Liveliness Detection using Thermograph Patterns in Face Recognition

Betty Paulraj[1*] and Avani R Vasant[2]

Assistant Professor, Drs Kiran & Pallavi Patel Global University, Vadodara, Gujarat[1]

Professor, Drs Kiran & Pallavi Patel Global University, Vadodara, Gujarat [2]

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Abstract --Face recognition has proved its effectiveness in authentication with its highest accuracy rate and performance. An improved method for face recognition was devised in association with the thermograph to eliminate the risk of malpractices. The experimental evaluations were tested for its performance and the results are discussed. This method can easily distinguish the livelihood and non-livelihood like photography, mannequin, dead body etc.

Index Terms—Liveliness, thermograph, quality analysis.

I. Introduction

Face recognition system is getting more significance since the development and growth of the digital imaging in last two decades. It became the easy way of providing privileged access since most of the handheld devices like mobile phone, tablet, laptop etc. have preinstalled digital cameras. Therefore, no additional hardware is required for the face recognition in manycases. Though it is simple and easy, more chances of malfunctioning and lot of security threatswere also witnessed. There are many cases which causes the malfunctioning like emotional changes on face, hair style, beard and mustache etc. On the other hand, it is equivalently vulnerable in some cases where a photograph or a mannequin or even a dead body can be usedto fool the system. Most of the failure modes has been addressed from the fundamental research work happened in the area of image analysis methodology. At the same time, liveliness detection is the most primary step in face recognition based biometric systems sincethe authorization is directly dependent upon the genuineness of the sample. This motivated theresearchers to work more on liveliness detection methods for face biometric as the face recognition technology is growing rapidly. Ongoing research on liveliness detection can be broadly classified as image analysis based and ensuring the sample with additional sensing systems. ____

Dr. Betty P is Assistant Professor in Computer Science & Engineering at Drs Kiran & Pallavi Patel Global University, Vadodara, Gujarat, (e-mail: berylbetty@gmail.com).

Dr. Avani R Vasant is Professor & Head in Computer Science & Engineering at Drs Kiran & Pallavi Patel Global University, Vadodara, Gujarat, (e-mail: avani.vasant@gmail.com).

Many research work had been reported on the image analysis principle. Only very few researches are made with add-on sensing systems to detect the liveliness of the sample. This particular research work is about improving the liveliness detection using a non-contact and non-intrusive type of add on sensing system. It is found that the proposed system has significantly produced better results in comparison to the image analysis methods.

II. Literature Survey

Liveliness detection usually required in the verification stage. Liveliness detection steps has to be taken to authorize the genuine persons after the face detection done on the input image from a digital camera. The liveliness detection can be of either intrusive or non-intrusive type. As it was mentioned earlier, the intrusive method requires end user's cooperation. For example, methodologies based upon the movements of the user as per the required respective instructions, based on the movement of lip, sequence of number is asked to spell out by the user and the movement of lip is being recorded etc. On the other hand, the non-intrusive methods does not require end user's cooperation. .

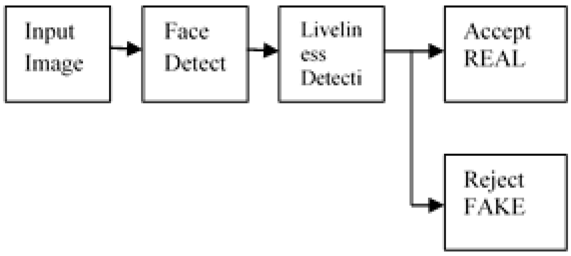

Fig. 1. General Concept of Liveliness Detection

For example, various facial skin properties such as eye blinking, skin texture analysis, skin elasticity and thermography is used to detect life signs from the face of user. It is always better to have non-intrusive method of liveliness detection. Also, few approaches are based on the framework which uses the combination of both intrusive and non-intrusive biometric traits

Figure 1 shows the general concept of liveliness detection. Several attempts were reported on non-intrusive liveliness detection approaches but still there can be cases it fails. The systems which may fail if there is a chance of presenting a dead body. Some systems may not produce correct results due to the non-availability of all the classification and evaluation principles between a genuine person and an imposter. Other few available methods suggested in the literature reported an incorrect perception if the input presented in any form of a 2D or 3D photograph. Hence, the available systems fails to produce a correct decision in the unconstrained environment. Therefore, it is necessary to address such kind of issues.

