https://arxiv.org/abs/1801.07698

ArcFace: Additive Angular Margin Loss for Deep Face Recognition

Jiankang Deng, Jia Guo, Niannan Xue
Stefanos Zafeiriou Imperial College London
CVPR 2019

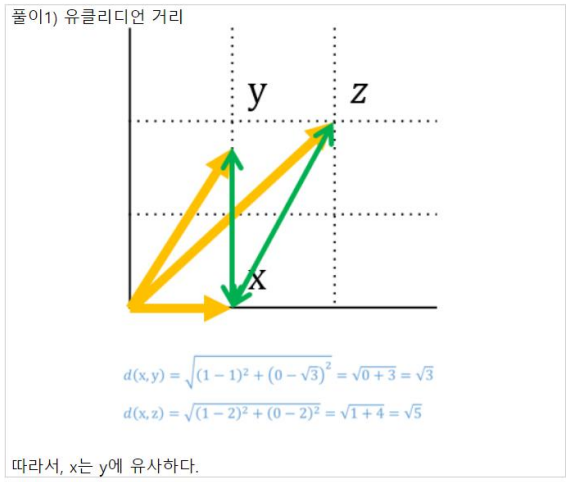
인공지능 연구실
석사과정 구자봉

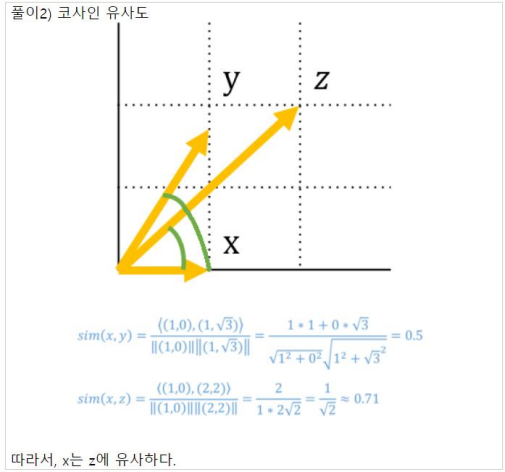
문제 정의 :
Face Recognition

https://m.blog.naver.com/PostView.nhn?blogId=cjh226&logNo=220810613028&proxyReferer=https%3A%2F%2Fwww.google.com%2F

Embedding :

Embedding은 고차원의 정보를 상대적으로 낮은 차원으로 변환하는 것을 의미한다. 아무 숫자로 바꾸는 것이 아니라 **정보를 보존**해야 한다.





$$d(x,y) = \sqrt{(x_1-y_1)^2 + (x_2-y_2)^2 + \cdots + (x_n-y_n)^2}$$

where $x = (x_1, x_2, \ldots, x_n), y = (y_1, y_2, \ldots, y_n)$

$$sim(x,y) = \frac{\langle x,y \rangle}{\|x\|\|y\|}$$

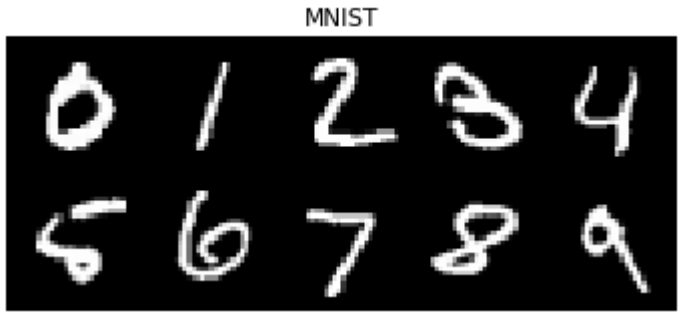
where $x = (x_1, x_2, \ldots, x_n), y = (y_1, y_2, \ldots, y_n)$

$$\|x\| = \sqrt{\sum_{i=1}^{n}(x_i)^2}, \langle x,y \rangle = \sum_{i=1}^{n} x_i y_i$$

https://jsideas.net/ImageEmbeddingWithTripletLoss/ https://wwiiiii.tistory.com/entry/Pairwise-Triplet-Loss

Image Embedding :

Embedding은 고차원의 정보를 상대적으로 낮은 차원으로 변환하는 것을 의미한다. 아무 숫자로 바꾸는 것이 아니라 **정보를 보존**해야 한다.



