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Smart and Energy Efficient Gesture Controlled Home Automation

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Abstract

This paper proposes a vision based static hand gesture recognition system for controlling different electronic appliances for smart living. Gestures are a natural way of communication, which can be interfaced with a computer to establish a human machine interface for controlling devices through hand gestures as a remote control. By using mathematical algorithms to translate the hand postures, the gesture recognition system can prove to be a possible solution for centralized control of multiple gadgets. We propose a fast user independent MATLAB based algorithm using skin detection in HSV color space for automatically recognizing gestures and interfacing the system with PIC16F877A to control the appliances connected to the hardware setup through a relay controlling circuit. This technology has the advantage of being energy efficient, cost effective and convenient.

Keywords: *Gesture, Gesture Control, Vision based Gesture Recognition, Home Automation, MATLAB.*

1. Introduction

Technology has advanced manifolds over the last decade, giving rise to computerization in all fields of everyday living. In current times, it is not only required for the technology to have utility but also have other factors such as smartness or intuitiveness, energy-efficiency and high degree of automation. Networking of home appliances is being realized for establishing a smart house and smart living system. The development in technology aims to add luxury to common devices which merely served utilitarian purposes in the past.

Gestures play a major role during communication for providing easier understanding. Gesture recognition refers to interpretation of meaningful postures by a human, involving hands, face, head, and /or body. Among all the gestures performed, hand gestures play an important role as hand are more flexible and convey more meaning in less time. Hand gestures can be interpreted by investigating the patterns of hand shape, hand movement, orientation and classification. [1], [2].

Two approaches are commonly used to recognize the gestures. They are vision-based systems and glove based systems. [3] Vision based systems provide a more natural form of communication because they do not require a physical contact to be maintained.

Gestures can be divided into two types; static gestures and dynamic gestures. They can be considered as a change of the hand position in a particular time interval with a given velocity or as a change of the hand shape. Gestures belonging to the first group are called dynamic gestures while from the second group are referred to as static gesture. [4]

This paper presents a vision based static hand gesture recognition systems using skin detection algorithm in MATLAB for home automation. Usage of any additional hardware such as gloves, sensors etc. is eliminated to reduce the complexity and make the system more user friendly. Skin detection is carried out in HSV color space. The software module is interfaced with microcontroller PIC16F877A through USB to TTL convertor. Serial communication is used to communicate with the microcontroller from MATLAB. A relay driver is used to connect the microcontroller with the relay circuit of each appliance that needs to be controlled using the gesture which has been fed as an input to the gesture controlled home automation system.

2. Related Work

The use of hand gestures is a natural and intuitive way of communication and has led to many research efforts aiming for the development of intelligent human interaction systems for home automation. This section summarizes the findings of the literature survey that was carried out to study the technologies previously employed in this field.

A glove-based portable communication system having multiple sensors for American Sign Language Recognition was developed to transmit the gestures to driver circuit of appliances via ZigBee. They employed feature extraction and artificial neural network model for gesture recognition and microcontroller 8051 for controlling the equipment. [3]

Hand localization, segmentation and extraction of a 1-dimensional signal by tracking the circle centered at the

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center of gravity of the hand region were employed to recognize gestures and control the electronic appliances via ZigBee. [4]

Max232 was used to convert signals from RS-232 serial port to TTL compatible digital logic circuits as suitable signal to change the TV program. [5]

Skin based thresholding in YCbCr color space was used to identify the presence of hand and marking skin like pixels in the image. [6] [7]

A range was calculated to fix a boundary for skin pixels from HSV color model. In addition to this, edge detection and morphological operations were performed for developing a vision based static hand gesture recognition system. [8]

Another Gesture recognition systems design involved pattern matching and hand tracking to open up software application on laptop and operate different electronic equipment using LabView. [9]

