Face Mask Detection Using Yolo

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Introduction

Problem:
We would like to run an object detection algorithm to detect whether a person is wearing a mask or not. It is especially interesting to detect if a person is wearing mask correctly, since many people tend to wear incorrectly.

Importance:
As the COVID is still around us, mask is becoming a must in some situations. Such a detection algorithm may be helpful for some facilities to ensure a mask-requirement.

Dataset

Data link:
https://www.kaggle.com/datasets/andrewmvd/face-mask-detection

Consist of: 853 images with xml annotations belonging to 3 classes

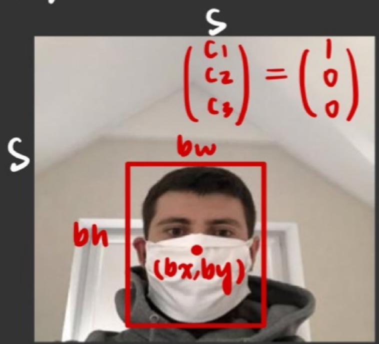
- With mask
- Without mask
- Mask worn incorrectly

Train set: 767 images (~90%)
Test set: 86 images (~10%)


```xml
<annotation>
    <folder>images</folder>
    <filename>maksssksksss0.png</filename>
    <size>
        <width>512</width>
        <height>366</height>
        <depth>3</depth>
    </size>
    <segmented>0</segmented>
    <object>
        <name>without_mask</name>
        <pose>Unspecified</pose>
        <truncated>0</truncated>
        <occluded>0</occluded>
        <difficult>0</difficult>
        <bndbox>
            <xmin>79</xmin>
            <ymin>105</ymin>
            <xmax>109</xmax>
            <ymax>142</ymax>
        </bndbox>
    </object>
    <object>
        <name>with_mask</name>
        <pose>Unspecified</pose>
        <truncated>0</truncated>
        <occluded>0</occluded>
        <difficult>0</difficult>
        <bndbox>
            <xmin>185</xmin>
            <ymin>100</ymin>
            <xmax>226</xmax>
            <ymax>144</ymax>
        </bndbox>
    </object>
    <object>
        <name>without_mask</name>
        <pose>Unspecified</pose>
        <truncated>0</truncated>
        <occluded>0</occluded>
        <difficult>0</difficult>
        <bndbox>
            <xmin>325</xmin>
            <ymin>90</ymin>
            <xmax>360</xmax>
            <ymax>141</ymax>
        </bndbox>
    </object>
</annotation>
```

