ASMNet: a Lightweight Deep Neural Network for Face Alignment and Pose Estimation

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1. Introduction and Contributions

- ASMNet is a lightweight Convolutional Neural Network (CNN) which is designed to perform face alignment and pose estimation efficiently while having acceptable accuracy.
- ASMNet proposed inspired by MobileNetV2, modified to be suitable for face alignment and pose estimation, while being about 2 times smaller in terms of number of the parameters.
- Inspired by Active Shape Model (ASM), ASM-assisted loss function is proposed in order to improve the accuracy of facial landmark points detection and pose estimation.

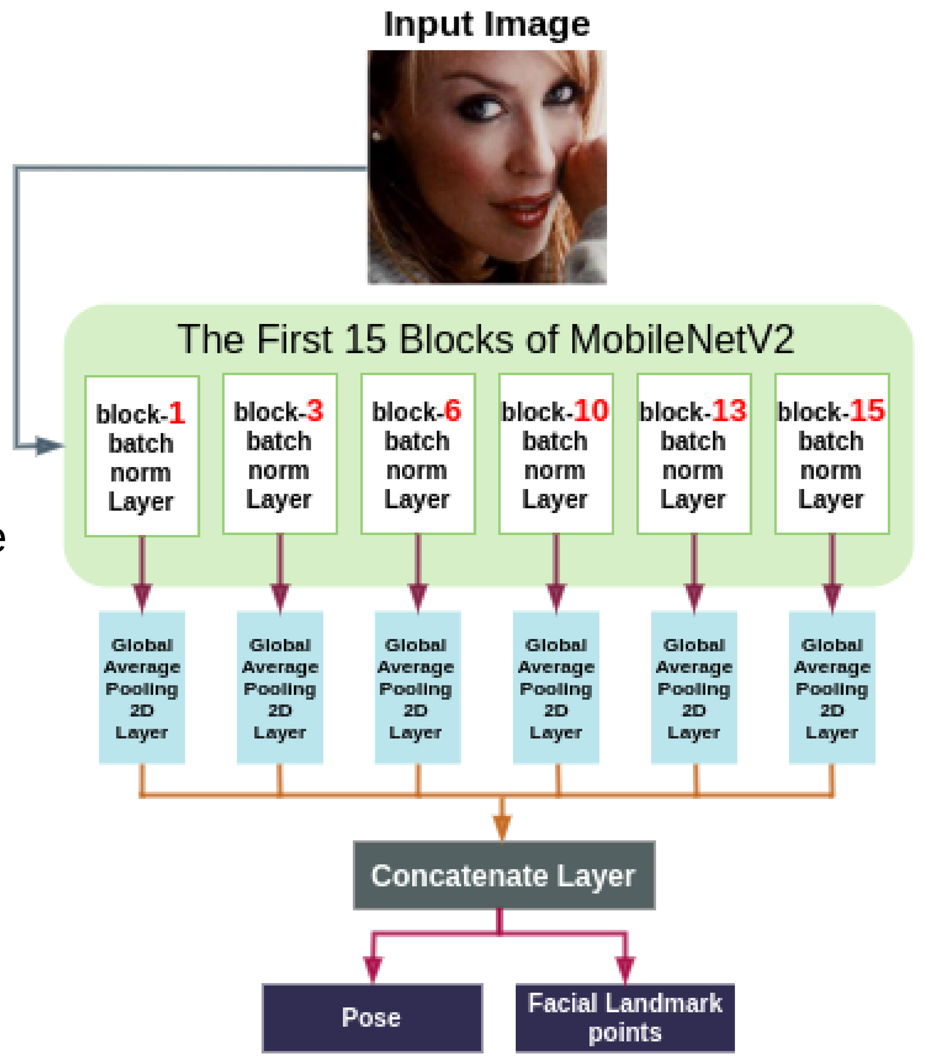
2. ASM Review

- Active Shape Model is a statistical model of shape objects. Each shape is represented as ***n*** points. We define $\mathcal{ASM}$ operator which transforms each input point to a new point such that the distribution of ***A*** set is smoother than the distribution of the ***P*** set.

$$\mathcal{ASM} : (P_x^i, P_y^i) \mapsto (A_x^i, A_y^i)$$

3. ASMNet Architecture

- Features in a CNN are distributed hierarchically. So, the lower layers have features such as edges, and corners which are more suitable for tasks like landmark localization and pose estimation, and deeper layers contain more abstract features that are more suitable for tasks like image classification and image detection.
- Training a network for correlated tasks simultaneously builds a synergy that can improve the performance of each task.
- We designed ASMNe by fusing the features that are available if different layers of the model. Furthermore, by concatenating the features that are collected after each global average pooling layer in the back-propagation process, it will be possible for the network to evaluate the effect of each shortcut path.



