CSE 676: Deep Learning, Spring 2025

DL Final Project

# Self-Supervised Learning for Image Representation Learning and Classification of Alzheimer Disease

## Objective

In this project, we are exploring the application of self-supervised learning (SSL) for identifying Alzheimer's disease from MRI brain scans. We will be making use of a large dataset of unlabeled images i.e, around 86,000 images. We have developed a SimCLR-based self-supervised learning model to learn important image representations through effective image processing techniques and then fine-tuning it with a limited labelled dataset of 450 images for each image class, i.e. Non-Demented, Very Mild Dementia, Mild Dementia, and Moderate Dementia. For comparison, we are also training a classification model using ResNet-50 architecture from scratch. Our goal is to train self-supervised models like BYOL, MoCo, etc. and fine-tune it to get better accuracy. We will be utilizing the pre-trained models, which would perform classification of other MRI scans related to the disease.

## Dataset

### Source:

OASIS Alzheimer's MRI dataset available on Kaggle
OASIS Dataset Link

### Dataset Description:

The dataset consists of T1-weighted MRI images categorized into four classes based on the Clinical Dementia Rating (CDR):

- Non-Demented
- Very Mild Dementia
- Mild Dementia
- Moderate Dementia

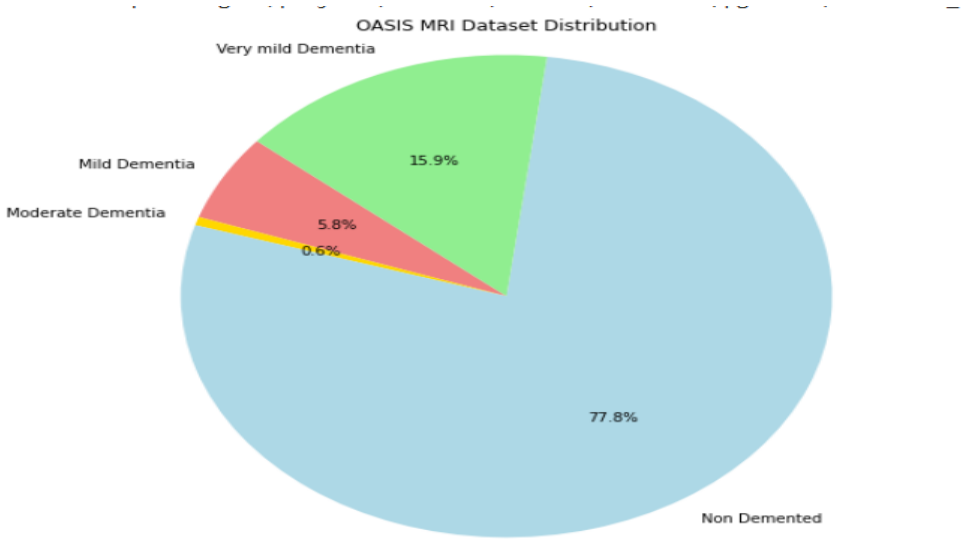
### Data Preparation:

- **Extraction & Organization:** Images were unzipped and organized into class-specific folders.

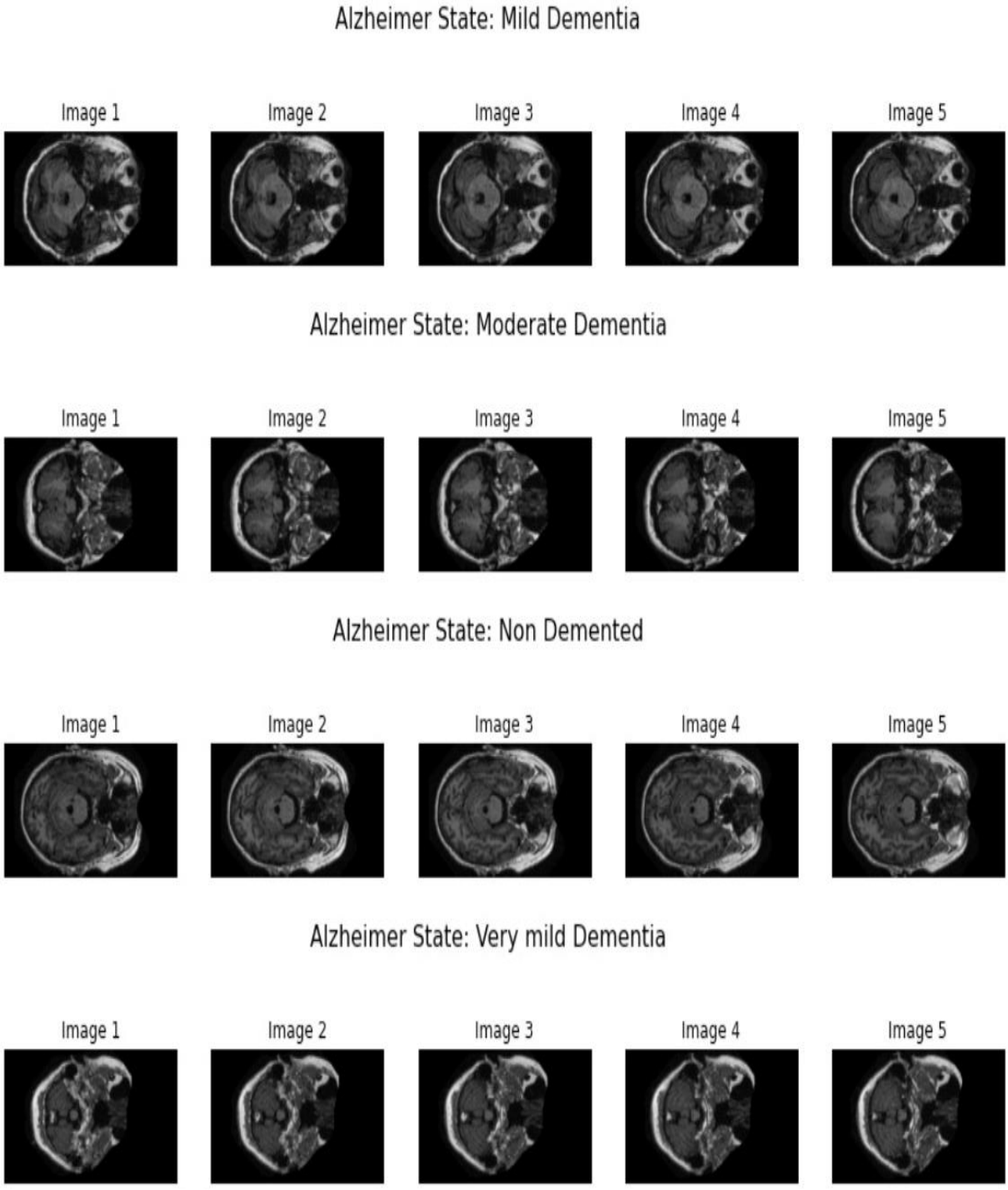
```
Root: /projects/academic/courses/cse676s25/pgulhane/alzheimer_dataset
Directories: ['Mild Dementia', 'Moderate Dementia', 'Non Demented', 'Very mild Dementia']
Files: []
Root: /projects/academic/courses/cse676s25/pgulhane/alzheimer_dataset/Mild Dementia
Directories: []
Files: ['OAS1_0028_MR1_mpr-1_100.jpg', 'OAS1_0028_MR1_mpr-1_101.jpg', 'OAS1_0028_MR1_mpr-1_102.jpg', 'OAS1_0028_MR1_mpr-1_103.jpg', 'OAS1_0028_MR1_mpr-1_104.jpg']
Root: /projects/academic/courses/cse676s25/pgulhane/alzheimer_dataset/Moderate Dementia
Directories: []
Files: ['OAS1_0308_MR1_mpr-1_100.jpg', 'OAS1_0308_MR1_mpr-1_101.jpg', 'OAS1_0308_MR1_mpr-1_102.jpg', 'OAS1_0308_MR1_mpr-1_103.jpg', 'OAS1_0308_MR1_mpr-1_104.jpg']
Root: /projects/academic/courses/cse676s25/pgulhane/alzheimer_dataset/Non Demented
Directories: []
Files: ['OAS1_0001_MR1_mpr-1_100.jpg', 'OAS1_0001_MR1_mpr-1_101.jpg', 'OAS1_0001_MR1_mpr-1_102.jpg', 'OAS1_0001_MR1_mpr-1_103.jpg', 'OAS1_0001_MR1_mpr-1_104.jpg']
Root: /projects/academic/courses/cse676s25/pgulhane/alzheimer_dataset/Very mild Dementia
Directories: []
Files: ['OAS1_0003_MR1_mpr-1_100.jpg', 'OAS1_0003_MR1_mpr-1_101.jpg', 'OAS1_0003_MR1_mpr-1_102.jpg', 'OAS1_0003_MR1_mpr-1_103.jpg', 'OAS1_0003_MR1_mpr-1_104.jpg']
```

