Frontal view face detection

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ABSTRACT

This paper presents a symmetry measurement based on the correlation coefficient. This symmetry measurement is used to locate the center line of faces, and afterward, to decide whether the face view is frontal or not. A 483-face image database obtained from the U. S. Army was used to test the algorithm. Though the performance of the algorithm is limeted to 87%, this is due to the wide range of variations present in the database used to test our algorithm. Under more constrain conditions, such as uniform illumination, this technique can be a powerful tool in facial feature extraction. In regards its computational requirements, though this algorithm is very expensive, three independent optimizations are presented; two of which are successfully implemented, and tested.

Keywords: symmertry, symmetry measurement, face detection, frontal view face detection.

1 INTRODUCTION.

This paper presents an algorithm based on symmetry measurements, useful to extract information about symmetric objects from images. The proposed technique was developed and tested in the context of face recognition, but it might find applications in other areas of computer vision in which symmetry is involved. The motivation for this work is the high amount of symmetry present in frontal view faces; the claim is that this information can be useful in the estimation of face orientation, as well as in the extraction of feature points.

In a face recognition system based on template matching, estimating the orientation of the probe faces helps in discarding templates that do not need to be searched reducing the computational requirements and the execution time.[1] On the other hand, this algorithm as a preprocessing step, provides information usually assumed as input data in facial feature extraction techniques. In a more general context, symmetry measurements combined with some knowledge can be used to verify the presence of (symmetrical) objects in a given image.

Much work has been previously done in this area; from the development of symmetry operators[2–4] for detection of interesting points, to fast algorithms for the location of axis of symmetry on images.[5] However, the problem has been stated as the location of the regions with the largest amount of symmetry to guide the feature extraction assuming their presence. In the context of face recognition, we use a symmetry measurement to decide if the probe image is a frontal view; for each case, we also provide an estimation of the tilt angle, and the location of the center line.

Our measurement of symmetry is a line-by-line analysis of the correlation coefficient between a region around the face and its reflection with respect to its center line. We first locate the center line of the face by searching for the position of an axis of symmetry with maximum symmetry; the search is speed up by using an approximation of the measurement of symmetry, and an fast-search algorithm. Once the center line is located, the actual measurement of symmetry is evaluated and compared to a threshold level to decide if the face view is frontal or not. This also gives a level of confidence on the center line of the face. The input images are preprocessed such that we have a loose bounding box of the heads; histogram equalization and Gaussian filtering are also used to deal with pour lighting conditions present in the testing database.

The next section describes the measurement of symmetry based on correlation. Section 3 and 4 give details of our implementation of the algorithm. In section 5, results are presented and discussed. Finally, conclusions are given in section 6.

2 A CORRELATION-BASED MEASUREMENT OF SYMMETRY.

In the context of face recognition, we were interested on utilizing the symmetry of the frontal view faces; that is, the symmetry with respect to only one axis – i.e. the vertical axis. We measured the overall symmetry of the face area by analyzing line segments independently. Our measure of symmetry is based on the correlation coefficient between a line segment and its flipped version.

Let $x[n]$ be a sequence (1-D signal) and $x_m[n]$; $n = 0, 1, \cdots, N-1$ be a segment of $x[n]$ defined as $x_m[n] = x[n-m]$. The mean value of the $x_m[n]$ is:

$$\overline{x_m} = \frac{1}{N} \sum_{k=0}^{N-1} x_m[k]$$

and the variance is:

$$\sigma_{x_m} = \sqrt{\frac{1}{N} \sum_{k=0}^{N-1} (x_m[k] - \overline{x_m})^2}$$

Also, let $x'_m[n] = x_m[N-1-n]$; $n = 0, 1, \cdots, N-1$ be the flipped version of $x_m[n]$. Then, we measure the symmetry around the position $m' = m + \frac{1}{N}$ with the correlation coefficient:

$$Symm[m'] = \frac{1}{\sigma_{x_m} \sigma_{x'_m}} \sum_{k=0}^{N-1} (x_m[k] - \overline{x_m})(x'_m[k] - \overline{x'_m}) \quad (1)$$

Fig. 1 (top) shows an example of a 1-D signal and its most symmetrical window of size $N = 101$. Fig. 1 (bottom) shows the symmetry measurement. Note that a correlation coefficient of value near 1 means high symmetry while values near -1 mean anti-symmetry. In this example, the maximum value is 0.6966; it can be noticed that the highlighted window is not perfectly symmetrical.

