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Research Article

Hand Gesture Recognition By Deep Convolutional Neural Network

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Abstract: Today the hand gesture is increasingly in the human-computer interactions. In all project, there is a minimum number of the process involved in the hands only and maximum contains the body, background, etc., In this paper, it shows that the location of the hand, hand gesture, and applies it in home and also the interaction between the system and the users. Hand gesture means that it is the form of sign language in the form of passing the signals and expressions. The movement occurred in the hand is called the hand gesture which can be used in hearing loss peoples. The processing of the hand gesture is that it shares the communication to others with the help of hands. The different symbols and numbers are forming with the hands and the signs form a group of words that can be understood by other people. There are two types of hand gestures like a glove based and vision-based.In this paper, a new approach called deep convolutional neural networks, which used in hand gestures to classify the images held in the hand gesture. The deep convolutional hand gesture can be used to find a more number of hand gestures. The hand gestures require more time for processing. The convolutional neural network can be used for saving the timing and reducing the time used in the separation of things or images. Finding the state of hand gesture, which will also, needs more time. The deep CNN provides a faster process in that. Using the deep CNN method, provide the system with more accuracy, specificity, sensitivity compared to the other systems. The proposed method as CNN, which separates the different sections, provides good accuracy, specificity, sensitivity from the dataset. The system process ends until the hand gesture image is leaving from the camera.

Keywords: Hand gesture, deep CNN, feature extraction, sign languages

I. INTRODUCTION

The hand gesture is mainly important for the human-computer interaction for providing signs to the touchless devices. Lee, et.al (2013) explains how to use hand gestures in smart TV applications. The hand gesture is occupied with different locations. In the hand image, inside its several unwanted places occurred that could complications in the image processing. Because in this image the hand occupies only a small portion of the image.

To overcome this complex process Park et.al (2009) [9] proposed a method using the attractive skin color and the separation of background from the image thus would help to signs the hand easily. Each hand gesture must follow this recognition method. The skin color is extracted from the hand separation. Also, the camera needs to activate while processing. The Photoelectric infrared sensor, which helps to activate the camera, while processing the hand gesture.

Another method explains the deep learning method like CNN [10]. Finding the location of the hand and the hand gesture perform jointly. Selects the image regions and verifying the hand gesture in that location is working or not. Initially, the hand contained images monitored and passes the monitored images for classification for it contains the hand gesture or not. On the other side the proposed region of images used different sizes this removes the useless sizes for getting good accuracy. These two approaches use the hand gesture. It is difficult to collect the hand rather than the hand gesture. Given this paper, it describes the hand gesture recognition system. It can predict the hand gesture from the images without the help of using any algorithms. The proposed method for recognizing the hand gesture is that convolutional neural networks that can find out the hand gesture images from the specified area and occupy the locations and the background. The only drawback of the system is that it can store the trained data, but it cannot make the new data. At this training stage, it cannot limit the boxes. This system has cooperated with the real-time system for finding the hand gesture. Different methods can be used in the handshake gesture.

Han et.al (2016) [11] proposes the hand recognition process in a hand gesture. If the presence of notice or background is made, a similarity in the skin color will be deleted or remove the background and selects the new gesture. The background elimination is happening because of the disruption. The limit of the background is the desktop area. This system provides the detection and recognition for securing the background and the skin color for tracking the hand at a similar time. Hand gesture detection has several steps as follows hand detection, hand

tracking, monitoring. Initially, it performs hand detection. In this process, it performs the separation skins and removes the unwanted background information then carries some process for reducing the noise, which interferes.

Background subtraction method [12] for finding the hand from hand gesture. After this process, a new method defined called the deep CNN method which for the recognition of hand gesture. Two methods are used in deep CNN for achieving the hand gesture. This proposed method can be used in the home appliances and the interactions between the system and the user. The convex hull of the hand involved in the recognition process can use skin separation. The lens facing is a more complex process in the hand gesture. The reason for approaching the convolutional neural network is that it is the efficient recognition model for hand gestures. It provides solutions not only for the images also for the various image processes. The hand gesture process several characteristics that need to be proved as accuracy, efficiency, recognition, etc., some proposed methods consisting different CNN and it forces the power and the storage. Here there are two different datasets are used [13] which are the ego gesture dataset and dynamic hand gesture dataset. Both the dataset uses the architecture of CNN network without the internet. We propose to use the Levenshtein distance as an evaluation metric to compare the captured single-time activations with ground-truth labels. This metric is more suitable and evaluative since it can measure misclassifications, multiple detections, and missing detections at the same time.

