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Iris Center Localization Based Hough Transform on Eye Image

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Abstract

Localization iris center localization is stage crucial to the system biometrics eyes , tracking view (gaze tracking), as well analysis health based image . Research This propose method detection iris -based center Hough transform on image eye with channel work that emphasizes robustness to noise, variations lighting , and differences iris size . Stages used covering conversion image colored to grayscale for simplify information intensity , noise reduction using Gaussian Blur so that the iris edges are clearer stable , detection candidate iris circle using Hough Circle Transform with setting certain parameters , as well as , determining iris center based on coordinate circle best Hough voting results . Method performance evaluated in a way quantitative through error distance center (center localization error) to ground-truth and in general qualitative through visualization circle results detection on the image . Expected results show that Hough's transformation is capable of give estimate consistent iris center in the image with condition moderate until complex , especially when the iris border is sufficient contrast to sclera . Research This contribute as relative approach simple , fast , and easy implemented For need localization iris center , at the same time provide base development advanced like adaptive iris segmentation and integration with method learning deep For increase resistance to conditions lighting extreme and occlusion by the eyelids or hair eye .

Keywords *: Iris Center Localization, Hough Circle Transform , Detection Eye Image Circle*

1. Introduction

Iris is one of the very strong biometrics Because pattern the texture is rich, relatively stable , and can differentiated between individuals ; as a result , many irises used in the system verification / identification as well as application computer vision related image eyes . Within the framework of iris recognition, the success of recognition is highly dependent on ability system find and isolate the iris area precision , including estimate center and radius of the iris/pupil as base mapping geometric next . [1][2]. In In general , the iris recognition *pipeline* includes segmentation (finding the inner boundary / pupil and outer boundary / limbus), normalization , extraction features , then matching .Error small at the stage localization especially on coordinates center can trigger distortion in normalization (e.g. mapping to the polar domain) and lowers reliability extracted features , so that impact straight to performance introduction . Therefore , research iris/pupil segmentation and localization is seen as module essential that determines quality overall system . [3][4]. Challenges main localization iris center appears in non-ideal images : the presence of reflection specular , shadow , variation illumination , motion (blur), and disturbance petals and feathers eyes that cover part edge circle . In addition , the angle view (off-axis) can make the iris/pupil border visible ellipse so that assumptions circle pure become not enough accurate to the conditions certain . Literature iris segmentation in " less " images under control " shows that improvement robustness is necessary taking into account real noise on acquisition image . [5][6].

Various approach traditional For detect center of pupil/iris can grouped become method based characteristics (e.g. gradient / contrast / edge) and methods model -based (e.g. circle / ellipse). Comparative studies on detection pupil center highlights four the most common approach referred to , namely *Circular Hough Transform* , *ellipse fitting* , integro -differential operator, and *radial symmetry transform* , each with compromise accuracy – cost computational robustness in noise/occlusion. In the context of study This , Hough Transform is relevant Because formalize search form circular through mechanism *voting* on the parameter space , so that still can Work although edge circle No complete . [7][8]. The Hough transform is classic used For detect curve parametric on digital images with map dot, dot, dot edge to parameter space and search peak accumulator as candidate form . For circle , its general parameters covering coordinate center $(x_0, y_0)$and radius r, so the complexity increases if the search is performed over a wide range of parameters; therefore, many developments propose restricted search space or variations of generalized Hough for efficiency. The application of Hough to iris localization is also reported in studies that combine Hough with segmentation/preprocessing strategies to improve robustness to real-world noise. [9][11]. Based on runway said , the research " Iris Center Detection Based on "Hough Transform of Eye Images" is focused on designing channel localization iris/pupil center which is (i) effective on non-ideal images , (ii) its computation efficient through proper ROI/radius limitation and preprocessing , and (iii) measurable through metric error center and processing time per image on relevant public datasets . Focus this is also important because , even though approach *deep learning* show accuracy high in many studies latest needs computation and training data often become constraint For implementation light / real-time; so that method Hough -based more " concise and explanatory " remains worth For context certain . [12][14].

2. Research Methods

2.1. Iris center localization

Iris center localization is the process of estimating coordinate center $(x_c, y_c)$of the iris structure (and often also the pupil) in an image of the eye, usually simultaneously with estimation of the radius of the inner border (pupil) and outer border (limbus/iris). In the literature , *iris localization* defined as detection of the inner and outer boundaries of the iris area; whereas *iris segmentation* produce *mask* For differentiate iris and non-iris pixels .[17]
In iris recognition systems , localization center important Because become reference For normalization (eg. mapping to polar coordinates) and consistent iris ROI determination inter-image . Error center will creeping to stage extraction features and matching , so that lower accuracy system iris recognition .[17]
In a way biologically and geometrically , the pupil and iris tend to shaped almost circular (although can become not ideal because corner off-axis view , eyelid occlusion eyes , reflections , and blur). Therefore Lots method classic modeling the iris/pupil boundary as circle /ellipse and search the center from detected contours / edges .[22]