Several aspects of this measurement of symmetry shall be pointed out. First, the size of the window should be chosen close to the size of the symmetrical feature we are to detect; smaller sizes might locate other symmetrical windows while larger sizes might result in a low correlation coefficient. Also, it is highly recommended to smoothen the signal accordingly to the size of the window in order to reduce the efect of noise and small details; i.e. use a Gaussian filter with σ approximately one tenth of the window size. Finally, constant signals are singularities,

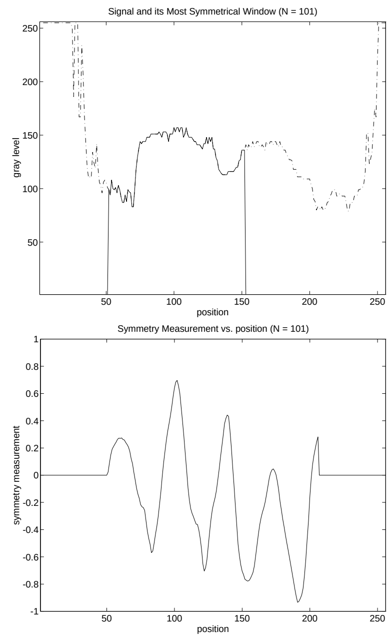

Figure 1: Top: example of a signal, and its most symmetrical window of size 101 . Bottom: plot of the symmetry measurement vs. the position of the axis of symmetry – i.e. $m' = m + \frac{1}{N}$

but near constant signals might result in correlation coefficients of value near 1. To overcome this lapse in our measurement, we analyze the variance together with the correlation coefficient. Too low values of the variance prevent us to conclude on the symmetry; such line segments might be ignored.

2.1 A fast algorithm.

An exhaustive search for a maximum can be efficiently implemented if the mean of the window is approximated with the mean of the whole signal; that is, $\overline{x_m} = \overline{x'_m} \approx \overline{x}$. This approximation has experimentally shown to give similar results, and saves computation time. First, the mean $\overline{x}$ is computed and subtracted from $x[n]$ only once. Then, the computation of the variances $\sigma_m = \sigma'_m$ can be implemented via fast additions – i.e. taking advantage of the window shifting. Additionally, coarse-to-fine resolution measurements can be used through the search by subsampling the smooth signal.

3 LOCATION OF THE AXIS OF SYMMETRY.

The location and tilt angle of the axis of symmetry is obtained by searching for the maximum of the symmetry measurements of small image regions around the face area. The symmetry measurement of a rectangular window is computed as the average of the symmetry measurement of all of its rows with σ_{x_m} greater than a fixed threshold. The size of the rectangular window is taken proportional to a loose bounding box of the head; the algorithm used for finding the bounding box is based on edge detention,[1] and works well since the images in the database have uniform background.

In a first approach, an exhaustive search for the maximum of symmetry is carried out not only on the loose

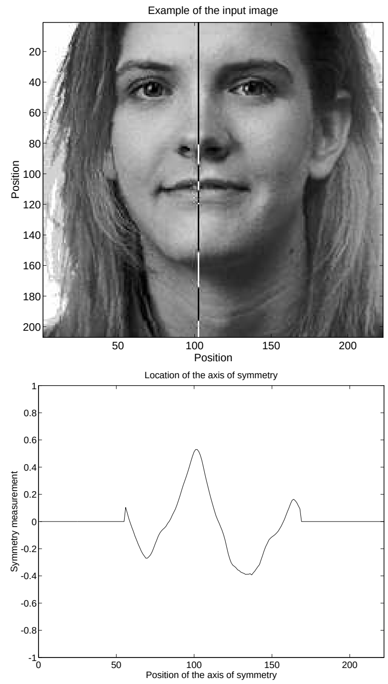

Figure 2: Top: example of the searched window, and its best axis of symmetry. Bottom: plot of the symmetry measurement vs. the position of the axis