II. LITERATURE SURVEY

Bao, et.al (2017) proposes hand gesture recognition with the use of a Deep Convolutional Neural Network. This paper describes that the recognition of hand gestures. Here there are many problems with a hand gesture. In this method, it does not care about the location. Without location, it provides a recognition method to the hand gesture. It provides accuracy, specificity in hand recognition. Dividing the hand gesture from the various images without including the location information. CNN method does not involve any algorithm-based purposes but involves real-time applications. This method is self-algorithms and processing without the involvement of regions. Here, it uses simple methods and requires fewer functionalities. It achieves more functionalities in memory and speed compared to the previous algorithms.

Another paper by Chung et.al (2019) proposed gesture recognition with a machine learning algorithm. In this paper, a deep convolutional neural network has been constructed. The comparison between the previous methods is that it uses the location information and region of interests. Several processes are involved in the hand gesture as monitoring, tracking, detection. The two architecture defined in the deep CNN such as Alex net and VGG net. After finishing the tracking and the recognition the hand's images leaving from the processing is the main thing behind this process. Several phases are done in the hand gesture. Initially, the phase separates the image and after reduces the interference and at last, it reduces the background images. This application is helpful for in-home and human-computer interactions.

Jayanthi et.al (2017) shows the same process as gesture recognition. However, there is a difference in the operations. It tells about the sign language conversation. The hand gesture is also a sign language. This calculates the signs from the users feeling like hand movement, body movement, eye movement, facial expressions, etc. This paper explains an interesting method as the way of communication held in the form of hand signs as if with the help of fingers it forms several structures, which provides the meaning in the form of signs. Comparing with the existing method the deep CNN method provides the facility that it provides accuracy in results and without using the location information. Also, it providing the results compatible with the time. This method is mainly used for the sign language detection running on the backgrounds.

Kopuklu et.al (2019) hand gesture recognition from the videos. Here, the starting and the ending does not possible based on the power and providing the recognition only one time. Two approaches designed for this method are that its convolutional neural network takes responsibility for the detection and separates these detections. The accuracy of this system is much larger than the other methods. The proposed method uses two different datasets that provide the same amount of data this will help to increases the system efficiency. The proposed approach is evaluated on two dynamic hand gesture datasets and achieves similar results for both of them. For real-time evaluation, we have proposed to use a new metric, Levenshtein accuracy, which we believe is a suitable evaluation metric since it can measure misclassifications, multiple detections, and missing detections at the same time. Moreover, we have applied weighted-averaging on the class probabilities over time, which improves the overall performance and allows early detection of the gestures at the same time. The acquired single-time activation per gesture by using the difference between the highest two average class probabilities as a confidence measure. However, we would like to investigate more on the statistical hypothesis testing for the confidence measure of the single-time activations as future work.

Another method was proposed by Xing (et.al) 2018 deep learning method for the hand gesture. This paper mainly focuses on increasing the accuracy. The process is classified into databases and datasets. Preprocessing and feature extraction are done after the dataset. Here, the convolutional networks provide the five types of architectures. The CNN-based methods provide high accuracy without going to the preprocessing steps. The results show after the finishing of multiple processes. Compared with the other processes this process takes the

mean and the standard deviation for comparing the results. However, there is a drawback in the mean and the standard deviation. They provide inconsistency and incorrect values.

The same concept is explained by Hang et.al (2017). Here, it discusses some difficulties done in the detection of hand gestures like the light and the background will affect to get the accurate hand gesture image. By solving this problem, a new method called the convolutional neural network, which will, integrated into the recognition mechanism in a hand gesture. Also, this convolutional network process reduces the feature extraction processes. It has some benefits like reduces the number of requirements and autonomous learning. There is a different method used in this method that is it provides the error propagation for reducing and clearing all the errors. Support vector machine is integrated into the convolutional neural network, which provides an efficient result and fast processing. Removal of the image background and removing the background noises will also increase the system speed and results. The results show that this system is highly efficient compared with the other system. The advantage of this system is that it recognizes multiple images for getting more accuracy. Here in this the movement of the hand position and the background collecting more information about the hand gesture.

Strezoski et.al (2015) explains that the definition of hand gesture is that the motion of a hand from the human body. The advancement and the applications of the hand gesture will be applicable in controlling, monitoring, and learning. This paper executes the models with the use of different convolutional networks. The dataset used in this method provides the evolution of different convolutional structures that changes the system. Here, the Marcel dataset can be used to performing this operation. Here, the usage of Xbox Kinect sensor, which integrated into the datasets for improving the accuracy rates. In future work, this method provides continuous learning and training to improve system performance. The existing methodologies provide the techniques for enhancing the power. The result was taken from Google Net by using the different architectures.

