Report Homework 4
CS 682

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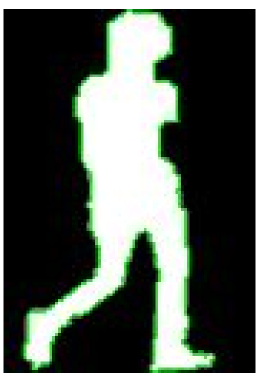
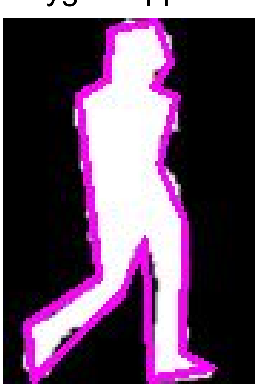
1.
The features of all images in GaitImages are calculated using functions in OpenCV's 'Structural Analysis and Shape Descriptors'.
For all images, first the image is converted to binary with foreground silhouette as white and background as black. This image is then used to compute 'contours'.
These contours are a list of pixels of the boundary of the silhouette. If there are more than one contours present with different hierarchy, i.e. images with 'holes', the main contour chosen for feature calculation is the outer boundary.

Contours: findContour()



The following features are computed using the contour.

Polygon Approximation: approxPolyDP()

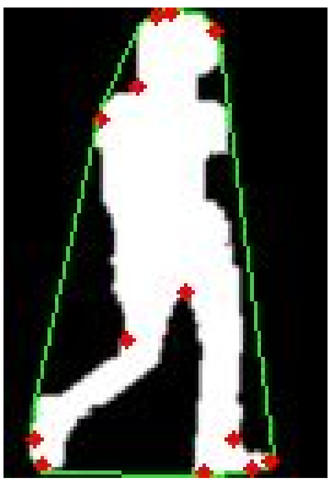


Area: contourArea()
Perimeter: arcLength()
Moments: moments()

    First Order Moments: M['m10'], M['m01']
    Second Order Moments: M['m20'], M['m02'], M['m11']

Convex Hull: convexHull()

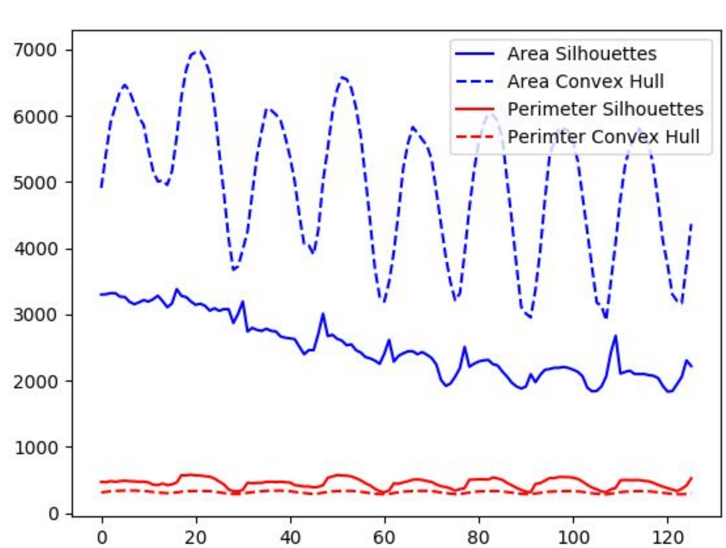
    Deficits of convexity: convexityDefects() using resulting convex hull. Returned is a list of 3 points for each deficit in convexity.

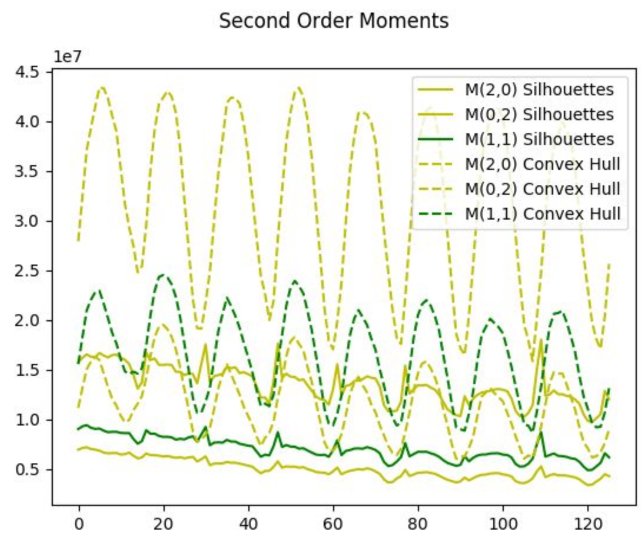


    Area, Perimeter, and moments for convex hull using points returned by convex hull.

All features are stored in an array of dictionaries and later saved in a CSV file 'features.csv' as well as depicted as line graphs.