bounding box, but also on others tilted version of it. In that way, we detect symmetry on images of tilted faces. Fig. 2 (top) shows an example of the searched area around the face and its best axis of symmetry; (bottom) is the plot of the symmetry measurement vs. the position of the axis of symmetry. The location of the peak on symmetry measurement corresponds to the location of the center line of that face. Fig. 3 is a plot of the maximum symmetry measurement vs. the tilt angle. The global maximum corresponds to the tilt angle of the face, and withing a region, approximately ± 10 degrees, there is no other local maximum. Finally, Fig. 4 shows six examples of the input images and their center lines.

3.1 Our implementation.

An exhaustive search for the best axis of symmetry is too computational expensive, particularly if a wide range of tilt angle is allow in the input image. Three independent optimizations can be implemented to reduce the computation time of this algorithm. First, by using the approximation described in section 2.1, the number of numerical operations is significantly reduced. Next, since there is not local maximum in the vicinity of the global maximum, exhaustive search is not fully required; fast search-for-maximum algorithms can be implemented. Finally, lower image resolution can be used in the first part of the search i.e. a coarse-to-fine algorithm.

In our implementation, we use the approximate symmetry measurement for the search. Exhaustive search is carried out only at tilt angles: -8, 0, and $+8$. Then, we do a fast-search within ± 4 degrees of the tilt angle with the greatest symmetry measurement, and within a region of positions around of the best position; this region is chosen $\pm \frac{1}{3}$ of the window size. However, full image resolution is always used.

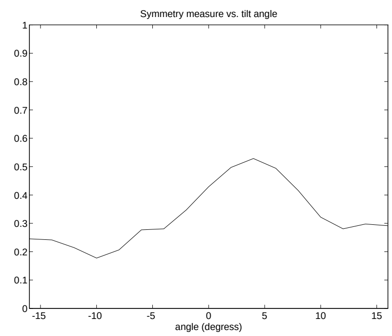

Figure 3: Plot of the symmetry measurement vs. tilt angle

4 DECIDING IF THE FACE VIEW IS FRONTAL.

Once we have the symmetry measurement of the face area, we compare it to a fix threshold level. If the former is greater than the latter, then we conclude the face view is frontal. Since this algorithm is to be used with the purpose of avoiding correlating frontal views with non-frontal templates, the number of false alarms – non-frontal probe images detected as frontal, has to be minimized. This is, the threshold level has to be taken high enough so that non-frontal views never reach it. This of course, reduces the performance of the system, but increases its reliability.

At this point, once the center line of the face has been located, further analysis might be done; in fact, our symmetry measurement is the simplest approach to decide the presence of a frontal view face.

5 RESULTS.

The results presented here were obtained using a 483-image database. 241 images of frontal view, 126 images of half view – i.e. 45 degrees, and 116 images of profile view. Though the background is uniform, the lighting conditions and the scale vary withing the database.

Although several parameters were fixed arbitrarily, they are not changed interactively through the test. Also, the results are not too sensitive to those parameters. In that sense, the implementation is fully automatic. Given an input face image (or the bounding box of the head instead), the algorithm always returns the location of a line as well as an indication of the confidence that the view of the face is frontal, and that this line is the center line of that face.

5.1 Locating the center line of the face.

In regards the location of the axis of symmetry, the algorithm successfully located the center line of the face on 211 out of the 241 frontal view images. That is a performance of approximately 87 %. Fig. 5 shows six examples of those 30 images for which the algorithm failed. There are five factors that make the algorithm fails:

1. Non-symmetrical illumination: In 18 cases, the face area is not symmetrical because of the shadows due to non-uniform illumination.

Figure 4: Examples of input images and their center lines

Figure 5: Examples of images that make the algorithm fails.