A. Studies Related to Hardware Based Solutions

A number of hardware and software solutions have been proposed to implement biometric template protection. The commercial product in the market like privaris PlusID implements a closed recognition system design. In such case, the template cannot be linked or inverted since they are hardly prone or never leave the physically secured module. The whole system with the sensor included is encased in most of the commercially available hardware based products. During enrolment, the device generates a template from the biometric sample provided by the user and stores it inside the device. And during authentication, if the query provided by the user matches with the stored template, the device wirelessly instructs the authentication is successful and the needed access is been provided. One of the major limitations of the hardware based solution is that they are expensive and inconvenient mainly because of a user has to carry them always and are prone to be lost. Moreover, such systems cannot be used if the enterprise using them intends to match the biometric data collected from its users against the large database maintained by the government. Various approaches implemented in the face liveness detection system is broadly classified as two segments. They are Intrusive and Non-intrusive. Some actions such as smiling, chewing, rotating head in a particular direction etc. is required in the intrusive approach whereas no user response is required in the non-intrusive approaches.

B. Intrusive type liveliness detection approaches:

User response is mandatory in the intrusive liveness detection approaches. Various kinds of intrusive approaches are presented in literatures are explained below: [1] Frischholez et al(2003) have illustrated an approach where the user response is recorded in terms of moving or rotating his head in accordance to the instructions generated randomly by the system. The comparative analysis by the based on the user movements according to the instructions were recorded and analysed. This is accomplished by using pose estimation algorithm. This methodology seems to be robust enough to handle the spoof attacks with pictures and video replays. However, the major disadvantage of this method is its time utilization and the inconvenience throughout the process. An approach proposed by [2] Kollreider et al. (2007) was again based on user response. It is associated with the movements of lip. In this approach, the lip movement of the user is recorded and recognized sequentially while he complete a random sequence of digits from 0 to 9. Support vector machine is used as the classifier of lip movements. Comparing to the previous study, this method occupy less computation time since no specific pre-processing is required. The major disadvantage of this method is the absence of audio recording provision. Hence, the system may be prone have video or sequence of picture frame attacks.[3,4] Chetty et al. (2010) proposed another approach for liveliness detection based on cross modal fusion. Combination of audio and the video synchronization were taken into account in this method. The measure of synchronization between the lip and voice were extracted from the video. This method prevents the spoofing attacks like video replay and pictures. This method overcomes the demerits of the previous methods few other methodologies of intrusive liveliness detection is achieved by the multilevel verification by combining the relationship between the face biometric features and voice features. In addition, this method used the voice and face biometric traits and their relationships.

[5] C Kant et al. (2013) proposed a methodology which integrates the basic user characteristics along with the thermal imaging. This method also requires user intervention. The elasticity of the facial image is obtained by applying the correlation coefficient and linear discrimination to the input. [13] Liu et al.(2019) proposed CNN-LSTM Network with the Fusion of SkeGEI and DA Features in the face liveliness detection scenario. A provision of thermal image capturing set up was also done. This approach was effective against both 2D photo attacks and video

replays.[14] Arashloo et al,(2019) , [15] Fatemifar, has presented their thoughts on Unseen Face Presentation Attack Detection Using Class-Specific Sparse One-Class Multiple Kernel Fusion Regression. The major disadvantages of these methodologies were the continuous user activities along with the usage of special hardware which is expensive and not always possible in reality. The computation of the elasticity of the face may also varies due to the age factor.

C.Non-Intrusive Type Liveliness Detection Approaches:

The user response is not required in the non-intrusive approach. The facial properties are in turn used as a measuring parameter for the liveliness detection. The features like elasticity of skin, blinking of eye can be the predominantly used parameter in this category. The analysis of the texture properties of the skin and thermographic pattern is also reported in few literatures. [6] Choudhury et al. (1999) presented a method by computing the structural information of the face in motion. Though this method sounds complementary, the major drawback is that the computation of in-depth facial features are challenging. This method is sensitive to noise. [7] Lagorio et al. (2013) proposed an approach based on the three dimensional face structure and its associated properties of live face. To implement the mentioned methodology, a 3D scanner was used. Due to the usage of 3D optoelectronic sensor which is very expensive, the cost of the system increased considerably. [8] Bao et al. (2009) put forward another methodology of liveness detection was based on the difference generated optical flow fields. It was found that there was a difference in the optical flow fields of a 2D planar objects and 3D objects. Few findings were also reported by[9] L Sun et al. (2007) based on the movement of eye and eye blinking.[10] Li et al. (2004) explained the method focused on fourier spectra. It was found that the frequency component of live face is relatively more than a fake image.[11] Kim et al. (2012) illustrated the method based on texture analysis. In this methodology the Local BinaryPattern were used to analyse the texture pattern. The micro texture analysis of face input werereported by [12] maatta et al. (2011) based on analyzing the micro texture patterns in the live or fake facial image. [16] Pan, S.; Deravi et al,(2019) portray their work on the Spatio- Temporal Texture Features for Presentation Attack Detection in Biometric Systems. [17] Tang, D. et al found that Secure Liveness Detection Protocol Based on Light Reflections can be arrived. [18] M. Alghaili et al, (2020) proposed methodologies with deep learning and filter algorithm.

