A Detection Technique for Rotated Multiple Faces in High Definition Images

Jeahoon Choi, SeongJoon Yoo, SungWook Baik, and Dongil Han*

Abstract**—**In this paper, a rotation invariant face detection algorithm is proposed that analyzes changes in rotated faces, which have been regarded as the performance degradation factor of existing face detection algorithms. When a 0° rotated face image was detected 100% using the face detection architecture by means of existing modified census transform (MCT) and AdaBoost learning techniques for rotated face detection, the detection rate was verified to be higher than 98% for –14°~+14° rotated images. Using this detection result, when input images were rotated in 22.5° increments, face detection could be achieved at all angles. Furthermore, an optimized face detection architecture was implemented through an algorithm for the rotation and reduction of images in consideration of the available face detection distance and a memory management technique that can minimize unnecessary regions.

Index Terms**—**multiple face detection, modified census transform (MCT), AdaBoost, human sensing.

I. Introduction

In recent years, face detection and recognition technology has rapidly developed. Face recognition has an advantage over other types of biometric recognition because of its non-contact connection and long-distance recognition. In particular, face detection has been applied to bio-information-based authentication technologies such as accurate face extraction for face recognition as well as a number of various areas for the detection and tracking of persons in images. Most previous face detection algorithms have been used to detect user recognition, while users have to wait until faces are accurately detected. However, the areas in which human face information is utilized have also increased in biometrics, and the need for high-performance rotated face detection technology has increased as well.

A number of researchers have proposed ways to improve the detection rate and speed, as shown in existing face detection algorithms. Some of the representative algorithms include the AdaBoost-based algorithm [1,2,3,4,5] in which faces are detected using learned data, the PCA-based algorithm [6] in which faces are determined by extracting feature points of faces and then comparing and analyzing these feature points, and the SVM-based algorithm [7] in which faces are extracted with high reliability by selecting specific regions. However, they have limited real-time processing due to their complex computational processes; therefore, they cannot be utilized in real daily applications.

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In this paper, the structural information of objects is extracted to reduce the cost required for illumination compensation operations, thereby transforming images using a modified census transform (MCT) [2] that reduces changes in illumination; a technique that rotates input images was applied to respond to rotation changes. Furthermore, a parallel technique for face detection windows, which can reduce the cost generated during input image rotation, and an efficient method for managing image rotation memory were also applied.

II. Techniques for Rotated Face Detection

Existing face detection architectures have had the drawback of performance degradation due to various external factors, such as changes in illumination, face rotation, face size, and face expression. To resolve this, an algorithm is proposed in this paper that can overcome such limitations by analyzing the causes of the performance degradation.

More particularly, a rotated face detection algorithm is presented that can detect rotated faces within a range of ±102°. This is accomplished using an efficient technique for the rotation and reduction of images, a parallelization method for face detection windows based on a previous study [8] using size transform techniques to respond to various size changes, the AdaBoost learning algorithm to generate the optimized learning data for face detection, and the MCT technique, which is robust to illumination changes.

Normally, the AdaBoost-based face detection algorithm can detect face images, with ±14 degree rotated faces. Fig. 1 shows the AdaBoost learning algorithm's detection range.

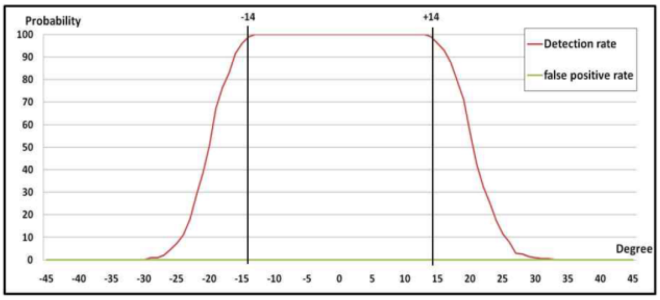


Fig. 1 Results of the face detection rate on rotated faces.

