A Review of Sign Language Recognition Techniques

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ABSTRACT

Sign language recognition is important for natural and convenient communication between deaf community and hearing majority. Hand gestures are a form of nonverbal communication that makes up the bulk of the communication between mute individuals, as sign language constitutes largely of hand gestures. Research works based on hand gestures have adopted many different techniques, including those based on instrumented sensor technology and computer vision. In other words, the hand sign can be classified under many headings, such as posture and gesture, as well as dynamic and static, or a hybrid of the two. This paper focuses on a review of the literature on computer based sign language recognition approaches, their motivations, techniques, observed limitations and suggestion for improvement.

Key words : Communication, Features Extraction, Hand Gesture, Recognition, Sign Language.

1. INTRODUCTION

Communication is incredibly vital to human beings, as it helps us to express ourselves. We communicate by voice, gestures, body language, reading, and writing or through visual aids, speech being one of the most widely used among them. The main representation of communication is language [1]. Sign Language is a language in the very same way any other internationally recognized language is. It is a nonverbal communication method used by the deaf and mute people to interact with one another and with others [2], because non-mute people rarely learn Sign Language, mute people have difficulty communicating with them. This is why Sign language recognition is important for natural and convenient communication between deaf community and hearing majority. Hand gestures are a form of nonverbal communication that makes up the bulk of the communication between mute individuals, as sign language constitutes largely of hand gestures. Despite the fact that a lot of researches have been done regarding sign language recognition, it is still a challenging problem as it requires the understanding of the combination subtle movements and

expressions such as hand pose and movement, facial expressions, and body posture. Sign language has at least thousands of words including very similar hand poses, while gesture recognition mostly includes small subset of well-defined gestures. Moreover, some of the s

igns are only distinguished by the degree of contact between fingers and in addition, there is a lot of variations due to varied camera angles and signers [3, 4]

Research papers based on hand gestures have adopted many different techniques, including those based on instrumented sensor technology and computer vision. In other words, the hand sign can be classified under many headings, such as posture and gesture, as well as dynamic and static, or a hybrid of the two[4]. This paper focuses on a review of the literature on sign language recognition; their motivations, approaches and limitations.

2. REVIEW OF RELATED WORKS

Literature associated with gesture recognition and image processing is described below. The section discusses the methods used by the authors to accomplish their proposed systems, the troubles they faced when developing their desired systems.

A) Hand gesture recognition in real world scenarios using approximate string matching implemented by Alonso *et al* (2020) in [4]

A lot of research and work has been done regarding the applications of Leap Motion Controller (LMC) which showed encouraging results but also highlighted several challenges to be overcome. In particular, the LMC Application Program Interface (API) only provides support for 3 gestures. This research was started to find a way to increase the recognition of different gestures in a way different from past research done involving LMC. The aim of this paper was to present a robust and lightweight approach for hand gesture recognition with LMC. The authors proposed a system that utilizes a classifier called Approximate String Matching (ASM).The trajectory of hand joints were encode as character sequences using K-Means algorithm, then the character sequence was analyzed using the ASM. The system proposed to use leap

motion to detect the presence of the hand in the video feed and to model the hand to depict its motion and trajectory. This system achieved 93.52% accuracy, had some troubles differentiating gestures that were similar in nature.

B) Computer Vision Based Human-Computer Interaction Using Colour Detection Techniques by Dhule Chetan and Trupti Nagrare (2014)[8]

Previous works rely on gesture recognition algorithms that need different hardware, often involving complicated setups, limited to a constrained environment. Algorithms which are being used so far for gesture recognition are not practical or responsive enough for real-world use, which might be due to the inadequate data on which the image processing is done. As existing methods or systems are based on gesture recognition algorithms, some of them require Artificial Neural Network model training', which makes the whole process slow and reduces accuracy. The method they have formulated is based on real time mouse motion controlling in windows according to the motion of hand and fingers by calculating the change in pixels values of RBG colours from a video, without using any ANN model to get exact sequence of motion of hands and fingers.

The main objective of the study was to design a real time mouse motion controlling in windows according to the motion of hand and fingers by calculating the change in pixels values of RBG colours from a video, without using any ANN model to get exact sequence of motion of hands and fingers.

