On Experiences with (In)direct Marking Techniques for Eye Features within Evaluation of Irides Recognizing Biometric Authentication Systems

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Abstract: In this paper we're giving a report of our experiences with different (in)direct eye feature marking techniques for revealing eye features. The coordinates of the found regions of the here considered eye features - eyelids and eye corners - can be used as reference data for rapid human iris feature tracking (RHIFT) systems reaching up to 1.000 frames per second for detection and tracking of irides as preprocessing step in irides recognizing biometric authentication systems. The main conclusion of this work is that automatically collected eye features reference data with indirect marking will deliver higher accurate evaluation results if the marking techniques are developed further. So far, manual direct marking by experts on single images are available for the evaluation of the accurateness of an eyelids and eye corners detection and tracking method. A tool for collecting such data was implemented for validation. Tool-based manual gathered eye feature reference data were used for the accurateness evaluation of an eye feature detection and tracking method.

1 Introduction

The BioP II report by the Bundesamt für Sicherheit in der Informationstechnik (BSI) for Evaluation of Biometric Verification/Authentication Systems shows a surprisingly high false rejection rate (FRR) of more than 20% for a tested iris recognition system [BSI05, p.16]. It is reported that mainly the user-based positioning of his eye in front of the sensor leads to these unwanted results.

An automatic approach for finding the irides of a person to be authenticated can be done by applying a rapid human iris feature tracking (RHIFT) system as a preprocessing step of the irides recognition. The task can be solved in executing several steps in sequential order given by Brömme in [Br04, Br05]. First, the face is detected from the whole image like shown by Tiedge in [Ti05]. Second, the eye regions are localized on the face and tracked over the sequence with the method by Mack in [Mac05]. Finally, the irides are detected and tracked by using a specialized Hough Circle Transform (HCT) within the eye regions like approached by Huang in [Hu05]. A HCT approach for real-time (eye|iris) tracking was applied by Young et al. in [YTS95], which was affirmed within literature by Tönnies et al. in [TBA02] with a feasibility assessment.

By tracking the iris in an eye region image, the direction of the gaze can be derived. If the iris is close to the right eye corner, a person to be recognized is looking to the left and in the same way with the other direction. By localizing the iris on images, only, the gaze direction information cannot be revealed. Displacement to one side might mean changing the gaze direction, but might be caused by the head translation as well (the gaze direction does not change at all). To distinguish between these two movements, a set of reference points is needed in the extracted eye region images. We consider eye corners to be suitable for this task, because they are salient features on the face. For detecting eye blinks - considered here as system states of non availability of iris features - the positions of the upper and lower eyelid and their distance are used. Thus, the eyelids and eye corners are interesting features for a RHIFT system.

Detection of the features eyelids and eye corners in greyscale images is not a trivial task. Both features can be defined differently. The features eyelids are defined here as the contours of the upper and lower eyelid with start and end points in the left and right eye corners, respectively. The eye corners are defined as the intersection points of the upper and lower eyelid contours. To localize these intersection points is the aim of the eyelids and eye corners detection algorithm. Based on a subpart of the work by Uzunova in [Uz05], we report about our experiences in collecting adequate reference data for the evaluation of the accurateness of methods for eyelids and eye corners detection and tracking as preprocessing step for iris recognition systems.

The best way to collect reference data in large image sequences is by automatic extraction of marked eye features (passive markers). The other alternative (tool-based), which is widely used in medical image processing area, is to ask experts to mark manually on the images the features of interest. Both ways have their advantages and disadvantages. The first way is an automatic process, not biased by experts' opinions and imprecision of manual marking and is less time-consuming. The information is recorded on the images and is directly available for further analyses. Manual selection, in contrast, is time-consuming and an experts-biased process, but it works in any cases independent of the eye opening grade and quality of the images. The attempts of both techniques are explained here.

Marking special facial (eye region) features directly or indirectly has many applications. A literature survey shows that the authors rarely address the techniques of producing the markers. Kouadion et al. [KPL98] uses face markers for realistic animation of the facial expression. The markers are put directly on the facial features, to observe their movements. The markers are glued to features of interest making this approach not appropriate for our task. Face markers are used to measure the face deformation during speech production in Maeda [Mae05]. Marking used as a reference data, was produced by manual selecting the interesting features on the images, for example in Gu et al. [GSD03]. A lip cream is mentioned as possible marking technique for marking the lips by Goto et al. [GEZM99]. Within further related literature, Adenaike proposes in [Ad04] a method and tool for facial markers removal. He does not mention details of producing the facial markers, but from the context and the example images it can be revealed that the input images are colourful and the markers are of white color.

