October 4th, 2019

Comparison of Face Feature Extraction Methods and Clustering Algorithms

Input: 2180 images—5 Categories

Feature Extraction Methods:

1. FaceNet (2015)
- https://github.com/davidsandberg/facenet
- https://arxiv.org/pdf/1503.03832.pdf

2. OpenFace (2016)
- https://cmusatyalab.github.io/openface/
- https://www.cs.cmu.edu/~satya/docdir/CMU-CS-16-118.pdf

3. Dlib (2017)
- Alignment and Feature Extraction: 1698.65 seconds ~ 28 minutes
- https://github.com/ageitgey/face_recognition
- http://blog.dlib.net/2017/02/high-quality-face-recognition-with-deep.html

4. ArcFace (2019)
- Alignment and Feature Extraction: 964.16 seconds ~ 16 minutes
- https://github.com/deepinsight/insightface
- https://arxiv.org/pdf/1801.07698.pdf

Feature Extraction Method	**Alignment**	**Learning Feature Embeddings**	**Number of Features**	**Model**
FaceNet	MTCNN (160 x 160 px)	Triple Loss Function	512	nn4 network – GoogLeNet
OpenFace	Histogram of Oriented Gradients (HOG) (96 x 96 px)	Triple Loss Function	128	nn4.small2
Dlib	Histogram of Oriented Gradients (HOG)	Triple Loss Function	128	ResNet 34 network with 29 conv layers
ArcFace	MTCNN (112 x 112 px)	Additive Angular Margin Loss Function	512	LResNet 100E-IR model that uses ResNet100

Results
- The results below show that a combination of **ArcFace** and **K-means** clustering yield the highest F-measure of 0.54
- ArcFace also had the highest F-measure for Spectral and EM clustering algorithms
- FaceNet had the highest F-measure for Hierarchical Agglomerative and Birch clustering

Comparison of Feature Extraction Methods and F-Measure of Clustering Algorithms

Clustering/Feature Extraction Method	**FaceNet**	**OpenFace**	**Dlib**	**ArcFace**
K-Means	0.48	0.38	0.39	**0.54**
Hierarchical Agglomerative	**0.44**	0.39	0.36	0.42
Spectral	0.45	0.34	0.36	**0.47**
EM (Gaussian Mixture Model)	0.50	0.38	0.39	**0.51**
Birch	**0.44**	0.33	0.41	0.41

Evaluation of Clustering Algorithms

1. FaceNet

Clustering method	Number of clusters	F-Measure	Precision	Recall	False Positives	Runtime (seconds)
K-Means	5	**0.48**	0.52	0.44	249330	1.50
Hierarchical Agglomerative	5	0.44	0.46	0.43	306,756	1.28
Spectral	5	**0.45**	0.51	0.4	236,078	1.21
EM (Gaussian Mixture Model)	5	**0.50**	0.56	0.45	216786	4.80
Birch	5	0.44	0.45	0.43	319743	1.15

2. OpenFace

Clustering method	Number of clusters	F-Measure	Precision	Recall	False Positives	Runtime (seconds)
K-Means	5	**0.38**	0.41	0.36	315014	0.85
Hierarchical Agglomerative	5	**0.39**	0.37	0.42	438934	1.03
Spectral	5	0.34	0.36	0.33	362277	1.36
EM (Gaussian Mixture Model)	5	**0.38**	0.41	0.35	312268	1.29
Birch	5	0.33	0.37	0.3	322518	0.73

3. Dlib

Clustering method	Number of clusters	F-Measure	Precision	Recall	False Positives	Runtime (seconds)
K-Means	5	**0.39**	0.41	0.37	319255	1.36
Hierarchical Agglomerative	5	0.36	0.38	0.34	336283	0.80
Spectral	5	0.36	0.39	0.34	331956	1.16
EM (Gaussian Mixture Model)	5	**0.39**	0.42	0.37	313557	1.14
Birch	5	**0.41**	0.33	0.53	675900	0.91

4. ArcFace

Clustering method	Number of clusters	F-Measure	Precision	Recall	False Positives	Runtime (seconds)
K-Means	5	**0.54**	0.61	0.48	185839	1.79
Hierarchical Agglomerative	5	0.42	0.43	0.42	345606	1.49
Spectral	5	**0.47**	0.54	0.42	220327	1.43
EM (Gaussian Mixture Model)	5	**0.51**	0.58	0.46	208091	1.61
Birch	5	0.41	0.44	0.39	309016	1.70