The study proposed a pixel calculation based hand signal recognition method for human computer interaction. They proposed the technique keeping in view that most the prior strategies depend on motion recognition calculations that required the training and use of an Artificial Neural Network (ANN) model, which is extremely tedious to train and has very little accuracy. So by utilizing shading recognition methods, they designed a real time application to control the mouse's movement in windows by recognizing change in pixel estimation of RGB (coloured) hues and which is achieved without an ANN model. The drawback might include - the reaction speed of controlling the mouse is expected to be slow compared to using a touch pad.

C) A temporal hand gesture recognition system based on hog and motion trajectory by Lin Jing and Yingchun Ding (2013) [5]

A real-time, rapid and robust gesture recognition system is usually hindered by difficulty of hand localization and complexity of hand gesture modeling, especially under complex background. For eliminating these obstacles, in this paper, Lin Jing and Yingchun Ding proposed a method using histograms of oriented gradients features (HOG) and motion trajectory information for temporal hand gesture recognition in natural environment, to solve the problems faced with hand

localization and complex background. The aim of this work was to implement a gesture recognition system using the HOG method for hand detection to overcome the limitations of complex backgrounds. The researchers proposed the use of Histograms of Oriented Gradient features (HOG) with a specific end goal to expel the impediment brought on by complexity of hand signs amid hand limitations and the ever changing background in a real time recognition system. HOG and Support Vector Machine (SVM) are connected to detect and confine the hand and afterward movement directions of consecutive hand gestures are separated and a standard database was made. Mahalanobis separation was used for recognition. The method was tried on six standard motions and normal exactness of 91.7% was acquired. With this approach, it is doubtful if this system is robust enough because it cannot recognize complex signs.

D) Automatic recognition of finger spelled words in British Sign Language. By Liwicki Stefan and Everingham Mark (2009) [6].

The motivation for this paper/work is to investigate the problem of recognizing words from video, finger spelled using the British Sign Language (BSL) fingerspelling alphabet. This is a challenging task since the BSL alphabet involves both hands occluding each other, and contains signs which are ambiguous from the observer's viewpoint. The objectives of this work include: Recognition based on hand shape alone not requiring motion cues; robust visual features for hand shape recognition; scalability to large lexicon recognition with no re-training.

The work proposed a British Sign Language recognition system that understands finger spelled words from a video. The system first detects the hand by colour variation between the hand and non-hand pixels, then recognized hand shape using a Histogram of Gradients (HOG) descriptors. The recognized hand shape is then classified using a Hidden Markov Model (HMM)-based lexicon model. The dataset in use corresponds to a single inexperienced signer, which poses a limitation to the robustness of the system at its speed of recognition. The system achieved 98.8% accuracy.

E) Hand Gesture Recognition System by Mohamed Alsheakhali *et al* (2011) [9].

Unlike previous gesture recognition systems, their system neither uses instrumented glove nor any markers. The new barehanded proposed technique uses only 2D video input. The motivation for this work was to create a less method of detecting and recognizing gestures than the ones shown in previous works. Objectives aim to develop a system that will work with a low budget camera for input that will work under different degrees of scene background complexity.

This research proposed a system which begins by extracting frames from a video stream, splitting them into two parts, then processes them simultaneously. This is done to increase the speed of the system to make it as real time as possible . They detected the hand in the video stream by determining the skin pixel colour. There is a possible flaw in this method since there are many objects which close to the same spectrum of pixel colour. The hands were distinguished by motion, and then they proceed to detecting the motion of the hand by subtracting two frames from each other, and then thresholding the output image. They calculated the center of the hand to track the trajectory and location. Lastly, they analysed the hand position variation to determine the gesture being portrayed. Only small amount of gestures were used, which was 12.

F) Analysis on Hand Gesture Spotting using Sign Language through Computer Interfacing by Neha Chourasia *et al.*(2014) [10].

