IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Issue-5, May 2019 E-ISSN: 2347-2693

Computer Vision based Hand Gesture Recognition: A Survey

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DOI: https://doi.org/10.26438/ijcse/v7i5.507515 | Available online at: www.ijcseonline.org

Accepted: 10/May/2019, Published: 31/May/2019

Abstract— Gestures are the most common way of interaction for physically challenged people. Owing to this, many researchers are interested in the direction of automated hand gestures recognition. Major applications include extremely wide range: from sign language to robot control or from virtual reality to intelligent home systems. In addition, these enable deaf and dumb to interface with machine in a more natural way. As a result, immense endeavours have been done in this domain and this article, therefore, reviews the major researches in a comprehensive manner.

Keywords— Gesture Recognition; Artificial Neural Networks; Computer Vision; Classification.

I. INTRODUCTION

Human hand gestures provide the most important means for non-verbal interaction among people. They range from simple manipulative gestures that are used to point at and move objects around to more complex communicative ones that express our feelings and allow us to communicate with others.

Hand gesture recognition based man-machine interface is being developed vigorously in recent years. Due to the effect of lighting and complex background, most visual hand gesture recognition systems work only under restricted environment. Hand Gestures Recognition techniques have been divided into two categories- Sensor based and Vision Based recognition.

Sensor based recognition collects the gesture data by using one or more different types of sensors. These sensors are attached to hand which record to get the position of the hand and then collected data is analysed for gesture recognition. Data glove are an example of sensor based gesture recognition other sensors used were Wii controller, EMG sensors, accelerometer sensors, etc. Sensor based recognition has certain limitations.

First of all it requires a proper hardware setup which is very expensive. Secondly, it hinders the natural movement of the hand. So to overcome the limitation of sensor based recognition vision based techniques came into existence.

Vision based techniques make use of camera to capture the image for hand gesture. Vision based recognition make use of many image processing algorithms to get hand posture information and movement of hand. This approach recognizes gesture from shapes, orientations, contours, and color or motions features of a hand. Coloured markers are an example of vision based recognition. But the vision based recognition also has some limitations that it is affected by illumination changes and cluttered backgrounds.

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Recently, development of depth camera sensors like Kinect sensor [135], RGB sensor has removed limitations of above techniques. These sensors are able to capture even a small object and also these depth cameras offer a very effective way to isolate hand from the background using depth thresholding.

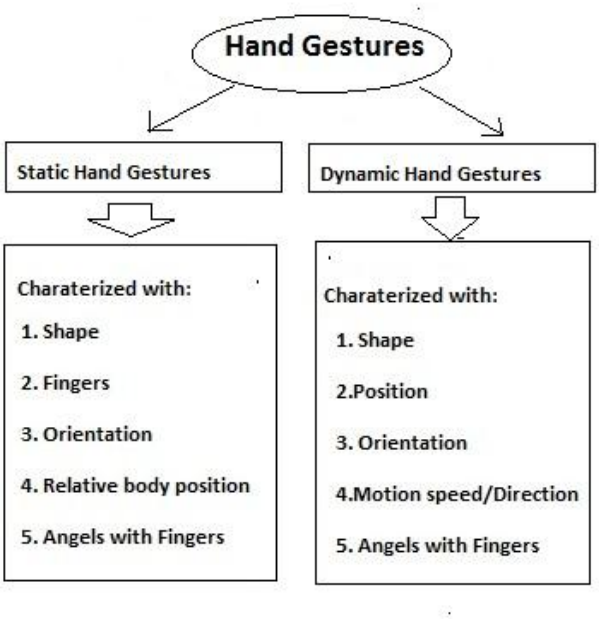

Figure 1: Types of Hand Gesture Recognition

In this article Section 1 gives an introduction about the hand gesture recognition and computer vision systems. Section 2 gives a brief description of the researches in the field of hand gesture recognition using various image processing techniques classifiers for recognition. In the last, we summarized our conclusions in Section 3.