III. Proposed Method

The proposed system is a non-intrusive system of liveliness detection. Liveliness detection of face biometrics is done using the combination of CMOS and thermography. As mentioned earlier, there is a chances of failures in existing systems when presenting a photograph or a mannequin or a dead body. Therefore, it has been decided to design a robust liveliness detection system to eliminate the above fraudulent methods. It is found that the live human body exhibits different temperature across the body. Therefore, body temperature and the temperature gradient can play a vital role in the determination of the liveliness of an individual. For example, the temperature on the nose and forehead is always on the higher side when compared to the other places on the face of the human. Capturing the temperature gradient is called as thermography and it is also non-intrusive. The temperature gradient across the face of the livelihood can be taken as a reference to conclude the liveliness. .

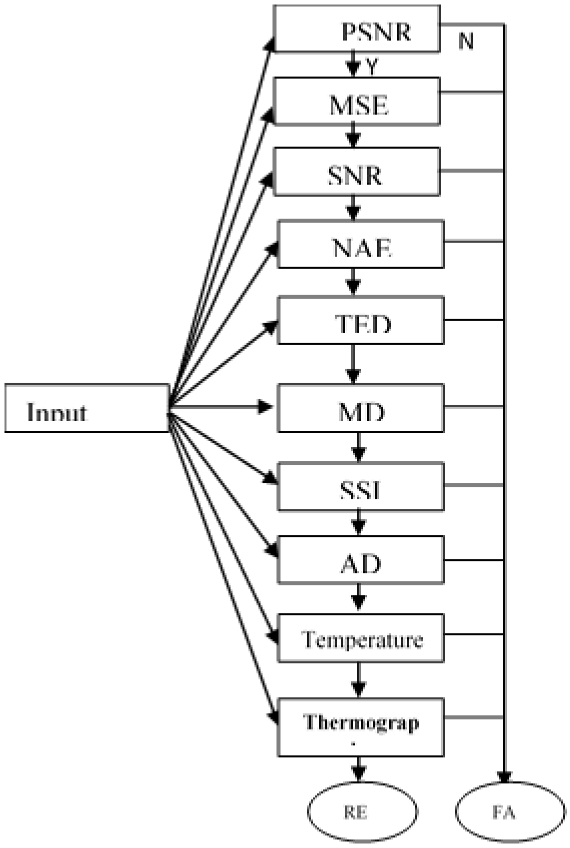

Fig. 2. Proposed Liveliness Detection along with Existing Systems

In this proposed liveliness detection method, thermography image is also taken along with photography The temperature gradient calculation can be made to analyze the livelihood in addition to the conventional image analysis methods of face recognition. Proposed liveliness detection using temperature gradient (thermography imaging technique) with all available liveliness detection is illustrated in Figure 2. Hence, it is expected that this proposed method will be relatively robust which can easily differentiate whether it is genuine or a photograph or a mannequin or a dead. This may eliminate the deficiencies of the previous studies. Hence, it requires a CMOS cum thermography camera to capture the photography and thermography images simultaneously.

