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All about Anigma-View

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ABSTRACT

This article provides a detailed analysis of the functions within Anigma-View, with each one thoroughly explained. Please cite this report in your academic papers or manuscripts when referencing any Anigma-View functions. It's important to note that this report focuses on the technical reasoning behind the software's value measurement and does not cover specific methods for optimizing or fine-tuning the functions, such as alignment or segmentation.

CCS CONCEPTS

• Applied computing; • Computing methodologies → Image processing;

KEYWORDS

Computer Vision, Medical Image

1 BASE PIPELINES

1.1 Alignment

All input face images to Anigma-View undergo a face alignment process, which aligns the images to the proper position and angle. More details about face alignment systems can be found in Jin et al. [JT17].

1.2 Segmentation

Measurement functions in Anigma-View are processed after segmenting the input face image. Anigma-View utilizes the segmented image to measure facial features. See Figure 1 for an example.

1.3 Measurement&Settings

This technical report is written with the assumption that the coordinate values are based on the OpenCV [Its14] library. In OpenCV, the x and y coordinates start from the top-left corner rather than

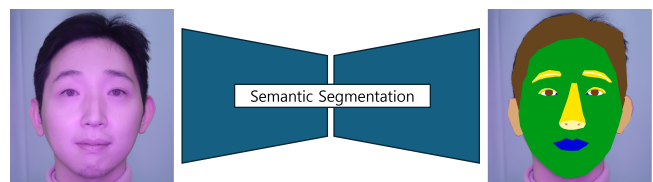


Figure 1: Anigma-View segments the input face image before measuring the features of the face.

the bottom-left. See Figure 2 for the coordinate system used in OpenCV.

Default values in Anigma-View are calculated relative to an assumed iris radius of 11.5 mm. However, these values can be customized using size-known objects in the image, particularly a 5 mm sticker. When present in a facial image, this 5 mm sticker is automatically detected (if exists), allowing Anigma-View to adjust size values accordingly. In addition to the sticker method, a custom measurement feature has been implemented, enabling manual scale setting using any known-size object in the image (e.g., a ruler). See examples in Figure 3

Compared to ImageJ [SRE12], a well-known image measurement tool that relies on user-defined scaling settings, Anigma-View shows similar measurement values. We customized the ImageJ scale by setting the iris radius to 11.5 mm. The results are shown in Figure 4. The two software tools show only a slight difference in measurement values. Note that ImageJ's scaling setting is based on the user's manual input for each image, which can introduce slight errors in the values.

2 FUNCTIONS

2.1 Base functions

2.1.1 Circle detection. To detect the coordinates of circle shape object center (x,y) and radius, we used circle detection function which is well known from previous studies [DH72]. The detection process is written below.

- (1) Edge Detection: Apply an edge detection algorithm [Can86] to the input image to highlight the edges.

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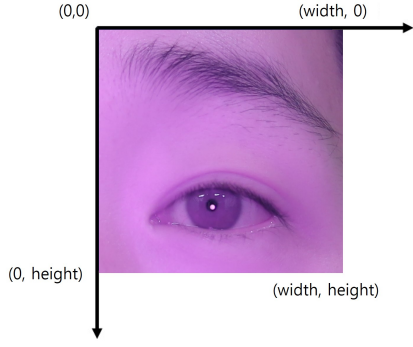


Figure 2: Coordinate system in OpenCV

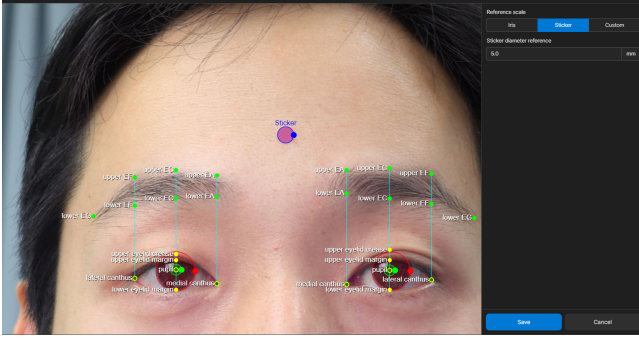


Figure 3: Setting scale based on size-known object in photo (e.g. 5 mm sticker)

- (2) Voting in Hough Space: For each edge pixel (x, y) , vote in the Hough parameter space for all possible circles that could pass through the point. This involves varying the radius r and voting for the center points (a, b) such that:

$$a = x - r \cos(\theta)$$

$$b = y - r \sin(\theta)$$

where θ ranges from 0 to 360 degrees.

