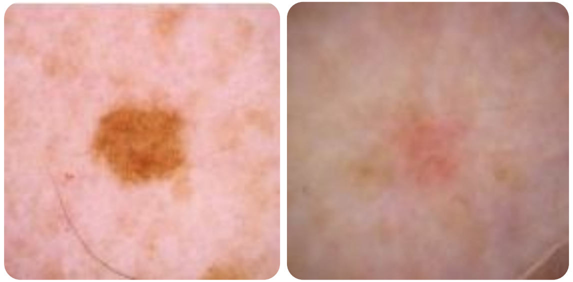
Classifying Melanoma

What Is the Melanoma Dataset?

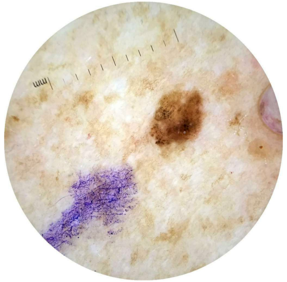
- Annual competition on Kaggle
  - Lots of highly skilled veterans!
- Expert Judgement: 74.1% sensitivity and 60% specificity by dermatologists
- Challenges
  - Large Data Set: 35 GB+ of JPEGs
  - Unbalanced classes: Only 500 positive examples out of n=30,000+)
  - Heterogeneous format: Inconsistent image quality/shape/brightness/orientation
  - Visually ambiguous classes

Can you tell which one is Melanoma?



Sexy hair...

Round crop!?



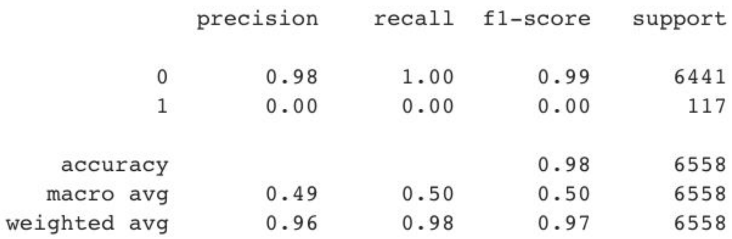
Baseline Models

Baseline Models

- Logistic Regression
- Support Vector Machine

Baseline Results

Logistic Regression

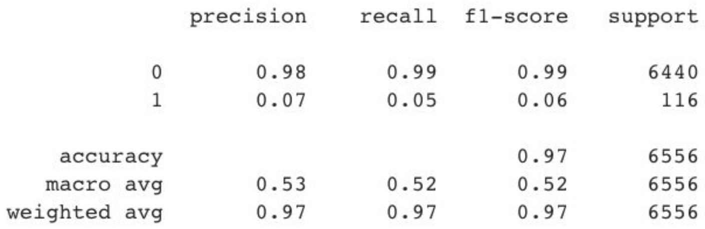


```
              precision    recall  f1-score   support

           0       0.98      1.00      0.99      6441
           1       0.00      0.00      0.00       117

    accuracy                           0.98      6558
   macro avg       0.49      0.50      0.50      6558
weighted avg       0.96      0.98      0.97      6558
```

Notes:

- 10 Epochs
- Sigmoid Threshold = 0.5
- No Regularization

SVM (Linear Kernel)

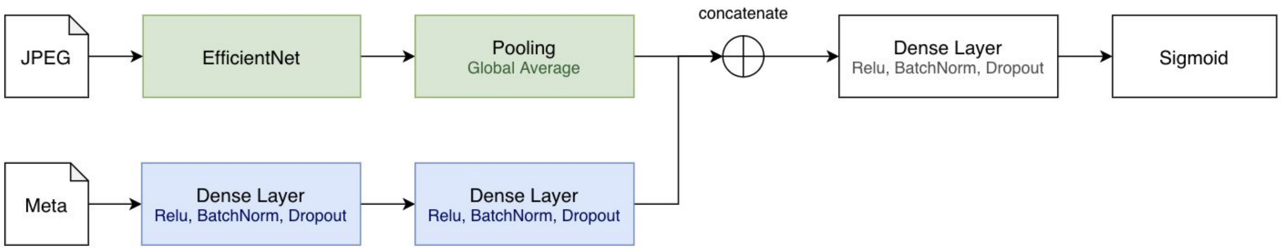


```
              precision    recall  f1-score   support

           0       0.98      0.99      0.99      6440
           1       0.07      0.05      0.06       116

    accuracy                           0.97      6556
   macro avg       0.53      0.52      0.52      6556
weighted avg       0.97      0.97      0.97      6556
```

