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Motion Trajectory Based Human Hand Tracking for Sign Language Recognition

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Abstract: *Sign Language is the only formal way of communication for the mute persons and the hearing impaired. Developed systems that can recognize these signs provide an interface between signers and non{signers by which the meaning of sign can be interpreted. The aim of this project work was to design a user independent framework for automatic recognition of Sign which can recognize various one handed dynamic isolated sign and interpreting their meaning. The proposed approach consists majorly of three steps: preprocessing, feature extraction and recognition. We proposed system which we have compared different approaches of image processing for Motion trajectory based human hand tracking for sign language recognition.*

Keywords: Preprocessing, Feature Extraction, Recognition, Trajectory, CNN.

I. INTRODUCTION

In last two decades human has made a huge evolution in field of Artificial Intelligence and data processing. It has been beneficial to every field in each aspect such as growing in sales of companies, easy and quick services to customers and clarity in transactions. We can use this type of technology to make lives easy and convenient of disabled people like normal people. Due to this idea, we have decided to develop a system which can used to make ease in communication of mute or disabled people.

A Convolutional Neural Network (CNN) is a Deep Learning algorithm which can take in an input image, assign importance to various aspects. The CNN or convolutional neural networks are the most commonly used algorithms for image classification problems. They have applications in various fields like driver less cars, defense, healthcare. An image classifier takes a photograph as an input and classifies it into one of the possible categories that it was trained to identify.

We have used CNN for gesture recognition

1.1 Overview

The sign detection is a very important way of communication for deaf-dumb people. In sign detection each gesture has a specific meaning. So therefore, complex meanings can be explained by the help of combination of various basic elements. Sign language is a gesture-based language for communication of deaf and dumb people. It is basically a non-verbal language which is usually used to deaf and dumb people to communicate more effectively with each other or normal people

1.2 Motivation

Normal people assume some specified syntactic meaning for the expressions performed by people of deaf and dumb community to work in communication analytics. This is needed to develop a dictionary of signs system is invariant with locality and the morphology of deaf and dumb people. The objective of sign communication system is identifying the sequence of signs with exact meaning. Sign language is more than gesture communication and requires highly challenging machine algorithms to work on unconstraint and unspecified datasets.

The biggest issues created due to inadequate dataset to incorporate all type of sign as global platform. Technically, the objective of this work is to process the expression to establish a mapping between phoneme and sign communications by studying hearing impaired people. The sections of SLR system can be specified manual, non-manual and finger spelling. The manual signs include the orientation, shape, size and position of the hand during communication. Non-manual signs are considered in facial expression, lip moment and body gestures. In finger spelling part, the words of sign language are spelt locally by the sign of figures. The problem of automated recognition of sign language can be divided into several modules

1.3 Problem Defination

"To develop a robust motion trajectory based Human Hand Tracking System to recognize signs using convolutional neural networks (CNN) to have a better communication for mute persons via sign language."

1.4 Objective Statements

Following are the objective of this proposed work

- To acquire/create dataset for generated trajectories.
- To preprocess the data set for model building.
- To train the model using Train data set.
- To observe the performance of the model.

Activities:

- To acquire /create dataset for generated trajectories
- For training the model we need to Acquire or create dataset for the model.
- Dataset for this project is maybe some random gesture images that can used in future for pre-processing.
- To preprocess the data set for model building.
- Pre-processing is carried out on hand gesture dataset images and certain features are extracted from it.
- CNN model is trained and used to detect the sign language given by respective gestures.

To train the model using Train data set.

- According to the respective preprocessing of data, the model for the project is trained
- Convolutional Neural Network (CNN) model and Hidden Markov Model (HMM) is trained with the use of derived algorithms.
- To observe the performance of the model.
- Loading, Training and testing of dataset is done to apply on CNN and hence prediction of constraints is carried out.
- Then the actual output is compared to expected output to observe accuracy of model

II. LITERATURE SURVEY

The first chapter described proposed work. The problem statement gave a brief idea about the proposed work and the objectives gave a step-wise execution process of the proposed work. This chapter includes the details of the related papers with this system and the respective author's work. These papers are close to the objectives of this system and the observations of these research papers are analyzed in the proposed work.

2.1 Literature Review

While calculating higher order Hu invariant moments, higher computational precision is needed. Dr. Anand Singh Jalal et al.[1] in 2014 .The author presented an approach where they used Fourier descriptor for the recognition of hand gesture trajectories and probabilistic neural network for gesture classification. Rajat Shrivastava proposed a methodology where the set of features included Hu invariant moments as shape descriptors and hand orientation.

There are varied techniques available which can be used for recognition of sign language. A Comprehensive Analysis on Sign Language Recognition System Was Proposed by Rajesh George Rajan et al [2] in 2019.Different authors have used different techniques according to the nature of sign language and the signs considered. Sign language recognition is mainly consisting of three steps:

preprocessing, feature extraction and classification. In preprocessing, a hand is detected from sign image or video. In feature extraction, various features are extracted from the image or video to produce the feature vector of the sign.

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Finally, in the classification, some samples of the images or videos are used for training the classifier then test sign is identified in image or video. A lot of work has been done on static signs but unfortunately, till date not much research work has been reported for dynamic signs in Indian Sign Language.

In earlier work on two handed sign recognition,Hand Gesture Recognition Based on Karhunen-Loeve Transform Was Proposed by Joyeeta Singha et al [3] in 2016. proposed a two-stage recognition approach for 23 alphabets. Signs are produced by wearing red gloves on both hands for segmentation purposes. The segmented images serve as an input to the feature extraction and recognition phase. In stage-I the features that are describing the overall shape of gestures, were calculated and recognition is done through training feature vectors without use of any classifier.

