AN ADAPTIVE ALGORITHM BASED AUTHENTICATION SYSTEM FOR REAL-TIME BIOMETRIC TIME-ATTENDANCE SYSTEM

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Abstract

Biometric features are physical and biological characteristics that are unique to a person and can be used to accomplish authentication based on the particular modality. The main purpose of implementation of an Adaptive auto-correction technique for biometric time-attendance system is to improve the matching rate of fingerprint verification under the condition when fingerprint patterns vary due to environmental parameter like temperature. An Adaptive auto-correction technique is proposed which auto-corrects the reference fingerprint template at the time of genuine user rejection. The proposed technique is implemented on commercially available biometric device which uses Innovatrics, a standard commercially available extractor and matcher. Evaluation is carried out on 250 fingerprint templates of 10-users captured at varying temperature from 25^0C to 0^0C. The experimental analysis will be carried out to improve the recognition rate.

Keywords*: Biometric, minutiae, Innovatrics, template, Adaptive, auto-correction, matching score*

1. Introduction

Automatic identification of individuals based on their physical and/or behavioral characteristics is termed as Biometrics. Advancement in the technology has led biometrics to replace the conventional access control and time attendance systems [10]. These biometric traits are very unique features of humans that remain stable throughout the life span under normal conditions [1]. Indeed, it's observed that this unique fingerprint pattern differs as a result of environmental variations like temperature, humidity, dust and also due to ageing of the person [11].

Biometric devices play vital role in identification of genuine user/subject. It is necessary for the devices to be robust to avoid fraudulent. Principle behind fingerprint based biometric system is comparison of live fingerprint image with the stored reference fingerprint image to find the matching [1]. Any variations in the captured fingerprint image will affect the quality leading to poor matching with the stored reference fingerprint image which in turn fails to recognize the same person's identity [4][10] [12], leading to the false rejection of the genuine user/subject. [3].

Commercially available biometric devices exhibit varied performance due to seasonal variations with the variation of environmental parameters like temperature. These variations lead to poor fingerprint matching which in turn fails to match same user fingerprint with the reference fingerprint template stored in the database. This calls for re-registration of fingerprint many times to match with the reference fingerprint due

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to temperature variation. As the temperature decreases, the failure rate increases due to variation in fingerprint pattern which are quite sensitive to temperature. Some of the popular commercially available fingerprint-based extractor and matching algorithm are Suprema [21], Morpho [22], Innovatrics [23], Mega matcher [24], secugen [25] etc.

2. Related Work

Jacqueline A. Speir [5] proposed a frequency filtering algorithm to enhance the fingerprint image quality. To quantify the impact of proposed algorithm, two database of same fingerprint images were created, one with high quality fingerprint image and other with noise or low quality. The proposed algorithm was applied on the low quality images and compared with the high quality image. The results indicated a reasonable increase in quality and pairwise similarity.

Ajay Boyat and Brijendra Kumar Joshi [13] proposed a novel method for de-noising the fingerprint images. The proposed method combines wavelet transform with neighborhood processing for removal of noise. The proposed method is intended to remove Gaussian, Speckle and Salt &Pepper noise. Experimental analysis was carried out and evaluation of PSNR was done which was improved remarkably.

Ayushi Gupta Ȧ and Yugshakti Kaushik [2] discussed about various noise removal techniques for de-noising the fingerprint image. The comparative study gives an idea of which noise removal technique is best suitable for removal of Gaussian noise and Salt & Pepper noise. The experimental analysis is carried out by comparing parameters such as mean, variance and entropy of an image before and after de-noising.

Jie *et al* [7] proposed a novel approach to deal with False Rejection Rate (FRR). The minutiae feature and orientation field highlight are separated and then intertwined to get a pivot of perpetual quality. Later the entropy pattern is measured by examining the closeness of fragmented fingerprints. Validation is done by comparing the prominent fingerprint image database with the created database which consists of more deficient fingerprint images. The results proved that proposed method is more efficient by reducing FRR.