In section 2 we briefly explain the image sequence acquisition set up and the character of the input data. Section 3 delivers the description of the different attempts of indirect marking of the eye region features. In section 4 the results of tool-based direct manual marking are presented. Section 5 shows an example of applying the direct marking technique for subsequent evaluations. In the final section 6 we conclude from our results for the usage of eye marking techniques for revealing reference data for the evaluation of preprocessing steps for iris recognizing (mono|multi)modal biometric authentication systems and highlight aspects future work.

2 Image Acquisition

The image sequences are captured under laboratory conditions by a high-speed camera BASLER A500k with CMOS sensor. The set-up is shown in figure 1. The test person is sitting frontal with the face in direction to the camera, without moving his body. The distance between the camera and a test person's face is fixed and is about 0.8m. The test image sequences are captured with 94 frames per second (fps) having a resolution of 1280x500 pixels for each image. The size of a single eye region is about 220x120 pixels.

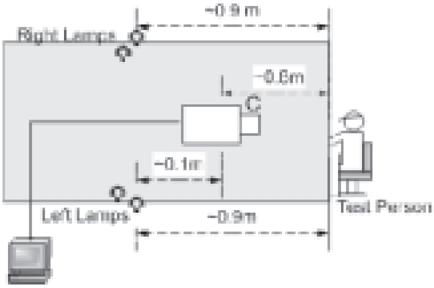


Figure 1. Image acquisition set-up

3 Automatic Collection of the Reference Data

3.1 General Remarks

The straight forward decision for automatic reference data collection is to mark the features of interest, as gluing to them markers, which can be easier extracted with image thresholding techniques. By putting markers on the eye corners and along the eyelids an occlusion of the eye corners and an over emphasizing of the eyelids will result. This is not suitable for our application, because the method to be evaluated would work on partially not visible features and the evaluation result is misleading.

This consideration leads us to experimenting with indirect marking of the eye features. Two questions raise: (a) ‘Where to put the markers?’, so that they do not disturb the data in sense of method expectations, (b) ‘How to produce the markers?’. These two questions are discussed within the different subsequent attempts.

3.2 Attempts of Indirect Marking of Eye Features for Automatic Reference Data Collection

3.2.1 Indirect eye feature marking with make-up eyeliner

Since the lower eyelid is a more static feature, which does not move a lot, and the face shape, below it, is plain, the markers can be set on the cheek. The upper eyelid is in image sequences a very dynamic feature.

‘Where to put the markers?’: If markers are set on the upper eyelid, but not on the contour they are hidden when the eye is open. If they are further away, close to the eyebrow, they do not follow the curvature of the eyelids, when the eye is closed and the distance assumption does not hold. When the eye is closed the eyelid is concave with respect to the iris centre, and translated downwards at a certain distance, but the markers remain convex. Therefore, for the upper eyelid, two markers are used, one, when the eye is closed and the other one, when it is open (see figure 2).

‘How to produce the markers?’: Especially for the eyelids, it is important that the markers can be bended in way to follow the eyelid curvature. Make-up white eyeliner allows to draw flexible lines on the skin. An example of the session with such markers can be seen in figure 2.

Figure 2. First attempt of indirect eye features marking for automatic collection of reference data by using white eyeliners

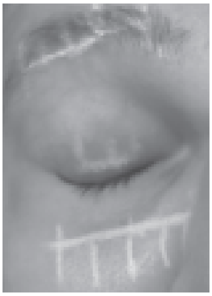
Images from this session suffer from some problems. Among them, the biggest one is that the eye corners can not be extracted along the markers due to the limitations of the marking model. The other problem is that after several eye blinks the line on the eyelid vanishes due to the non permanence of the eyeliner’s colour. This effect can be seen in the right image of figure 2.