Kalin Stefanov et al.[4] in 2016 Proposed A Real-time Gesture Recognition System for Isolated Swedish Sign Language Signs.A recognition criterion was tough, and the feature vector had a binary coefficient. Finally, an output was given whether the gesture is correct or not, a method for the recognition of 10 two handed Bangla characters using normalized cross correlation is A RGB color model is adopted to select heuristically the threshold value for detecting hand regions and template-based matching is used for recognition. However, this method does not use any classifier and tested on limited samples.

Gesture Recognition for Alphabets from Hand Motion Trajectory Using Hidden Markov Models Was Proposed by 1.Gerald Krell et al.[5] in 2007.(Principal Component Analysis (PCA) feature is used for feature extraction. This method consists of 20 samples of 100 signs by one signer. 15 samples of each sign were used for training a Support Vector Machine to perform the recognition. The system was tested on the remaining 5 samples of each sign. A recognition rate of 99.6 on the testing data was obtained. When the number of signs in the vocabulary increases, the support vector machine algorithm must be parallelized so that signs are recognized in real time. The drawback of this method was to employ 75 images for training and remaining 25 for testing.

In 2020, Iker Vazquez Lopez et al.[6] Work on two handed signs has been done in Rekha et al. Here, Principal Curvature Based Region (PCBR) is used as a shape detector, Wavelet Packet Decomposition (WPD-2) is used to find texture and complexity defects algorithms are used for finding features of fingers. The skin color model used here is YCbCrfor segmenting the hand region. The classifier used is Multi class non-linear support vector machines (SVM). The accuracy for static signs is 91.3. However, three dynamic gestures are also considered which uses Dynamic Time Warping (DTW). The feature extracted is the hand motion trajectory forming the feature vector. The accuracy for the same is 86.3.

Paulo Trigueiros in 2018 [7] Vision-based Portuguese Sign Language Recognition System In threshold models have been designed to differentiate between signs and non-sign patterns of American Sign Language in Conditional Random Field (CRF). The recognition accuracy for this system is a 93.5. Aran et have developed a system called the sign tutor for the automatic sign language recognition. The three stages in this system are: face and hand detector, analysis and classification. User is made to wear colored glove in order to easily detect the hand and remove occlusion problems. For both the hands,kalman filters are used for smoothening hand trajectories and thereafter, features for finding the hand shape are extracted. The classifier used is Hidden Markov Model (HMM). The dataset consisted of 19 signs from ASL.

Bhumika Nandwana in 2017 [8] proposed on basic method of hand gesture recognition and find that kinect sensor is used widely in comparison of vision based technology and glove-based The accuracy for signer-dependent systems is 94.2, while for signer-independent systems it is 79.61. Lekhashri and Pratap developed a system for both static as well as dynamic ISL gesture recognition. The various features extracted are skin tone areas, temporal tracing and spatial filter velocimetry. This obtains the motion print of image sequence. Then pattern matching is used to match the obtained motion prints with the training set which contains the motion print of the trained image sequences.

In 2020, Dinh-Son Tran et al.[9] proposed Real-Time Hand Gesture Spotting and Recognition Using RGB-D Camera and 3D Convolutional Neural Network an approach using direction histogram features. The classification is done through Euclidean Distance and with K-nearest neighbors also and both are compared. In the dataset, only isolated hand gestures of 22 ISL signs are taken. The recognition rate is found out to be 90. The limitation of this approach is the poor performance in case of similar gestures. Sandjaja and Macros also used color -coded gloves for tracking human hands easily. Multi-color tracking algorithm is used to extract the features. The recognition is done through the Hidden Markov Model. The dataset consisted of Filipno sign language numbers. The recognition rate is 85.52.

In 2019, Mengna Zhou et al.[10] proposed Facial Expression Sequence Interception Based on Feature Point Movement and Achieving automatic Facial Expression Sequence. proposed method performs well on FESI, it fails to handle the non-frontal face images, which is the most challenging task for all of the researches. the proposed work recognizes static and dynamic sign of ISL. Different researchers use the numerous types of approaches in different sign language

2.2 Gap Analysis

The accuracy of the proposed system was 92.4. But the major drawback of their entire system is the use of Kinect Sensor which makes their system very costly and this amount of accuracy can also be achieved at a low cost. In this paper, we have proposed a system for sign language gesture recognition which makes use of only one camera thereby, making our system cost effective. Our concentration is on solving the major issues like gesture segmentation, key frame extraction and use of Zernike Moments as shape descriptors.

Zernike moments are scale, translation and rotationally invariant and most importantly they require much lower computational precision while calculating higher order Zernike Moments as compared to the commonly used Hu Invariant Moments. Hence, we are using ZMs as our shape descriptor for determining hand posture because even if two signs follow the same trajectory pattern, we can differentiate them based on the posture of the hands.

2.3 Summary of Literature Review

Table 2.1: Literature Review

Author /Year of Publication	Title	Strength	Weakness
1.Dr. Anand Singh Jalal (2013-14)	Automatic Recognition of Dynamic Isolated Sign in Video for Indian Sign Language	hand shape, hand orientation and hand motion improve the performance of the system.	Sign dataset will not include two handed dynamic signs.
1.Rajesh George Rajan 2.M Ju-dith Leo (2019)	A Comprehensive Analysis on Sign Language Recognition System	capable of recognizing both hand and facial gestures is a key challenge. feature extraction methods and classification methods are required to achieve the final objective of human computer interface	Nothing is said about the running time of the method.
1.Joyeeta Singha 2.Karen Das	Hand Gesture Recognition Based on Karhunen-Loeve Transform	recognizing different hand gestures are skin filtering, edge detection, K-L transform and finally a proper classifier, where author was used angle-based classification to detect which symbol the test image belongs to	
Paulo Trigueiros Fernando Ribeiro	Vision-based Portuguese Sign Language Recognition System	The proposed solution was tested in real time situations, were it was possible to prove that the obtained classification models were able to recognize all the trained gestures being at the same time user independent, important requirements for this type of systems	Small Data set is used so comparing is minimum
Gerald Krell Bernd Michaelis (2007)	Gesture Recognition for Alphabets from Hand Motion Trajectory Using Hidden Markov Models	This paper presents a method for gesture recognition of alphabets from A to Z according to the motion trajectory of a single hand using HMM. 92 per accuracy	There is no Skin color detection models
Iker Vazquez	Hand gesture	focus was hand images and I parallelized	Most of the methods