Consolidated approach about the strategies implemented for improving the recognition by authors- W. Ser X. Jiang [6], K. Hakil et al [14], G. L. Marcialis et al [8], G. L. Marcialis et al [15], G. L. Marcialis et al [20] are discussed below, Size of the memory plays a vital role as we cannot store all collected intra-class variations of user biometric features in real time applications. Also, throughput reduces with the increase in number of templates in the gallery of a user. The common procedures so far adopted for updating the templates are as follows: (1) super template based, in which the input data is always fused to a common single template called "super template" embedding all the information together [16] [17], or (2) instance based, in which the input data is always added as a separate instance to the gallery set of the respective client [23]. Most of the self-update online methods have followed super template-based approach [16] [17], However, the offline based self-update [9] and template co-update methods [9] [18] have followed instance-based approach. For updating the templates for intra class variations in constraint environment, FIFO, LFU and clustering algorithms have been modified [19] for implementing template replacement strategy.

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3. Motivation

Increase in rejection rate of fingerprint belonging to the genuine user can be addressed by different methods like, Non-Automated, Automated and Adaptive methods.

i. Non-Automated Methods: In this method, whenever there is problem with the matching of user fingerprint, they usually go for multiple (re)enrolment sessions or store multiple templates of the same user in the database. It is time consuming as, many times the same user's fingerprint has to be registered and also it is a manual process.
ii. Automated Methods: In this method, however they adopt subjective and objective process to increase the recognition rate of a fingerprint image such as image enhancement and image restoration. Automated methods use existing mathematical models for improving the image quality to some extent. These methods are not real-time analysis based.
iii. Adaptive methods: In this method, template which is already collected during the time of enrolment phase is updated by a technique of supervised and semi-supervised learning methods. In adaptive method, techniques are used to update templates without re-enrolment. It is also called as Adaptive Reference auto-correction system.

In most of the commercial matching algorithm, filters have been used to remove the noises from the fingerprint image at the time of capturing [10]. It has been observed or understood that, the filters have been optimized to remove noises to the maximum extent. Further optimization of filters to remove the noises may degrade the quality of the fingerprint image by removing main features. Hence in this work, adaptive methods are considered for improving the performance against the degradation of fingerprint image due to environmental variation on real-time basis. Adaptive method involves template update method. During the operation, when fingerprint image exhibits intra-class variations, semi-supervised learning methods are used to update the user template.

4. Methodology

In the proposed Adaptive auto-correction method, initially during enrollment phase, fingerprint images of the user/subject are collected at room temperature and stored as reference fingerprint template in the database. When the user/subject place the finger for authentication, matching score is computed by comparing captured input fingerprint template with the reference fingerprint template stored in the database. If matching score obtained is greater than Threshold value set then, the user/subject is authenticated else rejected.

If the matching score obtained is greater than Threshold value, store the fingerprint template in the cache database. The recognized fingerprint templates are stored in the defined cache in FIFO (first in first out) order for future analysis. This is because, even though the matching score is above Threshold value, due to environmental variations (temperature variations) the minutiae features of the captured input fingerprint image might be deviated from the reference fingerprint image collected during enrollment phase. This deviation leads to varied matching score.

In case of rejection of authentication, the captured input fingerprint image is

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varied beyond certain range due to presence of noise. In such case, corrections need to be applied. While applying correction, first the input rejected fingerprint image of the user/subject must be checked to know whether the rejected input fingerprint image belongs to the same user/subject or to an intruder. In order to find whether the rejected input fingerprint image belongs to the same user/subject, ANN algorithm is used. ANN algorithm classifies the input rejected fingerprint as genuine user/subject or intruder. If the rejected input fingerprint image is of intruder's then, corrections should not be applied on the user's/subject's reference fingerprint template stored in cache database. If the rejected input fingerprint image belongs to the genuine user/subject then, analysis of the fingerprint templates stored in the cache database is performed. Flow chart for the proposed Adaptive Reference auto-correction algorithm is depicted in Figure 1.