3.2.2 More precise indirect eye feature marking with make-up eyeliner

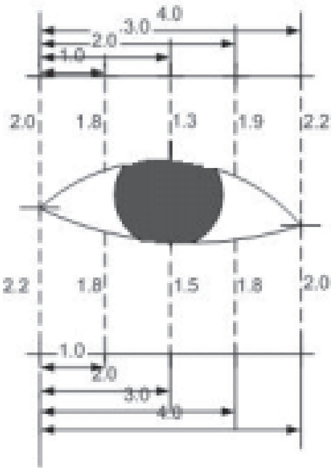
A more precise marking set-up is done in the next session (see figure 3), which applies a user eye region specific scheme (see figures 3c and 3d). They are especially designed to extract the eye corners. The eye corners are lying on the lines, connecting the end points of the markers above and below them at a known distance from both of them. The scheme shows that the used frame around the eye is expected to be rectangular. Due to the fact that a human face is not a flat surface, it is impossible to draw a precise rectangle with an eyeliner, which remains rectangular after face deformation and 2D projection on the images as well. Moreover, due to negative experience with the vanishing markers on the upper eyelid, the markers needs to be refreshed periodically. This gave another artifact – because of drawing one over the other the lines became thicker and more difficult to be emphasized later with an edge detector. An example with vanishing markers in the upper eyelid is given in figure 3b. The resulting images from this attempt have the following disadvantages:

1) the desired rectangle from the model isn't rectangular
2) the end of the marking are not exact
3) the line on the upper eyelid is nearly connected to the eyelid contour, so the algorithm will be disturbed
4) it is difficult to extract the markers in the eyebrow area, because it is hairy

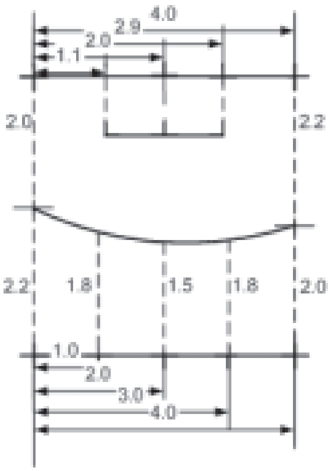
(a)



(b)



(c)



(d)

Figure 3. Second attempt of indirect eye features marking for automatic collection of reference data: Sample images for (a) open and (b) closed eye, and applied user specific schemes for (c) open and (d) closed eye (the measures are given in cm).

3.2.3 Indirect eye feature marking with paper markers

The gained experiences from the experiments described in subsections 3.2.1 and 3.2.2 are that the chosen marking techniques are not the appropriate, because of vanishing markers after several eye blinks and imprecision of drawing the markers. Therefore, in the next experiment, stripes of paper were glued on the skin (see figure 4) instead of using an eyeliner. The ends of the markers are more distinguished than on the previous attempts. Although the colour of the paper is pink, the markers are visible and distinguishable on the skin. This gives a good promise to continue with setting paper markers. Because the paper itself is not rigid so it can not follow the curvature of the eyelids. This approach is suitable for the eye corners, only.

Figure 4. Third attempt of indirect eye features marking for automatic collection of reference data

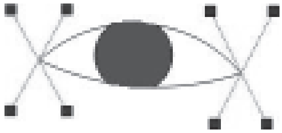


Figure 5. The model for marking by gluing the paper points on the face

3.2.4 Indirect marking of the eye corners with paper points and stripes

A scheme for marking the eye corners is designed as the one shown in figure 5. The markers are set away from the eyelids and eye corners. They are small squares of paper and represent the ends of lines, intersecting each other at the eye corners. Each line can be reconstructed from the centres of two rectangles – one above the eye corner and the other below. This method was rejected on fly, because the small pieces of paper cannot be stacked on the skin. The bigger the markers' size is, the better they can be fixed. It can be assumed for future experiments that a better gluing techniques would be of significant help for paper points.

This experience leads to the usage of paper stripes instead of paper points. The both ends of each line are emphasized by stripes. The example image in figure 6 shows the disadvantages of this technique:

1) the stripes crossing the eyebrow can not be stucked, because of the hairy region
2) the leftmost stripe on the row above the eye is not a line because it follows the shape of the head
3) the rightmost stripe on the row below the eye is difficult to be placed and projected on the image as a line, because of the oval shape of the head

On the other hand only one stripe is already enough to extract the line, since they are not any more points but lines. The stripes are placed in a way to avoid the 'inconvenient' places (like oval areas or eyebrows). The desired model is shown in figure 7 and figure 8 - an example of the applied model.

The difficulty with this approach (only one marker is responsible for a line) is to fix the stripes so that the extensions of two stripes intersect on the eye corners. This means that each line of a pair should pass through the eye corner. The precise direction towards the eye corner cannot be taken without a positioning help and therefore a ruler is used to guide the direction of the stripe.

