Facial Keypoint Recognition

Final Presentation

w207 03, Spring 2021

The Black Boxes
(Jackie, Joanie, Rakesh, Sandip)

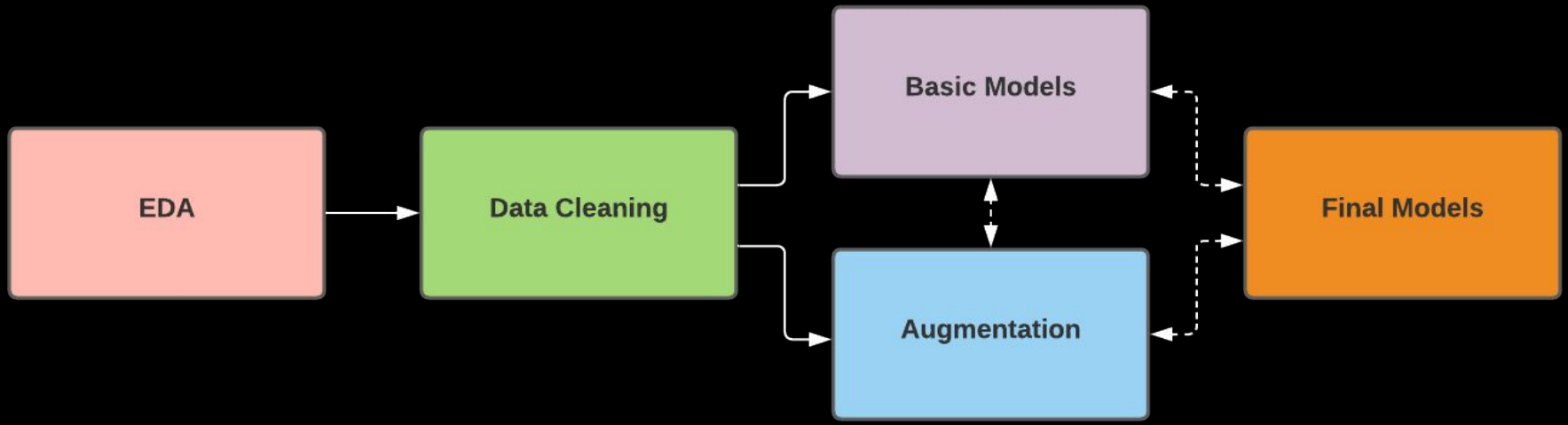
Project Goals

- Given an image, predict the location of (x,y) key points like nose_tip, right_eye_center, etc
- Achieve best possible performance (RMSE):

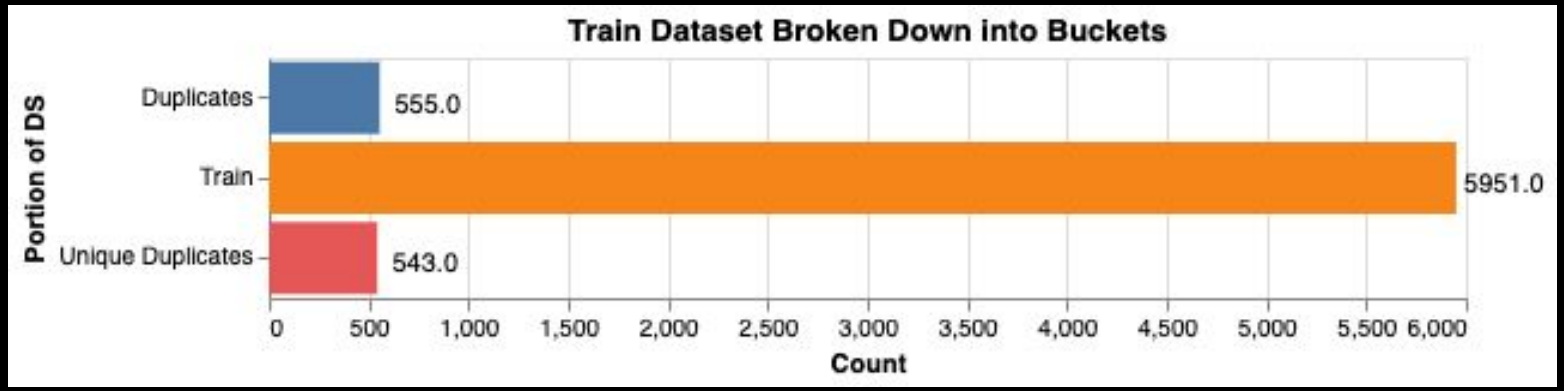
$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}}$$

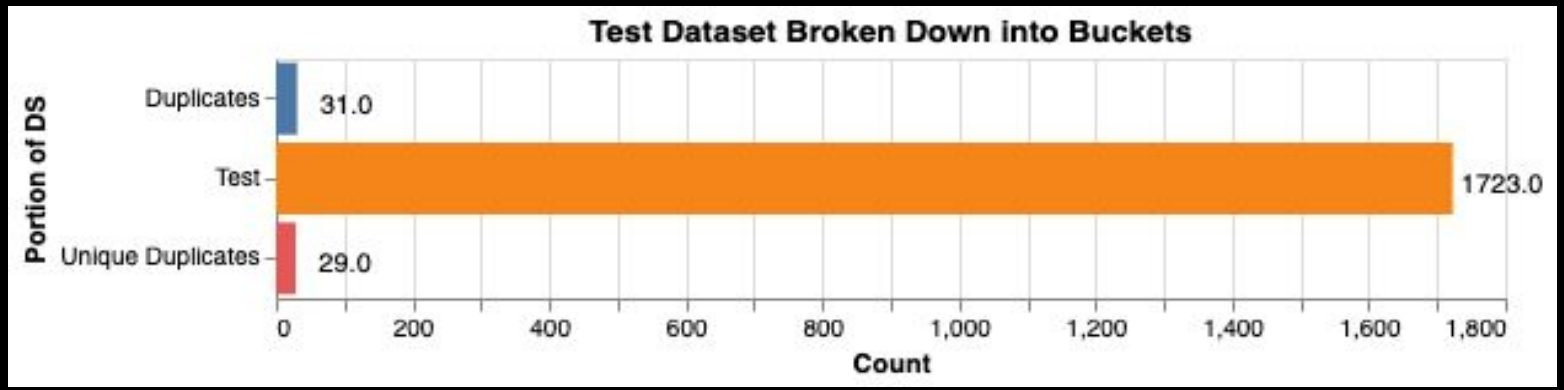
- **Training dataset:** 7049 images, ≤ 30 X,Y co-ords.
- **Testing dataset:** 1783 images.

