The Design and Development of a Lie Detection System using Facial Micro-Expressions

Michel Owayjan, Ahmad Kashour, Nancy Al Haddad, Mohamad Fadel, and Ghinwa Al Souki
Department of Computer and Communications Engineering
American University of Science & Technology (AUST)
Beirut, Lebanon
mowayjan@aust.edu.lb, {ahmad_s13, nancy.had}@hotmail.com, mohd.fadel@ymail.com, ghino2007_souki@hotmail.com

Abstract— **Detecting lies is crucial in many areas, such as airport security, police investigations, counter-terrorism, etc. One technique to detect lies is through the identification of facial micro-expressions, which are brief, involuntary expressions shown on the face of humans when they are trying to conceal or repress emotions. Manual measurement of micro-expressions is hard labor, time consuming, and inaccurate. This paper presents the Design and Development of a Lie Detection System using Facial Micro-Expressions. It is an automated vision system designed and implemented using LabVIEW. An Embedded Vision System (EVS) is used to capture the subject's interview. Then, a LabVIEW program converts the video into series of frames and processes the frames, each at a time, in four consecutive stages. The first two stages deal with color conversion and filtering. The third stage applies geometric-based dynamic templates on each frame to specify key features of the facial structure. The fourth stage extracts the needed measurements in order to detect facial micro-expressions to determine whether the subject is lying or not. Testing results show that this system can be used for interpreting eight facial expressions: happiness, sadness, joy, anger, fear, surprise, disgust, and contempt, and detecting facial micro-expressions. It extracts accurate output that can be employed in other fields of studies such as psychological assessment. The results indicate high precision that allows future development of applications that respond to spontaneous facial expressions in real time.**

Keywords— Lie Detection; Facial Micro-Expressions; LabVIEW; Image Processing; Vision System

I. INTRODUCTION

For as long as human beings have deceived one another, people have tried to develop techniques to detect deception and find the truth. Lie detection took on aspects of modern science with the development in the twentieth century of techniques intended for the psycho physiological detection of deception, most prominently, polygraph testing. The polygraph instrument measures several physiological processes and changes in those processes. On a polygraph test, examiners observe the charts of the above measures in response to questions, and then infer whether a person is lying or telling the truth [1]. Polygraph testing is used for three main purposes: event-specific investigations, employee screening, and reemployment screening. Each use involves the search for different kinds of information and has different implications [2].

Researchers are developing several techniques to detect lying individuals. British airport authorities are testing one system based on the Facial Action Coding System (FACS) [1]. The human face is a sign vehicle that sends messages using not only its basic structure and muscle tone, but also changes in the face conveying expressions, such as smiles, frowns, etc. The person's mood and intentions can be read from the facial expressions. Moreover, micro-expressions could be developed based on certain physiological responses that most of humans undergo when attempting to deceive another person. They are denoted as micro-expressions because they are present for fractions of a second besides being involuntarily expressions. In addition to lie detection these systems may also be used in detecting some diseases or in testing for alcohol where some changes in the face may occur. Another domain that may use these kinds of systems is psychiatry [3].

Facial micro-expressions were proven to be an important behavior source for hostile intent and danger demeanor detection [4]. The specific objective of this paper is to design and develop a lie detection system using facial micro-expressions recognition in real-time.

II. BACKGROUND

Many systems were developed to detect lying subjects in several domains, such as police investigations, airport and homeland security, clinical testing, and human resource departments in organizations and companies.

The polygraph, popularly referred to as a lie detector, measures and records several physiological indices such as blood pressure, pulse, respiration, and skin conductivity while the subject is asked and answers a series of questions. The belief is that deceptive answers will produce physiological responses that can be differentiated from those associated with non-deceptive answers. However, several countermeasures designed to pass polygraph tests have been described [5-6].

Recent advances in camera and computer technology have led to the development of a method that uses body heat to detect deception. Special thermal cameras capture subtle changes in temperature of the person's face, usually around the

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eyes, that are associated with physiological arousal. When these areas become warmer, they signal that the person has reacted to the picture, word, or question that was presented to him or her. These changes may also be triggered during deception. One of the main advantages of thermal imaging is that it is non-contact, so it does not entail the placing of sensors on the body as with the polygraph. This opens the potential for rapid screening applications, such as at airports. The main disadvantage of thermal imaging is that the cameras and associated instrumentation are very expensive. Also, the changes that occur during deception are very fast and very small, so algorithms are necessary to detect the patterns that appear during lying. These algorithms have not yet been validated [7].

On the other hand, US researchers at Temple University have found out that a medical scan that can pick up brain tumors can also be used to tell whether a person is lying or not. According to [8], when a person is telling the truth they use different parts of their brain than when people lie. These changes were detected by functional magnetic resonance imaging. The method may prove more accurate than traditional machines; however, it requires huge and expensive scanners [8].

Researchers at Drexel University and the University of Pennsylvania in Philadelphia, have developed a new lie detection method that relies on infrared waves beamed directly into the brain. Called the functional near-infrared sensor (FNIR), their headband monitors the amount of oxygen in the blood in various portions of the brain to determine when subjects are lying. The headband can also be used to detect and differentiate between guilt, anxiety, and fear. This new method significantly limits both false positives and false negatives by more accurately differentiating between intentional deception, guilt, and anxiety. The specifics of the hardware, detection method, and signal processing analysis are not currently publicly available [9].