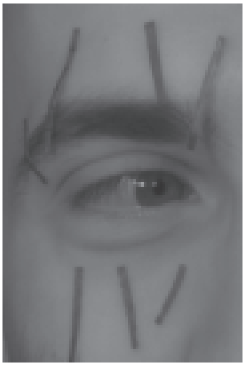


Figure 6. The lines marked with two stripes

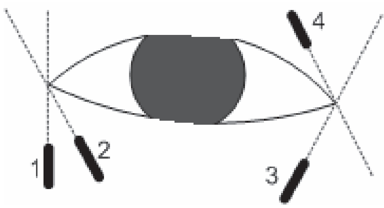


Figure 7. A model for the stripes, where each line is presented by only one marker

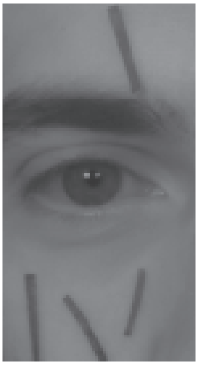


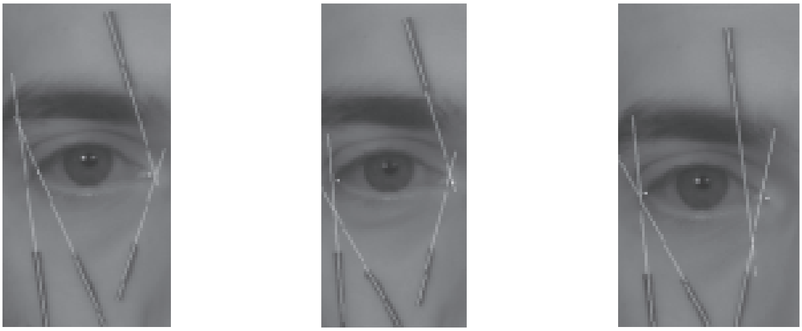
Figure 8. The applied model from figure 7

It was expected that from each stripe a line, which is nearly in its middle, would be extracted. This was used to verify whether the current set-up of the stripes fulfills the requirements. Figure 9a-c are showing examples of three different sequences. After the images are acquired, in the middle of each stripe the ideal, desired to be extracted line, is drawn by hand (the white lines in Figure 9). The target points (the eye corners) are plotted with white dots. None of the pairs of lines intersect on the target image points. The errors (in pixels) reveals best approximation of 10 pixels to the target region (see table 1).

	Left Eye Corner	Right Eye Corner
Figure 9 a	*77.6*	*10.3*
Figure 9 b	*48.3*	*14.9*
Figure 9 c	*11.3*	*71.5*

Table 1. Calculated error (in pixels) from the target (real) eye corner and those, calculated by reference extractions

As it turns this method has problems in correct pointing the eye corners. The first problem is that the ends of the stripes cannot be fixed and thus they change the shape of the line. It is no more a line, but a curve at the ends. The biggest difficulty, however, is, that already small changes of the position of the marker have higher influence on the intersection point. Since the markers are connected to the active surface, already fixed stripes do not keep fixed for long, because of the dynamic change of the face. They are disturbed additionally when the other stripes are modified. The error from the position of the real corner is in the best case 10 pixels, when the eye corners are indirectly marked by stripes.



(a) (b) (c)

Figure 9. Ideal lines constructed from stripes. The white dots represent the target's eye corners.

4 Tool-based Direct Marking of Eye Features for Manual Reference Data Collection

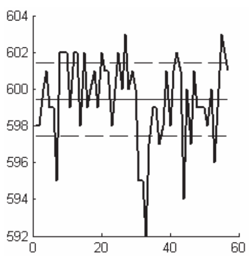
The other way for reference data collection is by manual direct marking the eye features by experts on the already recorded image sequences, given a suitable tool.

The experts do not need special education to recognize the eye features and most adults can manage this task. With this assumption and with the aim not to influence experts' mind with explanations about the purpose, he was confronted with some tasks: 'Please, select the inner/outer corner of the eye.' and 'Please, select three points along the upper/lower eyelid.'. An interview after the fulfilled tasks shows that the expert thought in a 'user-oriented' manner and marked points under the assumption 'I just help the program to extract the upper and the lower eyelid.'. This assumption delivered points, which are not located on the eyelid contour, but under or above the eye. During the marking sessions, however, the experts reminds the more specific task and starts selecting the points more precisely along the contour. The turning point is when the expert is confronted with images of (partially) closed eyes. We have experienced, that obviously a training effect of the expert with the task of direct manual marking took place. Even though the markings are correct at the end of a marking session (in terms of defined eye features). Therefore we have decided before collecting the real reference data to provide several images of different states of the eye to the experts, without telling them that they are for training, only, and the markings are not further used.

