

Logical Consistency and Greater Descriptive Power for Facial Hair Attribute Learning

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This supplementary material provides: a) statistical information for the attributes, b) examples of 28 categories, c) the consistency estimation table and analysis, d) the positive accuracy and negative accuracy on each facial hair attribute, e) logically inconsistent prediction detection f) part of the training and testing code in Code 1 and Code 2, and g) the facial hair area based demographic analysis on recognition accuracy across Asian male (AM) and Indian male (IM).

Attributes	# of positive samples	Attributes	# of positive samples
Clean Shaven	9,562	Mustache Connected to Beard	15,887
Chin Area	9,381	Mustache Info Not Vis	1,343
Side to Side	17,375	Sideburns-None	14,004
Beard area Info Not Vis	3,001	Sideburns-Present	7,361
5 O'clock Shadow	11,759	Sideburns Connected to Beard	9,809
Short	11,693	Sideburns Info Not Vis	6,391
Medium	2,475	Bald False	31,085
Long	747	Bald Top Only	1,065
Beard length Info Not Vis	2,757	Bald Top and Sides	1,321
Mustache-None	10,228	Bald Sides Only	161
Mustache-Isolated	10,107	Bald Info Not Vis	3,933

Table 1. Statistic information of the FH37K dataset.

Attributes	Consistency rate	Attributes	Consistency rate
Clean Shaven	0.99	Mustache Connected to Beard	0.83
Chin Area	0.92	Mustache Info Not Vis	0.99
Side to Side	0.93	Sideburns-None	0.90
Beard area Info Not Vis	0.98	Sideburns-Present	0.92
5 O'clock Shadow	0.91	Sideburns Connected to Beard	0.90
Short	0.83	Sideburns Info Not Vis	0.94
Medium	0.89	Bald False	0.99
Long	1	Bald Top Only	0.98
Beard length Info Not Vis	0.98	Bald Top and Sides	1
Mustache-None	0.98	Bald Sides Only	1
Mustache-Isolated	0.84	Bald Info Not Vis	0.99

Table 2. The estimated consistency rate of each attribute in the FH37K dataset.

Statistic information of the attributes: Table 1 shows the number of positive samples of each attribute. Due to the particularity of some attributes, e.g. long beard and bald, it is hard to collect samples for a balanced number of positive and negative samples. For example, we only find 59 samples that are clearly Bald Sides Only from 608,184 images in the WebFace260M dataset. Since the dataset distributes in a long-tail pattern, the attributes are in a fine-grained level, and the most important is the robustness of the annotations is promised, this dataset has a great potential for use in other research areas.

	Clean Shaven	Chin Area	Side to Side	Beard area Info Not Vis	5 O'clock Shadow	Short	Medium	Long	Bread length Info Not Vis	Mustache-None	Mustache-Isolated
Overall acc	86.86	87.46	88.05	92.28	80.62	83.44	92.40	96.75	91.34	86.26	85.74
Negative acc	93.88	91.41	88.34	96.11	80.62	94.32	98.04	97.27	94.36	91.24	90.27
Positive acc	70.21	71.14	87.59	76.05	80.61	55.42	23.60	78.81	78.18	77.36	66.42
	Mustache Connected to Beard	Mustache Info Not Vis	Sideburns-None	Sideburns-present	Sideburns Connected to Beard	Sideburns Info Not Vis	Bald False	Bald Top Only	Bald Top and Sides	Bald Sides Only	Bald Info Not Vis
Overall acc	89.11	93.11	80.33	86.05	89.86	88.94	92.80	95.46	97.37	98.57	95.79
Negative acc	91.15	94.75	87.17	88.61	93.25	92.39	84.00	96.44	98.58	98.96	97.25
Positive acc	85.64	74.57	70.97	70.77	78.46	75.57	95.10	78.17	66.25	0	84.21

Table 3. Performance of the BCELoss + LCPLoss + label compensation strategy on the logically inconsistent predictions counted case.

Samples of the 28 categories: Figure 4 to Figure 9 indicates that the attributes in the FH37K dataset are able to cover the most real-world cases, e.g. occlusion, blurriness, various head poses and lighting angle, etc., on facial hair attributes. Moreover, the pattern of how we design the attributes can be used for future dataset creation.

Consistency rate estimation: The overall consistency rate is 94.05%. Table 2 gives the estimated consistency rate on each attribute. Consistency occurs in two main situations: edge cases of two attributes, and low image quality. The edge cases usually happen between (Chin Area, Side to Side), (5 O'clock Shadow, Short), (Short, Medium), (Medium, Long). It is hard to make a definition to differentiate the edge images within these pairs, because it could be caused by head pose, ratio of the face area in the image, etc. Since the images are in-the-wild, the quality of the images cannot be controlled, which is a key factor that increases the consistency for all the annotations. Especially for those connectedness-related attributes: Mustache Connected to Beard, Mustache-Isolated, Sideburns Connected to Beard, and Sideburns-Present. These two situations cause the high consistency rate on: Short (83%), Medium (89%), Mustache-Isolated (84%), Mustache Connected to Beard (83%), and Sideburns Connected to Beard (90%).

Positive accuracy and negative accuracy on each facial hair attribute: Table 3 shows the performance of our approach - BCELoss + LCPLoss + label compensation strategy - on the logically inconsistent predictions counted cases. Due to the unbalanced number of positive and negative data, the model performs differently on negative and positive side, especially for Bald Sides Only - 98.57 on negative, 0 on positive. There has been a number of research papers that aim to solve this problem, but to our best knowledge, none of them also considers the logical consistency of predictions. Therefore, it is a new challenge that we will continue to investigate in the future.

BUPT-B	N_{pairs}	AM	N_{pairs}	IM	N_{pairs}	BM	N_{pairs}	WM
(CA,CA)	20,023,701	0.3106	5,650,812	0.1077	11,600,143	0.0124	69,315,624	0.0469
		0.344		0.1166		0.0112		0.0435
(CA,CS)	135,322,667	0.1212	42,724,509	0.0762	63,921,210	0.0076	65,111,816	0.0265
		0.1357		0.0749		0.0072		0.0264
(CA,S2S)	4,592,669	0.1763	29,576,598	0.0875	29,684,747	0.0085	97,099,372	0.0362
		0.201		0.096		0.0089		0.0341
(CS,CS)	228,110,497	0.1129	80,428,098	0.1781	87,789,833	0.0111	15,234,314	0.0465
		0.1137		0.159		0.0102		0.0429
(CS,S2S)	15,511,399	0.0711	111,629,961	0.0469	81,693,502	0.0073	45,573,411	0.0189
		0.0796		0.051		0.0075		0.0185
(S2S,S2S)	259,663	0.2045	38,505,245	0.1898	18,893,399	0.0281	33,893,992	0.0606
		0.2465		0.1809		0.0278		0.0536

Table 4. False match rate and corresponding fraction of each beard area comparison group. For the false match rate and fraction of each category, top number is ArcFace model, bottom is MagFace.

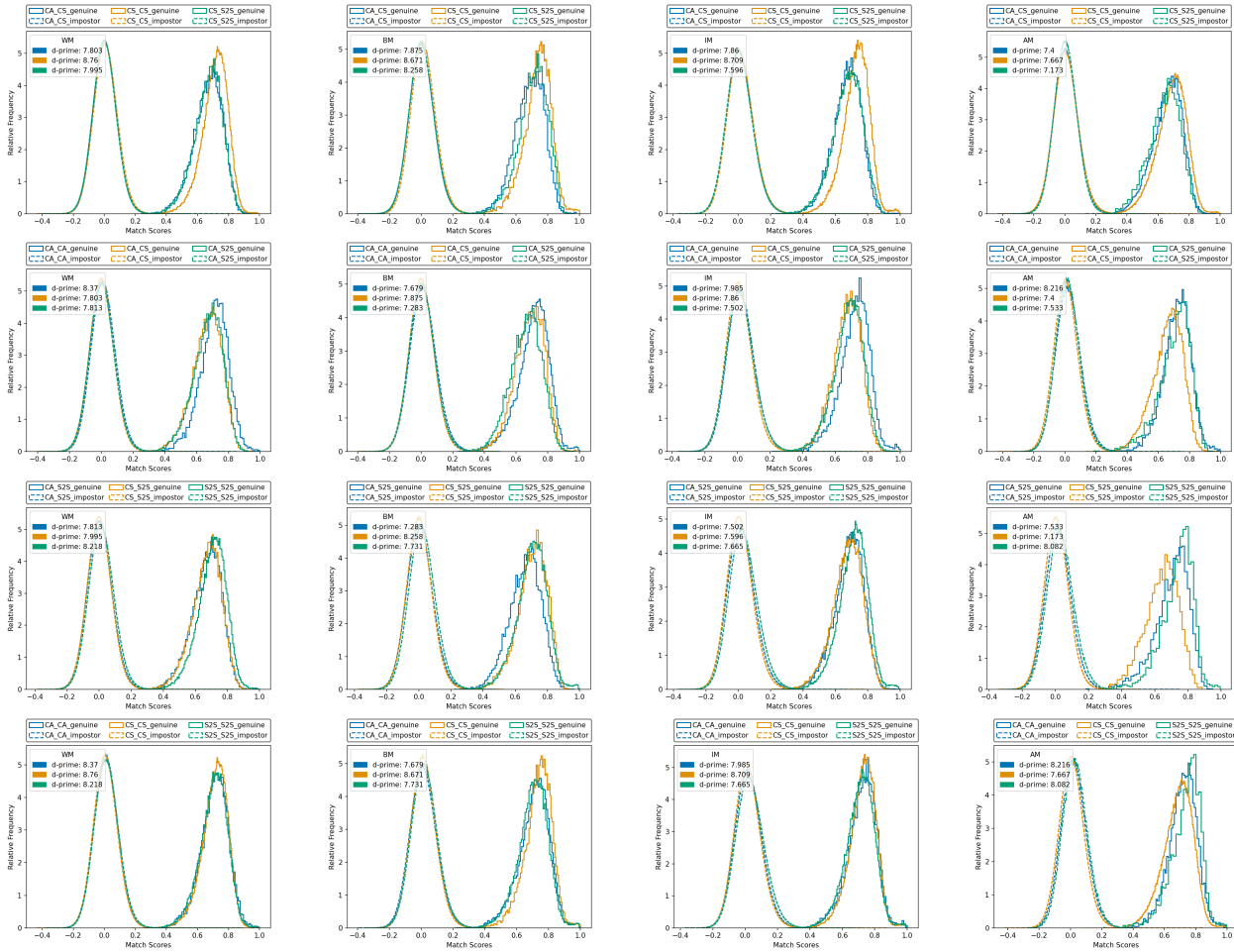


Figure 1. Facial hair attribute based genuine and impostor distributions for WM, BM, IM, AM in BA-test dataset. First row is CS focused plots, second is CA focused plots, third is S2S focused, and last row is same-beard-area focused plots. The feature extractor is ArcFace.

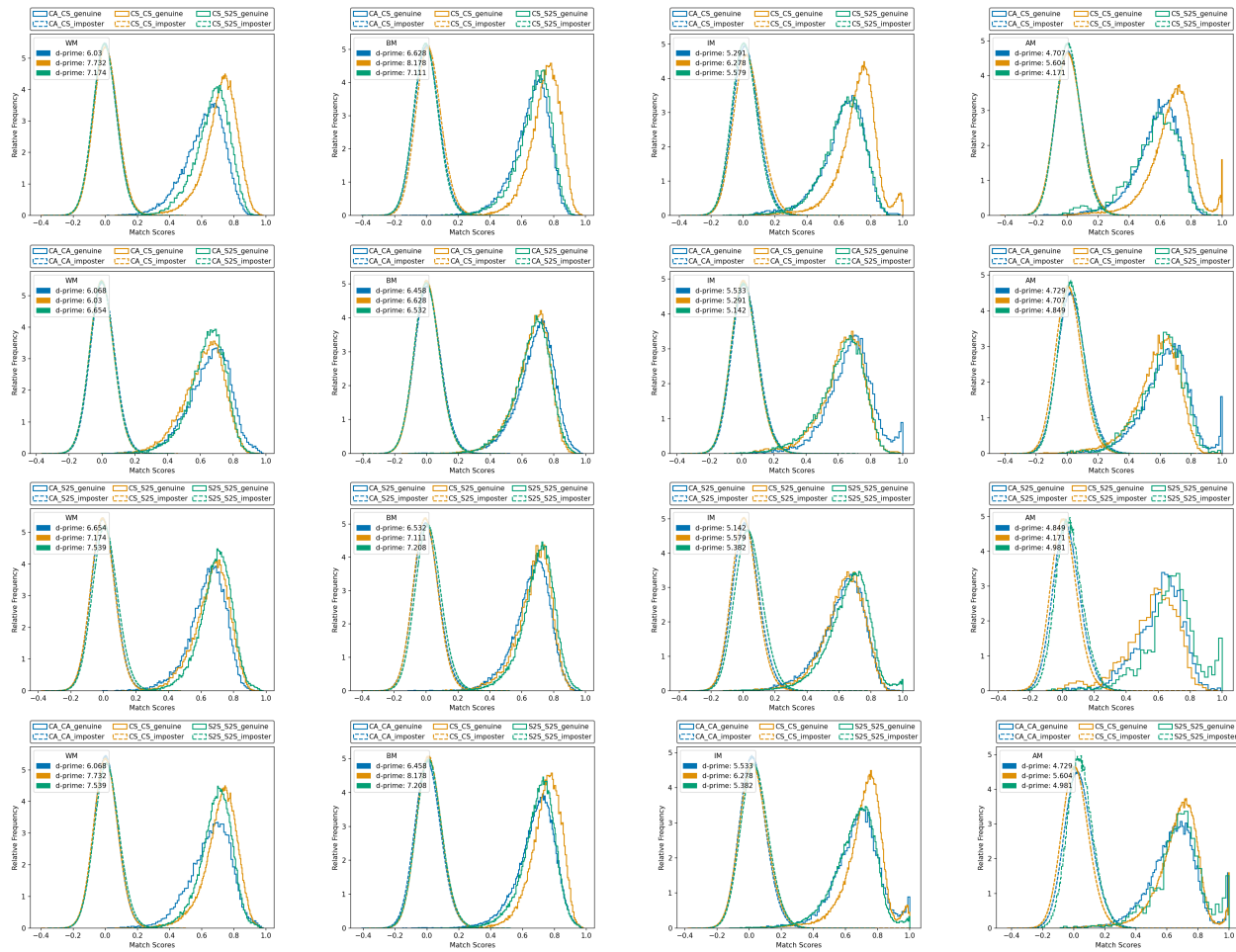


Figure 2. Facial hair attribute based genuine and impostor distributions for WM, BM, IM, AM in BUPT-B dataset. First row is CS focused plots, second is CA focused plots, third is S2S focused, and last row is same-beard-area focused plots. The feature extractor is ArcFace.

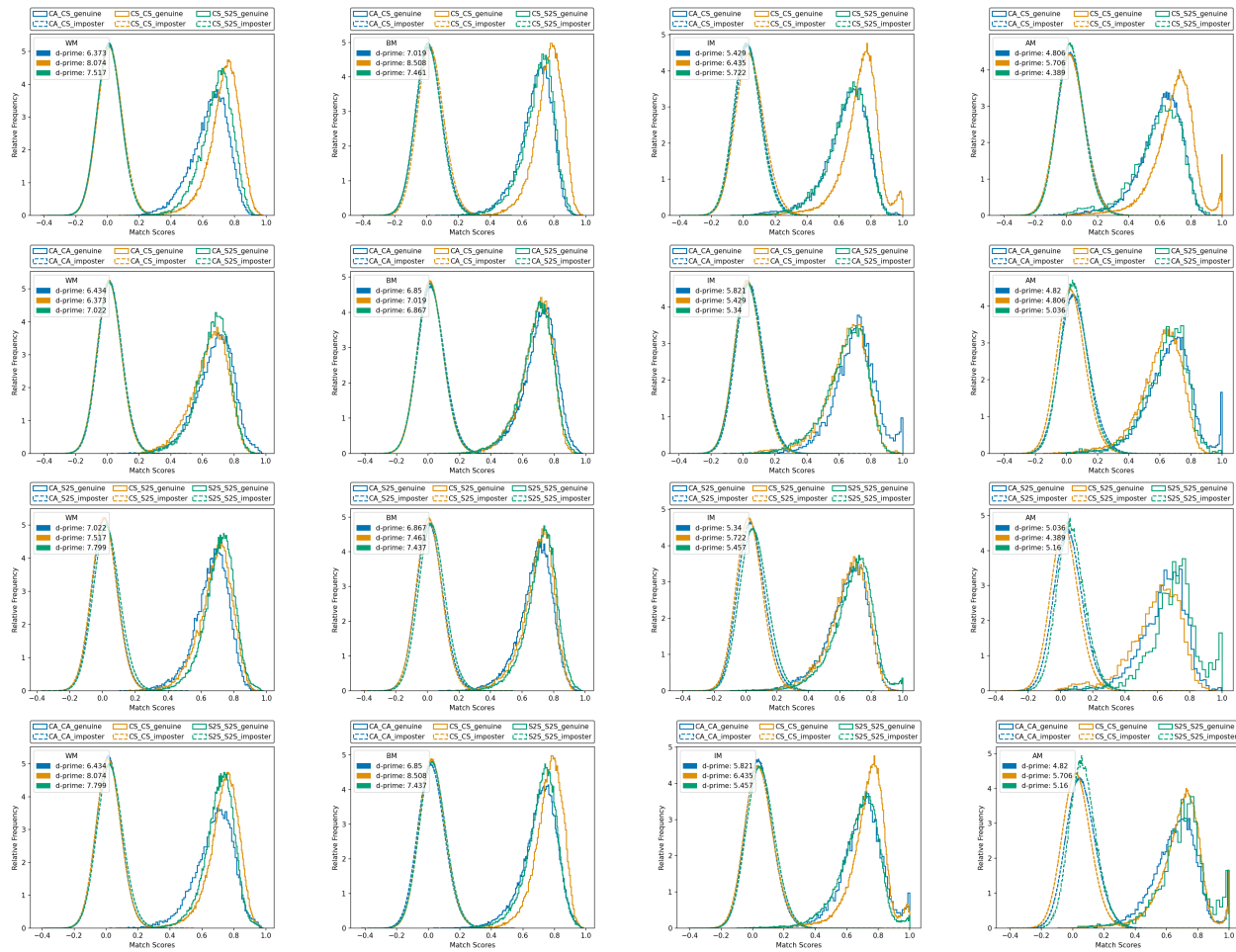


Figure 3. Facial hair attribute based genuine and impostor distributions for WM, BM, IM, AM in BUPT-B dataset. First row is CS focused plots, second is CA focused plots, third is S2S focused, and last row is same-beard-area focused plots. The feature extractor is MagFace.

Algorithm 1 Failed prediction detection

Attribute groups

Beard areas: Clean Shaven, Chin Area, Side to Side, Info not Vis

Beard lengths: 5 O'clock Shadow, Median, Long, Info not Vis

Mustache: None, Isolated, Connected-to-beard, Info not Vis

Sideburns: None, Present, Connected-to-beard, Info not Vis

Bald: False, Top only, Sides only, Top and Sides, Info not Vis

Fail conditions

Mutually exclusive:

1. More than one positive predictions in Beard areas (except Info not Vis), Beard lengths (except Info not Vis) Mustache, Sideburns, Bald group
2. Clean Shaven + any of the Beard lengths/Mustache Connected-to-beard/Sideburns Connected-to-beard
3. Chin area + Sideburns Connected-to-beard
4. Bald (Top and Sides or Sides only) + having sideburns (Sideburns Present, Sideburns Connected-to-beard)

Dependency:

1. Having beard (Chin Area, Side to Side) + one of the beard lengths must be true
2. Mustache is connected to beard + !(Chin Area, Side to Side)
3. Sideburns is connected to beard + !Side to Side

Collectively exhaustive

No positive prediction in Beard area/Beard lengths/Mustache/Sideburns/Bald

Impossible: prediction fits any of the conditions in *Mutually exclusive* and *Dependency*

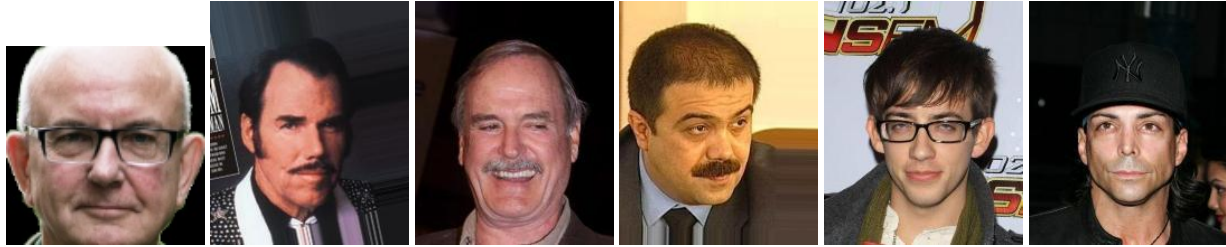
Incomplete: prediction fits any of the conditions in *Collectively exhaustive*

Code 1 Part of the training code for using the LCPLoss and label compensation strategy.

```
for i in range(self.epoch):
    self.model.train()
    for j, (inputs, labels) in self.train_loader:
        inputs, labels = inputs.cuda(), labels.cuda()
        self.opt.zero_grad()
        output = self.model(inputs)
        binary_output = self.label_compensation(output)
        loss = (1 - self.config.lmbda) * self.bceloss(output, labels) + self.config.lmbda *
            ↪ self.lcploss(binary_output)
        loss.backward()
```

Code 2 Part of the testing code for using the label compensation strategy.

```
with torch.no_grad():
    for j, (inputs, labels) in self.test_loader:
        inputs, labels = inputs.cuda(), labels.cuda()
        self.opt.zero_grad()
        prediction = self.model(images)
        predicted = self.label_compensation(prediction)
```



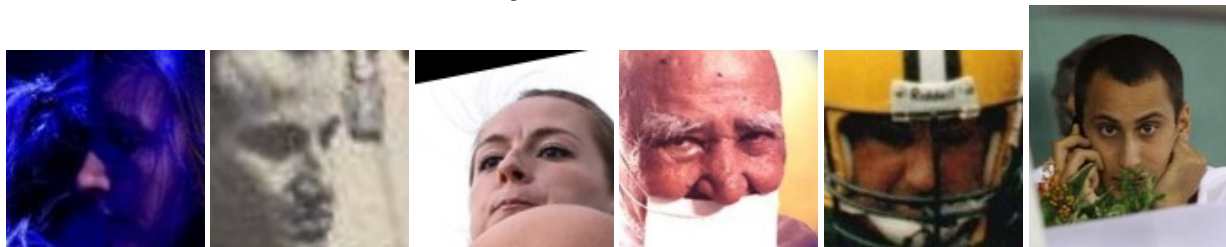
(a) Samples of the attribute Clean Shaven.



(b) Samples of the attribute Chin Area.



(c) Samples of the attribute Side to Side.



(d) Samples of the attribute Beard Area Info Not Vis.

Figure 4. Examples of the Beard Area attributes.



(a) Samples of the attribute 5 O'clock Shadow.



(b) Samples of the attribute Short.



(c) Samples of the attribute Medium.



(d) Samples of the attribute Long.



(e) Samples of the attribute Beard Length Info Not Vis.

Figure 5. Examples of the Beard Length attributes.



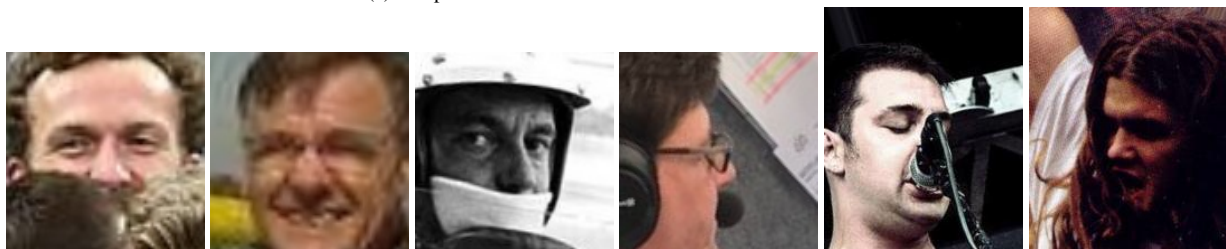
(a) Samples of the attribute Mustache-None.



(b) Samples of the attribute Mustache-Isolated.



(c) Samples of the attribute Mustache Connected to Beard.



(d) Samples of the attribute Mustache Info Not Vis.

Figure 6. Examples of the Mustache attributes.



(a) Samples of the attribute Sideburns-None.



(b) Samples of the attribute Sideburns-Present.



(c) Samples of the attribute Sideburns Connected to Beard.

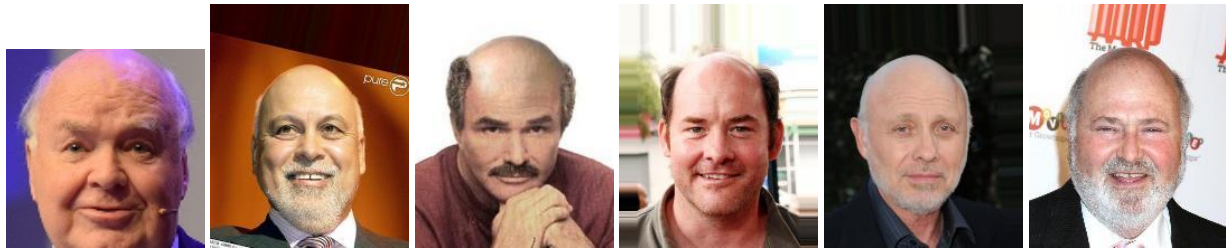


(d) Samples of the attribute Sideburns Info Not Vis.

Figure 7. Examples of the Sideburns attributes.



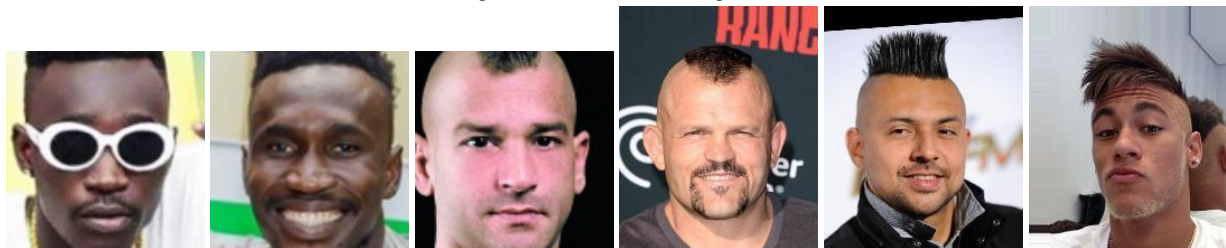
(a) Samples of the attribute Bald-False.



(b) Samples of the attribute Bald Top Only.



(c) Samples of the attribute Bald Top and Sides.

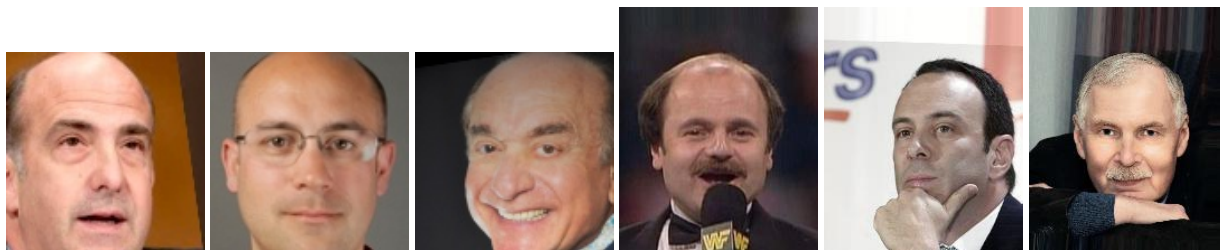


(d) Samples of the attribute Bald Sides Only.



(e) Samples of the attribute Bald Info Not Vis.

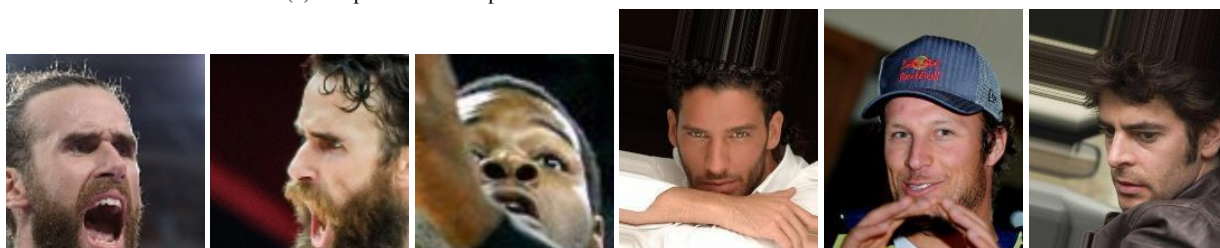
Figure 8. Examples of the Bald attributes.



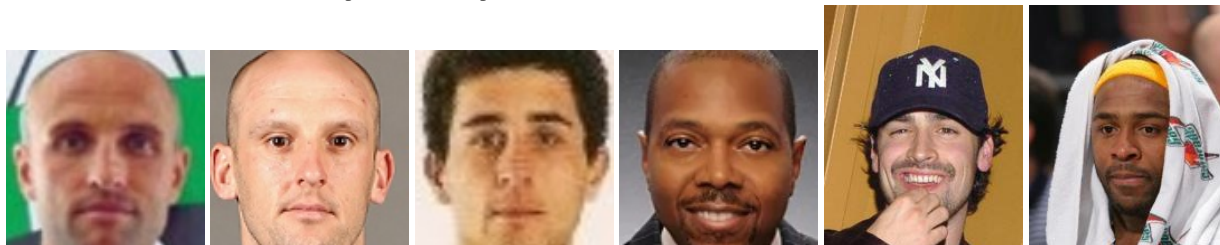
(a) Samples of the Info partial visible - Clean Shaven + Beard Area Info Not Vis.



(b) Samples of the Info partial visible - Chin Area + Beard Area Info Not Vis.



(c) Samples of the Info partial visible - Side to Side + Beard Area Info Not Vis.



(d) Samples of the Info partial visible - 5 O'clock Shadow + Beard Length Info Not Vis.



(e) Samples of the Info partial visible - Short + Beard Length Info Not Vis.



(f) Samples of the Info partial visible - Medium + Beard Length Info Not Vis.

Figure 9. Examples of the Info partially visible.