Ghosh et.al (2015) static hand gestures without using convolutional networks. This paper only takes gesture recognition. The working is behind in this model is that based on the vision. It finds the hand gesture with the continuous monitoring of the movement, location, rotation, separation, classification. It consists of three modules that are the feature extraction and prediction, preprocessing. The preprocessing phase includes all the movements and the process of the images. This process can be done in three steps. In feature extraction process it extracts the work and the use of mixing features coincides with the other features. The proposed system provides sensitivity with the different databases. They propose the new different algorithms as homomorphic separation and gray world algorithm used for normalization in color and background of the image. For removing and reducing the amount of noise held in the background it separates the structures or the images. With the separation, it gives a very clear and complete hand gesture will get. The result is evaluated based on the various databases for analyzing the hand gesture. This system predicts the different specificity from different databases. The three databases provide efficient results.

Muneer et.al (2020) explains the hand gesture with the use of 3D CNN. Here, they propose automatic hand gesture recognition for the translation of sign languages into natural languages. Three different types of datasets can be used in the 3D CNN model. The image mapping is done with t selecting the image frame. To provide a solution for the unknown dataset usage, the transformation of training is considered. This proposed technology achieves more accuracy compared to the other process but still many processors need the autonomous signing mode. Also, more techniques, which will help to increases the frame, section, image selection, etc. The proposed system consists of removing the irrelevant information from the video, Learning feature and separate it into different classes. The datasets are used in the sign independent and dependent nodes. After the all process completed the proposed system compared to all the previous system there is the only difference is that it uses the convolutional network is three-dimensional.

Han et.al (2016) tells the hand gesture recognition based on the vision. This convolutional network decreases the hand gesture recognition from the camera image. Image recognition is difficult from the camera. It enhances the fastest performance possible and it uses the various models related to the skin and the background for getting the relevant data for the convolutional neural networks. Adoption of Gaussian skin colors set which will help the image from the light reflection. This system provides a medium level of separation and feasibility. This method provides the two different layers of convolutional network for reducing the difficulties that are faced by the images. Background elimination can be used to avoid the interferences done within the hand gesture. And the other method called Gaussian skin color used to monitor the type of skin color and it formatted into the binary format. After all the stages are completed the gesture takes only the relevant information and removes the background unwanted information. Around ten number of gesture provides the systems efficient result.

The more advanced process in hand gestures using CNN Felix (2019) gives a process that is more advanced in the gesture image. With the use of nine datasets, the hand gesture system provides an accuracy of 98%. A two-dimensional convolutional network appears here. It monitors the data temporarily for decreasing or removing the over transformations. The minimum and maximum resolution of networks provide more accuracy in this system. Using the test set the hand gesture recognizes the performance of an overall system. Testing provides system efficiency and evaluation. By separating the hand images and the two-dimensional

convolutional network apply to it. An effective Spatio-temporal data can be used to improve the general characteristics in the hand gesture. Further implementation should provide for achieving the hierarchical performance. Argumentation was also incorporated with the Spatio-temporal data. The data is driven from the dataset after that it separates data and then puts it into different batches. From this, it providing different training and learning related to the image gesture.

A new concept behind the hand gesture with deep CNN is that deep gesture by Mohanty et.al (2016). Here it takes the static image for the hand gesture recognition. This paper proposes a deep learning network for processing fast understanding. The use of the convolutional network in deep learning for easily understand the hand sizes, hand symbols, rotation. The symbols can be formed by the hand can easily understand with the integration of CNN. The benefit of the method is that it doesn't use the feature separation of the images. In several stages, the CNN monitors the hand position or location. It can detect hand gestures from one of the most popular datasets. In the proposed CNN we acquire the multilevel accuracy from the datasets. The proposed method can find application in areas such as sign language recognition and HCI. In the future, we plan to extend this work to handle dynamic hand gestures also.

Javier (2017) shows that the architecture for this purpose.MatConVet library which used for architectures. The two structures are the start and the end. There are six architectures are used in the convolutional networks for providing the accuracy and separation of images. From these six architectures, it uses the most efficient one. The different architectures provide the behavior of different pieces of training and perform the two hand gesture called "start" and "end" and the presence of extra gestures known as the “unknown”. The training can be provided for getting good accuracy and performance and classification. The dataset called "unknown" held because several hands do not open or close. And this dataset is deleted from the list. After the different structures used and parameter variation, it was possible to converge to a convolutional network architecture that allows identifying the two desired states of the hand, open and closed. This allows inferring an intention of acting on the part of the user, which would allow the consequent execution of a robotic agent, for example for delivery of objects.

III. PROPOSED METHOD

In the proposed technology, it explains the various stages. Initially, the input image is selected. The input image is taken from the different hand gesture databases. A different dataset is also chosen for collecting more data about the image. The preprocessing can be used for removing unwanted information about the system. And the final steps consist of feature extraction and feature prediction. The above block diagram explains the hand gesture process.

