at 5V. A 12V,5W DC bulb was used as lamp . Coding was done using Arduino IDE.

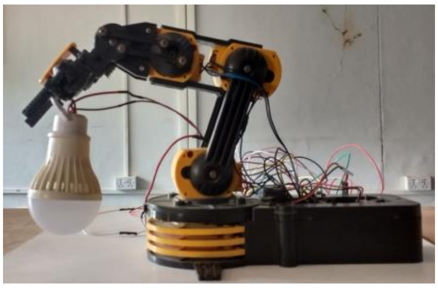

Fig 8: Receiver side setup

8. Conclusion and Future Scope

Using the proposed system in operation theatres doctor's need not rely on an assistant to adjust the direction and position of lighting for better view. It saves time as no human error is involved due to miscommunication of instructions as the doctor himself can make the necessary changes. The gestures are easy to learn and are directly related to the task to be performed. Automatic robotic control is efficient as they do not suffer from fatigue after operating for long hours and deliver the same efficiency and throughout. It helps in proper lighting of the surgical site and hence proper localization of the surgical lighting is very essential. Hand gesture based solution to adjust the position of the surgical light structure avoids unwanted issue of sterilization.

The size of the transmitter side embedded in the hand gloves can be further reduced by using SOC like CC430F6137 which has integrated RF. Low power modes of the nRF module and arduino nano can be employed to further reduce the power consumption of the wearable device. Angular movements of the hand can be used to achieve angular motion of the robotic arm held light structure.

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