Neural Networks

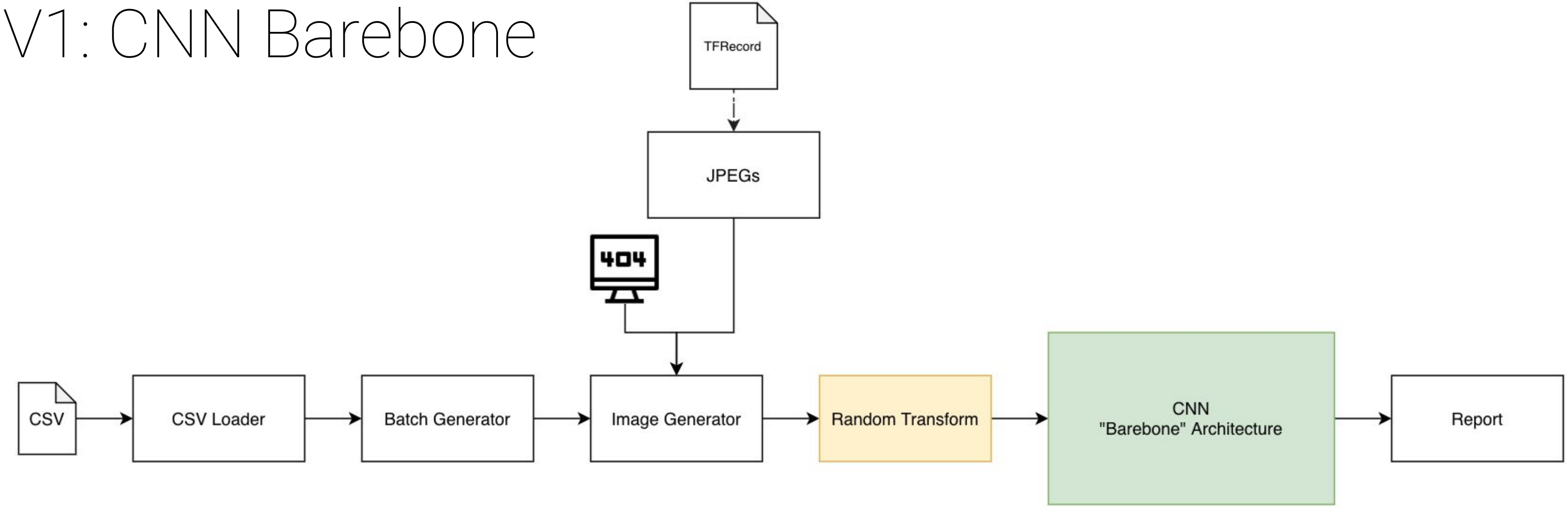
Three Attempts

- **V1**: CNN Barebone
- **V2**: CNN Advanced
- **V3**: CNN (Image) + Neural Network (Metadata)



- **Bonus EDA**: Can neural network learn?

V1: CNN Barebone



Architecture 1

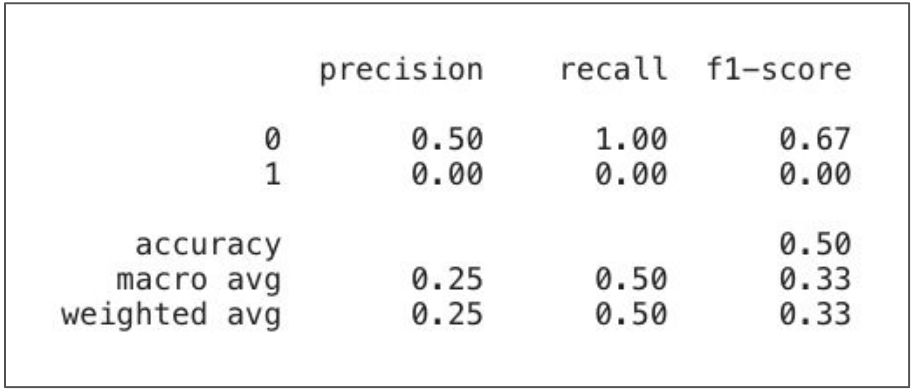
- Input
- Conv. 3x3x64, ReLu
- Conv. 3x3x32, ReLu
- Flatten
- Dense, Softmax

Architecture 2

- Input
- Conv. 3x3x75, ReLu
  - Pool 2x2
  - Dropout 0.15
- Conv. 3x3x125, ReLu
  - Pool 2x2
  - Dropout 0.15
- Flatten
- Dense, Softmax

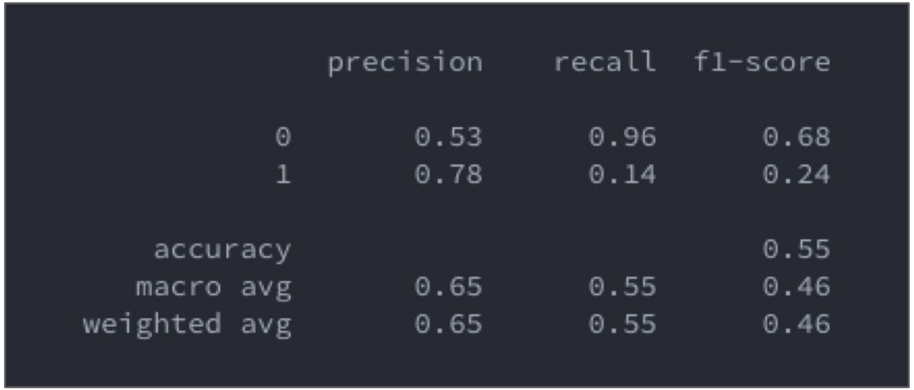
V1: Miserable Failure

First run...



```
              precision    recall  f1-score

           0       0.50      1.00      0.67
           1       0.00      0.00      0.00

    accuracy                           0.50
   macro avg       0.25      0.50      0.33
weighted avg       0.25      0.50      0.33
```

After countless hours of tweaking...



```
              precision    recall  f1-score

           0       0.53      0.96      0.68
           1       0.78      0.14      0.24

    accuracy                           0.55
   macro avg       0.65      0.55      0.46
weighted avg       0.65      0.55      0.46
```

And... a full epoch takes ~1 hour to complete...
Scrapped 1,000+ lines of codes... Ouch!