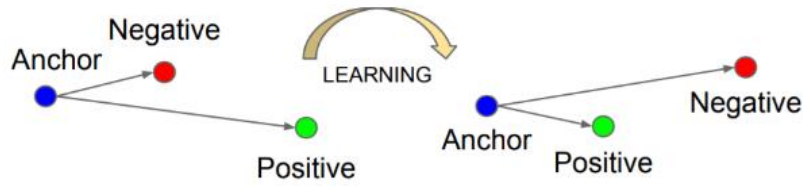
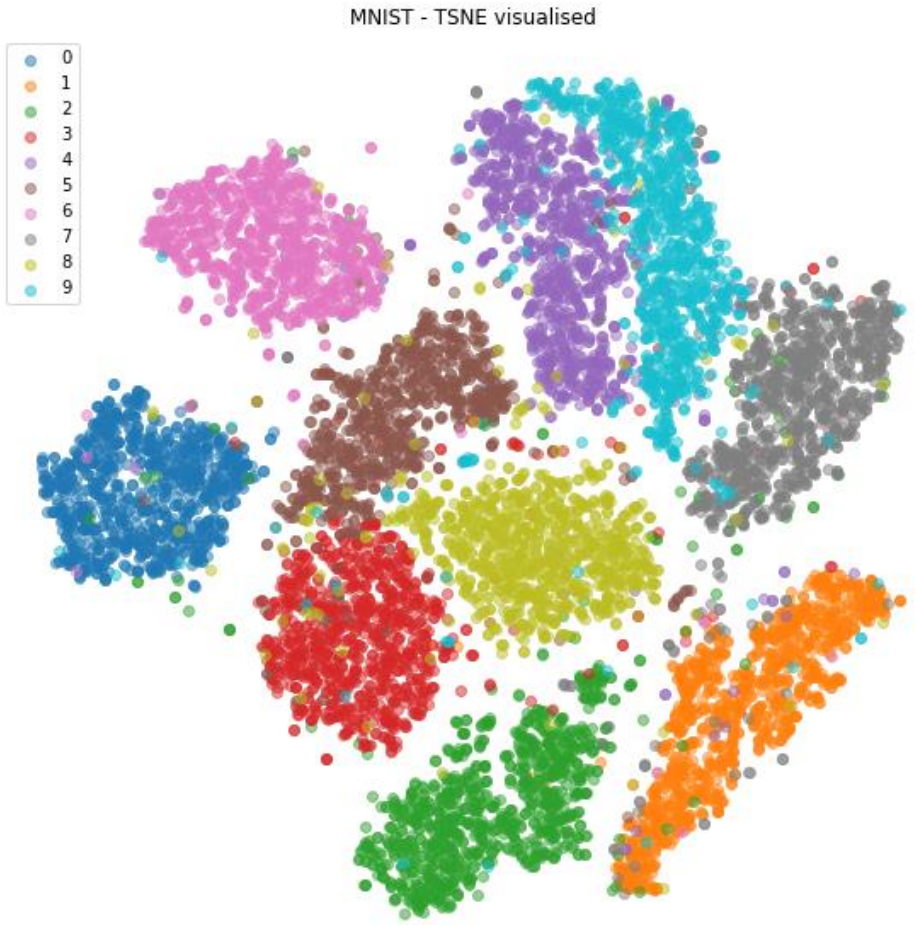
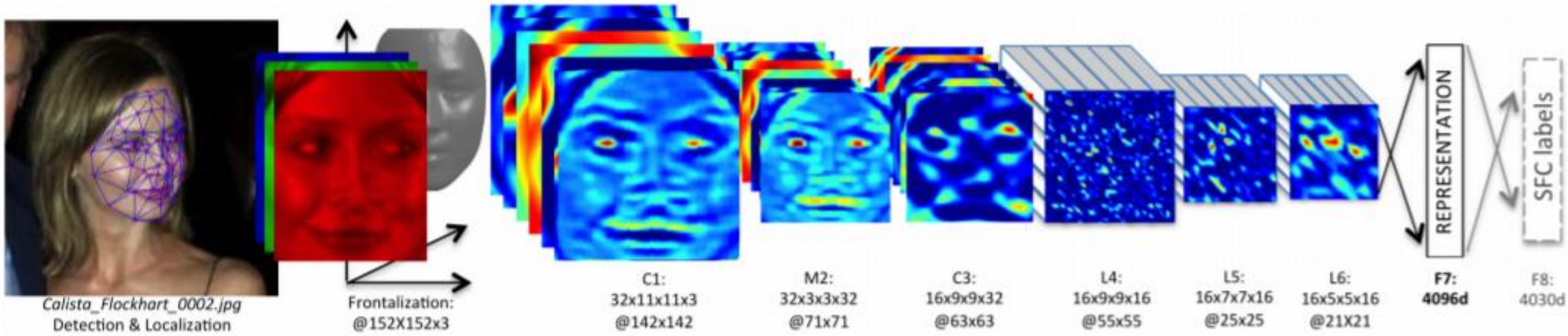


Figure 3. The **Triplet Loss** minimizes the distance between an *anchor* and a *positive*, both of which have the same identity, and maximizes the distance between the *anchor* and a *negative* of a different identity.



https://www.cv-foundation.org/openaccess/content_cvpr_2014/papers/Taigman_DeepFace_Closing_the_2014_CVPR_paper.pdf

DeepFace :