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Lopez	recognition or sign language transcription.	the method using the GPU to in-crease the efficiency	reported in the literature fail to characterize kinds of transitions.
Kalin Stefanov Jonas Beskow (2016)	A Real-time Gesture Recognition System for Isolated Swedish Sign Language Signs	The size of the recorded vocabulary is 51 signs from the Swedish Sign Language so time complexity is high	Small Data Set is Used
Paulo Trigueiros Fernando Ribeiro	Vision-based Portuguese Sign Language Recognition System	The proposed solution was tested in real time situations, were it was possible to prove that the obtained classification models were able to recognize all the trained gestures being at the same time user independent, important requirements for this type of systems	Small Data set is used so comparing is minimum

III. SOFTWARE REQUIREMENT SPECIFICATION

The second chapter described the study of different papers and documents related to the proposed work. It specified the summary of each paper. In the table 2.1, the highlights and observations in each paper were specified which guided the chapter three in mentioning the requirements. The third chapter is Software requirement specification. The points included in this chapter are functional requirements, non-functional requirements, hardware and software requirements, external requirements, system requirements. This chapter also includes the software development lifecycle model which is to be used.

3.1 Assumptions and Dependencies

- User has to perform hand gestures to get detected from system.
- User follows instruction as shown by the application.
- Maintenance and updates will be provided by Administrators.
- Application should be able to display results based on camera input

3.2 Functional Requirements

3.2.1 System Feature 1

We are developing a system that can recognize these signs provide an interface between signers and non–signers by which the meaning of sign can be interpreted.

3.2.2 System Feature 2

We will design a user independent framework for automatic recognition of Sign which can recognize various one handed dynamic isolated sign and interpreting their meaning. The proposed approach consists majorly of three steps: preprocessing, feature extraction and recognition.

3.3 Nonfunctional Requirements

Non-functional requirements are requirements which specify criteria that can be used to judge the operation of a system, rather than specific behaviors. This should be contrasted with functional requirements that specify specific behavior or functions. Typical non-functional requirements are reliability, scalability, and cost. Other terms for non-functional requirements are ”constraints”, ”quality attributes” and ”quality of service requirements”.

- Reliability-If any exceptions occur during the execution of the software, it should be caught and there by prevent the system from crashing.

- Scalability-The system should be developed in such a way that new modules and functionalities can be added, thereby facilitating system evolution.
- Accuracy-System should correctly execute process, display the correct output of respective human gesture.

3.4 Performance Requirements

- The performance of the functions and every module must be well.
- The overall performance of the software will enable the users to work efficiently.
- Human gesture detection should be fast.

3.5 Software Quality Attributes

- The software is user friendly while using it.
- Image Quality in real time environment is clear (Noise free).
- Gestures should be accurately detected.
- Output should be up to mark.
- Communication between mute or hearing-impaired person and a normal person should be smooth.

3.6 System Requirements

Software Requirements (Platform choice)

- Windows 7 and above 3.5.3(Server Side)
- Language – Python
- Libraries NumPy,Pandas,OpenCV,Matplotlib,Scikit Learn,Keras,Tensorflow
- It is recommended to use Anaconda Python 3.6 distribution and using a Jupyter Notebook.

Hardware Requirements :

- Camera: 5MP and above.
- Hard Disk Space: 10 GB
- Processors: Intel Atom R processor or Intel R CoreTM i3 processor and above

3.7 Analysis Models: SDLC Model to be applied

Iterative Model

Implementation of SDLC that focuses on an initial, simplified implementation which then progressively gains more complexity and a broader feature set until the final system is complete.

The iterative model is used for building of our system because the modules are to be deployed independently which requires testing, validation, verification.

Steps consist of: -

- Planning and requirement analysis
- Defining Requirements
- Designing the Software
- Developing the project
- Testing
- Deployment
- Maintenance

The process of building the Video summarization system consist of two steps:

- Building the Video summarization system independently testing the system.
- The system is tested to form the final system which is ready to be deployed.
- Both of the modules are integrated and tested to form the final systemwhich is ready to be deployed.

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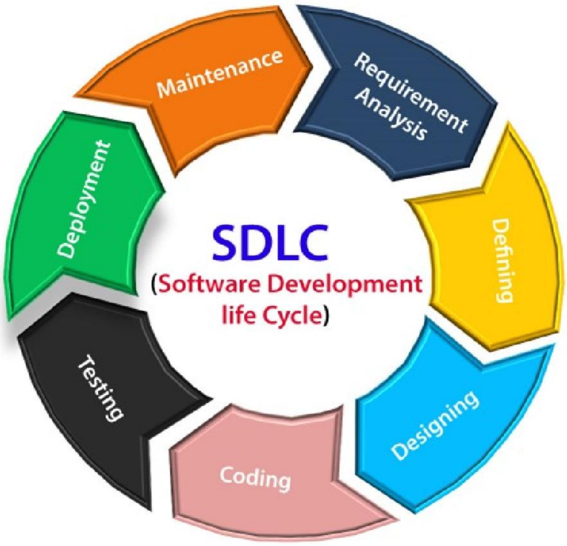

Figure 3.1: Iterative Model

IV. SYSTEM DESIGN

The third chapter described the study of Software requirement specification. It included functional requirements, non-functional requirements, hardware and software requirements, external requirements, system requirements. This SRS needed to be represented into pictorial form for better understanding. This chapter is about system design. The system design consists of architecture and the system implementation flow. It includes diagrams like system architecture, data flow diagram, use case diagram, activity diagram, class diagram. These diagrams help in understanding the functioning of the system.