The motivation for this work is to provide a real time interface so that signers can easily and quickly communicate with non-signers. To efficiently and accurately recognize signed words, from Indian Sign Language, using a minimal number of
training examples. The objectives: to use natural image sequences, without the signer having to wear data gloves or coloured gloves, and to be able to recognise hundreds of signs; develop an automatic sign language recognition system with the help of image processing and computer vision techniques

The work provided a motion recognition system to recognize Indian Sign Language. Procedure proposed by Neha Chourasia *et al* utilizes Hu invariant moment descriptor, merging HU invariant moments and SURF for the hand shape detection and extraction of hand features. They after utilized K-Nearest Neighbours (KNN) and Support Vector Machine for classification of signed letters. The proposed system achieved 96% accuracy in identifying and matching 256 set of hand signs detected. Achieving a promising performance on clustered backgrounds might be a challenge of the system.

G) Human-Computer Interaction Based on Hand Gestures Using RGB-D Sensors by Palacios *et al.*(2013) [7].

However, despite all the previous work, a reasonable solution to the gesture recognition problem has not been found yet. The motivation for this work is to find a solution to the clustered background problem and also the problem of differentiating the hands between all the skin regions segmented by a colour filter. One of the main aims of this work is to provide the user with freedom of movement when using the system.

The system proposed "Human-Computer Interaction Based on Hand Gestures Using RGB-D Sensors" , Palacios *et al* created a hand signal recognition system utilizing RGBD

sensors taking the benefits of depth data to expel the issues brought on by lightning conditions and cluttered backgrounds. The proposed method incorporates four essential strides - Hand division, Feature extraction, Static signal characterization and Dynamic motion arrangement. For hand division skin shading division and background subtraction is utilized. Above all else face is identified from the picture and is evacuated and after that wrist is distinguished and hand is extricated, then a featured-based decision tree for gesture recognition. For static signal acknowledgment, fingertip location is utilized and fingertip is distinguished using greatest ebb and flow and convexity deserts. For motion acknowledgment, different components extricated from the hand are used, such as the palm center and the trajectory of the movement is recorded and classified. The system is restricted to users wearing clothes different from their skin tone.

H) Sign Language Recognition Using Convolutional Neural Networks by Pigou *et al.*(2015) [11].

In this work, the authors improved on the results of Roel Verschaeren,   who proposed a CNN model that recognizes a set of 50 different signs in the Flemish Sign Language with an error of 2.5%, using the Microsoft Kinect. They worked to overcome the limitations of Roel Verschaeren.'s work which is unfortunately limited in the sense that it considers only a single person in a fixed environment. The purpose of this work is to contribute to the field of automatic sign language recognition using Italian sign language as a case study. Pigou *et al.*(2015) proposed an Italian sign language recognition system using a RGB-D camera to capture the input data with thresholding, background removal using the user index, and median filtering performed on the image for preprocessing and then feed to a CNNs to recognize and classify the gesture. They reported 95.68% accuracy for 20 classes.

I) A Hand Gesture Recognition using Feature Extraction by Pradhana *et al.*(2012) [2].

The development of procedure for realizing gestures into meaningful information plays a pivotal role in instances where linguistic feature cannot be taken as a basis and gestures can be used as the alternative for the conveying the same. This paper presents a very simple and efficient approach for recognizing the hand gesture that represents numbers from zero to nine. This research basically deals with the design of a system that acquires a user's hand gesture and classifies it based on the predefined hand gestures, stored in a database.

The researchers proposed a method with a straightforward and proficient approach for perceiving hand signals that represents numbers from zero to nine. The work fundamentally recognizes the non-dynamic fingers with

double esteem 0 and 1 individually, in various blends for saying various numbers in terms of signs. The technique for speaking to the double signal in paired example contributes a considerable measure for expanding the execution of arrangement process. The parallel Support Vector Machine (SVM) is considered as a recognition tool in their paper. The designed system is able to classify only the static images

J) Real-time ASL fingerspelling recognition by Pugeault and Bowden (2011) [13].

The motivation for this paper is to efficiently and accurately recognize signed words from American Sign Language using a minimal number of training examples. This article presents an interactive hand shape recognition user interface for American Sign Language (ASL) finger-spelling.