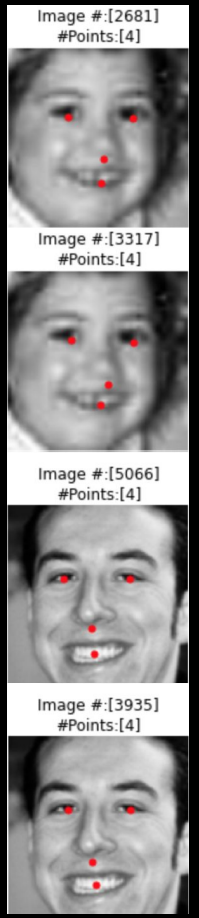
Project Approach



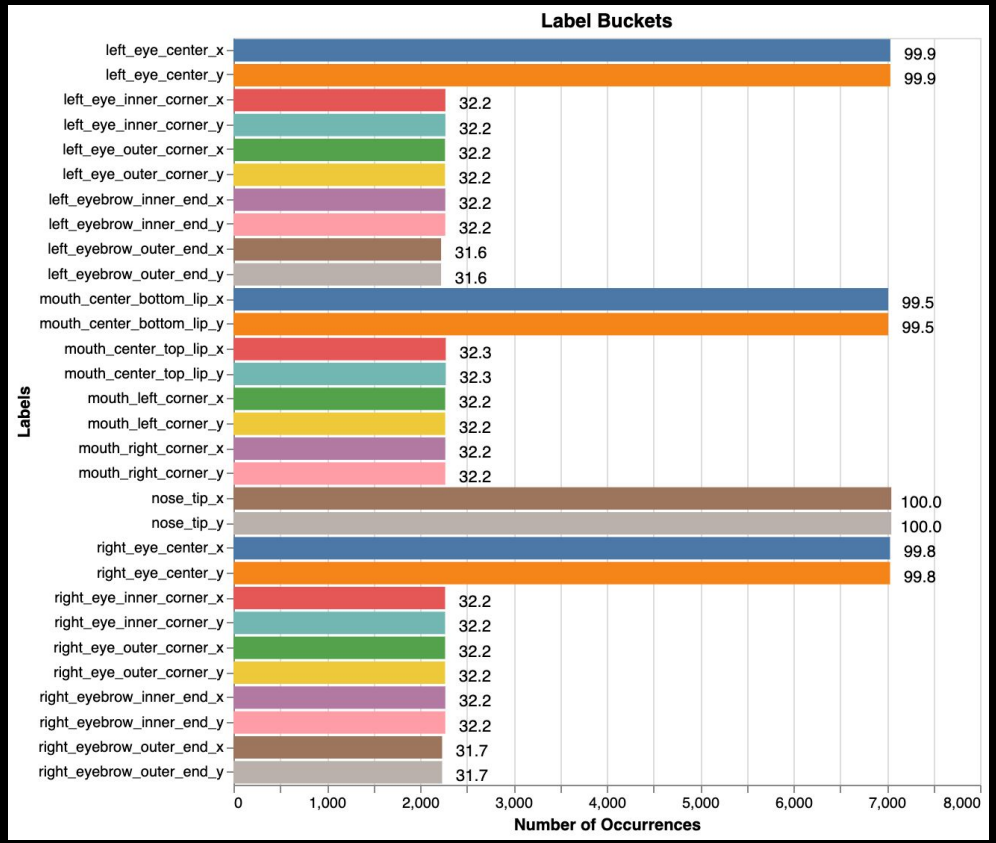
Exploratory Data Analysis: Duplicates







Exploratory Data Analysis: Missing Data

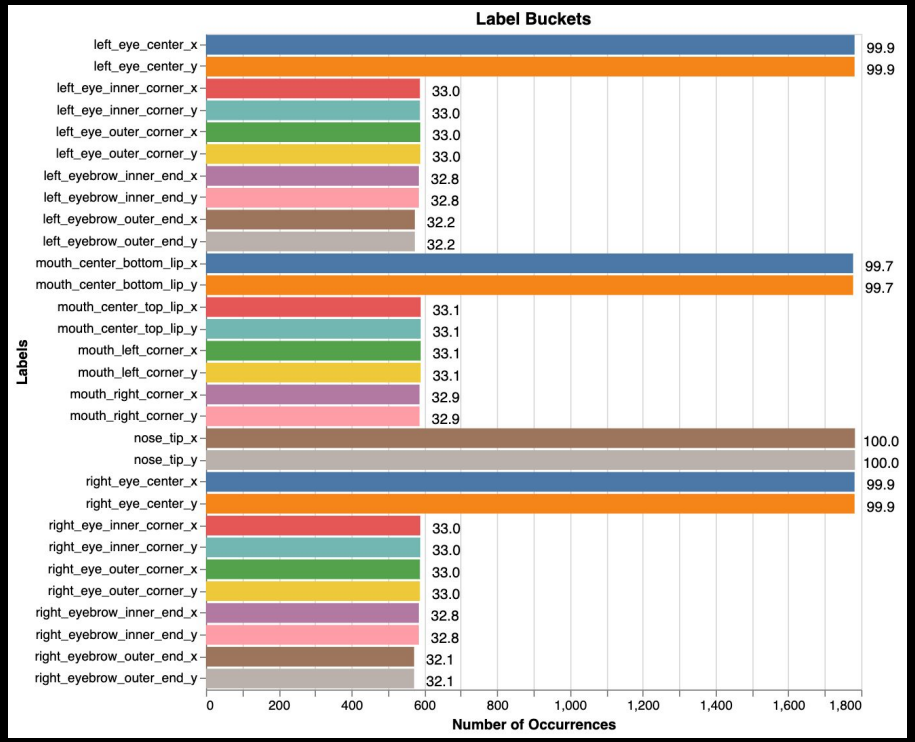


(x, y) Keypoints to predict:

- left_eye_center
- right_eye_center
- left_eye_inner_corner
- left_eye_outer_corner
- right_eye_inner_corner
- right_eye_outer_corner
- left_eyebrow_inner_end
- left_eyebrow_outer_end
- right_eyebrow_inner_end
- right_eyebrow_outer_end
- nose_tip
- mouth_left_corner
- mouth_right_corner
- mouth_center_top_lip
- mouth_center_bottom_lip

~70% of data is missing for certain keypoints!

Exploratory Data Analysis: Test Predictions

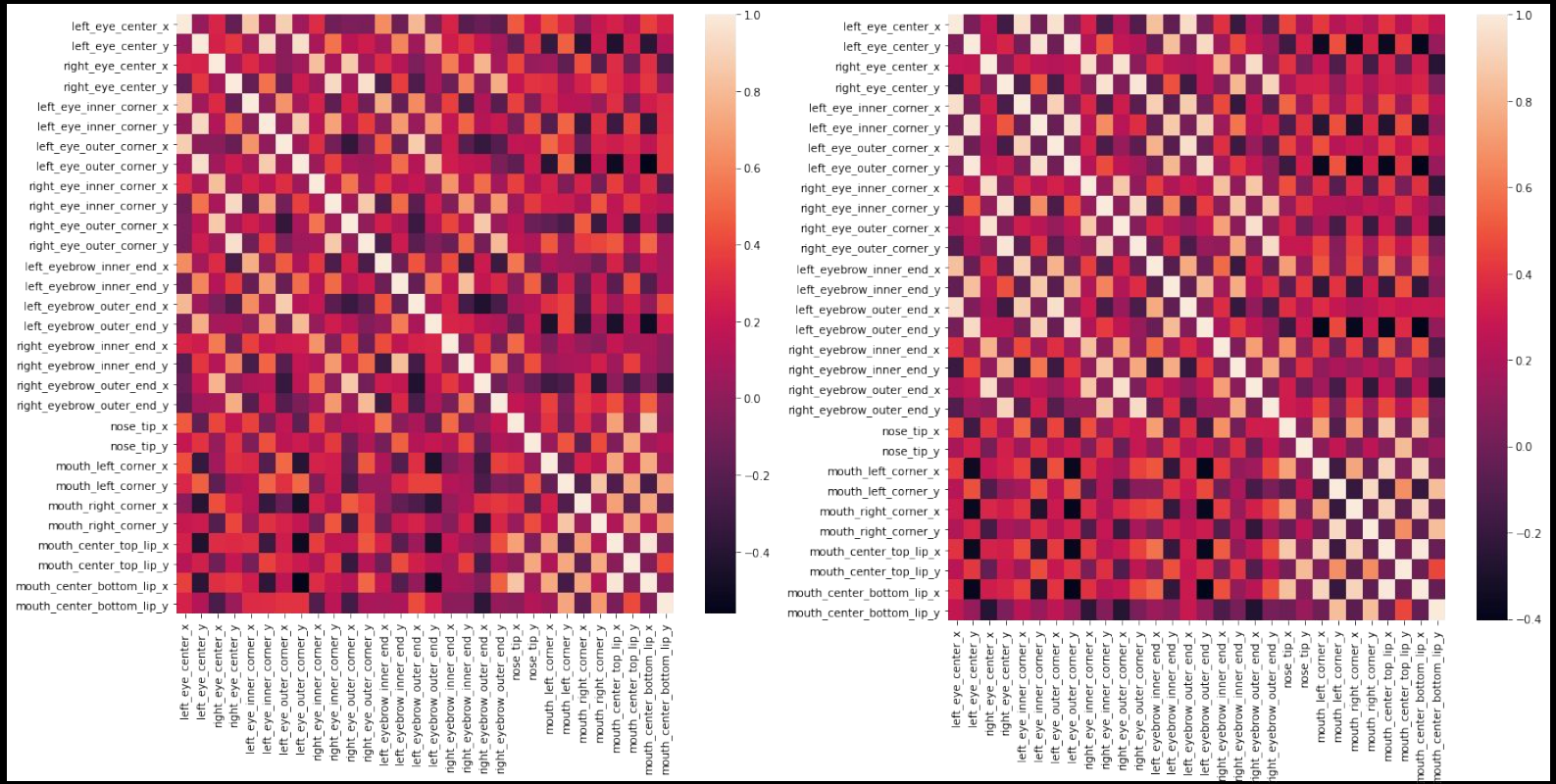


Most of the images we will need to predict only require 8 keypoints.