4.1 System Architecture

System architecture is the conceptual model that defines the structure, behavior, and more views of a system. System architecture of our project is System design defines the system architecture. It also describes the modules and inter-faces.

As shown in fig 4.1 explains the architecture of our system. The system architecture provides an insight of how the flow of process will be. Entire process of

Figure 4.1: System Architecture

how the system will move forward that will generate the end-result is depicted. There are main in system Architecture: In first part Acquiring Images or Video to detect the Sign. We have a dataset of different Hand Signs. We will carry out classification with the help of SVM (Support Vector Machine) algorithm. And then after applying CNN (Convolution neural network) model we can detect the Hand Signs.

4.2 Data Flow Diagrams

A data-flow diagram (DFD) is a way of representing a flow of a data of a process or a system (usually an information system). The DFD also provides information about the outputs and inputs of each entity and the process itself.

1. DFD (Level 0)

In figure 4.2 shows the abstract level of data in this project. It is also known as context diagram.
it's designed to be an abstraction view, showing the system as a single
process with its relationship to external entities. it represent the entire system as single bubble with input and output data. In figure 4.2 Test image is fed as input to the system and Sign Detection are generated as output.

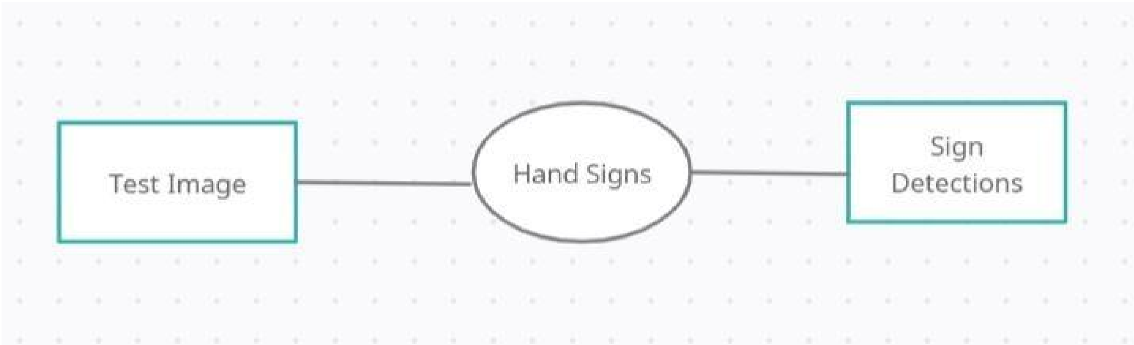

Figure 4.2: Level 0 Data Flow Diagram

It is also known as context diagram. It's designed to be an abstraction view, showing the system as a single process with its relationship to external entities.
It represent the entire system as single bubble with input and output data indicated by arrows.

2. DFD (Level 1)

In figure 4.3 DFD, context diagram is decomposed into multiple processes like dataset training, feature extraction and Hand Sign prediction. This level one data flow diagram (DFD) template can map out information flow, visualize an entire system, and be shared with your stakeholders. A data-flow diagram (DFD) is a way of representing a flow of a data of a process or a system (usually an information system).
The DFD also provides information about the outputs and inputs of each entity and the process itself.

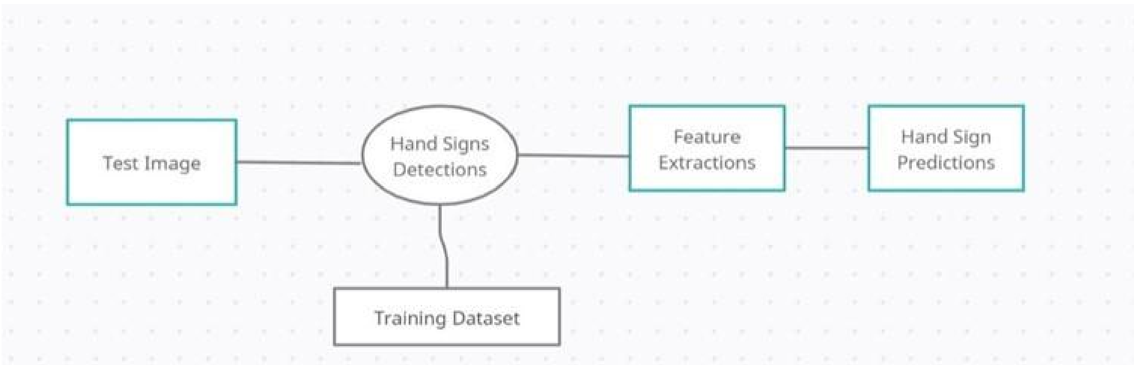

Figure 4.3: Level 1 Data Flow Diagram

3. DFD (Level-2)

In figure 4.4 DFD goes one step deeper into parts of 1-level DFD. It is used to plan or record the specific/necessary detail about the system's functioning. In figure 4.4 the detailed process extended from DFD (Level1) are shown.