- (3) Finding Circles: Identify peaks in the Hough parameter space, which correspond to the most likely circle centers and radii.
- (4) **Return:** x, y and radius of detected circle.

2.2 Distance

2.2.1 MRD1. To measure MRD1, we detected the **UpperEyelidMargin** coordinate using an algorithm with a segmentation mask as input. Based on the segmentation mask, the y -coordinates of the pupil, iris, white area, and upper eyelid crease, whose x -coordinates correspond to the center of the pupil (estimated via the circle detection function mentioned above), are extracted and stored as lists. The initial value of the upper eyelid margin coordinate is set to the minimum y -coordinate of the iris and pupil ($\min(\text{IrisYCoords}[0], \text{PupilYCoords}[0])$). If there are y -coordinates for the white area (WhiteYCoords), the **UpperEyelidMargin** is updated to the minimum y -coordinate among the current **UpperEyelidMargin** and

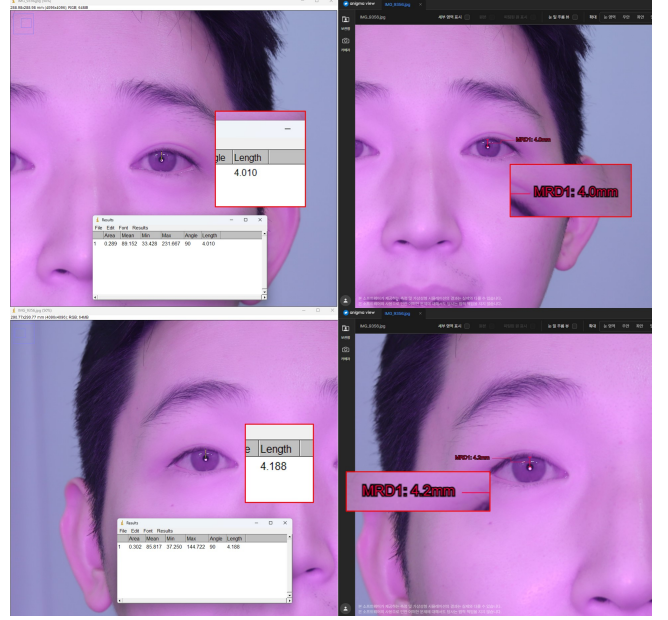


Figure 4: Comparing measure scale with imageJ, Anigma-View SW shows only slight differences

the white area ($\min(\text{UpperEyelidMargin}, \text{WhiteYCoords}[0])$). See Algorithm 1 for more details.

By calculating the distance between center of pupil and **UpperEyelidMargin**, MRD1 value is measured.

Algorithm 1 Detect Upper Eyelid Margin

- 1: **Input:** PupilMask, IrisMask, WhiteAreaMask, UpperEyelidMask
- 2: **Output:** UpperEyelidMargin
- 3: Estimate PupilCenterX via circle detection function
- 4: **Initialize** lists PupilYCoords, IrisYCoords, WhiteAreaYCoords, UpperEyelidYCoords
- 5: **for** each row y in PupilMask **do**
- 6: **if** PupilMask[y][PupilCenterX] is not 0 **then**
- 7: Append y to PupilYCoords
- 8: **end if**
- 9: **end for**
- 10: **for** each row y in IrisMask **do**
- 11: **if** IrisMask[y][PupilCenterX] is not 0 **then**
- 12: Append y to IrisYCoords
- 13: **end if**
- 14: **end for**
- 15: **for** each row y in WhiteAreaMask **do**
- 16: **if** WhiteAreaMask[y][PupilCenterX] is not 0 **then**
- 17: Append y to WhiteAreaYCoords
- 18: **end if**
- 19: **end for**
- 20: **for** each row y in UpperEyelidMask **do**
- 21: **if** UpperEyelidMask[y][PupilCenterX] is not 0 **then**
- 22: Append y to UpperEyelidYCoords
- 23: **end if**

```

24: end for
25: Set UpperEyelidMargin ←
    min(IrisYCoords[0], PupilYCoords[0])
26: if len(WhiteAreaYCoords) > 0 then
27:   UpperEyelidMargin ←
    min(UpperEyelidMargin, WhiteAreaYCoords[0])
28: end if
29: return UpperEyelidMargin