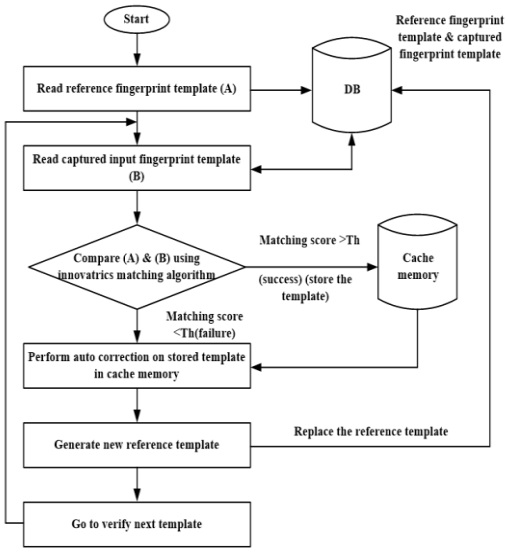

Figure 1: Flow chart of the proposed Adaptive Reference auto-correction algorithm

Fingerprint images of the user are captured using 500DPI optical sensor which is STQC certified to obtain good quality fingerprint image. The captured fingerprint image is used with Innovatrics extractor to extract minutiae template. Then the verification of fingerprint templates is performed using Innovatrics matching algorithm to obtain matching scores. Based on the matching scores, the matching is decided as success or failure. When the user fingerprint is failed to match with the genuine user, the reference template of the genuine user is auto-corrected by Adaptive Reference auto-correction algorithm.

Steps involved in the implementation process are as discussed,

1. Fingerprint images captured at room temperature are given as input for Innovatrics extractor to obtain ISO 1974-2 compatible minutiae templates. These templates are stored in flash memory under the respective user ID as file name.

2. The captured input fingerprint images from 25^0C to 0^0C of 10-users are given as input to Innovatrics extractor to obtain equivalent ISO 1974-2 compatible minutiae templates and they are stored in Flash memory as files with user ID and file names affixed with temperature.

Ex: User1 fingerprint templates are stored as, User1.25, User1.24, and User1.23 and so on.

The API call used to extract the template from a bmp file is,

IEngineExportUserTemplate Function Exports user template

IDKIT API intIEngineExportUserTemplate(IENGINE USER user, IENGINE TEMPLATE FORMAT format, unsigned char * templateData, int * length);

3. The captured input fingerprint template of 10-users from 25^0C to 0^0C are compared using Innovatrics matching algorithm with the respective reference fingerprint template stored in the file to

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obtain matching score. The threshold (Th) used for obtaining the status of matching, success or failure is Th=8000.

4. If matching score is greater than the Threshold value (Th), the result is success (means user Fingerprint is verified). In such case, the ISO template of the captured input Fingerprint image is stored in the cache file. This process is repeated on all ISO template of captured input fingerprint images from 25^0C to 0^0C.

5. If the matching score is less than the Threshold value (Th), the result is failure (means user Fingerprint is not verified) indicating the ISO template of captured input fingerprint image has failed to match with the reference fingerprint template. At this stage, Adaptive Reference auto-correction algorithm is automatically invoked to correct the reference ISO fingerprint template & replace.

6. The Adaptive Reference auto-correction algorithm uses the principle of averaging all non-matched or deviated minutiae points of ISO templates stored in the cache file. The ISO templates stored in cache memory are the templates which are succeeded but, with the mix of matched and non-matched minutiae points. Since these templates have succeeded in matching with the reference templates, the number of matching points is more than the number of non-match points satisfying the minimum Threshold of Th=8000.

5. Results and Discussions

The proposed Adaptive Reference auto-correction algorithm is implemented on ARM-9 based microcontroller using commercially available Innovatrics extractor and matching algorithm. The processor used is i.MX28 32-bit ARM (ARM926EJ-S CPU) with the speed of 454 MHz Innovatrics algorithm uses ISO 1974-2 minutiae template format to maintain interoperability. In our proposed work we are considering only the genuine user rejection for invoking auto-correction algorithm.

10-users/subjects fingerprint data are considered for validation of the proposed technique. Fingerprints of the users are captured and stored in the database at varied temperature between 25^0C to 0^0C. First, ISO 1974-2 compatible minutiae templates are extracted from the fingerprint image captured at room temperature and stored in the respective files as reference fingerprint template. Now, expose the user finger for a minimum of 3 minutes in a closed chamber of controlled temperature and capture the fingerprint images by varying temperature from 25^0C to 0^0C. Total of 26-fingerprint images are captured for every user/subject with a temperature variation of 1^0C.The verification process is performed for all 10-users/subjects using the captured fingerprint images from 25^0C to 0^0C considering one-user at a time. The experiment is conducted using without and with Adaptive Reference auto-correction technique. The results are tabulated in Table 1 and the captured fingerprint images at varied temperature is shown in figure 2.