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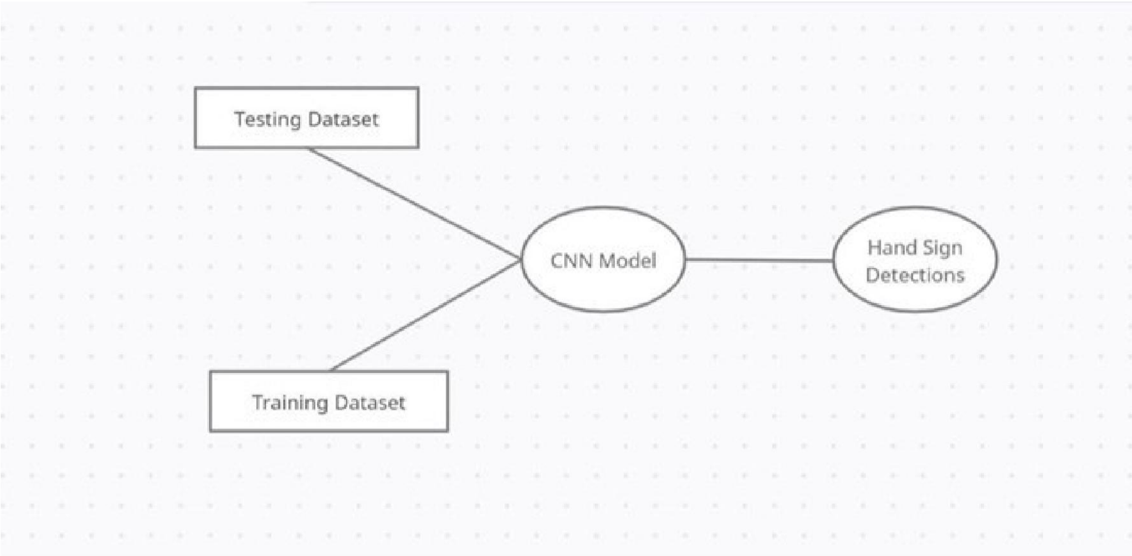

Figure 4.4: Level 2 Data Flow Diagram

4. DFD (Level-3)

In figure 4.5 DFD, context diagram is decomposed into multiple bubbles/processes.

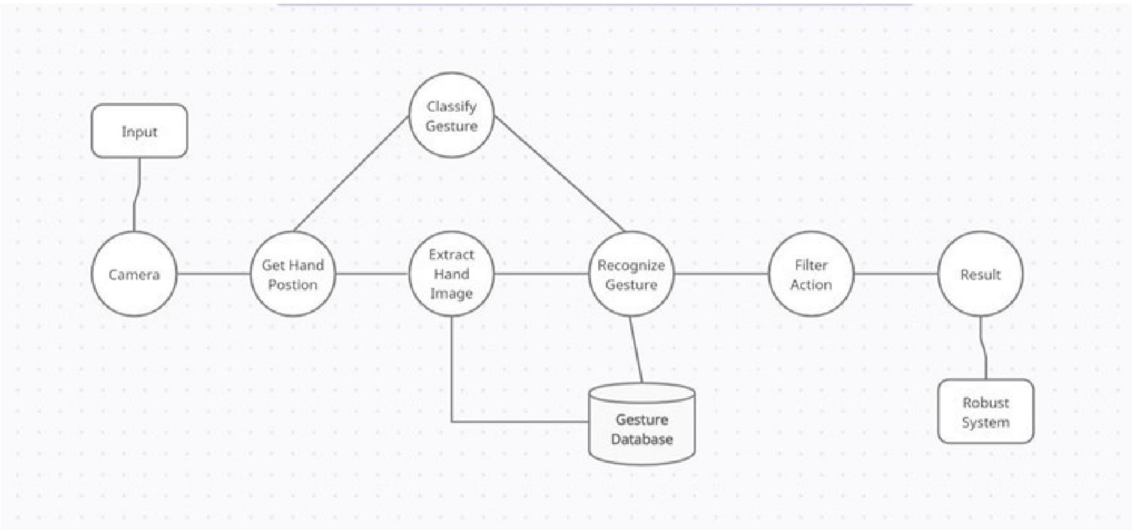

Figure 4.5: Level 3 Data Flow Diagram

4.3 UML Diagrams

4.3.1 Use Case Diagram

Figure 4.6 depicts the use case diagram which shows the interaction between the actors and the system

4.3.2 Activity Diagram

Activity diagram fig. 4.7 is basically a flowchart to represent the flow from one activity to another activity. The activity can be described as an operation of the system. The control flow is drawn from one operation to another. Firstly, the application will be started. The user can select the architectural plans according to their wish

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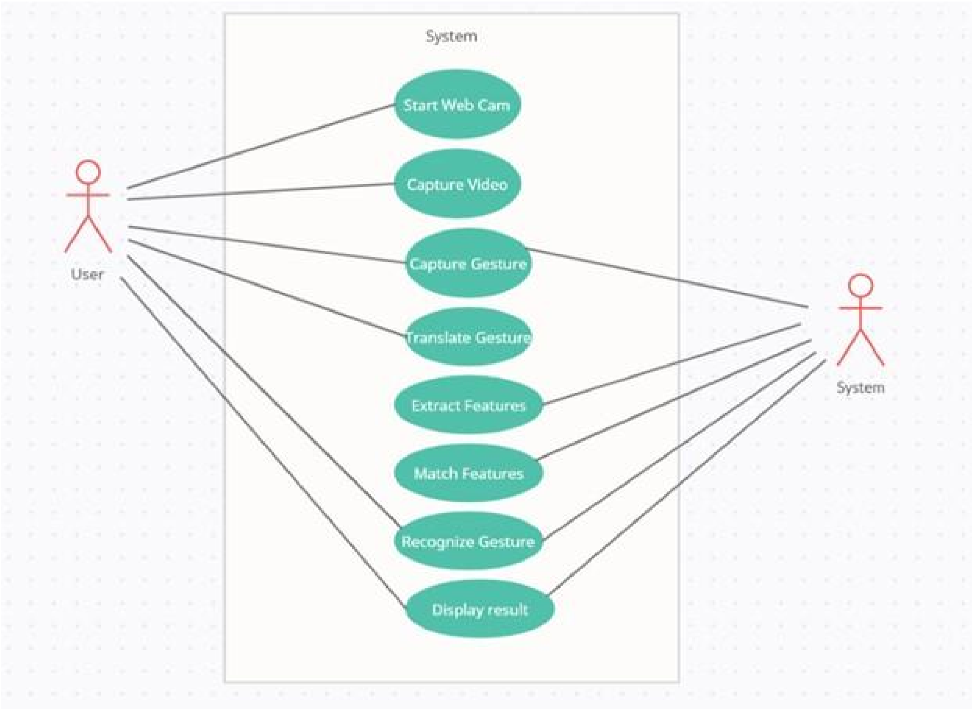