Network

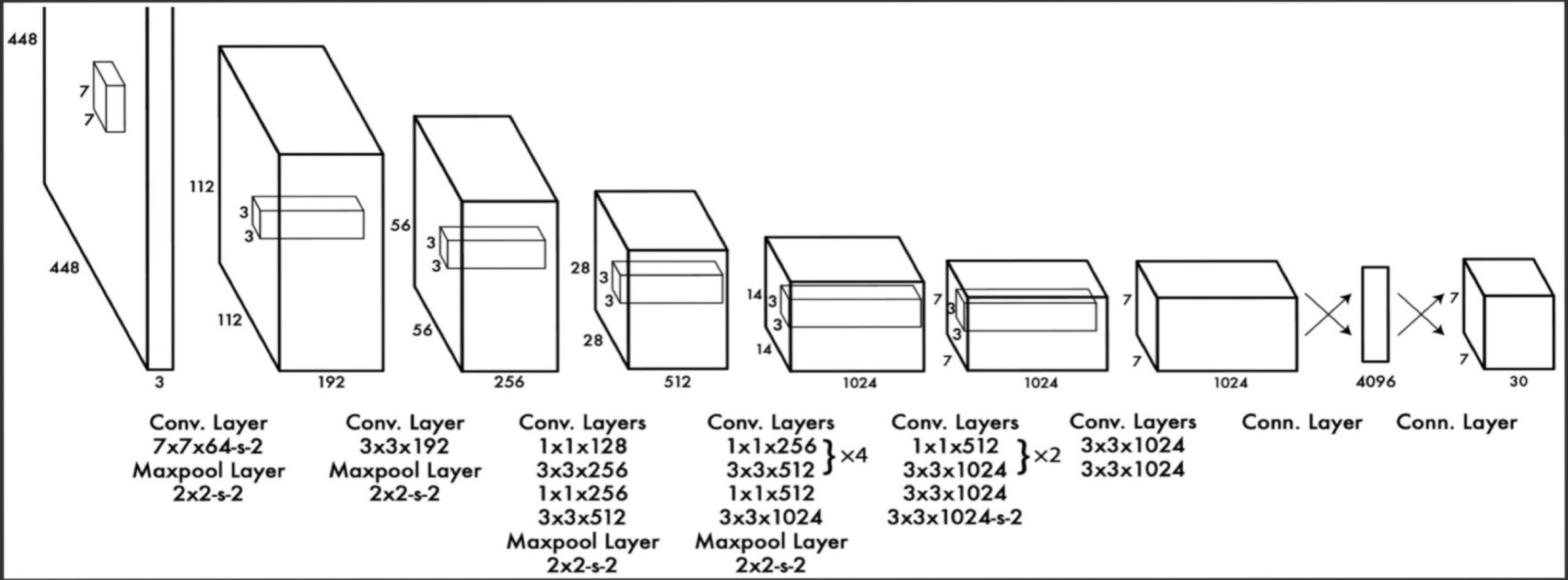
input & ground truth =



output:

$$\begin{bmatrix} P_c \\ b_x \\ b_y \\ b_w \\ b_h \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

- P_c ← confidence prediction represents IOU
- b_x ← x-axis of center of box
- b_y ← y-axis of center of box
- b_w ← width of box
- b_h ← height of box
- c_1 ← $Pr(\text{class with masks}) \in (0,1)$
- c_2 ← $Pr(\text{class without masks}) \in (0,1)$
- c_3 ← $Pr(\text{class wearing mask incorrectly}) \in (0,1)$



Loss Function

$$\lambda_{coord} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{i,j}^{obj} (bx_i - \hat{bx_i})^2 + (by_i - \hat{by_i})^2$$ localization loss

$$+ \lambda_{coord} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{i,j}^{obj} (\sqrt{bw_i} - \sqrt{\hat{bw_i}})^2 + (\sqrt{bh_i} - \sqrt{\hat{bh_i}})^2$$

confidence loss

$$+ \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{i,j}^{obj} (C_i - \hat{C_i})^2 + \lambda_{noobj} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{i,j}^{noobj} (C_i - \hat{C_i})^2$$

$$+ \sum_{i=0}^{S^2} \mathbb{1}_{i}^{obj} \sum_{k \in classes} (P_i(k) - \hat{P_i}(k))$$ classification loss

notation:

$$\mathbb{1}_{i}^{obj} = \begin{cases} 1, & \text{object appears in cell } i \\ 0, & \text{otherwise} \end{cases}$$

$$\mathbb{1}_{i,j}^{obj} = \begin{cases} 1, & j\text{th boundary box in cell } i \text{ for detection} \\ 0, & \text{otherwise} \end{cases}$$

λ_{coord} : increase weight for loss in boundary box

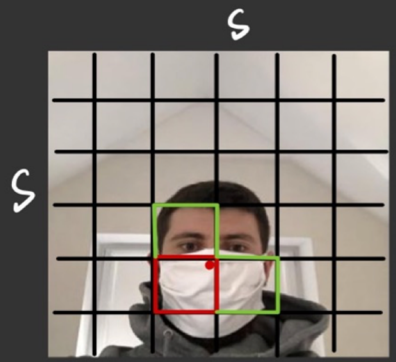
λ_{noobj} : weights down the loss when detecting b.g.

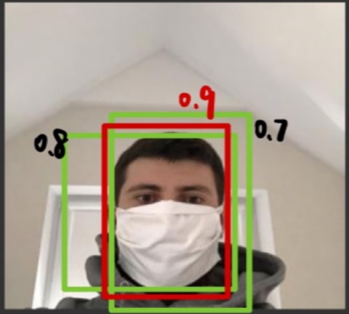
$\hat{C_i}$: box confidence score of box j in cell i

$$\begin{bmatrix} P_c \\ b_x \\ b_y \\ b_w \\ b_h \\ c_1 \\ c_2 \\ c_3 \end{bmatrix} \begin{array}{l} \leftarrow \text{confidence prediction represents IOU} \\ \leftarrow x\text{-axis of center of box} \\ \leftarrow y\text{-axis of center of box} \\ \leftarrow \text{width of box} \\ \leftarrow \text{height of box} \\ \leftarrow Pr(\text{class with masks}) \in (0,1) \\ \leftarrow Pr(\text{class without masks}) \in (0,1) \\ \leftarrow Pr(\text{class wearing mask incorrectly}) \in (0,1) \end{array}$$

