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Thermal Imaging in Face Recognition and Deception Detection

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Abstract- Face recognition is a wide area having many techniques to achieve the same. The aim of the paper is to introduce Thermal Imaging and to study how it can be used for facial recognition and also for deception detection. This paper looks into the single modal and multi modal face recognition techniques involving infrared (IR) imaging. It then moves to analyze facial variations to study deception using thermal imaging. It also uses a generalized approach to get familiar with how deception detection is performed. It finally seeks to establish a link where improvements in face recognition can lead to improvements in deception detection.

Index terms - Face Recognition; infrared; 3-D; deception detection.

1. INTRODUCTION

Face recognition is widely being used in today's world in terms of surveillance and identification. The general problem with face recognition are the constraints regarding variations in pose, facial expressions and illumination which deter successful identification of the face. One of the commonly used techniques, the Visual Face Recognition relies on the visible spectrum of light. It gives high recognition rates of above 90% under controlled environments [1], [2], [3], allowing for very slight variations in illumination, pose and facial expressions. The 3D face recognition model is much less restricting and is relatively invariant to lighting conditions, although not completely [4].

IR face recognition looks promising, as it is nearly invariant to illumination changes including total darkness and has the potential to identify individuals with time-delay, makeup or in simple disguise [5].

Due to this reason, IR thermal imaging is finding great use in deception detection. The thermal images obtained are a result of the radiation of heat by different objects. Visual deception detection techniques are becoming more and more outdated as different methods of fooling the system are being generated every day. The world is looking at other ways of countering this problem and its finding some answers in IR Imaging. This paper tries to study how Thermal imaging is making face detection simpler and more accurate and how it can be extended to help fight crime by using it in the Deception Detection Industry.

This paper characterizes recognition techniques into Single Modal and Multi Modal as addressed in Sections 2 and 3. Section 4 discusses Deception Detection using Thermal Imaging and presents a Procedural architecture commonly employed in the area. Discussion and conclusions drawn are cited in Section 5.

2. SINGLE MODAL INFRARED FACE RECOGNITION

2.1. *Infrared Face Recognition.*

Fig.1. A thermal image.

Fig.1 shows a sample thermal image. IR face recognition techniques canbe classified into 2 different types: statistical and feature-based approaches [6].

1) **Statistical Approaches**: The techniques generally serving as standard face recognition procedures for 2D data are Principal Component Analysis (PCA) [7], Linear Discriminant Analysis (LDA) [8] and Independent Component Analysis

(ICA) [9]. [7] PCA is a technique applied to each histogram of a thermal image, forming facial features which are then used for recognition. Left eye, Right eye and other features can be individually expressed [10] using PCA and expressions such as happiness or anger can also be expressed. The LDA technique can be used to recognize near-IR images [11].

2) **Feature Based Methods**: This method is based on employing the features pertaining to the cardiovascular system of the human body for face recognition. Blood flows within blood vessels and the blood vessels' pattern reveal the anatomical structure of the face. Each person has a unique structure because the anatomical structure of each person is unique [12]. A database can be built by including all the structures for different poses required for identification.

The thermal IR images are sensitive to skin temperature while near-IR images are not [13], [14]. The advantages of using IR Imaging is that external makeup or disguise doesn't affect an IR image. However, a few limitations to using IR imaging are that external temperatures can affect face temperatures and IR sensors are opaque to glass [15].

3. MULTI MODAL INFRARED FACE RECOGNITION

3.1. *Visual + IR Face Recognition*

This hybrid technique hasn't matured enough to occupy commercial usage in the present age. Independent research is being carried out by fellow researchers. This technique is showing performance improvements [16] in face recognition as compared to other techniques.J. Ahmed et al. [17] carried out a study where a Gabor filter was used for extracting facial features, thereby leading to a recognition rate of 97.4%. Bhowmik et al.[18] studied in what proportions the results must be weighed for optimum results and found that by taking 40% of the visual and 60% of the IR results, optimal recognition rate of around 93% was achieved. Additional research in this area led to data fusion and fusion schemes being implemented and studied. In another study, [19] features from both the visual as well as IR were captured and an Eigen space was introduced for features having low variations caused by expressions or makeup and recognition rates of 99.24% and 95.5% were achieved by using this combined technique of decision level fusion and data level fusion.