II. LITERATURE SURVEY

Kaur Sarabjit et.al presented a vision based system that provides a feasible solution to Indian Sign Language (ISL) recognition of static gestures of alphabets. It deals with images of bare hands, which allows the user to interact with the system in a natural way. An image was processed and converted to an Eigen vector that compared with the Eigen vectors of a training set mean of signs. The most important part of the recognition method was a feature extraction process using Eigen value algorithm in MATLAB coding. An image was processed and converted to a feature vector that compared with the feature vectors of a training set mean of signs. The system was implemented and tested using a data set of 650 samples of hand sign images; 25 images for each sign. The system recognizes one handed alphabet signs from Indian sign language (ISL). The proposed system achieved a recognition accuracy of 100 % [1].

Chaudhari Parul Et al. presented a vision based static sign gesture recognition system using neural networks. The system firstly convert images of static gestures of American Sign Language into Lab color space where L for lightness and (a, b) for the color-opponent dimensions, from which skin region i.e. hand is segmented using thresholding technique. The region of interest (hand) is cropped and converted into binary image for feature extraction. Then height, area, centroid, and distance of the centroid from the origin (top-left corner) of the image are used as features. Finally each set of feature vector was used to train a used to train a feed-forward back propagation networks. Experimental results showed successful recognition of static sign gestures with an average recognition accuracy of 85 % on a typical set of test images [2].

Sahoo K. Ashok Et al. described a system for automating recognition of Indian sign language static single handed and double handed character signs, in which a regular camera is used to capture the gestures. The system is designed to recognize isolated signs, i.e. each input image contains exactly one ISL character sign. To recognize images in real environment, two data sets were created, which contains 2600 images for single handed characters and 2340 gestures of double handed characters (A-Z). Structural features, local histogram features and direct pixel values of gray scale images extracted from these gestures are used as input to the recognition system. After extracting features from images, KNN classifier and neural networks classifier were used to classify the gestures. In single handed data set 95.30% recognition rates were achieved, and in double handed data set 96.37% accuracy rates were achieved [3].

Nancy Et al. developed a technique for recognizing the gestures made by user using MATLAB® and implemented this technique to control the computer remotely without any keyboard or mouse. A real-time hand tracking technique presented by using a white cloth glove with a red color marker placed at fingertip. In this paper, a hand gesture recognition method based on color marker detection was presented as we have used a red color marker that is mounted on the fingertip of right hand to track the user's hand [4].

Chadhuary Et al. discussed work done in the area of hand gesture recognition where focus was on the soft computing based methods like artificial neural networks, fuzzy logic, genetic algorithms, etc. They also described hand detection methods in the pre-processed image for detecting the hand image [5].

D. Shroffe E.H. Et al. worked to identify the hand gestures that was predefined using artificial neural networks which was particularly useful for classification purpose. The EMG patterns were extracted from the signals for each movement and the features extracted from the signals were given to the neural networks for training and classification since it was the good technique for classifying the bio signals. The features like mean absolute value, root mean square, variance, standard deviation, Mean frequency, zero crossing and slope sign change were chosen to train the neural networks [6].

Rautaray Et al. provided an analysis of comparative surveys for hand gesture recognition. It focused on the three main phases of hand gesture recognition i.e. detection, tracking and recognition. Different application which employed hand gestures for efficient interaction has been discussed under core and advanced application domains. This paper also provided an analysis of existing literature related to gesture recognition systems for human computer interaction by categorizing it under different key parameters. It further discussed the advances that were needed to further improvise the present hand gesture recognition systems for future perspective that can be widely used for efficient human computer interaction. The main goal of this survey was to provide researchers in the field of gesture based HCI with a summary of progress achieved to date and to help identify areas where further research is needed [7].

Falco I.D Et al. used differential Evolution to perform automatic classification of hand gestures in a thirteen–class database. Performance of the resulting best individual was computed in terms of error rate on the testing set, and is compared against those of other ten classification techniques well known in literature. Results shown the effectiveness and the efficiency of the approach in solving the classification task. Furthermore, the implemented tool allowed to extract the most significant parameters for differentiating the collected gestures [8].

