A Diagnostic review of different approaches for Hand Gesture Recognition

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Abstract: The growth of the gesture technology has accelerated very swiftly in recent years. The reason behind the fast evolution of gesture recognition is that it has its numerous applications in many fields and also it is potent to interact with machines via Human-Computer Interaction (HCI). In this paper, introduction to various gesture recognition technique and their drawbacks, application of this recklessly developing technology are mentioned. The key reasons and important points are mentioned to illustrate some algorithm's efficiency in terms of complexity, time consumption, better output, fast responding, cost, etc. and to conclude the best among them. The intention of this work is to conclude the best and efficient approach of the implementation of the gesture recognition systems so that our society can be firm to implement the system by understanding its pros and cons and trusting upon the type of implementation they adopt for any of their purpose would be more beneficial for them in all aspects.

Index Terms **- Hand Posture, Hand Gesture, Hand Gesture Recognition (HGR), RADAR, Digital Image Processing, Computer Vision, Electronic Gloves, Feature Extraction, Neural Networks**

I. INTRODUCTION

Every day in our day-to-day life we use gestures to express something that is not understood by speech or sometimes gestures adds a flavour to our speech. Gestures are made by everyone from a child to an old man, from greeting someone using handshake to warning someone by showing index finger. How would it be if these gestures can be understood by machines near us? What if these gestures recognition systems are used in place of remotes and other devices that are used to operate such machines like Television, Air-Conditioner, and other appliances that are used. It would be more natural if its applications are analysed, let say for an instance consider a remote that is used to operate a Television, and if the remote is lost what can be done then (assuming that if it was the only remote available) and even if the remote is available in market and again bought for use and if again if it is lost or any damage occurs to it then again the TV cannot be operated by user. As there was a dependency of user on that remote, so the gesture recognition systems can be a much better substitute for it.

The aim of the hand gesture recognition (HGR) is to create a natural link between human and machine (computer) that convey a meaningful command to the machine so that the machine can respond and perform the following task. These systems successes in achieving user convenience, in the Human-Computer Interaction (HCI) process, by reducing the dependency of user on devices like mouse, keyboard, touchscreen, joysticks, etc. Instead the use of these devices, the proper use of the human body i.e. full use of the human body parts and every patterns and angles made by the human body can be used. A gesture recognition system includes different mathematical algorithms in order to perceive the actual meaning of gestures. With the help of this system, any machine and human can interact freely i.e. any machine can communicate with a human just like other human does i.e. the gestures becomes the mode (language) of communication that machines can understand. Gestures are of two types, one is static also known as postures and the other one is dynamic which comprises of continuous series of such postures. As we are seeing this system with the vision of lessening the dependency of other devices to control machines and make this interaction more natural and efficient as possible. But still in gesture recognition systems, some methods and approaches of this technology uses additional and traditional hardware devices like data glove, cyber glove and color markers in order to easily extract the information and features about the gesture input that is being given by the user side [1]. It has wide range of applications in different fields such as in automobiles, gaming, television and many more. The purpose of this paper is to study different approaches and methods comparatively in which some of the hand gesture recognition system techniques or methods can be more efficient related to different factors if implemented.

II. DIFFERENT METHODS AND APPROACHES FOR GESTURE RECOGNITION

1. Electrical field (or electro-magnetic field) based sensing technology

In this type of technology, RADAR is used to sense the gesture i.e. an electro-magnetic field is created and if a gesture is made in that field then the device interprets the input and understands the input given and follow corresponding commands. Let's see an

analogy of it, that a bat flying in the air, they are blind. No bat can see any object or obstacles coming in their path but still they can sense it with their capability to transmit and receive ultrasonic sounds. The bat sends an ultrasonic waves while flying. These waves passes in its way and if any obstacles comes between the path then then waves gets reflected back to bat and bat senses it. This is the way how ultrasonic waves has wide applications in various fields.

