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Implementation of a Wireless Gesture Controlled Robotic Arm

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Abstract— **In this model, we propose a way to accomplish Human Computer Interface absolutely in electronic way (without mechanical sensors). The idea is to extirpate old techniques of controlling Robotic arm using joysticks, buttons and supersede with more intuitive technique i.e., to control robotic arm by hand motion or gesture. Here, we illustrate the controlling of the movements of such manipulator i.e. robotic arm in accordance with the movements of human arm using real time image processing. It is kind of master-slave control methodology where slave i.e. robotic arm synchronously replicates the motion of master i.e. human arm. The arm is tele-operated i.e. wirelessly operated. There will be no wired connection between human arm and the robotic arm, which allows us to operate it in the wide range of up to 30 m irrespective of any disturbance. This model gives a proper guidance to control a robotic arm (prototype of exact human arm) using real time image processing and is supported by the MATLAB codes, components and layout. A simple and fast process for gesture recognition and direction control is implemented. SIFT algorithm is used for hand gesture recognition by generating and comparing the feature vectors. Once the gesture is confirmed for particular system (e.g. motor) selection, further procedure would be to drive the system in required direction.**

Index Terms— **Human Computer interaction, Microcontroller, Webcam, MATLAB tool, RF module.**

I. INTRODUCTION

A robotic arm is a robot manipulator, which can perform similar functions to a human arm. Robotic arms are the vital part of almost all the industries. Hand Gesture recognition system provides us an innovative, natural, user friendly way of interaction with the computer which is more familiar to the human beings. Gesture Recognition has a wide area of application including human machine interaction, sign language, immersive game technology etc. The communications between persons are performed by using not only voice but also the gesture. In noisy environment, if machines can recognize the human gesture as a command, one operates the machine easily like making command to another person by his gesture. Then, we propose the communication method from human to machines by recognition of human gesture with an image processing system. This system makes communication with machines as likely communication with another person. This system needs no special environment, for example a data grove, data suit or a black background for monochrome image processing.

Interpretation of human gestures by computer is used for human-machine interaction in the area of computer vision. Our aim is to make the computer comprehend human body language, thereby bridging the gap between machine and human. Several approaches have been developed for sensing hand movements and controlling robotic hand. One of the most popular techniques is Glove based technique that measure hand and arm joint angles and spatial position. It utilizes sensor attached mechanical glove devices which limits freedom as it requires users to wear clumsy device always. Another prominent technique is Gesture recognition. Hand gestures are broadly used for tele-robotic and control applications. The main intent of gesture recognition in this model is to detect a particular hand gesture and send corresponding specific command for execution of action to robotic system. For capturing hand gestures accurately using image processing techniques, light condition of surrounding and positioning camera needs to be taken care. It's quite complicated to visual hand recognition and traces it. Early approaches used position markers or colour bands to simplify the problem of hand recognition, but definitely it's a hindrance, they cannot be considered as a natural interface for the robot control. In this model, we have proposed a fast as well as automatic hand gesture detection and recognition system. A smart algorithm is developed to accurately detect hand gestures without any prerequisite tangled set-up. Once a hand gesture is recognized, an appropriate command is sent to a robot. Once robot receives a command, it does a pre-defined work and keeps doing until a new command arrives. Depending on received command robot performs various actions like moving forward, backward, right, left, rotate, hold the object using arm etc.

II. RELATED WORK

In some passed decades Gesture recognition becomes very influencing term. There were many gesture recognition techniques developed for tracking and recognizing various hand gestures. Each one of them has their pros and cons.
The older one is wired technology, in which users need to tie up themselves with the help of wire in order to connect or interface with the computer system. In wired technology user cannot freely move in the room as they connected with the computer system via wire and limited with the length of wire. Instrumented gloves also called electronics gloves or data gloves is the example of wired technology. These instrumented gloves made up of some sensors, provide the information related to hand location, finger position

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orientation etc through the use of sensors. These data gloves provide good results but they are extremely expensive to utilize in wide range of common application. Data gloves are then replaced by optical markers.

