S³FD: Single Shot Scale-invariant Face Detector

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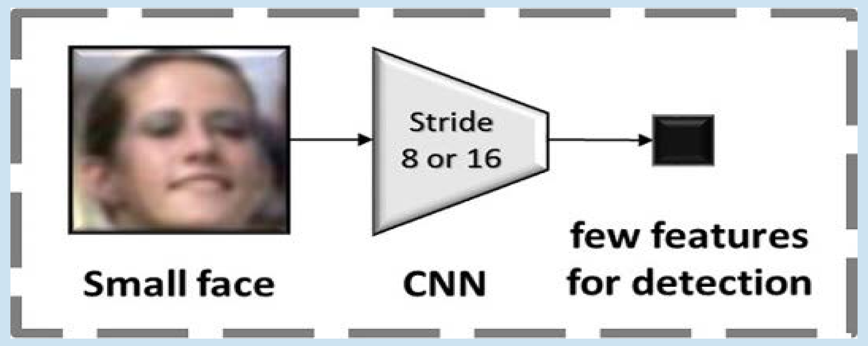
Problem

Though tremendous strides have been made in object detection, one of the remaining open challenges is detecting small objects, since **anchor-based detectors deteriorate dramatically as the objects become smaller**. In this work, we analyze this problem in three aspects and propose three corresponding solutions to solve it.