Approach to Missing Data: Linear Model

- Features which have ≤ 50-missing data-points are considered Dense.
- Features which have no missing-data-points are considered full.
- ≥ 2 significantly correlated reference points used to triangulate.
- Correlations of more than 0.5 are considered significant.
- Data-points which are full in ('X' and 'y') are used to train the corresponding linear-model.
- Data-points which are full in 'X' but empty in 'y' are augmented by this model.
- This augmentation was possible by setting the acceptable accuracy (R^2) to 0.45.
- >0.45 the augmentation does not converge;
- for a few features, the models that came up were less than 50% accurate.

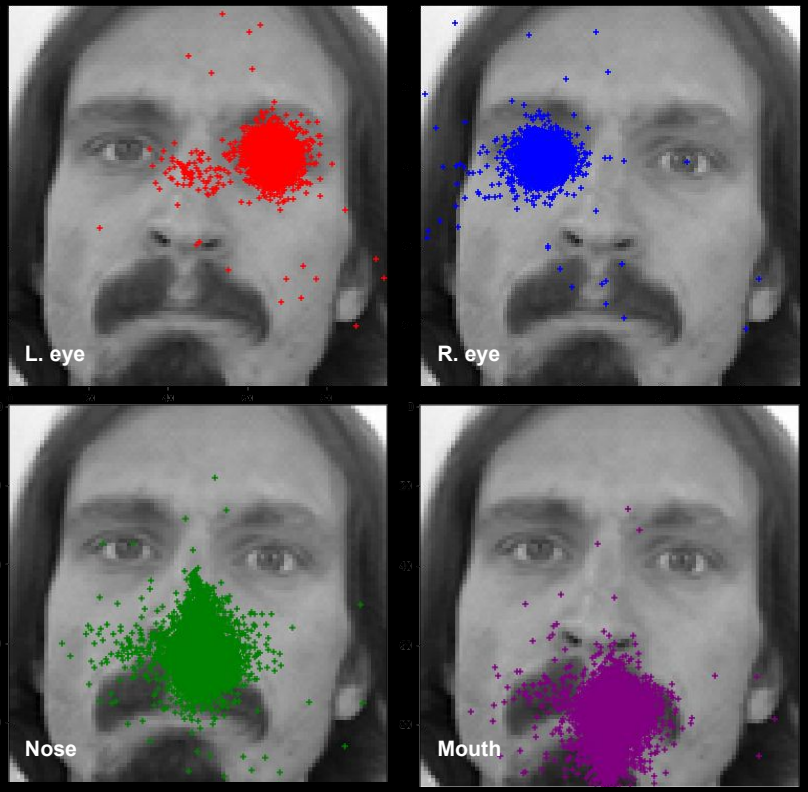
Approach to Missing Data: Linear Model

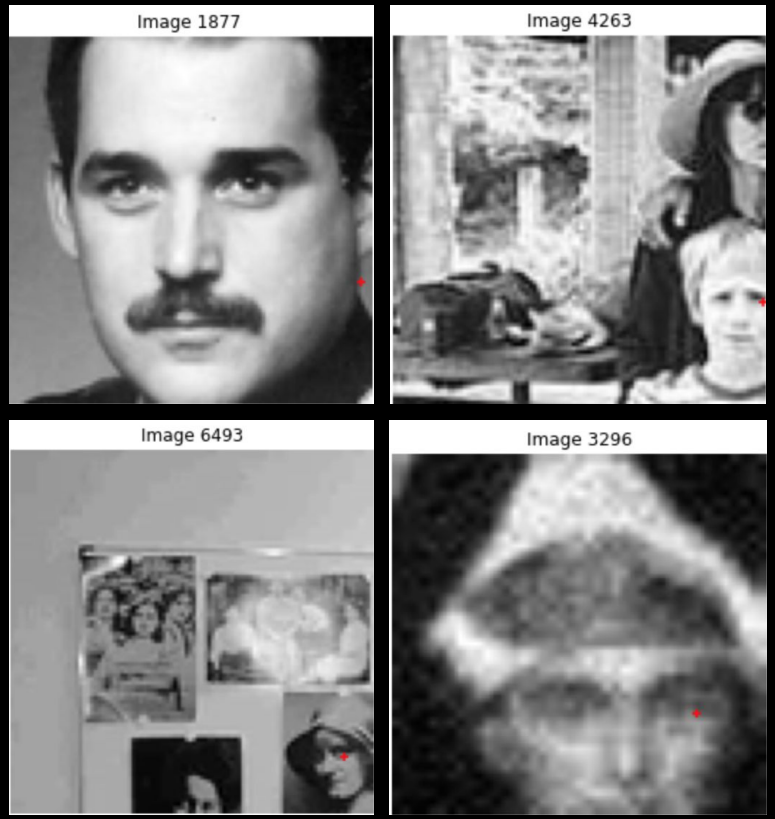


Before Augmentation

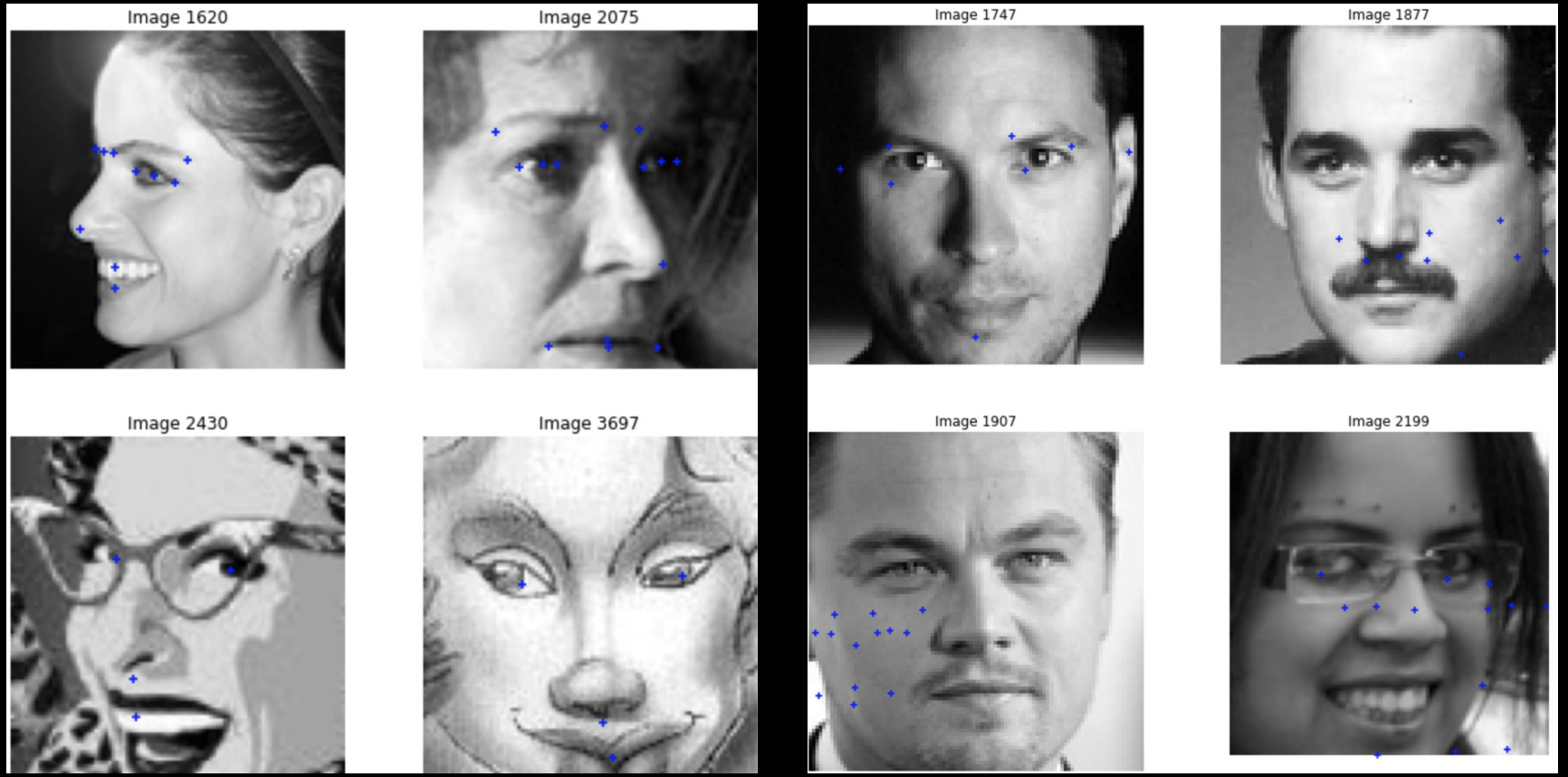