The optical markers project Infra-Red light and reflect this light on screen to provide the information about the location of hand or tips of fingers wherever the markers are wear on hand, the corresponding portion will display on the screen. These systems also provide the good result but require very complex configuration. Later on some advanced techniques have been introduced like Image based techniques which requires processing of image features like texture, color etc. If we work with these features of the image for hand gesture recognition the result may vary and could be different as skin tones and texture changes very rapidly from person to person from one continent to other. And also under different illumination Condition, color texture gets modified which leads to changes in observed results. For utilizing various hand gesture to promote real time application we choose vision based hand gesture recognition system that work on shape based features for hand gesture recognition. This is universal truth that every person poses almost same hand shape with one thumb and four fingers under normal condition. The success of approach discussed in paper [1] for hand gesture recognition based on shape features is highly influenced by some constraints like hand should be straight for orientation detection in image, if it will not be followed then result could be unexpected or wrong and also we fix the new parameter to detect the presence of thumb. In paper [2], the approach is based on calculation of three combined features of hand shape which are compactness, area and radial distance. Compactness is the ratio of squared perimeter to area of the shape. If compactness of two hand shapes are equal then they would be classified as same, in this way this approach limits the number of gesture pattern that can be classified using these three shape based descriptors and only 10 different patterns have been recognized[1].

III. System Description

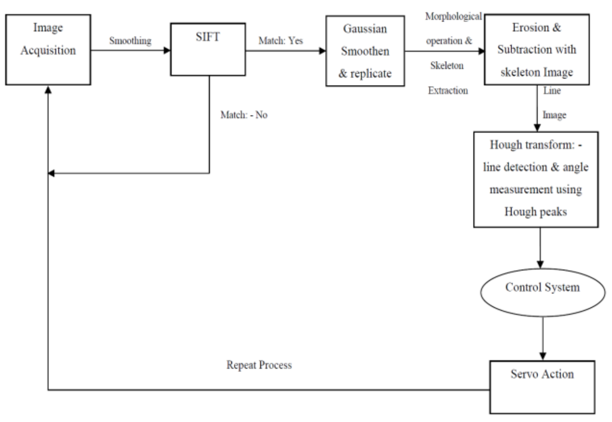
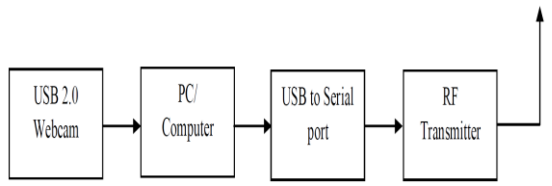


Figure 1 Block Diagram describing the entire process

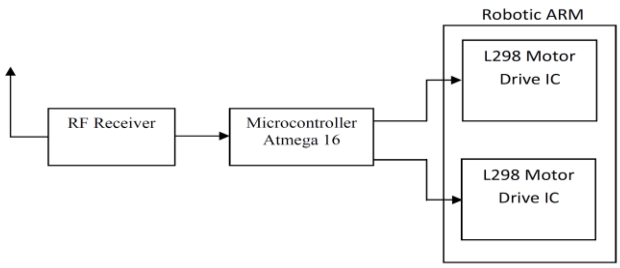
This model presents a Visual Framework for machine control which allows the user to interact with computer through hand postures adaptable to different light conditions. This research focuses on the application of SIFT algorithm with morphological processing and image segmentation for gesture recognition and visual servoing for real time images.

Frames from the video sequences are processed and analyzed for key points after smoothing operation. After performing the matching process with database image using SIFT, the identified posture is selected or discarded. If a posture is selected, a morphological skeleton operation is carried out with Hough transform for angle extraction and measurement. These angle values are sent to the control system for servo action. The image itself is the representation of control selection like servo 1 or servo 2 and the orientation for angle measurement.

IV. Block Diagram



(a)Transmitter Section



(b)Receiver Section

Figure 2 (a, b) Proposed System

Figure 2 shows the systematic block diagram of wireless gesture controlled robotic arm. In transmitter section, we use USB webcam which captures different hand gestures. As webcam is connected to PC/ Laptop, capture image is now under preprocessing. Preprocessing includes features extraction, noise cancellation etc. Actually, some images are already stored in databases which are used to compare with capture image. Initially, Scale Invariant Feature Transform (SIFT) algorithm is already installed in PC/ Laptop by using Matlab tool. SIFT is an efficient method in Object recognition leading to very satisfying results due to invariance to translation, rotation, partial illumination changes and affine or 3D projection. SIFT generates the feature vectors describing image region sampled relative to its scale space co-ordinates for stored database and image capture then compares the features vectors under Matlab tool. Matlab generates the Graphical User Interface to show image reorganization for respective captures image under comparison and sends the generated digital output through RF transmitter via serial port.

At the receiver section, RF receiver collects the transmitted output and sends it to the Atmega 16 microcontroller. Basically, microcontroller stored some algorithm which compares the stored values with received values and gives the respective commands to motor drive IC which moves the robotic arm that was incorporated by DC motors in respective direction.