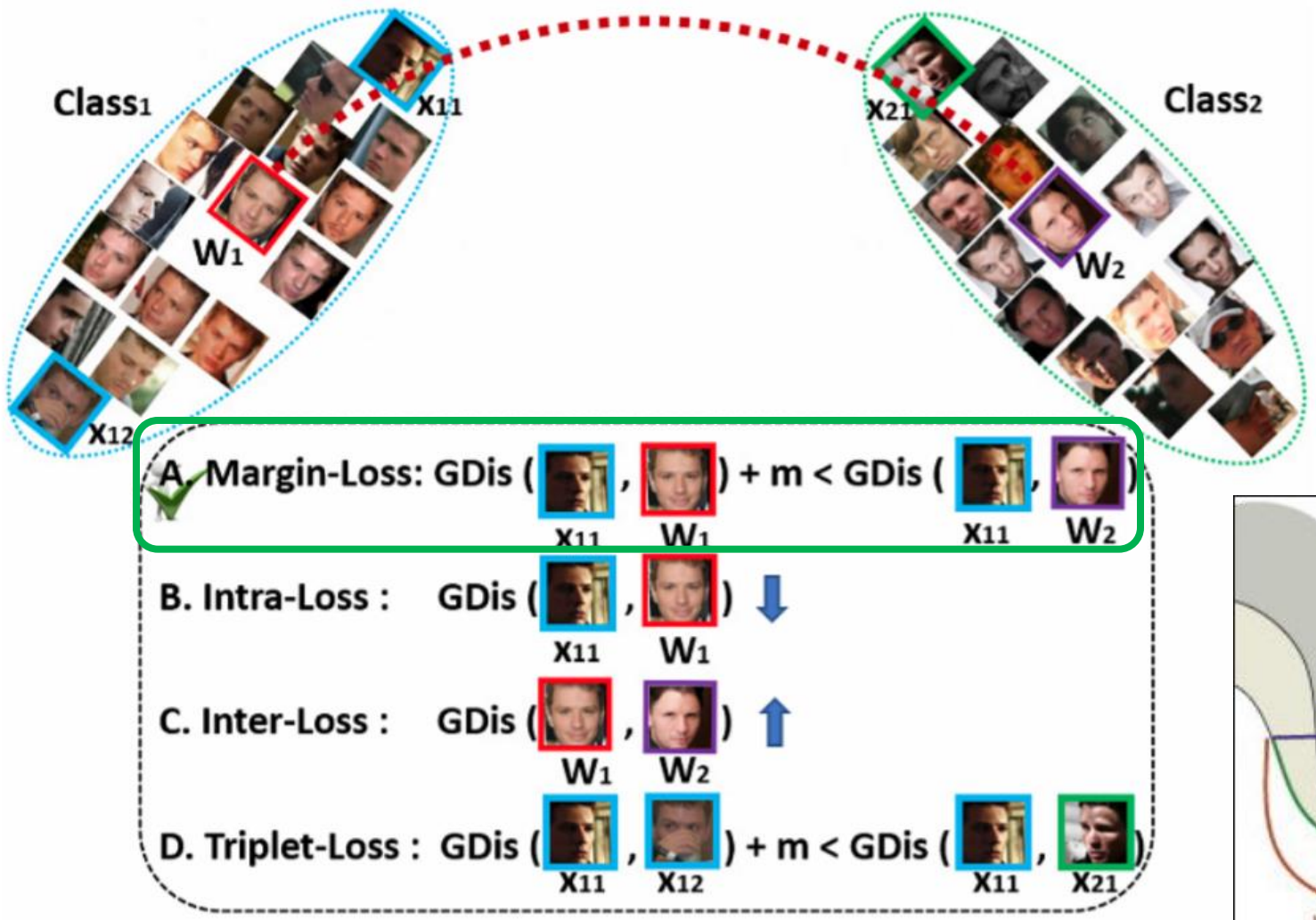


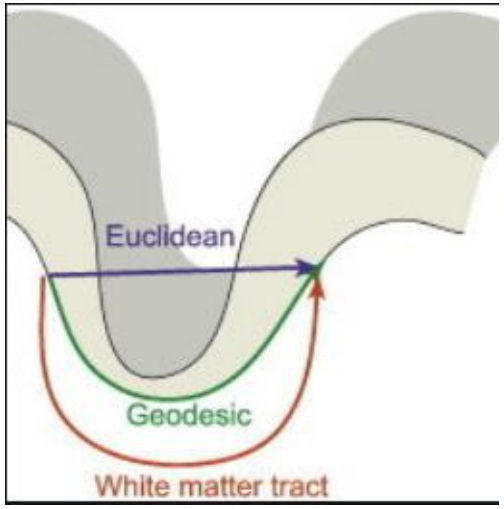
목표 :
더 잘 임베딩 시키는 것 (with ArcFace loss)

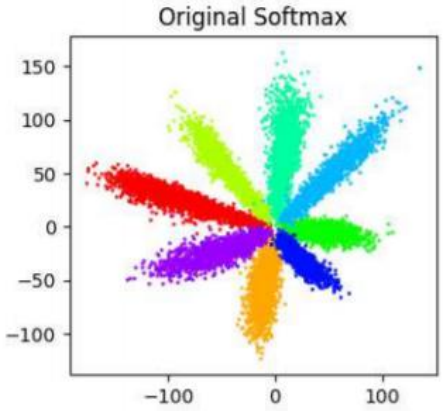
제안하는 모델 :

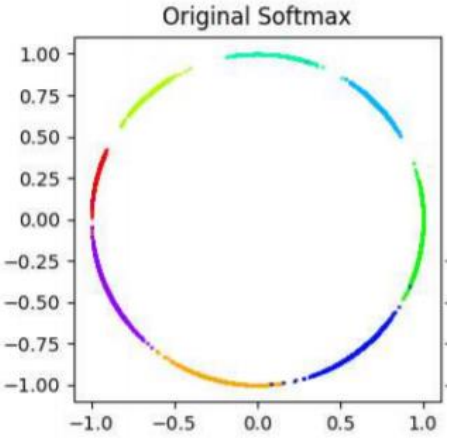
https://www.researchgate.net/figure/Distance-measures-Geodesic-distance-measures-the-shortest-path-between-two-points-across_fig7_272944982

http://openaccess.thecvf.com/content_cvpr_2018/papers/Wang_CosFace_Large_Margin_CVPR_2018_paper.pdf