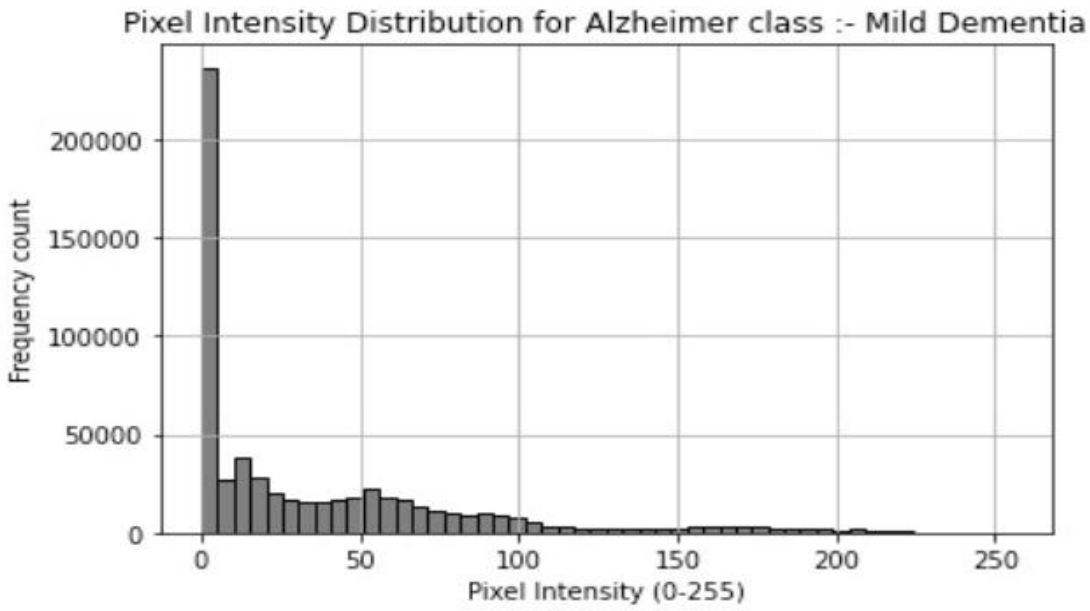
- **Exploratory Data Analysis (EDA):** Sample images were visualized and analyzed for pixel intensity distributions, class counts, and image sizes.