Premaratne Et al. presented research that described a mechanism to accurately interpret dynamic hand gestures using a concept known as ‘gesture primitives’ where each dynamic gesture described as a collection of many primitives over time that can drive a classification strategy based on Hidden Markov Model to reliably predict the gesture using statistical knowledge of such gestures[9].

S.Rajaganapathy Et al. focused their attention to vision-based recognition of hand gestures. In order to make the review of the related literature tractable, this paper did not discuss the techniques that are based on cameras operating beyond the visible spectrum (e.g. thermal cameras, etc.), active techniques that require the projection of some form of structured light and invasive techniques that require modifications of the environment, for instance that the user wears gloves of particular color distribution or with particular markers [10].

S.Rajaganapathy Et al. proposed a technique with the help of Microsoft Kinect a motion capture device from Microsoft. There are a few systems available for sign language to speech conversion but none of them provide natural user interface. For consideration if a person who has a disability to speak can stand perform the system and the system converts the human gestures as speech and plays it loud so that the person could actually communicate to a mass crowd gathering. Also the system was planned in bringing high efficiency for the users for improved communication [10].

Wei J. Et al. presented new hand shapes and the corresponding recognition system for the HCI with robot or Coordinate Measuring Machine. Using a touchpad to precept the touching of fingers, hand shapes posed to express HCI instructions were defined by the combinations of 2 binary status, i.e. status of touching /detaching on touchpad and status of stretching /retracting over touchpad, of Index, Middle, Ring and Little fingers. Method of extracting the features in hand shape image was presented based on Neural Networks, a decision binary tree used in the real-time recognition of the hand shapes. A correctness ratio of about 95% obtained when implemented by DSP processor in the recognition of 12 hand shapes [11].

Gutta S. Et al. introduced the methodology of hybrid classification architectures for face and hand gesture recognition tasks and shown their feasibility through experimental studies using the FERET data base and gesture images. The hybrid architecture, consisting of an ensemble of connectionist networks - radial basis functions (RBF) - and inductive decision trees (DT), combines the merits of 'holistic' template matching with those of 'abstractive' matching using discrete features and subject to both positive and negative learning. The hybrid architecture, quite general as it applies to both face and hand gesture recognition, derives its robustness from (i) consensus using ensembles of RBF networks, and (ii) flexible matching using categorical classification via decision trees. The experimental results, proving the feasibility of our approach, yield (i) 93 % accuracy, using cross validation, for contents-based image retrieval (CBIR) subject to correct ID matching tasks, such as 'find Joe Smith without glasses: on a data base of 200 images, and (ii) 96 % accuracy, using cross validation, for forensic verification on a data base consisting of 904 images corresponding to 350 subjects (of whom 102 are duplicates). Cross validation results on the hand gesture recognition task yield a false negative rate of 3.6 % and a false positive rate of 1.8 % , using a data base of 750 images corresponding to 25 hand gestures[12].

Byung-woo Min Et al. considered the planar hand gesture in front of camera and therefore 8-directional chain codes as input vectors. For training an HMM networks, a simple context modeling method was embedded as training on “left-to-right" HMM model. This model was applied to draw graphic elements such as triangle, rectangular, circle, arc, horizontal line, vertical line and edit the specified graphic elements such as copy, delete, move, swap, undo, close. Therefore, the overall objectives are 12 dynamic gestures. In these experiments, higher classification results have been achieved on a pre-confined test environment : 1) the spotting time is synchronized at the static state of a hand,

2) other limb parts except hands is motionless, 3) the change of hand posture during movement is meaningless[13].

Sazonov E. Et al. introduced a non-invasive wearable sensor system (Personal Automatic Cigarette Tracker – PACT) that was completely transparent to the end user and does not require any effort to achieve reliable monitoring of smoking behavior in free living individuals. A key component of PACT was a sensor that captures a characteristic hand-to-mouth gesture preceding cigarette smoke inhalations.

