DA-3
SIGN LANGUAGE RECOGNITION USING DEEP LEARNING AND IMAGE PROCESSING

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INTRODUCTION

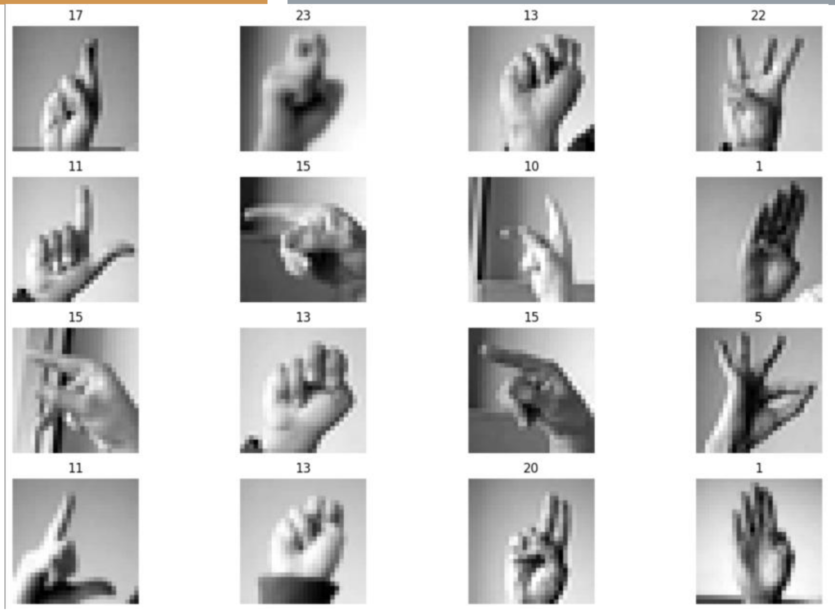
- MNIST dataset served as a benchmark for machine learning.
- Fashion-MNIST dataset introduced to address limitations of MNIST.
- Sign Language MNIST dataset aims to provide a more challenging task for computer vision.
- Inspired by Fashion-MNIST, Sign Language MNIST follows a similar CSV format.
- Represents a multi-class problem with 24 classes of letters in American Sign Language (ASL).

OBJECTIVES

- Train a deep learning model to recognize hand gestures representing letters in ASL.
- Evaluate the model's performance using metrics like precision, recall, and F1 score.
- Develop a real-world application for sign language recognition using computer vision techniques.

