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Aviation Sign Language Detection System Using Machine Learning Techniques

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***Abstract*—Aviation Signs refers to those signs or hand signals which are primarily used in airfields and air marshals for a clear and a non-verbal communication between the ground staffs or the crew members and the pilots. Its main purpose is to provide a safe and efficient aircraft handling on the ground. There may be many critical solutions where verbal communication may not be happened due to high noise and irrelevant language barriers problems, in those places Aviation Sign language plays a huge part. Aviation Sign language is not a lexical sign language like American Sign Language (ASL), Indian Sign Language (ISL) or any other sign language , it is a universal set of gestures planned for only Aviation Industry. Mainly the crew members give the sign to the pilot for better understanding and take decisions based on the sign language used by the ground Staffs, any miscommunication can lead into accidents. Effective communication between the pilots and the ground staffs during aircraft ground operations, where safety and precisions are supreme, in such high noise environments the verbal communication becomes impossible for both the crew members and the pilots to understand. In such situations manual Hand Signals are used but using these gestures totally depends on human perception, there may be a human error, inconsistency in training and environmental constraints such as poor visibility due to lightning. Further, there is no such real time verification or technological support of a system to detect whether the signs used by the crew members or the ground staffs are correct or not. Therefore, there is a need of such system which can easily detect the aviation sign language system which can solve the problem as early and easily as possible.**

***Index Terms*—Transformer Architecture, OpenNMY-py, Machine Translation, BLEU score, Assamese**

I. INTRODUCTION

A. Background of Machine Translation

Machine Translation (MT) refers to the automated process of converting text or speech from one language into another using computational methods. It is a subfield of natural language processing (NLP) and has become increasingly important in our globally interconnected world.

The development of machine translation systems has evolved through several major phases. Initially, early systems were rule-based, relying on hand-crafted linguistic rules and dictionaries. These systems performed adequately for limited, domain-specific tasks but struggled with complex grammatical structures and idiomatic language. As computational resources grew and larger bilingual datasets became available, statistical machine translation (SMT) emerged as a dominant approach in the early 2000s. SMT systems used probabilistic models trained on aligned parallel corpora to generate translations based on word and phrase probabilities. While SMT provided more flexibility than rule-based methods, it often resulted in translations that were literal, disjointed, or contextually inaccurate4particularly when dealing with morphologically rich or syntactically different languages.

The most recent shift in the field has been towards Neural Machine Translation (NMT), which employs deep learning techniques to model translation as a sequence-to-sequence learning problem. Instead of translating phrases independently, NMT processes entire sentences, allowing for better preservation of context and semantic meaning. This approach has led to significant improvements in translation fluency and quality across many language pairs. In particular, the introduction of the Transformer model[3], which relies entirely on self-attention mechanisms rather than recurrent or convolutional structures, has pushed NMT performance to new heights. This model enables parallel computation, greater scalability, and improved handling of long-range dependencies in text.

Despite these advances, a key challenge remains: the lack of high-quality training data and computational resources for low-resource languages. Languages like Assamese, spoken by millions yet underrepresented in digital corpora, have not benefited as much from these technological advancements. This creates a pressing need to develop efficient NMT systems that can perform well even with limited data. The present project addresses this need by exploring Transformer-Based translation from English to Assamese, contributing to the growing body of research focused on making machine translation more inclusive and equitable across languages.

B. Design of hand signal detection and recognition system

Primarily the main objective of this project is to design and develop such a system that can easily and accurately detect and recognize the hand signals that are used during the aircraft ground operations. The System generally aims to enhance the safety and efficiency of the ground crew members and the pilot communication by using technologies such as computer vision, hand gestures recognition and machine learning purpose.

The main goal of this project is to develop a sensor based smart system that can automatically refuel the required amount of fuel to the aircrafts just by the hand signals which will be analyzed by the fuel tank as per the hand gestures. In the above image a person connecting the fuel pipe to the aircraft and after its completion the aircraft pilot just check the meter status on its screen and show the hand gesture directly to the fuel tank there wouldn't be any 3rd party involvement and the fuel would be filled easily.

II.AVIATION SIGN COMMANDS

Aviation Sign Commands are basically those commands that are based on "ICAO" and "NATO" Standards. These hand gestures are used by ground crew members to direct the pilots during ground operations such as parking, fuel filling or any other emergencies.