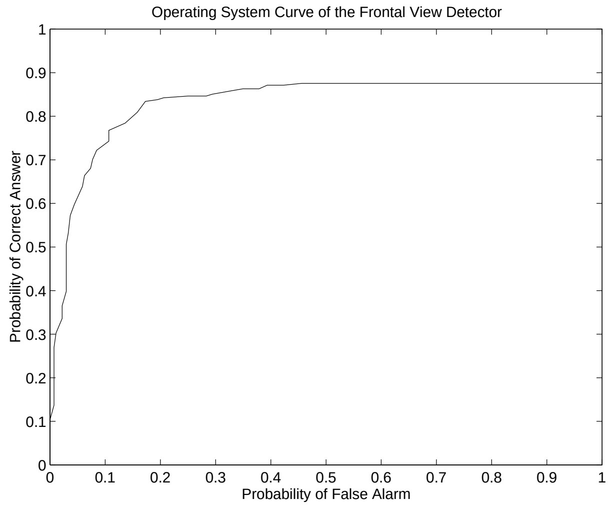

Figure 6: Operating curve of the system.

2. Too large window size: In 12 cases, since the loose bounding box was too large, the rectangular window used to measure the symmetry was much larger than the face area.
3. Not frontal view: In 5 cases, the face view was not quite frontal so the face area is not symmetrical.
4. Too small window size: In 3 cases, the rectangular window used to measure the symmetry was much smaller than the face size.
5. Non symmetrical features: in one case, the glasses made the image non symmetrical. There are other cases in which the faces are simply non-symmetrical.

Note that these conditions are not mutually exclusive so there are images that suffer from several of them. In 12 cases out of 15, in which the size of the rectangular window were too different from the face area size, it was possible for the algorithm to locate the center line of the face by iteratively selection of the loose bounding box of the head. The other 3 cases presented at least one of the others problems. This is reasonable since we estimate the face size to be proportional to the head size; this is particularly wrong on several hair stiles. By increasing the complexity of the search to a range of different rectangular window sizes, this limitation should be overcome.

5.2 Detecting frontal view faces.

Taking the 30 cases on which the center line of the face was not successfully located as false alarms or incorrect answer, the performance analysis of the system was carried out including the 483 images of the database. In this way, the symmetry measurement works not only as an indicator for the the frontal view detector, but also as confidence level of the algorithm to find the center line of the face. Fig. 6 shows the operating curve of the system; the y-axis corresponds to the probability of correct answer while the x-axis corresponds to the probability of false alarm. A correct answer means that the image has a frontal view face, the algorithm successfully found the center line of the face, and the symmetry measurement is greater than the threshold value. A false alarm means that the symmetry measurement is greater than the threshold value, but either the image does not contain a frontal view face or the algorithm did not find the center line of the face on an image with a frontal view face. The threshold level is the varying parameter in the curve; for example, setting the threshold level of 0.668, the number of false alarms is three, and the number of correct answer is 73 out of 241 – giving a performance of 30% of correct answer at 1% of false alarm. By allowing up to 10% of false alarm – threshold equals to 0.388, the performance is increased to 74%.

6 CONCLUSIONS.

We have presented a simple technique to measure symmetry on images, and used it to locate faces, estimate their tilt angle, and decide whether their views are frontal or not. Though the results indicate a low performance, this is due to wide range of variations present in the database used to test it. The algorithm for locating the center line of the face would perform much better if the input images are reasonably constrained; i.e. if uniform illumination is used. Additionally, further analysis can be done after the center line is found in order to increase the confidence level of the frontal view face detector. One mayor drawback of the algorithm is that it is computationally expensive. However, three independent optimizations are presented; two of which were successfully implemented.

Finally, it is important to note that since this method for locating frontal view faces is fully based on symmetry, it automatically weakens in the presence of exceptions such as non-symmetrical faces, gestures, and the like. However, this together with other techniques might provide a powerful tool for facial feature extraction.

7 ACKNOWLEDGEMENTS

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