ArcFace :

$$L_1 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{W_{y_i}^T x_i + b_{y_i}}}{\sum_{j=1}^{n} e^{W_j^T x_i + b_j}}, \qquad (1)$$

기본적인 소프트맥스 함수 로스

$b_j = 0$

$W_j^T x_i = \|W_j\| \|x_i\| \cos\theta_j$

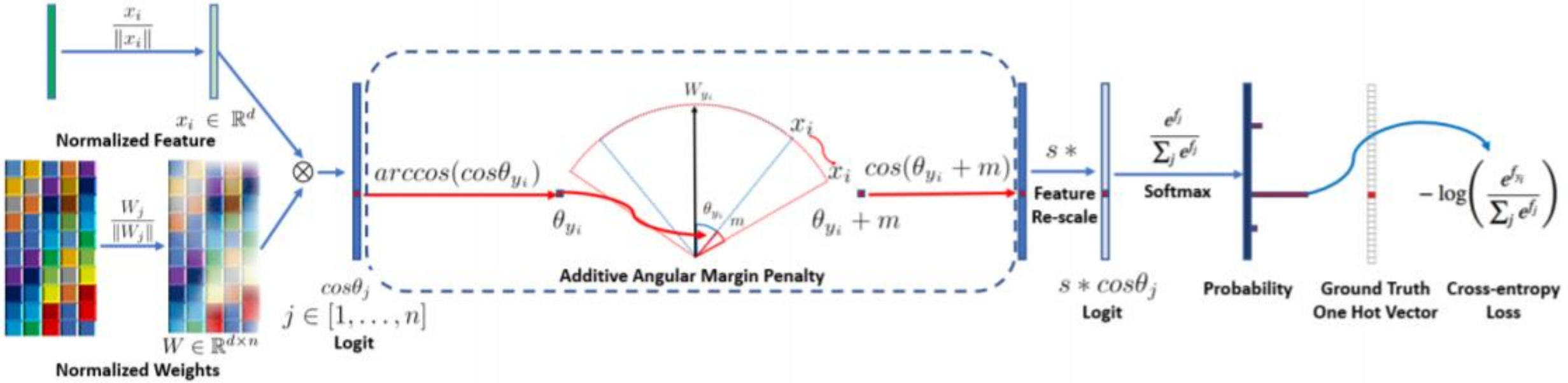
$\|W_j\| = 1$ by l_2 normalisation

$\|x_i\|$ by l_2 normalisation re-scale it to s.

여러 논문의 방법들을 가져오고
간단히 만들기 위해

$$L_2 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{s\cos\theta_{y_i}}}{e^{s\cos\theta_{y_i}} + \sum_{j=1, j\neq y_i}^{n} e^{s\cos\theta_j}}. \qquad (2)$$

변형된 로스



Algorithm 1 The Pseudo-code of ArcFace on MxNet

Input: Feature Scale s, Margin Parameter m in Eq. 3, Class Number n, Ground-Truth ID gt.

```
x = mx.symbol.L2Normalization (x, mode = 'instance')
W = mx.symbol.L2Normalization (W, mode = 'instance')
fc7 = mx.sym.FullyConnected (data = x, weight = W, no_bias = True, num_hidden = n)
original_target_logit = mx.sym.pick (fc7, gt, axis = 1)
theta = mx.sym.arccos (original_target_logit)
marginal_target_logit = mx.sym.cos (theta + m)
one_hot = mx.sym.one_hot (gt, depth = n, on_value = 1.0, off_value = 0.0)
fc7 = fc7 + mx.sym.broadcast_mul (one_hot, mx.sym.expand_dims (marginal_target_logit - original_target_logit, 1))
fc7 = fc7 * s
```

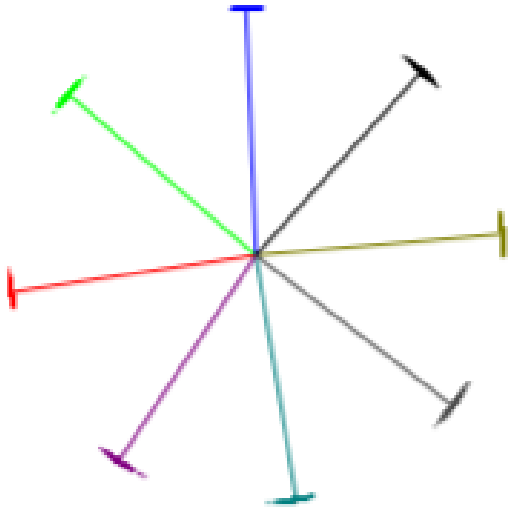
Output: Class-wise affinity score $fc7$.