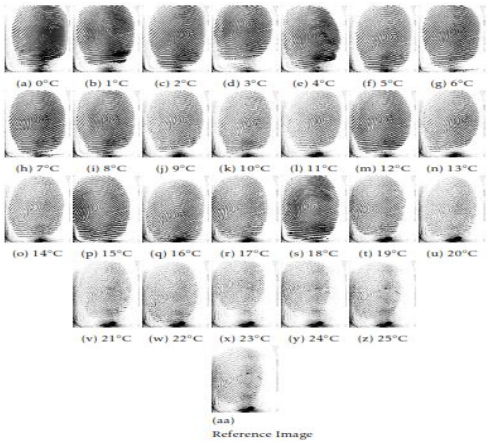

Figure 2: Captured fingerprint images of Subject 1

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Table 1: Subject 1 matching score without and with Auto correction algorithm on microcontroller board

User1/subject1						
Temp. in ^{0}C	Matching score	Conclusion		Temp. in ^{0}C	Matching score	Conclusion
25	16000	Recognized		25	16000	Recognized
24	14000	Recognized		24	14000	Recognized
23	15000	Recognized		23	15000	Recognized
22	12000	Recognized		22	12000	Recognized
21	13567	Recognized		21	13567	Recognized
20	14557	Recognized		20	14557	Recognized
19	15034	Recognized		19	15034	Recognized
18	12960	Recognized		18	12960	Recognized
17	13250	Recognized		17	13250	Recognized
16	13757	Recognized		16	13757	Recognized
15	12865	Recognized		15	12865	Recognized
14	13365	Recognized		14	13365	Recognized
13	12623	Recognized		13	12623	Recognized
12	12122	Recognized		12	12122	Recognized
11	12427	Recognized		11	12427	Recognized
10	11622	Recognized		10	11622	Recognized
9	11356	Recognized		9	11356	Recognized
8	11534	Recognized		8	11534	Recognized
7	10897	Recognized		7	10897	Recognized
6	10211	Recognized		6	10211	Recognized
5	10345	Recognized		5	10345	Recognized
4	9678	Recognized		4	9678	Recognized
3	8798	Recognized		3	8798	Recognized
2	8102	Recognized		2	8102	Recognized
1	0	Not Recognized		1	14000	Recognized
0	0	Not Recognized		0	13120	Recognized

(a) without auto-correction technique (b) with auto-correction technique

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From Table1 (a), the matching score obtained for user1/subject1 shows that, the fingerprint image has satisfied to be recognized until the temperature of 1^0C. This fingerprint image is quite stable against the variation of temperature. Even though the matching scores are decreased due to the decrease in temperature, it satisfies the minimum matching score requirement of 8000, hence they are declared as recognized. But below 1^0C the matching score is less than 8000, hence they are declared as not recognized.

Success rate: 92.3%; Failure rate: 7.7%

From Table1(b), the matching scores obtained after applying Adaptive Reference auto-correction technique shows that, even for temperature below 1^0C the matching scores have improved above 8000 hence, declared recognized. At 1^0C, the matching points have been increased to 14000, due to the correction applied for the reference fingerprint template.

Success rate: 100%; Failure rate: 0%

Similarly, analysis is carried out for rest of the users. As all the values cannot be shown in detail due to spacing, a consolidated matching scores of all the 10-suers/subject is tabulated in the Table 2 and Table 3.