V. SIFT

Computation of SIFT image features is performed through the four consecutive phases which are briefly described in the following:

1. **Scale-Space Local Extrema Detection**
   This stage of the filtering attempts to identify those locations and scales that are identifiable from different views of the same object. This can be efficiently achieved using a "scale space" function. Further it has been shown under reasonable assumptions it must be based on the Gaussian function. The scale space is defined by the function:
   $L(x, y, \sigma) = G(x, y, \sigma) * I(x, y)$ (1)
   where * is the convolution operator, $G(x, y, \sigma)$ is a variable-scale Gaussian and $I(x, y)$ is the input image.
2. **Keypoint Locaizlation**
   The detected local extrema are good candidates for keypoints. However, they need to be exactly localized by fitting a 3D quadratic function to the scale-space local sample point. The quadratic function is computed using a second order Taylor expansion having the origin at the sample point. Then, local extrema with low contrast and such that correspond to edges are discarded because they are sensitive to noise.
3. **Orientation Assignment**
   Once the SIFT-feature location is determined, a main orientation is assigned to each feature based on local image gradients as shown in figure 2.6 for each pixel of the region around the feature location the gradient magnitude and orientation are computed respectively as:
   $m(x, y) = \sqrt{(L(x + 1, y) - L(x - 1, y))2 + (L(x, y + 1) - L(x, y - 1))2}$ (2)
   $\theta(x, y) = \tan{-1}((L(x, y + 1) - L(x, y - 1))/(L(x + 1, y) - L(x - 1, y)))$ (3)
4. **Keypoint Descriptor**
   The local image gradients are measured at the selected scale in the region around each keypoint [8]. These are transformed into a representation that allows for significant levels of local shape distortion and change in illumination [3].

VI. FLOWCHART

Considering the methodology used in gesture reorganization process that will used to controlled robotic arm motions for various hand gestures, the flow chart can be drawn for transmitter section as below:

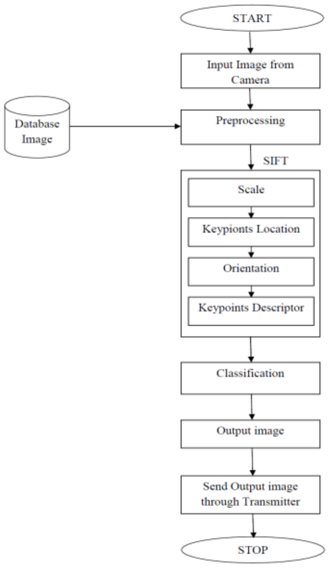


Figure 3 Flow Chart of Gesture Reorganization Process

VII. MORPHOLOGICAL OPERATION

Once the Gesture is recognized the major task is to extract the angle orientation. Morphological operation and Segmentation process was carried out to extract the line features in the image. To remove the unwanted lines from the image, only those lines closest to a certain threshold distance from the centroid is considered and others are changed to black. Further Hough Transform is applied for line detection and angle measurement.

The image after converting into logical format (black and white) is dilated with Gaussian low pass filter of sigma 0.5 to remove the rough edges. The image is then replicated with 1.5 times gray threshold value to extend in its outer border.Since the gesture is matched only a square region enclosing the hand is selected and remaining unnecessary components are rendered black. This would retain only the gesture part in the image.