### *Data Distribution Pie Chart*

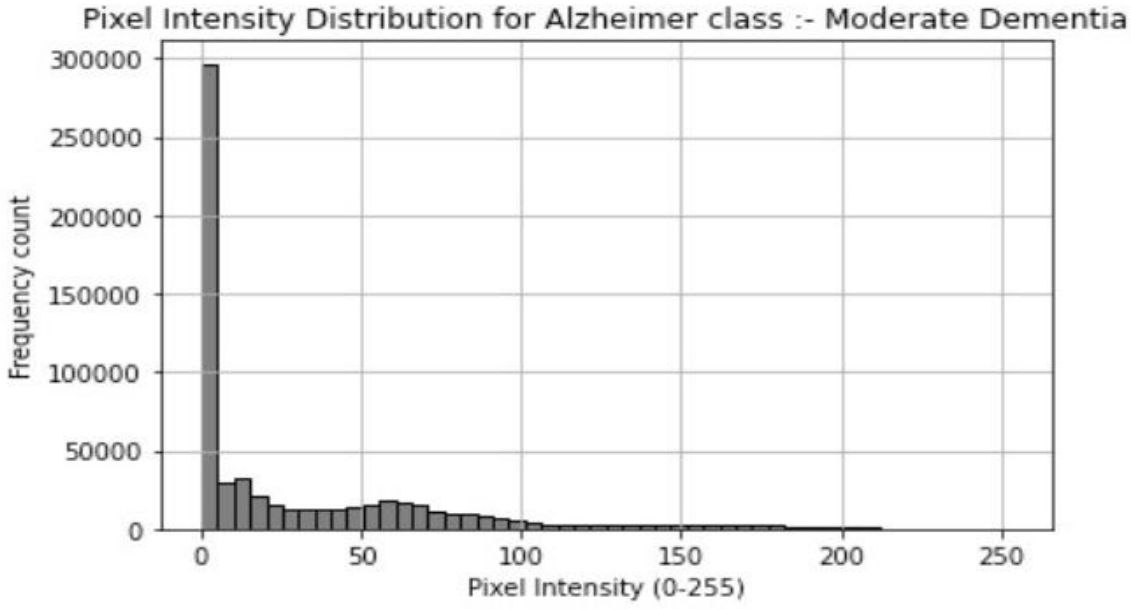


*Sample Images from Each Class*

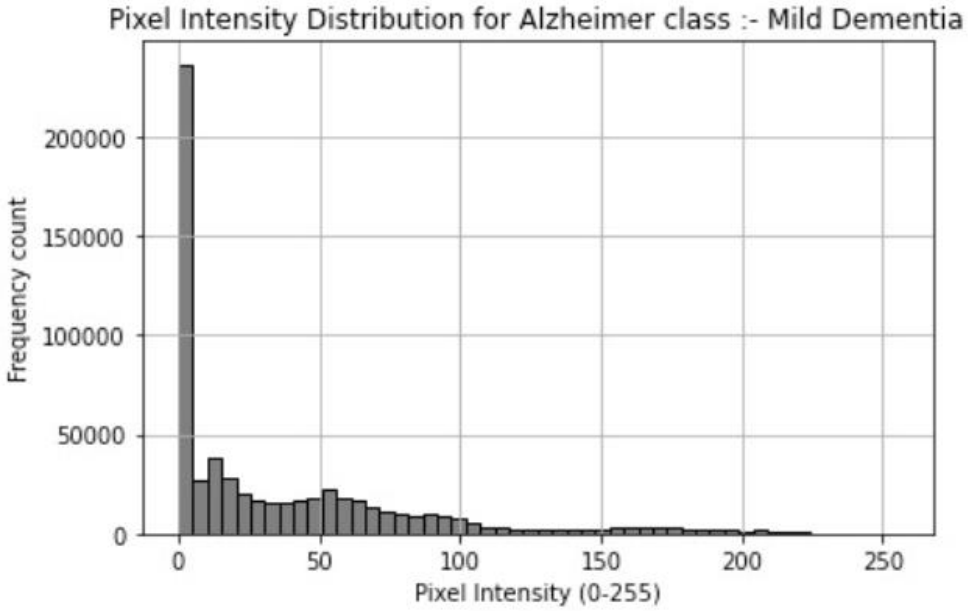




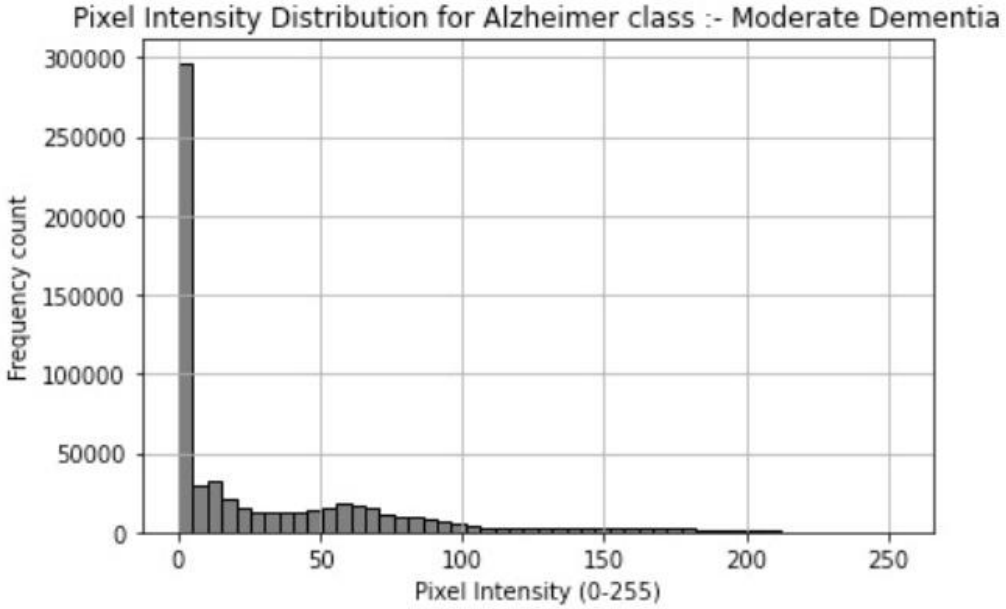

<Figure size 1080x216 with 0 Axes>

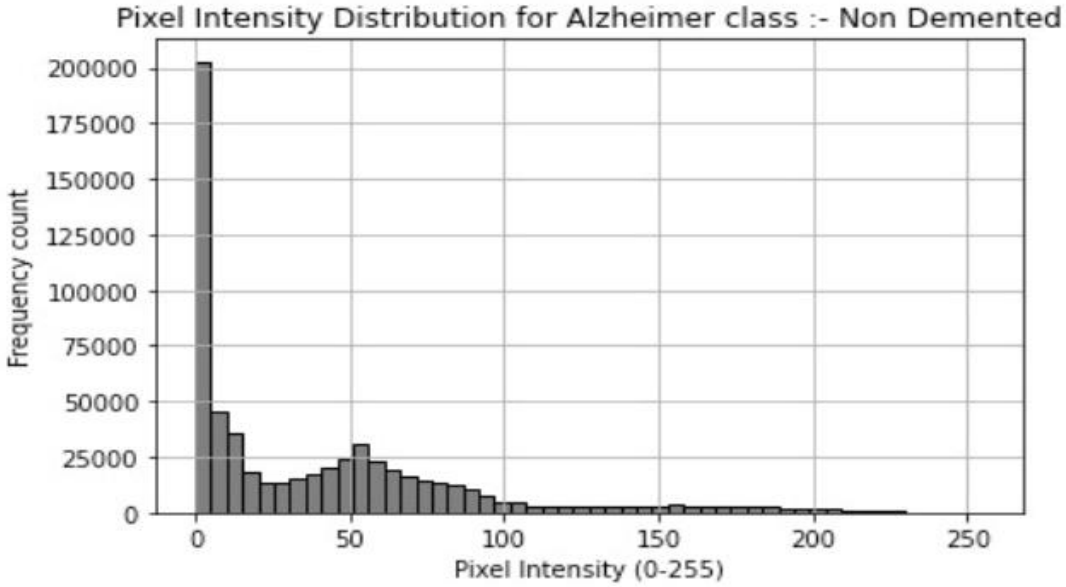


*Pixel Intensity Distribution for Each Class*

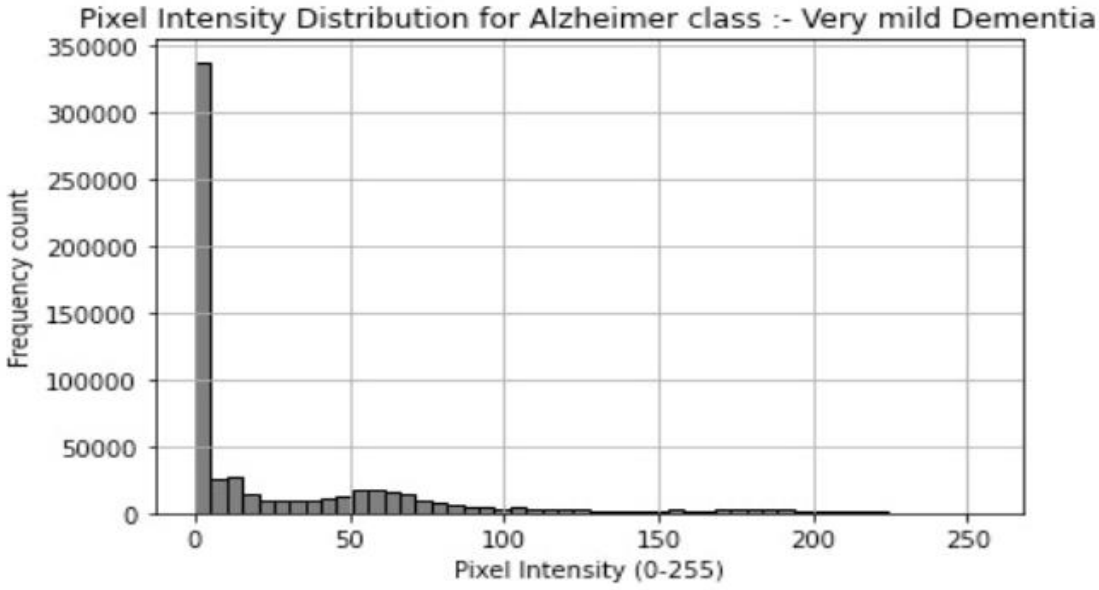



```
<Figure size 1080x216 with 0 Axes>
```






<Figure size 1080x216 with 0 Axes>



```
Could not open image: /projects/academic/courses/cse676s25/pgulhane/alzheimer_dataset/Very mild Dementia/OAS1_0247_MR1_mpr-4_129.jpg
DATASET SUMMARY
--------------------
Total images      : 86437
Number of classes : 4
Images per class  :
  - Mild Dementia: 5002 images
  - Moderate Dementia: 488 images
  - Non Demented: 67222 images
  - Very mild Dementia: 13725 images

Image Size Info
Average size      : 496.0 x 248.0
Min size          : 496 x 248
Max size          : 496 x 248
```

- **Data Augmentation:**
  There is class imbalance in our dataset, where the 'Mild Dementia' class contains 5,002 images, while the 'Moderate Dementia' class has only 488 images. We will balance these classes by scaling up the class image size to 10,000 images per class

  We have applied the following transformations,
  - **Random Rotation:** Here the images will be randomly rotated by 10 degrees.
  - **Random Horizontal Flip:** This operation mirrors the images.
  - **Color Jitter:** Adjustments to brightness and contrast within a 20% range were applied.

```
Augmenting 'Mild Dementia': 5002 → 10000
Augmenting 'Moderate Dementia': 488 → 10000
Data augmentation complete.
```

- **Data Splitting:** The labelled dataset (450 images per class) is split into training (70%), validation (15%), and testing (15%). Unlabelled images are used for self-supervised pretraining.

```
Dataset after Splitting into Labelled and Unlabelled images
LABELLED DATASET
-----------------
  - Mild Dementia: 450 images
  - Moderate Dementia: 450 images
  - Non Demented: 450 images
  - Very mild Dementia: 450 images

UNLABELLED DATASET
-------------------
Total unlabelled images: 99147
```

# Methodology and Pipeline

## Self-Supervised Learning (SSL) Approach:

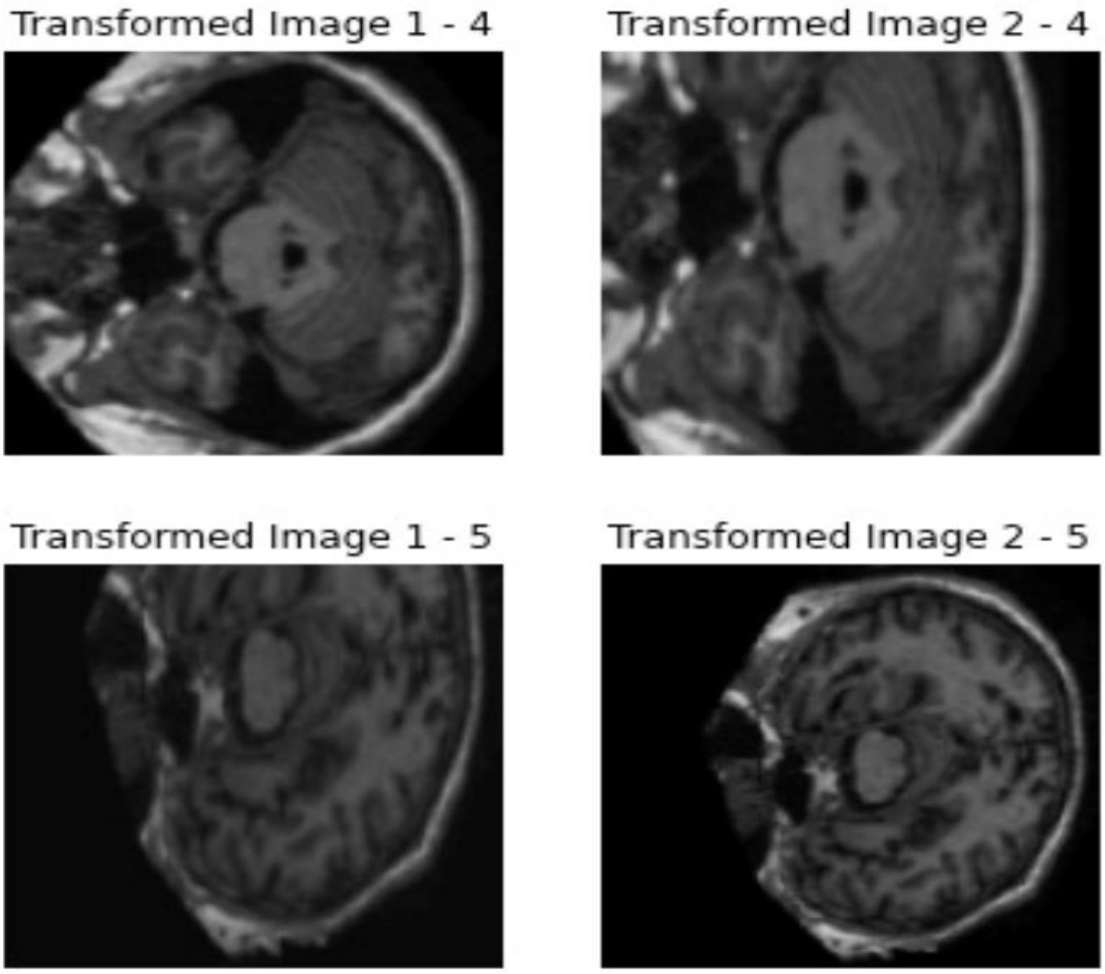
### SimCLR Implementation:

- **Data Augmentation (Unlabeled Images):**
  Inorder to generate to views of an image we performed data augmentation on the images using the SimCLRTransform function defined in the program.We performed image resizing to match 128 x1 28 pixels along with random resized corp.We also flipped the images horizontally and adding random jitter to change brightness ,hue etc
  Normalized the images for better performance.