Non-max Suppression (NMS)

- make sure the algorithm detects only once





the one in the center

the other mis-identified ones

① select the one with highest confidence score

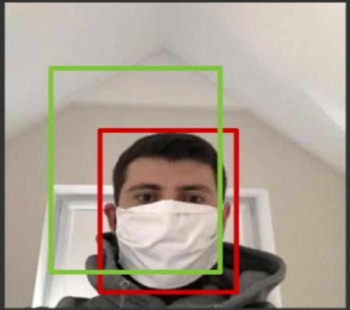
② get rid of the rest with high IOU

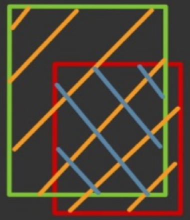
(if ≥ threshold (usually 0.5))

confidence score

$= Pr(class_k) * IOU^{truth}_{pred}$

Intersection over Union (IOU)

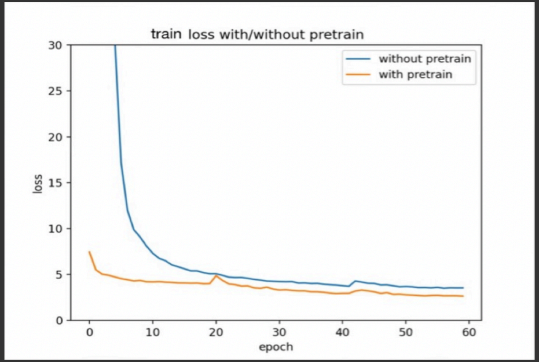


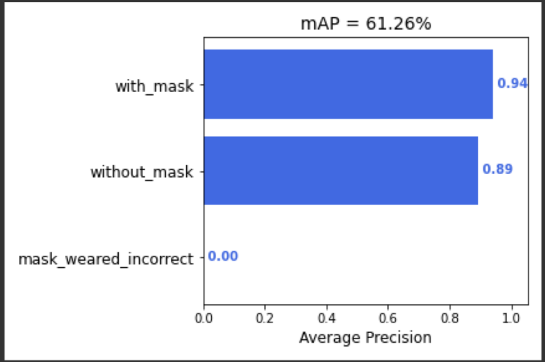


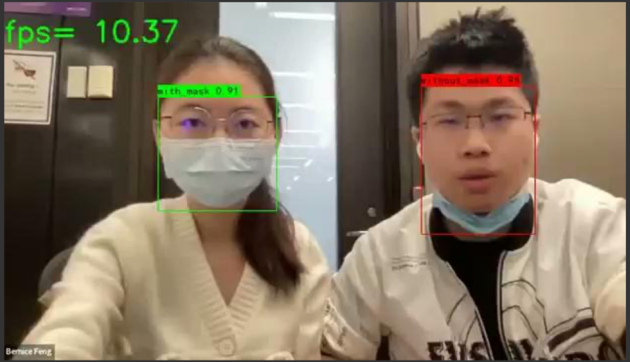
$$IOU = \frac{\text{size of intersection}}{\text{size of union}}$$

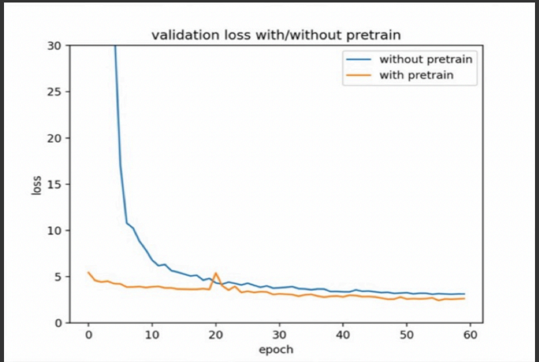
$$= \frac{\text{size of}}{\text{size of}}$$