DATASET AND ATTRIBUTES

- **Sign Language MNIST:**
  - Format closely mimics classic MNIST dataset.
  - Consists of 27,455 training cases and 7,172 test cases.
  - Each case represents a label (0-25) corresponding to an alphabetic letter A-Z.
  - No cases for 9=J or 25=Z due to gesture motions.
  - Each image is 28x28 pixels with grayscale values between 0-255.
  - Data augmentation techniques used to expand the dataset, including cropping, resizing, rotation, and pixelation.




```
label,pixel1,pixel2,pixel3,pixel4,pixel5,pixel6,pixel7,pixel8,pixel9,pixel10,pixel11,pixel12,pixel13,pixel14,pixel15,pixel16,pixel17,pixel18,pixel19,pixel
6,149,149,150,150,150,151,151,150,151,152,152,152,152,152,153,153,151,152,152,153,152,152,151,151,150,150,150,149,150,150,150,152,152,151,152,152,152,152,
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```

PROPOSED METHODOLOGY

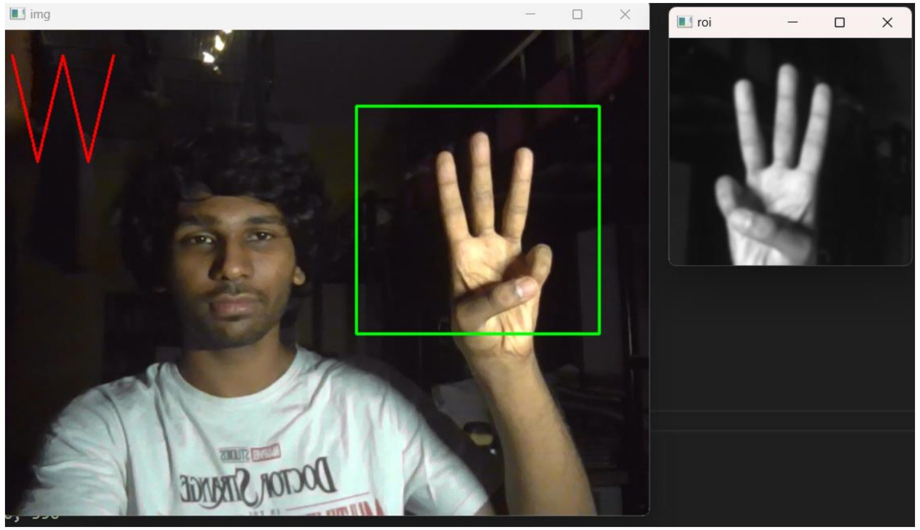
Proposed Methodology:

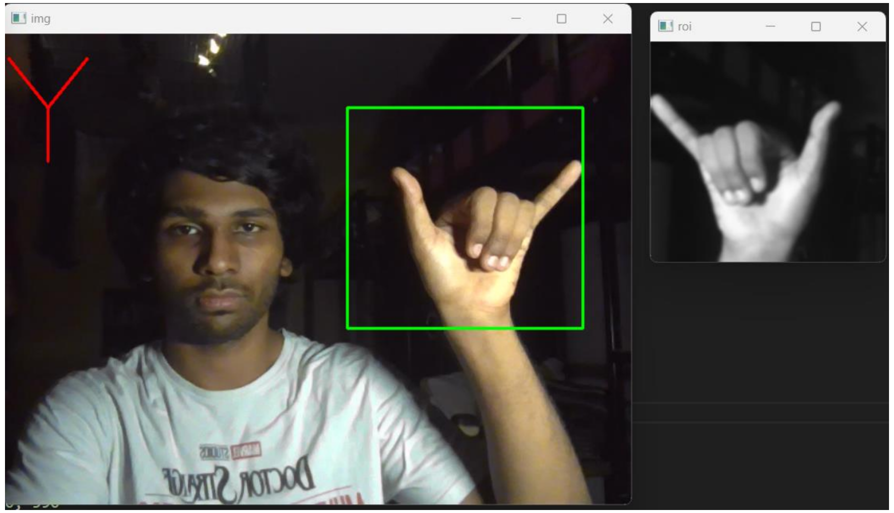
- **Custom CNN Architecture:**
  1. Designing a tailored CNN architecture for sign language gestures.
  2. Experimenting with layers to optimize feature extraction and model complexity.
- **Data Augmentation:**
  1. Applying preprocessing (cropping, resizing, grayscale) for standardization.
  2. Employing augmentation (rotation, zoom, shifts) to increase dataset diversity.
- **Optimization Algorithms:**
  1. Using RMSprop, Adam, etc., for efficient loss minimization.
  2. Employing early stopping, learning rate adjustments for dynamic training.
- **Model Evaluation:**
  1. Assessing performance with accuracy, precision, recall, F1 score.
  2. Validating on training/test datasets for generalization.
- **Interpretability:**
  1. Visualizing CNN activations, feature maps for insights.
  2. Analyzing misclassifications for model refinement.
- **Interactive User Interface:**
  1. Creating an interactive application for real-time gesture recognition.
  2. Enabling users to communicate through sign language gestures in an intuitive manner.
- **Evaluation and User Feedback:**
  1. Collecting user feedback to assess the effectiveness and usability of the application.
  2. Evaluating model performance and user experience for further refinement.

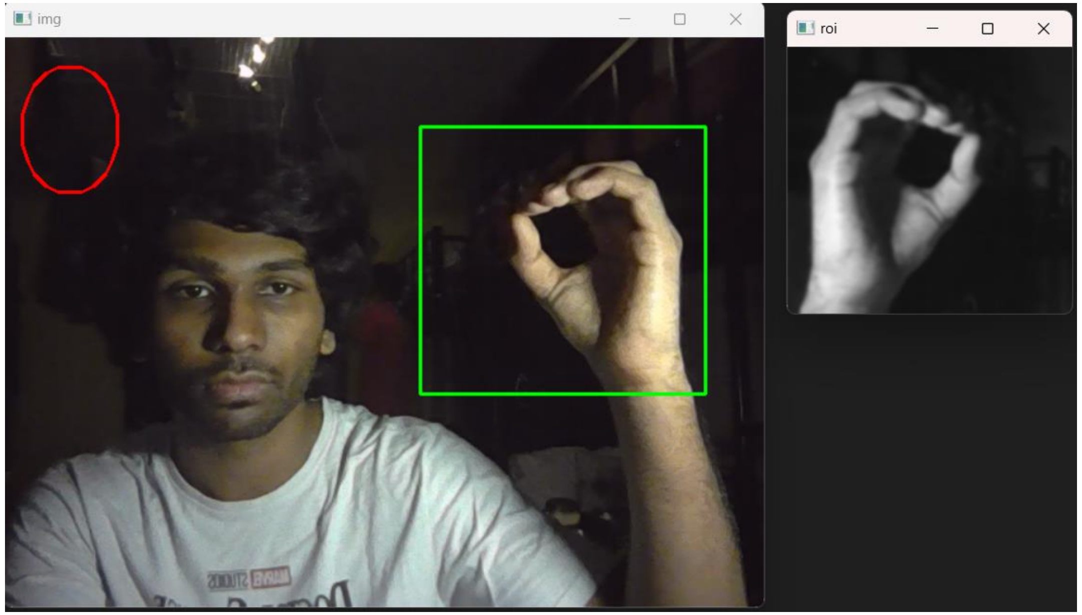
```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 64)        1664