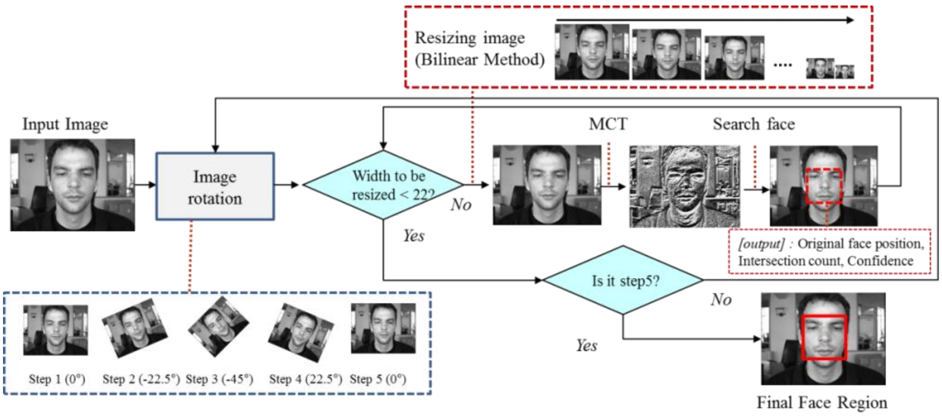


Fig. 2 flow chart of the face detector.

Based on the above results, face detection was performed while rotating detected face images within a ±22.5° range by taking the abovementioned error into account. The results verified that the front face detection rate was the same as that of the existing architecture while detecting rotated faces.

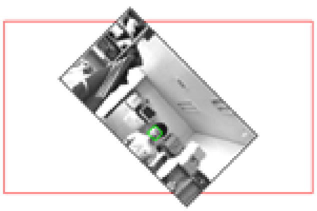
Therefore, in this paper, a design is presented to obtain a highly reliable detection rate of rotated face images by rotating high definition images at variable angles to resolve the face detection performance degradation problem with such images as well as enabling face detection of various sizes by reducing the images in 15 steps.

The flow chart of the face detector is shown in Fig. 2.

A. Image reduction technique for rotation

In this paper, the fixed memory rotation and image reduction rotation techniques are mixed and employed to prevent the need to adjust images' memory size and to reduce the non-detection problem at a certain distance as much as possible. For learned face data, information from the upper end of the eyebrows to the chin was used, and the length of most faces was approximately 15cm. Assuming that the available face detection distance in an indoor environment is set to 3.5m, the size of a face shot from the 3.5m distance with a lens at a 25° viewing angle will have about 35 pixels. Since the face detection window used in this paper is 20x20 pixels, if the image is reduced by up to 58% and rotated, the non-detection problem can be minimized, as shown in Fig. 3, so that face detection can be achieved within a distance of 3.5m.

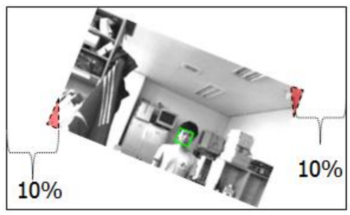
(a) Image reduced 62% and rotated 22.5°.



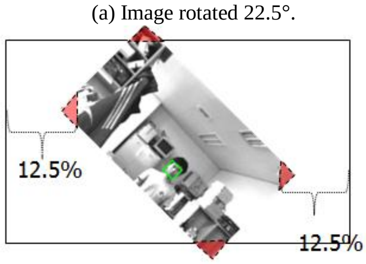
(b) Image reduced 58% and rotated 45°.
Fig. 3 Optimum reduction ratio according to angles.

B. Efficient management method of the rotated image memory

When an image is reduced and inputted into the image memory, a space is produced on the right and left sides of the image. If image reduction is performed on such a space according to the reduction steps, it will take more time to reduce the image since the space has no meaningful data. Therefore, the space areas were removed in this study, including some boundary regions that have low face detection rates, and those for which even if detected, low utilization is expected. As shown in Fig. 4, an image rotated 22.5° can have 20% of the right and left sides omitted, while one rotated 45° can be missing 25% of the right and left sides, thereby shortening the face detection time.



(a) Image rotated 22.5°.



(b) Image rotated 45°.
Fig. 4 Removal of space regions due to rotation.

In this paper, a method was designed for face detection within a range of ±102° using only five steps by means of a parallelization technique that performs dual processing of face detection windows. The parallelization technique takes advantage of the characteristic that face probability value data learned by AdaBoost can be rotated by ±90 so that face detection can be done without additional learning with respect to the rotated angle.