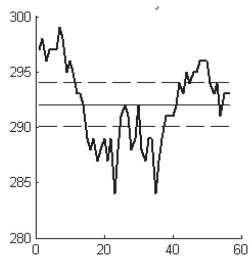
One of the experts defined the eye corners as the leftmost and rightmost visible points of the eyeball. But the aim of the eye features detection and tracking algorithm is the eye corners as the intersection points of the eyelids. This makes the direct manual marking on the sequence biased by the experts' opinion. Therefore, a little discussion has to be done with the experts, explaining the purpose of marking the eye features and how the features are defined.

For collecting and analyzing the data, a tool has been developed. It provides a graphical user interface to help the expert to control the selections. The expert is asked to mark the two eye corners and three additional points along each eyelid contour. The markers are set with a mouse. They are about 5 pixels in diameter, which means that the expert gave his decision with an accuracy of 5 pixels. Such inaccurateness is permissible in our case, because the eye corners are not a single pixel features but feature regions.

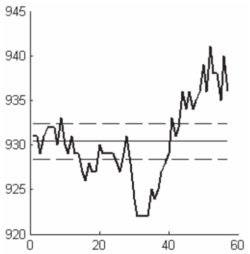
The direct manual marking on the sequence is uncertain in measuring small variations. Firstly, the marker, which is used, is 5 pixels in diameter. Secondly, this is a manual work, which has to point out small objects. It is unrealistic to expect that the experts would mark always the same pixel in the same image of size 220x120 pixels in two different marking sessions. In figure 10 a-d an example of the manual marking accuracy of the most precise working expert for the outer eye corner (figure 10 a,b) and the inner eye corner (figure 10 c, d) is shown. The manually marked image sequence consists of three parts: (i) gaze changing from the straight to the right eye corner (subsequent frames #1-28), (ii) gaze changing from right eye corner to straight (stepwise selected frames #29-47) and (iii) gaze changing from the straight to the left eye corner (subsequent frames #48-60), where the eye corners positions do not change visually. If we consider the eye corners as a region and take the average value over the whole sequence as its coordinates, the permissible corridor of horizontal/vertical variation due to the size of the marker is ± 2 pixels, which is shown in figure 10 with dashed lines. It can be seen that the expert set some of the markers outside this corridor. From figure 10 the error, which is produced by manual marking, can be derived. The manual marking error in subsequent frames of part (i) and (iii) in figure 10 is varying about 8 pixels in x- and y-direction separately.



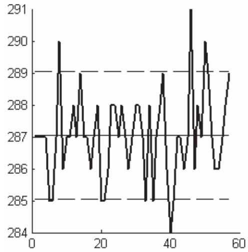
(a) Variations in manual marking of the outer eye corner in x direction



(b) Variations in manual marking of the outer eye corner in y direction



(c) Variations in manual marking of the inner eye corner in x direction



(d) Variations in manual marking of the inner eye corner in y direction

Figure 10. Manual marking selections of the inner eye corner (a and b) and the outer eye corner (c and d) in a selected image sequences

The preferable way to minimize these variations in manual marking is to collect the markings of more experts for one sequence and to average the coordinates of markings. Because of the limited number of experts each of the 15 sequences, containing 715 images each, was worked on by a single expert, only. In overall, all experts manually marked about 300 images.

5 Application of Marking Techniques for Evaluation

One method for direct manual and four methods for indirect automatic eye features marking were tested and analyzed. The smaller error of manual marking in average makes it preferable for an evaluation of an eyelids and eye corners detection and tracking method as a preprocessing step for irides recognizing biometric authentication systems. The interested reader can derive and find detailed results in the work by Uzunova in [Uz05].

An accuracy threshold for defining a positive detection of the eye features should be set in accordance to the application. For an application, where the eye corners are used as reference points to distinguish the iris from the head movement, the threshold depends on the physiologically given maximal displacement of the projected iris in two subsequent frames with respect to a certain frame rate. In figure 11 statistics of the success at different thresholds are given. In the here considered application a threshold of 12 pixels is set.

Independent of the threshold it can be seen that the outer corner is better detected than the inner one, although the experts judgements of their results votes on the contrary. This results from the character of the input data and experts' opinion. The inner corner is easier to be recognized by the experts, whereas occluded outer corners by eyelashes and shadow makes them more difficult to be marked.