ArcFace :

$$L_3 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{s(\cos(\theta_{y_i}+m))}}{e^{s(\cos(\theta_{y_i}+m))}+\sum_{j=1,j\neq y_i}^{n}e^{s\cos\theta_j}}. \quad (3)$$

마진 m을 더함

(a) Softmax

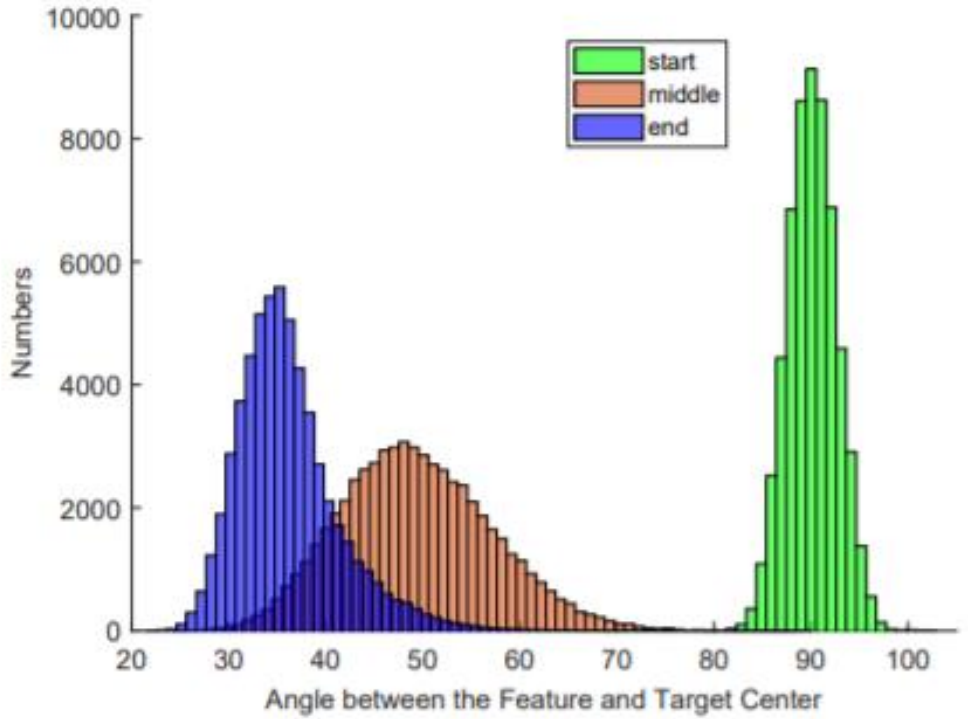


(b) ArcFace

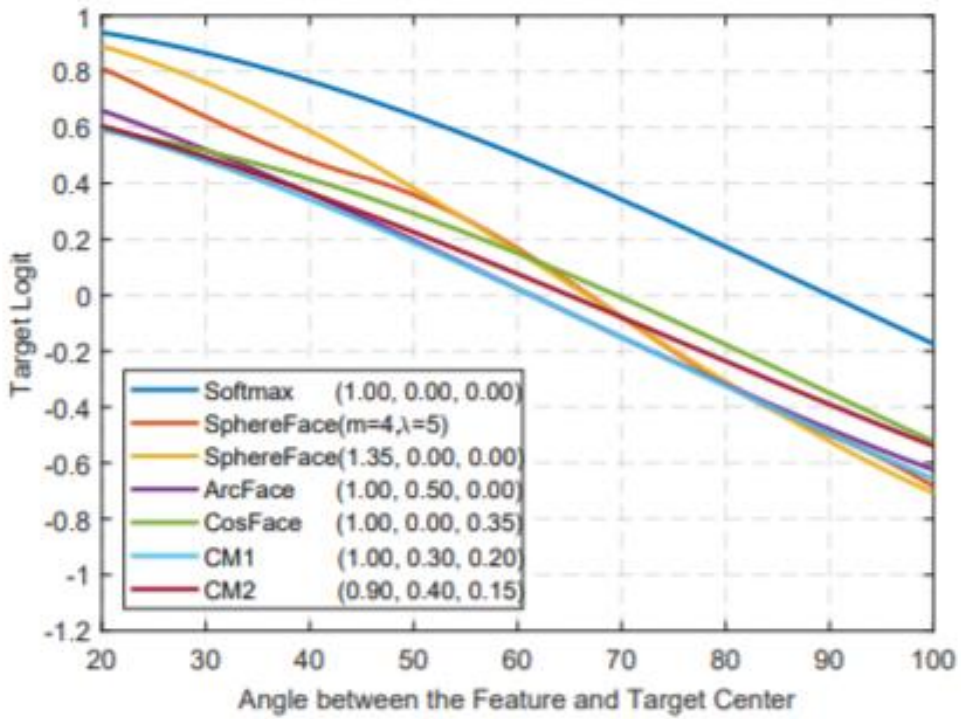
마진 m은 일종의 패널티임, 하이퍼 파라미터, 마진을 세분화 시키면

$$\cos(\theta_{y_i}+m) \longrightarrow (\cos(m_1\theta+m_2)-m_3)$$

$$L_4 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{s(\cos(m_1\theta_{y_i}+m_2)-m_3)}}{e^{s(\cos(m_1\theta_{y_i}+m_2)-m_3)}+\sum_{j=1,j\neq y_i}^{n}e^{s\cos\theta_j}} \quad (4)$$



(a) θ_j Distributions



(b) Target Logits Curves

마진 디자인에 따른 기하학적 속성(with 2진 분류)