Common Aviation Sign Commands are: -

1. Move Forward: - It signals the pilot repeatedly to move upward and backward.
2. Turn Right/Left: - It signals one arm extended out to the side the other arm moved in a circular motion.
3. Slow Down: - It signals arms horizontally out and moved slowly downwards and upwards.
4. Stop: - It signals arms crossed above the head.
5. Start Engine: - It signals the arm extended with index finger making a basic circular motion.
6. Emergency Stop: - It signals rapidly crossed arms above the head multiple times.

A. Safety Commands

Safety commands generally include the critical hand signals and lexical commands which are used in safety operations to ensure safety and clean functioning of onboard aircraft carriers. It generally includes standardized hand gestures and signals which are used by the deck operations and emergency procedures on aircrafts, especially where the rate of noise is extremely high.

Few Common Safety Commands are: -

1. Aircraft take off: - It signals should be thumbs up or arms are raised and moved upward.
2. Aircraft Landing Clear: - It signals in a circular motion with one arm.
3. Move the aircraft forward/back: - It signals should be arm extended and sign should be forward/backward.
4. Stop Aircraft: -It signals both the arms should be crossed above the head or palms facing forward in a stopping motion.
5. Emergency Stop: - It signals rapid and repeated crossing of arms above the head [7].

B. Fuel Quantity Commands

In aviation operations, the fuel tank commands are used for refueling or defueling procedures. These commands are essential to ensure safety, co-ordination and communication between ground deck crew and pilots. Here's the fuel tank commands are related to quantity that is measured in liters often represented using hand signs or structured commands in aviation. While traditional system generally uses visual gauges or electronic communication for each volume, in manual system the fuel quantity can be indicated in several steps like 1000,2000,5000(in liters) etc.[8][9].

C. Fuel Quantity Signals

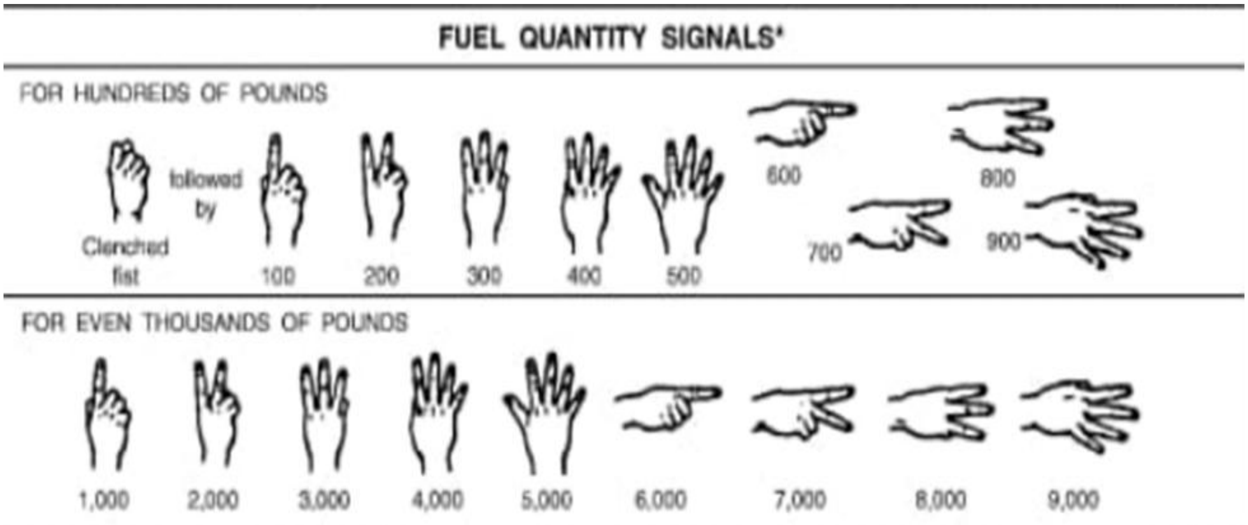


Fig: - Aviation Sign language for fuel quantity signals

Fuel Quantity Commands in liters (Represented L in liters by visual hand signals): -

