Summary of paper

ArcFace: Additive Angular Margin Loss for Deep Face Recognition

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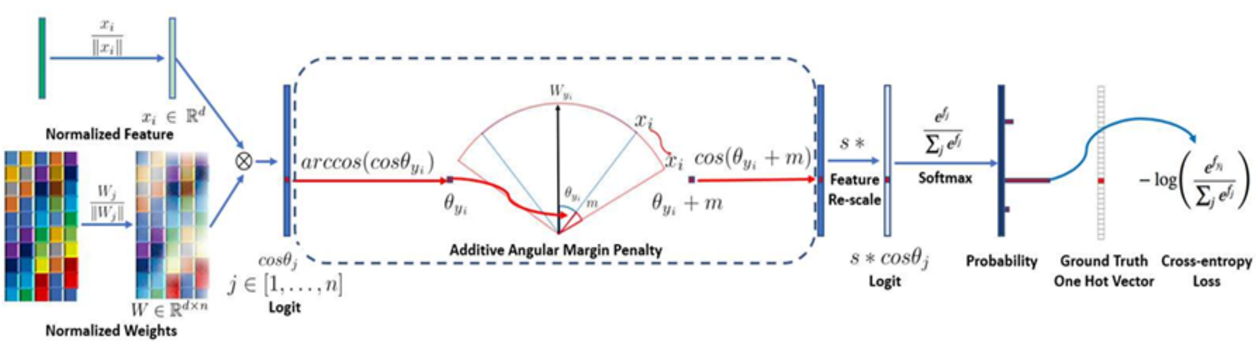
Introduction:

Conventionally in Deep convolutional Neural Networks we have face limitation with the loss function. ArcFace paper defines a loss function that gives clear geometric interpretation due to its exact correspondence to geodesic distance, that gives higher discriminative features when compared with Centre Loss (uses Euclidean space distances for intra-class correctness) and SphereFace (linear transformation matrix in the last fully connected layer for representation of the class centers in the angular space).

The two existing classifier loss functions – SoftMax Loss and Triple Loss – in field of face recognition have issues of size of linear transformation matrix and non-discriminative for face recognition in case of SoftMax loss, and issues of combinatory explosion and semihard sample mining in case of Triple loss. For ArcFace four geodesic distances – Margin-Loss, Intra-Loss, Inter-Loss, and Triple-Loss were experimented, where margin loss implemented in Arc-Face brings the extraordinary innovative results. By using margin loss ArcFace aims to optimize the geodesic distance on a hypersphere. The margin is applied on the angles between the features and their corresponding weights/center in the final layer of the network.

The approach:

To overcome the disadvantages of widely used face recognition function SoftMax, ArcFace extend it to completely depends upon angular distance between feature & weights, and angular margin penalty in normalized hypersphere. Important steps in ArcFace methodology includes:



1. **Bias reset and Normalization of features**: Normalizing both the feature embeddings and the weight vectors to the hypersphere. This will lead to only dependency on the angular relationship for the predictions.
2. **Angular Distance (Gap) Computation**: Inverse cosine is used to extract the angle between the normalized weight W and the normalized feature x to calculate the baseline for the target logits.
3. **Addition of Angular Margin**: Here the angular margin (margin-loss) is applied. This pushes the different classes further apart by enhancing the separation between them in the process pulling the same class further together.
4. **Scaling of hypersphere**: The flexibility of radius of hypersphere s, allow sufficient space for grouping of all features and maintaining gap between them. With there is virtual infinite feature groups can be formed without effecting any overlapping between different groups.
5. **SoftMax applied**: Finally, the logits go through the SoftMax function ultimately contributing the cross-entropy loss.

The loss function formulated by ArcFace, that comprises all above steps, can be expressed as follows:

$$L = -\frac{1}{N}\sum_{i=1}^{N}\frac{e^{s(\cos(\theta_{y_i}+m))}}{e^{s(\cos(\theta_{y_i}+m))}+\sum_{j=1,j!=y_i}^{n} e^{s(\cos\theta_{y_i})}}$$

Advantages:

The advantages of ArcFace are defined by E4 properties that are its being Engaging, Effective, Easy and Efficient. ArcFace optimizes the margin in normalized hypersphere with no. limitation of number of dimensions making it an engaging loss function. It gives highest performance results till now in field of face recognition, make it an effective loss function. It is easy to implement as per the steps mentioned above. At the same time ArcFace is efficient as it adds negligible computational complexity to model training.

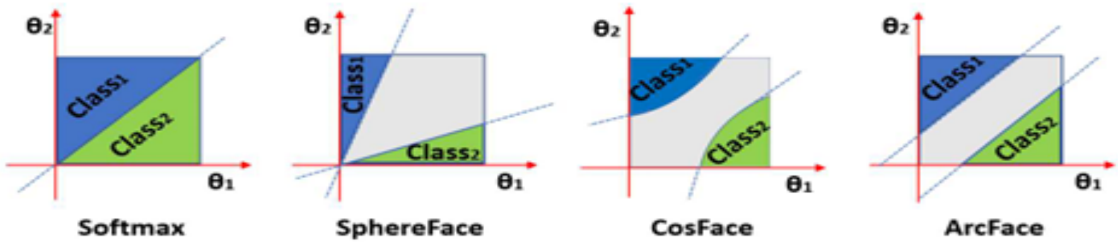
Comparison:

Compare to SoftMax, SphereFace and CosFace, ArcFace demonstrates constant linear angular margin throughout the whole interval while sphere and cos have non-linear angular margin. The equation that incorporates three loss functions SphereFace, CosFace, and ArcFace can be expressed as:

$$L = -\frac{1}{N}\sum_{i=1}^{N}\frac{e^{s(\cos(m_1*\theta_{y_i}+m_2)-m_3)}}{e^{s(\cos(m_1*\theta_{y_i}+m_2)-m_3)}+\sum_{j=1,j!=y_i}^{n} e^{s(\cos\theta_{y_i})}}$$

Where m_1, m_2, and m_3 represents SphereFace, ArcFace and CosFace losses.

This difference benefit ArcFace greatly as unlike ShpereFace we can skip the integer requirement on the margin by employing the arc-cosine function instead of using the complex double angle formula. The angular margin in ArcFace corresponds directly to the geodesic distance, making it intuitively appealing for geometric understanding.



Conclusion:

ArcFace is the state of the art loss function that can enhance the discriminative power of feature embedding learned via DCNNs. It outperforms the performances making it most effective face recognition method till date.

Reference:

J. Deng, J. Guo, N. Xue and S. Zafeiriou, "ArcFace: Additive Angular Margin Loss for Deep Face Recognition," 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), Long Beach, CA, USA, 2019, pp. 4685-4694, doi: 10.1109/CVPR.2019.00482