The researchers proposed a real-time ASL fingerspelling recognition system using Gabor Filters and Random Forest. Their system recognizes 24 different ASL fingerspelling for alphabets. They collected dataset from five subjects and reported a recognition rate of 75% using both coloured and depth, 73% using only colour, and 69% using only depth. Although N. Pugeault and R. Bowden reported that combination of colour and depth improves the recognition rate, they only use depth to achieve better consistency to illumination changes and skin pigment differences and to avoid calibration process for general users.

K) Video-based isolated hand sign language recognition using a deep cascaded model by Rastgoo, R. *et al* [14].

Nowadays that the communication technologies and tools such as Imo and WhatsApp have become an important part of our life, they can be used to facilitate the communication between deaf community and hearing majority. While deaf people could communicate with each other using these technologies, they have many problems for communicating with people who do not know sign language. So, development of automatic sign language translation systems is necessary to provide equal communication opportunity and improve public welfare. This work was motivated by the need to automated sign language communication using deep learning techniques. The aim was to design an efficient cascaded model for sign language recognition taking benefit from spatio-temporal hand-based information using deep learning approaches, especially Single Shot Detector (SSD), Convolutional Neural Network (CNN), and Long Short Term Memory (LSTM) from videos. They proposed a sign language recognition system which is divided into two parts Hand Detection and Sign Recognition. The hand detection was done using a Single Shot detector(SSD) that predicts the objects bounding boxes along with the classes scores using small convolutional filters and a Non-Maximum Suppression (NMS) step was used in the final step to estimate the final detection. Then, the resulting output is fed to a ResNet50 CNN model, the extracted features are fused with ESHR and

HP features to feed them to a LSTM for temporal feature extraction. The system does not have a high detection accuracy using the SSD method.

L) Robust Part-Based Hand Gesture Recognition Using Kinect Sensor by Ren *et al.*(2013) [15]
Compared to the entire human body, the hand is a smaller object with more complex articulations and more easily affected by segmentation errors. It is thus a very challenging problem to recognize hand gestures. This work is a research into segmenting hands using Finger-Earth Mover's Distance (FEMD) to measure the dissimilarity between hand shapes. This paper focuses on building a robust part-based hand gesture recognition system using Kinect sensor.

The study developed a robust part based technique using kinect sensor keeping in view the limitations of glove based and vision based techniques. In their approach, first of all, kinect sensor was used to capture the both coloured images and depth maps corresponding to that image. Using depth maps, hand can be easily detected even in cluttered background, also by using depth thresholding. After detecting the hand it was represented by its finger parts using time series curve. Then for gesture recognition, a dissimilarity measure called Finger-Earth Mover's Distance (FEMD) was proposed which can recognize noisy hand contours as compared with other recognition methods and was robust to change in scale, orientation, local distortions and background conditions.

M) Hand Gesture Recognition by Thinning Method , Rokade *et al* (2009) [16].

The motivation for this project is to devise a system that overcome the limitations specified in the following methods; Stergiopoulou and Papamarkos proposed YCbCr segmentation. The limitation for YCbCr segmentation method is that background should be plain and uniform. Chen *et al*. introduced a hand gesture recognition system to recognize continuous gestures before stationary background. Peer *et al* proposed RGB segmentation which is more sensitive to light conditions. Ribeiro and Gonzaga proposed different approaches of real time GMM (Gaussian Mixture Method) background subtraction algorithm using video sequences for image segmentation.

The aim of this project was to devise a recognition system that would be able to recognize gestures in non-uniform backgrounds and does not require post-processing for feature extraction, implemented using the thinning method. The study proposed a system for recognizing static American Sign Language (ASL) gestures for numbers from 1-5. They have used a novel segmentation technique based on histogram matching YIQ colour space and YCbCr colour space mapping skin colour pixels to white and backgrounds pixels to black. Thinning is employed in order to extract features over thinned image. The recognition gestures were done by comparing the

measures of features extracted namely; angle and radial distance. The angle between raised fingers is calculated. The radial distance is the distance from fingertip to end point of the wrist. Based on the ranges of these features, raised fingers and hence the gestures of numbers were identified. Accuracy of 92.13% was seen in recognition and a little amount of gesture was used to train this system, meaning it is not diverse.