For Hundreds of pounds

1. 100L: - We need to show both of our hands left one clenched fist and right one showing 1st finger.
2. 200L: - We need to show both of our hands left one clenched fist and right one showing 2 fingers.
3. 300L: - We need to show both of our hands left one clenched fist and right one showing 3 fingers.
4. 400L: - We need to show both of our hands left one clenched fist and right one showing 4 fingers.
5. 500L: - We need to show both of our hands left one clenched fist and right one showing 5 fingers.
6. 600L: - We need to show both of our hands left one clenched fist and right one showing 1st finger horizontally.
7. 700L: - We need to show both of our hands left one clenched fist and right one showing 2 fingers horizontally.
8. 800L: - We need to show both of our hands left one clenched fist and right one showing 3 fingers horizontally.
9. 900L: - We need to show both of our hands left one clenched fist and right one showing 4 fingers horizontally.

For Even Thousands of pounds

1. 1000L: - We need to show our 1st finger of right hand and point to fuel tank.
2. 2000L: -We need to show our 2fingers of right hand.
3. 3000L: - We need to show our 3 fingers of right hand.
4. 4000L: - We need to show our 4 fingers of right hand.
5. 5000L: - We need to show our 5 fingers of right hand.
6. 6000L: -We need to show our 1st finger of right hand horizontally.
7. 7000L: - We need to show our 2 fingers of right hand horizontally.
8. 8000L: - We need to show our 3 fingers of right hand horizontally.
9. 9000L: - We need to show our 4 fingers of right hand horizontally.

III. LITERATURE REVIEW

A Survey has been done by us on several journal papers to come up an idea of what study we need to go through to get up with an idea of Aviation Sign Language using deep learning. A detailed overview is presented :

A. Overview

H. Orovwode, I. Oduntan, and J. Abubakar (Aug. 3, 2023): -The goal of their project "Development of a Sign Language Recognition System Using Machine Learning" is to build a system that will let people who use sign language communicate with each other. It probably uses machine learning to translate sign language motions into text or speech using methods like computer vision, gesture recognition, or natural language processing. To guarantee the correctness and usability of the system, the research would involve data collection, model training, and performance evaluation. Its goal is for making the deaf and short-of-hearing communities more accessible [1].

It is said by the following authors as D. Kothadiya, C. Bhatt, K. Sapariya, K. Patel, A.-B. Gil-González, and J. M. Corchado, (Jun. 2022): -The paper "Deep sign: Sign Language Detection and Recognition Using Deep Learning" describes a system that recognizes and detects Indian Sign Language (ISL) gestures using deep learning models. The researchers used LSTM and GRU layers in various configurations to process video inputs and extract attributes using the IISL2020 dataset. The video clips in this dataset contain eleven commonly used ISL indicators in natural environments. The best-performing model has a 97% accuracy rate. The technology aims to improve communication for those who have hearing or speech impairments [2].

Aviation call signs are unique identifiers used in air traffic communication to distinguish between different aircraft and operators. These call signs can be either official designations assigned to airlines and military units or temporary identifiers used for specific flights. Commercial airlines typically use telephony callsign, which combine the airline's designated name with the flight number for instance, "Speed bird 75" for British Airways. In contrast, general aviation and military aircraft may use a combination of registration numbers or mission-specific terms. The purpose of call signs is to ensure clear, unambiguous communication between pilots and air traffic control, especially in congested airspace. Standardization is overseen internationally by bodies such as the International Civil Aviation Organization (ICAO) to prevent confusion and maintain safety during flight operations [4].

The ASL Single Tank 0-5V Fuel Level Sensor is a precision device designed to measure the fuel level in a single tank system and provide output in the form of a 0 to 5-volt analog signal. This sensor is widely used in aviation applications to offer real-time, accurate fuel readings that can be interfaced with various onboard monitoring systems or gauges. Its voltage-based output is compatible with many standard aircraft avionics, ensuring flexible integration and ease of use. The sensor enhances flight safety by enabling continuous fuel level monitoring, helping pilots and engineers detect fuel depletion or system irregularities early. Compact and reliable, this type of sensor is essential for modern aircraft fuel management, where precision and durability are critical [3].