Table 2: Matching scores of 10-users/subjects without Adaptive auto-correction

Temp. in ^{0}C	Matching scores									
	Sub1	Sub2	Sub3	Sub4	Sub5	Sub6	Sub7	Sub8	Sub9	Sub10
25	16000	14238	12569	12988	13252	14591	12010	15201	13210	12991
24	14000	14650	12345	12712	14234	13891	11672	14751	12978	12702
23	15000	13678	12785	13105	14521	14230	11102	14201	12652	12201
22	12000	13567	12432	12867	13987	14981	11754	15104	13103	12834
21	13567	13722	11987	12610	13671	14421	10109	14892	12867	11994
20	14557	13210	12112	12823	14012	13891	9201	15452	12451	11682
19	15034	12567	11723	12590	13891	14190	8348	14691	11102	12105
18	12960	12311	11465	12301	13201	13691	8521	14301	12934	11702
17	13250	11785	12023	12452	13634	13201	8104	13792	12387	11104
16	13757	11201	11678	11569	13802	12607	0	14288	12692	10823
15	12865	10862	11124	12341	13103	12981	8092	13432	11931	11451
14	13365	10621	10987	12478	12956	12510	0	12845	11731	10921
13	12623	9942	10673	11201	13450	13612	0	13102	12045	10201
12	12122	10102	10110	11834	12780	12782	0	12642	11209	9720
11	12427	9231	10451	11390	12431	12102	0	12904	11701	9540
10	11622	8329	10213	10856	12941	11823	0	12329	10810	9210
9	11356	0	9981	10201	13450	12002	0	12744	11405	8976
8	11534	8002	9946	9451	12301	11750	0	11893	10720	8502
7	10897	0	1021	8512	11972	11421	0	12241	10392	8105
6	10211	0	9834	0	12671	11103	0	11723	10930	0
5	10345	0	9578	0	12010	10519	0	11610	9292	0
4	9678	0	8967	0	11792	11610	0	11892	8701	0
3	8798	0	8356	0	11421	11109	0	10562	0	0

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2	8102	0	8120	0	10013	10102	0	10329	0	0
1	0	0	0	0	92018	97120	0	10620	0	0
0	0	0	0	0	9329	9210	0	9782	0	0

score on success but, zero matching score on failure.

Figure 2 and Figure 3 shows the plot for matching scores tabulated in Table 2 & Table 3.

Table 3: Matching scores of 10-users/subjects with Adaptive auto-correction

Temp. in ^{0}C	Matching scores								
	Sub1	Sub2	Sub3	Sub4	Sub5	Sub6	Sub7	Sub8	Sub
25	16000	14238	12569	12988	13252	14591	12010	15201	132
24	14000	14650	12345	12712	14234	13891	11672	14751	129
23	15000	13678	12785	13105	14521	14230	11102	14201	126
22	12000	13567	12432	12867	13987	14981	11754	15104	131
21	13567	13722	11987	12610	13671	14421	10109	14892	128
20	14557	13210	12112	12823	14012	13891	9201	15452	124
19	15034	12567	11723	12590	13891	14190	8348	14691	111
18	12960	12311	11465	12301	13201	13691	8521	14301	129
17	13250	11785	12023	12452	13634	13201	8104	13792	12387
16	13757	11201	11678	11569	13802	12607	11892	14288	12692
15	12865	10862	11124	12341	13103	12981	11341	13432	11931
14	13365	10621	10987	12478	12956	12510	11572	12845	11731
13	12623	9942	10673	11201	13450	13612	10902	13102	12045
12	12122	10102	10110	11834	12780	12782	10793	12642	11209
11	12427	9231	10451	11390	12431	12102	10201	12904	117
10	11622	8329	10213	10856	12941	11823	10411	12329	108
9	11356	13500	9981	10201	13450	12002	9612	12744	114
8	11534	12753	9946	9451	12301	11750	9810	11893	107
7	10897	13021	1021	8512	11972	11421	8651	12241	103
6	10211	12236	9834	11023	12671	11103	8211	11723	109
5	10345	11301	9578	11452	12010	10519	0	11610	929
4	9678	9086	8967	10367	11792	11610	0	11892	870
3	8798	8992	8356	9782	11421	11109	0	10562	125
2	8102	8102	8120	8210	10013	10102	0	10329	114
1	14000	0	11245	0	92018	97120	0	10620	118
0	13120	0	10564	0	9329	9210	0	9782	110