N) A Communication Aid System for Deaf and Mute using Vibrotactile and Visual Feedback. Sobhan M., Chowdhury M. Z., Ahsan I., Mahmu H., and Hasan M. K. (2019) [17].

The motivation for this work is most mute communication works are limited to only sign language or gesture detection and for these reasons, they cannot be used as a bi-directional communication aid for the users. As these approaches are heavily dependent on sign language detection, the users of these systems must learn the sign language beforehand. To this end, they proposed a system that uses smart-phone for communication with no use of the sign language and very easy to use. The objective of the system was to provide a low cost and easily accessible communication aid for deaf and mute that will not require any learning of sign language. The work proposed an android system that accepts input gestures provides the resulting text meaning by mapping. This system was proposed to aid deaf or mute community communication with a non-mute person and vice-versa. The system was divided into two modules. The first module deals with the situation when a deaf and mute person tries to communicate with a non-mute person and the second module is just the vice-versa of the previous one. Small sample data was used.

O) Generic system for human-computer gesture interaction by Trigueiros *et al*. (2014) [18].

This paper was motivated by the need of creating a vision-based approach, to implement a system capable of performing posture and gesture recognition for real-time applications. The aim of this project was to develop a prototype that combines a vision-based hand gesture recognition system with a formal language definition, the Referee CommLang, into what is called the Referee Command Language Interface System (ReCLIS). The second one is to develop a real-time system able to interpret the Portuguese Sign Language. This research proposed a general human PC interaction system in the use of hand signs. The system utilizes vision based approach as they have advantage contrasted with customary information glove approaches as regarding accessibility. Essentially, the system comprises of three models - preprocessing and hand segmentation model, static gesture interface model and dynamic gesture interface model. For recognition, machine learning classifier was utilized. For static gesture recognition Support Vector Machine (SVM) was utilized and for dynamic signed elements, Hidden Markov Model was utilized. The

experiment resulted in 99.7% correctness with Support Vector Machine and 93.7 % with Hidden Markov Model with 11 predefined motions. Limited sample data was used.

P) Combining rgb and tof cameras for real-time 3d hand gesture interaction by Van den and Van Gool (2011) [19].

The motivation for this work is to try and address the limitations noted in Van den work, by using ToF camera. This paper aims to improve a real-time hand gesture interaction system by augmenting it with a ToF (Time-of-Flight) camera. The work proposed a hand gesture recognition system using a normal RGB camera with a ToF camera to capture input data and implementing Haar wavelets and database searching for detection and recognition. The system detects hand gestures by employing a novel hand detection algorithm is introduced based on depth and color extracts features using Haar wavelets and classifies input image by finding the nearest match in the database. This method considers only six gesture classes.

Q) A Novel Approach to Hand-Gesture Recognition in a Human-Robot Dialog System by Ziaie *et al* (2008) [20].

In some fields the interaction of humans and robots is inevitable. Imagine a robot which is serving the people at a bar as bar-tender. This robot needs to communicate with people to see what their demands are and then carry out the corresponding task. Not every customer at a bar needs to know how to program a robot and insert the right instructions, thus a natural way of interaction should be constructed so that the robot can obtain the relevant data from the surrounding people. Trying to address these needs, new methods have been sought to ease the process of communication. Creating a gesture recognition system for Human-Robot Interaction or HRI addresses this need. The aim of this work was to design a reliable, fast and robust approach for static hand gesture recognition in the domain of a Human Robot interaction system. The researcher proposed a strategy of first registering distinctive gesture and after that allocates probabilities to them utilizing Bayesian Inference Rule. For this purpose, two classes of geometric invariant were described; the invariant classes were estimated utilizing a modified KNN (K-Nearest Neighbour). These classes comprise of Hu- moments with geometrical qualities like turn, change and scale in variety which was utilized as elements for order. The recognition was done using a Bayes decision tree. Execution of this procedure was exceptionally well with 95% correct classification results on average for three types of gestures (pointing, grasping and holding-out) under various lighting conditions and hand poses.