IV. SYSTEM DESIGN AND METHODOLOGY

A. Techniques used for Aviation Sign Language

The following techniques that are used in designing an aviation sign language are represented below: -

a) Computer Vision

Computer vision is the most important technique used in this project as because the input as well as the output all the places computer vision is required. Despite from that computer vision uses are: -

1. Hand detection and tracking purpose: - It uses the media pipe hands where a computer vision pipeline is used to detect and track the hands in each frame in real time.

2. Landmark detection and gesture representation: - It extracts 126 key features of the hand, finger tips, joints, wrist using media pipe. It provides a values (x, y, z) co-ordinates that generally describes the hand poses and the analysis of motion and positions.

3. Real- time processing: - It is continuously processing the video frames using open-cv to detect hand and easily it can recognize it[5].

b) Recurrent Neural Network (RNN)

In deep learning process the RNN (Recurrent Neural Network) uses vary more several features of RNN are:

1. Sequential Data Processing: - RNN generally process the sequences of hand key-points over the time, by capturing a temporal movement of gestures.

2. Learning patterns: - RNN learns the motion and order of the hand movements severally across multiple frames to distinguished between similar signs with different sequences

3. Features Representation The inputs that are given by the webcam the model learns by the time of

series.

4. Sign Classification: - Later learning the temporal patterns, the RNN outputs are predicted sign label for the given gestures.

5. Improved Accuracy: - RNN especially effective for involvement of signs as it remembers previous frames while processing the new one[6].

c) Frameworks and Libraries Used

Frameworks: -

1. TensorFlow: - TensorFlow is an open source for deep learning framework that is developed by Google. It generally handles model building, training and deployment.

2. Keras: - Keras is a high-level API that is built on the top of TensorFlow. It generally simplifies creating and training neural network with minimum efficient code.

Libraries: -

1. Media pipe: - It is a computer vision library that is used to extract real time hand landmark.

2. Open cv: - It is a type of computer vision library that is used to handle video input, image pre-processing and drawing landmarks.

3. NumPy: - It is a numerical Computing Library that is efficient for handling of arrays, sequences and several mathematical operations.

4. Scikit-learn: - It is a machine Learning library that is used to label encoding, data splitting and evaluation metrices.

5. Pandas: - It is a type of Data Analysis Library that handles and organizing datasets in tabular format.

V. IMPLEMENTATION

A. Methodology

- Data Collection: - Images are to be captured with the specific hand signs using webcam.
- Hand Landmark detection: - Using media pipe detect the hand signs key features so that the model can learn patterns easily, for one hand values should be 63. But for 2 hands values should be 126 key points so that the model could easily recognize the hand points.
- Image Pre-processing: - A sequence of several images will be pre-processed easily
- Model Design: Using Deep Learning techniques train the model using several layers like LSTM, DENSE layer.
- Train the model: - Using Sequential model train the model and save the file.

B. Implementation

a. Datasets

To support this research, a novel dataset AVSIG-2025 was developed by me consisting of 540 labeled images 30 images for each aviation signs related to hand gestures, which includes, Fuel quantity Signals.

Fig: fuel signals dataset

b. Experimental Set-up

1. Taking Input: - The input is generally taken by my hand gestures images with the help computer vision using open-cv.

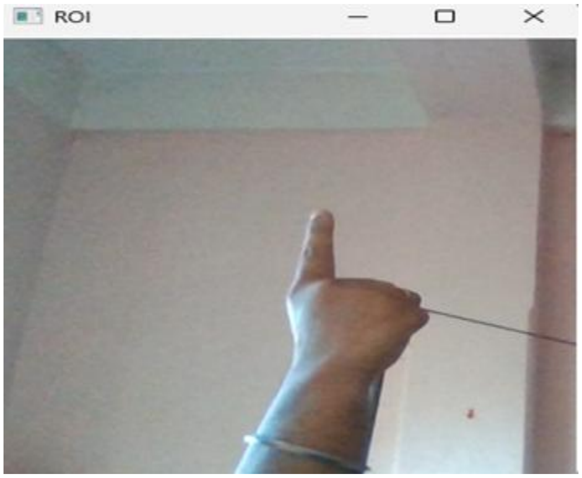


Fig: - Collect Data

2. Data Collection- Images of Hand- Gestures for 1000, 2000 etc. are collected using webcam and the hand landmarks are detected using media pipe.
3. Extract hand land marks: - Created a function to extract key points using media pipe values (x, y, z).