```

2.2.2 *MRD2*. We detected the **LowerEyelidMargin** coordinate using a segmentation mask as input to measure MRD2. Similar to the **UpperEyelidMargin**, the y-coordinate lists from the pupil, iris, and white area, where the x-coordinates correspond to the center of the pupil, are stored as lists. Therefore, the **LowerEyelidMargin** is detected using these y-coordinate lists with a similar algorithm to the **UpperEyelidMargin**, but by finding the maximum value in this case. See Algorithm 2 for more details.

By calculating the distance between center of pupil and **LowerEyelidMargin**, MRD2 value is measured.

Algorithm 2 Detect Lower Eyelid Margin

```

1: Input: PupilMask, IrisMask, WhiteAreaMask
2: Output: LowerEyelidMargin
3: Estimate PupilCenterX via circle detection function
4: Initialize lists PupilYCoords, IrisYCoords, WhiteAreaYCoords
5: for each row  $y$  in PupilMask do
6:   if PupilMask[ $y$ ][PupilCenterX] is not 0 then
7:     Append  $y$  to PupilYCoords
8:   end if
9: end for
10: for each row  $y$  in IrisMask do
11:   if IrisMask[ $y$ ][PupilCenterX] is not 0 then
12:     Append  $y$  to IrisYCoords
13:   end if
14: end for
15: for each row  $y$  in WhiteAreaMask do
16:   if WhiteAreaMask[ $y$ ][PupilCenterX] is not 0 then
17:     Append  $y$  to WhiteAreaYCoords
18:   end if
19: end for
20: LowerEyelidMargin ←
    max(IrisYCoords[-1], PupilYCoords[-1])
21: if len(WhiteAreaYCoords) > 0 then
22:   LowerEyelidMargin ←
    max(LowerEyelidMargin, WhiteAreaYCoords[-1])
23: end if
24: Set UpperEyelidMargin ←
    min(IrisYCoords[0], PupilYCoords[0])
25: return LowerEyelidMargin

```

2.2.3 *PFH*. PFH is measured by calculating the distance between value of **UpperEyelidMargin** and **LowerEyelidMargin**.

2.2.4 *DH*. To measure DH, we detected the **DoubleEyelidMargin** coordinates by using the detected **UpperEyelidMargin** value and the double eyelid area from the segmentation mask. The y-coordinate list from the double eyelid area, where the x-coordinates

correspond to the **UpperEyelidMargin**, is stored as lists. Therefore, the **DoubleEyelidMargin** is determined by using the smallest value from this list. See Algorithm 3 for more details.

By calculating the distance between the **DoubleEyelidMargin** and the **UpperEyelidMargin**, the DH value is measured.

Algorithm 3 Detect DoubleEyelidMargin

```

1: Input: DoubleEyelidMask, UpperEyelidMargin
2: Output: DoubleEyelidMargin
3: Initialize list DoubleEyelidYCoords
4: if DoubleEyelidMask exists then
5:   for each row  $y$  in PupilMask do
6:     if DoubleEyelidMask[ $y$ ][UpperEyelidMarginX] is not 0
       then
7:       Append  $y$  to DoubleEyelidYCoords
8:     end if
9:   end for
10: Set DoubleEyelidMargin ← min(DoubleEyelidYCoords)
11: return DoubleEyelidMargin
12: end if

```

2.2.5 *IPD*. Based on the pupil area in the segmentation mask, we detected the center of the pupil coordinates using a circle detection function. Therefore, the IPD is measured by calculating the distance between the centers of each pupil.

2.2.6 *ICD*. Based on the detected medial canthus in the segmentation mask, ICD is measured by calculating the distance between the medial canthus of each eye.

2.2.7 *PFW*. Based on detected medial canthus and lateral canthus in the segmentation mask, PFW is measured by calculating the distance between medial canthus and lateral canthus.