3.2. *Visual+IR+3D Face Recognition*

Experiments show that greater accuracy and recognition rates are got by using the hybrid of the 3 techniques and that noise or facial expressions seem to have lower effects during recognition by this method [20] [21].

Performance Evaluations: Varying parameters in imaging such as illumination, pose, makeup and aging are a few challenges which must be addressed in the practice of face recognition. IR imaging by itself doesn't have the required potential to fully deal with every issue. Multi modal techniques offer promising future in image recognition. Multi modal techniques aren't applicable to deception detection during this stage when the technique itself needs more maturity and understanding and also due to the lack of available devices to carry out deception detection using multi modal recognition techniques.

4. DECEPTION DETECTION: THERMAL ANALYSIS

Deception detection is a technique used to detect patterns or changes in the human body which suggests if a person is lying or telling the truth. The famous Polygraph test has been the leader in deception detection for many years now. The test measures changes in blood pressure, respiratory and cardiovascular activity [22], [23], [24]. It provides an accuracy of about 90% in controlled environments [25], but however it faces some challenges in the process such as:-

1) The recipient is made to take the test and is fully aware that he/she is being tested.

2) The process is dependent on human decisions.

3) Analysis takes a long time and usually requires expert skill.

Thermal imaging on the other hand measures changes in blood flow, pulse rate and breathing rate to name a few [26]. Thermal imaging captures the blood flow in the facial region. While controlling facial expressions can be trained into, controlling emotional variations is relatively much harder when trying to tell a lie. Instantaneous stress causes increased blood flow around the eyes and sustained stress causes increased blood flow in the forehead region [27]. Classifying observations into truth and lie is done by repetitive and iterative techniques like machine learning and dynamic programming

Research done in the deception detection field has contributions from various fields of study including behavioral phycology, physiology and machine intelligence. The most commonly used approaches attempt to view changes in the behavior and facial expressions caused by stress. The concealment of truth causes stress formation and other behaviors such as blushing [28]. A study [29] was performed to detect anxiety using thermal imaging. It was found from that study that all the subjects in the study had an increase in the blood flow around their

eyes under stress. The temperatures remained unchained in the nasal area and was completely independent of the movement of eyes or face.

4.1. *Conditions of work.*

Research has been done in controlled environments [30], [31] as well as uncontrolled environments [32]. Controlled environments consist of those environments wherein the participants are told to practice their lies before the interview so that their facial parameters' changes can be studied. These also include interviews wherein the participant is told to lie or tell the truth [15]. Uncontrolled environments are those where the participant decides to lie or tell the truth. A study [31] suggests that when participants are faced with questions they hadn't anticipated, the detection rate went to 80%, much higher than when they faced anticipated questions.

4.2. *Detecting Deception*

Studies carried out by Pavlidis et al [33] [34] were done in a manner wherein 2 groups were formed for the research, a deceptive group and a non-deceptive group and the results were noted. A subject was classified as deceptive if his thermal changes matched with the changes experienced by the deceptive group. The studies were able to achieve a classification rate of 84%.

Pollina et al [35] also conducted a study where the number of frames of pictures captured was increased to capture before and after pictures of subjects after the question had been asked.

To explore how thermal imaging detection is conducted in different studies, the structural architecture of the research is generalized and discussed below:

4.2.1. The interview

Separate examination sessions are conducted for analyzing the parameter changes in the facial region when the participant is telling the truth and when the participant is made to tell lies. Relatively comparing and individually studying these scenarios helps in gaining an insight into how the body reacts to different stimuli.