Figure 4.6: UML Use Case Diagram

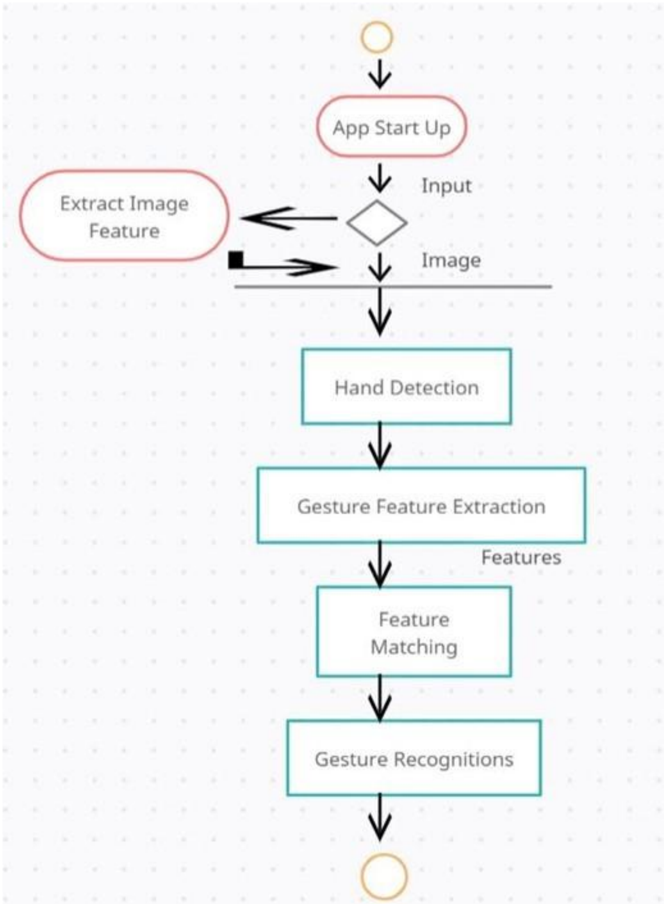

Figure 4.7: UML Activity Diagram

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4.3.3 Sequence Diagram

A sequence diagram shown in fig. 4.8 is a type of interaction diagram because it describes how and in what order a group of objects works together. These diagrams are used by software developers and business professionals to understand requirements for a new system or to document an existing processSequence diagrams are sometimes known as event diagrams or event scenarios.

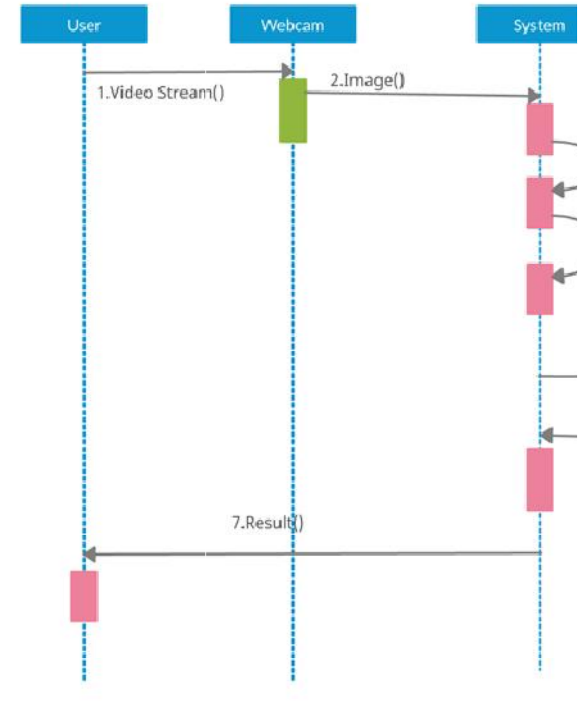

Figure 4.8: UML Sequence Diagram

4.3.4 Class Diagram

In figure 4.9 the class diagram is shown which represents the relationship between classes. Each class contains some attributes and functions. System is the interface in the class diagram to be used with machine learning

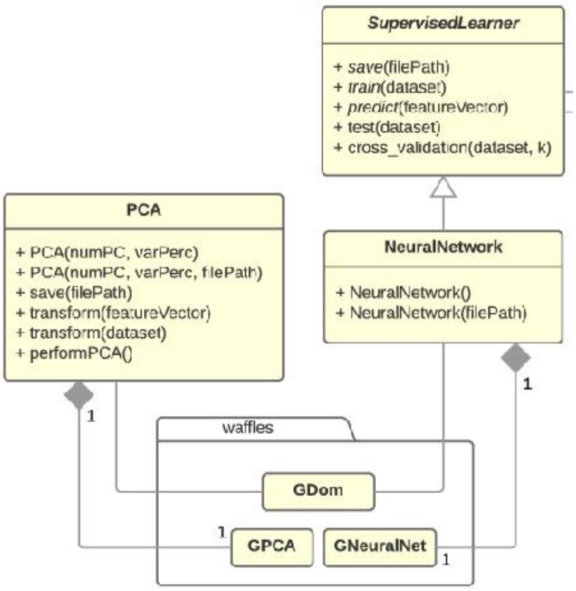

Figure 4.9: UML Class Diagram

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V. PROJECT IMPLEMENTATION

The fifth chapter described about the overall project plan along with its cost estimation, risk management, schedule, team structure, etc. It included identification and prioritizing the risks. The project plan explained all the phases involved in the development of the project. Here in this chapter, the project implementation details such as various project modules, different technologies and tools used to implement system functionalities are discussed. Also, the algorithms of various system modules are stated.