After Augmentation

Exploratory Data Analysis: Outliers



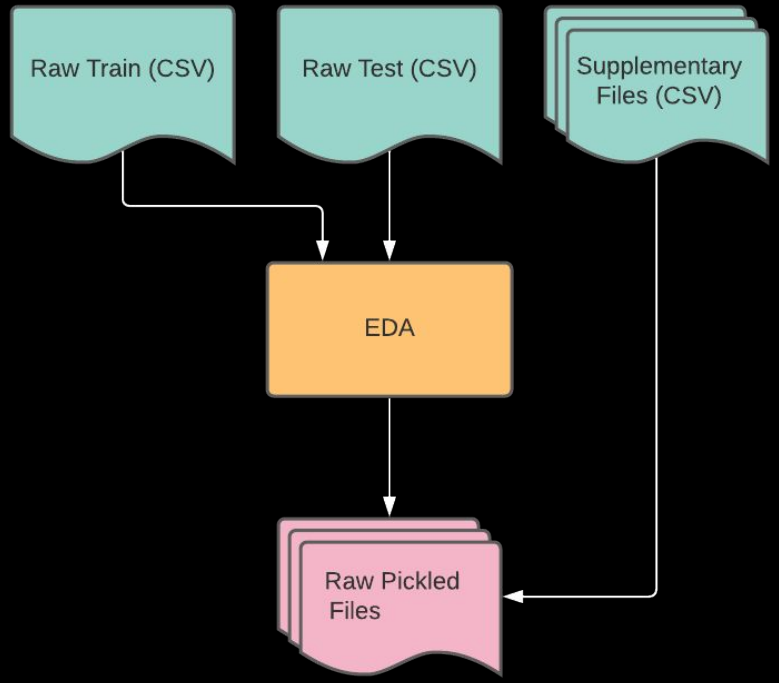


Exploratory Data Analysis: Interesting & Mislabelled



Exploratory Data Analysis: Conclusions

- **Duplicates:**
  - Same image repeated.
  - Same person, different angles/expressions.
- **Distractions:**
  - Eyewear, hats, moustaches.
  - Blurry, grainy photos.
  - Multiple people in same.
  - Collages.
  - Angled.
- **Unconventional Images:**
  - Cartoons.
  - Babies.
  - “Pictures” of people.
- **Mislabelled:**
  - Labels in wrong place.
- **Outliers:**
  - Labels very far off their intended position.
- **Miscellaneous:**
  - Extreme angles.
  - Cut off pictures.

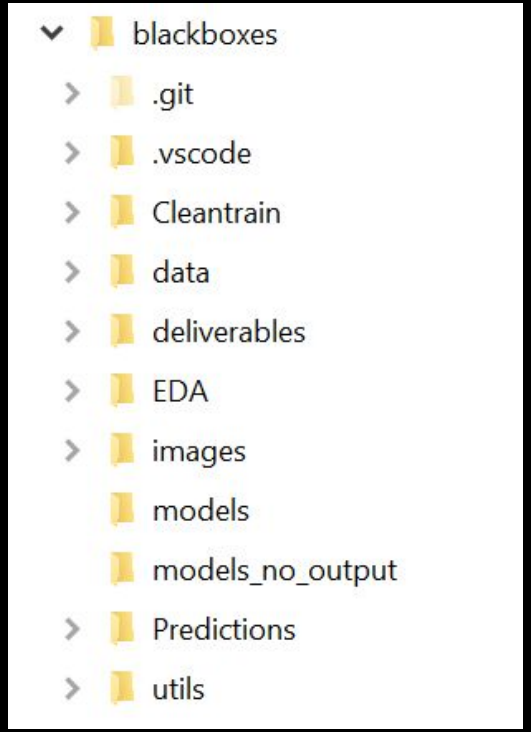


Exploratory Data Analysis: Conclusions

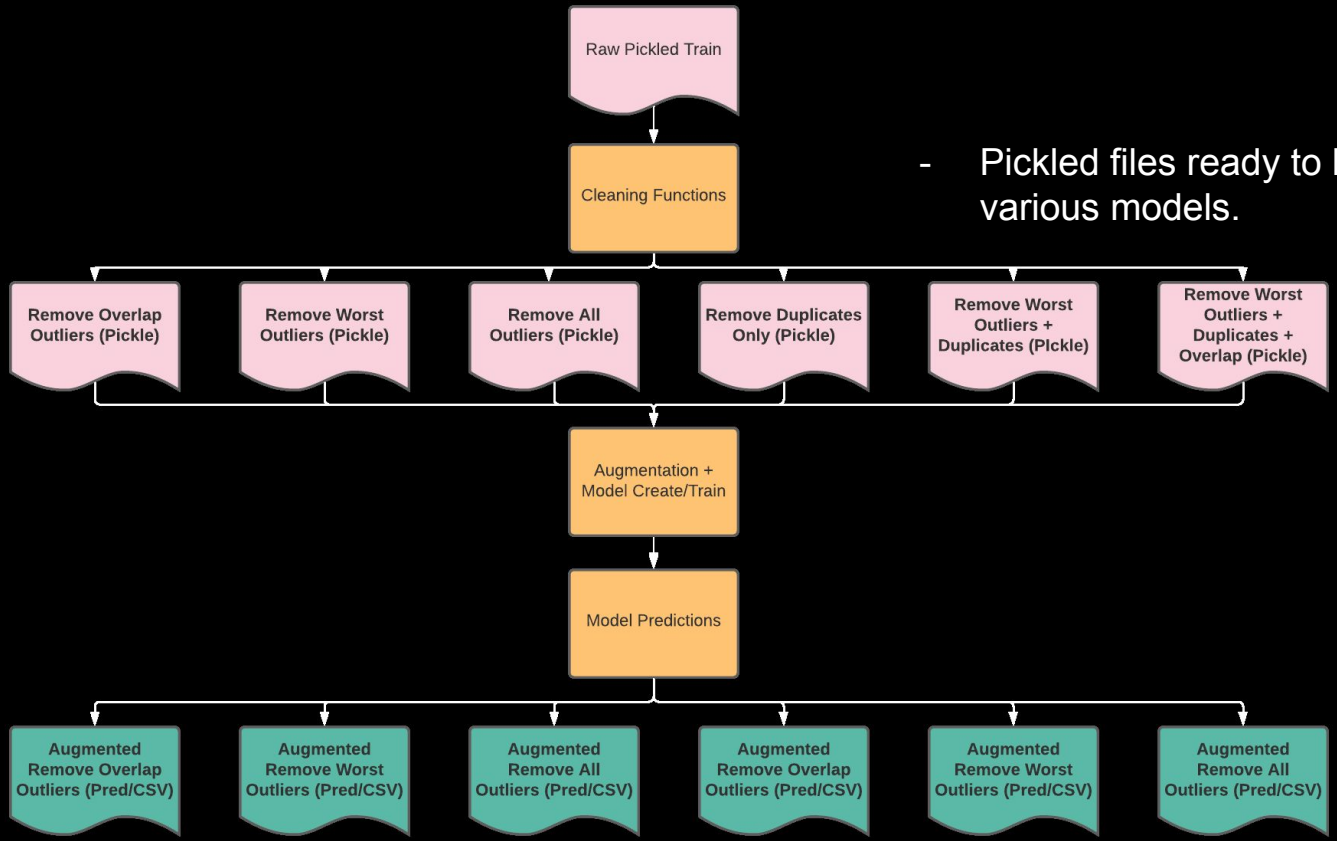
Repository Structure

Level 0 / Main Categories:

- EDA
- Predictions
- README
- CleanTrain
- Data
- Deliverables
- Images
- Models
- Models_no_output
- Utils

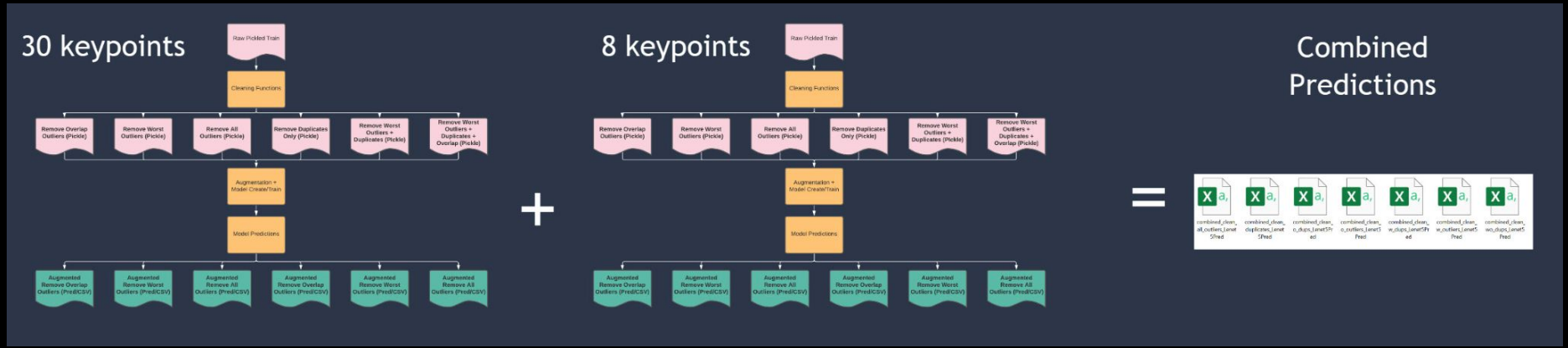


Data Cleaning & Augmentation

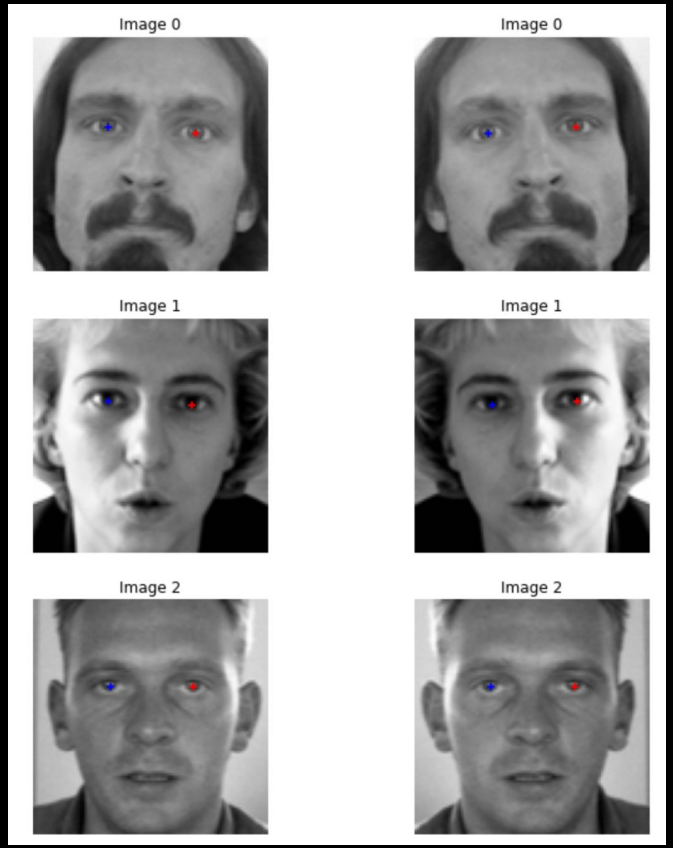


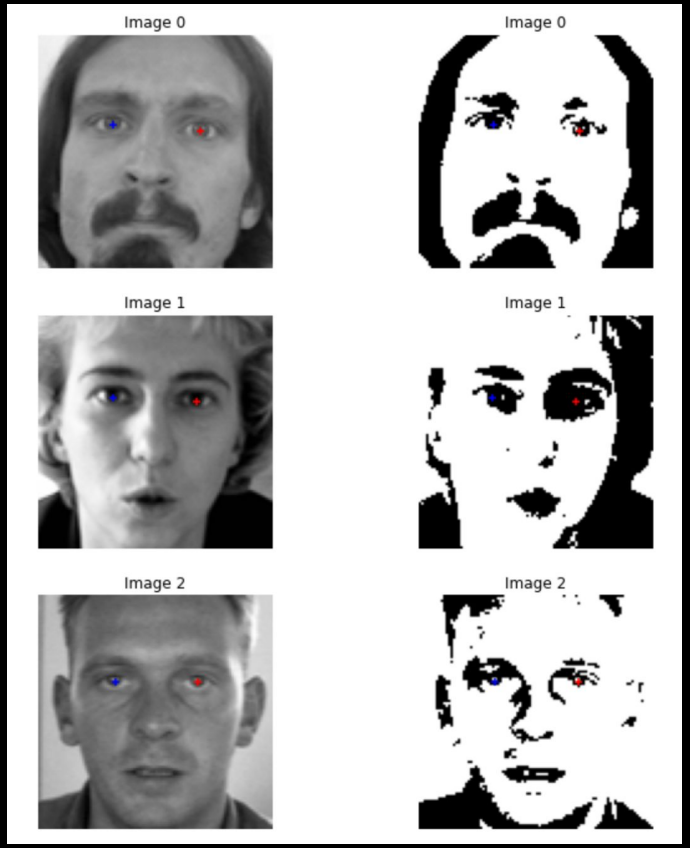
- Pickled files ready to be used to create various models.