Area and Perimeter

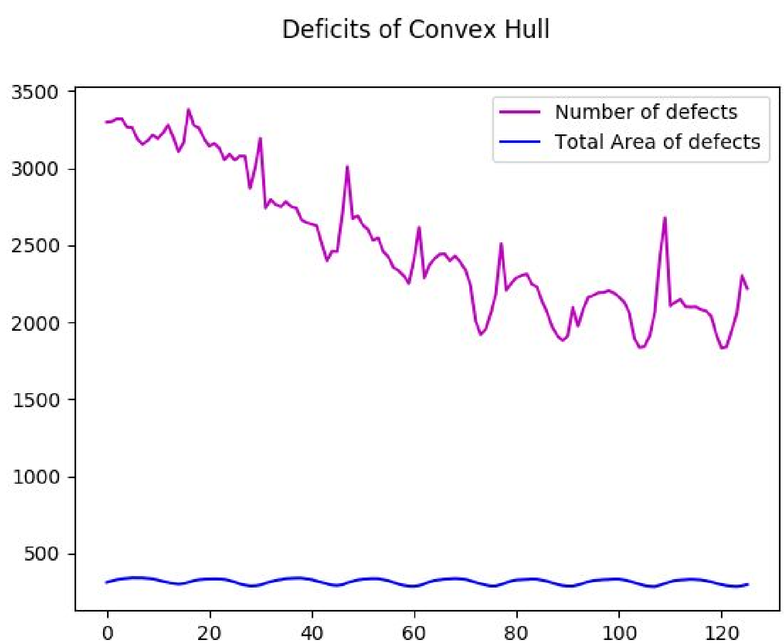




The marked polygons and boundaries are saved in 'results' folder in corresponding folders.

2.

On computing the convex hull and it's deficits, three points are returned for each 'defect'.
The area in these defects can be approximated by calculating the area of the triangle formed by these three points.The total area and number of defects for each image is saved in the 'features' data structure.



3.

Curvature along the boundary is computed using the contour points as boundary of images. It is calculated following the Curvature of a Parameterized Arc. For each pixel in the boundary, x(t) and y(t) are locally interpolated by second order polynomials:

$x(t) = a_0 + a_1 t + a_2 t^2$

$y(t) = b_0 + b_1 t + b_2 t^2$

By solving simultaneous equations, $(x(0) = x_i , x(1) = x_{i-k} , x(2) = x_{i+k})$:

a0=x0

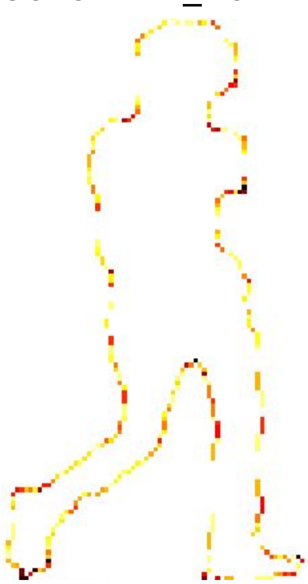
a2=(a0 + x2 - 2*x1)/2

a1=(4*x1 - 3*a0 - x2)/2, and similarly for y.

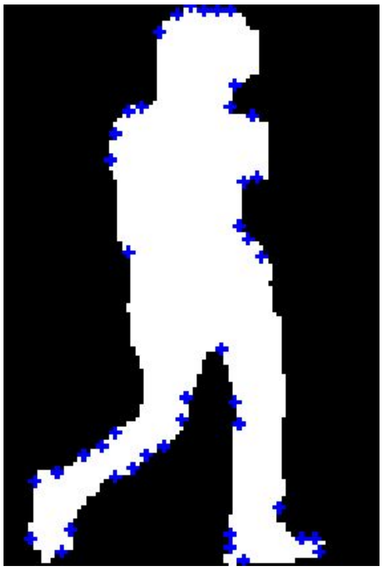
The curvature is: $K = 2*(a1*b2 - b1*a2) / (a1*a1 + b1*b1)^{1.5}$

Here, by hit and trial and the appropriate **value of 'k' is is taken as 4** for all images in the sequence.

The curvature is normalized to grayscale 0-255 range, and depicted by heat map 'COLORMAP_HOT'. White pixels: low curvature, Dark Red pixels= high curvature.



Local Maxima is depicted by blue dots on the boundary where the curvature is maximum in the neighbourhood.

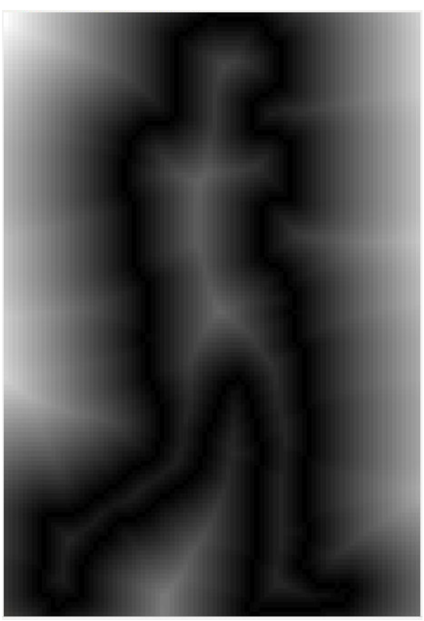


4.