The first face detection window in Step 1 (Fig. 5) detects faces using the probability value data from an image that was not rotated, and the second face detection window detects faces rotated +90° simultaneously using the probability value data from an image that was rotated +90°. In Step 2, the first

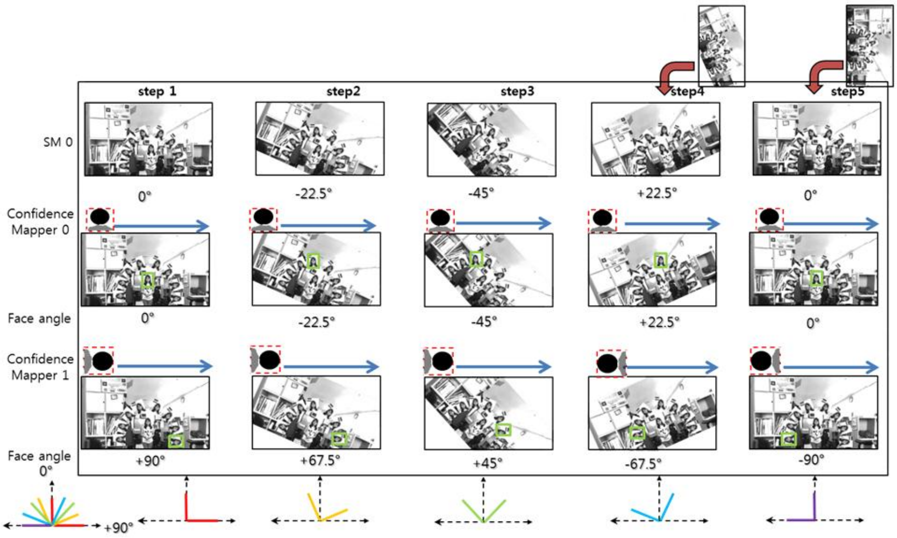


Fig. 5 Face detection angles per rotation step.

face detection window detected images rotated –22.5° using images rotated –22.5°, and the second face detection window detected faces rotated +67.5° simultaneously using the probability value data from an image that was rotated +90°. By applying this method to all five steps, faces within a range of ±102° can be detected.

III. Experiment and Verification of the Results

An experiment was conducted and the results verified in a PC-based with the Yale Test Set [9] and the BioID Test Set [10] that include various changes in face expression and illumination. To compare the detection rate according to changes in rotation, a test high definition image was rotated at 10° increments from -90° to +90° in a total of 19 steps to verify performance.

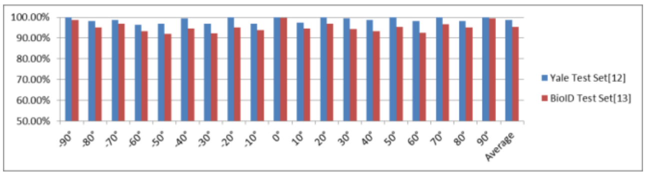


Fig. 6 Face detection rate.

TABLE I: Comparison of Face Detection Performance Using the BioID Test Set

Implementation	Detection rate	False positive	Detection speed
Wang et al.[11]	95.6% [a]	N/A	N/A
Huang et al.[12]	90% [a]	N/A	230ms [a]
Marami et al.[13]	94.08% [a]	N/A	N/A
S. Anila et al.[14]	95.33% [a]	4.5% [a]	N/A
Proposed system	95.33%, 99.80%[a]	0.85%, 0.79%[a]	120ms [a]

a. Detection rate and speed under 0° rotation only

The test results of the proposed algorithm are shown in Fig. 7.

Fig. 7 Detection results for faces of various sizes and at various angles.

IV. Conclusion

In this paper, face rotation changes were singled out as the main performance degradation factor, and rotated face detection architecture was proposed to overcome the problems of existing algorithms as well as to utilize it for various application areas. To achieve this goal, the parallelization technique for a face detection window, an efficient memory management method for image rotation, and an algorithm were developed in addition to the existing MCT transformation and AdaBoost learning algorithm. As a result, a high-performance, real-time face detection engine that can detect rotated images within a range of ±102° for high definition input images regardless of illumination and face size changes was developed. Furthermore, the engine's performance met the performance goal in various surrounding environments and face databases.

The accurate acquisition of face position through the high-performance face detection engine developed in this study can contribute not only to face recognition technology, but also to improving technologies in various areas such as face expression recognition and user location recognition and biometrics.

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