Data Augmentation - Another approach

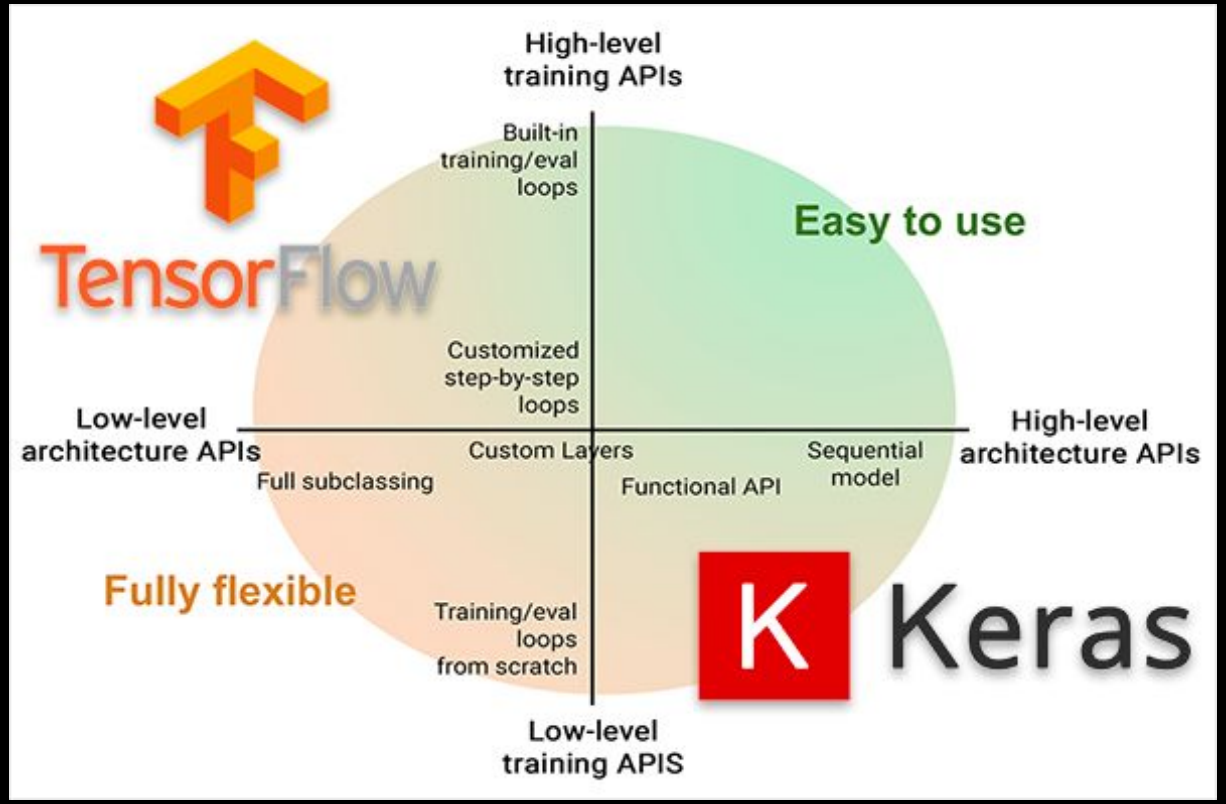


Exploratory Data Analysis: Augmentations





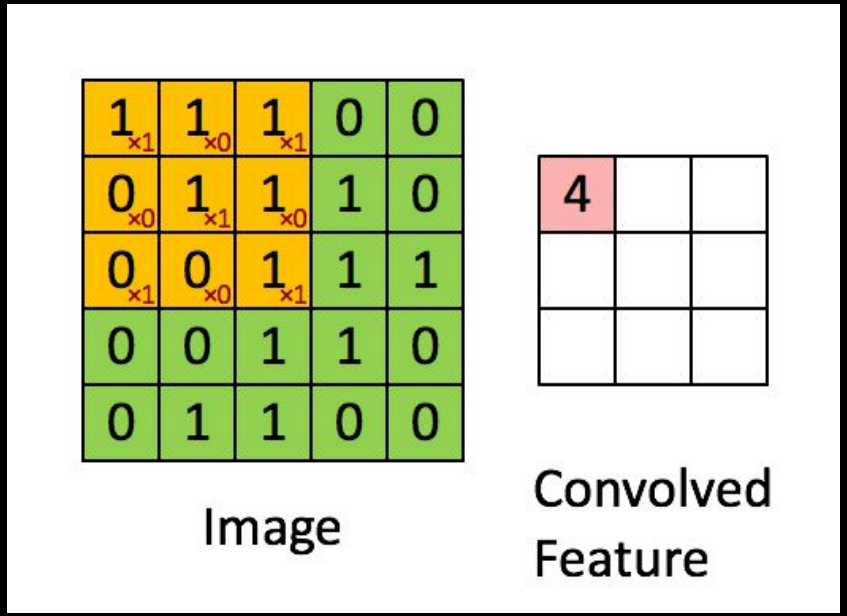
TensorFlow vs. Keras



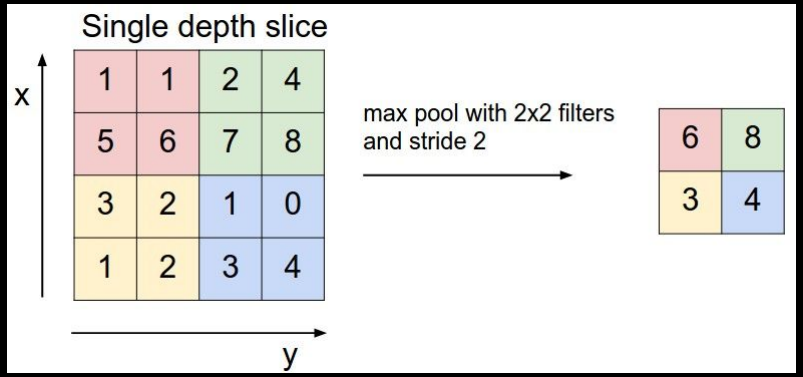
- Keras is the user-friendly user interface to create CNN's using a TensorFlow backend.
- https://www.pyimagesearch.com/2019/10/21/keras-vs-tf-keras-whats-the-difference-in-tensorflow-2-0/

Some modelling terminology

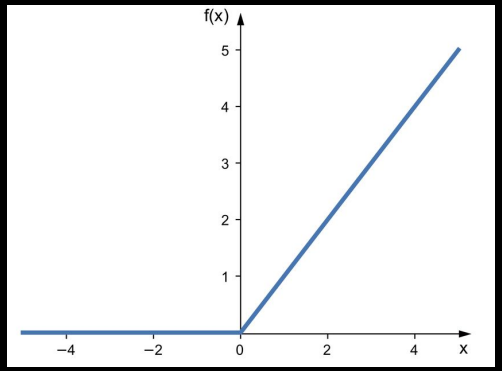
Convolution



Pooling

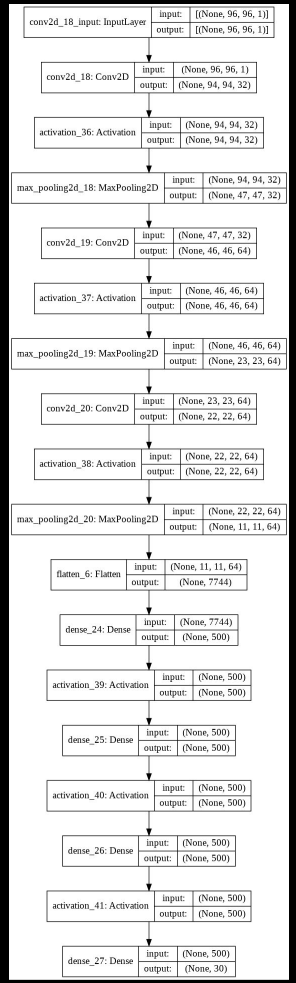


ReLU (Rectified Linear Unit)



Model 1 (SP)

- Based on approaches by Shinya Yuki and Daniel Nouri.
- Input layer takes 4D array (Nsample, NRow, NCol, 1)/(1, 96, 96, 1)
- 3 x 2D convolution layers.
- 32-64-128 filters (doubles each layer).
- Each convolutional layer is followed by a 2x2 max-pooling layer.
- 2 x fully-connected layers.
- Densely-connected layers have 500 units.
- Rectified linear unit (‘ReLU’) activation in each layer.
- Optimizer: Stochastic gradient descent (SGD), learning rate = 0.01, momentum = 0.9, Nesterov = True.
- Batch size of 128.
- Trained for 300 epochs.



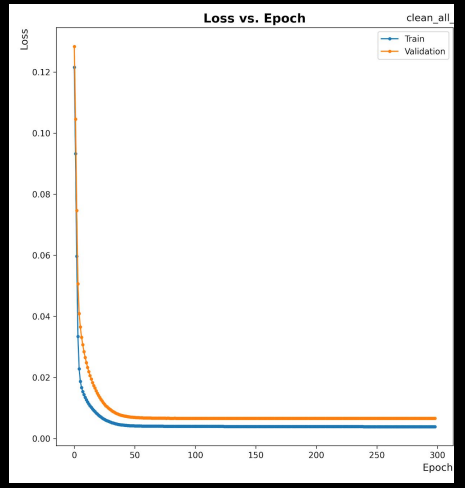
Model 1 (SP): Performance

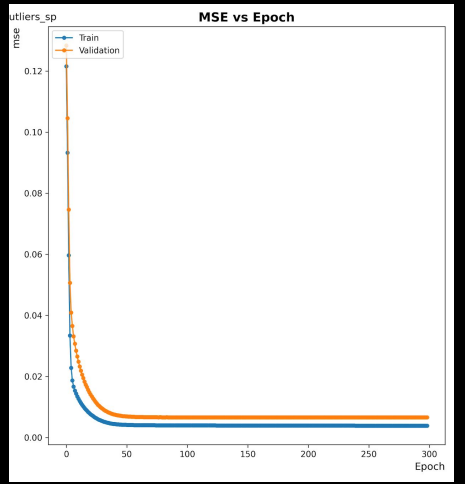
- Model achieved top score of ~3.53
- Used approach combining predictions using 8 and 30 keypoints.