- **SimCLR Model Architecture:**
  We are utilizing the features learned from SimCLR model and then fine tuning it using resnet 50 architectre for 20 epochs to classify the images.

- **Loss Function - Contrastive Loss (NT-Xent):**
  We will train our model using the NT-Xent loss, with ‘temparature = 0.1’. This loss function learns representations of distinct images while knowing similarity across representations from different views of the same image.
- **Model Pretraining:**
  Our model is initially trained on the unlabeled dataset that we created initially.After the training, we are saving the weights of the encoder to use it for downstream supervised tasks.

*Sample Augmented Images*

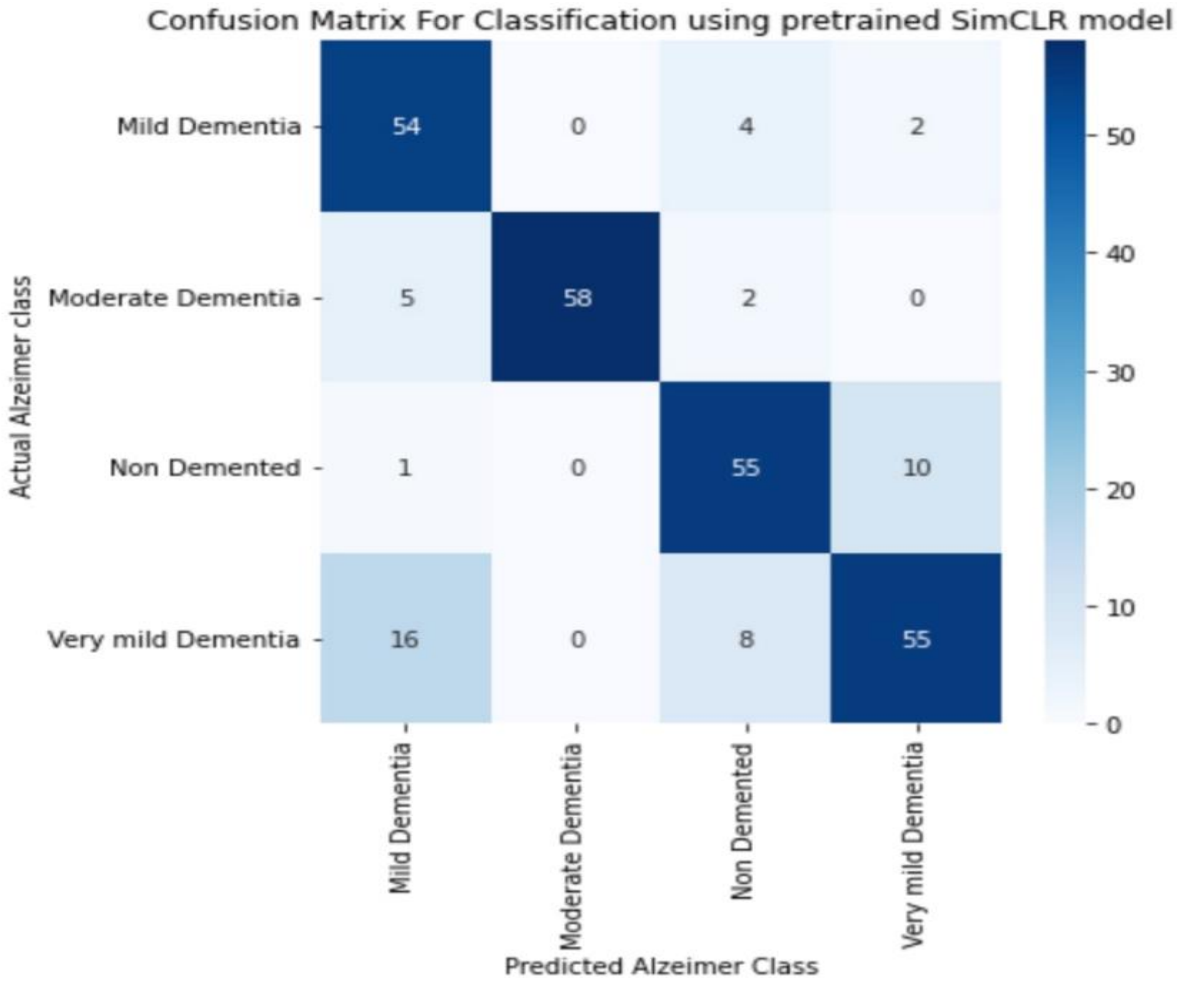



- **Downstream Supervised Task:**
    - We have used linear classifier with the SSL trained encoder weights to perform Alzheimer's classification on the limited labelled dataset with four image classes.
    - For comparison, a separate ResNet-50 model is trained from scratch on the same labelled dataset.

## Baseline Supervised Approach:

- **ResNet-50 Model:**
    - We have implemented a standard ResNet-50 architecture and modified it to output four classes. Then we trained the model using a supervised approach.
    - The model's performance is compared to the SSL-based approach on the same evaluation metrics.

# Evaluation and Analysis



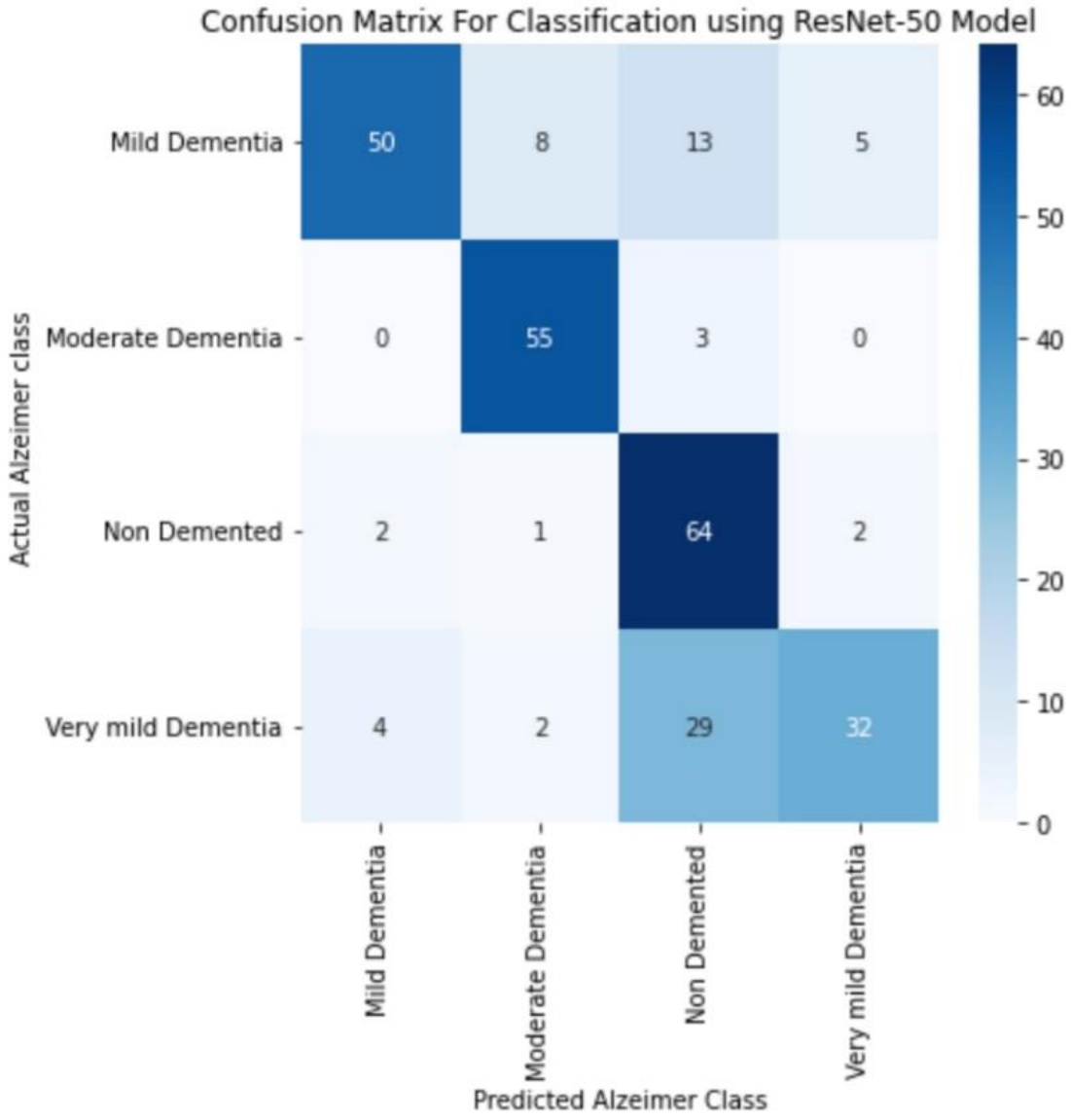
```
Classification Report:
                     precision    recall  f1-score   support

     Mild Dementia       0.82      0.84      0.83        76
 Moderate Dementia       0.94      1.00      0.97        58
      Non Demented       0.79      0.78      0.79        69
Very mild Dementia       0.76      0.70      0.73        67

          accuracy                           0.83       270
         macro avg       0.83      0.83      0.83       270
      weighted avg       0.82      0.83      0.82       270


PERFORMANCE SUMMARY
--------------------
Class: Mild Dementia
  Precision : 0.8205
  Recall    : 0.8421
  F1-Score  : 0.8312
  Support   : 76.0
--------------------
Class: Moderate Dementia
  Precision : 0.9355
  Recall    : 1.0000
  F1-Score  : 0.9667
  Support   : 58.0
--------------------
Class: Non Demented
  Precision : 0.7941
  Recall    : 0.7826
  F1-Score  : 0.7883
  Support   : 69.0
--------------------
Class: Very mild Dementia
  Precision : 0.7581
  Recall    : 0.7015
  F1-Score  : 0.7287
  Support   : 67.0
--------------------
Overall Metrics:
  Accuracy              : 0.8259
  Macro Avg Precision   : 0.8270
  Macro Avg Recall      : 0.8316
  Macro Avg F1-Score    : 0.8287
  Weighted Avg Precision: 0.8230
  Weighted Avg Recall   : 0.8259
  Weighted Avg F1-Score : 0.8239
```