This paper detailed design and validation of a wearable radiofrequency proximity sensor that measures the distance between an individual's wrist and chest in real-time. Hand-to-mouth gestures detected with this device provide quantitative data that can be used for analysis of behavioral patterns during smoking and other activities [14].

Zhu C. Et al. suggested an online hand gesture recognition algorithm for a robot assisted living system. A neural network-based gesture spotting method was combined with the hierarchical hidden Markov model (HHMM) to recognize hand gestures. In the segmentation module, the neural networks was used to determine whether the HHMM-based recognition module should be applied. In the recognition module, Bayesian filtering was applied to update the results considering the context constraints. They implemented the algorithm using an inertial sensor worn on a finger of the human subject [15].

Hsieh H. Et al. used an adaptive skin color model based on face detection is utilized to detect skin color regions like hands. To classify the dynamic hand gestures, they developed a simple and fast motion history image based method. Four groups of Haar like directional patterns were trained for the up, down, left, and right hand gestures classifiers. Together with fist hand and waving hand gestures, there were totally six hand gestures defined. It was observed that it was suitable to control most home appliances. Five persons were doing 250 hand gestures at near, medium, and far distances in front of the web camera were tested. Experimental results shown that the accuracy was 94.1% in average and the processing time was 3.81 ms per frame [16].

Haitham Hasan Et al. presented a novel technique for hand gesture recognition through human–computer interaction based on shape analysis. The proposed system presented a recognition algorithm to recognize a set of six specific static hand gestures, namely: Open, Close, Cut, Paste, Maximize, and Minimize. The hand gesture image was passed through three stages, preprocessing, feature extraction, and classification. In preprocessing stage some operations were applied to extract the hand gesture from its background and prepare the hand gesture image for the feature extraction stage. In the first method, the hand contour was used as a feature which treats scaling and translation of problems (in some cases). The complex moment algorithm was, however, used to describe the hand gesture and treat the rotation problem in addition to the scaling and translation. The algorithm used in a multi-layer neural networks classifier which uses back-propagation learning algorithm. The results shown that the first method has a performance of 70.83%recognition, while the second method, proposed in this article, has a better performance of86.38% recognition rate [17].

Ehsan M.R. Et al. proposed the process of detecting different predefined hand gestures (left, right, up and down) using artificial neural network (ANN). The EMG pattern signatures were extracted from the signals for each movement and then ANN utilized to classify the EMG signals based on features. A back-propagation (BP) networks with Levenberg-Marquardt training algorithm has been used for the detection of gesture. The conventional and most effective time and time-frequency based features (namely MAV, RMS, VAR, SD, ZC, SSC and WL) have been chosen to train the neural networks [18].

Uebersax D. Et al. presented a system for recognizing letters and finger-spelled words of the American Sign Language (ASL) in real-time. The letter classification was based on average neighborhood margin maximization and relies on the segmented depth data of the hands. For word recognition, the letter confidences were aggregated. Furthermore, the word recognition was used to improve the letter recognition by up-dating the training examples of the letter classifiers on-line [19].

Ren Z. Et al. Compared the performance in terms of speed and accuracy between FEMD and traditional corresponding based shape matching algorithm, Shape Context. And then we introduced several HCI applications built on top of an accurate and robust hand gesture recognition system based on FEMD. This hand gesture recognition system performed robustly despite variations in hand orientation, scale or articulation. Moreover, it worked well in uncontrolled environments with background clusters. They demonstrated that this robust hand gesture recognition system can be a key enabler for numerous hand gesture based HCI systems [20].
Ghosh D.K. Et al. coincided the principal component of the segmented hand gestures with vertical axes. A localized contour sequence (LCS) based feature was used here to classify the hand gestures. A k-mean based radial basis function neural network (RBFNN) was also proposed here for classification of hand gestures from LCS based feature set. The experiment was conducted on500 train images and 500 test images of 25 class grayscale static hand gesture image dataset of Danish/international sign language hand alphabet. The proposed method performed with 99.6%

classification accuracy which was better than earlier reported technique [21].