4. ASM Assisted Loss Function

- We proposed a new loss function called ASM-LOSS which utilizes ASM to improve the accuracy of the network. In other words, during the training process, the loss function compares the predicted facial landmark points with their corresponding ground truth as well as the smoothed version the ground truth which is generated using ASM operator. Accordingly, ASM-LOSS guides the network to first learn the smoothed distribution of the facial landmark points. Then, it leads the network to learn the original landmark points.

$$G_{set} = \{(G_x^1, G_y^1), \ldots, (G_x^n, G_y^n)\} \qquad A_{set} = \{(A_x^1, A_y^1), \ldots, (A_x^n, A_y^n)\}$$

$$P_{set} = \{(P_x^1, P_y^1), \ldots, (P_x^n, P_y^n)\} \qquad \mathcal{ASM} : (G_x^i, G_y^i) \mapsto (A_x^i, A_y^i)$$

- $$\mathcal{L}_{mse} = \frac{1}{N}\frac{1}{n}\sum_{j=1}^{N}\sum_{i=1}^{n}\|G_j^i - P_j^i\|_2 \qquad \mathcal{L}_{asm} = \frac{1}{N}\frac{1}{n}\sum_{j=1}^{N}\sum_{i=1}^{n}\|A_j^i - P_j^i\|_2$$

$$\mathcal{L}_{facial} = \mathcal{L}_{mse} + \alpha \times \mathcal{L}_{asm} \qquad \alpha = \begin{cases} 2 & i < \frac{l}{3} \\ 1 & \frac{l}{3} < i < \frac{2l}{3} \\ 0.5 & i > \frac{2l}{3} \end{cases}$$

i : epoch number

l : Number of total epochs

- Estimating face pose with the assistant of smoothed facial landmark points can lead to a better accuracy. We defines the loss function L_{pose}, where yaw(y^p), pitch (p^p), and roll(r^p) are the predicted poses and y^t, p^t , and r^t are the corresponding ground truths:

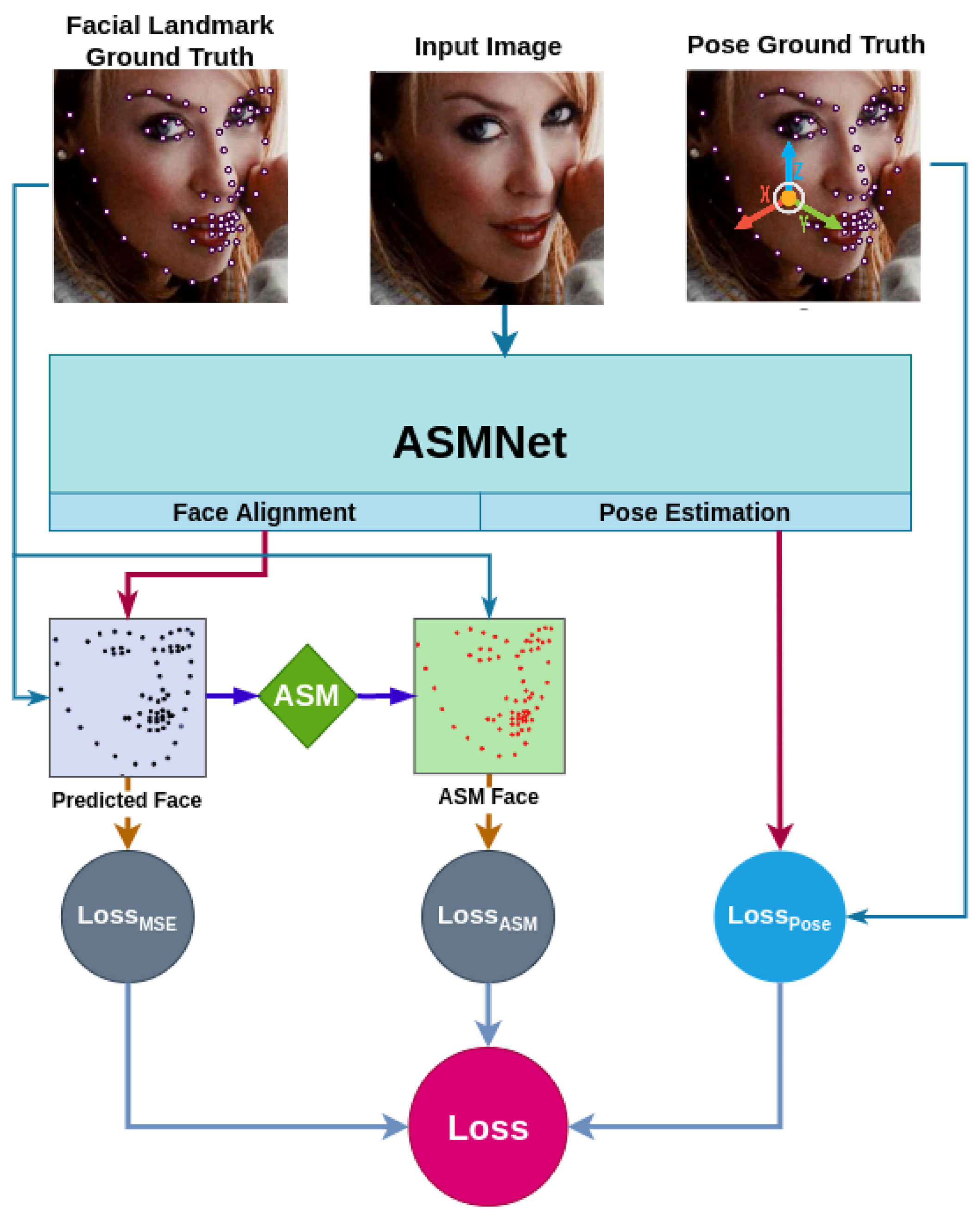
$$\mathcal{L}_{pose} = \frac{1}{N}\sum_{j=1}^{N}\frac{(y_j^p - y_j^t)^2 + (p_j^p - p_j^t)^2 + (r_j^p - r_j^t)^2}{3}$$

- Finally, we calculate the total loss as the total weighted loss of the 2 individual losses using:

$$\mathcal{L} = \sum_{i=1}^{2}\lambda_{task_i}\mathcal{L}_{task_i}$$

T = { $\mathcal{L}_{facial}$, $\mathcal{L}_{pose}$ }

$\lambda_{task} = \{1, 0.5\}$



5. Evaluation

- Comparison of Number of Parameters (in Million) and Flops (in Billion):

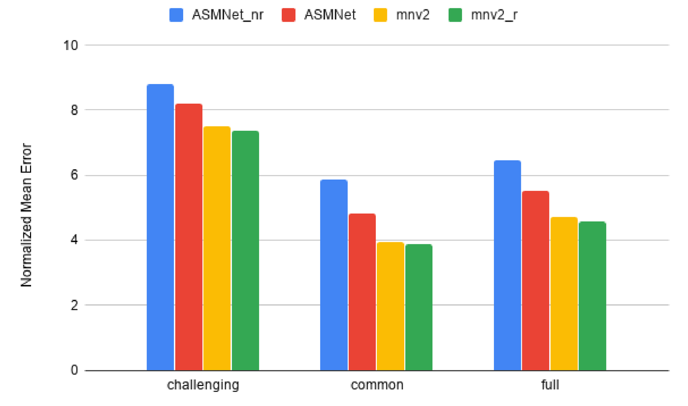
Method	NME		Params (M)	FLOPs (B)
	300W	WFLW		
mnv2	4.70	9.57	2.42	0.60
mnv2_r	4.59	9.41		
ASMNet_nr	6.49	11.96	1.43	0.51
ASMNet	5.50	10.77		

Method	Backbone	#Params (M)	FLOPs (B)
DVLN [45]	VGG-16	132.0	14.4
SAN [12]	ResNet-152	57.4	10.7
LAB [44]	Hourglass	25.1	19.1
ResNet50 (Wing + PDB) [15]	ResNet-50	25	3.8
ASMNet	MobileNetV2 [33]	1.4	0.5
MobileNetV2 [33]	-	2.4	0.6

- Face Alignment Accuracy on 300W:

Table 2: Normalized Mean Error (in %) of 68-point landmarks localization on 300W [31] dataset.