In another approach, Canny edge detection and K-L transform were deployed to recognize gestures to control a MP3 player. The MP3 player is interfaced to the PIC16F8779 controller and relay driver with the help of RS232 cable. [10]

3. System Description

The system architecture can be divided into two parts: gesture recognition and home automation. The vision based solution focuses on functionality and usability of the system. It aims to operate electronic appliances by creating a man machine interface without the usage of any additional input hardware like gloves or sensors devices. Figure 1 shows the block diagram of the proposed system. The acquired image is fed an as input to the gesture recognition system based on skin detection in HSV color space. Upon the closest successful match, the gesture recognition system transmits a code to the hardware module to switch the connected home appliances on or off.

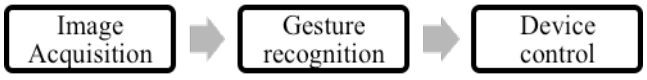

Fig. 1 Block diagram.

The system designed to recognize the input hand gestures and subsequently controlling the appliances in the smart home consists of 9 steps. The flowchart given in figure 2 depicts the flow of the working of the gesture recognition and home automation systems.

A live frame is grabbed spontaneously though the webcam or the camera attached to the computer in RGB format. It is then converted into HSV color space. Skin detection is carried out to differentiate between the skin like pixels and the non-skin like pixels. The image is then converted into grayscale intensity image and background subtraction is carried out for gesture segmentation. The obtained image is matched with the database using suitable mathematical matching algorithm. This constitutes the gesture recognition system.

After matching the gesture, the MATLAB program accordingly transmits a suitable code to the microcontroller PIC16F877A. The microcontroller sends its output to the relay circuit of the device that needs to be switched on through a relay driver. This constitutes the home automation system.

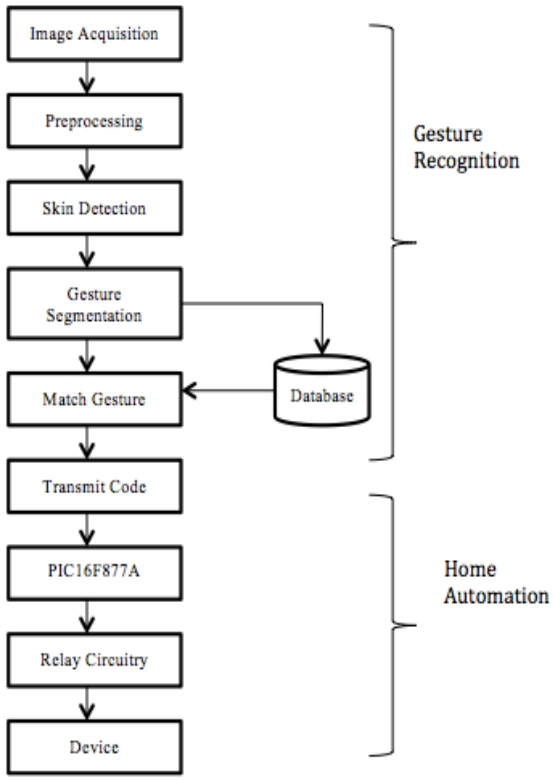

Fig. 2 Flowchart.

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3.1 Image Capture

The input images are captured using a digital camera of 8MP against a clear background for creation of the database. This database, consisting of a limited set of gestures, is used to train the software in MATLAB. Two sets of gestures are used; one set is used for specifying which device needs to be operated and the other set is used to specify what action must be taken on that device. The RGB images are resized to 200x200 to reduce the size of the image and increase the computational speed of the gesture recognition algorithm.

3.2 Gesture Recognition System

Gesture recognition system involves image acquisition, its preprocessing and skin detection for gesture segmentation to match the gesture with the database that has been used to train the system. Color is a powerful descriptor for object detection [11] and thus we are using color information to extract out the gesture from the background. Preprocessing is an operation that improves the image data by suppressing unwanted distortions or enhances some important features in the image for further processing. This operation is performed with images at the lowest level of abstraction.