5.1 Overview of Project Modules

5.1.1 To acquire /create dataset

In this module only sign of human hand is stored in dataset. Only sign images are stored in dataset and other unwanted part from image is removed. Multiple images of hand sign are captured and preprocessed for detecting only the sign of dumb people.

5.1.2 To train the model using Train data set.

In this module, python script is written to train data.

5.1.3 Sign Recognition

Sign recognition is a method of identifying or verifying the identity of an signs using their hand action. In this module images of hand sign are taken and compared with previously stored image dataset.

5.1.4 Generation of result

In this module, python script is written to detect recognized hand sign.

5.2 Tools and Technologies Used

The following table 5.1 shows all the tools and technologies used to develop different modules of the 'Sign Recognition' along with their purpose.

MOTION TRAJECTORY BASED HUMAN HAND TRACKING FOR SIGN LANGUAGE RECOGNITION

Table 5.1: Tools and Technologies

Tool/Technology used	Purpose
Idle	Python IDE used to perform all the python implementations.
OpenCV	OpenCV (Open-Source Computer Vision Library) is an open-source computer vision and machine learning software library. It is used for computations related to images.
CNN	CNN help in running neural networks directly on images and are more efficient and accurate than many of the deep neural networks
TensorFlow and Keras	TensorFlow which will recognize the realtime input of the hand signs of the user and will display the corresponding letter of the sign language
Anaconda notebook Jupyter	used to perform all the python implementations in cells.

5.3 Algorithm Details

5.3.1 Algorithm for building Convolutional Neural Networks

Convolution Operation

The first building block in our plan of attack is convolution operation. In this step, we will touch on feature detectors, which basically serve as the neural network's filters.

ReLU Layer

The second part of this step will involve the Rectified Linear Unit or ReLU.

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Pooling

In this part, we'll cover pooling and will get to understand exactly how it generally works. Our nexus here, however, will be a specific type of pooling; max pooling. We'll cover various approaches,though, including mean (or sum) pooling

Flattening

This will be a brief breakdown of the flattening process and how we move from pooled to flattened layers when working with Convolutional Neural Networks.

Full Connection

In this part, everything that we covered throughout the section will be merged together. By learning this, you'll get to envision a fuller picture of how Convolutional Neural Networks operate and how the "neurons" that are finally produced learn the classification of images.

5.3.2 Algorithm for Getting Sign Language detected

1. Start
2. Train CNN model
3. Run Camera.py file
4. Camera will automatically popup if if fails to open then Goto step 1
5. Show hand gestures in the box
6. End

VI. RESULTS

The seventh chapter explored the topic software testing. Test cases used for testing the modules of the project along with their expected and actual outputs are also mentioned. This chapter describes the final output of the proposed systems. It also is the proof that all the functional models are efficiently implemented.

6.1 Outcomes

According to the plan, the proposed system is successfully built. The proposed system gave following outcomes as a result:

- Anyone Can Use this System For recognized Dumb People Hand Gesture.
- Using This System, It Is easy to interact with Dumb people.
- If user our system it easy to interact with following 5 Cs (Communication, Cultures, Connections, Comparisons, and Communities)

6.2 Snapshot

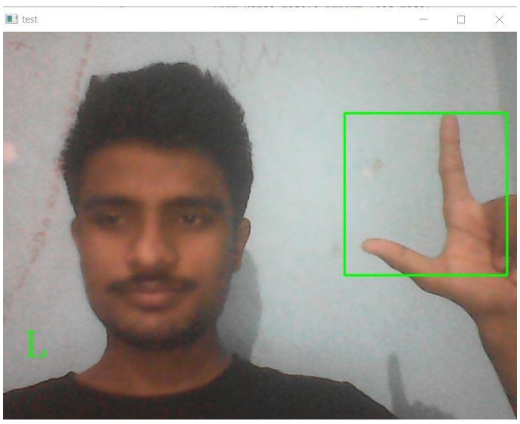

Figure 6.1: Detection of L

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Testing Of Sign Detection

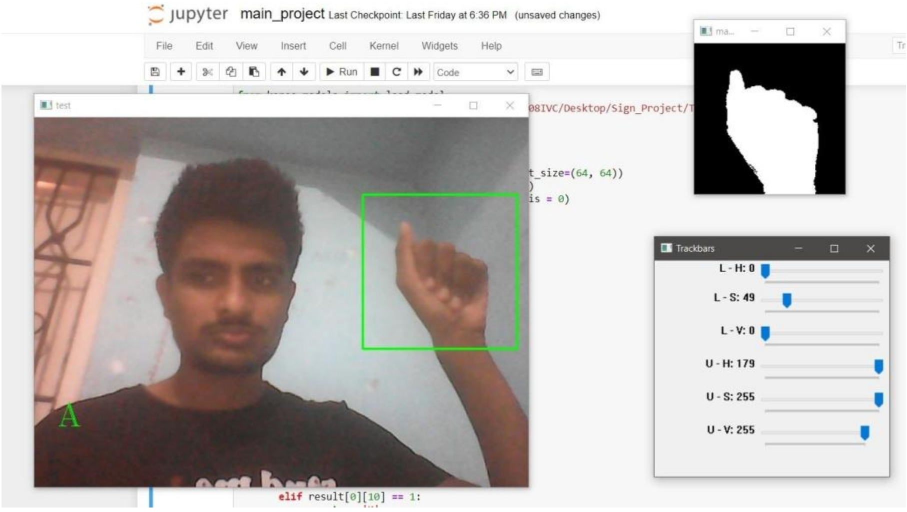

Figure 6.2: All Modules

Images of the Sign are captured and are compare with trained images.