The above results are for SimCLR baseline model trained with self-supervised learning, the model was run on unlabeled dataset for 25 epochs and 100 epoch for fine tuning the model with labelled dataset. The model performed good and gave an accuracy of 82%. The model performed good in classifying Moderate dementia and Mild dementia.


Confusion Matrix For Classification using ResNet-50 Model
Mild Dementia
Moderate Dementia
Non Demented
Very mild Dementia
Actual Alzeimer class
50
8
13
5
0
55
3
0
2
1
64
2
4
2
29
32
60
50
40
30
20
10
0
Mild Dementia
Moderate Dementia
Non Demented
Very mild Dementia
Predicted Alzeimer Class

```
Classification Report:
                    precision    recall  f1-score   support

     Mild Dementia       0.89      0.66      0.76        76
 Moderate Dementia       0.83      0.95      0.89        58
      Non Demented       0.59      0.93      0.72        69
Very mild Dementia       0.82      0.48      0.60        67

          accuracy                           0.74       270
         macro avg       0.78      0.75      0.74       270
      weighted avg       0.78      0.74      0.74       270


PERFORMANCE SUMMARY
--------------------
Class: Mild Dementia
  Precision : 0.8929
  Recall    : 0.6579
  F1-Score  : 0.7576
  Support   : 76.0
--------------------
Class: Moderate Dementia
  Precision : 0.8333
  Recall    : 0.9483
  F1-Score  : 0.8871
  Support   : 58.0
--------------------
Class: Non Demented
  Precision : 0.5872
  Recall    : 0.9275
  F1-Score  : 0.7191
  Support   : 69.0
--------------------
Class: Very mild Dementia
  Precision : 0.8205
  Recall    : 0.4776
  F1-Score  : 0.6038
  Support   : 67.0
--------------------
Overall Metrics:
  Accuracy              : 0.7444
  Macro Avg Precision   : 0.7835
  Macro Avg Recall      : 0.7528
  Macro Avg F1-Score    : 0.7419
  Weighted Avg Precision: 0.7840
  Weighted Avg Recall   : 0.7444
  Weighted Avg F1-Score : 0.7374
```

The above results are for ResNet50 model trained on labelled data with limited sample around 450 per class and this model gave an accuracy of 74.44%. The model is good in classifying moderate dementia samples but struggles to distinguish between Non demented and very mild dementia samples. This shows the importance of Self Supervised Learning Model for Alzheimer Disease.

| Model | Test Accuracy | Test Loss | Precision | Recall | F1 Score | Training Time |
|---|---|---|---|---|---|---|
| Base ResNet50 Model | 74.44% | 1.1514 | 0.7835 | 0.7528 | 0.7419 | 22.76 sec |
| SimCLR preTrianed-FineTuned Model | 82.59% | 0.8359 | 0.8270 | 0.8316 | 0.8287 | 43.71 sec |

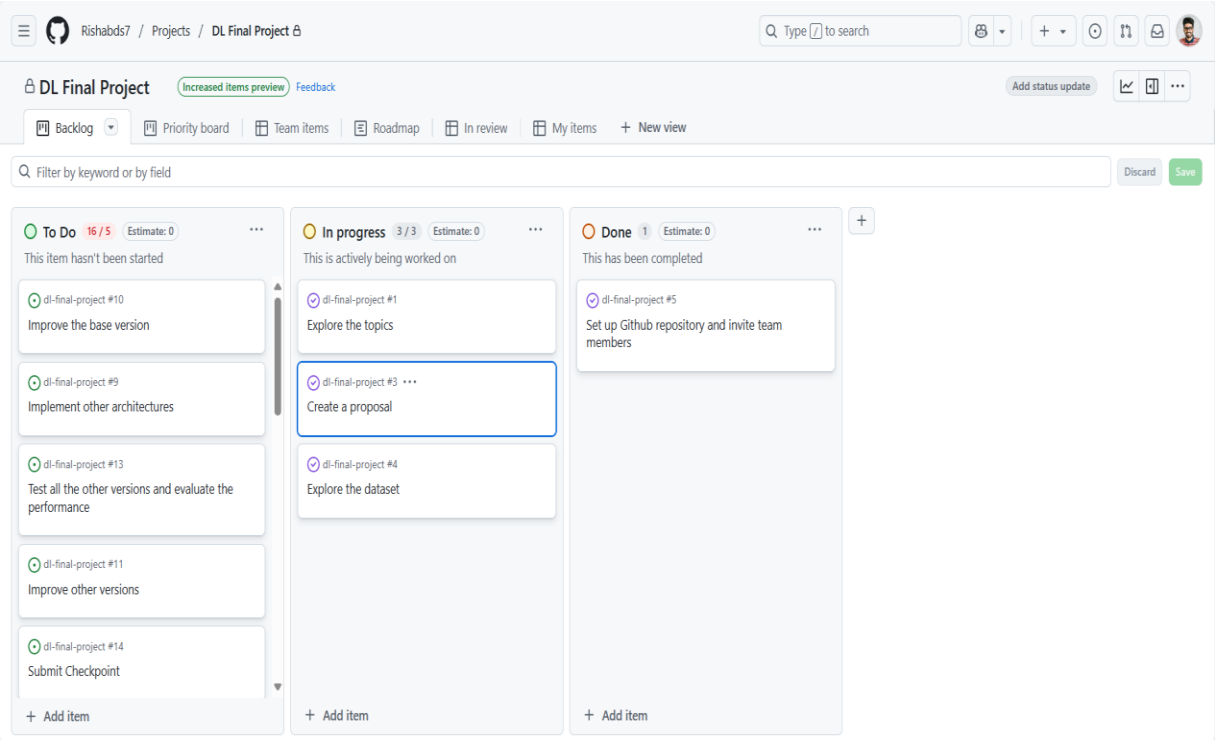
The evaluation result of SimCLR model and ResNet50 have been tabulated. We see that the SimCLR model has converged well and has given a higher accuracy than Base ResNet50. The

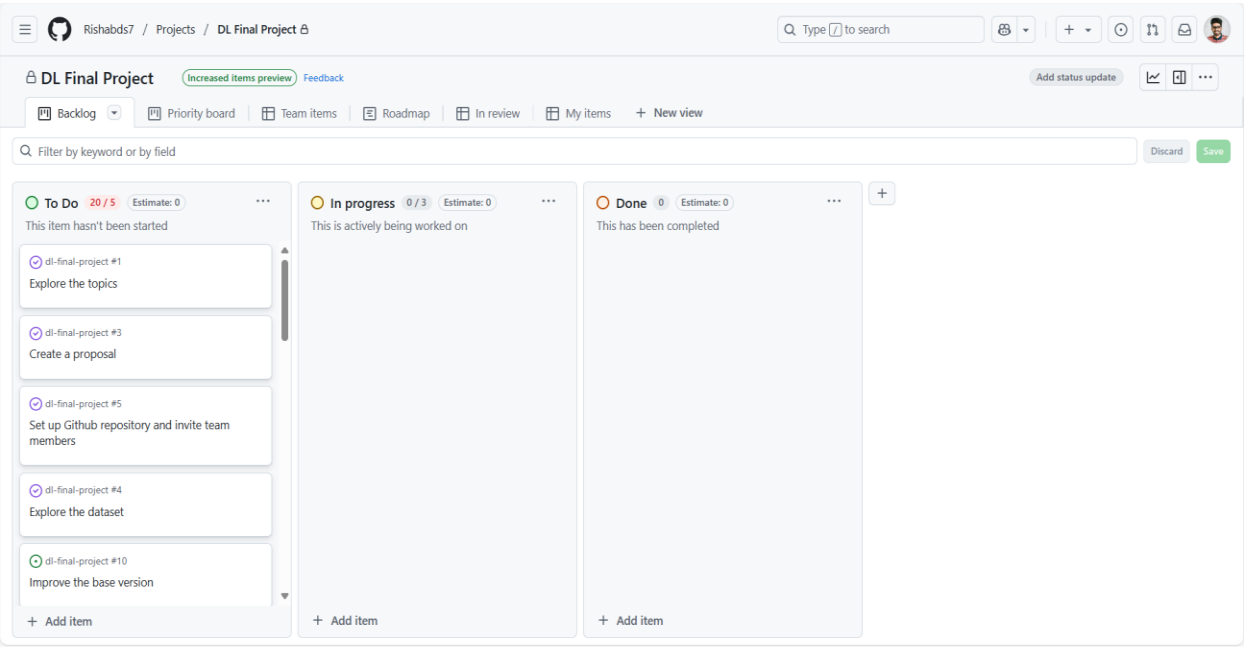
SimCLR model has given good results with respect to evaluation parameters like precision, Recall and F1 Score.

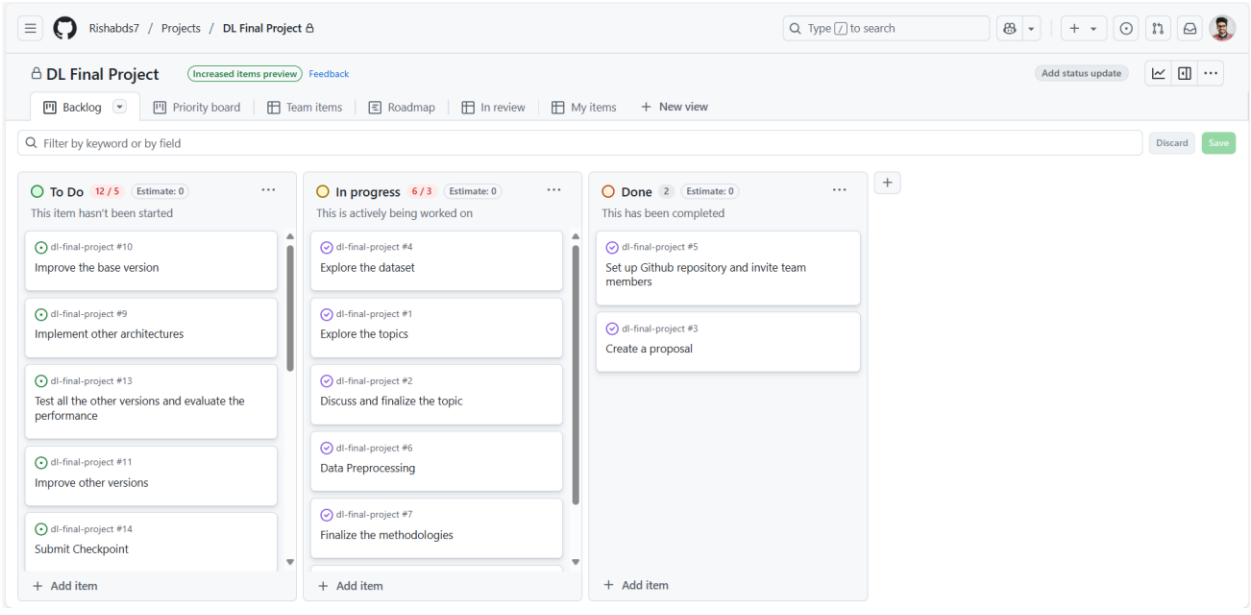
Thus, the SimCLR model becomes extremelyuseful when the dataset isn’t classified or labelled well.

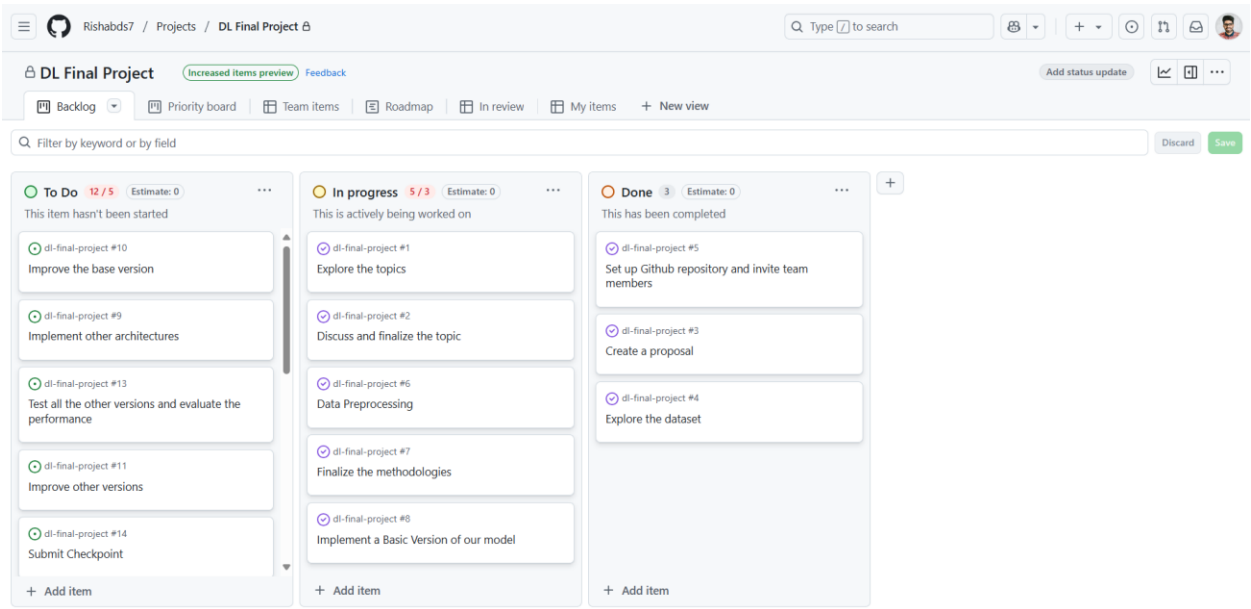
# Board Activities

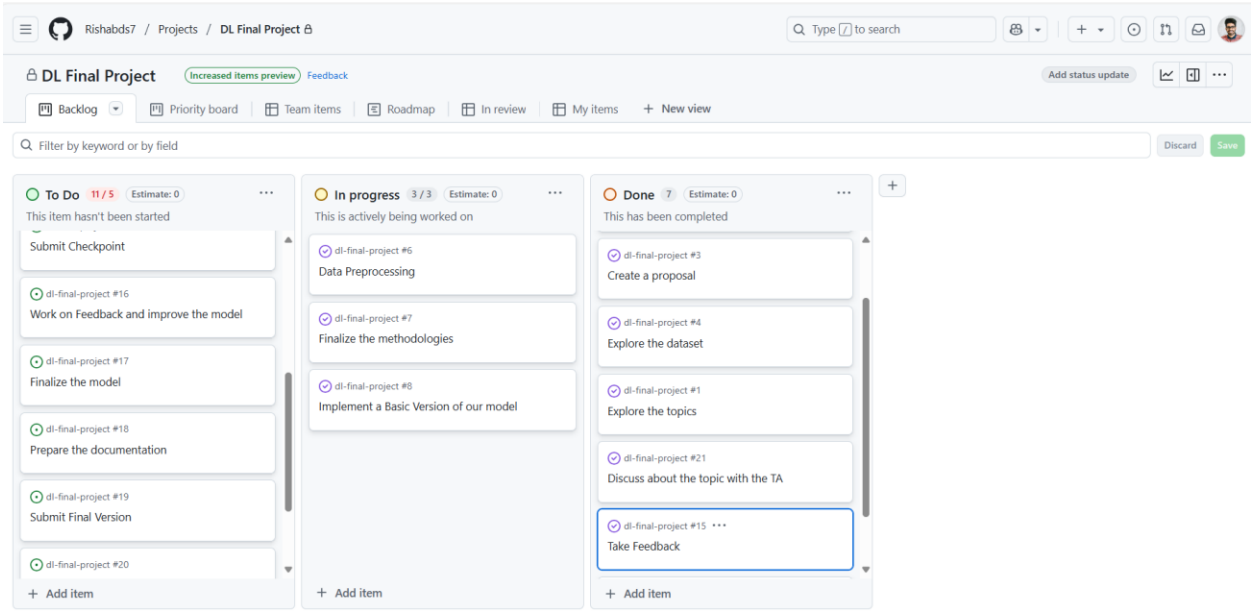
Link: https://github.com/users/Rishabds7/projects/2/views/1