 conv2d_1 (Conv2D)           (None, 28, 28, 64)        102464

 max_pooling2d (MaxPooling2  (None, 14, 14, 64)        0
 D)

 dropout (Dropout)           (None, 14, 14, 64)        0

 conv2d_2 (Conv2D)           (None, 14, 14, 32)        18464

 conv2d_3 (Conv2D)           (None, 14, 14, 32)        9248

 max_pooling2d_1 (MaxPoolin  (None, 7, 7, 32)          0
 g2D)

 dropout_1 (Dropout)         (None, 7, 7, 32)          0

 flatten (Flatten)           (None, 1568)              0

 dense (Dense)               (None, 256)               401664
...
Total params: 539929 (2.06 MB)
Trainable params: 539929 (2.06 MB)
Non-trainable params: 0 (0.00 Byte)
```

EXPERIMENTAL RESULTS

- **Camera Calibration:** Prior to gesture capture, camera calibration is performed to ensure accurate depth perception and spatial mapping of hand gestures.
- **Real-time Processing:** The system employs efficient algorithms for real-time processing of captured frames, minimizing latency and ensuring smooth interaction.
- **Cross-Platform Compatibility:** The software is designed to be compatible with multiple platforms, including Windows, macOS, and Linux, enhancing its accessibility and versatility.
- **User Interface Design:** A user-friendly interface is developed to provide intuitive controls and visual feedback, enhancing the user experience during gesture recognition.



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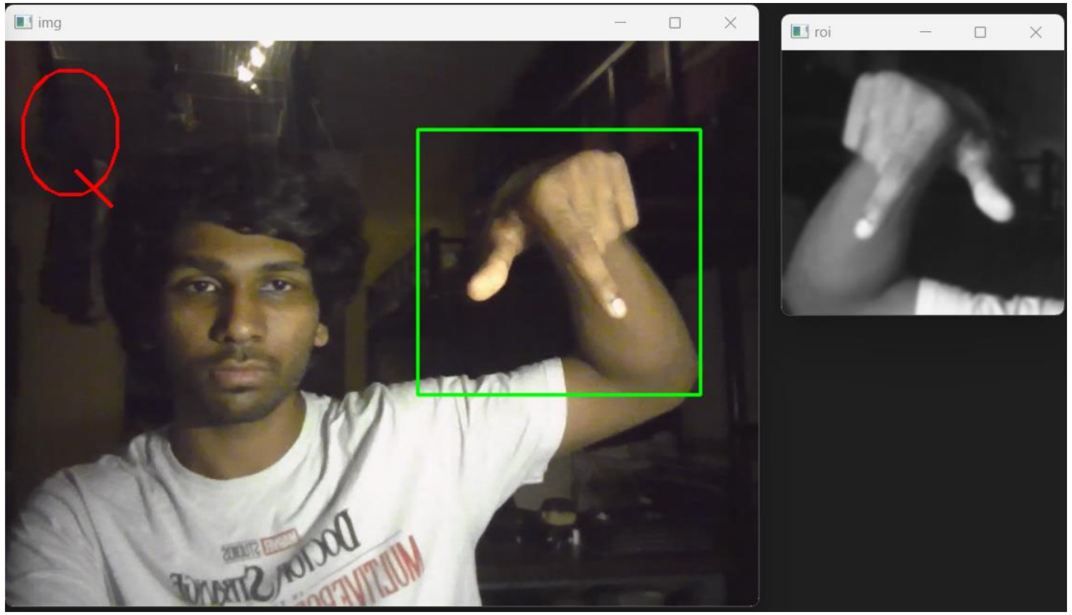
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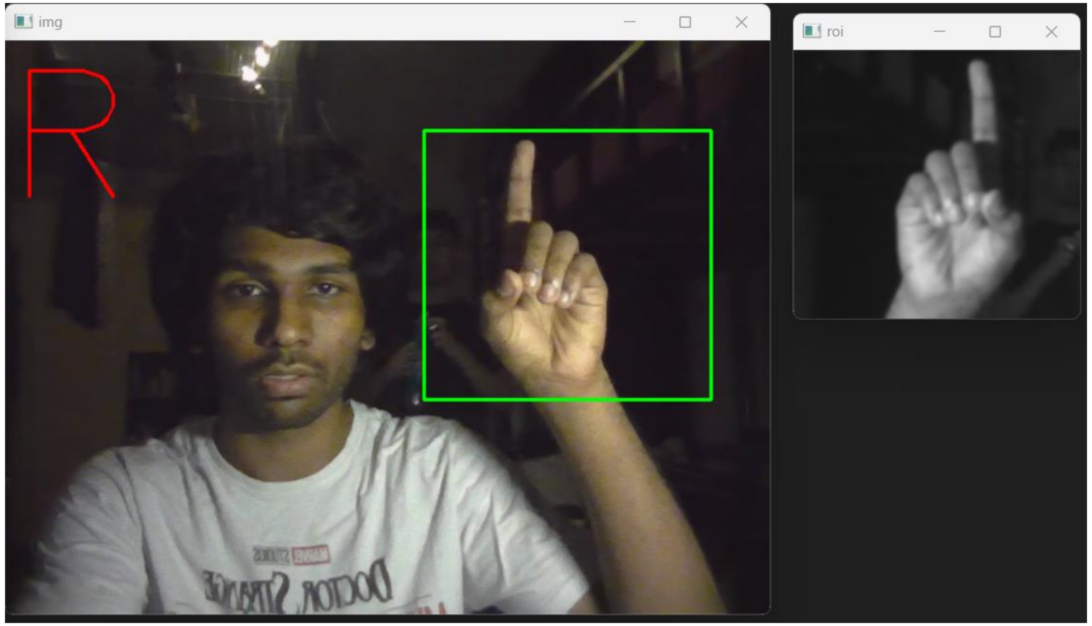
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roi
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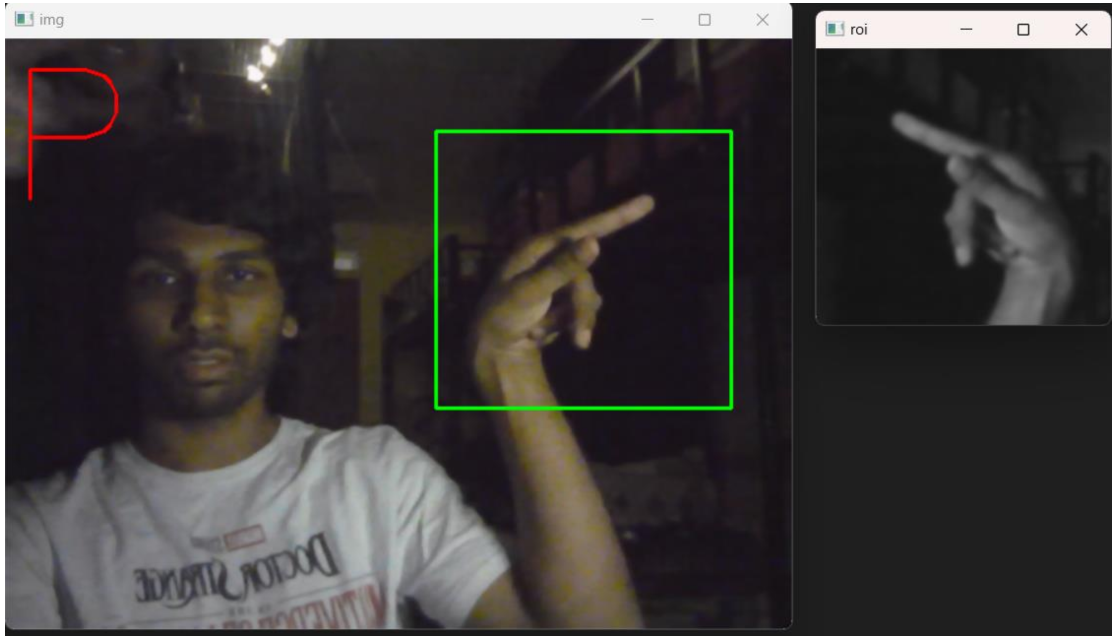