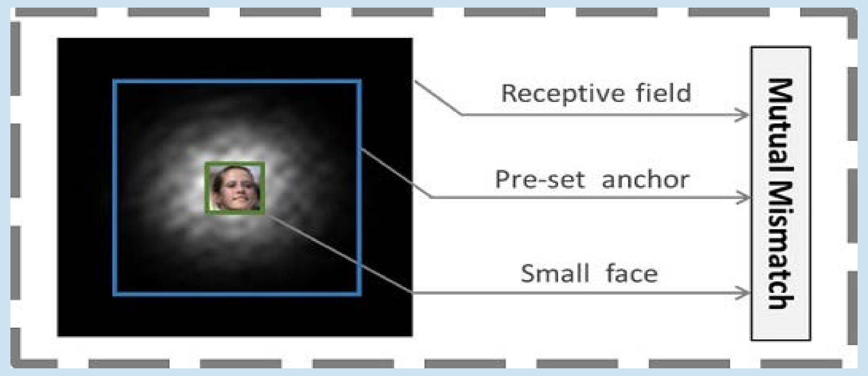
Reasons

Reason1: Biased framework

- Small faces have few features at detection layer

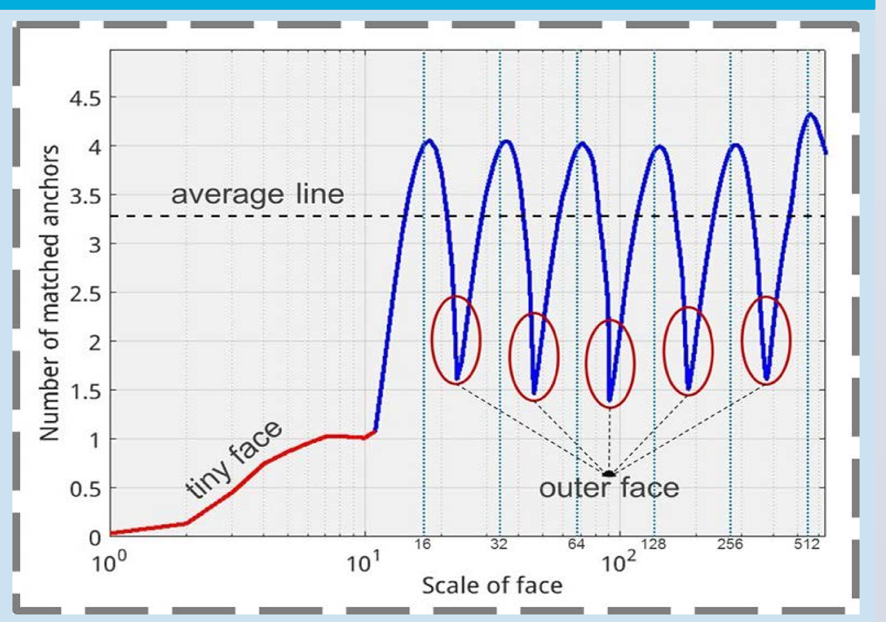


- Small face, anchor scale and receptive field are mutual mismatch



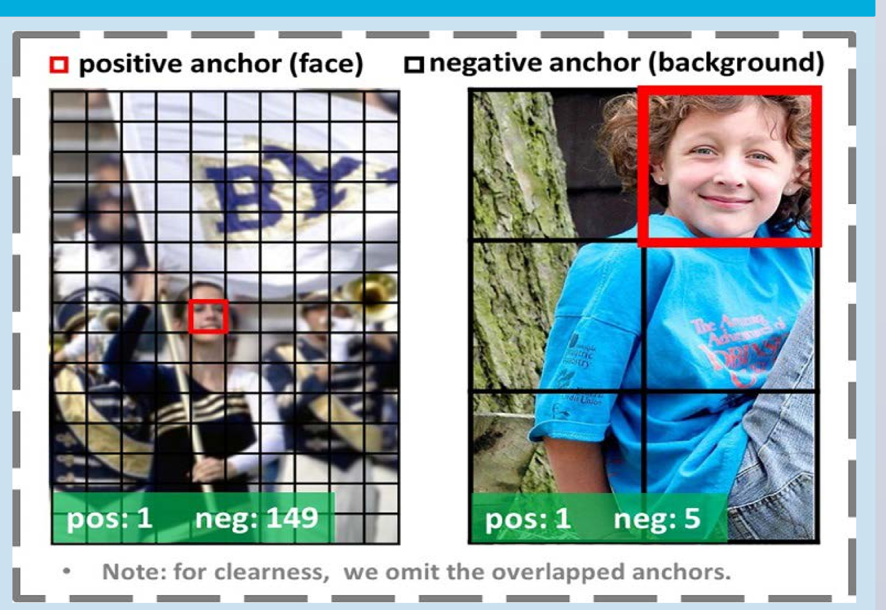
Reason2: Anchor matching strategy

- Some faces can not match enough anchors, such as tiny and outer face



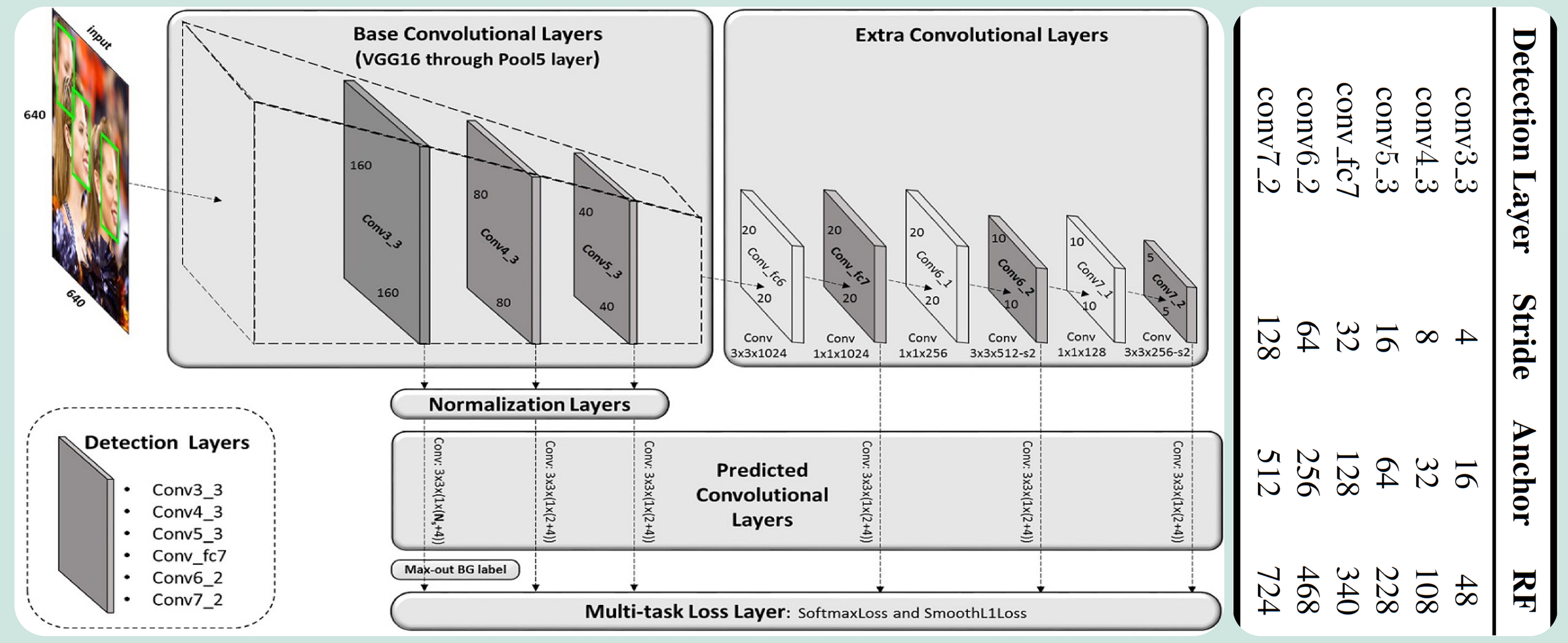
Reason3: Background from small anchors

- Detecting small faces needs to tile plenty of small anchors, which may bring about many false positive faces



Solutions