Radar (RAdio Detection And Ranging**)** is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving) and a receiver and processor to determine properties of the object(s). Radio waves (pulsed or continuous) from the transmitter reflect off the object and return to the receiver, giving information about the object's location and speed [2]. A new robust and an high-resolution which can work on low-power and very main thing is that it is miniature gesture sensing technology which is introduced by Google ATAP for human-computer interaction (HCI) based on millimetre -wave radar. They describe a new approach for developing a radar-based sensor optimized for HCI, building the sensor architecture from the ground up with the inclusion of radar design principles, high temporal resolution gesture tracking, a hardware abstraction layer (HAL), a solid state radar chip and system architecture, interaction models and gesture vocabularies, and gesture recognition [3].

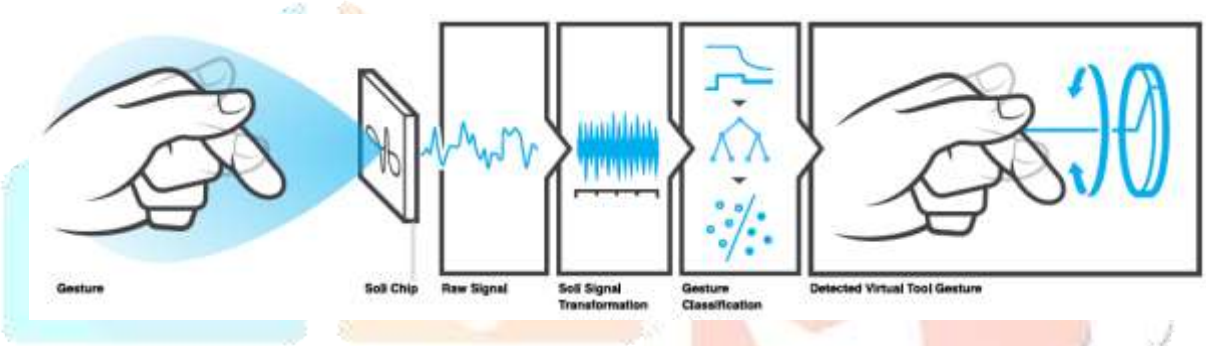


Figure 1: Soli is the first millimetre-wave radar system designed end-to-end for ubiquitous and initiative fine gesture interaction [4].

The basic principles of radar sensing are straight forward (see Figure 2). A modulated electromagnetic wave is emitted toward a moving or static target that scatters the transmitted radiation, with some portion of energy redirected back toward the radar where it is intercepted by the receiving antenna. The time delay, phase or frequency shift, and amplitude attenuation capture rich information about the target's properties, such as distance, velocity, size, shape, surface smoothness, material, and orientation, among others. So these properties may be extracted and approximated by appropriately processing the received signal. The goal of radar system design is to optimize radar functional performance for the specified application, such as gesture tracking in the case of Soli, within the application's constraints.

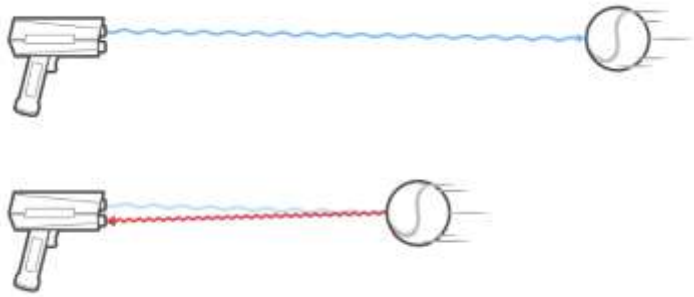


Figure 2: The fundamental principles of radar sensing are based on transmission and reflection of RF waves [4].

The design of any radar system includes a) hardware, such as antennas and internal circuitry components, b) signal processing techniques to modulate the transmitted waveform and extract information from the received waveform, and c) radar control software that executes radar operation and algorithms [Richards et al. 2010]. The design of all these elements is strongly interconnected and cannot be specified independently from each other or the specifics of the application [4].