img
roi
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PERFORMANCE EVALUATION

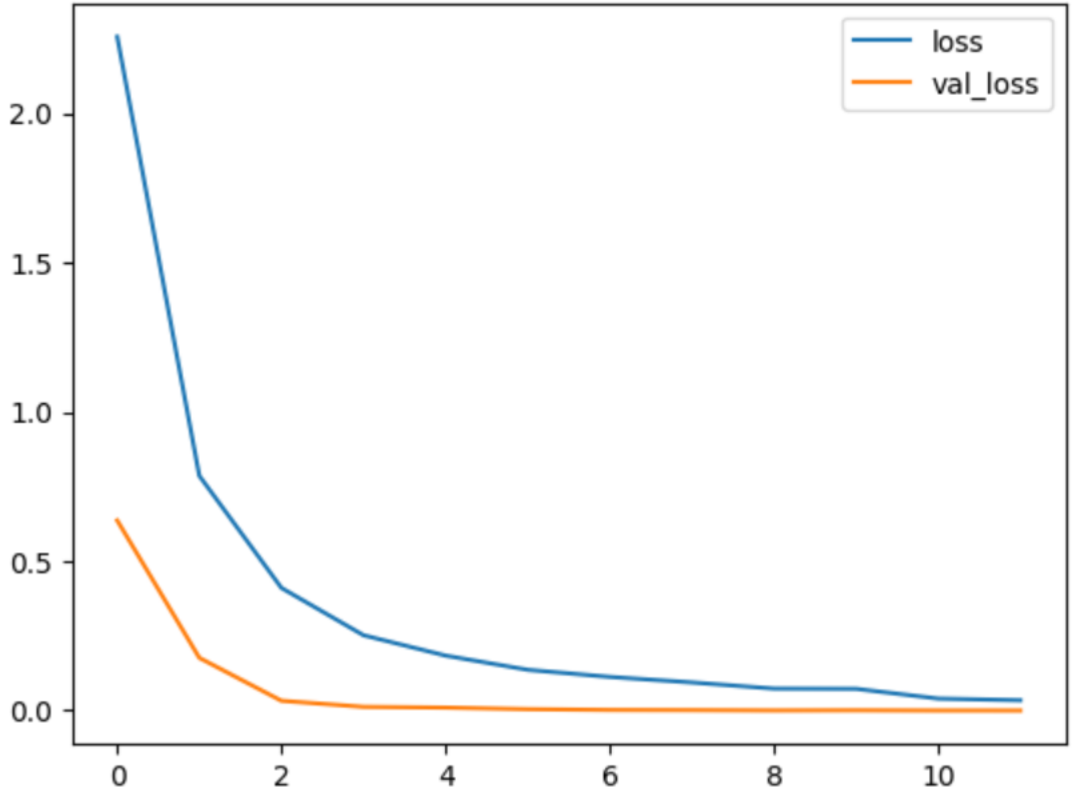
- **Model Tuning:** The project explores various hyperparameters and optimization techniques to fine-tune the CNN architecture for optimal performance.
- **Validation Strategies:** Cross-validation techniques such as k-fold validation are utilized to ensure robustness and reliability of the model's performance evaluation.
- **Scalability Assessment:** The scalability of the system is evaluated to determine its capability to handle increased workload and user interactions without compromising performance.
- **Error Analysis:** Detailed error analysis is conducted to identify common misclassifications and areas for model improvement, guiding future iterations and refinements.