3. SUMMARY OF THE FINDINGS FROM THE REVIEW

The review shows that there have been a number of systems with different approaches to tackling the problem being faced in Sign Language Recognition (SLR). Most of which focused

on vision based approach to SLR. Observed motivation for most of the approaches adopted for SLR where based on the need to improve recognition or detection in clustered or complex backgrounds and also the need for more real time and efficient system; all of which are justifiable. Table 1 below shows the summary of the review at a glance.

Table1: Tabular view of the reviewed works on Sign Language Recognition

Researcher(s)	Year	Motivation(s)	Method(s) used	Accuracy
Alonso *et al* [4]	2020	-To increase the recognition of gestures using Leap Motion -To present a robust light weight approach to SLR	Use of Leap Motion, Approximate String Matching and k-Means algorithm	93.52%
Dhule *et al* [8]	2014	-The relatively large training time and low accuracy of an ANN problem	pixel estimation of RGB hues and shading recognition methods	_
Lin *et al* [5]	2013	-The problem of recognition in complex backgrounds	HOG features and Support Vector Machine	91.7%
Liwicki *et al* [6]	2009	-To tackle problems faced in recognizing BSL from video	HOG descriptors and HMM-based lexicon model	98.8%
Mohamed *et al* [9]	2011	-The complexity in use of existing systems	skin pixel colour based recognition and frame difference subtraction	94%
Neha *et al* [10]	2014	-The need for efficient and robust ISL recognition system.	HU invariant moments ,SURF , KNN and SVM	96%
Palacios *et al* [7]	2013	-to find a solution to the clustered background problem -the problem of differentiating the hand between all the skin regions segmented by a colour filter	RGB-D Sensors, skin shading division and background subtraction and featured-based decision tree	92.1%
Pigou *et al* [11]	2015	-Trying to overcome the limitations faced by Roel Verschaeren	CNN	95.8%
Pradhana *et al* [12]	2012	-Design of a simple system	Support Vector Machine (SVM)	100%
Pugeault *et al* [13]	2011	-The motivation for this paper is to efficiently and accurately recognize signed words using a minimal number of training examples.	Gabor Filters and Random Forest	74% and 69%
Rastgoo *et al* [14]	2020	-The need to automated sign language communication using Deep Learning techniques.	Single Shot detector(SSD), Non-Maximum Suppression (NMS) step, ResNet50 CNN, LSTM	_
Ren *et al* [15]	2013	-Find a solution to the errors that occur during segmentation process	kinect sensor, Finger-Earth Mover's Distance	93.2%

Rokade *et al* [16]	2009	-The motivation for this project is to devise a system that overcome the limitations specified in the following methods; Stergiopoulou and Papamarkos proposed YCbCr segmentation.	histogram matching YIQ color space and YCbCr color space , thinning method	92.13%
Sobhan *et al* [17]	2019	- Most sign recognition system are dependent on the knowledge of sign language and do not offer enough diversity.	Visual Aids	_
Trigueiros *et al* [18]	2014	-The need to develop a real time system.	Support Vector Machine(SVM) Hidden Markov Model.	99.7% on static and 93.7 on dynamic
Van den *et al* [19]	2011	-The motivation for this work is to try and address the limitations noted in Van den work, by using ToF camera.	ToF camera, Haar wavelets and database search	_
Ziaie *et al* [20]	2008	-The need to create a gesture recognition system for HRI	Bayesian Inference Rule KNN Hu- moment Bayes decision tree	95%

4. CONCLUSION

The Study shows that Sign Language Recognition has come a long way as a result of the ensuing researches being carried out in the area due to its importance in our society; there have been varieties of ideas and techniques resolving some of the problems plaguing SLR but sadly these approaches have not addressed the problems completely. In this study, a few techniques and approaches showed great promising results as they addressed some of the contending issues but they are not without their own limitations. The study tends to expose some of the challenges in Sign Language Recognition, those fairly addressed and much work to be done. This work is not done to demerit the authors of the articles reviewed but to make others improve on their work and if possible, the authors. It is hopeful this study will be an added advantage to the researchers working in this area. A robust Sign Language Recognition system that can recognise gestures captured in both binary form and RGB form is also suggested.

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