29 submissions for span852 — Sort by: Private Score

All | Successful | Selected

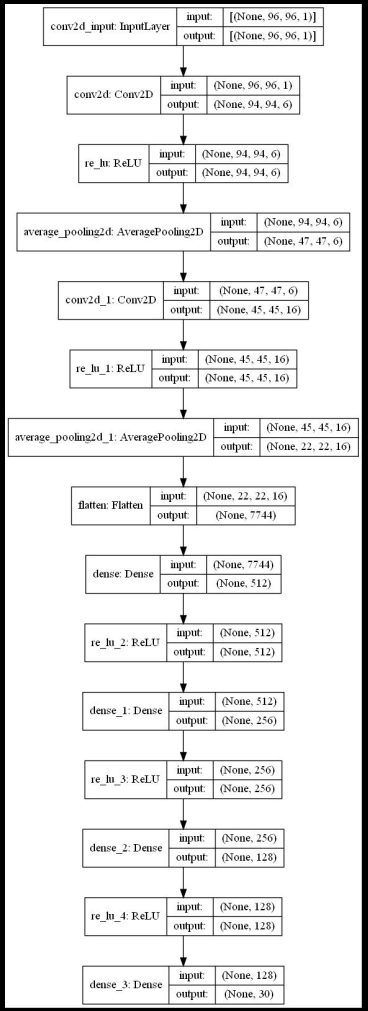
Submission and Description	Private Score	Public Score
combined_clean_o_outliers_spPred.csv a minute ago by span852 combined_4	3.53171	3.76181
combined_clean_w_dups_spPred.csv a few seconds ago by span852 combined_5	4.01852	4.14986
combined_clean_duplicates_spPred.csv 2 minutes ago by span852 combined_2	4.05111	4.16324





Model 2 (JN)

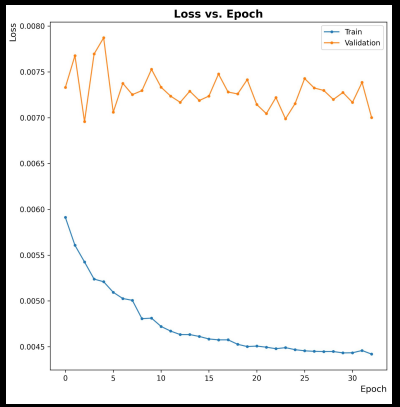
- Inspired by the famous LeNet-5 model
- Input layer takes 2D array (96, 96, 1)
- 2 sets of [2D convolution layers + rectified linear unit (RELU) + 2DAverage Pooling] x 3 Dense layers
- 128 batch size, 300 epochs with a patience set at 30 (with early stop set).
- Adam optimizer - stochastic gradient descent method that is based on adaptive estimation of first-order and second-order moments and recommended for CNN
- `act = Adam(lr = 0.001, beta_1 = 0.9, beta_2 = 0.999, epsilon = 1e-8)`
- `lss = 'mean_squared_error'`
- Various flavors of this model were created and used for predictions

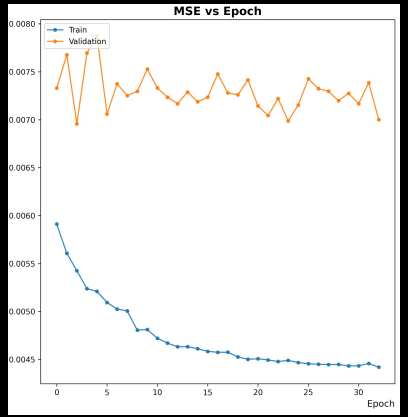


Model 2 (JN) - Approach and Performance

The following variations of models were created:

1. Baseline, no augmentation (3.29689 RMSE)
2. Approach 1: all versions of cleaned train data (clean section) set were used to create models and predictions (3.23581)
3. Approach 2: all versions of cleaned train data (clean section) set were used + varying the layers in the model used to create models and predictions (3.31447)
4. Approach 3: all versions of cleaned train data (clean section) set were used + varying layers + image augmentation (brightness and dim) to create models and predictions (3.31447)
5. Approach 4: Use different cleaned versions of train data set flip the images, add brigthness=0 dim = 0 for 30 keypoints and 8 keypoints. (2.8062)
6. **Approach 5:** Use only clean_all_outliers of train data set flip the images, add brigthness=1.4 dim = 0.3 for 30 keypoints and 8 keypoints - full layers (2.48797)



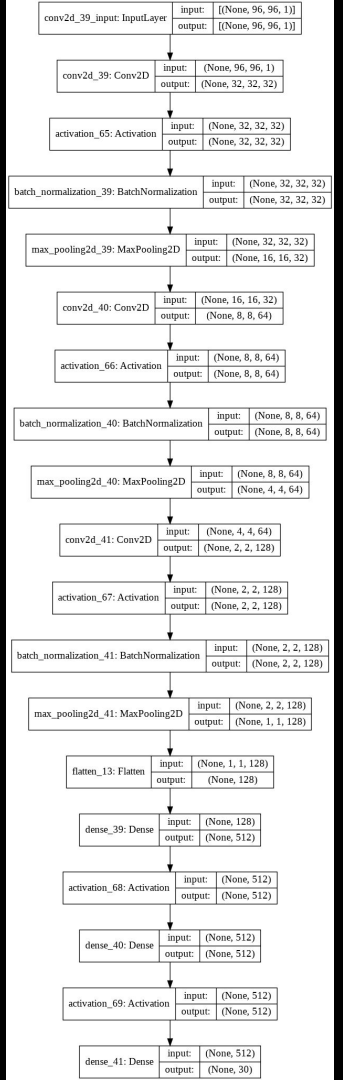


Thank goodness for GPUs!

Submission and Description	Private Score	Public Score
combined_clean_all_outliers_Lenet5Pred.csv a few seconds ago by JackieN 8+30+flip+bright=1.4+dim=0.3+extra layer	2.21913	2.48797
combined_clean_all_outliers_Lenet5Pred.csv 9 minutes ago by JackieN 8+30+flip+bright=1.4+dim=0.3	2.25203	2.52140
combined_clean_all_outliers_Lenet5Pred.csv 33 minutes ago by JackieN 8 + 30 + horizontal flip + bight = 0 + dim = 0	2.49707	2.80652

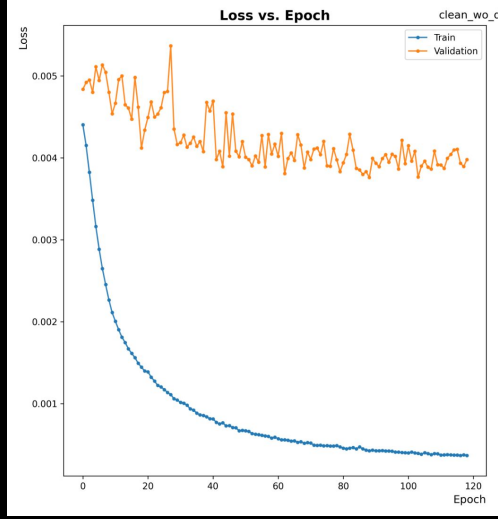
Model 3 (JCW)

- Following Shinya Yuki's tutorial
- Convolutional NN with 3 convolutional layers and 2 fully connected layers
- Performed maximum pooling of 2x2 after each convolutional layer
- 'Relu' activation function
- Adam optimizer - stochastic gradient descent method that is based on adaptive estimation of first-order and second-order moments and recommended for CNN