V2: CNN Advanced

TPU + TFRecord + K-Fold = Efficient Training

Stratified Training Data

EfficientNet

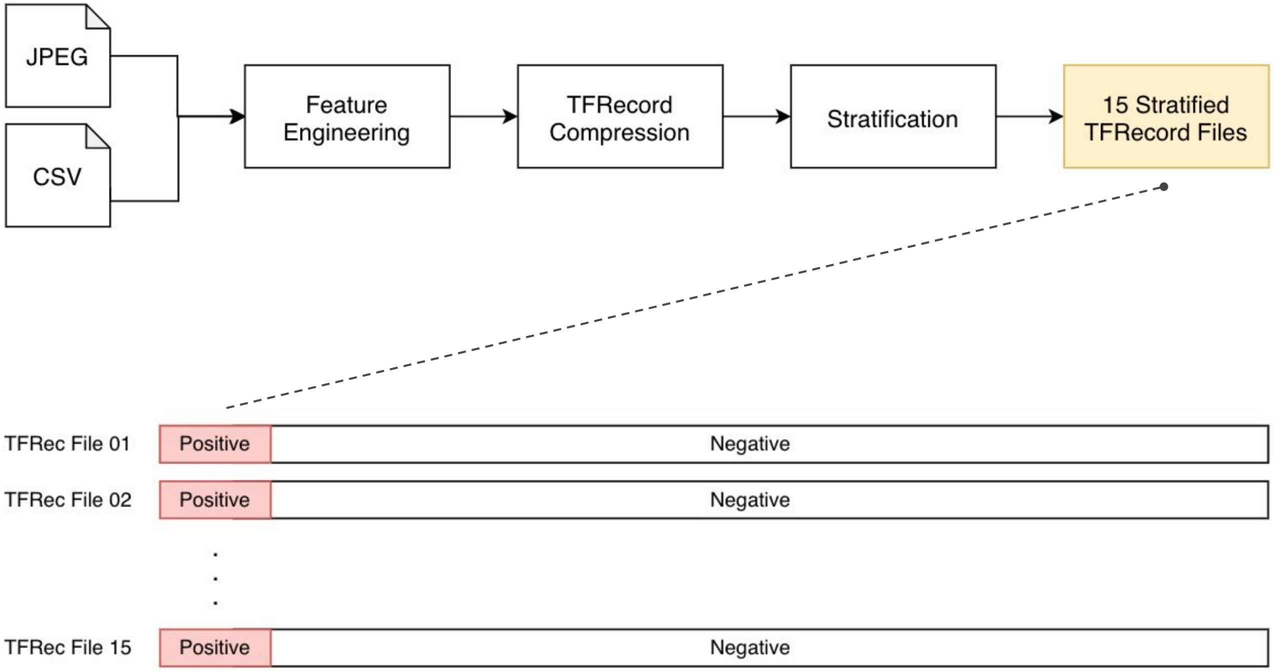
Transfer Learning

Focal Loss

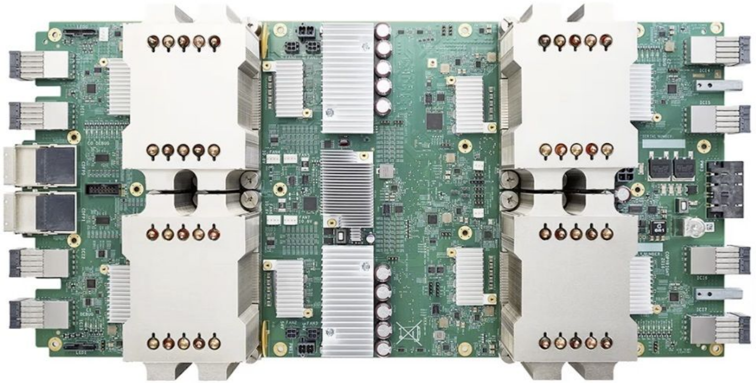
Others

- Additional feature engineering
- Apply random transformation on both training and test datasets
- Restrict image augmentation (e.g. avoid black edges)
- Experiment with hyperparameters using k-fold CV

Stratified Training Data & K-Fold



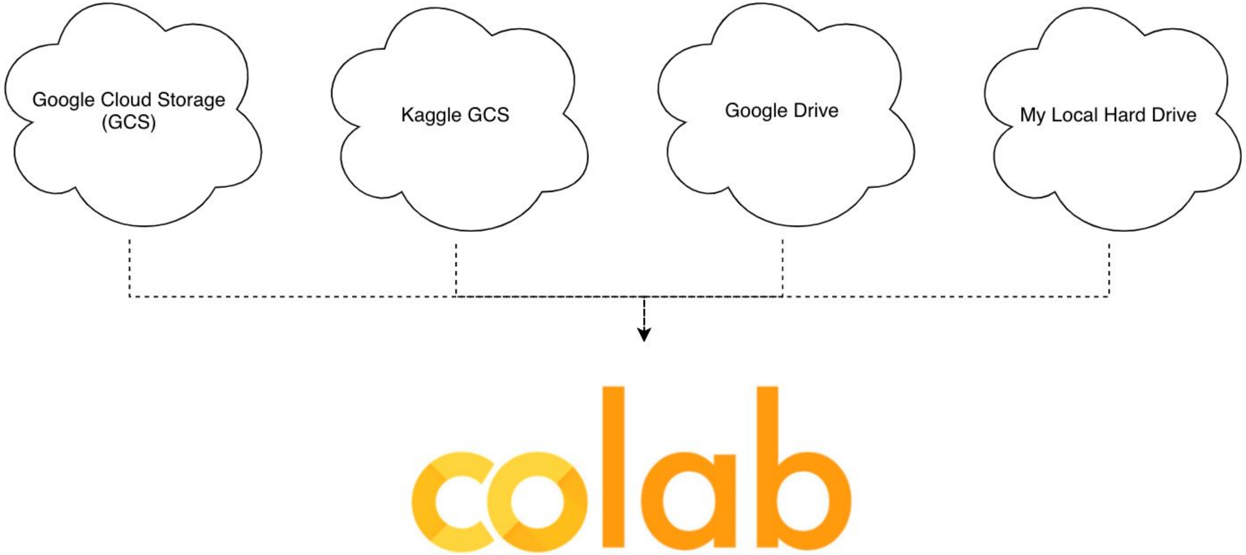
What Is TPU?