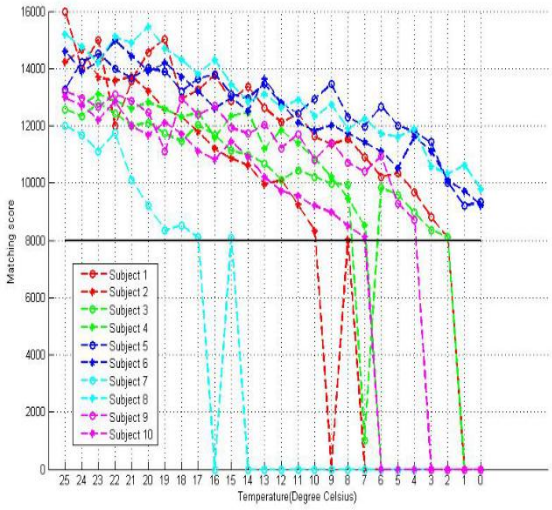

Figure 2: Graph of matching scores versus temperature of 10-users/subjects without Adaptive auto- correction technique.

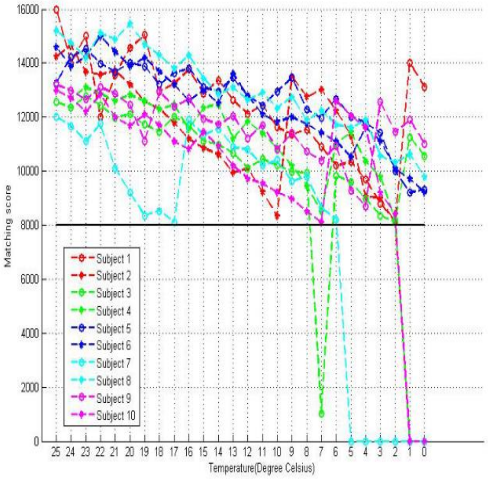

Figure 3: Graph of matching scores versus temperature of 10-users/subjects with Adaptive auto-correction technique.

From the Tables 1, 2 and 3 it can be observed that, whenever the matching is success matching scores are recorded but, whenever the matching is failed there are no matching scores recorded. This is because, the commercial Innovatrics algorithm provides matching

The results obtained for all 10-users without Adaptive auto-correction and

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with auto-correction technique indicate that, there is a significant improvement in the matching score and success rate after applying Adaptive auto-correction technique. Summary of the results are tabulated in Table 4.

Table 4: Summary of success and failure rate

Total No. of users	Without Adaptive Reference auto-correction				With Adaptive Reference auto-correction			
10	No. of success	In percentage	No. of failure	In percentage	No. of success	In percentage	No. of failure	In percentage
	3	30 %	7	70 %	6	60 %	4	40 %

Table 4 indicates the performance of 10-users on an average. Without Adaptive Reference auto-correction technique, 3-users or 30% of user fingerprint images are matched or success for temperature range 25^0C to 0^0C. But, 7-users or 70% of user fingerprint images are failed to recognize at different temperature levels as the temperature varies. Hence, there is 30% success and 70% failure on an average for 10-users put together when algorithm is executed on microcontroller board with ISO 1974-2 Innovatrics extractor and matcher.

With Adaptive Reference auto-correction technique, result shows 6-users or 60% of user fingerprints matched, but only 4-users or 40% of user fingerprints as failed to match for temperature range from 25^0C to 0^0C. There is 60% success and 40% failure on an average for all 10-users after applying Adaptive Reference auto-correction technique with Innovatrics commercial algorithm and ISO 1974-2 templates. Thus, there is an improvement of 30% in the success rate for the temperature range 25^0C to 0^0C on an average.

Analysis is carried out for the temperature variation based on the seasons and regions. Based on the regions, temperature variations may be few degrees like 20^0C, 18^0C, 15^0C, 12^0C, 10^0C, 8^0C, 6^0C etc. Considering the regional variations in temperature, the results are analyzed for various temperature ranges to show the performance. The results are analyzed for various temperature ranges like 25^0C to 20^0C, 25^0C to 15^0C, 25^0C to 10^0C etc. as show in the Table 5.

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Table 5: Success rates and Failure rates analysis without and with Adaptive auto-correction technique.