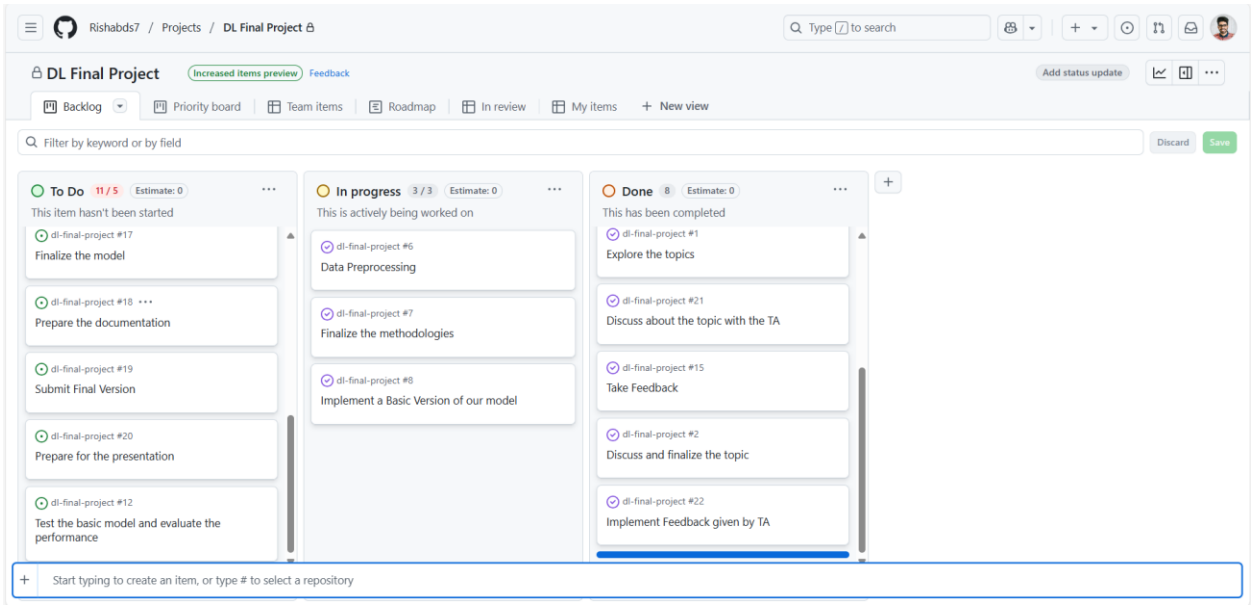


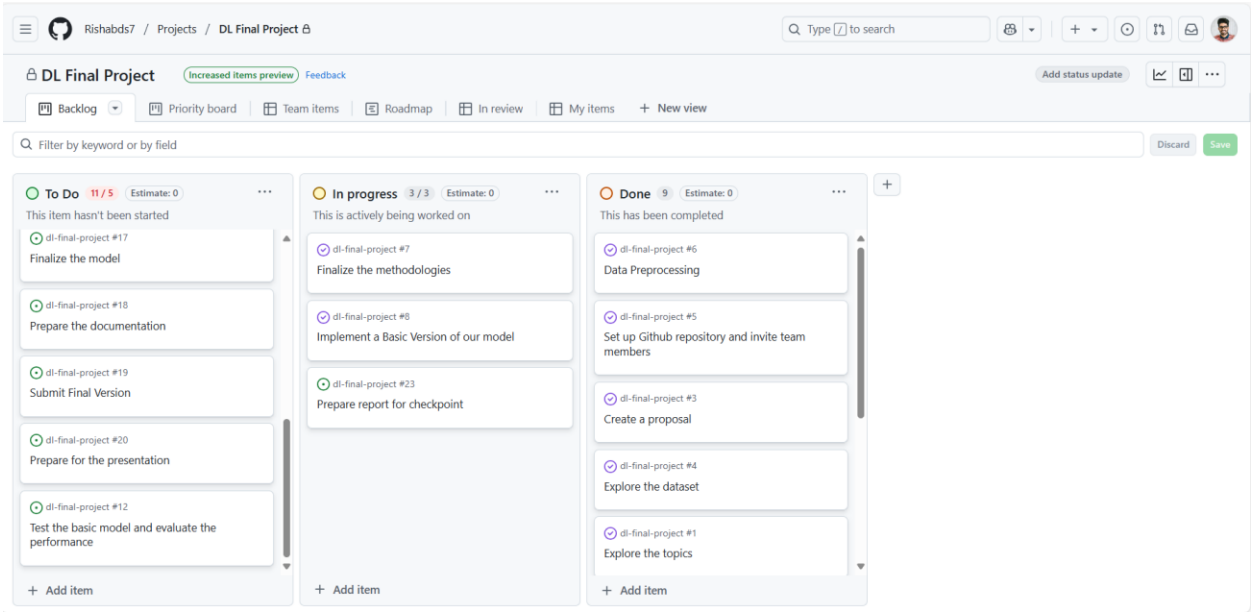



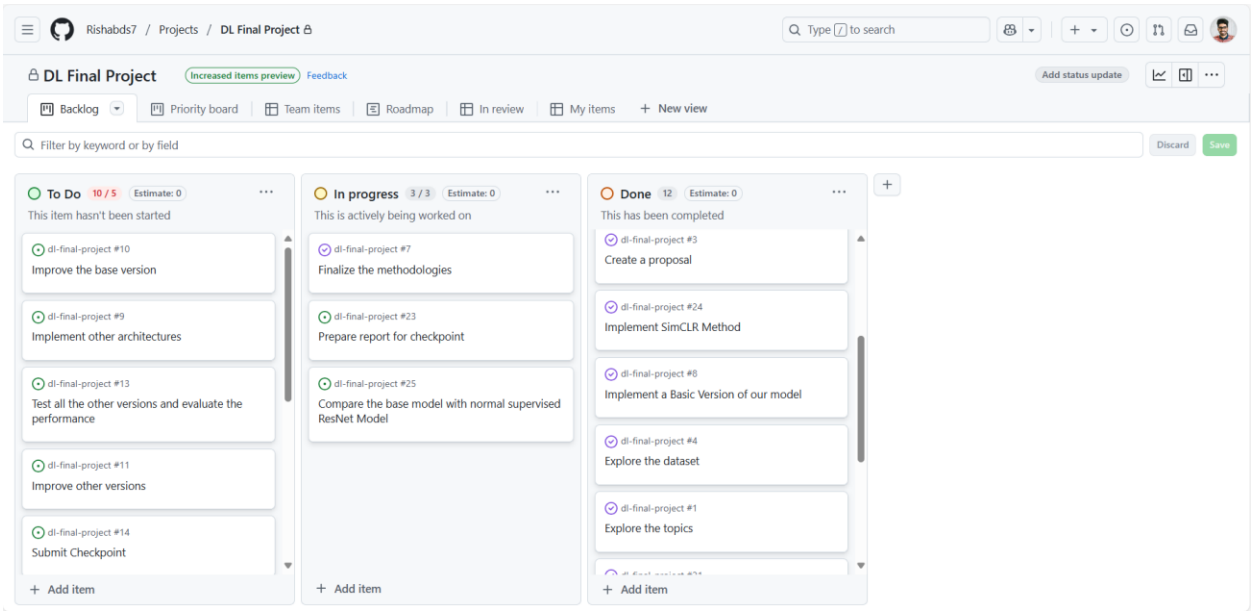

Rishabds7 / Projects / DL Final Project
Type / to search
DL Final Project
Increased items preview
Feedback
Add status update
Backlog
Priority board
Team items
Roadmap
In review
My items
New view
Filter by keyword or by field
Discard
Save
To Do 12 / 5 Estimate: 0
This item hasn't been started
dl-final-project #10
Improve the base version
dl-final-project #9
Implement other architectures
dl-final-project #13
Test all the other versions and evaluate the performance
dl-final-project #11
Improve other versions
dl-final-project #14
Submit Checkpoint
Add item
In progress 6 / 3 Estimate: 0
This is actively being worked on
dl-final-project #4
Explore the dataset
dl-final-project #1
Explore the topics
dl-final-project #2
Discuss and finalize the topic
dl-final-project #6
Data Preprocessing
dl-final-project #7
Finalize the methodologies
Add item
Done 2 Estimate: 0
This has been completed
dl-final-project #5
Set up Github repository and invite team members
dl-final-project #3
Create a proposal
Add item