Panwar M. presented a real time system for hand gesture recognition on the basis of detection of some meaningful shape based features like orientation, centre of mass (centroid), status of fingers, thumb in terms of raised or folded fingers of hand and their respective location in image. The approach introduced in this paper was totally depending on the shape parameters of the hand gesture. It did not consider any other mean of hand gesture recognition like skin color, texture because these image based features are extremely variant to different light conditions and other influences. To implement this approach they utilized a simple web cam which was working on 20 fps with 7 mega pixel intensity. On having the input sequence of images through web cam it used some pre-processing steps for removal of background noise and employs K-means clustering for segmenting the hand object from rest of the background, so that only segmented significant cluster or hand object was to be processed in order to calculate shape based features. This simple shape based approach to hand gesture recognition could identify around 45 different gestures on the bases of 5 bit binary string resulted as the output of this algorithm. This proposed implemented algorithm had been tested over 450 images and it provided approximate recognition rate of 94% [22].

Huang Y. Et al. proposed a hybrid method for hand gesture recognition, which extended their previous work on a gesture recognition method based on concept learning by the addition of an association learning process. They used association learning to reveal the frequent patterns in gesture sequences, and then used such patterns to help recognize incomplete gesture sequences. Experiments presented the use of association learning does indeed improve recognition accuracy. Experiments also presented the hybrid method was comparable to two state of the art methods (HMMs and DTW) for hand gesture recognition, but outperforms them in the larger datasets[23].

Ghafauri S. Et al. proposed a method for hand gesture recognition. The proposed method increased hand gesture recognition rate and decreased false positive error rate by using combination of Haar-like and Histogram of Oriented Gradients (HOG) features. Also some new Haar-like features were proposed proportional to hand posture to solve major Haar-like problem that is high false positive error rate in hand posture recognition. These features improved recognition rate to 83%. The experiments showed that hybrid method could recognize hand gesture by 93.5% accuracy which is 25% higher than previous method, and decreased the false positive error from 92% to 8% [24].

Leach M. Et al. offered the methodology and results of examining various classifiers (Nearest Neighbor-like algorithm with non-nested generalization (Mange), Naive Bayes, C4.5 (J48), Random Tree, Random Forests, Artificial Neural Networks (Multilayer Perceptron), Support Vector Machine (SVM) used for static gesture recognition. A problem of effective gesture recognition was outlined in the context of the system based on a camera and a multimedia projector enabling a user to process sound in audio mixing domain by hand gestures. The image processing method and hand shape parameterization method were described in relation to the specificity of the input and data classifiers. The SVM classifier was considered the optimum choice for the engineered gesture based sound mixing system [25].

Dhawale P. Et al. described a simple and inexpensive single camera-based video input system which allows 3D interaction with existing computer application using bare hands. However, conventional input devices such as a mouse or track-pad generally restricted direct manipulation interaction to a 2D paradigm. More sophisticated 3D input devices such data-gloves had been available for some time, but these tend to be expensive or restrictive in their use [26].