The proposed method will have a hardware having both CMOS camera and thermography camera. CMOS camera will capture the photography of the face. At the same time, the thermography camera will capture the thermography of the face. Thermography will illustrate both the temperature and its gradient across the face. The photography image will be compared with the specimen image and subsequently the conventional image analysis will be made to ensure the face detection. At the same time, the thermography image will be analyzed for the temperature and the temperature gradient across the image. Face detection will be approved once both the photography and thermography are qualified. Therefore, the proposed system is expected to be robust and it will eliminate all disadvantages of the conventional system. The Figure 5 shows the flowchart of the proposed experiment where the CMOS sensor and a thermography sensor has been used as the inputs for the proposed liveliness detection system. Both these inputs will be taken at one particular time simultaneously. Images from CMOS and thermography are given in Figure 6.6 for the understanding. Later, the inputs will be processed as per the algorithm given in the flowchart. For example, a genuine person's image will have a particular contrast, brightness and other image quality assessment parameters. At the same time, a genuine person will have a human body temperatures which ranges from 95 to 105 degree Fahrenheit even the person is suffering from fever. Also, the temperature of the human body need to meet certain criteria, the genuine human face should have temperature gradient at different parts of the face. In any of the cases, if the input does not meet out the requirement, the conclusion can be made like the reported input is not genuine.

IV. Experimental Setup

As per the methodology, the samples were collected. Each sample includes both photography and thermography images. The experim ent was conducted on the sample size of 100 numbers. Examples of each case which includes genuine, photography, mannequin and a dead are shown in the Figure 3 to 6 respectively. This will give an idea of how non-living things looks in thermography images. As the comparison of live and dead is nearly impossible, the dead was studied only for the verification stages i.e. it was not compared with the registration image.

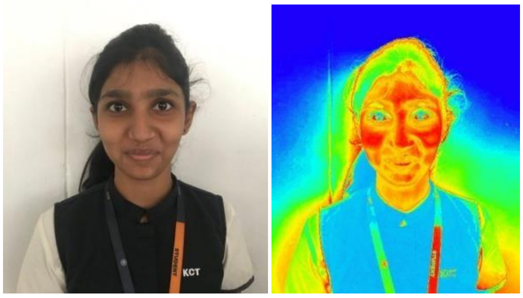

Fig. 3. CMOS and Thermography Images of a Live Human

Fig. 4. CMOS and Thermography Images Taken From a Photograph

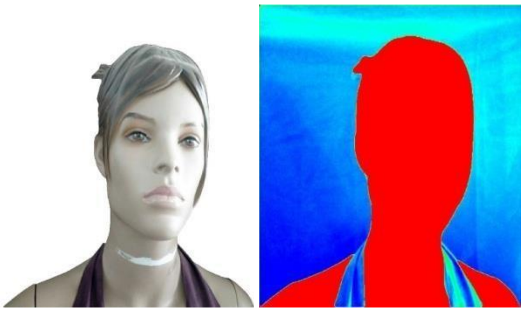

Fig. 5. CMOS and Thermography Images of a Mannequin

Fig. 6. CMOS and Thermography Images of a Dead

All these photography images were went to regular image analysis tests to qualify the liveliness. At the same time the clearance were obtained from the corresponding thermography image to endorse the liveliness. The liveliness will not qualify in case of any of photography or thermography image got failed to prove the conditions stated in respective algorithms. The importance of the thermography image can be easily understood with these images.

For the proof of concept, the experimentation is carried out with 75 real persons. Altogether, the data set makes 75 samples. Each sample includes six sub samples in variant positions. Experimental evaluation were also carried out in six variant disguised positions to validate the effectiveness of the proposed system in the non-constrained environment. Followed by the photographs of the real samples were also presented as input to the system in variant positions. Twenty mannequins pictured in variant environmental conditions were also presented as the third case and finally a few sample of non-living objects other than mannequins were also presented for the proof of validation of the proposed methodology.

V. Results Evaluation

The results of the proposed system was compared with the Image Quality Assessment (IQA) system. In the case of live inputs, both the IQA and proposed system performed equally well. Both the systems were able to distinguish the genuine or non-genuine. Results of the live inputs are folowing. The Figure 8 to 11presents the validation of the proposed system with the 75 real samples. The proposed system effect to result with an accuracy of 100 percentage. The existing method also prove to be equally robust in the case of real samples. The accuracy of validation is about 7% improved with the presented dataset in comparison with the existing methods as shown in Figure 12. The system aligned only with the image quality assessment were considered as the existing methodology throughout the experiment.