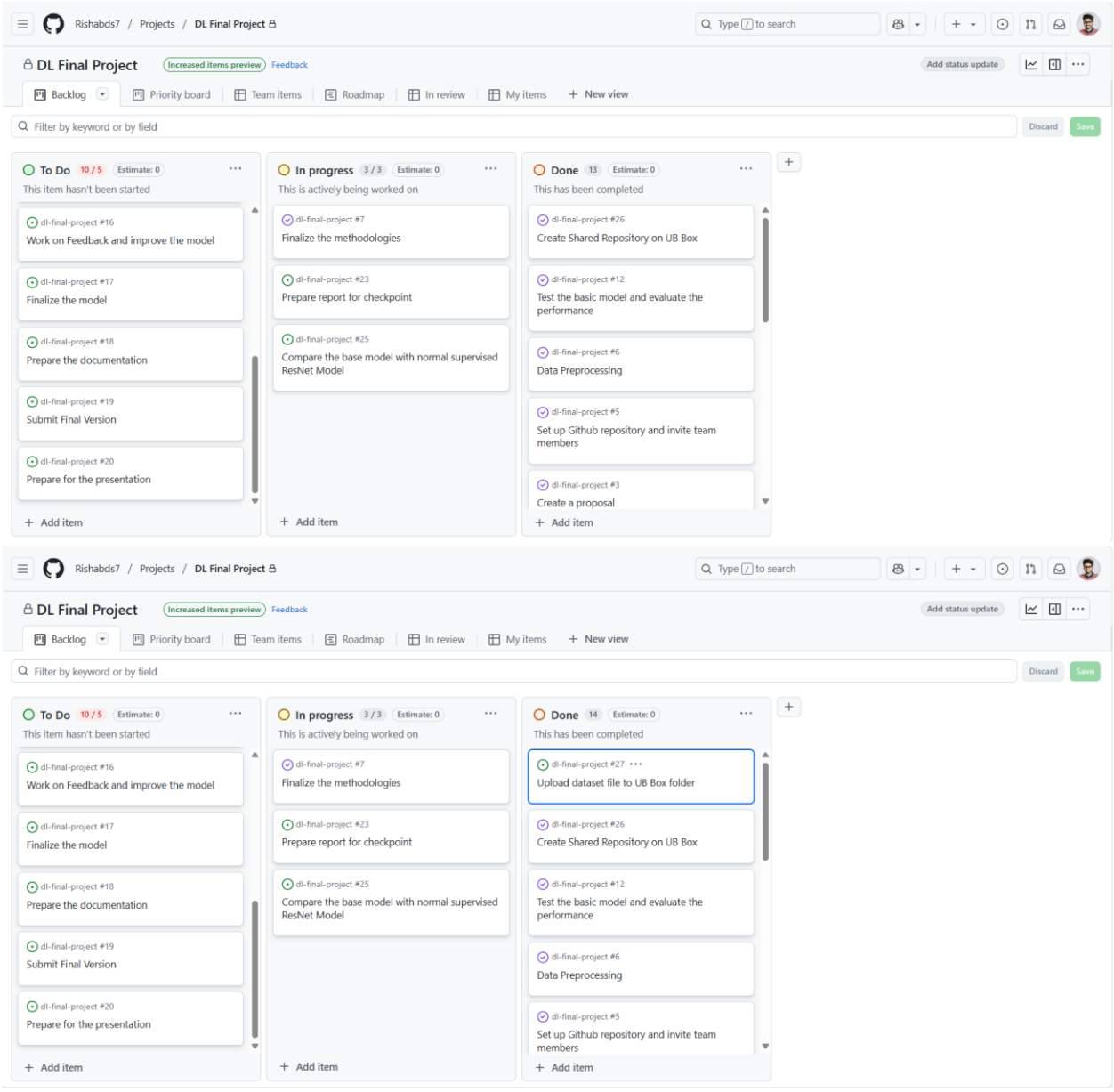

Rishabds7 / Projects / DL Final Project
Type / to search
DL Final Project
Increased items preview
Feedback
Add status update
Backlog
Priority board
Team items
Roadmap
In review
My items
New view
Filter by keyword or by field
Discard
Save
To Do 12 / 5 Estimate: 0
This item hasn't been started
dl-final-project #10
Improve the base version
dl-final-project #9
Implement other architectures
dl-final-project #13
Test all the other versions and evaluate the performance
dl-final-project #11
Improve other versions
dl-final-project #14
Submit Checkpoint
Add item
In progress 5 / 3 Estimate: 0
This is actively being worked on
dl-final-project #1
Explore the topics
dl-final-project #2
Discuss and finalize the topic
dl-final-project #6
Data Preprocessing
dl-final-project #7
Finalize the methodologies
dl-final-project #8
Implement a Basic Version of our model
Add item
Done 3 Estimate: 0
This has been completed
dl-final-project #5
Set up Github repository and invite team members
dl-final-project #3
Create a proposal
dl-final-project #4
Explore the dataset
Add item


Rishabds7 / Projects / DL Final Project
Type / to search
DL Final Project
Increased items preview
Feedback
Add status update
Backlog
Priority board
Team items
Roadmap
In review
My items
New view
Filter by keyword or by field
Discard
Save
To Do 11 / 5 Estimate: 0
This item hasn't been started
Submit Checkpoint
dl-final-project #16
Work on Feedback and improve the model
dl-final-project #17
Finalize the model
dl-final-project #18
Prepare the documentation
dl-final-project #19
Submit Final Version
dl-final-project #20
Add item
In progress 3 / 3 Estimate: 0
This is actively being worked on
dl-final-project #6
Data Preprocessing
dl-final-project #7
Finalize the methodologies
dl-final-project #8
Implement a Basic Version of our model
Add item
Done 7 Estimate: 0
This has been completed
dl-final-project #3
Create a proposal
dl-final-project #4
Explore the dataset
dl-final-project #1
Explore the topics
dl-final-project #21
Discuss about the topic with the TA
dl-final-project #15
Take Feedback
Add item


Rishabds7 / Projects / DL Final Project
Type / to search
DL Final Project
Increased items preview
Feedback
Add status update
Backlog
Priority board
Team items
Roadmap
In review
My items
New view
Filter by keyword or by field
Discard
Save
To Do 11 / 5 Estimate: 0
This item hasn't been started
dl-final-project #17
Finalize the model
dl-final-project #18
Prepare the documentation
dl-final-project #19
Submit Final Version
dl-final-project #20
Prepare for the presentation
dl-final-project #12
Test the basic model and evaluate the performance
In progress 3 / 3 Estimate: 0
This is actively being worked on
dl-final-project #6
Data Preprocessing
dl-final-project #7
Finalize the methodologies
dl-final-project #8
Implement a Basic Version of our model
Done 8 Estimate: 0
This has been completed
dl-final-project #1
Explore the topics
dl-final-project #21
Discuss about the topic with the TA
dl-final-project #15
Take Feedback
dl-final-project #2
Discuss and finalize the topic
dl-final-project #22
Implement Feedback given by TA
Start typing to create an item, or type # to select a repository


Rishabds7 / Projects / DL Final Project
Type / to search
DL Final Project
Increased items preview
Feedback
Add status update
Backlog
Priority board
Team items
Roadmap
In review
My items
New view
Filter by keyword or by field
Discard
Save
To Do 11 / 5 Estimate: 0
This item hasn't been started
dl-final-project #17
Finalize the model
dl-final-project #18
Prepare the documentation
dl-final-project #19
Submit Final Version
dl-final-project #20
Prepare for the presentation
dl-final-project #12
Test the basic model and evaluate the performance
Add item
In progress 3 / 3 Estimate: 0
This is actively being worked on
dl-final-project #7
Finalize the methodologies
dl-final-project #8
Implement a Basic Version of our model
dl-final-project #23
Prepare report for checkpoint
Add item
Done 9 Estimate: 0
This has been completed
dl-final-project #6
Data Preprocessing
dl-final-project #5
Set up Github repository and invite team members
dl-final-project #3
Create a proposal
dl-final-project #4
Explore the dataset
dl-final-project #1
Explore the topics
Add item


Rishabds7 / Projects / DL Final Project
Type / to search
DL Final Project
Increased items preview
Feedback
Add status update
Backlog
Priority board
Team items
Roadmap
In review
My items
New view
Filter by keyword or by field
Discard
Save
To Do 10 / 5 Estimate: 0
This item hasn't been started
dl-final-project #10
Improve the base version
dl-final-project #9
Implement other architectures
dl-final-project #13
Test all the other versions and evaluate the performance
dl-final-project #11
Improve other versions
dl-final-project #14
Submit Checkpoint
Add item
In progress 3 / 3 Estimate: 0
This is actively being worked on
dl-final-project #7
Finalize the methodologies
dl-final-project #23
Prepare report for checkpoint
dl-final-project #25
Compare the base model with normal supervised ResNet Model
Add item
Done 12 Estimate: 0
This has been completed
dl-final-project #3
Create a proposal
dl-final-project #24
Implement SimCLR Method
dl-final-project #8
Implement a Basic Version of our model
dl-final-project #4
Explore the dataset
dl-final-project #1
Explore the topics
Add item




## References


- [2309.13167] Flow Factorized Representation Learning
- [2301.05712] A Survey on Self-supervised Learning: Algorithms, Applications, and Future Trends
- Self-Supervised Representation Learning | Lil'Log
- classification_report — scikit-learn 1.6.1 documentation
- confusion_matrix — scikit-learn 1.6.1 documentation
- 1512.03385