2.2.8 *HL*. Based on detected medial canthus and lateral canthus in the segmentation mask, HL is measured by calculating the x-axis distance between medial canthus and lateral canthus.

2.2.9 *VL*. Based on detected lateral canthus in the segmentation mask, VL is measured by calculating the y-axis distance between **LowerEyelidMargin** and lateral canthus.

2.2.10 *Pupil to canthus*. Based on detected medial canthus in the segmentation mask, Pupil to canthus is measured by calculating the distance between medial canthus and center of pupil.

2.2.11 *Sup border, Inf border and Mid-portion*. Based on the detected medial canthus of both eyes, draw a straight line to establish the base height of the eye border. By calculating the distance from points in the eyebrow (upper and lower), the Sup and Inf border values are measured. The Mid-portion value is calculated from the median point between the upper and lower eyebrow area points. The eyebrow points are detected based on the segmentation map in the order of A, C, F, and G, named according to Asaad et al. [AK]⁺19]. The X-axis of these points are aligned based on the medial canthus (A), pupil (C), and lateral canthus (F). Point G is not aligned to a specific point from the eye part. See Figure 5 for a detected example

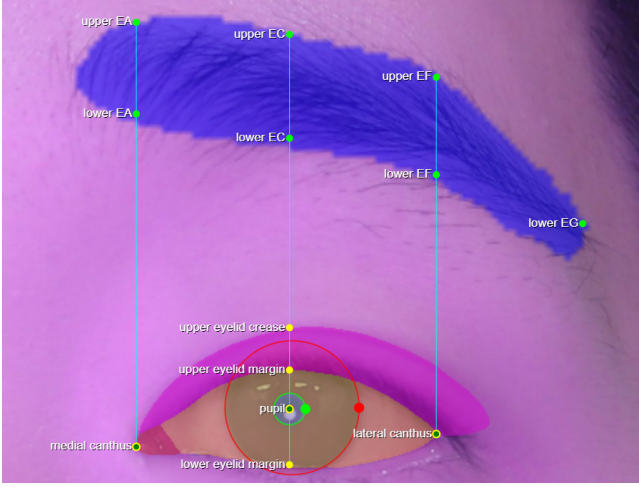


Figure 5: Detected and aligned points of eyebrow area (upper and lower). Points are named in order of A,C,F and G.

2.3 Angle

2.3.1 ES. Based on the detected medial canthus and lateral canthus in the segmentation mask, we created another point using the x-value from the medial canthus and the y-value from the lateral canthus. Using this newly created point and the existing two canthus, we measured the ES angle value.

2.4 Ratio

2.4.1 CER. To measure the Cornea Exposure Ratio (CER), we detected the pupil and iris coordinates using circle detection on the segmented image. We combined the pupil and iris masks to create a cornea mask. For the exposed eye mask, we combined the cornea mask with the white area mask. We then initialized a boolean mask of the same shape as the cornea mask to create the full iris mask, setting each pixel to True if it lies within the iris radius from the center coordinates of the iris. Subsequently, we updated the cornea mask by performing a logical AND operation with the full iris mask and the exposed eye mask. We computed the areas of the full iris and the cornea by counting the non-zero elements in their respective masks. Finally, we calculated the Cornea Exposure Ratio (CER) as the ratio of the cornea area to the full iris area, multiplied by 100. See Algorithm 4 for details.

Algorithm 4 Measuring Cornea Exposure Ratio (CER)

```

1: Input: pupil coordinates ( $pupil_x, pupil_y, pupil_r$ ), iris coordinates ( $iris_x, iris_y, iris_r$ ), PupilMask, IrisMask, WhiteAreaMask
2:  $mask\_cornea \leftarrow mask\_pupil \vee mask\_iris$ 
3:  $mask\_exposed\_eye \leftarrow mask\_cornea \vee mask\_white\_area$ 
4: Initialize  $mask\_full\_iris$  as a boolean array of the same shape as  $mask\_cornea$ 
5: for each pixel ( $x, y$ ) in  $mask\_full\_iris$  do
6:   if  $(x - iris_x)^2 + (y - iris_y)^2 < iris_r^2$  then
7:      $mask\_full\_iris[y, x] \leftarrow \text{True}$ 
8:   end if
9: end for