Phu J.J. Et al. termed the research and development of a computer vision based hand gesture recognition system that interpreted a set of static hand gestures. It could be further implemented as a sign language interpreter as well as novel approach for human computer interaction (HCI). Hand segmentation was based on Fleck'sHuman Skin Color Detection model using hue and saturation values of a human skin, based on an optimal range in color spectrum to distinguish human skin colors from background using the values formulated based on Logarithm Opponent Component of a three-channeled pixel. Evaluation on this approach exposed a satisfactory result using 40,000 evaluation pixel samples of skin and non-skin color cropped from 40 random human images and 40 background images, where it achieved 2.005 % of False Rejection Rate (FRR) and 1.68% of False Acceptance Rate(FAR) under an investigated condition in several experiments. Ideas on solving several segmentation problems (i.e. multi foreground objects problem) due to skin detection model approach were also presented, in which collaboration of Connected Component Labeling and Edge Detection was proposed. Techniques on image clipping, using a wrist detection algorithm based on local minimum width was suggested in this paper. This paper also acknowledged and analyzed several image preprocessing techniques (i.e. image smoothing) for noise reduction optimization problem. In this work the evaluation of MLP using 10 classes of web cam captured live samples have shown an accuracy up to92.97% based on 0.7% rejection threshold. Another evaluation using 10 classes of Triesch's Hand Gesture Dataset demonstrated the accuracy of only 50.81% which may be caused by other factors such as different approach used in segmentation process due to lack of color information [27].

Vamplew P. Et al. described a recurrent neural networks which has been trained to classify sixteen different hand trajectories, including relatively complex paths such as circles and back-and-forth motions. The network's ability to anticipate the classification of an incomplete gesture was also examined, and its implications for segmentation of gestures is discussed[28].

Licsar A. Et al .proposed a vision-based hand gesture recognition system. It was implemented in a camera-projector system to achieve an augmented reality tool. In this configuration the main problem was that the hand surface reflects the projected background, thus they applied a robust hand segmentation method. Hand localizing was based on a background subtraction method, which adapted to the changes of the projected background. Hand poses were described by a method based on modified Fourier descriptors, which involved distance metric for the nearest neighbor classification. The proposed classification method was compared to other feature extraction methods. They also conducted tests on several users. Finally, the recognition efficiency was improved by the recognition probabilities of the consecutive detected gestures by maximum likelihood approach [29].

Mapari R. Et al. offered a simple method to recognize sign gestures of American Sign Language using features like number of Peaks and Valleys in an image with its position in an image. They extracted the skin part which represents the hand from an image using L*a*b* Color space. Every hand gesture was cropped from an image such that hand was placed in the middle of image for ease of finding features. The system does require hand to be properly aligned to the camera and does not need any special color markers, glove or wearable sensors. The experimental results shown that 100% recognition rate for testing and training data set [30].

This research paper gave the overview of ANN for gesture recognition. It also described the process of gesture recognition using ANN [31].

Ibraheem N.A. Et al. deliberated that several hand gesture recognition researches that use Neural Networks , comparisons between these methods were presented, advantages and drawbacks of the discussed methods also included, and implementation tools for each method were presented as well[32].

Binh N.D.Et al. introduced a new approach to gesture recognition based on incorporating the idea of fuzzy ARTMAP in the feature recognition neural networks. It has already shown that neural networks are relatively effective for partially corrupted images. However, a distinct subnet was created for every training pattern. Therefore, a big network was obtained when the number training patterns was large. Furthermore, recognition rate could be hurt due to the failure of combining features from similar training patterns [33].

Yewale S.K. gave an overview of different methods for recognizing the hand gestures using MATLAB. It also gave the working details of recognition process using Edge detection and Skin detection algorithms [34].

Bailador G. Et al. offered a new approach to the problem of gesture recognition in real time using inexpensive accelerometers. This approach was based on the idea of creating specialized signal predictors for each gesture class. These signal predictors forecast future acceleration values from current ones. The errors between the measured acceleration of a given gesture and the predictors were used for classification. This approach was modular and allows for seamless inclusion of new gesture classes. These predictors were implemented using Continuous Time Recurrent Neural Networks (CTRNN).On the one hand, this kind of networks exhibits rich dynamical behavior that was useful in gesture recognition and on the other, they have a relatively low computational cost that was interesting feature for real time systems[35].

Suma S L Et al. performed face detection using Viola Jones face detection algorithm, feature extraction is executed by using Local Binary Patterns Histograms and classification by using Euclidean distance classifier. The proposed system is implemented using Opencv and Anaconda. From the above graphs I can conclude that LBPH and Euclidean distance has better recognition rate. The results achieving for this methods is of accuracy 85%-95% [36].