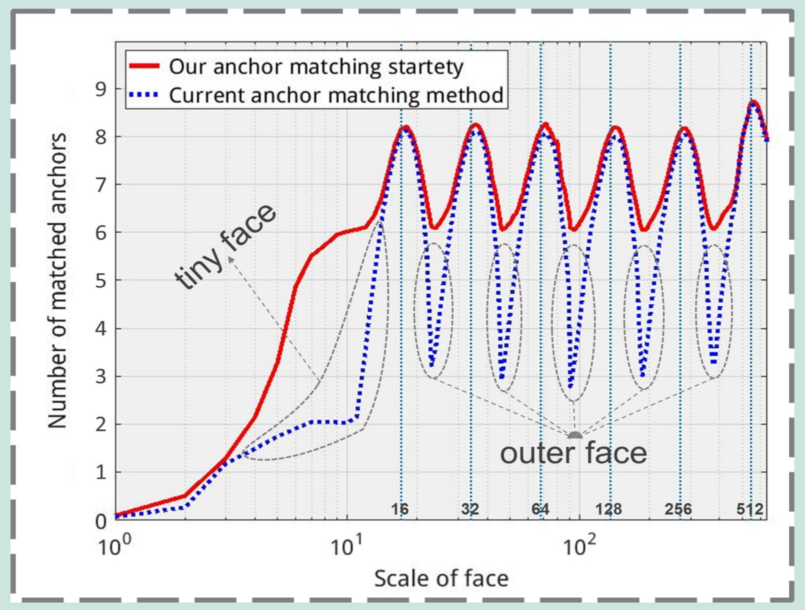
Solution1: Scale-equitable framework



- **Anchor locations**: To ensure various scales of faces have adequate features for detection, we associate anchors with layers whose stride size gradually double from 4 to 128
- **Anchor scales**: To make anchors match the effective receptive field and keep them have the same density, we design scales from 16 to 512 pixels based on effective receptive field theory and equal-proportion interval principle

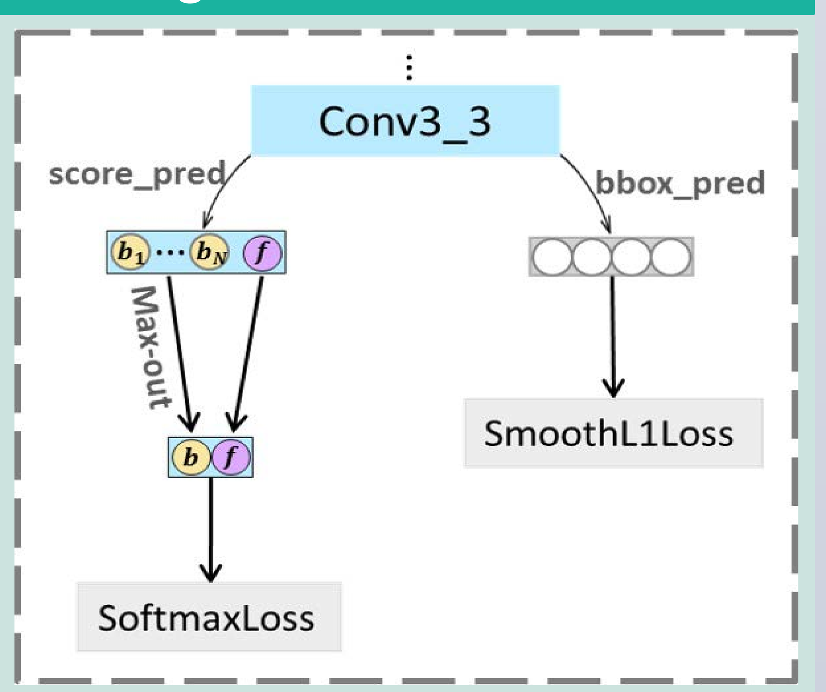
Solution2: Scale compensation anchor matching strategy