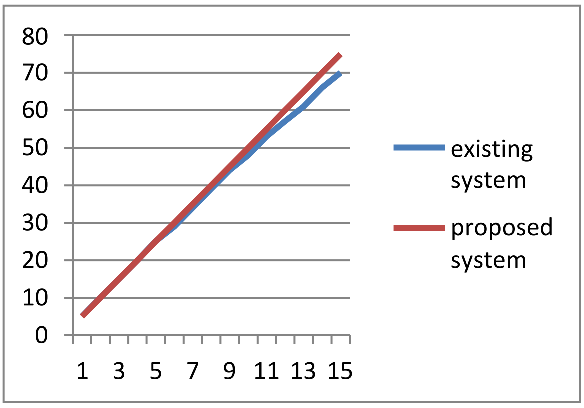

Fig. 7. Results of the Live Inputs on the Database Containing 75 Samples

When the photograph of the genuine is presented in front of both IQA and proposed system, almost two third of the cases were failed in IQA system. However, all were detected by proposed system. Therefore, it is proven that the proposed system will detect all fraudulent related to presenting the photograph of the genuine in verification stage. The Figure 9 contains the results of the photograph presented in both IQA and proposed system. An experiment is carried out with the photographs of the 75 genuine faces. The photographs inputs should be arrived at a decision fake or non-real. The importance of thermography plays the role in the decision. The existing system fail to produce the decision when high quality photograph were presented. The evaluation is depicted in the Figure 9. The proposed system validate the input with higher level of accuracy of about 97.3 %.

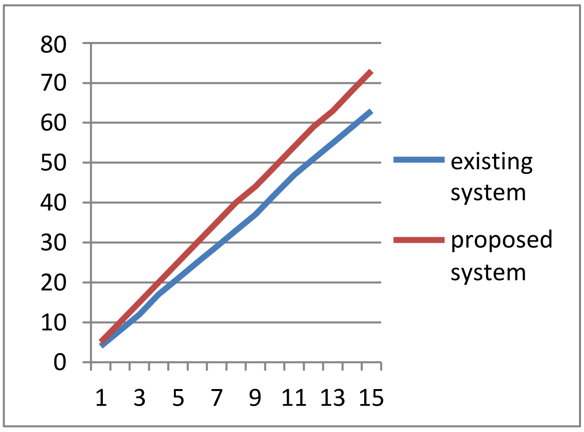

Fig. 8. Results of the Photograph Inputs on the Database Containing 75 Samples

Results of presenting a mannequin or a dummy in the verification stage was presented following. The results are similar to that of presenting a photograph of the genuine. The proposed system was able to detect all fraudulent attempts whereas the IQA could not. The IQA could able to detect only few instances. This has been proven when, the mannequins were presented to the system, and the decision has to be fake / non-real in this case. The results and accuracy of the existing and the proposed system were illustrated in the Figure 10

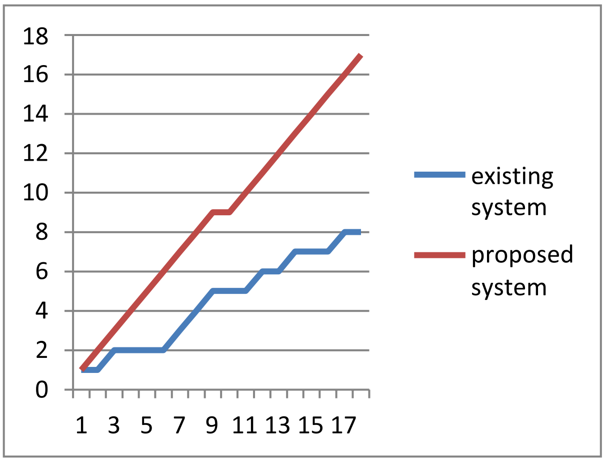

Fig. 9. Results of the Dummy Inputs-Mannequins on the Database Containing 20 Samples

the proposed thermography based system was very effective to identify the dead. Unfortunately, there is no verification stage for this case. The results of non-living samples other than mannequins presented as input to the system and it is illustrated in the Figure 11.

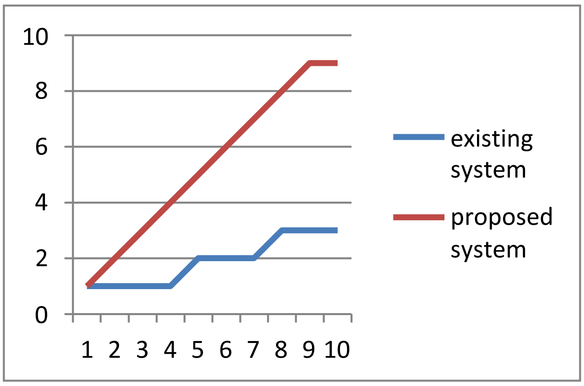

Fig. 10. Results of the Dummy Inputs-Non Living on the Database Containing 10 Samples