colab

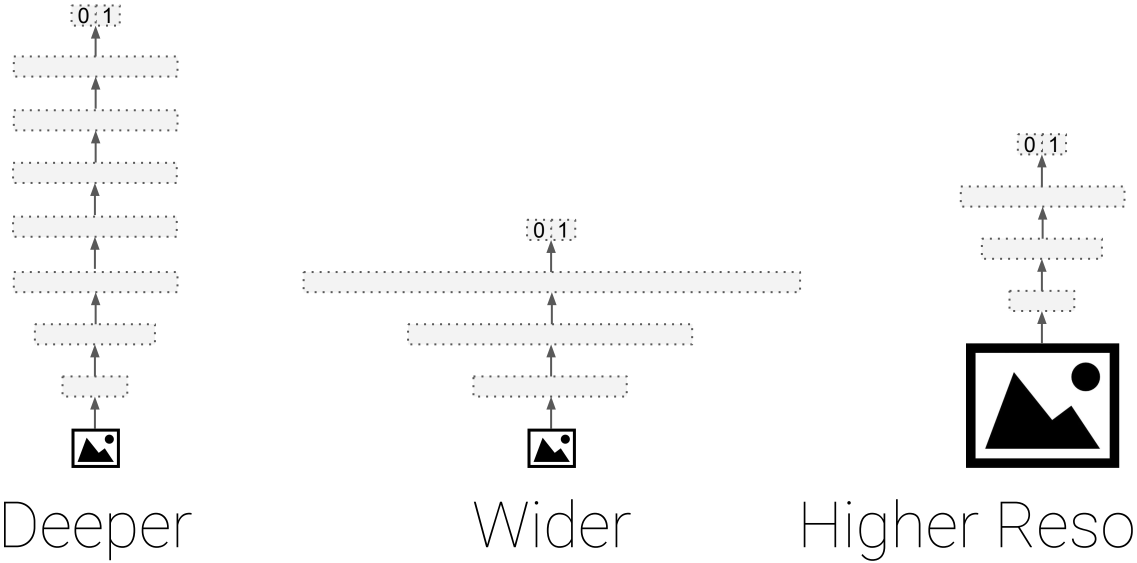
- 4 chips, each has 2 cores
- Processor designed for NN & Tensorflow
- GCS & code changes required (e.g. batch size)!

Colab & TPU


Google Cloud Storage (GCS)
Kaggle GCS
Google Drive
My Local Hard Drive
colab

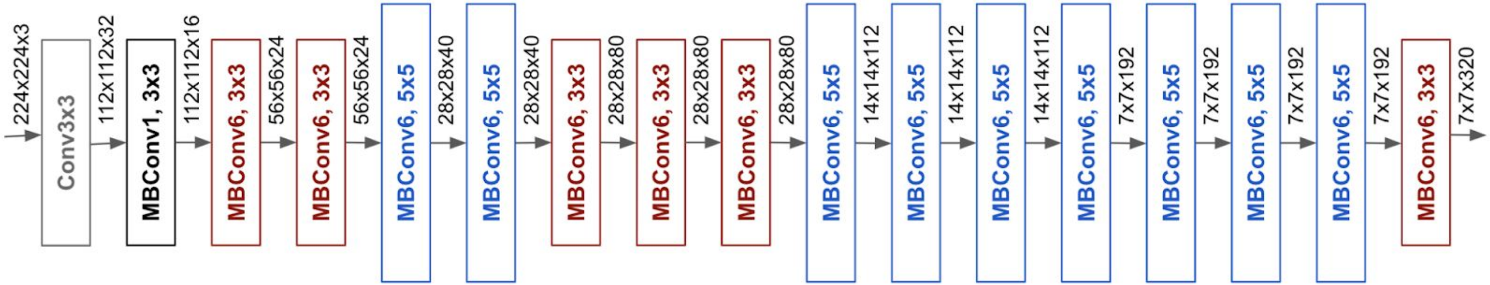
EfficientNet

Problem: How do we scale up a CNN?