4.2.2. Methodology

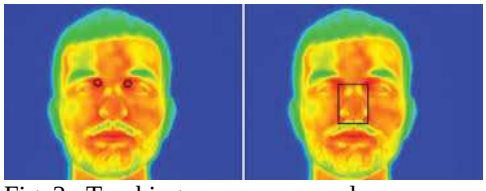

Fig. 2. Tracking eye corners and nose.

Thermal Pattern Extraction: Specific regions are tracked and the changes caused in blood flow around these regions is studied [25], [28], and [29]. Figure 2 shows the tracking of eye corners and the nose region of a thermal image. This region is also called the region of interest (ROI). In a study [15], the two eye corners formed the ROIs and the ROI's sizes were taken as 17x17 pixels each and a high number of frames were captured during the question and answer sessions. Both the ROIs were tracked and represented in subspaces and the average values were taken.

4.2.3. Approaches for Deception Detection

The different approaches for deception detection can be classified into 2 types [36], [15] - The Between Person Approach and The Within Person Approach.

1) **Between Person Approach**: This approach [15] uses all but one's truth/lie dataset among participants and compares it with the left out person's dataset, this is done at different instances and the process iterates itself across the whole group. This approach believes that everyone behaves the same way when answering into either category and hence the dataset can be generalized for the entire population. An average accuracy of 58-62% was achieved across 25 participants [15].

2) **Within Person Approach**: This approach [36] compares a person's behavior against the expected norms and looks for deviations. In a particular study [15], an n-fold cross validation model was used to help classify performances and by using five-fold cross validation, the average classification accuracy for subject 1 was 72.60% with a standard deviation of 6.48% and the performance across all persons averaged to 85.56%.

4.3. *Effect of Different Parameters*

1) **Choice of Eye-Corner Positions**: The selection process for eye-corners can be manual as well as automatic and there can be small variations in the start position of the tracker. The tracked image (ROI) must be stable enough to extract data from it. There can be significant variations in the classification accuracy on using different positions [15] and thus having similar initial eye corner positions will lead to better accuracy.

2) **Size of ROI**: The smaller the size of the ROI, the average temperature across it will have more variations [15]. This can be handled by employing a greater size for the ROI.

Instead of using pre-determined values for size and choice of position, averaging across observed values can lead to better accuracies.

5. DISCUSSION AND CONCLUSIONS

IR face recognition and deception detection is a growing area. IR face detection deals with the limitations of Visual Face Recognition and 3D Face Recognition. However, countering all the limitations when dealing with face recognition such as pose, expression, illumination, disguise, background clutter etc. is difficult by using any one type of recognition mechanism alone. Multi Modal Face Recognition seems to provide some hope but the area still requires extensive research. When IR imaging is used in deception detection, it encounters problems such as dealing with the baseline temperature, non-generalized behavior of the population towards questions and non-accurate tracking of all points affected by stress [15]

Thermal signatures can be extracted at a greater accuracy and number when using multi-modal imaging approach leading to formation of higher data points than a single modal IR imaging approach, which suggests that improvements in face recognition also directly affect the capability in dealing with deception detection as both seem to have similar limitations restricting their respective accuracy rates.

It has also been found that the Within-Individual approach gives a better accuracy rate than a Between-Person approach [15]. Maximum recognition rates for Visual + IR face recognition at present is 95.5% for data level fusion [19] and the maximum accuracy rate for deception detection using IR imaging at present is 91.7%[25].

The limitations of Visual Imaging are restricting the growth of various image processing fields and Thermal Imaging can take its place. Better accuracy results in the field of thermal imaging will lead to future scope in Surveillance, Military operations, Tomography and other notable fields. These fields find vital importance in the security of our country and will seek to improve it.

Nevertheless, this paper has brought out a link between how improvements in face recognition can also lead to improvements in deception detection and progressing forward in one field will take with it the progress being made in the other field too.

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