```
57/57 [==============================] - 1s 8ms/step - loss: 0.0211 - accuracy: 0.9916
Testing accuracy of model : 99.16%
```

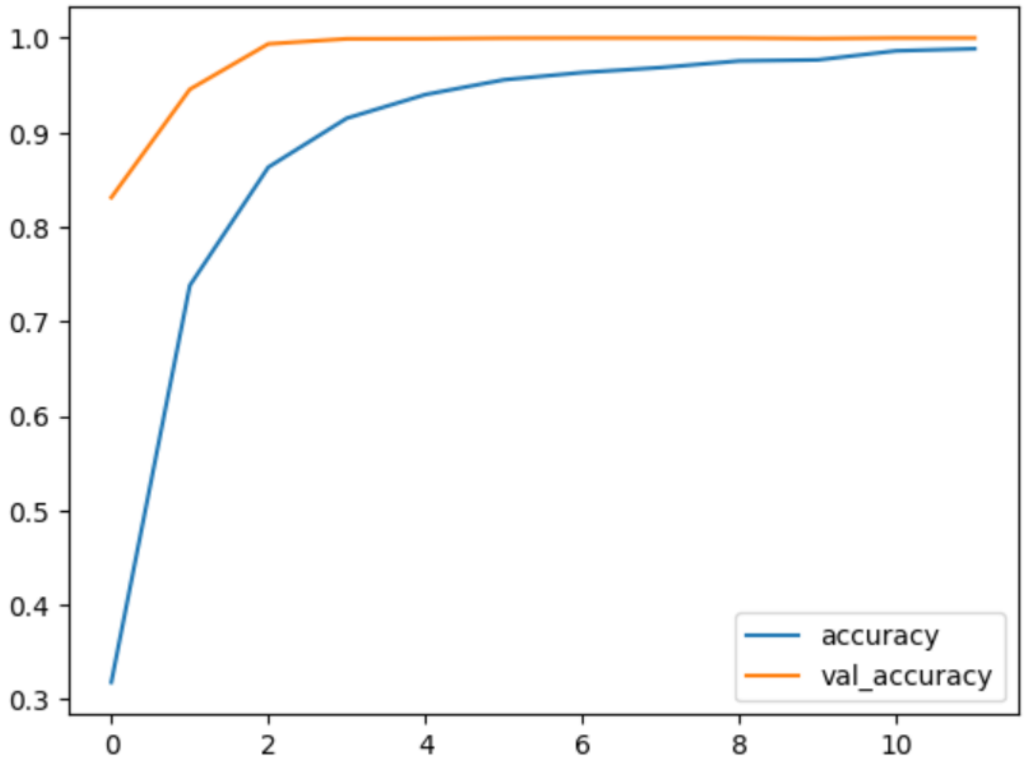
```
225/225 [==============================] - 0s 2ms/step
F1 Score: 0.9537261059762697
```