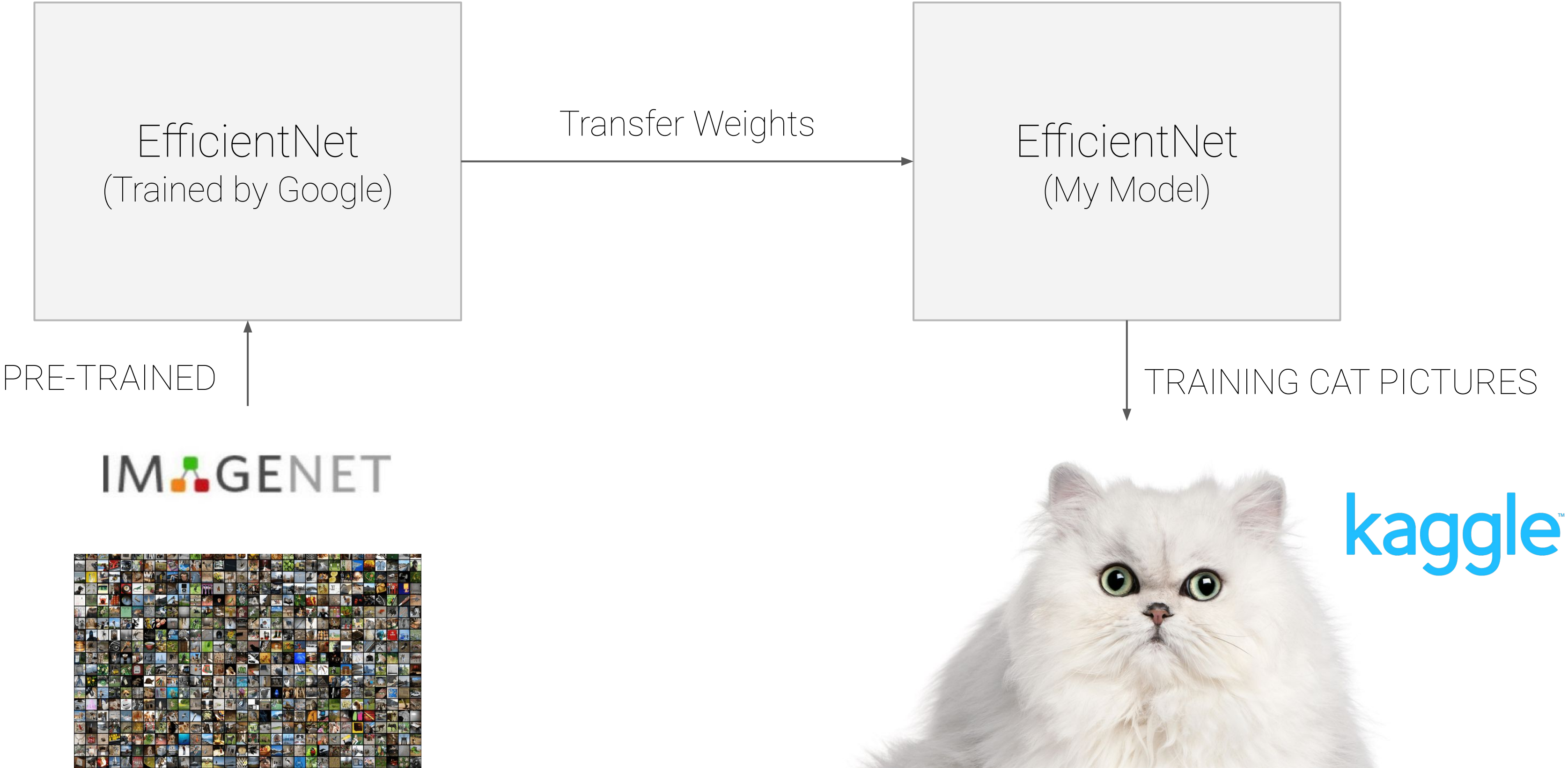
EfficientNet

- Baseline Network
  - EfficientNet-B0 is constructed using neural architecture search, which optimizes both accuracy and efficiency (FLOPS).
- Compound Scaling
  - Grid search to optimally scale up EfficientNet-B0 under a fixed resource constraint
  - Result: B0, B1, B2, ..., B7



EfficientNet-B0

Transferred Learning



EfficientNet
(Trained by Google)

Transfer Weights

EfficientNet
(My Model)