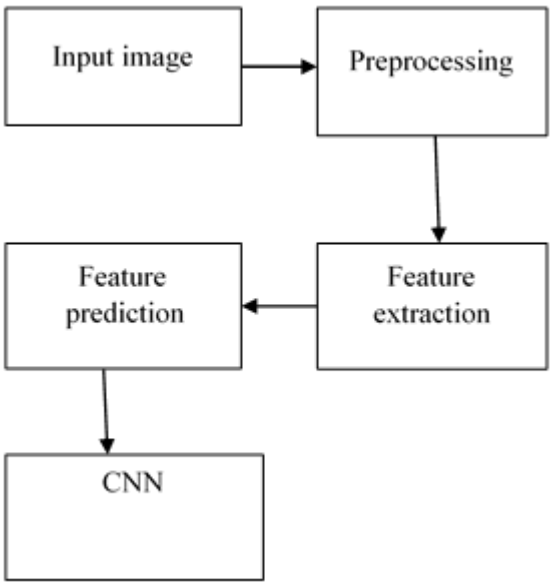

Fig 1: Block diagram of the proposed technique

After the preprocessing the irrelevant information are removes and the relevant information enters into the feature extraction process. In this feature extraction, several processes are executed as Grayscale, image versatile, median filter. After completing these three feature prediction can be obtained. Here also it uses several mechanisms as Gray level co-occurrence matrix (GLCM), local binary pattern. At last, the final step is the feature prediction which has been done in one process as Cacchy PSO. After finishing all processes the convolutional neural networks are performed in hand gesture recognition for getting accurate results. The next section explains the various techniques used in the proposed technique as explained in the block diagram.

INPUT IMAGE

In the proposed technique, initially, the images were taken in the form of RGB. But the RGB color is more sensitive to the different light conditions. So, change this format and converted it to the YCbCr.This format is dealing the information held in the image. This format requires a white background. Because some background interferences the hand gesture image recognition. Previous articles explained that this input image is converted in binary format. Before processing, it eliminates all the noise inside the background. For removing, the noises behind the background this process uses some noise elimination methods to remove all the smudges considered with the pixels. These smudges should less than the pixel value. The pixel value is denoted as P the process hole filling is done in the converted image. The holes mean that the combination of several background pixels but the pixel cannot remove the holes in the images. These two processes are held in the binary images. Then after we want to take the hand image by finding the area of boundary contours. At first monitoring the images from the left to right. If it occurs any pixel that put into the right of the hand. More importantly, it occurs only the pixel color is white. We find Boundary contours for locating the hand in the image. And the scanning is based on the horizontal and vertical. If vertical scanning occurs, it considers the picture to scan top to bottom. And the same procedure is followed that is the first pixel is put into the top. And the process is finished by filling the image until the bottom hand is full.

Fig 2: Input image

Hand Gesture Database

In the project, the dataset is taken from the prima database [27]. The database consists of a different set of sign languages. Now the sign language is represented using the different alphabet. The representation and processing of the dataset are explained below. The user sends the input image to the database after the finishing of processing in databases the database provides the gesture image associated with the particular letters. There is a static and dynamic database is used. Our database is static. The letters j, z is denoted the dynamic database. The black background can be used to perform the overall process in the image. The user should wear black gloves from hand to their shoulders. If the arm color is the same as the background color, the separation becomes easy. The camera carries out the comparison of images. The final database consists of 4145 recordings, stored separately in .csv extension and Armadillo binary format files. The database consists of the total number of steps, systems, participating code, hand gestures, time is stored in the different files the database is available at http://gestures.iitis.pl/.

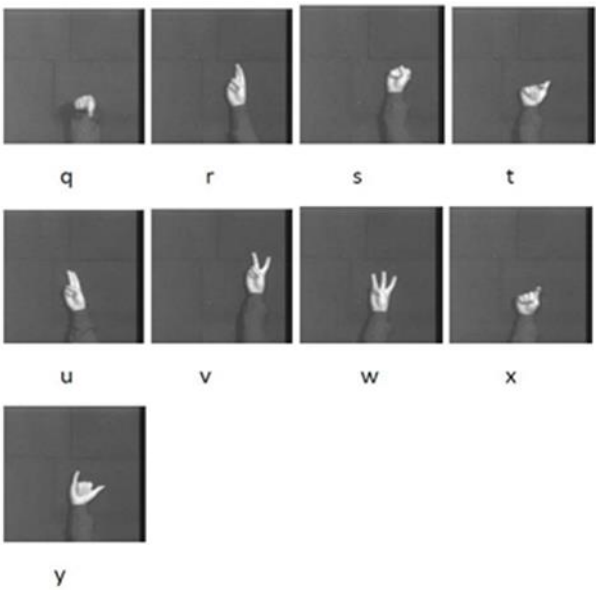

Fig 3: Sample picture from database

PRE-PROCESSING

Preprocessing is the most important task in the hand gesture. Here our data set is prima [27], which is the most efficient database in a hand gesture. The preprocessing is done before the feature extraction process. In our system the preprocessing consists of three stages