Temp. in ^{0}C	Without Adaptive auto-correction				With Adaptive auto-correction			
	No. of Success	In percentage	No. of Failure	In percentage	No. of Success	In percentage	No. of Failure	In percentage
25 to 0	10	100	0	0	10	100	0	0
25 to 5	10	100	0	0	10	100	0	0
25 to 0	9	90	1	10	10	100	0	0
25 to 5	6	60	4	40	9	90	1	10
25 to 0	3	30	7	70	6	60	4	40

From Table 5 it can be noticed that, there is a significant improvement in the success rate and 100% matching up to 10^0C and almost 90% success up to 5^0C, after applying Adaptive Reference auto-correction technique. So, in the regions where the temperature variation from 25^0C to 5^0C affected the recognition rate, there is significant improvement in recognition rate.

The graph of Success rates and Failure rates, without Adaptive Reference auto-correction and with Adaptive Reference auto-correction are shown in Figure 4.

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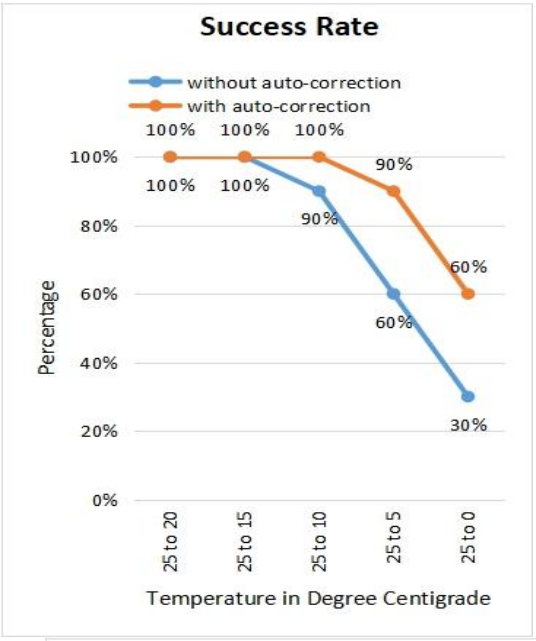

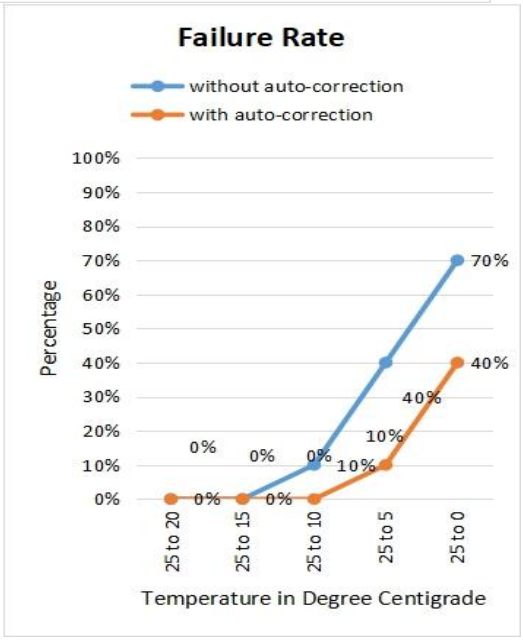

Figure 4: Graph of Success rates and Failure rates with and without Adaptive auto-correction technique between 25^0C to 5^0C.

6. Conclusion

The proposed Adaptive auto-correction technique which mainly focused on biometric time-attendance system was implemented on commercially available biometric device to verify the credibility of the technique. The results and performance analysis for the temperature variation based on the seasons and regions were carried out. It is noticed that, there is a significant improvement in the success rate and almost 100% matching for temperature variation from 25^0C to 10^0C and 90% matching for temperature variation from 25^0C to 5^0C. Even, in the case when temperature falls below 5^0C, there is a significant improvement in the success rate up to 60%.

From the graphs it is observed that, the proposed adaptive auto-correction technique is quite consistent and achieves an improvement in the recognition rate of biometric systems against the variation of temperature.

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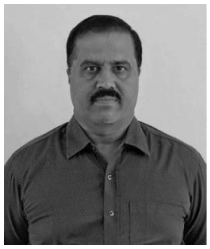

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