PRE-TRAINED

IMAGENET

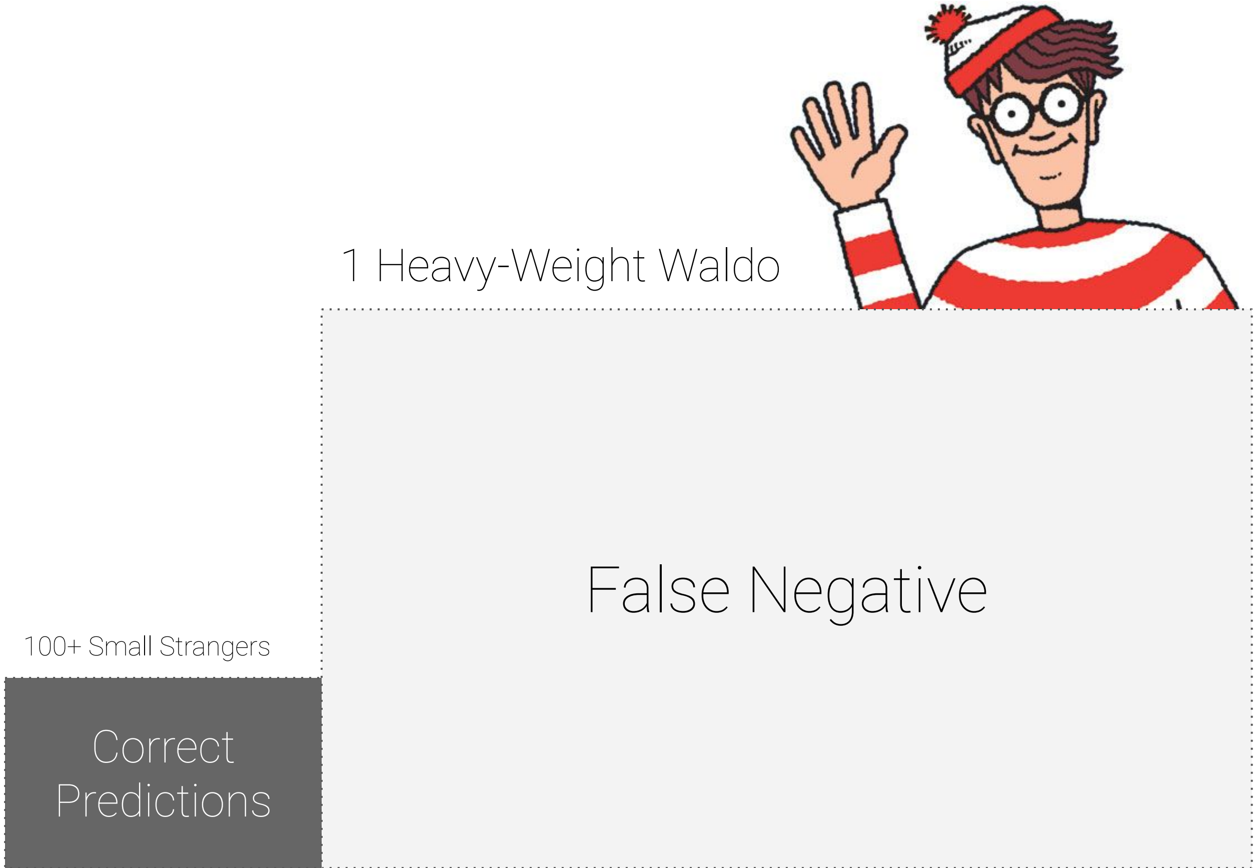
TRAINING CAT PICTURES

kaggle

Focal Loss: ~~Finding~~ Learning Waldo

What if... for every positive example, you have 100+ negative examples?

Solution: Weight Adjustment



1 Heavy-Weight Waldo

False Negative

100+ Small Strangers

Correct Predictions

What Is Focal Loss?

$$FL = -\sum_{i=1}^{C=2} (1 - s_i)^{\gamma} t_i \log(s_i)$$

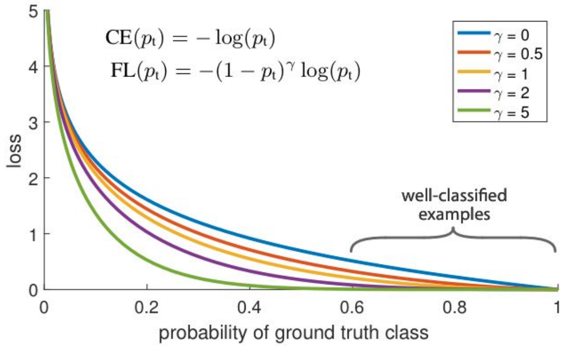
C is the class being predicted
Si is the probability predicted by the neural network

Hyperparameters

- t_i ($\boldsymbol{\alpha}$ on FB's paper) is the probability for positive case
  - 1 in the ideal world
  - Can be adjusted to offset the imbalance in the dataset
- γ is used to adjust the loss curve
  - 2 is the proposed default by FB

Binary Cross-Entropy

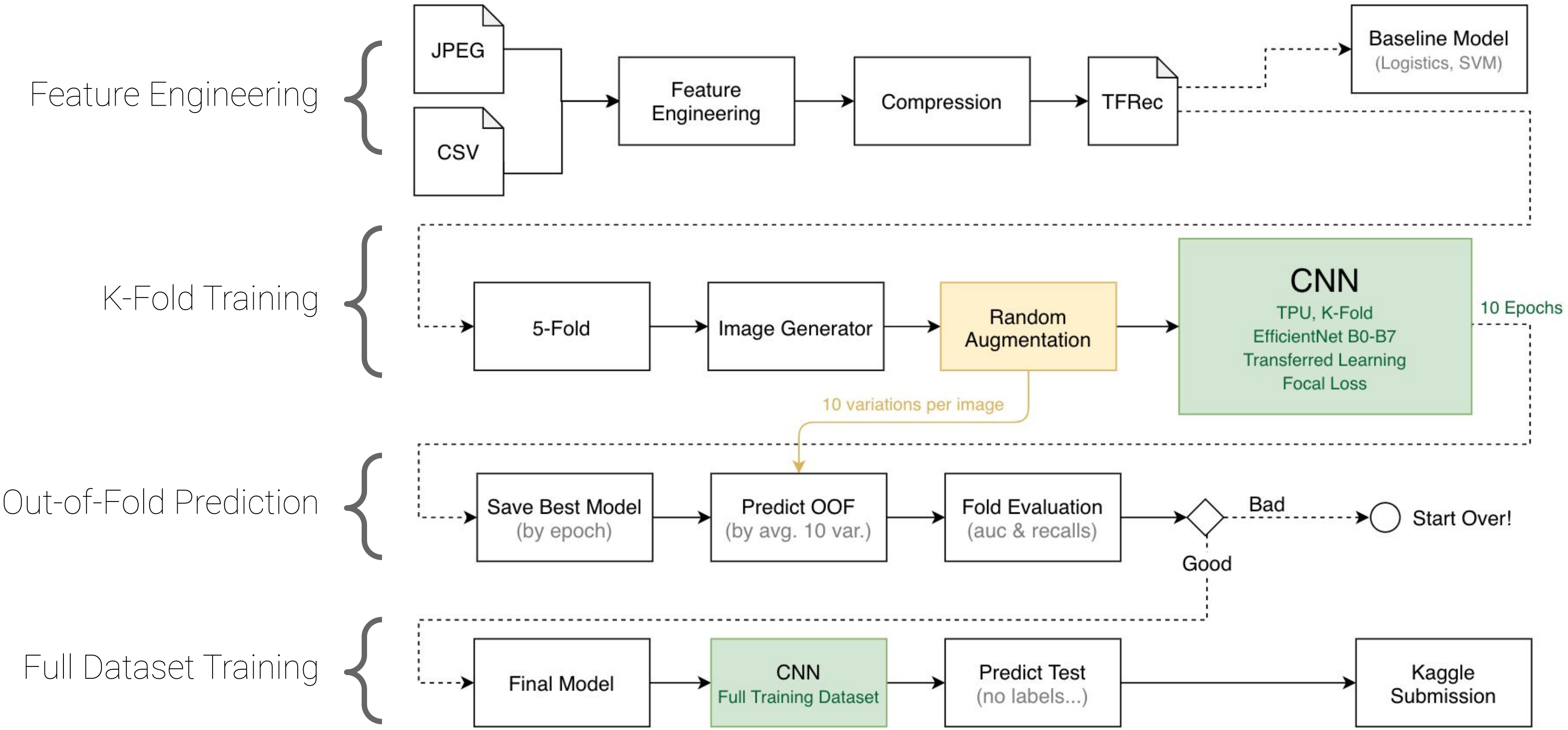
$$CE = -\sum_{i=1}^{C=2} t_i \log(s_i)$$