```
Label: 0
Precision: 1.0
Recall: 1.0
F1 Score: 1.0

Label: 1
Precision: 1.0
Recall: 1.0
F1 Score: 1.0

Label: 2
Precision: 0.9841269841269841
Recall: 1.0
F1 Score: 0.992

Label: 3
Precision: 1.0
Recall: 1.0
F1 Score: 1.0

Label: 4
Precision: 1.0
Recall: 1.0
F1 Score: 1.0

Label: 5
Precision: 1.0
Recall: 1.0
F1 Score: 1.0
```

```
Label: 6
Precision: 0.9935691318327974
Recall: 0.8879310344827587
F1 Score: 0.9377845220030349

Label: 7
Precision: 0.956140350877193
Recall: 1.0
F1 Score: 0.9775784753363229

Label: 8
Precision: 0.9442622950819672
Recall: 1.0
F1 Score: 0.9713322091062394

Label: 9
Precision: 0.0
Recall: 0.0
F1 Score: 0.0

Label: 10
Precision: 1.0
Recall: 1.0
F1 Score: 1.0

Label: 11
Precision: 1.0
Recall: 1.0
F1 Score: 1.0
```



loss
val_loss
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
2
4
6
8
10
accuracy
val_accuracy

RELATED WORKS AND LIMITATIONS

- **Comparison:** Existing sign language recognition systems often require complex setups and specialized hardware, limiting their scalability and practicality. While some systems achieve high accuracy, they may lack real-time performance or require extensive training data.
- **Pros and Cons:** Prior approaches have demonstrated advancements in gesture recognition accuracy, but they often face challenges related to cost, hardware requirements, and real-world deployment.
- **Citations:**

  - *Wadhawan, A., Kumar, P. Deep learning-based sign language recognition system for static signs. Neural Comput & Applic 32, 7957–7968 (2020). https://doi.org/10.1007/s00521-019-04691-y*
  - *N. Adaloglou et al., "A Comprehensive Study on Deep Learning-Based Methods for Sign Language Recognition," in IEEE Transactions on Multimedia, vol. 24, pp. 1750-1762, 2022, doi: 10.1109/TMM.2021.3070438*
  - *https://www.kaggle.com/datasets/datamunge/sign-language-mnist*

CONCLUSION AND FUTURE WORK

- **Conclusion:** In conclusion, the project demonstrates significant progress in real-time sign language recognition, contributing to accessibility and inclusivity for the deaf and hard-of-hearing community.
- **Future Directions:** Future research directions include investigating multimodal approaches incorporating audio and text-based inputs, enhancing the system's robustness in challenging environments, and expanding its functionality to support additional sign languages and communication modalities.
- **Community Engagement:** Engaging with the deaf and hard-of-hearing community in co-designing and co-developing future iterations of the system is essential to ensure its relevance, effectiveness, and inclusivity.
- **Long-term Impact:** The long-term impact of the project on society, education, and healthcare is considered, emphasizing the importance of leveraging technology for positive social change and empowerment.

THANK YOU