VIII. HOUGH TRANSFORM

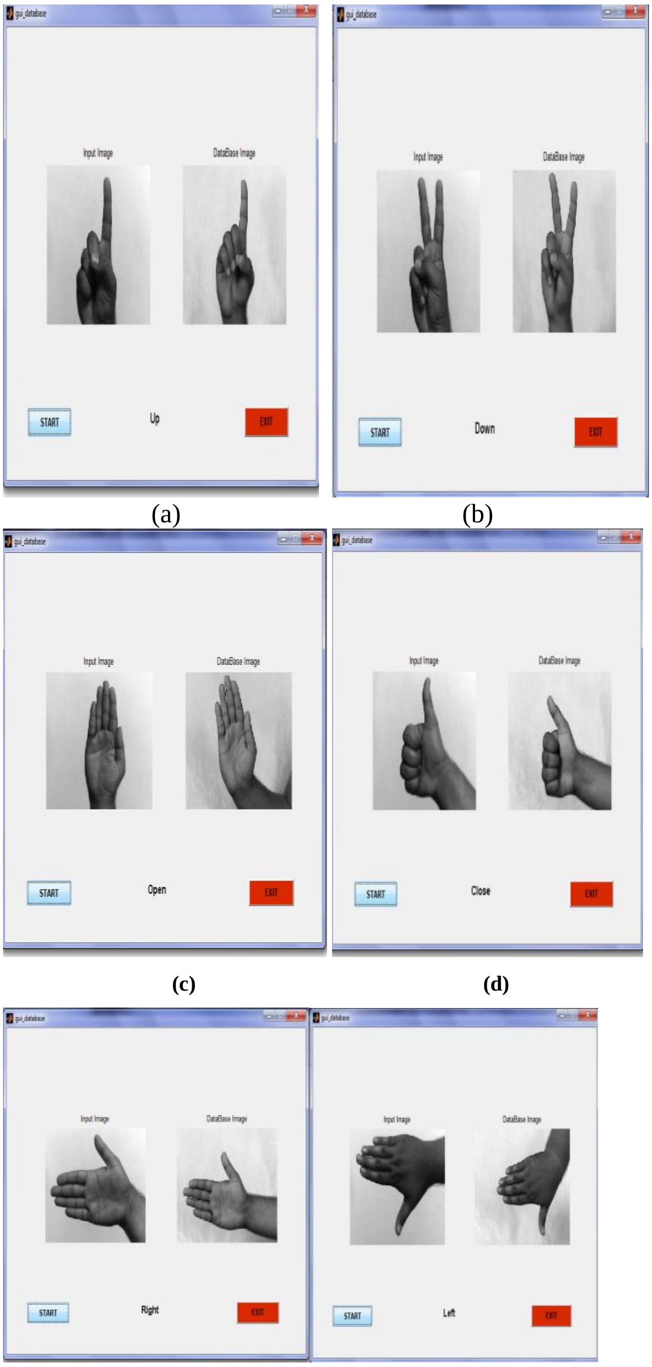
Hough Transform invented by Richard Buda and Peter Hart is the most popular algorithm used in line detection. The technique uses a voting procedure for parameter space, from which the object candidates are obtained as local maxima or minima and stored in accumulator space. The output of the Hough Transform consists of two main parameters ρ and θ where ρ represents the distance between the line and origin and θ is the angle from the origin to its closest point. Using this parameterization, the equation can be given as

$$y = (-\cos\theta / \sin\theta)\, x + \rho/\sin\theta \quad (4)$$

Hence it is possible to associate (ρ, θ) which is unique if $\theta \in [0, \pi)$ and $\rho \in R$ or if $\theta \in [0, 2\pi)$ and $\rho \geq R$

IX. RESULT

The entire gesture recognition system runs in real-time (25 frames/sec) on a Dual core 1.2 GHz processor based computer with a captured image resolution of 192x144. We have done some preliminary tests using a set of 6 different gestures used for robotic arm Up, Down, Left, Right, Grip Open and Grip close. Each gesture was learned using compared with database images & few of them are listed as fellows.



(a) (b)

(c) (d)

(e) (f)

Fig. 4 Results of GUI

X. CONCLUSION

We described a generic approach for the detection and recognition of segmental hand gesture in image sequences. Gesture extraction and recognition rely on the invariant moment that describes the different appearance of gesture in a real-time [192x144 pixels], the proposed method is applied to the 'Poppy' robot as a tested to communicate with Human and shows the robustness to the change in scale and rotation.

In this model, we have presented the design, implementation, and evaluation of an imitative robotic arm control system. The system detects user motions in real time, without the need of model training before using the system. The motion tracking approach achieves 90% precision and recall rate with blank background, and shows acceptable robustness under the change of cluttered background and user-to-camera distance. The realtimeness, the robust performance, and the intuitive imitative human- robot interaction make the system particularly desirable for controlling home robots in a smart home environment.

XI. FUTURE WORK

There are plenty of research opportunities for future work. Currently the tracking model is limited to 2D. In future we will try to investigate a 3D hand tracking technique using stereo vision analysis. Focus will be to improve the system performance for large number of hand database for recognition. Image classifiers can be used for speeding up the process. The idea of the project was to develop a mechanism for robot control through hand direction measurement. As it can be seen that it is efficiently achieved through SIFT, but this is an exception for huge databases due to large processing time. The above procedure aims at providing cost efficient and much simpler approach by reducing the use of special hardware components. This could be made even faster if written in C/C++/Open CV but resulting in much complexity. MATLAB approach is slightly slower but allows the user to work faster and concentrate on results and not on design.

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