- Grayscale
- Image resize
- Median filter

The Grayscale is a single value representation used in color represents the light. Sorting the color image, which gives them more information about the images. The grayscale images can perform any task and it is easy to do the processes in the color images. Image resizing arranges the image's size because each image is in different sizes. By resizing, the images are in a fixed size. By using the median filter, it will remove all the background noise from our picture.

Gray Scale

In digital photography and computer-related image processing, the grayscale is important for representing the single-pixel value to color light sensitivity. It represents the value of light in the pixel format. In the name itself, the grayscale images are in gray or black and white color. There are the minimum and maximum intensity values based on the black and white separation. The images are in the form of binary images each image has a bit. The image's color is black and white but there is a shadow available in gray color.

Fig 4: Sample grayscale image

The input image is converted into grayscale images. For this purpose, the colorimetric calculates the grayscale values. The conversion uses the gamma compressed RGB model. This compressed function will be removed by the gamma expansion and it applies to RGB color space. The Grayscale is also applicable for multiple images. Here the input image is splitting into an RGB model and extracts the independent images from RGB and the relevant grayscale image is represented.

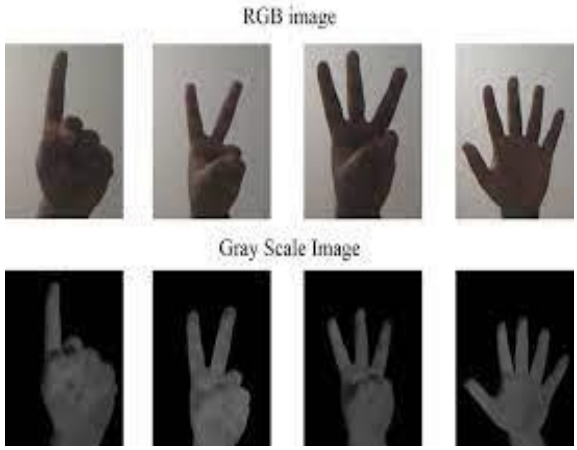

Fig 5: Sample image for the composition of RGB from Grayscale

Image resize

The image resizing is for the images in our method that have no exact sizes. It is kept in different images of different sizes. So, this method is very important to resize the images properly. If the image size will be resized its pixel value is also changed. The image will be resized at that time the needed information is deleted from the

images as a pixel value. So, the user wants to add the new pixel value into the image. If the image wants to high quality, it has some high-resolution process for moving the high quality.

Median filter

It is a digital filtering technique, which can be used to remove the background noises, which affects the images. So this type of noise reduction is one of the important methods in preprocessing for improving the results. Median filtering is the most advanced technique, which removes the noise from the edges. The processing of the median filter is moving from entry to entry and replacing each entry with neighboring entries.

The median filter has a one-dimensional and two-dimensional process. The representation for the one-dimensional signal is represented as

x=(2, 3, 80, 6, 2, 3)

After performing some operations the output of the signal is,

Y = (3, 6, 6, 3)

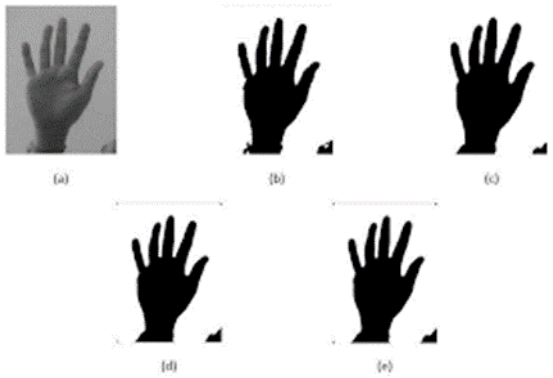

Fig 6: Sample median filter image

FEATURE EXTRACTION

Feature extraction means extracting or separate the important parts of the images. This extraction is useful in larger-size images. The feature extraction methods in our systems are explained below.

Gray-level-occurrence matrix (GLCM)

The relationship of the pixel is represented in the form of a matrix is called Gray Level Co-Occurrence Matrix. The GLCM of images is calculated based on how much time the pixels pairs with the particular value. And these values are showed in the matrix. The calculations are done by the GLCM is that 7(a) The matrix representation shows that the pixel pairs

And table 7(b) shows that the general form of GLCM. Frequency normalization can be employed by dividing the value in each cell by the total number of pixel pairs possible.