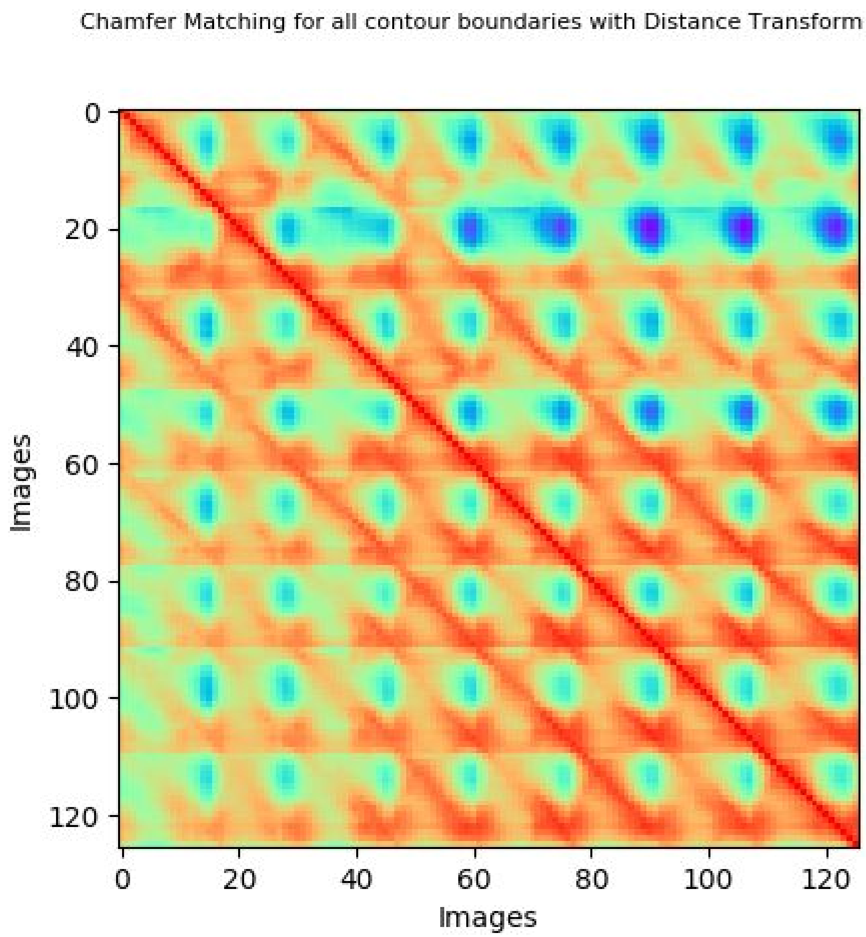
Euclidean Distance Transform is implemented for all images is calculated for all points in image. Boundary points for all contour levels are used in this. Value of each pixel in resulting distance transform is the euclidean distance from that point to the nearest boundary pixel.

The result is then normalized for displaying in grayscale.

This function returns distance transform matrix of image size that is saved in an array for all images which is used in part 5.



5.
Chamfer Matching:
Used to compute the best fit of one image over another. Here, it is used to find similarity between all gait images. A template is used to match a pattern of image 1 on the distance transform on image 2. The result is a similarity value for each pair of image.
Chamfer matching is done for all pairs of images in the sequence with contour of images as templates, and matched on the distance transforms for the image, to obtain the match score. This score is then depicted by the confusion matrix.



6.
[a] In both parts, 2 and 5, periodicity can be noticed in the same pattern. The gait of silhouette of the person walking can be seen as the limbs of the person move to and fro. The images have similar features for similar positioning of the limbs. This pattern is repeated with every walking step of the silhouette.

The graphs for area, perimeter, and moments for image and convex hulls for the sequence show the same periodicity pattern as does the confusion matrix of similarity between images.

[b] In part 2, the area and perimeter of the silhouettes and convex hull increase and decrease in a similar periodic manner. The line graphs can be corresponded to the gait phases with maximum area of convex hull(peak of wave) being the widest profile, and the minimum area of convex hull(trough of wave) being the narrowest profile.
There is not much difference in the perimeters of convex hull, but it is enough for the difference to be visible.
However, there is no difference at all in the perimeter of the silhouette while walking.
The overall decline in the wave of the silhouette and hull is due to the apparent direction change of the walking person from facing slightly front to completely right, causing the total area from side view to reduce.

[c] Curvature is depicted in the image with heat map showing high curvature points in the image with hotter colors. Therefore, the joints and body parts of the silhouette can be judged by the points with high curvature.