2. Device Sensing (or Glove-based) Technology

As in hand gesture recognition, the most necessary part of the whole procedure is to accept the right input i.e. if the gesture is shown by the user and the gesture shown is different from what the machine has interpreted then everything will go wrong. For this

there are some instruments and accessories that can be used by the user for giving more accurate and less erroneous gesture input and avoiding any type of misinterpretation of input. Besides this, there are few challenges that are faced in this type of technology. As discussed now that this approach uses certain electronic devices and gloves to accomplish the goal so the major drawback of this technology is that the user is dependent on these devices like gloves and color markers.

For this there are different devices like instrumented gloves which have some types in it. Data Glove, Z-Glove, Space Glove, Super Glove, Cyber Glove [5].Wired gloves can provide input to the machine (computer) about the position and rotation of the hands using magnetic or inertial tracking devices. Furthermore, some gloves can detect finger bending or any activity done by the fingers with a high degree of accuracy (5-10 degrees) i.e the degree of freedom, or even provide tactual feedback to the user, which is a simulation of the sense of touch. The first commercially available hand-tracking glove-type device was the Data Glove, a glove-type device which could detect hand position, movement and finger bending. This uses fiber optic cables running down the back of the hand. Light pulses are created and when the fingers are bent, light leaks through small cracks and the loss is registered, giving an approximation of the hand pose [6].The hand gesture input devices here, the Z-Glove and the Data Glove, are lightweight cotton gloves containing flex sensors which measure finger bending, positioning and orientation systems, and tactile feedback vibrators [7]. Different types of sensors used in this technology are Accelerometers, photoelectric sensors, color sensors and kinect sensors. The table given below shows some essential gloves used for this type of technology, sensors used in them and their short description [5][8].

Name of Glove	Sensors used	Description
Data Glove & Z-Glove	5 – 15 sensors	10 DOF Developed by VPL Research Designed for applications that required direct object manipulation with the hand, finger spelling, evaluation of hand impairment through the general purpose interface devices.
Space Glove	Sensors with 12 bit analog to digital converters	6 DOF A unique in that the user placed his fingers and thumb through plastic rings that sat between the proximal interphalangeals and the metacarpophalangeal joints.
Super Glove	10 – 16 bend sensors	Developed by W Industries in 1991 With its minimal and standard configuration, the Super Glove measures flexion of both themetacarpophalangeal and proximal interphalangeal joints for all four fingers and the thumb. The glove comes in two different sizes and is available for both the left and right hand.
Cyber Glove	18 bend sensors	6 DOF Two bend sensors on each finger, four abduction sensors, plus sensors measuring thumb crossover, palm arch, wrist flexion, and wrist abduction.
	22 bend sensors	Three flexion sensors per finger, four abduction sensors, a palm-arch sensor, and sensors to measure wrist flexion and abduction. Each sensor is extremely thin and flexible being virtually undetectable in the lightweight elastic glove.

3. Vision Based Technology

The glove based technology has the main drawback that the user has to depend on those gloves i.e. the gesture recognition input can only be collected if user is wearing glove and that has to be attached to the computer else it wouldn't be possible to pass input to the system. This dependency shrinks the freedom of movement and constricts the natural interaction between the human and computer. Vision based technology has no involvement of gloves instead there are different types of algorithms used to accept the gestures from the user. Previously the traditional methods were used but due to the enhancement in computer vision and digital image processing, new, better and fast algorithms are used and can be adopted practically for any purpose. In vision based technology, the techniques included in this paper are Feature Extraction, Edge Detection, Histogram Orientation, Finger Segmentation and some soft computing approaches like Artificial Neural Networks, Fuzzy Logic and Genetic Algorithm [5][9].