A.K.Gupta Et al. exhibited a calculation for lip development following and lip signal acknowledgment in the paper. It shapes the middle of the multimodal human-PC interface (HCI) called Lip Mouse. Consequences of the trials did demonstrate that the viability of the calculation is adequate for agreeable and productive utilization of a PC by any individual who does not need or can't utilize a conventional PC mouse [37].

From the survey, it is found that hand gestures are not universal. Moreover, most of the studies have been performed using HMM and ANN classifier. Although in some cases results are quite good, these are performed for small datasets. The details of various hand gestures studies are summarized in table 1.

Table 1: Summary of Computer Vision Techniques for Hand Gesture Recognition

	Data Set Size	Classifier	Image Processing Technique	Accuracy	Reference
1.	650 Samples	-	--	100%	[1]
2.	-	ANN	Shape based features	85%	[2]
3.	2600 (Single Hand) 2340 (Double Hand)	KNN ANN	--	95.30% 96.37%	[3]
4.	20 Gestures	HMM	--	70%	[9]
5.	-	HMM	Microsoft Kinect, PCA		[10]
6.	-	ANN	Finger Based	95%	[11]
7.	200 Images 904 Images	ANN	RBF(Radial Basis Functions) DT(Inductive Decision Trees)	93% 96%	[12]
8.	12 Gestures	HMM	--	98.3%	[13]
9.	20 Gestures	HHMM	--	92.86%	[15]
10.	250 Hand Gestures	--	Haar Like Features	94.1%	[16]
11.	6 Static Hand Gestures	ANN	--	86.38%	[17]
12.	4 Gestures	ANN	BP with Levenberg Marquardt	88.4%	[18]
13.	50 Samples	ANMM,DD,ROT	--		[19]
14.	500 Images	RBFNN	K-mean based Radial Basis Function Neural Network (RBFNN)	99.6%	[21]
15.	45 Gestures(450 Images)	--	--	94%	[22]
16.	4 Classes	SVM	Haar Like and Histogram of Oriented Gradient (HOG)	83% 93.5%	[24]
17.	40 Images of Static Hand Gesture	ANN	--	92.97%	[27]
18.	10 Characters	ANN	Skin Color Detection	100%	[30]
19.	36 Gestures	Fuzzy ARTMAP	--	92.19%	[33]

III. CONCLUSION

In this article, various studies conducted for automated hand gesture recognition have been reviewed. Following conclusions have been reached from the survey:

- Hand gesture recognition is usually performed in two main ways: direct detection and indirect detection. The former means detection methods in which simply hands are used as input, without any special devices. However, the latter is performed employing some kind of equipment such as sensor gloves or simple gloves.
- It is observed that the performance of indirect detection is far better than the direct method. Nevertheless, these are only feasible in the constrained environment such as in laboratories. And, for real time scenarios, the direct detection methods are more appropriate.
- Also, majority of the experiments have been conducted for static hand gestures as compared to the dynamic ones, thereby, providing a wide scope of research for the latter.
- In some cases, the results demonstrate accuracy rates nearly 100%, but, these researches were done considering limited datasets with very few hand gestures. This implies to the obvious conclusion that for larger datasets, the performances would be different.
- Hand gesture recognition is application oriented. This means that the techniques, used in the past, were purely dependent upon the context for which the hand gestures were used. Major classifiers used for classification included Artificial Neural Networks, HMM, Fuzzy C-means clustering. For dynamic gestures, ANNs have been widely used, both for classification as well as segmentation while capturing the appropriate hand shape.
- Most of the studies performed feature extraction by computing shape based features to correctly extract the morphology of the hand. Some studies, however, calculated the features so precisely that they kept even rotation-invariance factor into consideration.
- Last but not the least, hand gestures are not universal. To put it another way, these vary from region to region. As a result, in the absence of standardized hand gesture dataset, a uniform model cannot be proposed.

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