The uncertainty of the manual marking can be shown when the results from tracking are evaluated. On the part of a sequence of eye region images of size about 220x120 pixels, where there is no movement in the images, the reported position of the eye corners changes within 4 pixels. In comparison with the manual collected reference data the error is about 10 pixels.

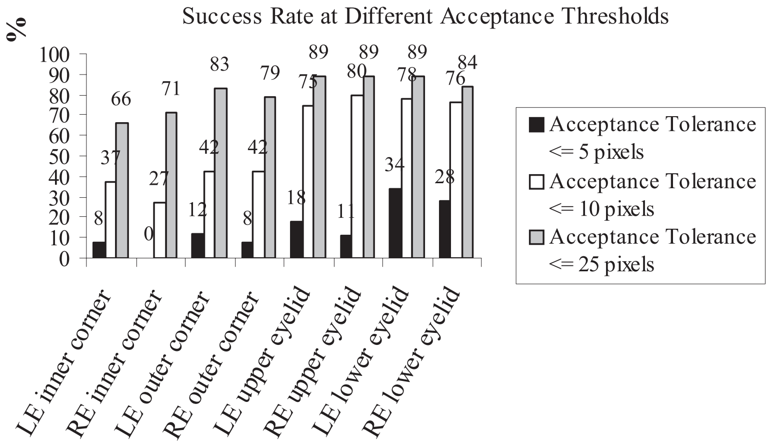


Figure 11. Success rates of the eye features detection algorithm with different acceptance thresholds (LE = left eye, RE = right eye)

6 Conclusions and Future Work

Locating the eyelids and eye corners in eye region images can be used as a preprocessing step for iris recognition systems. To evaluate a method fulfilling this task four attempts for collecting indirectly reference data for the eye features (eyelids and eye corners) and one for direct manual collection by experts are tested and the results are analyzed and discussed in this paper.

For indirect marking of eye features, the markers have to be glued, displaced at certain distance from the eye features. The used marking techniques differ from each other in generating the markers and in the set-up of the eye markers on the human face. Two techniques were employed in our experiments – make-up eyeliner and gluing paper. They were chosen, because they are flexible and allow adaptation to the curved surface of the face.

The biggest disadvantage of the markings, produced by the eyeliner, is that they are vanishing after several eye blinks and that the ends of the marking are difficult to extract. The paper stripes are not suitable for marking the eyelids, because they can not follow the changes from convex to concave (and vice versa) of the upper eyelid contour. The challenge in producing such markers is to find an appropriate location on the face for gluing the paper stripes. This should not be a hairy area (eyebrows) or area, which follows strong changes of the face (the leftmost marking in figure 6).

Depending on the technique, employed to produce the marking, different marking set-ups were explored. The marking set-up has to be chosen in a way that the eye features can be extracted adequately. So far we conclude for the here proposed indirect marking techniques for eye features that they are not sufficient for enabling automatic collection of reference data over large image sequences.

The direct manual collection of eye features reference data by experts, supported by the here proposed tool, has two main disadvantages. First, it is an extensive and time-consuming method, which can be used for selected single images of large image sequences, only. Second, in strong dependence of the expert's ability of manual eye feature point marking, which is alternating in about 8 pixels in x- and y-direction in the best case, the revealed reference data varies in quality.

With regard to the reported surprisingly high false rejection rates of a tested iris recognition system by the BSI in [BSI05] and a general architecture of biometric processes for enrollment, authentication, and derollment by Brömme in [Br03] we conclude that the crucial preprocessing of biometric processes needs to be tested separately from the matching algorithms. This paper demonstrates the difficulties in automatically and manually collecting adequate high quality reference data for an appropriate evaluation of the preprocessing steps for irides recognizing (mono|multi)modal biometric authentication systems and performance comparisons between different instantiations of such systems.

From our collected experiences in indirect and direct manual eye feature marking we conclude that if better indirect marking techniques for automated collection of reference data is available, this method needs to be preferred in comparison to manual direct markings by experts.

For the aspects of future work, a semi-automatic approach can be employed, where the experts show the region of the eye features and an automatic image processing techniques is employed for further refinement of the position of the eye features. Such techniques could be *deformable models*, which automatically fit to the contours of the eye. A completely automatic two camera technique could be tested, where the eye features are marked directly visually, which are captured by one camera, only. The images captured at the same time by another camera should not be influenced by these markings.

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