There are different angles like 0°, 45°, 90°, and 135°in GLCM and radius become 1. The normal GLCM with values is explained in the below table.

Table 7a. Matrix representation

Gray no	**0**	**1**	**2**
0	#(0,0)	#(0,1)	#(0,2)
1	#(1,0)	#(1,1)	#(1,2)
2	#(2,0)	#(2,1)	#(2,2)
3	#(3,0)	#(3,1)	#(3,2)

Table 7(b) general form of GLCM

0	0	0	1
0	1	1	2
0	1	2	2
0	2	3	3

Table 8(a): sample GLCM for δ=1 and θ=0°

0	2	1	1
1	0	0	6
1	0	4	0
2	6	0	2

Table 8(b): Sample GLCM for δ=1 and θ=45°

0	2	2	1
0	0	0	0
4	6	2	2
2	2	1	1

Local Binary Pattern

In LBP, the texture representation is formed as an appearance. Here we want to find the LBP factor that is applied to the pixel in every image. Here the LBP factor will be found based on the hand images. The hand image in the LBP factor is applied to the pixel images. The created LBP image is divided into different blocks and each block took the pixels image.LBP captures the hidden information inside the picture. The local binary pattern is a set of the binary images and the pixels around tithe values in the local binary pattern are two types. If the value is less than the pixel, the intensity value is considered as 0. And the values higher than the pixel is 1.This histogram in the LBP measures the images in the sub-block. This factored takes the information to the hand with the help of infrastructure. Another benefit is the image resolution. The handshape size will help to take the information so this method is established at various hand images. The above figures show that the Local binary pattern at different pixels in the hand image

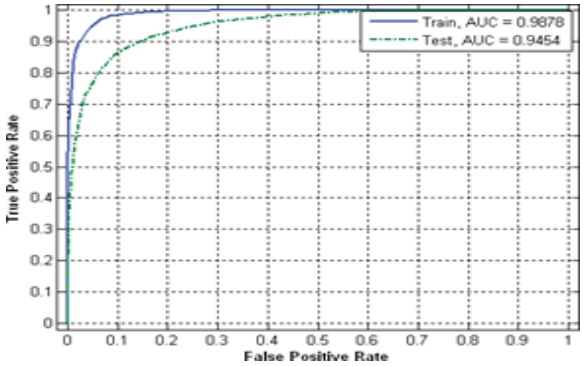

Fig 7 (a) Sample LBP image at 40*30 pixel

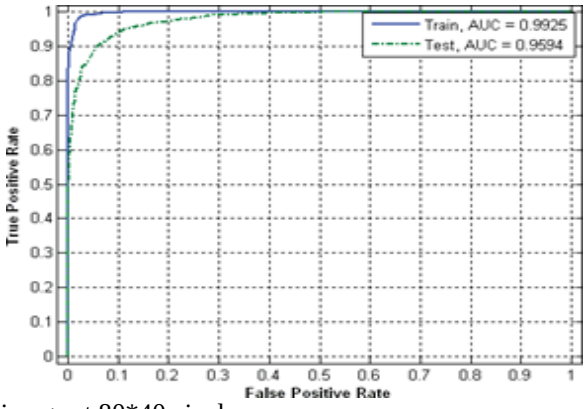

Fig 7(b): Sample LBP image at 80*40 pixel

The feature prediction in hand gestures can be done in the Cauchy PSO means particle swarm optimization.

Cauchy Particle Swarm Optimization

1. ***Gesture representation***

The hand gesture recognition representation is based on the sequence of hand images. The first-hand image is recognized it represents as H_s with the length l

H_s = [H1, H2, HLs] with length l^5

Initially find the Euclidean distance from the starting and the ending point of the image.

Euclid′s H = d (Hs n − Hs 1). (1)

After finding the Euclidean distance the orientation of the image will be taken

θs = [θ1, θ2, … , θl s − 1], (2)

2. Gesture spotting using PSO

The gesture spotting in PSO is represented in the form of matrix,

Hn, m= (h1, 1 h1, 2 h1, n)

H is the matrix and n.m are the particles inside the matrix. Initially, it checks the image is inside the matrix. If the detected image is not in the matrix it is the normal image. If the resulting image is held in the matrix it is considered as the sub-hand gesture.

CLASSIFICATION

The classification is based on the performance analysis of the proposed techniques compared with the previous system. Here the convolutional network provides 98.5% of accuracy, 95.3% of specificity, and 94% of sensitivity. Hence, the CNN method coordinated with the CC algorithm gives a high amount of performance. The classification of the CNN method with the different algorithms is mapped in the below tables. The CNN method is compared with the SVM method. The analysis of both systems is based on the parameters like accuracy, sensitivity, and specificity.