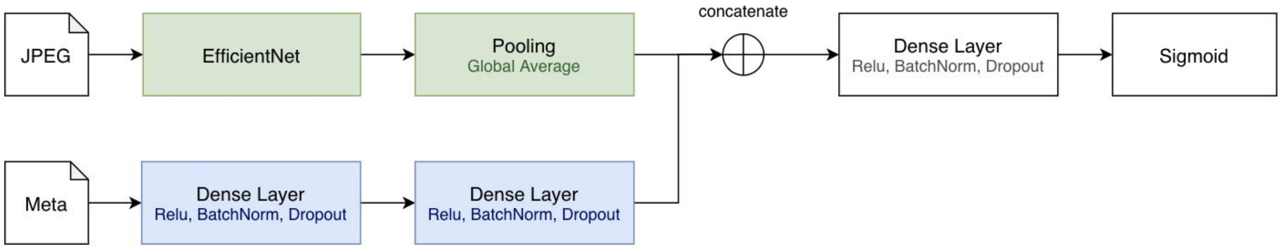
$$L = -\alpha_t (1 - p_t)^{\gamma} \log(p_t)$$

$$\alpha_t = \begin{cases} \alpha & \text{if } y = 1 \\ 1 - \alpha & \text{otherwise} \end{cases}$$