The study were presented by the disguised samples since we claim that our system works with better accuracy in the non-constrained environment. As presented in the above tables, the real inputs, photographs, mannequins and dead/non-living samples and their corresponding thermography equivalent were presented to the system. The liveliness detection using image quality assessment works well on the real samples but they seem to provide non-convincing level of accuracy as a whole when the inputs like photographs, mannequins and non-living samples were presented. Hence, the importance of thermography plays a majour role. The temperature is added up as an additional hardware ingredient as to improve the robustness of the system to the next extent. Again, the summary of the visual spectrum samples from database tested on different methodology are given below in Table 1. It clearly shows that the proposed system is capable of detecting the live genuine under variable environment.

Table. 1. Results of Visual Spectrum Sample on Different Techniques

Decision	Genuine	Fake	Fake	Fake	Fake
CMOS-IQA	True	False	True	False	True
IR-IQA	True	True	False	False	True
Only Temperature	True	True	False	False	False
Proposed Thermography	True	False	False	False	False

The image quality is assured in addition to the temperature and the thermograph patterns using the following measures the measures like PSNR which is used as a quality measure between the original and the compressed image. The quality of the reconstructed image or the compressed image is validated based on higher the value attained during the process. The PSNR is calculated using the Equation 1.

$$\text{PSNR}(\text{I}, \hat{\text{I}}) = 10\log\left(\frac{\max(\text{I}^2)}{\text{MSE}(\text{I}, \hat{\text{I}})}\right) \quad \text{-------} \quad (1)$$

This is another common metric MSE – Mean Squared Error which is used to find out the cumulative squared error to validate the quality of image after compression. The MSE is calculated using the Equation 2. The MSE is expected to be relatively low for the better outcomes.

$$MSE(I, \hat{I}) = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}(I_{i,j} - \hat{I}_{i,j})^2 \text{ ------ } (2)$$

The Normalized Absolute Error (NAE)should compute as a lower value for the best quality of the image. The NAE is calculated using the Equation 3.

$$NAE(I, \hat{I}) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M}|I_{i,j} - \hat{I}_{i,j}|}{\sum_{i=1}^{N}\sum_{j=1}^{M}|I_{i,j}|} \quad \text{--------} \quad (3)$$

Signal to Noise Ratio (SNR) is similar measure to PSNR used to calculate the quality of the image using the Equation 6.4.

$$SNR(I,\hat{I}) = 10\log\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{M}(I_{i,j})^2}{N.M.MSE(I,\hat{I})}\right) \quad \text{-------}\ (4)$$

Total Edge Difference(TED) is another metric of image quality assessment which is computed using the Equation 5.

$$TED(I,\hat{I}) = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}\left|I_{Ei,j} - \hat{I}_{Ei,j}\right| \quad \text{-----}\ (5)$$

Maximum Difference (MD) is calculated using the Equation 6. It is the maximum of the error signal between the reference sample and the test sample.

$$MD(I,\hat{I}) = Max|I_{i,j} - \hat{I}_{i,j}| \quad \text{-----------------------}\ (6)$$

Structural Similarity Index (SSI) is a measure of finding out the similarity between the reference sample and the test sample. The similarity is usually computed using the structural, luminous and the contrast information of the images. SSI is computed by the Equation 7.

$$SSI(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad \text{--------}\ (7)$$

Average Difference(AD) is the average of difference between the reference and the test image. The AD is calculated using the Equation 8.

$$AD(I,\hat{I}) = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}(I_{i,j} - \hat{I}_{i,j}) \quad \text{--------} \quad (8)$$

In the present proposed method, the thermographic image of the end user has been used to detect the liveliness which is of non-intrusive type. It is nothing but taking a thermographic image simultaneously when the photography of the end user is being taken and to evaluate the liveliness based on the thermography image.

VI. Conclusion

The proposed thermography based system has identified exactly the presented objects. Therefore, the proposed system is capable of detecting the livelihood and non- livelihood up to 99% accuracy. As the proposed system takes input from CMOS and the thermography sensor, it can identify and reject the non-livelihood inputs. It is found that this system meets the highest level of security when compared with the conventional techniques. Thermograph image technique can be implemented to any circumstances since it is one of the non-intrusive method of liveliness detection.

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