- For these faces that can not match enough anchors, we increase their matched anchors via an extra step that relaxes the matching threshold then selects the top N anchors



Solution3: Max-out background label

- For each of the small anchors on the lowest layer, we predict N_m scores for background label and then choose the highest as its final score, so as to reduce the false positive rate of small faces



Results

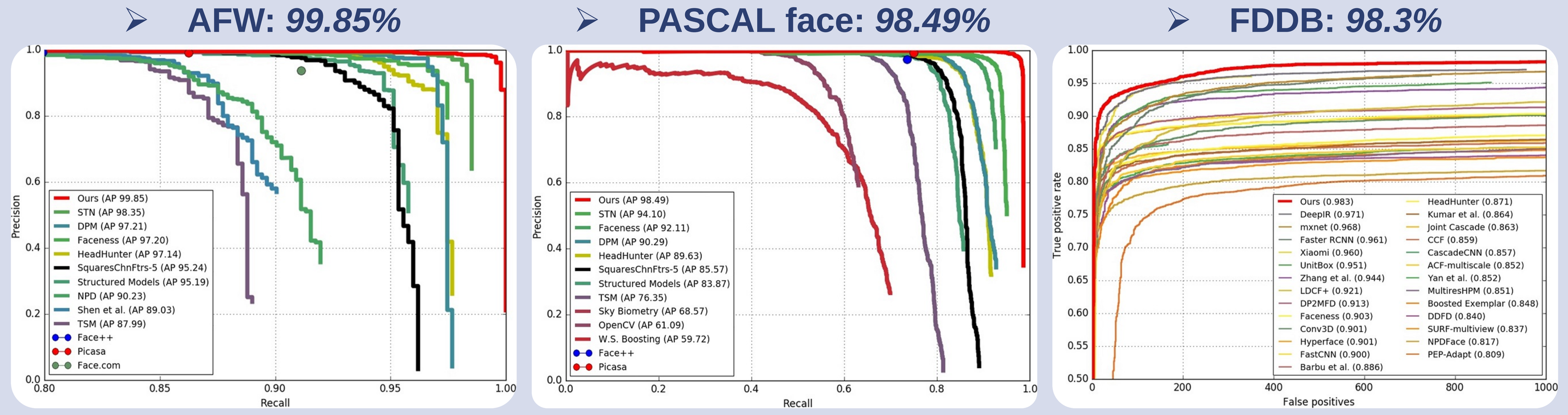
Model analysis

- Scale-equitable framework is crucial
- Scale compensation anchor matching strategy is better
- Max-out background label is promising