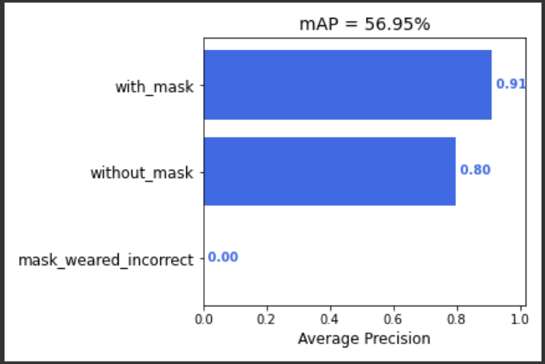
Pretrain

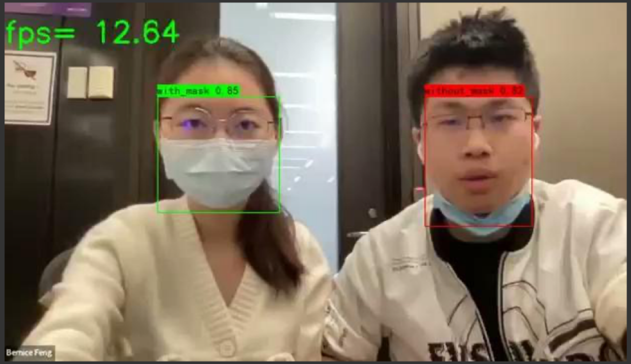

train loss with/without pretrain
without pretrain
with pretrain
loss
epoch
0
5
10
15
20
25
30
0
10
20
30
40
50
60


mAP = 61.26%
with_mask
without_mask
mask_weared_incorrect
0.94
0.89
0.00
0.0
0.2
0.4
0.6
0.8
1.0
Average Precision

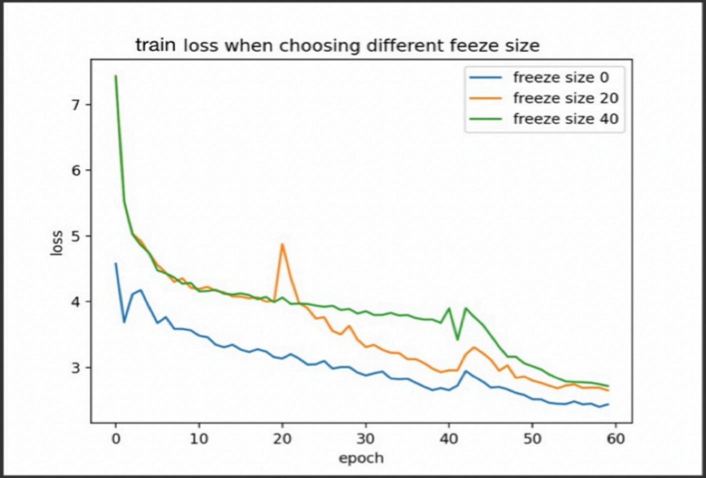

fps= 10.37
with_mask 0.91

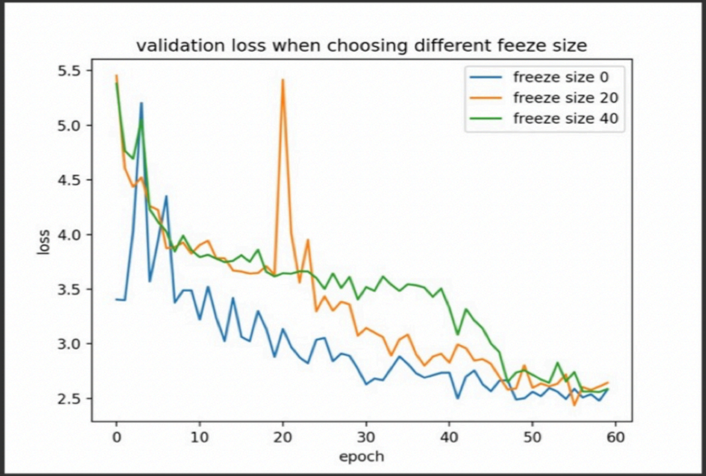

validation loss with/without pretrain
without pretrain
with pretrain
loss
epoch
0
5
10
15
20
25
30
0
10
20
30
40
50
60


mAP = 56.95%
with_mask
without_mask
mask_weared_incorrect
0.91
0.80
0.00
0.0
0.2
0.4
0.6
0.8
1.0
Average Precision