Here, HSV color model is used for preprocessing. Human skin color is clustered at a small area in the color space; it has a restricted range of hues and is not deeply saturated.[8] For marking out the pixels as skin or non-skin, the resized image is converted to HSV color space from RGB color space. Using some range of predefined values for h and s color components of the HSV model, good segmentation of the hand-like regions from the input image can be achieved. Since the range is found empirically and it varies with the skin complexion of ethnic groups, a wide range must be chosen to cover all skin tone and obtain accurate skin detection in the image of interest. This will make the system user independent.

After marking out the skin pixels the image is converted into grayscale intensity image and the results are stored in each row of a matrix. By converting the image into grayscale, the hue and saturation components are eliminated while retaining the luminance components. The database images as well as the input images for real time operation undergo the same algorithm for extracting the gesture components.

While training the software, the database matrix acts as the reference matrix with which the input image matrix is compared. When an input gesture is fed to the system for controlling an appliance the results are stored in another matrix after going through the aforementioned algorithm and is compared with the database matrix. The gesture with the minimum difference is given as the closest successful match.

3.3 Home Automation System

When a gesture is recognized successfully the MATLAB program transmits a code through the specified communication port using a USB to TTL converter to the microcontroller PIC16F877A. The data packet undergoes level shifter to make the output from computational device compatible with on board hardware. USB to TTL convertor is connected at the USART input and output pins of the microcontroller.

PIC16F877A accepts this control signal or data packet and is programmed in such a way that it drives the corresponding port pins high or low as per the command given by the gesture recognition system. A 16X2 LCD display is connected to it in order to display which devices are switched on and off.

PIC16F877A is a 40-pin CMOS FLASH-based 8-bit microcontroller. It has 256 bytes of EEPROM data memory, 8 channels of 10-bit Analog-to-Digital converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface or the 2-wire Inter-Integrated Circuit bus and a Universal Asynchronous Receiver Transmitter (USART). Thus, it is ideal for advanced level A/D applications.

Each electronic appliance that has to be controlled has a relay controlling circuit associated with it. The output of the microcontroller is fed to the relay driver ULN2003A through the general purpose I/O ports. ULN2003A is an array of 7 NPN Darlington transistors capable of 500mA, 50V output. This relay driver is required to interface the low voltage logic circuitry with the high voltage / current circuitry because the home appliances operate at 220V mains supply. According to the command given by the microcontroller, the relay driver drives the associated relay circuit of the device that is to be switched on or off. Thus, a centralized vision based gesture recognition system for home automation system is established.

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4. Results

The following figures show the results of the gesture recognition system of the proposed smart and energy efficient vision based hand static gesture controlled home automation system. Figure 3(a) shows the original input image in RGB color space. Figure 3(b) show the image obtained after converting the input image to HSV color space and marking the skin pixels using skin detection. Figure 3(c) shows the image obtained after grayscale conversion of the image obtained from figure 3(b). This image is used to create the matrix which is then compared with the database.

(a) (b)

(c)

Fig. 3 Results of Gesture Recognition System (a) Original input image, (b) Image obtained after converting the input image into HSV color model and marking the skin pixels using skin detection and (c) Image obtained after converting the HSV image into Grayscale image.

5. Conclusions

The proposed system presents a smart and energy efficient home automation system by means of designing and building a man-machine interface using static user defined hand gestures to control electronic equipments like laptop, TV, bulbs etc. With embedded computing of power and memory within domestic appliances, an energy efficient fully automated smart home is established. This can also prove to be a viable solution for physically challenged and blind individuals for operating multiple appliances. The gesture recognition system, developed using skin detection algorithm, is robust, user independent and cost effective. The need to wear additional hardware such as gloves, sensors and wires is eliminated to make it more user-friendly. The proposed model is sensitive to rough background and rotation of fingers. Overcoming these difficulties is suggested as future work.

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