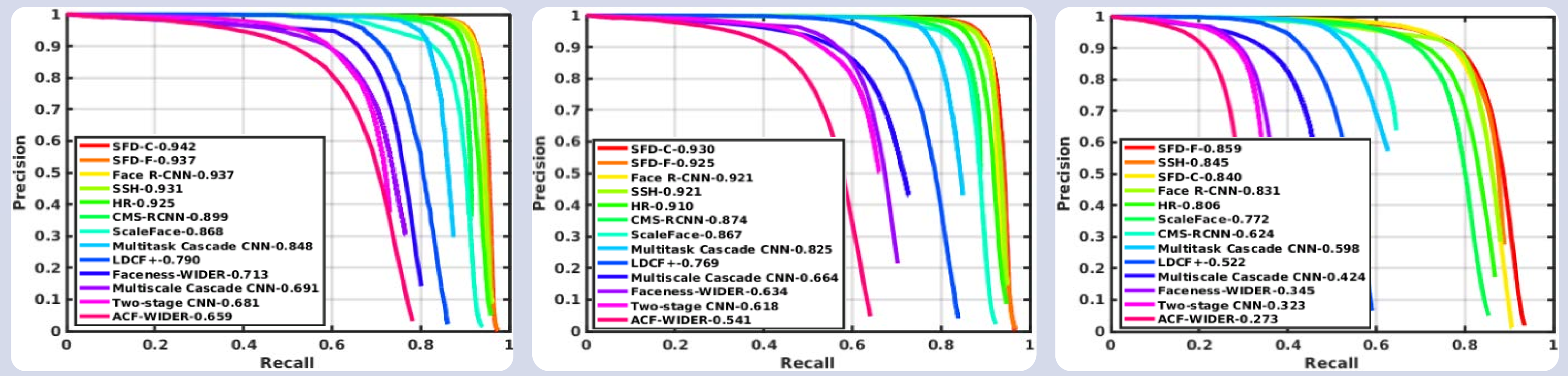
mAP(%) Methods \ Subsets	Easy	Medium	Hard
RPN-face	91.0	88.2	73.7
SSD-face	92.1	89.5	71.6
S³FD(F)	92.6	91.6	82.3
S³FD(F+S)	93.5	92.0	84.5
S³FD(F+S+M)	**93.7**	**92.4**	**85.2**

Evaluation on benchmark

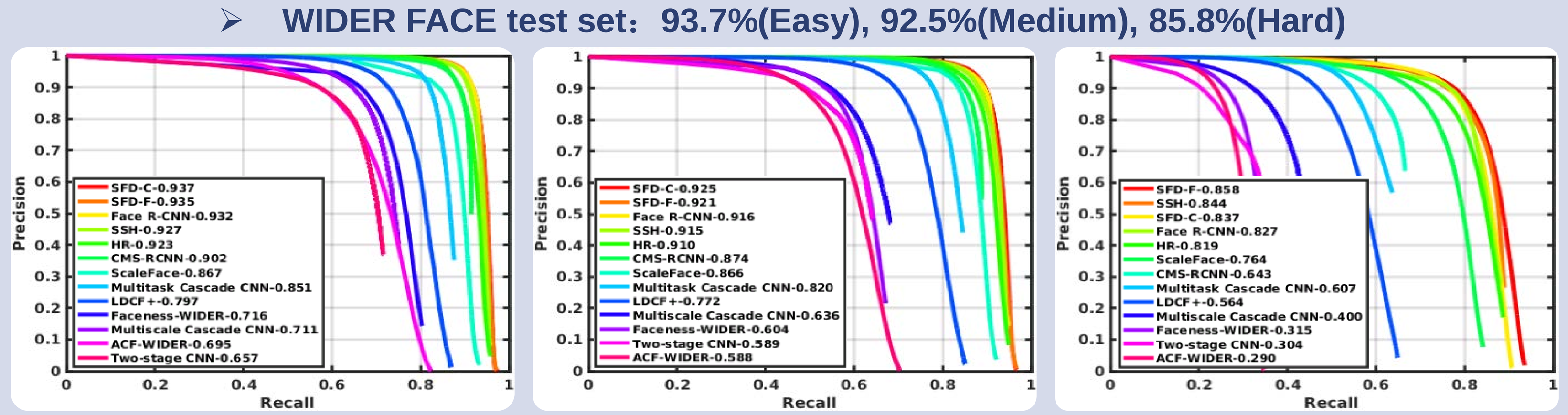
- AFW: *99.85%*
- PASCAL face: *98.49%*
- FDDB: *98.3%*



- WIDER FACE validation set: 94.2%(Easy), 93.0%(Medium), 85.9%(Hard)



- WIDER FACE test set: 93.7%(Easy), 92.5%(Medium), 85.8%(Hard)



Conclusion

We propose a scale-equitable framework, a scale compensation matching strategy and a max-out background label to solve the problem of finding small faces. Consequently, our detector achieves state-of-the-art detection performance on all the common face detection benchmarks, including the AFW, PASCAL face, FDDB and WIDER FACE datasets. Besides it can run at 36 FPS on a NVIDIA Titan X (Pascal) for the VGA-resolution images.

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