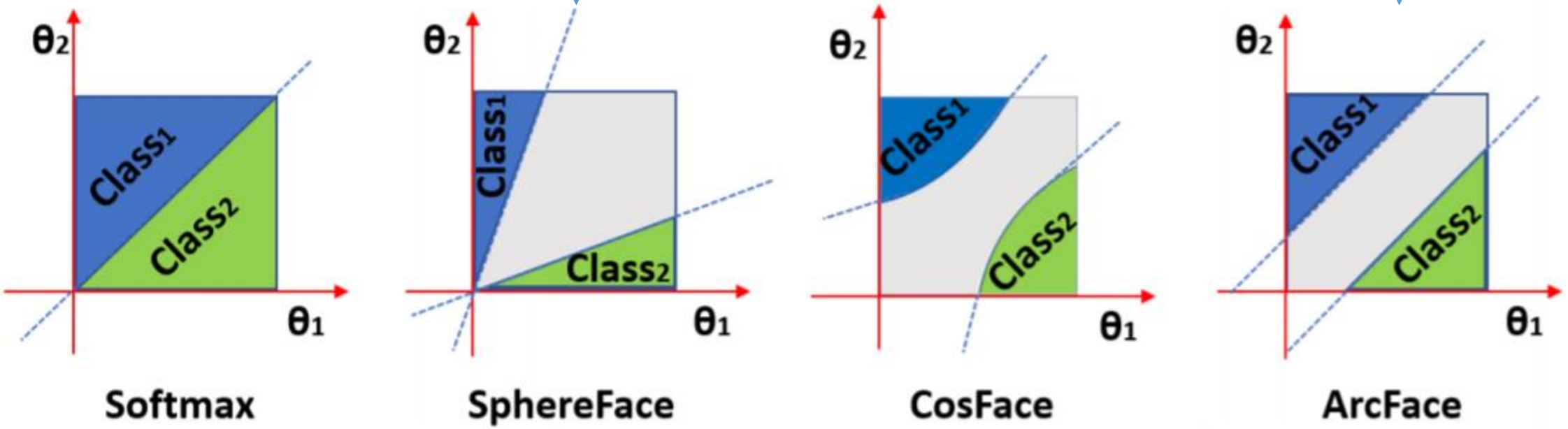
https://arxiv.org/pdf/1704.08063.pdf
https://arxiv.org/pdf/1801.09414.pdf

$$L_1 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{W_{y_i}^T x_i + b_{y_i}}}{\sum_{j=1}^{n} e^{W_j^T x_i + b_j}}$$

$$L_{lmc} = \frac{1}{N}\sum_{i} -\log\frac{e^{s(\cos(\theta_{y_i,i})-m)}}{e^{s(\cos(\theta_{y_i,i})-m)} + \sum_{j\neq y_i} e^{s\cos(\theta_{j,i})}},$$

$$L_{ang} = \frac{1}{N}\sum_{i} -\log\left(\frac{e^{\|\boldsymbol{x}_i\|\cos(m\theta_{y_i,i})}}{e^{\|\boldsymbol{x}_i\|\cos(m\theta_{y_i,i})} + \sum_{j\neq y_i} e^{\|\boldsymbol{x}_i\|\cos(\theta_{j,i})}}\right)$$

$$L_4 = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{s(\cos(m_1\theta_{y_i}+m_2)-m_3)}}{e^{s(\cos(m_1\theta_{y_i}+m_2)-m_3)} + \sum_{j=1,j\neq y_i}^{n} e^{s\cos\theta_j}} \quad (4)$$



Other Losses

$$L_5 = L_2 + \frac{1}{\pi N}\sum_{i=1}^{N}\theta_{y_i}.$$

Intra-Loss

$$L_6 = L_2 - \frac{1}{\pi N\,(n-1)}\sum_{i=1}^{N}\sum_{j=1,j\neq y_i}^{n}\arccos(W_{y_i}^{T}W_j).$$

Inter-Loss

$$\arccos(x_i^{pos}x_i) + m \leq \arccos(x_i^{neg}x_i)$$

Triplet-Loss

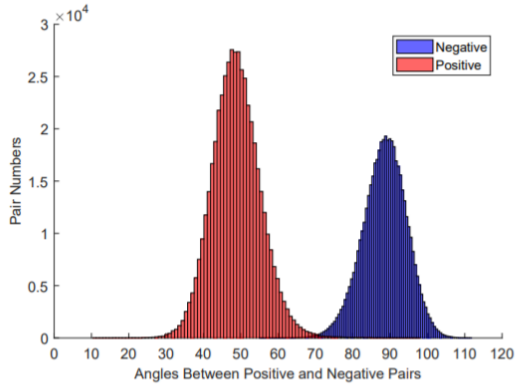
데이터셋

Datasets	#Identity	#Image/Video
CASIA [43]	10K	0.5M
VGGFace2 [6]	9.1K	3.3M
MS1MV2	85K	5.8M
MS1M-DeepGlint [2]	87K	3.9M
Asian-DeepGlint [2]	94 K	2.83M
LFW [13]	5,749	13,233
CFP-FP [30]	500	7,000
AgeDB-30 [22]	568	16,488
CPLFW [48]	5,749	11,652
CALFW [49]	5,749	12,174
YTF [40]	1,595	3,425
MegaFace [15]	530 (P)	1M (G)
IJB-B [39]	1,845	76.8K
IJB-C [21]	3,531	148.8K
Trillion-Pairs [2]	5,749 (P)	1.58M (G)
iQIYI-VID [20]	4,934	172,835