i. Feature Extraction

In vision based approach, the postures and gestures are recorded by video camera [10] and there can be one or more than one cameras depending on the need. The number and type of the camera depends on the requirement of that location and situation. It includes different strategies by which the features from an image can be extracted as an input like types of Segmentation which includes Thresholding, Region-based segmentation, Edge-based Segmentation, Matching, Mean Shift Segmentation, Graph cut segmentation and some other more ways [5][11].

ii. Edge Detection

In this method, the outlines of the hand (fingers) are observed in the camera and accordingly from the outlines of the fingers and hand the gesture or posture is interpreted by the machine. This approach of edge detection can be implemented using the Segmentation and also using Artificial Neural Networks [11][12][13][16].

iii. Histogram Based Recognition

In this method, the histogram of the image is formed and from the histogram variants and orientation the required information is extracted by analysing the height and other dimensions of the bars in an histogram chart (diagram) [14][15].

iv. Artificial Neural Networks

The basic processing elements of neural networks are called artificial neurons, or simply neurons [16]. Often they are simply called nodes, each of which takes a number of inputs and generates a single output. The inputs are denoted by v_1, v_2,…, and weights by w_1,w_2,...; the total input to the neuron is then $x = \sum_{i=1}^{n} v_i w_i - \theta$ where θ is a threshold associated with this neuron[11]. For this approach, the training data has to be given after which the input data can be matched or checked with the stored training data for inputting [9][17][18].

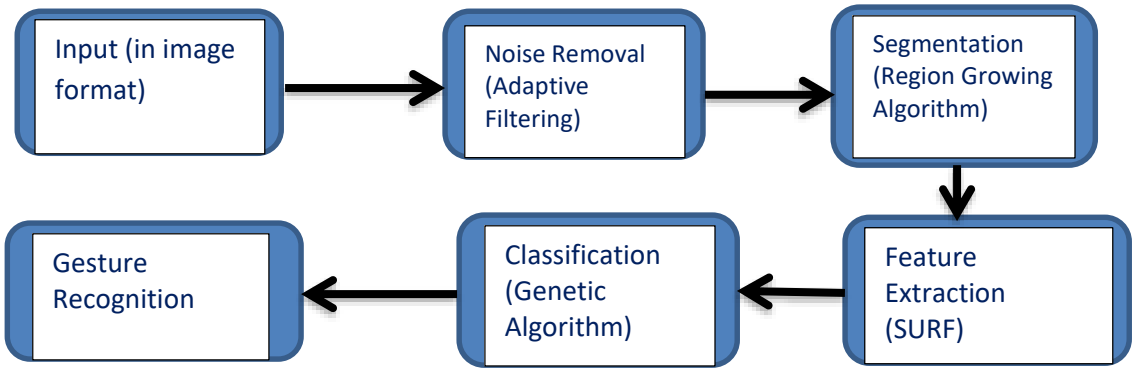
v. Fuzzy Logic

Fuzzy logic is a form of multi-valued logic in which the truth values of variables may be any real number between 0 and 1. It is operated to hold the concept of partial truth, where the truth value may range between completely true and completely untrue. On contrary, in Boolean logic, the truth values of variables may only be the integer values 0 or 1. Gesture recognition approach can also be based on representing hand movement trajectory by motion vectors analysed using fuzzy rule-based inference and also Kalman filters can be used for more efficiency in tracking hand[20]. Fuzzy logic is applicable to many fields, from control theory to artificial intelligence. This approach states that for the processing purpose, it is not always compulsory to have an accurate and rigid data instead with imprecise and partially true data also the processing can be done [19]. The processes in fuzzy logic are:

- Fuzzify all input values into fuzzy membership functions.
- Execute all applicable rules in the rulebase to compute the fuzzy output functions.
- De-fuzzify the fuzzy output functions to get "crisp" output values.

vi. Genetic Algorithms

This approach mainly consists of four major steps steps. Firstly, in preprocessing process, the noise removal can be done by using adaptive filtering and then the segmentation process will be done with the help of region growing algorithm. After segmentation, feature extraction will be done by speeded-up robust features (SURF) algorithm with respect to the point feature. Classification will be done using improved genetic algorithm. Finally, the results will be compared with support vector machine and neural network classifiers. Figure 1 shows the flow of our proposed system [21].