fps= 12.64
with_mask 0.85

Freeze





with freeze

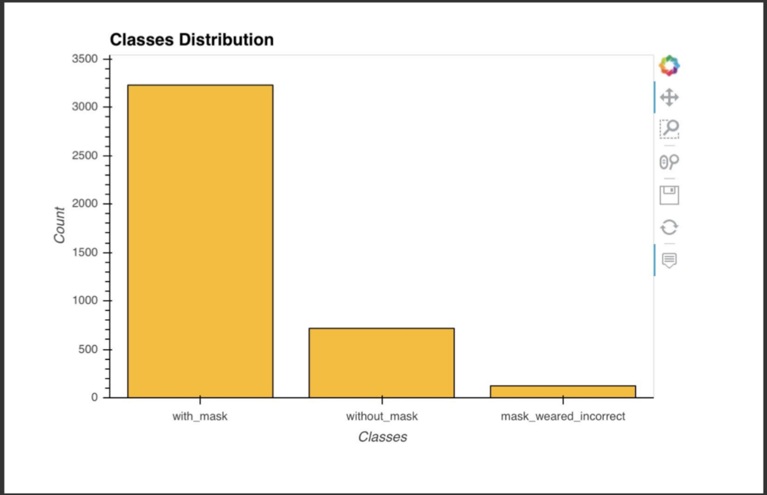
```
Epoch 2/60: 100%|██████████| 43/43 [00:34<00:00,  1.25it/s, loss=5.53, lr=0.0002]
Finish Train
Start Validation
Epoch 2/60: 100%|██████████| 4/4 [00:05<00:00,  1.30s/it, val_loss=4.77]
Finish Validation
Epoch:2/60
Total Loss: 5.531 || Val Loss: 4.766
Start Train
Epoch 3/60: 100%|██████████| 43/43 [00:34<00:00,  1.25it/s, loss=5.02, lr=0.0005]
Finish Train
Start Validation
Epoch 3/60: 100%|██████████| 4/4 [00:02<00:00,  1.34it/s, val_loss=4.69]
Finish Validation
Epoch:3/60
Total Loss: 5.024 || Val Loss: 4.693
Start Train
Epoch 4/60: 100%|██████████| 43/43 [00:34<00:00,  1.24it/s, loss=4.86, lr=0.001]
Finish Train
Start Validation
Epoch 4/60: 100%|██████████| 4/4 [00:02<00:00,  1.54it/s, val_loss=5.05]
Finish Validation
Epoch:4/60
Total Loss: 4.862 || Val Loss: 5.052
```

without freeze

```
Epoch 2/60: 100%|██████████| 86/86 [00:39<00:00,  2.15it/s, loss=3.63, lr=0.0002]
Finish Train
Start Validation
Epoch 2/60: 100%|██████████| 9/9 [00:02<00:00,  3.09it/s, val_loss=3.19]
Finish Validation
Epoch:2/60
Total Loss: 3.626 || Val Loss: 3.190
Start Train
Epoch 3/60: 100%|██████████| 86/86 [00:39<00:00,  2.15it/s, loss=4.01, lr=0.0005]
Finish Train
Start Validation
Epoch 3/60: 100%|██████████| 9/9 [00:02<00:00,  3.26it/s, val_loss=3.88]
Finish Validation
Epoch:3/60
Total Loss: 4.006 || Val Loss: 3.882
Start Train
Epoch 4/60: 100%|██████████| 86/86 [00:40<00:00,  2.14it/s, loss=4.5, lr=0.001]
Finish Train
Start Validation
Epoch 4/60: 100%|██████████| 9/9 [00:02<00:00,  3.26it/s, val_loss=6.31]
Finish Validation
Epoch:4/60
Total Loss: 4.503 || Val Loss: 6.311
```

Future Extensions

1. Our model does not perform well on our dataset, since it is does not have a relative even distribution on each class. We could do data augmentation and better split the dataset to make our train/test set less biased.
2. Yolo has several upgraded version, each incorporating new techniques to the original model. We could try it out see how the add-ons increase the performance of our network,



Reference

1. https://arxiv.org/pdf/1506.02640.pdf
2. https://jonathan-hui.medium.com/real-time-object-detection-with-yolo-yolov2-28b1b93e2088