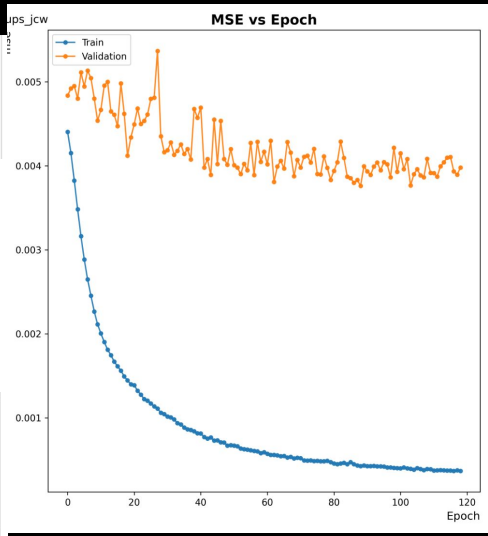


Model 3 (JCW) - Approach and Performance

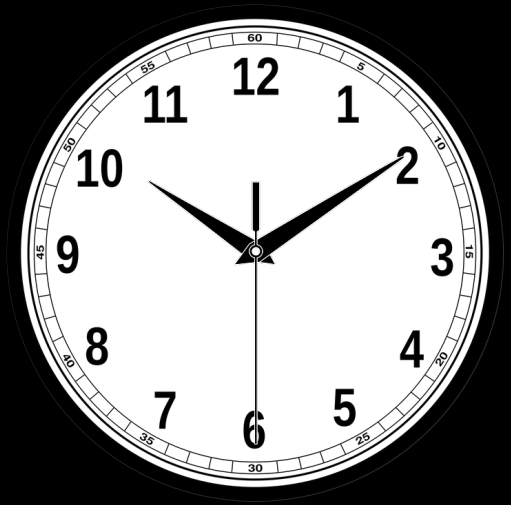
- Additional Approaches:
  - Setting use_bias to True/False
  - Removing/adding a BatchNormalization layer
  - Appending flipped images to the dataset
  - Brightening all the images
  - Appending flipped images and that whole set brightening
  - Appending both flipped and brightened to train set
  - 8 + 30 approach

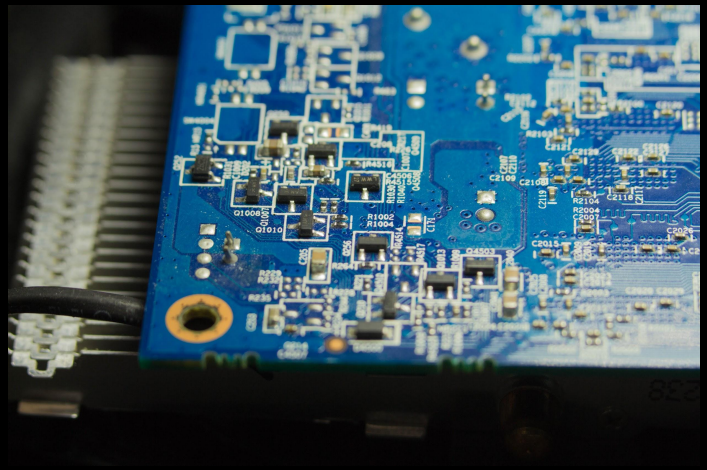


clean_wo_dups_jcwPred_nobatch.csv 2 days ago by Joanie Weaver add submission details	3.73212	3.85070
clean_wo_dups_jcwPred_flipped_append.csv 2 days ago by Joanie Weaver no batch, bias true, flipped appended to orig data	3.64806	3.64608
clean_wo_dups_jcwPred_nobatch_nobias.csv 2 days ago by Joanie Weaver add submission details	3.83627	3.83681
clean_wo_dups_jcwPred.csv an hour ago by Joanie Weaver appended flipped and brightened images to train	3.55585	3.56512



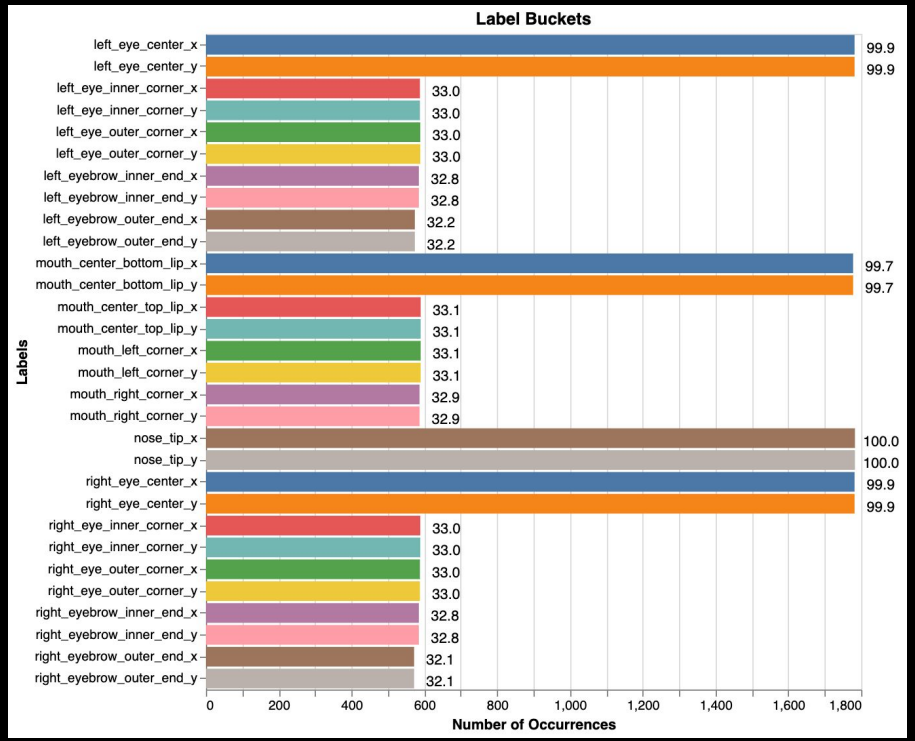
Challenges





jupyter

Conclusions: Test Predictions



IdLookup Table from Kaggle:

	row_id	image_id	feature_name
0	1	1	left_eye_center_x
1	2	1	left_eye_center_y
2	3	1	right_eye_center_x
3	4	1	right_eye_center_y
4	5	1	left_eye_inner_corner_x
...	...	...	...
27119	27120	1783	right_eye_center_y
27120	27121	1783	nose_tip_x
27121	27122	1783	nose_tip_y
27122	27123	1783	mouth_center_bottom_lip_x
27123	27124	1783	mouth_center_bottom_lip_y

Counts of the Number of Features Required for Each Test Images:

num_features	count
8	1190
30	556
28	18
26	9
24	3
6	2
20	2
22	2
18	1

Most of the images we will need to predict only require 8 keypoints.

Conclusions

- Success of cleaning
- Data is two datasets combined and it makes sense to treat it that way (30 vs 8 key points)
- Success of having more accurate data (vs. augmenting with inaccurate values)
- Learning about CNNs
- Wish we had more time to explore:
  - Stacking models in a k-fold approach
  - Additional augmentation on missing data
  - Transforming new variations of the training images
- We had fun :)

Conclusions and Challenges

- Cleaning and how we cleaned made an impact
- We could explore augmentation for weeks and there's a lot more here we didn't get to try
- Data is two datasets combined (30 vs 8 key points)
- Having more accurate data improved predictions vs. more inaccurate data
- The wonderful challenge of time and money!!
    - It was obvious that we could spend a lot more time on this challenge
    - More GPU's == More $$
    - Google Colab is free, pretty easy and provides a fair amount of GPU
- Collaborating in GitHub on Python notebooks
    - We managed but caution had to be taken
- CNN - New area outside of the scope of models we touched on in class. It's a big world!!
- Given time, we would have liked to have attempted stacking models in a k-fold approach, tried additional augmentation on missing keypoints as well as creating new variations of the training images.

Thank you

Thanks for listening! Any comments or questions?