III. Application Areas

This technology has wide range of applications from schools to factories everywhere [1][22].

- *Gaming*

In gaming, different devices like joysticks, mouse and keyboards and other different sensor devices are used which led to device dependency for the user. This approach of gesture recognition technology can be proved very comfortable for users to play games and interact more naturally and friendly and have a unique gaming experience.

- *Health Care*

In health care, gesture recognition have wide range of opportunities where it can be used like in diagnostic check-ups and tests.

- *Automobile*

Gestures are the future of automobile industries because as we know that the self-driving cars have been introduced in some countries and if the humans want to optimize then the HGR would be the better option to operate cars using just an hand.

- *Automation (Home & Industry)*

Due to the advancement in automation in Homes and Industries, the automated machines and robots can be handled using gestures in a more natural way.

- *Defence*

From wars to training, gestures can be a very comfortable and efficient way to operate devices in defence organizations. If an army officer using high-technical ammunitions then operate them through HGR can be the best way ever. Same in Navy and Air-Force too gestures can be very useful and natural. As in defence, anything can happen any time so to be more swift and natural gestures are the best choice.

- *Sign Language Interpretation & Recognition*

Gestures can be used as an intermediate or base language for the language translation, interpretation and recognition too. For phusically challenged ones, gestures are proved to be a boon for them.

- *Virtual Environments*

Since Virtual Reality is the echoes that we are hearing so much which actually spread in every activity of our whole day from reading news to watching movies, from learning to teaching, also for a better gaming experience, the gestures can be a very natural way for a convenient interaction with machines on virtual environments.

- *Alphabets and Numbers Recognition*

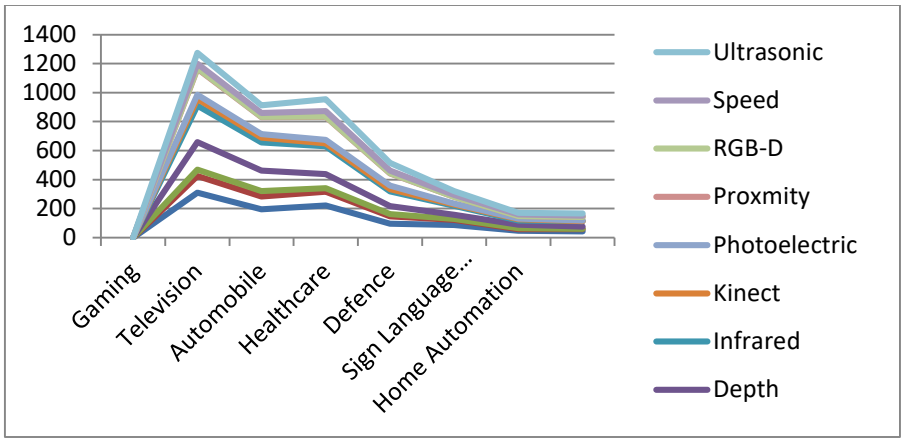
In case of communication between a dumb or deaf person and in case for the betterment of lives of physically challenged people this approach is very useful for conveying thought, views and ideas. On a large scale, this advantage can have a very good impact on their lives.