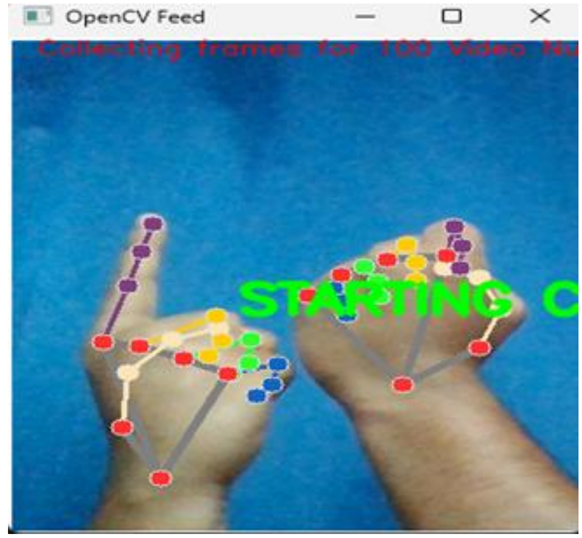


Fig: Extracting Key Hand Features

1. Data Preprocessing: - A sequence of 30 frames images is captured and each image are of numeric labels to each action. The model split the data into training and testing sets.

1. Save the hand key features: - Hand landmarks key points are extracted and put into an array and then save it as.np method and save the file name function.py, 126 key points are used here for both the hands.
2. Model Building: - Here, the LSTM- based deep learning model such as 3 LSTM Layers with Dense Layers are used and the model on the key-point sequence.
3. Train the model: - Here Sequential model have been used to train the model and save the file as train model.py.
4. Save the model: - Opened the model as model. Json and save the model's name as model.h5.
5. Real-Time Detection: -The hand gestures landmarks and key points are detected and accuracy is detected with output.