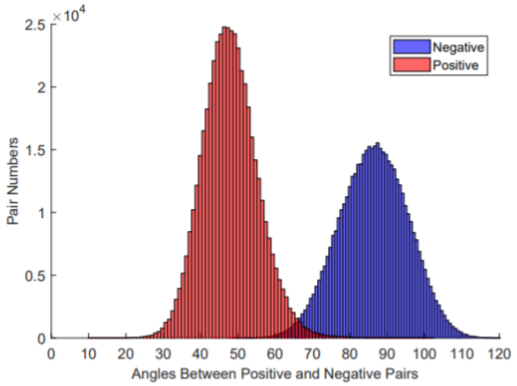
Loss Functions	LFW	CFP-FP	AgeDB-30
ArcFace (0.4)	99.53	95.41	94.98
ArcFace (0.45)	99.46	95.47	94.93
ArcFace (0.5)	**99.53**	**95.56**	**95.15**
ArcFace (0.55)	99.41	95.32	95.05
SphereFace [18]	99.42	-	-
SphereFace (1.35)	99.11	94.38	91.70
CosFace [37]	99.33	-	-
CosFace (0.35)	99.51	95.44	94.56
CM1 (1, 0.3, 0.2)	99.48	95.12	94.38
CM2 (0.9, 0.4, 0.15)	99.50	95.24	94.86
Softmax	99.08	94.39	92.33
Norm-Softmax (NS)	98.56	89.79	88.72
NS+Intra	98.75	93.81	90.92
NS+Inter	98.68	90.67	89.50
NS+Intra+Inter	98.73	94.00	91.41
Triplet (0.35)	98.98	91.90	89.98
ArcFace+Intra	99.45	95.37	94.73
ArcFace+Inter	99.43	95.25	94.55
ArcFace+Intra+Inter	99.43	95.42	95.10
ArcFace+Triplet	99.50	95.51	94.40

실험
(마진 비교)

	NS	ArcFace	IntraL	InterL	TripletL
W-EC	44.26	14.29	8.83	46.85	-
W-Inter	69.66	71.61	31.34	75.66	-
Intra1	50.50	38.45	17.50	52.74	41.19
Inter1	59.23	65.83	24.07	62.40	50.23
Intra2	33.97	28.05	12.94	35.38	27.42
Inter2	65.60	66.55	26.28	67.90	55.94



(a) ArcFace

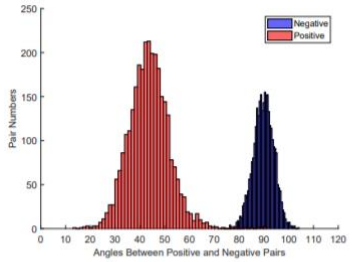


(b) Triplet-Loss

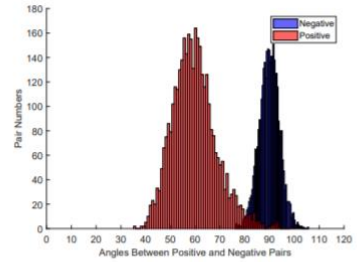
실험
(다른 모델과의 비교)

Method	#Image	LFW	YTF
DeepID [32]	0.2M	99.47	93.20
Deep Face [33]	4.4M	97.35	91.4
VGG Face [24]	2.6M	98.95	97.30
FaceNet [29]	200M	99.63	95.10
Baidu [16]	1.3M	99.13	-
Center Loss [38]	0.7M	99.28	94.9
Range Loss [46]	5M	99.52	93.70
Marginal Loss [9]	3.8M	99.48	95.98
SphereFace [18]	0.5M	99.42	95.0
SphereFace+ [17]	0.5M	99.47	-
CosFace [37]	5M	99.73	97.6
MS1MV2, R100, ArcFace	5.8M	**99.83**	**98.02**

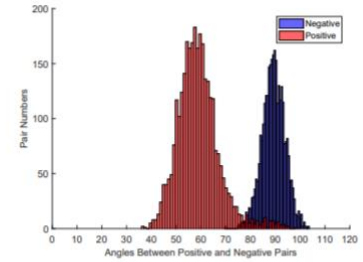
Method	LFW	CALFW	CPLFW
HUMAN-Individual	97.27	82.32	81.21
HUMAN-Fusion	99.85	86.50	85.24
Center Loss [38]	98.75	85.48	77.48
SphereFace [18]	99.27	90.30	81.40
VGGFace2 [6]	99.43	90.57	84.00
MS1MV2, R100, ArcFace	**99.82**	**95.45**	**92.08**



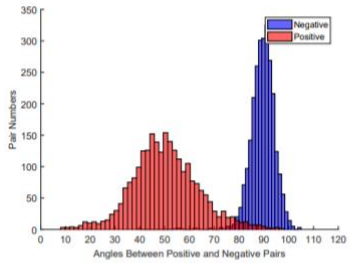
(a) LFW (99.83%)



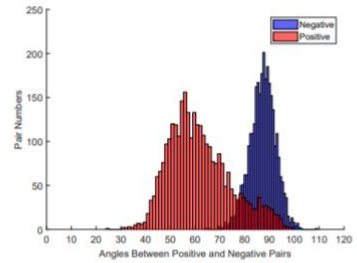
(b) CFP-FP (98.37%)



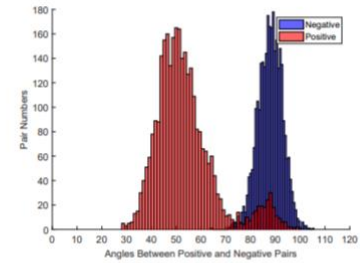
(c) AgeDB (98.15%)



(d) YTF (98.02%)