- *Television Control*

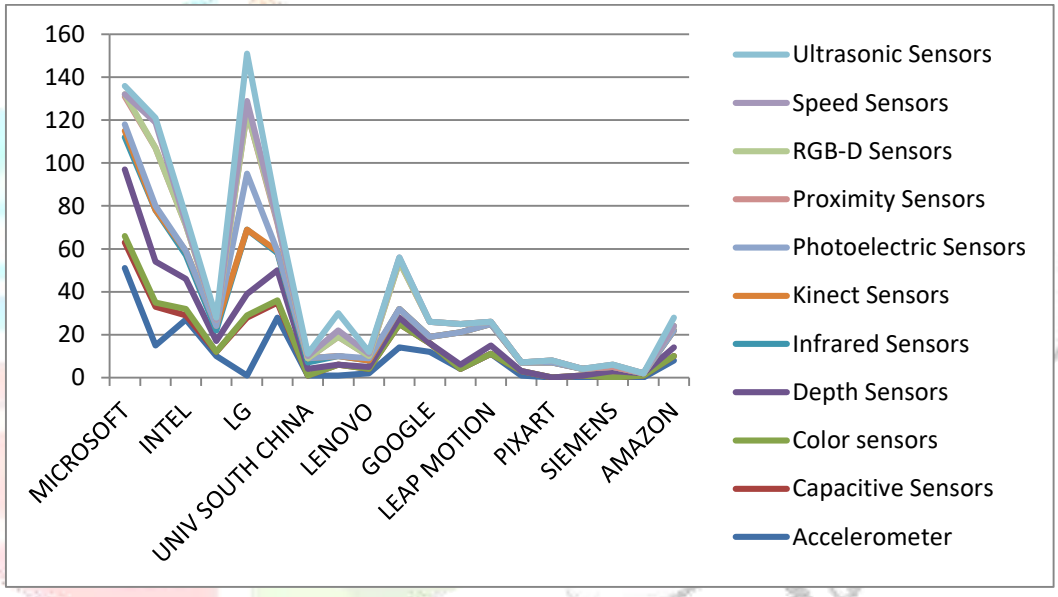
Everyone uses a TV remote to operate television what if the TVs are operated on the gestures of your hand. Many TV companies have used this approach for the advancement of their product and its usability. The channel, volume and other different functionalities of the TV can be operated and viewed just by the simple movements of your hand and fingers.

IV. Statistical Data

This survey collects the data which shows the usage of sensors for various applications. These different technologies uses different types of sensors like Accelerometer, Color Sensors, Depth Sensors, Infrared Sensors and some others [22].



This survey also presents the data which shows the usage of sensors by different companies. These different technologies uses different types of sensors [22].



V. Challenges (Drawbacks)

The challenges for the approaches that we discussed are that for the electro-magnetic sensing technology, the user need to be in the field of the radar and the field of electro-magnetism generated by the small chip[4]. In case of glove-based sensing technology, the user is dependent on these gloves that constricts user's freedom of movement in a natural way. In vision based sensing technology, the main precaution to be taken is the position of camera and the number of cameras used. The camera should capture the image of postures or the images of gesture in such a way that the image can be further processable for undergoing required algorithm and the information should be better extracted from the image[5].

VI. Conclusion

The very efficient and advanced approach to HGR is the electric (or electro-magnetic) field sensing technology, as it is miniature gesture recognition system and the user nor will required any additional devices like gloves or camera and neither there will be any user's dependency on any extra device[3][4]. The next efficient approach would be the vision based approach because once cameras are installed, the further task is done by the algorithm that we have implemented for input excerption from the image captured. In this approach, user has no restricted freedom of hand movement i.e. naturally the user can command to the machines through the camera by making hand gestures[5][9]. But in glove based sensing technology, it doesn't mean that just the dependency on gloves and other electronic hand wearables may prove it as an inefficient approach. Instead the input generated through this approach is very accurate

and precise, only the device dependency makes this approach less preferable in case if we are implementing a system in which user can naturally interact with machine at any instant of time irrespective of the availability of gloves, what if in case of glove-based approach the gloves are not available at that instant, might be missing or out of sight but that present need to interact with system wouldn't be accomplished only because of the dark side of the device dependency.

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