a. Data Flow Diagram

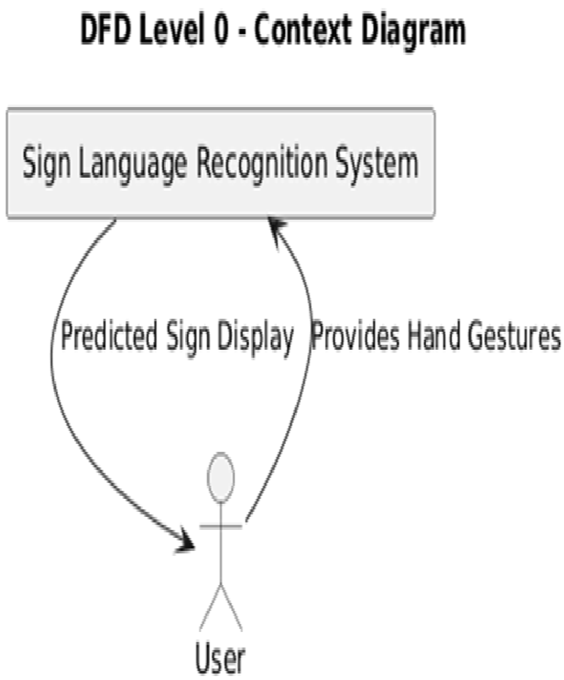


Fig: - Level 0 DFD

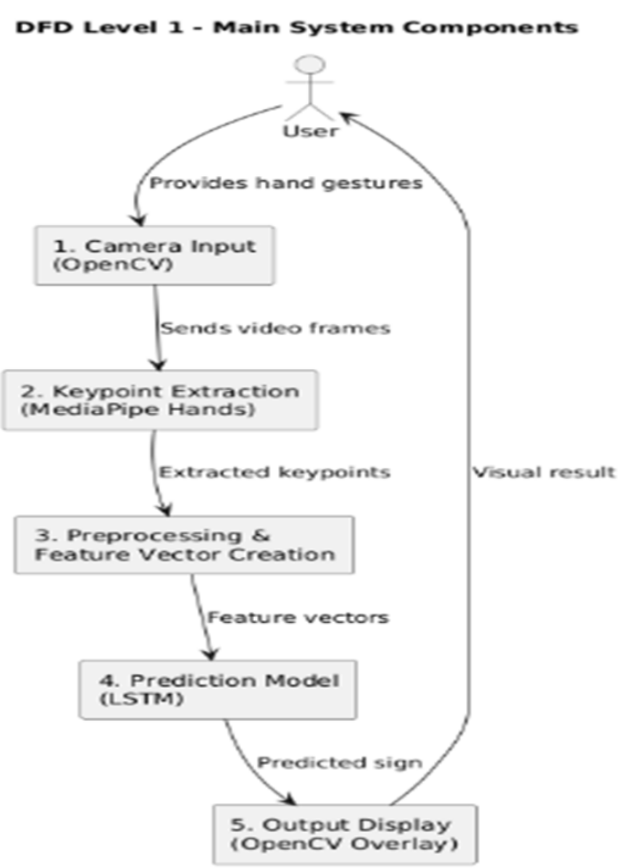


Fig: - Level 1 DFD

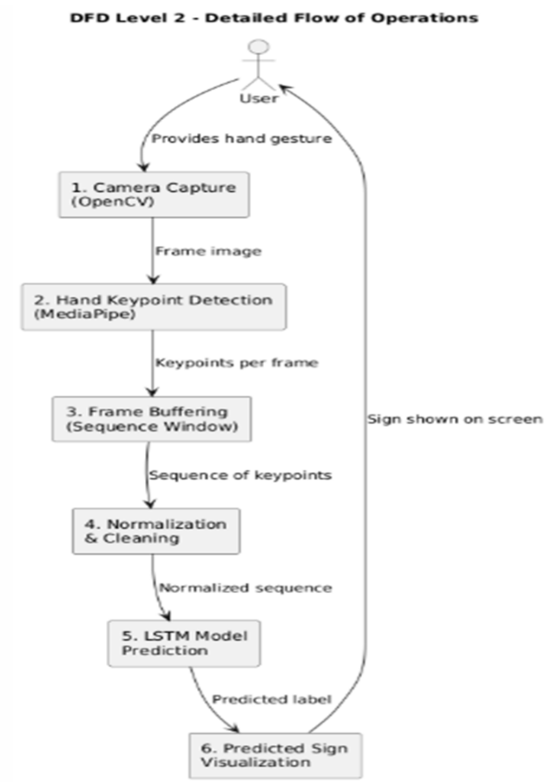
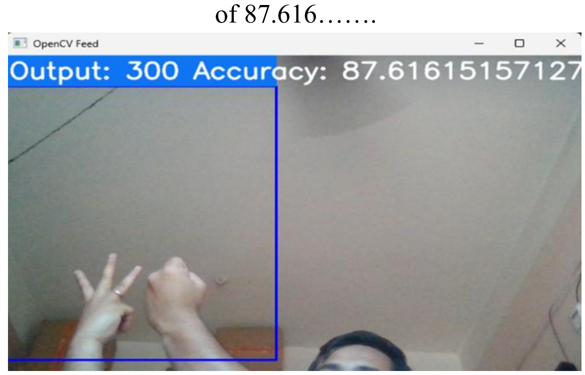


Fig: - Level 2 DFD Results and Snapshots

The results contain the output of 500 with an accuracy of 99.99…….

The results contain an output of 300 with an accuracy of 87.616…….



Confusion Matrix
The matrix is sparse and diagonal using high accuracy with no confusion between classes.
Here, the predicted value is matched with the actual value.

Training and Validation Accuracy

- Training Accuracy (Blue Line): - It is increasing steadily, shows that the model is learning.
- Validation Accuracy (Orange Line): - It is overly increasing following the training accuracy.