Table 9 (a) analysis of CNN with previous methods

parameters	**CNN**	**CC**	**AHE**
Accuracy	98.5	83	95
Sensitivity	94	90	90
Specificity	95.3	89	89
Gesture recognition	91	80	85

Here the feature extraction is done with a grey co-occurrence matrix and local binary pattern. This covert the image into the binary format. The detection of features takes some method, which will increase accuracy, sensitivity, and specificity.

Table 9b. Analysis of CNN with SVM

parameter	**CNN**	**SVM**
Accuracy	98.5	95
sensitivity	94	91
specificity	95.3	93

IV. RESULT AND DISCUSSION

In this paper, we discussed hand gestures using the convolutional network. Also, the proposed method includes preprocessing, feature extraction, and feature detection. The evaluation behind the hand gesture using CNN is based on three parameters like accuracy, sensitivity, and specificity. The classification of the CNN method with the different algorithms is mapped in the below tables.

Table 10: Evaluation of CNN

Metrics	**CNN**
Accuracy	98.5
Specificity	95.3
Sensitivity	94

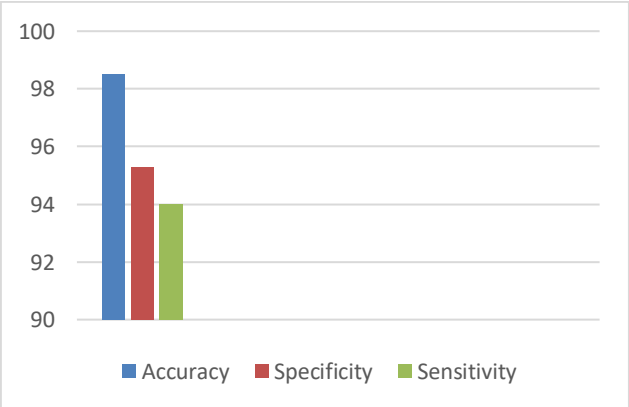

Fig8. Performance analysis chart

Compared with the previous process the convolutional network provides good performance by accuracy, sensitivity, specificity. As the results show that, the system provides 98% accuracy. Meanwhile, the preprocessing is also increases the accuracy by 6%.

V. CONCLUSION AND FUTURE SCOPE

The aim of this project is that to develop hand gesture recognition by convolutional networks. It is determined that feature extraction and detection are important and they process at various methods. Several methods explain in this project for removing the noise. Interference is held in the background. The preprocessing carries this elimination. Also, from the input image remove all noise by preprocessing. Grayscale, image resize, median filter are the methods. The results show that the process with preprocessing or without preprocessing provides fast system performance and results.