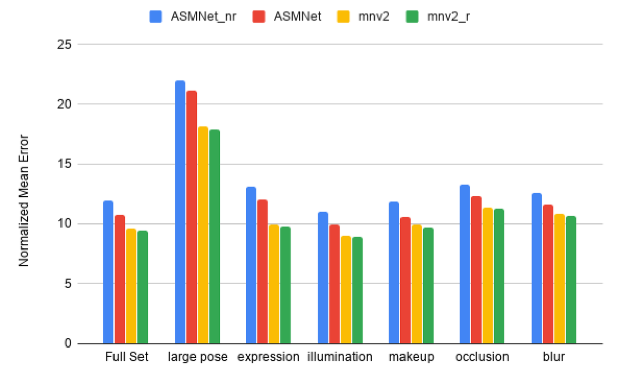
Method	Normalized Mean Error		
	Common	Challenging	Fullset
RCN [16]	4.67	8.44	5.41
DAN [21]	3.19	5.24	3.59
PCD-CNN [22]	3.67	7.62	4.44
CPM [13]	3.39	8.14	4.36
DSRN [26]	4.12	9.68	5.21
SAN [12]	3.34	6.60	3.98
LAB [44]	2.98	5.19	3.49
DCFE [40]	2.76	5.22	3.24
mnv2	3.93	7.52	4.70
mnv2_r	3.88	7.35	4.59
ASMNet_nr	5.86	8.80	6.46
ASMNet	4.82	8.2	5.50



- Face Alignment Accuracy on WFLW:

Table 3: Normalized Mean Error (in %), failure rate (in %), and AUC of 98-point landmarks localization on WFLW [44] dataset.

Metric	Method	Test set	Pose	Expression	Illumination	Make-Up	Occlusion	Blur
Mean Error (%)	ESR [5]	11.13	25.88	11.47	10.49	11.05	13.75	12.20
	SDM [47]	10.29	24.10	11.45	9.32	9.38	13.03	11.28
	CFSS [58]	9.07	21.36	10.09	8.30	8.74	11.76	9.96
	DVLN [45]	6.08	11.54	6.78	5.73	5.98	7.33	6.88
	LAB [44]	5.27	10.24	5.51	5.23	5.15	6.79	6.32
	ResNet50(Wing+PDB) [15]	5.11	8.75	5.36	4.93	5.41	6.37	5.81
	mnv2	9.57	18.18	9.93	8.98	9.92	11.38	10.79
	mnv2_r	9.41	17.86	9.78	8.90	9.67	11.25	10.66
	ASMNet_nr	11.96	21.95	13.08	11.02	11.84	13.24	12.60
	ASMNet	10.77	21.11	12.02	9.93	10.55	12.34	11.62



- Pose Estimation Accuracy:

Table 4: Mean Absolute Error of pose estimation on 300W [31], WFLW [44] datasets compared to HopeNet[30].

Method		ASMNet_nr	ASMNet	mnv2	mnv2_r
300W [31]	yaw	2.41	1.62	1.75	1.71
	pitch	1.87	1.80	1.93	1.89
	roll	2.115	1.24	1.32	1.30
WFLW [44]	yaw	3.14	2.97	3.06	3.08
	pitch	2.99	2.93	3.03	2.94
	roll	2.23	2.21	2.26	2.22

Table 5: Mean Absolute Error of pose estimation on using ASMNet, JFA [48], and Yang*et. al* [50] on 300W [31].

Method	Pitch	Yaw	Roll
Yang*et. al* [50]	5.1	4.2	2.4
JFA [48]	3.0	2.5	2.6
ASMNet	1.80	1.62	1.24

- Evaluation of Visual Accuracy: