AUA American University of Armenia

Face detection

Project

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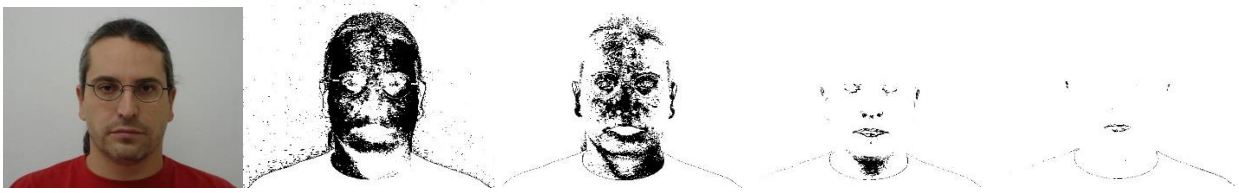
Images to work with from the FEI Face database (https://fei.edu.br/~cet/facedatabase.html)

2-11

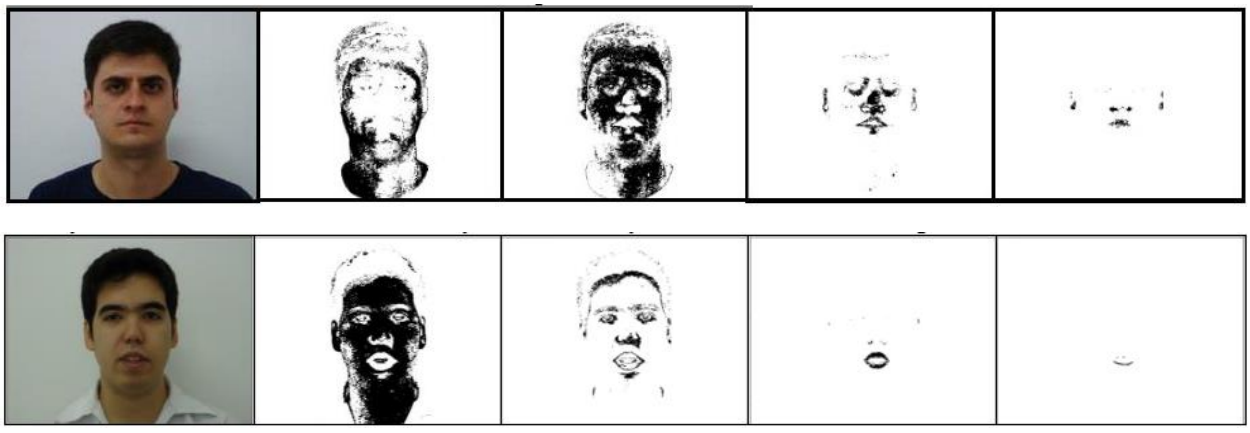
3-11

4-11

5-11



**Please note these two examples below, the first one exhibits standard behavior, while the second one does not.*



Consider these 4 binary layers:

The zeroth binary layer selects pixels mainly concentrated along the contours of the skin and hair areas.
The first binary layer selects pixels from the outer regions of the skin area and eyebrows.
The second binary layer selects pixels from the inner regions of the skin area.
The third binary layer selects pixels from the central region.

Above are represented different images with several modifications. The left-most image of all 6 is the original one, following is an image to which binary layer 0 is applied, then the one to which binary layer 1 is applied, then binary layer 2 and finally, the right-most image is the one to which binary layer 3 is applied.

Based on the examples, we can see that from the photos assigned to me, 2-11 and 4-11 exhibit the standard behavior, but 3-11 and 5-11 do not.

Characteristics of ***the standard behavior***:

- Zeroth binary layer selects pixels mainly concentrated along the face bounds.
- First binary layer selects the majority of the skin pixels,
- Second binary layer selects pixels from the central region around the nose, eyebrows and lips.
- Third binary layer selects pixels from the lips and, possible, ears.

Characteristics of the ***not standard behavior***:

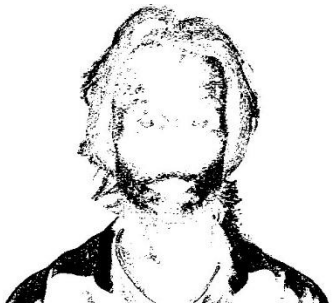
- Zeroth binary layer extracts practically all skin pixels, instead of the border pixels.
- First binary layer extracts some pixels around the nostrils, lips and eye sockets.
- Second binary layer concentrates on the lips.
- Third binary layer concentrates on the lips as well.

Stage 1.1

The task is to produce smoothened and prominent regions and minimize or remove insignificant details. In order to reach so we should consider different filters of different radii and apply before and/or after the extraction of the Binary Layers.

* The command from ImageJ **Process** ▷ **Filters** sub-menu is used.

Image 2-11

Consider 2-11 and the zeroth binary layer applied.

After extraction of Binary layer 0

1. Binary layer 0, Gaussian blur 1

2. Binary layer 0, Gaussian blur 1, Median 2

3. Binary layer 0, Gaussian blur 2, Maximum 1

4. Binary layer 0, Gaussian blur 1, Minimum 1

5. Binary layer 0, Minimum 1, Median 2, Maximum 1

6. Binary layer 0, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

7. Binary layer 0, Gaussian blur 1, Minimum 2, Median 2

8. ***Binary layer 0, Gaussian blur 1, Median 4***

Before extraction of binary layer 0

9. Gaussian blur 1, Binary layer 0

10. Gaussian blur 1, Median 3, Binary layer 0

11. Median 3, Minimum 1, Gaussian blur 2, Binary layer 0

Before AND after extraction of binary layer 0

12. Median 4, Gaussian blur 3, Maximum 2, Binary layer 0, Minimum 0.5

13. Gaussian blur 2, Binary layer 0, Median 3

14. Mean 2, Binary layer 0, Minimum 1, Gaussian blur 1

15. Median 4, Binary layer 0, Gaussian blur 1.5


Consider 2-11 and the first binary layer applied.

After extraction of Binary layer 1

1. Binary layer 1, Gaussian blur 1, Median 2

2. Binary layer 1, Gaussian blur 1, Minimum 1

3. Binary layer 1, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

4. Binary layer 1, Gaussian blur 1, Minimum 1, Median 4

5. Binary layer 1, Median 2, Median 3, Minimum 1

6. Binary layer 1, Gaussian blur 1, Median 4

7. Binary layer 1, Gaussian blur 1, Minimum 2, Median 2

8. Binary layer 1, Mean 2, Minimum 1

Before extraction of binary layer 1

9. Gaussian blur 1, Median 3, Binary layer 1

10. Median 3, Minimum 1, Gaussian blur 2, Binary layer 1

11. Mean 2.5, Median 1.5, Binary layer 1

Before AND after extraction of binary layer 1

12. ***Median 4, Gaussian blur 3, Maximum 2, Binary layer 1, Minimum 0.5***

13. Gaussian blur 2, Binary layer 1, Maximum 2.

-interesting case- left eye is vanished

14. Median 4, Binary layer 1, Gaussian blur 1.5

15. Mean 2, Binary layer 1, Minimum 1, Gaussian blur 1


Consider 2-11 and the second binary layer applied.

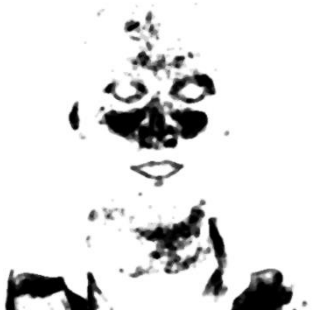
After extraction of Binary layer 2

1. Binary layer 2, Gaussian blur 1.5, Minimum 1

2. ***Binary layer 2, Gaussian blur 0.5, Mean 1***

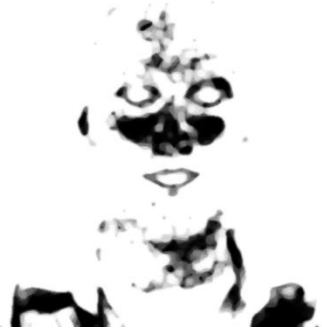
3. ***Binary layer 2, Gaussian blur 1, Median 4***

4. Binary layer 2, Gaussian blur 0.7, Minimum 1, Median 3



5. Binary layer 2, Mean 2, Minimum 1, Maximum 0.5

6. Binary layer 2, Gaussian blur 1, Minimum 2, Median 4, Maximum 1



Before extraction of binary layer 2

7. ***Median 3, Minimum 1, Gaussian blur 2, Binary layer 2***

8. Mean 2.5, Median 1.5, Binary layer 2

9. ***Minimum 1.5, Median 3.25, Maximum 1.5, Mean 2, Binary layer 2***

Before AND after extraction of binary layer 2

10. Median 4, Gaussian blur 3, Maximum 2, Binary layer 2, Minimum 0.5

-interesting case- the structure of the lip is changes because of the Max filter application

11. ***Mean 2, Binary layer 2, Minimum 0.3, Gaussian blur 0.5***

12. Median 4, Binary layer 2, Gaussian blur 1

13. Median 3, Mean 2.25, Binary layer 2, Gaussian blur 1.25, Maximum 2, Minimum 0.5

14. Mean 2.3, Maximum 1.2, Binary layer 2, Gaussian blur 1, Maximum 0.3

-interesting case- notice the change in the structure of the lips and also notice the Max filter application

15. Minimum 0.5, Binary layer 2, Mean 2.5

Consider 2-11 and the third binary layer applied.

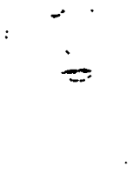
After extraction of Binary layer 3

1. Binary layer 3, Gaussian blur 0.5, Mean 1 (animast)

2. ***Binary layer 3, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

3. ***Binary layer 1, Gaussian blur 1, Median 4***

4. Binary layer 3, Median 0.3, Minimum 0.6



5. Binary layer 3, Gaussian blur 1, Minimum 1, Median 4

6. Binary layer 3, Mean 2, Minimum 1, Maximum 0.5

Before extraction of binary layer 3

7. ***Median 3, Minimum 1, Gaussian blur 2, Binary layer 3***

8. Minimum 3, Binary layer 3

-interesting case- the structure of the lips is changes here as well, however, as we can see it is because of the intense Minimum filter application

9. Minimum 2.5, Maximum 0.5, Median 3, Binary layer 3

10. Maximum 3, Median 2, Binary layer 3

-interesting case- the lips remind us a heart

11. Minimum 3.5, Maximum 1.5, Minimum 1, Binary layer 3 (similar to ***Minimum 2.5, Maximum 0.5, Median 3, Binary layer 3***)

-interesting fact – please refer to the mentioned case

Before AND after extraction of binary layer 3

12. Median 3, Minimum 1, Binary layer 3, Gaussian blur 1, Minimum 1

13. Median 3, Mean 2.25, Binary layer 3, Gaussian blur 1.25, Maximum 2, Minimum 0.5

14. Median 4, Binary layer 0, Gaussian blur 1.5

15. Median 3, Binary layer 3, Minimum 2

-important fact- please notice the intense Minimum filter effect which kind of thickened the lip outline

Successful filter combinations for Binary layer 0

6. Binary layer 0, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

8. Binary layer 0, Gaussian blur 1, Median 4

10. Gaussian blur 1, Median 3, Binary layer 0

11. Median 3, Minimum 1, Gaussian blur 2, Binary layer 0

12. Median 4, Gaussian blur 3, Maximum 2, Binary layer 0, Minimum 0.5

15. Median 4, Binary layer 0, Gaussian blur 1.5

Successful filter combinations for Binary layer 1

3. ***Binary layer 1, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

4. ***Binary layer 1, Gaussian blur 1, Minimum 1, Median 4***

6. ***Binary layer 1, Gaussian blur 1, Median 4***

8. ***Binary layer 1, Mean 2, Minimum 1***

10. ***Median 3, Minimum 1, Gaussian blur 2, Binary layer 1***

12. ***Median 4, Gaussian blur 3, Maximum 2, Binary layer 1, Minimum 0.5***

14. ***Median 4, Binary layer 1, Gaussian blur 1.5***

15. ***Mean 2, Binary layer 1, Minimum 1, Gaussian blur 1***

Successful filter combinations for Binary layer 2

2.Binary layer 2, Gaussian blur 0.5, Mean 1

3. ***Binary layer 2, Gaussian blur 1, Median 4***

6. ***Binary layer 2, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

7. ***Median 3, Minimum 1, Gaussian blur 2, Binary layer 2***

9. ***Minimum 1.5, Median 3.25, Maximum 1.5, Mean 2, Binary layer 2***

11. ***Mean 2, Binary layer 2, Minimum 0.3, Gaussian blur 0.5***

13. ***Median 3, Mean 2.25, Binary layer 2, Gaussian blur 1.25, Maximum 2, Minimum 0.5***

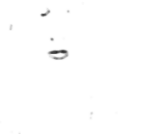
15. ***Minimum 0.5, Binary layer 2, Mean 2.5***

Successful filter combinations for Binary layer 3

2. ***Binary layer 3, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

3. ***Binary layer 1, Gaussian blur 1, Median 4***

5. ***Binary layer 3, Gaussian blur 1, Minimum 1, Median 4***



6. ***Binary layer 3, Mean 2, Minimum 1, Maximum 0.5***

7. Median 3, Minimum 1, Gaussian blur 2, Binary layer 3

9. ***Minimum 2.5, Maximum 0.5, Median 3, Binary layer 3***

14. Median 4, Binary layer 0, Gaussian blur 1.5

15. ***Median 3, Binary layer 3, Minimum 2***

Please note that with RED COLOR we indicate the filter combinations that take part in all 4 modifications' successful filter combo list. And as we can see there 3 of them.

Binary layer 3, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

Binary layer 1, Gaussian blur 1, Median 4

Median 3, Minimum 1, Gaussian blur 2, Binary layer 3

With GREEN COLOR we indicate the filter combination that takes part in 3 modifications: Binary layer 0's, Binary layer 1's and Binary layer 3's.

Median 4, Binary layer 0, Gaussian blur 1.5

With BLUE COLOR we indicate the filter combination that takes part in 2 modifications:

Binary layer 0's and Binary layer 1's.

Median 4, Gaussian blur 3, Maximum 2, Binary layer 0, Minimum 0.5

With YELLOWISH COLOR we indicate the filter combination that takes part in 2 other modifications: Binary layer 1's and Binary layer 3's.

Binary layer 3, Gaussian blur 1, Minimum 1, Median 4

Please also notice interesting cases and an important fact inside the trials above.

From 60 tries, 15 for each layer, respectively, 30 worked successfullish, where

6/15 for Binary layer 0

8/15 for Binary layer 1

8/15 for Binary layer 2

8/15 for Binary layer 3

In order to find the best combination for the photo itself, we should take into consideration all fair filter combinations for every Binary layer and take intersections of the chosen filter combos.

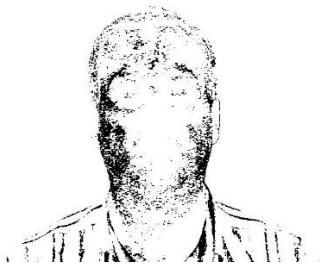
Therefore, from the small statistics above, for 2-11 image we will choose filter combos with RED COLOR, i.e.

Binary layer 3, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

Binary layer 1, Gaussian blur 1, Median 4

Median 3, Minimum 1, Gaussian blur 2, Binary layer 3

Image 4-11

Consider 4-11 and the zeroth binary layer applied.

After extraction of Binary layer 0

1. Binary layer 0, Median 2, Gaussian blur 1

2. Binary layer 0, Gaussian blur 2, Maximum 1

3. Binary layer 0, Gaussian blur 1, Median 4

4. ***Binary layer 0, Minimum 2, Maximum 1, Mean 2***

5. Binary layer 0, Gaussian blur 2, Minimum 1, Maximum 1, Median 3

6. Binary layer 0, Median 2, Gaussian blur 2, Minimum 2

7. ***Binary layer 0, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

Before extraction of binary layer 3

8. Gaussian blur 3, Median 5, Binary layer 0

9. Median 3, Minimum 1, Gaussian blur 2, Binary layer 0

10. Minimum 5, Maximum 2, Gaussian blur 2, Binary layer 0

11. Median 5, Gaussian blur 2, Binary layer 0

Before AND after extraction of binary layer 0

12. Gaussian blur 2, Binary layer 0, Maximum 0.5, Medium 3 (useless, but we are actually very interested in failures, so why not have them listed?)

13. Median 2, Minimum 2, Max 0.5, Binary layer 0, Gaussian blur 2

14. Median 4, Minimum 3, Binary layer 0, Mean 0.5

15. Median 5, Binary layer 0, Minimum 2, Gaussian blur 2

Consider 4-11 and the first binary layer applied.

After extraction of Binary layer 1

1. ***Binary layer 1, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

2. Binary layer 1, Median 0.3, Minimum 0.6, Gaussian blur 1

3. ***Binary layer 1, Gaussian blur 1, Minimum 1, Median 4***

4. ***Binary layer 1, Mean 2, Minimum 1, Maximum 0.5***

Before extraction of binary layer 1

5. ***Median 3, Minimum 1, Gaussian blur 2, Binary layer 1***

6. ***Mean 2.5, Minimum 2, Binary layer 1***

7. Gaussian blur 2, Maximum 1, Minimum 2, Binary layer 1

Before AND after extraction of binary layer 1

8. Minimum 3, Binary layer 1, Gaussian blur 1

9. Gaussian blur 2, Binary layer 1, Median 2

10. Median 5, Binary layer 1, Minimum 2, Gaussian blur 2 (useless)

11. Median 2, Minimum 2, Maximum 0.5, Binary layer 1, Gaussian blur 2

Consider 4-11 and the second binary layer applied.

After extraction of Binary layer 2

1. ***Binary layer 2, Minimum 2, Maximum 1, Mean 2***

2. Binary layer 2, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

3. ***Binary layer 2, Mean 2, Minimum 1, Maximum 0.5***

Before extraction of binary layer 2

4. Median 3, Minimum 1, Gaussian blur 2, Binary layer 2

5. Mean 2.5, Minimum 2, Binary layer 2

Before AND after extraction of binary layer 1

6. Median 2, Minimum 2, Max 0.5, Binary layer 2, Gaussian blur 2

7. Median 4, Minimum 3, Binary layer 0, Mean 0.5

Consider 4-11 and the third binary layer applied.

After extraction of Binary layer 3

1. Binary layer 3, Gaussian blur 1, Median 4

2. ***Binary layer 3, Gaussian blur 1, Minimum 1, Median 4***

3. Binary layer 3, Mean 2, Minimum 2.5, Maximum 0.5

Before extraction of binary layer 3

4. ***Median 3, Minimum 1, Gaussian blur 2, Binary layer 3***

5. Minimum 2.5, Maximum 0.5, Median 3, Binary layer 3

6. Mean 3, Minimum 3, Median 2, Binary layer 3

Before AND after extraction of binary layer 3

7. ***Median 4, Binary layer 3, Gaussian blur 1.5***

8. ***Median 2, Minimum 2, Max 0.5, Binary layer 3, Gaussian blur 2***

9. Gaussian blur 2, Binary layer 3, Median 2

10. Gaussian blur 2, Binary layer 3, Maximum 0.03

Successful filter combinations for Binary layer 0

3. ***Binary layer 0, Gaussian blur 1, Median 4***

4. ***Binary layer 0, Minimum 2, Maximum 1, Mean 2***

7. ***Binary layer 0, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

13.Median 2, Minimum 2, Max 0.5, Binary layer 0, Gaussian blur 2

15. ***Median 5, Binary layer 0, Minimum 2, Gaussian blur 2***

Successful filter combinations for Binary layer 1

1. ***Binary layer 1, Gaussian blur 1, Minimum 2, Median 4, Maximum 1***

3. ***Binary layer 1, Gaussian blur 1, Minimum 1, Median 4***

4. ***Binary layer 1, Mean 2, Minimum 1, Maximum 0.5***

5. Median 3, Minimum 1, Gaussian blur 2, Binary layer 1

6. Mean 2.5, Minimum 2, Binary layer 1

9. Gaussian blur 2, Binary layer 1, Median 2 (smoother)

11.Median 2, Minimum 2, Maximum 0.5, Binary layer 1, Gaussian blur 2

Successful filter combinations for Binary layer 2

1. ***Binary layer 2, Minimum 2, Maximum 1, Mean 2***

3. Binary layer 2, Mean 2, Minimum 1, Maximum 0.5

4. Median 3, Minimum 1, Gaussian blur 2, Binary layer 2

6. Median 2, Minimum 2, Max 0.5, Binary layer 2, Gaussian blur 2

Successful filter combinations for Binary layer 3

1. Binary layer 3, Gaussian blur 1, Minimum 1, Median 4

4. Median 3, Minimum 1, Gaussian blur 2, Binary layer 3

7. Median 4, Binary layer 3, Gaussian blur 1.5

8. Median 2, Minimum 2, Max 0.5, Binary layer 3, Gaussian blur 2

Please note that with RED COLOR we indicate the filter combinations that take part in all 4 modifications' successful filter combo list. And as we can see there 3 of them.

Median 2, Minimum 2, Max 0.5, Binary layer i, Gaussian blur 2

With YELLOWISH COLOR we indicate the filter combination that takes part in 2 other modifications: Binary layer 0's and Binary layer 1's.

Binary layeri0, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

With BLUE COLOR we indicate the filter combination that takes part in 3 other modifications: Binary layer 1's and Binary layer 2's and Binary layer 3's.

Median 3, Minimum 1, Gaussian blur 2, Binary layer i

Please also notice completely failed cases inside the trials above.

From 43 tries, respectively, 20 worked successfullish, where

5/15 for Binary layer 0

7/11 for Binary layer 1

4/7 for Binary layer 2

4/10 for Binary layer 3

In order to find the best combination for the photo itself, we should take into consideration all fair filter combinations for every Binary layer and take intersections of the chosen filter combos.

Therefore, from the small statistics above, for 4-11 image we will choose filter combos with RED COLOR, i.e.

Median 2, Minimum 2, Max 0.5, Binary layer i, Gaussian blur 2

Stage 1-2

The task is to formulate and construct an averaged optimal filter of minimal size that will be applied to the original image before extraction of the Binary layers and will produce reasonably smoothened binary regions in all cases based on the experiments from the previous task. Use **Process** ▷ **Filters** ▷ **Convolve…** command of ImageJ.

Binary layer i, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

Binary layer i, Gaussian blur 1, Median 4

Median 3, Minimum 1, Gaussian blur 2, Binary layer i

Median 2, Minimum 2, Max 0.5, Binary layer i, Gaussian blur 2

Based on the observations above, the first list when applied to 2-11 produces good results and the second one when applied to 4-11 produced a good result as well. In order to choose the universal filter applicable to both images we will take intersection of filters.

Please also refer to the colorful analysis above.

However, in the scope of interest, let's explore the best filters for 2-11 on 4-11 and vice versa.

On 2-11 applied 4-11's best filter.

Median 2, Minimum 2, Max 0.5, Binary layer i, Gaussian blur 2

On 4-11 applied 2-11's best filters.

Binary layer i, Gaussian blur 1, Minimum 2, Median 4, Maximum 1

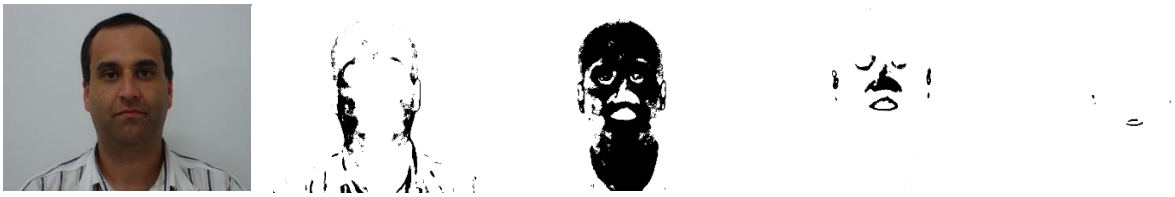
Binary layer i, Gaussian blur 1, Median 4

Median 3, Minimum 1, Gaussian blur 2, Binary layer i

As can be seen from the above results, all the filters exhibit a good behavior and face borders, skin pixels, eye sockets nostrils and lips ears are more or less explicitly distinguished.

As a universal good filter let's take ***Median 3 and Gaussian blur 2*** and see the applications on both photos.

Median is known to reduce the noise in the image by replacing each pixel with the median of the neighboring pixel values. ***Gaussian blur*** uses convolution with a Gaussian function to smooth the image. So, their combination is the best filter to be chosen to make images reasonably smoothened.



As we can see, all the characteristics mentioned in the very beginning are preserved, so the Good combination is found!

> *However, the ears, more specifically the ear, of the first boy is not selected in the universal filter, but as it is the average best, so I think it is not a problem.

To be more professional, let's find the convolution matrix.

-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	12	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1

This convolution matrix behaves good and the results are actually satisfiable, as the first layer selects the face area, the second skin, the third eye sockets and nostrils and the forth one lips and presumably ears.

Let's see on 2-11 and 4-11.

Original image -> Kernel (Convolution matrix) -> Binary layer I, where I = 0,1,2,3

As we can see, the results are quite good and reasonable, so this convolution matrix is working.

Stage 1-3

The next task is to investigate the dependence of the extracted regions on Binary Layers on the head rotations and smile. We can compute in necessity the Invariant Region Moments and Moment based Geometric properties of regions in the Binary Layers.

Let's consider 2 Moment based geometric properties of regions in the Binary Layers: ***Orientation*** and ***Eccentricity.***

Orientation: describes the direction of the major axis, the one that runs through the centroid. We use this aspect to investigate head rotations.

$$\theta_{\mathcal{R}} = \frac{1}{2} \cdot \tan^{-1}\left(\frac{2 \cdot \mu_{11}(\mathcal{R})}{\mu_{20}(\mathcal{R}) - \mu_{02}(\mathcal{R})}\right)$$

(From the main book Burger-Burge)

The resulting angle is between [-90, 90].

Eccentricity: a tool to uniquely characterize the shape of the object.

We use this aspect to investigate smile.

$$\mathrm{Ecc}(\mathcal{R}) = \frac{a_1}{a_2} = \frac{\mu_{20} + \mu_{02} + \sqrt{(\mu_{20} - \mu_{02})^2 + 4 \cdot \mu_{11}^2}}{\mu_{20} + \mu_{02} - \sqrt{(\mu_{20} - \mu_{02})^2 + 4 \cdot \mu_{11}^2}},$$

Let's consider our standard behavior images, 2-11 and several other head rotated versions of 2-xx.jpg. 2-01, 2-03, 2-08, 2-10

Let's consider the head rotation.

2-01, Binary layer 2, Moment

Orientation

-0.6598374616560234

Eccentricity

1.8675917919221872

Possible opposite direction

2-03, Binary layer 2, Moment

Orientation

-0.24381204242997775

Eccentricity

1.933921338381355

2-08, Binary layer 2, Moment

Orientation

-0.21700775370996694

Eccentricity

1.9375068591159363

2-10, Binary layer 2, Moment

Orientation

0.1947501250240961

Eccentricity

1.8417175271916921

I assume, if the number is small the person is turned left and as he turns with some steps to right it becomes bigger. Such behavior is seen above.

Let's consider our standard behavior images, 4-11 and several other head rotated versions of 4-xx.jpg. 4-01, 4-03, 4-08, 4-10

4-01, Binary layer 2, Moment

Orientation

-0.13623940483969554

Eccentricity

1.7788299236936504

Possibly opposite directions

4-03, Binary layer 2, Moment

Orientation

0.005714889175515675

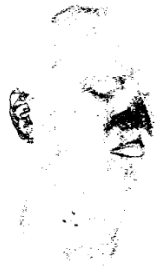
Eccentricity

1.7799927713255261

Not opposite directions

The statement is true till this moment.

4-08, Binary layer 2, Moment



Orientation

-0.01801897922458888 possibly opposite directions

Eccentricity

1.77786568422945

4-10, Binary layer 2, Moment

Orientation

0.03454727647219245

Eccentricity

1.7756841004074289

Opposite directions

Comparing only this two, the statement is still valid, however, considering the 4, it is not valid.

The orientation of the image of the second person rejects the suggested idea about the monotone increasing orientation from left to right.

The images where the person looks to the right have negative orientation it just decreases and the rotation angle increases. However, this is not the case for the images where the face looks to the right. The two orientation measures have different directions.

As we are interested in the rotation of head and smile, particularly, it is better to take Binary layer 2, as it intensifies the central region, the nostrils and eye sockets.

From the results above, we can see that the ears of the second person, 4-11, are very well highlighted, while for the first person they are not, actually one of 2-11's ears is closed by the hair, however, the one that is partially seen is not highlighted either.

Lips and eye sockets are clearly seen.

Let’s take the smiling examples.

2-12, Binary layer 2, Moment

Orientation

0.043913604608549955

Eccentricity

1.8620712556881744

Directions are not opposite.

4-12, Binary layer 2, Moment

Orientation

-0.03380193217031804

Eccentricity

1.781932438452587

Possibly, the directions are opposite.

Looking at the photos we can notice larger area devoted to lips and clearly that indicates that a person is smiling. Large region compared to previous trials indicates the smile.

Eccentricity for the first photo is bigger and we can clearly see that the first person’s smile is wider and larger.

The bigger the eccentricity the bigger the smile.

The same with orientation, when the orientation change is big, so is the head rotation.

Stage 2

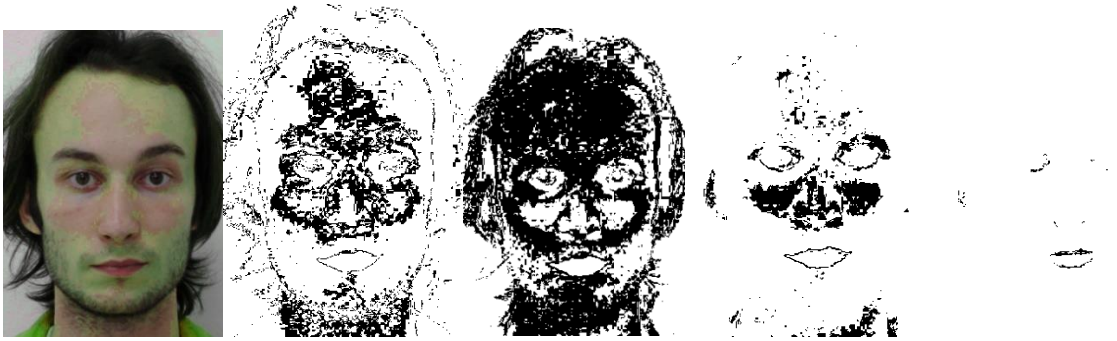
Extracting binary layers leads to vanishing.

Let’s consider the Cropped images.

2-11 Cropped

Match

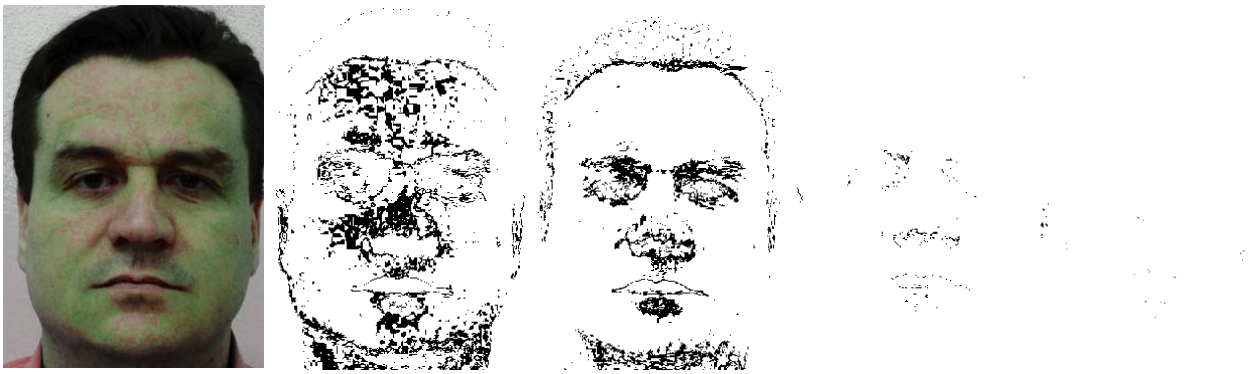
HSV Match



Match wins HSV Match, However, the latter performs okay.

3-11 Cropped

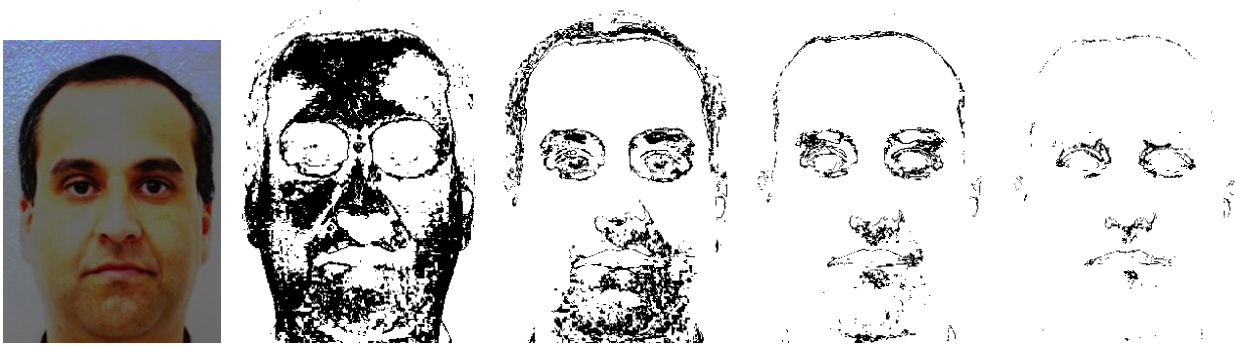
HSV Match



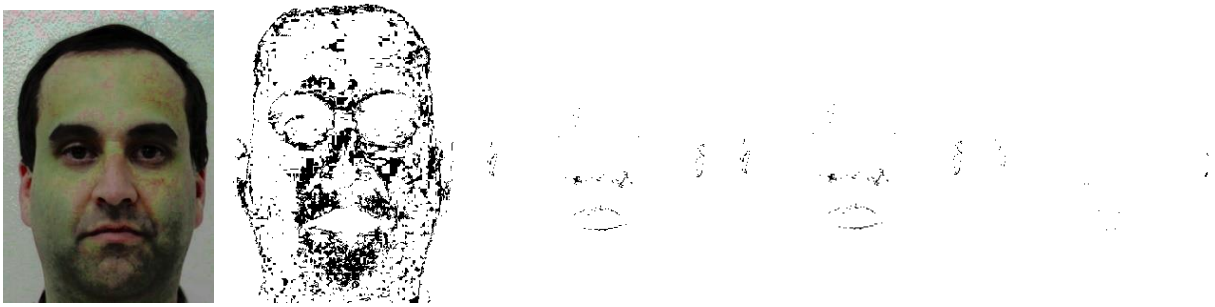
Match clearly wins, and the fact that this image does not exhibit the standard behavior is obvious.

4-11 Cropped

Match



HSV Match



The lips are more or less clear in HSV Match.

5-11 Cropped

Match

HSV Match

The binary layer 3 in HSV Match somehow shows lips but Match wins.

So, performing this actions, are a good practice and please notice that images from not the standard behavior set, somehow performed okayish and could actually distinguish lips, face borders and also ears.

For our interest, let's investigate the trials on the original images and see the results.

The interesting behavior is seen when applied Match. Here is the result of HSV Match.

Here is the result. I am not sure it is successful,

but it is what it is. (Smoother)

2-11

2-11, Binary layer 0,1,2,3

Match, Binary layer 0,1,2,3

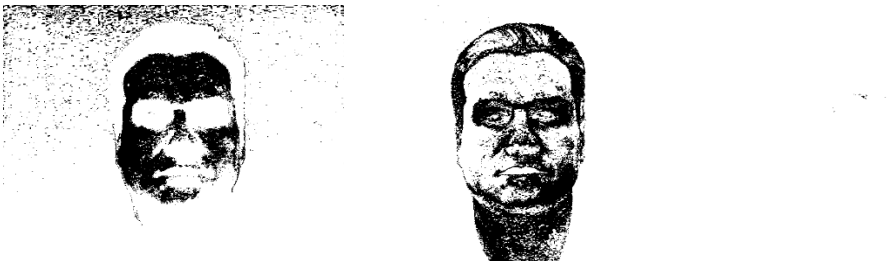
HSVMatch, Binary layer 0,1,2,3

Match wins HSVMatch arguable, as for 2nd image (Binary layer 1 extraction) HSVMatch is better.

3-11 Binary layer 0,1,2,3

Match, Binary layer 0,1,2,3

HSVMatch, Binary layers 0,1,2,3



Match wins HSVMatch

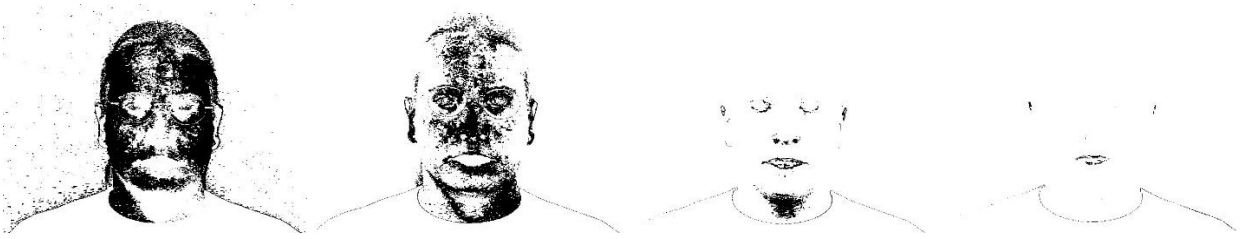
4-11, Binary layers 0,1,2,3

Match, Binary layers 0,1,2,3

HSVMatch, Binary layers 0,1,2,3

Match wins HSVMatch

5-11, Binary Layers 0,1,2,3



Match, Binary Layers 0,1,2,3

HSVMatch, Binary Layers 0,1,2,3

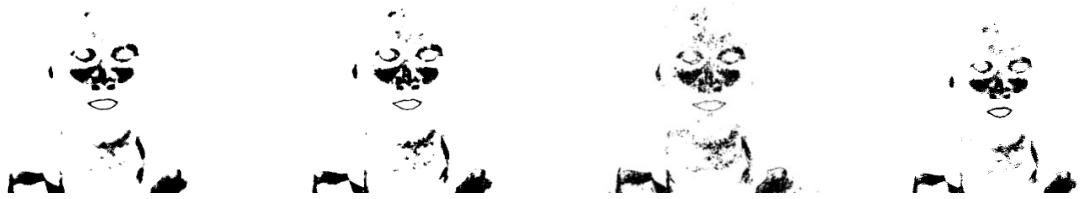
HSVMatch wins Match, the lobe is interpreted as something awful.

Stage 3

1. Eye socket detection

From the previous investigations we can see that there are several filters applied to an image that successfully detect the eye sockets.

Med3,Min1,Gaus2,BinLay2 Mean 2.5 Med 1.5 BinLay2 Universal filter



If I am about to suggest am eye socket detection method, I would suggest totake the upper part of the face and take the two oval-like objects that are white inside and with black pixel boundaries. As we can see the filters applied exhibit that results and can help to detect eye sockets.

However, in order to suggest more professional, noise free versions, some other combinations of filters may be applied. For example when applying max to third image it can reduce the noise.

2. Lip detection

Below are represented all the good cases when the lip section can be easily and clearly determined. As of the eye socket case, the suggestion is similar to take the oval-like section in the lower centroid part of the face that is bounded by black pixels and is noiseless inside the oval-like region is the area of lips. By taking a small width right inside the black pixels and surrounding it we can get the exact place of lips. However, many interesting cases were seen as well, so the lip detection may be thought as a simple one but very subtle details should also be considered.