REFERENCES

1. Chung, H. Y., Chung, Y. L., & Tsai, W. F. (2019, February). An efficient hand gesture recognition system based on deep CNN. In *2019 IEEE International Conference on Industrial Technology (ICIT)* (pp. 853-858). IEEE.
2. Bao, P., Maqueda, A. I., del-Blanco, C. R., & García, N. (2017). Tiny hand gesture recognition without localization via a deep convolutional network. *IEEE Transactions on Consumer Electronics*, *63*(3), 251-257.
3. Chung, Y. L., Chung, H. Y., & Tsai, W. F. (2020). Hand gesture recognition via image processing techniques and deep CNN. *Journal of Intelligent & Fuzzy Systems*, (Preprint), 1-14.
4. Köpüklü, O., Gunduz, A., Kose, N., & Rigoll, G. (2019, May). Real-time hand gesture detection and classification using convolutional neural networks. In *2019 14th IEEE International Conference on Automatic Face & Gesture Recognition (FG 2019)* (pp. 1-8). IEEE.
5. Jayanthi, P., & Bhama, P. R. S. (2018, December). Gesture Recognition based on Deep Convolutional Neural Network. In *2018 Tenth International Conference on Advanced Computing (ICoAC)* (pp. 367-372). IEEE.
6. S.H. Lee, M.K. Sohn, D.J. Kim, B. Kim, and H. Kim, "Smart TV interaction system using face and hand gesture recognition," in Proc. ICCE, Las Vegas, NV, 2013, pp. 173-174.
7. S. Kim, G. Park, S. Yim, S. Choi, and S. Choi, "Gesture-recognizing hand-held interface with vibrotactile feedback for 3D interaction," IEEE Trans. Consum. Electron., vol. 55, no. 3, pp. 1169-1177, 2009.
8. S. S. Rautaray, and A. Agrawal, "Vision-based hand gesture recognition for human-computer interaction: a survey," Artificial Intelligence Review, vol. 43, no. 1, pp. 1-54, 2015.
9. D. Lee and Y. Park, "Vision-based remote control system by motion detection and open finger counting," IEEE Trans. Consum. Electron., vol. 55, no. 4, pp. 2308-2313, 2009.
10. P. Molchanov, S. Gupta, K. Kim, and J. Kautz "Hand gesture recognition with 3D convolutional neural networks," in Proc. CVPR, Boston, MA, 2015, pp. 1-7
11. M. Han, J. Chen, L. Li, and Y. Chang, "Visual hand gesture recognition with convolution neural network," in Proc. The 17th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, Shanghai, China, May 30– June 1, 2016
12. Gopalakrishnan, R., Mohan, A., Sankar, L. P., & Vijayan, D. S. (2020). Characterisation On Toughness Property Of Self-Compacting Fibre Reinforced Concrete. In Journal of Environmental Protection and Ecology (Vol. 21, Issue 6, pp. 2153–2163).
13. Y. Zhang, C. Cao, J. Cheng, and H. Lu. EgoGesture: A New Dataset and Benchmark for Egocentric Hand Gesture Recognition. IEEE Transactions on Multimedia, 20(5):1038–1050, May 2018.
14. Xing, K., Ding, Z., Jiang, S., Ma, X., Yang, K., Yang, C., ... & Jiang, F. (2018, June). Hand gesture recognition based on deep learning method. In *2018 IEEE Third International Conference on Data Science in Cyberspace (DSC)* (pp. 542-546). IEEE.
15. Strezoski, G., Stojanovski, D., Dimitrovski, I., & Madjarov, G. (2016, September). Hand gesture recognition using deep convolutional neural networks. In *International Conference on ICT innovations* (pp. 49-58). Springer, Cham.
16. Li, G., Tang, H., Sun, Y., Kong, J., Jiang, G., Jiang, D., ... & Liu, H. (2019). Hand gesture recognition based on convolution neural network. *Cluster Computing*, *22*(2), 2719-2729.
17. Ahlawat, S., Batra, V., Banerjee, S., Saha, J., & Garg, A. K. (2019). Hand gesture recognition using convolutional neural network. In *International conference on innovative computing and communications* (pp. 179-186). Springer, Singapore.
18. Mohanty, A., Rambhatla, S. S., & Sahay, R. R. (2017). Deep gesture: static hand gesture recognition using CNN. In *Proceedings of International Conference on Computer Vision and Image Processing* (pp. 449-461). Springer, Singapore.

19. Al-Hammadi, M., Muhammad, G., Abdul, W., Alsulaiman, M., & Hossain, M. S. (2019). Hand gesture recognition using the 3D-CNN model. *IEEE Consumer Electronics Magazine*, *9*(1), 95-101.
20. Tholkapiyan, A.Mohan, Vijayan.D.S, A survey of recent studies on chlorophyll variation in Indian coastal waters, IOP Conf. Series: Materials Science and Engineering 993 (2020) 012041, 1-6..
21. Zhan, F. (2019, July). Hand gesture recognition with convolution neural networks. In *2019 IEEE 20th International Conference on Information Reuse and Integration for Data Science (IRI)* (pp. 295-298). IEEE.
22. Arenas, J. O. P., Murillo, P. C. U., & Moreno, R. J. (2017, August). Convolutional neural network architecture for hand gesture recognition. In *2017 IEEE XXIV International Conference on Electronics, Electrical Engineering and Computing (INTERCON)* (pp. 1-4). IEEE.
23. Głomb, P., Romaszewski, M., Opozda, S., & Sochan, A. (2011, May). Choosing and modeling the hand gesture database for a natural user interface. In *International Gesture Workshop* (pp. 24-35). Springer, Berlin, Heidelberg.
24. Panwar, M., & Mehra, P. S. (2011, November). Hand gesture recognition for human-computer interaction. In *2011 International Conference on Image Information Processing* (pp. 1-7). IEEE.
25. Khan, R. Z., & Ibraheem, N. A. (2012). Survey on gesture recognition for hand image postures. *Computer and information science*, *5*(3), 110.
26. A.I. Maqueda, C.R. del Blanco, F. Jaureguizar, N. García, "Human-computer interaction based on visual hand-gesture recognition using volumetric spectrograms of local binary patterns", Computer Vision and Image Understanding, Special Issue on Pose & Gesture, vol. 141, pp. 126-137, Dec. 2015. (doi:10.1016/j.cviu.2015.07.009)
27. http://www-prima.inrialpes.fr/FGnet/data/12-MoeslundGesture/database.html
28. Neethu, P. S., Suguna, R., & Sathish, D. (2020). An efficient method for human hand gesture detection and recognition using deep learning convolutional neural networks. Soft Computing.