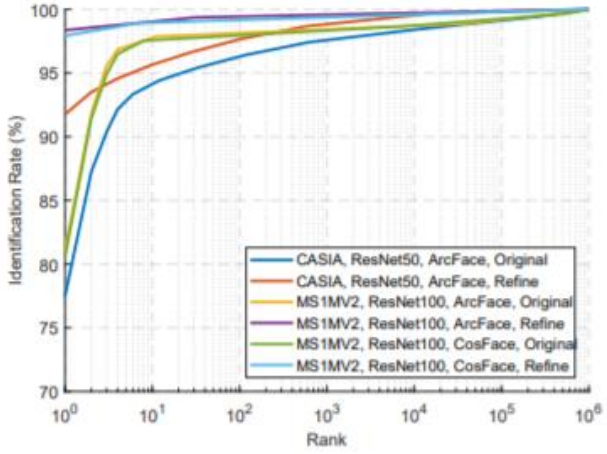
(e) CPLFW (92.08%)



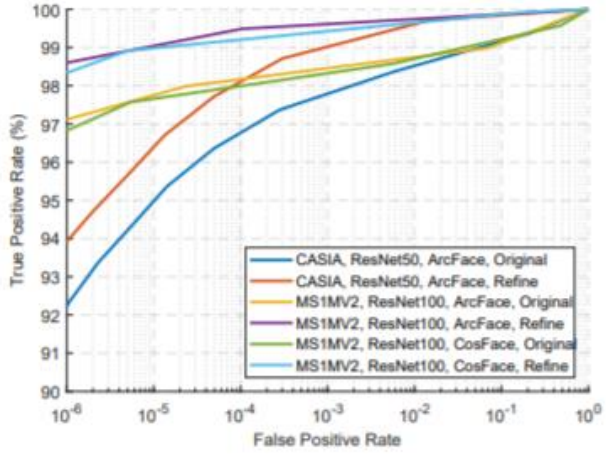
(f) CALFW (95.45%)

실험
(MegaFace)

Methods	Id (%)	Ver (%)
Softmax [18]	54.85	65.92
Contrastive Loss[18, 32]	65.21	78.86
Triplet [18, 29]	64.79	78.32
Center Loss[38]	65.49	80.14
SphereFace [18]	72.729	85.561
CosFace [37]	77.11	89.88
AM-Softmax [35]	72.47	84.44
SphereFace+ [17]	73.03	-
CASIA, R50, ArcFace	77.50	92.34
CASIA, R50, ArcFace, R	91.75	93.69
FaceNet [29]	70.49	86.47
CosFace [37]	82.72	96.65
MS1MV2, R100, ArcFace	81.03	96.98
MS1MV2, R100, CosFace	80.56	96.56
MS1MV2, R100, ArcFace, R	98.35	98.48
MS1MV2, R100, CosFace, R	97.91	97.91



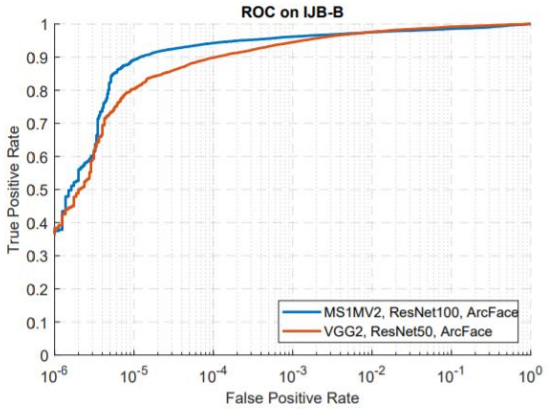
(a) CMC



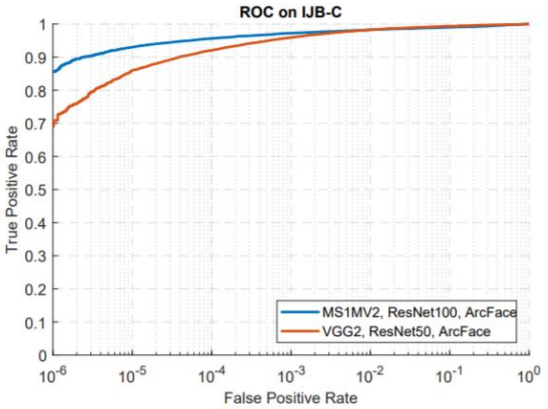
(b) ROC

실험
(IJB-B,C, Trillion Pairs)

Method	IJB-B	IJB-C
ResNet50 [6]	0.784	0.825
SENet50 [6]	0.800	0.840
ResNet50+SENet50 [6]	0.800	0.841
MN-v [42]	0.818	0.852
MN-vc [42]	0.831	0.862
ResNet50+DCN(Kpts) [41]	0.850	0.867
ResNet50+DCN(Divs) [41]	0.841	0.880
SENet50+DCN(Kpts) [41]	0.846	0.874
SENet50+DCN(Divs) [41]	0.849	0.885
VGG2, R50, ArcFace	0.898	0.921
MS1MV2, R100, ArcFace	**0.942**	**0.956**



(a) ROC for IJB-B



(b) ROC for IJB-C

Method	Id (@FPR=1e-3)	Ver(@FPR=1e-9)
CASIA	26.643	21.452
MS1MV2	80.968	78.600
DeepGlint-Face	80.331	78.586
MS1MV2+Asian	**84.840** (1st)	80.540
CIGIT_IRSEC	84.234 (2nd)	**81.558** (1st)


Chandler

Q & A