2.2. Hough Circle Transformation

2.2.1. Concept Hough Circle Transformation

Hough transform is technique For detect curve parametric with map evidence edges in space image to parameter space , then look for peak accumulator (voting peak) as candidate the most likely form . The principle This discussed classic by Duda & Hart, and then expanded For more forms generalized Hough.[16]

In the context of the iris/pupil, the Circular Hough Transform (CHT) works on the image binary edges and selecting circle parameters best past voting procedure in parameter space .[21]

2.2.2. Formula the circle that becomes CHT basics

Circle with center $(a, b)$and fingers $r$stated as:

$$(x-a)^2+(y-b)^2=r^2 \quad (1)$$

and form parametric :

$$x=a+r\cos(\theta) y=b+r\sin(\theta) \quad (2)$$

Formula This explicit used moment explain CHT for detects the pupil/iris border, while state that the CHT output provides coordinate center and radius of the detected circle . [21]

2.2.3. Voting mechanism in Circular Hough Transform (intuition) mathematical)

From the form parametric above , for A pixels edge (x, y)which is thought to be on the circumference of the circle, then the candidate center $(a, b)$for the radius $r$can be derived (algebraically) as:

$$a=x-r\cos(\theta), b=y-r\sin(\theta) \quad (3)$$

Meaning : every pixels edge " gives sound " for Lots possibility center (a,b) (for various $\theta$and r), and the most frequently "chosen" center becomes the top of the accumulator that is, the center of the detected circle. The basis of the parametric circle formula that allows the derivation of this voting form is referred to in the CHT formulation in the literature. [21]

2.3.4. Role of direction gradient (gradient direction) for efficiency

One of method increase efficiency is utilise direction edge / gradient . Gradient direction can calculated , for example , by :

$$\theta(m,n)=\tan^{-1}(\frac{g_n(m,n)}{g_m(m,n)}) \quad (4)$$

which represents orientation edge so that search center No need sweeping all θ, but simply follow the normal direction of the edge. This is relevant to reduce the complexity of voting on the image. eyes .[21]

2.2.3. Detection Circle in Eye Image (Pupil/Iris Circle Detection)

Many approaches Classic iris/pupil detection treats the pupillary border and the outer border of the iris as circle (approximation), then using CHT for get (a, b, r). This is commonly used because it is quite robust when the contour is not perfect (broken by eyelashes/lids) as long as there is still evidence enough edge For voting . [17]

3. Results and Discussion

Following This steps in the python program in Iris Center Localization Based Hough Transform of Eye Image

Step 1:

```python
import cv2
import numpy as np
import matplotlib.pyplot as plt
```

Fig. 1: Library Initialization

Information :

a. cv2 for operation processing image (read image , conversion color , blur, HoughCircles , drawing circle , histogram).
b. numpy For array manipulation and rounding coordinate results detection .
c. matplotlib for display image and histogram graph .

Step 2:

```python
# Menggunakan OpenCV untuk membaca gambar
img = cv2.imread('Mata Juling.png', cv2.IMREAD_COLOR)

# Mengonversi gambar dari BGR (format default OpenCV) ke RGB
img_rgb = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)

# Menampilkan gambar
plt.imshow(img_rgb)
plt.axis('off')  # Menghilangkan axis
plt.show()
```

Fig. 2 : Displaying Original Image Results

Information :

a. Load picture eye from file as image colored **BGR** format (OpenCV default).
b. Matplotlib displays image in RGB format, so that conversion required for color not " upside down ".
c. Showing input image for ensure image readable with Correct .

Step 3:

```python
# Mengonversi gambar ke grayscale
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

# Menerapkan Gaussian Blur untuk mengurangi noise
blurred = cv2.GaussianBlur(gray, (15, 15), 0)

# Menggunakan Hough Circle Transform untuk mendeteksi lingkaran (bola mata)
circles = cv2.HoughCircles(blurred, cv2.HOUGH_GRADIENT, dp=1.2, minDist=20,
                           param1=50, param2=30, minRadius=10, maxRadius=50)

# Jika lingkaran ditemukan
if circles is not None:
    # Mengonversi koordinat lingkaran ke integer
    circles = np.round(circles[0, :]).astype("int")

    # Menandai lingkaran pada gambar
    for (x, y, r) in circles:
        # Gambar lingkaran luar
        cv2.circle(img_rgb, (x, y), r, (0, 255, 0), 4)
        # Gambar titik tengah lingkaran
        cv2.circle(img_rgb, (x, y), 3, (0, 0, 255), 3)

# Menampilkan gambar dengan lingkaran yang terdeteksi
plt.imshow(img_rgb)
plt.axis('off')
plt.show()
```