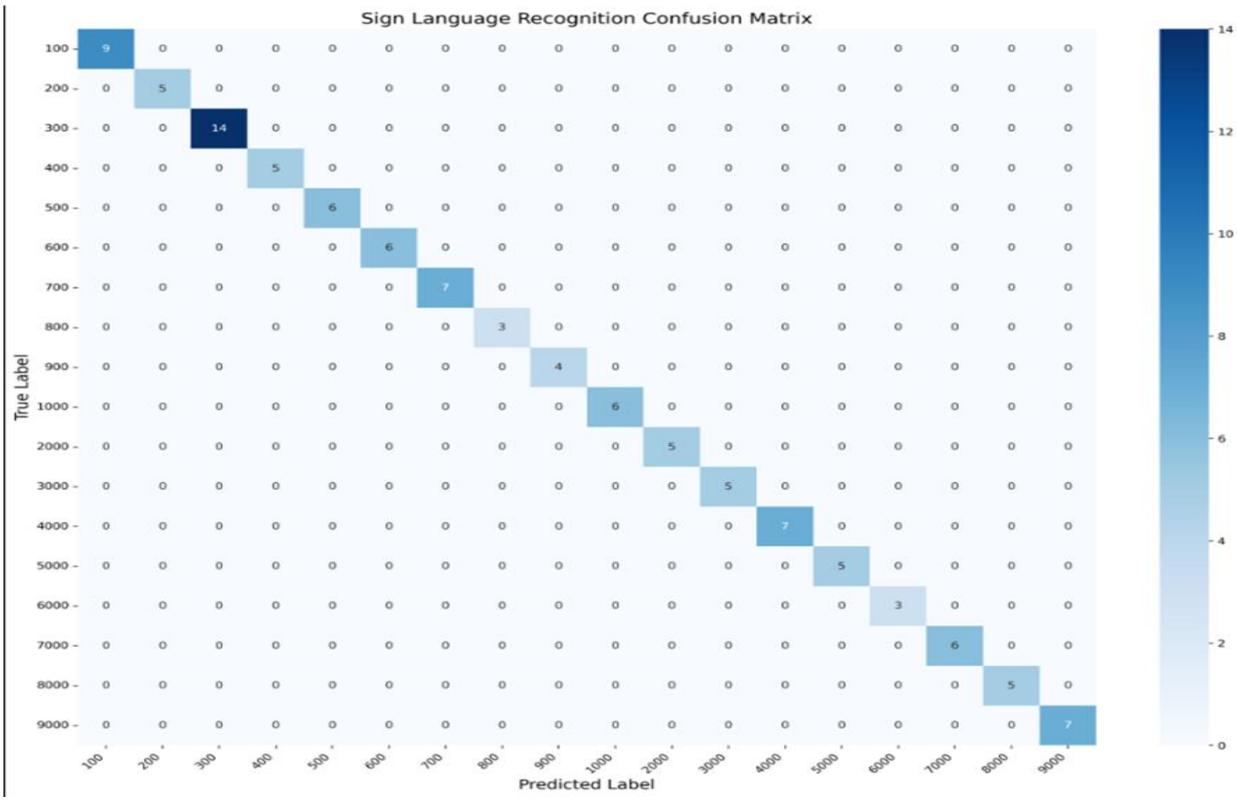


Fig: - Confusion Matrix

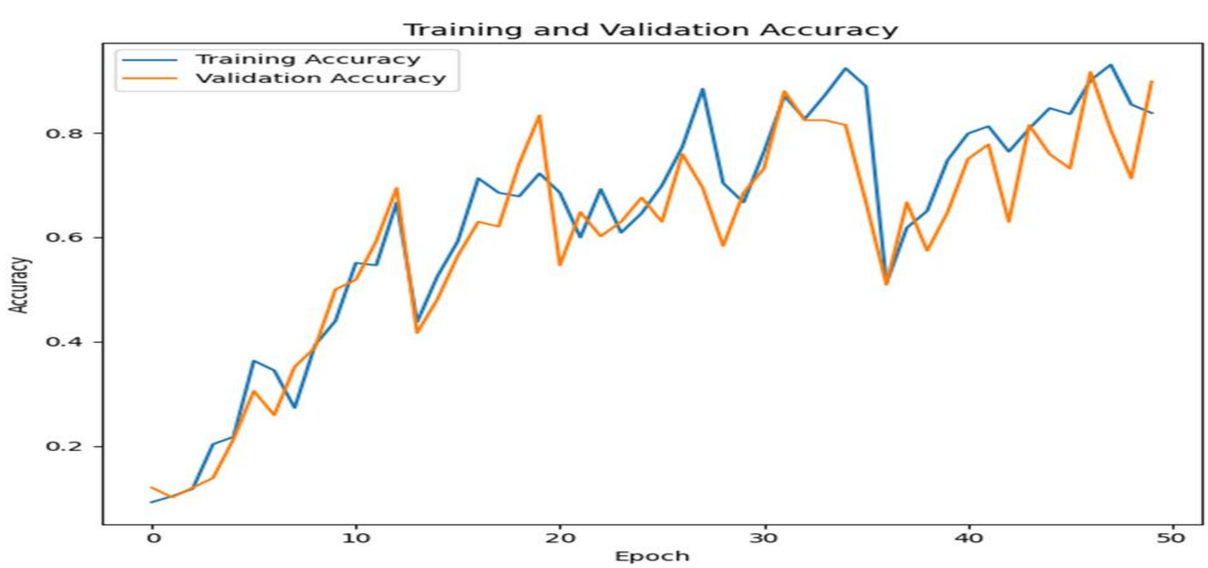


Fig: - Training and Validation Accuracy

Training loss, ETA Loss and Validation Loss

- Training Loss (blue line): - It decreases over time showing effectively learning.
- Validation Loss(orange): - It decreases over time showing effectively learning.
- Exponential Moving Accuracy (green and red dashed line): - It is fluctuating over the time.

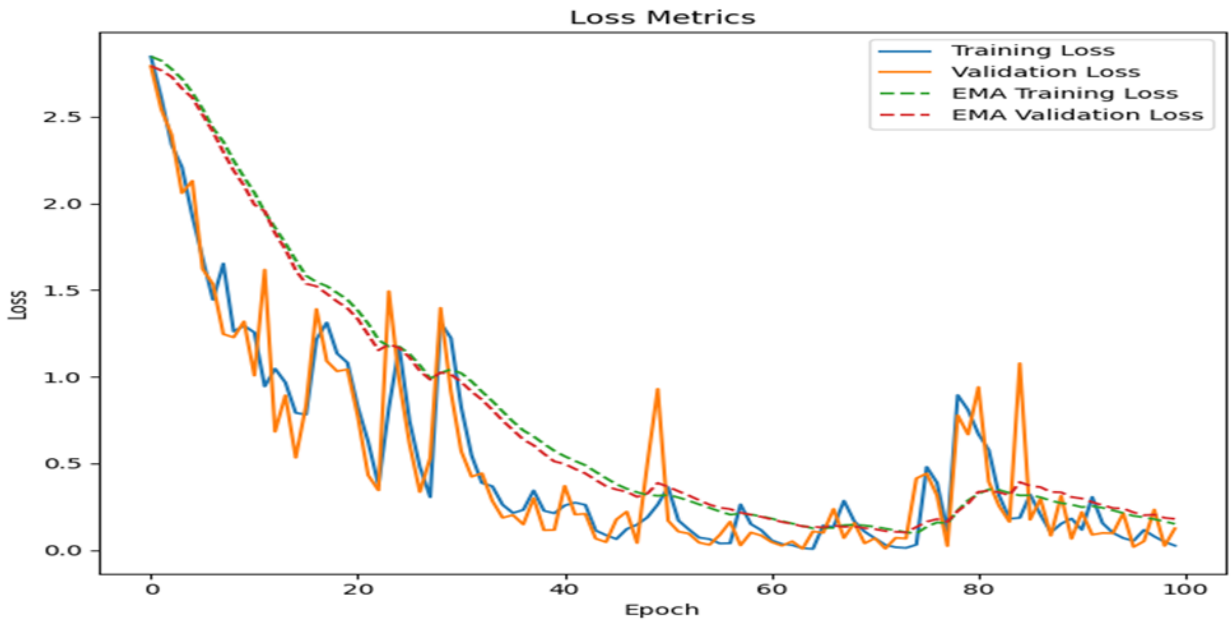


Fig: - Training, Validation Loss and ETA Loss

VI. CONCLUSION AND FUTURE WORK

The development of aviation sign language system has significantly enhanced communication between the crew members and the pilots generally in highly noisy areas where verbal communication is not possible. The aviation sign language system ensures a clear communication co-ordination in refueling purpose of fuel tanks. This System not only helps the ground crew member and the pilot but also helps in groundwork for better inclusivity and standardization through the global aviation practices.

The present implementation of the aviation sign language system has an involvement of only 1 sensor which is a proposed model for this work. In future the work may aim to expand its system through different sensors with User Interface present with different Safety Command Signs present in it and the system must be focused on detecting handgestures with more high accuracy and response.

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