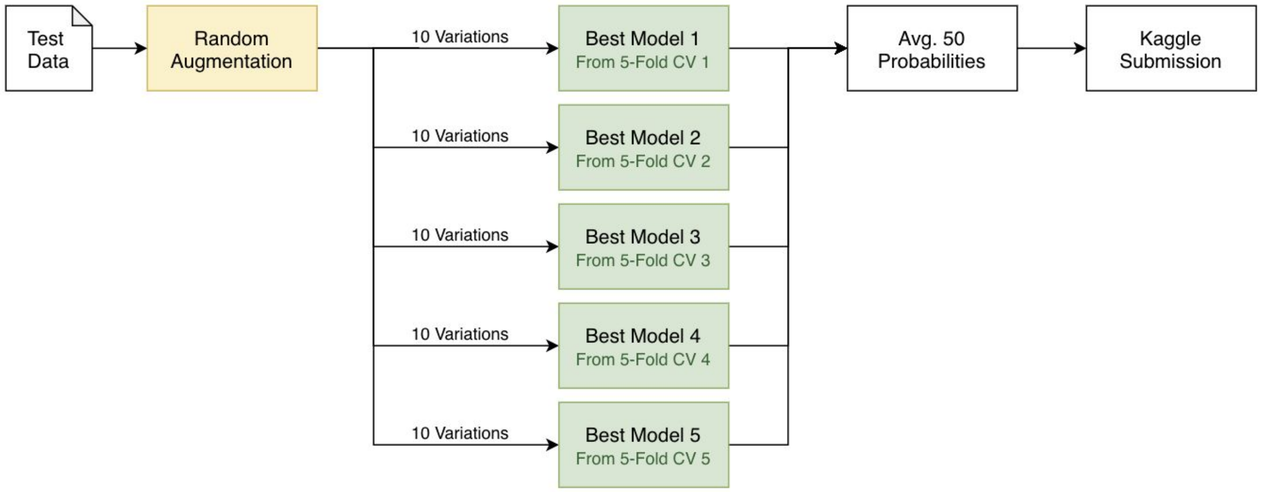
V2 Architecture



V3 Architecture



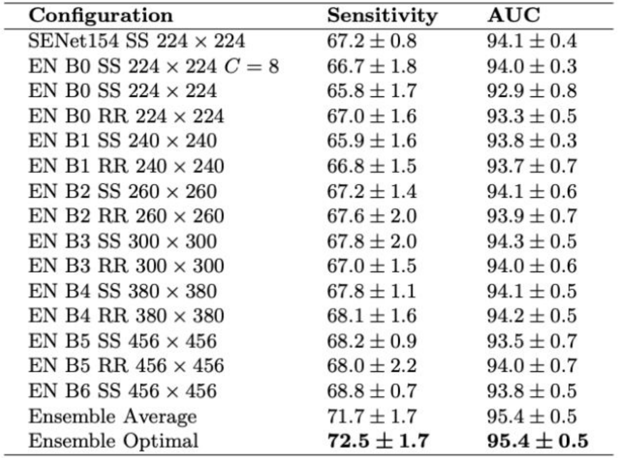
V3 Predictions



Results

V2 Results

Rank #1, 2019 Competition



Configuration	Sensitivity	AUC
SENet154 SS 224 × 224	67.2 ± 0.8	94.1 ± 0.4
EN B0 SS 224 × 224 $C = 8$	66.7 ± 1.8	94.0 ± 0.3
EN B0 SS 224 × 224	65.8 ± 1.7	92.9 ± 0.8
EN B0 RR 224 × 224	67.0 ± 1.6	93.3 ± 0.5
EN B1 SS 240 × 240	65.9 ± 1.6	93.8 ± 0.3
EN B1 RR 240 × 240	66.8 ± 1.5	93.7 ± 0.7
EN B2 SS 260 × 260	67.2 ± 1.4	94.1 ± 0.6
EN B2 RR 260 × 260	67.6 ± 2.0	93.9 ± 0.7
EN B3 SS 300 × 300	67.8 ± 2.0	94.3 ± 0.5
EN B3 RR 300 × 300	67.0 ± 1.5	94.0 ± 0.6
EN B4 SS 380 × 380	67.8 ± 1.1	94.1 ± 0.5
EN B4 RR 380 × 380	68.1 ± 1.6	94.2 ± 0.5
EN B5 SS 456 × 456	68.2 ± 0.9	93.5 ± 0.7
EN B5 RR 456 × 456	68.0 ± 2.2	94.0 ± 0.7
EN B6 SS 456 × 456	68.8 ± 0.7	93.8 ± 0.5
Ensemble Average	71.7 ± 1.7	95.4 ± 0.5
Ensemble Optimal	**72.5 ± 1.7**	**95.4 ± 0.5**

Our Results

AUC: 89.05
Problem: Underfitting (bias)

- Training and validation suffers from the same performance issue
- ~0.8 AUC, ~0.2 Recall

Rank: 1,498 (out of 2,600+ entries)
Configs:

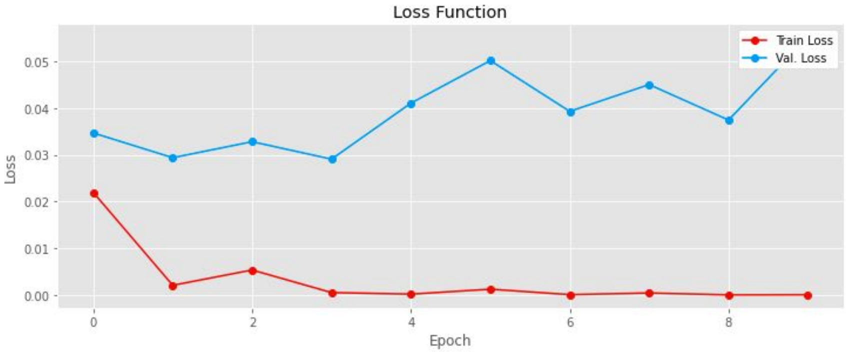
- Model: EfficientNet B7
- Loss Function: Focal Loss
- Transferred Learning: ImageNet
- Epochs: 8
- Batch Size: 64
- Image Size: 256x256
- Random Image Augmentation: True

V3 Results

Problem: Overfitting (high variance), large performance gap between training and validation

Epoch 5:

	Training Data	Validation Data
AUC	1.0	0.71
Recall	100%	0%



Demo

colab

What Else Can Be Done?

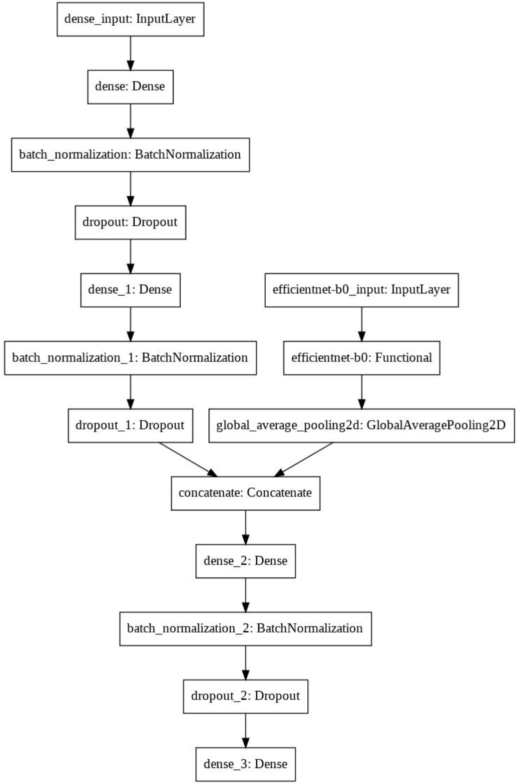
v2 (underfitting) and v3 (overfitting) suffer from different issues and require different treatments.

Other Things to Try:

- Ensemble!
- Hyperparameters Tuning
    - Gradient Clipping
    - Learning Rate Decay
    - Grid Search
- Feature Engineering
    - Hair Simulation
    - Microscope Vignette Simulation
    - Higher Resolutions

Appendix

V3 TensorFlow Model


dense_input: InputLayer
dense: Dense
batch_normalization: BatchNormalization
dropout: Dropout
dense_1: Dense
efficientnet-b0_input: InputLayer
batch_normalization_1: BatchNormalization
efficientnet-b0: Functional
dropout_1: Dropout
global_average_pooling2d: GlobalAveragePooling2D
concatenate: Concatenate
dense_2: Dense
batch_normalization_2: BatchNormalization
dropout_2: Dropout
dense_3: Dense

References

EfficientNet: Improving Accuracy and Efficiency through AutoML and Model Scaling
https://tinyurl.com/y6a78p98

What makes TPUs fine-tuned for deep learning?
https://tinyurl.com/yxqw5x4e

Understanding Categorical Cross-Entropy Loss, Binary Cross-Entropy Loss, Softmax Loss, Logistic Loss, Focal Loss and all those confusing names
https://tinyurl.com/y6x5n9w5

Focal Loss for Dense Object Detection
https://tinyurl.com/y2xua29r