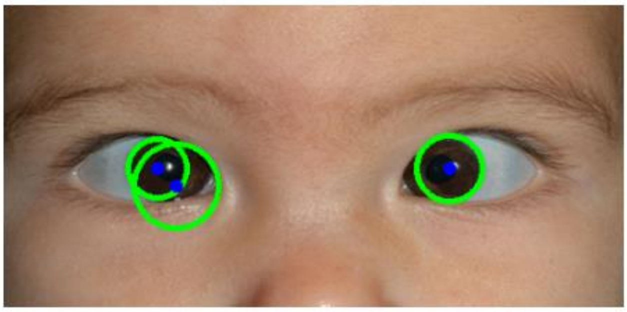


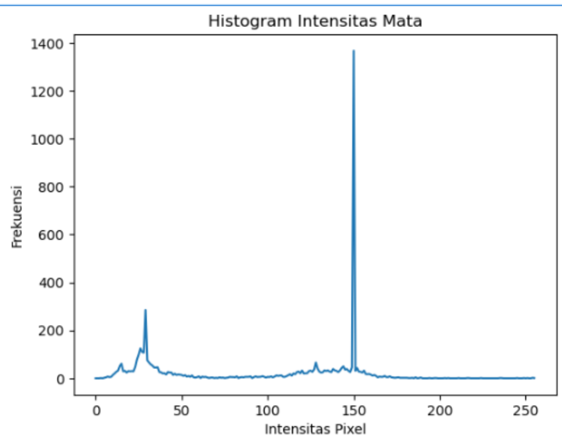
Fig. 3 : Detection Circle with Hough Circle Transform

Information :

a. Smoothing grayscale image to reduce noise and edges circle (eyeball /iris/pupil) becomes more consistent .
b. Look for object shaped circle on the image (assumed eyeball / pupil / iris).
c. HoughCircles Output in the form of float. The program rounds and converts it to be an integer so that it can used for pixel indexing and drawing .
d. Draw circle green as the boundary of the detected area .
e. Draw point red as center circle (iris/pupil center indication).
f. Validating visually whether circle truly regarding the eye area .

Step 4:

```python
# Jika ada lingkaran terdeteksi
if circles is not None:
    for (x, y, r) in circles:
        # Crop bagian mata dari gambar berdasarkan koordinat lingkaran
        eye_region = img_rgb[y - r:y + r, x - r:x + r]

        # Konversi ke grayscale untuk analisis lebih lanjut
        eye_gray = cv2.cvtColor(eye_region, cv2.COLOR_RGB2GRAY)

        # Hitung histogram dari area mata
        hist = cv2.calcHist([eye_gray], [0], None, [256], [0, 256])

        # Menampilkan histogram
        plt.plot(hist)
        plt.title("Histogram Intensitas Mata")
        plt.xlabel("Intensitas Pixel")
        plt.ylabel("Frekuensi")
        plt.show()

        # Definisikan threshold untuk membandingkan perbedaan intensitas
threshold = 50  # Sesuaikan nilai threshold sesuai dengan kebutuhan

# Analisis ketidakteratataan berdasarkan histogram
diff = np.max(hist) - np.min(hist)
if diff > threshold:  # Threshold adalah nilai yang perlu disesuaikan
    print("Terdeteksi ketidakteratataan pada bola mata.")
else:
    print("Bola mata terlihat rata.")
```




```
Terdeteksi ketidakteratataan pada bola mata.
```

Fig.4: Detecting unevenness of the eyeball

Information :

Make decision simple based histogram variation with method This more reflect inequality distribution intensity , not directly " squint " or " unevenness of the eyeball " . For detection squint , usually analyzed is shift relative pupil center to corner eye / canthus, or comparison left right pupil position (geometry), not just histogram .

4. Conclusion

Study This conclude that localization Circular Hough Transform (CHT) based iris/pupil center can used as effective foundation For extracting feature geometry eyes on digital images . Through stages preprocessing (grayscale and Gaussian blur) and detection circle use

HoughCircles , system capable obtain circle parameters (x, y, r)which represents the center and radius of the pupil/iris area. Information center This nature crucial Because become reference main in analysis continued , especially For evaluation iris position consistent across a range of condition image.More further research This confirm that detection strabismus (squint) more relevant analyzed in a way geometric than based distribution intensity (histogram). With compare position center of pupil/iris relative to angle landmark eye (medial and lateral canthus) **,** obtained indicator symmetry inter-ocular iris position (eg. ratio distance and index *positional similarity*). Indicator This in a way conceptual capable differentiate condition parallel eyes (value approaching 1/ symmetrical) and conditions that indicate deviation (value avoid from 1/ asymmetric), so that system worthy positioned as tool screening / support decision For detect strabismus - based indications image .

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