```

```

10:  $mask\_cornea \leftarrow mask\_full\_iris \wedge mask\_exposed\_eye$ 
11:  $full\_iris\_area \leftarrow count\_nonzero(mask\_full\_iris)$ 
12:  $cornea\_area \leftarrow count\_nonzero(mask\_cornea)$ 
13:  $CER \leftarrow \frac{cornea\_area}{full\_iris\_area} \times 100$ 
14: return CER

```

2.4.2 MWR. To measure the Medial White Area Ratio (MWR), we calculated the ratio of the Medial White Area (MWA) to the total area, multiplied by 100. To find the MWA, we counted the non-zero elements in the white area mask to the left of the pupil center ($:pupil_x$), if the eye is the left eye (eye_is_left is True), W . If the eye is the right eye (eye_is_left is False), count the non-zero elements in the white area mask to the right of the pupil center ($pupil_x$). The total area is defined by the sum of the non-zero elements in the white area mask and the cornea mask. Check Algorithm 5 for more details.

Algorithm 5 Measuring Medial White Area Ratio (MWR)

```

1: Input: pupil coordinates ( $pupil_x, pupil_y, pupil_r$ ), WhiteAreaMask,  $mask\_cornea$  (from Algorithm 4)
2: if  $eye\_is\_left$  then
3:    $MWA \leftarrow count\_nonzero(WhiteAreaMask[:, :pupil_x])$ 
4: else
5:    $MWA \leftarrow count\_nonzero(WhiteAreaMask[:, pupil_x:])$ 
6: end if
7:  $total\_area \leftarrow count\_nonzero(WhiteAreaMask) + count\_nonzero(mask\_cornea)$ 
8:  $MWR \leftarrow \frac{MWA}{total\_area} \times 100$ 
9: return MWR

```

2.4.3 LWR. To measure the Lateral White Area Ratio (LWR), we calculated the ratio of the Lateral White Area (LWA) to the total area, multiplied by 100. To find LWA, we counted the non-zero elements in the white area mask from the pupil center to the right edge ($:pupil_x$), if the eye is the left eye (eye_is_left is True), W . If the eye is the right eye (eye_is_left is False), count the non-zero elements in the white area mask from the left edge to the pupil center ($pupil_x$). The total area is defined by the sum of the non-zero elements in the white area mask and the cornea mask. Check Algorithm 6 for more details.

Algorithm 6 Measuring Lateral White Area Ratio (LWR)

```

1: Input: pupil coordinates ( $pupil_x, pupil_y, pupil_r$ ), WhiteAreaMask,  $mask\_cornea$  (from Algorithm 4)
2: if  $eye\_is\_left$  then
3:    $LWA \leftarrow count\_nonzero(WhiteAreaMask[:, pupil_x:])$ 
4: else
5:    $LWA \leftarrow count\_nonzero(WhiteAreaMask[:, :pupil_x])$ 
6: end if
7:  $total\_area \leftarrow count\_nonzero(WhiteAreaMask) + count\_nonzero(mask\_cornea)$ 
8:  $LWR \leftarrow \frac{LWA}{total\_area} \times 100$ 
9: return LWR

```

2.4.4 EER. Eyeball Exposure Area Ratio (EER) is calculated by the ratio of Based on Eyeball Exposure Area (EEA) to the whole area, multiplied by 100. See Figure 6 for segmentation of EER and whole area.

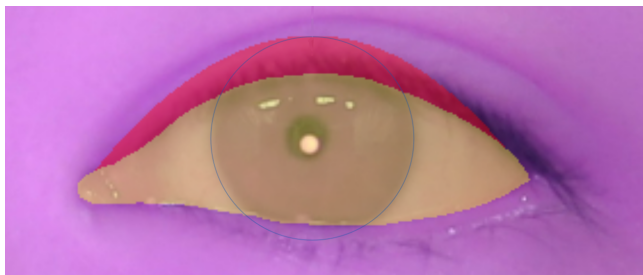


Figure 6: The segmented image is used for measuring EER. The yellow segmented area represents the EEA, while the combined red and yellow areas represent the whole area.

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