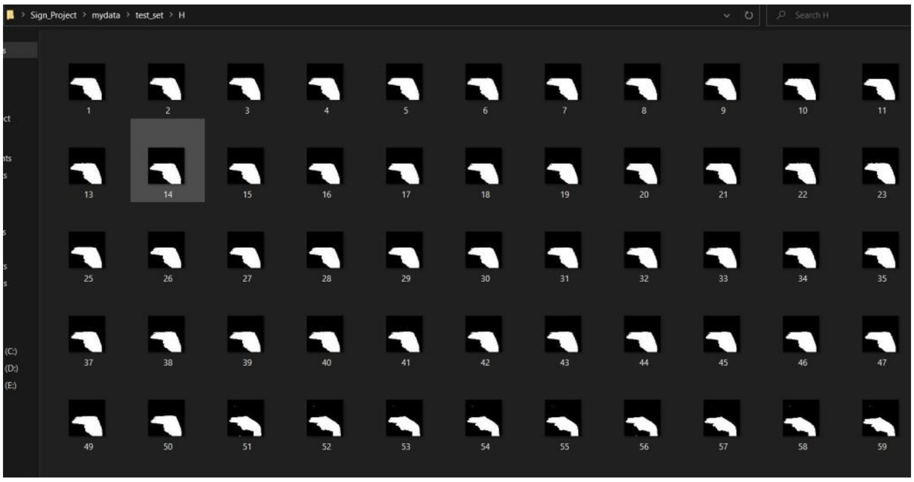

Figure 6.3: Trained Dataset We Train More than 50000 signs for comparison.

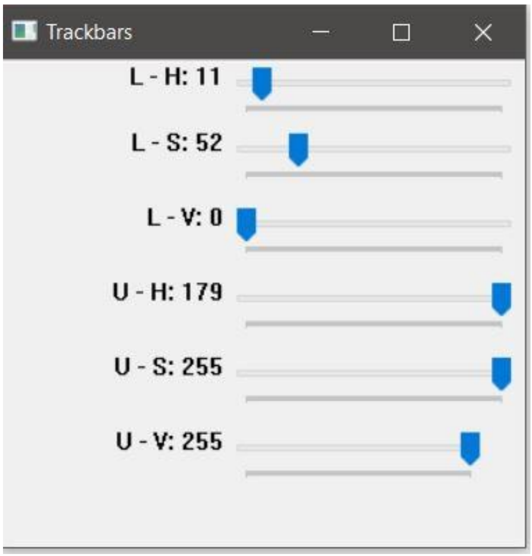

Figure 6.4: Trackbar

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Trackbar is used for adjust a track values for your background and hand color

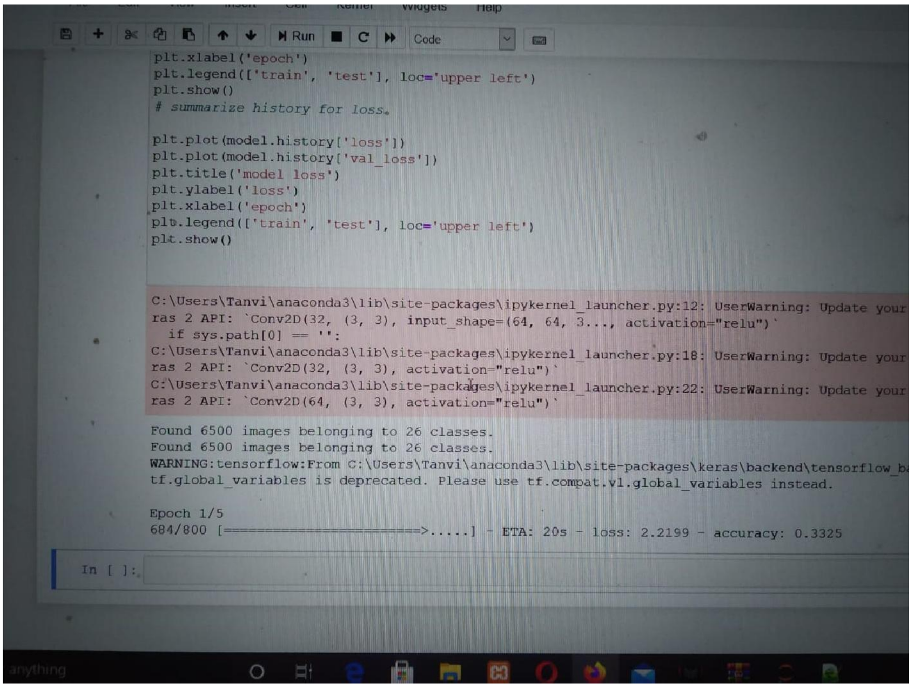

Figure 6.5: Training Dataset

A dataset in computer vision is a curated set of digital photographs that developers use to test, train and evaluate the performance of their algorithms.

The algorithm is said to learn from the examples contained in the dataset.

VII. CONCLUSION

7.1 Conclusion

The Robust Sign Recognition System Recognized the Sign of each user by continuous clicking of hand sign images for some time period and finds the best trained sign image for processing. The system allows the user to check hand signs automatically without any extra cost and effort whereas the proposed system needs very elementary things such as; camera,laptop or personal computer.

This method is secure, reliable and easy to use.

7.2 Future Work

We wish to extend our work further in recognizing continuous sign language gestures with better accuracy. This method for individual gestures can also be extended for sentence level sign language. And also add more signs of other language like Marathi, Hindi, and Tamil.

7.3 Applications

Effective in Medical and Emergency purposes

Use of this system in medical emergency it is very effective dumb people are interacting with medical people.

Police Station

It is important for dumb people interact with police so by using this it is easy Communicate with police.

Helping deaf-mute people

Helping deaf-mute people interact with real world

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