Another approach is based on detecting micro-expressions which are facial expressions that are exhibited during a short time interval, usually few milliseconds. This method is non-contact since it is based on pictures of the face of the individual, captured by high-speed cameras. Humans convey voluntarily and involuntarily messages using their faces. There are eight basic facial expressions: anger, contempt, disgust, fear, happiness, joy, sadness, and surprise. They are encoded as combinations of Action Units (AU) of different muscles in the face according to the Facial Action Coding System (FACS) developed by Ekman and summarized in Table I [10-12].

Facial muscle movements can be classified as two types: the obvious and easy to observe by the eye, and the micro muscle movement that is volatile and hard to be seen. As its name implies, the micro movement occurs in 1/25 of a second. The movement of these muscles may be horizontal, vertical or even oblique. For example, the extremities of the lips may go closer to each other (when a person is not smiling) or go far apart (when a person is smiling) creating an expanded horizontal line the distance of which can be measured and varies according to how the subject is responding to a given question [10-12].

TABLE I. EMOTIONS AND THEIR EQUIVALENT FACS CODES

Emotion	**FACS Code**	
	Muscle description	***Associated AUs***
Anger	Nostrils raised, mouth compressed, furrowed brow, eyes wide open, head erect	4,5, 24, 38
Contempt	Lip protrusion, nose wrinkle, partial closure of eyelids, turn away eyes, upper lip raised	9,10, 22,41,61 or 62
Disgust	Lower lip turned down, upper lip raised, expiration, mouth open, blowing out protruding lips, lower lip, tongue protruded	10,16, 22,25or 26
Fear	Eyes open, mouth open, lips retracted, eye brows raised	1,2, 5, 20
Happiness	Eyes sparkle, skin under eyes wrinkled, mouth drawn back at corners	6,12
Joy	Zygomatic, orbicularis, upper lip raised, nasolabial fold formed	6,7, 12
Sadness	Corner mouth depressed, Inner corner eyebrows raised	1,15
Surprise	Eyebrows raised, mouth open, eyes open, lips protruded,	1,2, 5, 25 or 26

Polikovsky *et al*. proposed, in 2010, a computer vision method of measuring the facial micro-expression with a GUI interface, which is useful for acquiring efficient ground truth tagging of micro expressions from the recorded videos. For initial testing, they prepared a simple database containing paused micro-expressions of 10 participants. It is another approach that is based on direct tracking of 20 facial feature points (eye, mouth corner, eyebrow edges, etc.) by particular filters. The 3D gradient oriented histogram descriptor was chosen for facial motion detection due to its ability to capture the correlation between the frames. 3D gradient descriptors were proved to be an effective approach for classifying motions in video signals [13].

Pfister *et al*. showed, in 2011, how temporal interpolation model together with Multiple Kernel Learning (MKL) and Random Forest (RF) classifiers have enabled them to accurately recognize these very short expressions which are the facial micro-expressions. Inside their framework, they used temporal interpolation method (TIM) to counter short video lengths, spatiotemporal local texture descriptors to handle dynamic features and SVM, MKL, RF to perform classifications. They created an algorithm that shows their framework for recognizing spontaneous micro-expressions with high accuracy. To address the large variations in the spatial appearances of micro expressions, they cropped and normalized the face geometry according to the eye positions from a Haar eye detector and the feature points from an Active Shape Model (ASM) deformation. ASMs are statistical models of the shape of an object that are iteratively deformed to fit an example of the object [14].

Fasel *et al*. developed, in 2006, an automatic detector which enables fully automated Facial Action Coding System (FACS).

The face detector employs boosting techniques in a generative framework; it is an extension on the work done by Viola & Jones in 2001. The system works in real time at 30 frames per second on a fast PC [15].

Impaired facial expressions of emotions have been described as characteristic symptoms of schizophrenia. Differences regarding individual facial muscle changes associated with specific emotions in posed and evoked expressions remain unclear [16]. Christian G. Kohler et al examined, in 2008, static facial expressions of emotions for evidence of flattened and inappropriate affect in persons with stable schizophrenia [16].

In 2001, Tian *et al*. divided the face in two areas and used two artificial neural networks to classify AUs in real time. The recognition of AUs averaged of 93.3% and their system achieved automatic face detection while handling head motion [17]. While in 2002, Pardas and Bonafonte used Hidden Markov Models to achieve 98% recognition with joy, surprise, and anger [18]. In 2003, Michel and Kaliouby used Support Vector Machine to build a real-time system that does not require any preprocessing [19]. A year later, Buciu and Pitas published their research in facial expression recognition using nearest neighbor classifiers [20]. Later on, Pantic and Patras achieved a 90% average recognition using temporal rules on 27 AUs and invariant to occlusions such as glasses and facial hair [21-22]. In 2006, Zheng *et al*. selected 34 facial landmark points that were converted into a Labeled Graph (LG) using Gabor wavelet transform. Then a semantic expression vector built for each training face. Kernel Canonical Correlation Analysis (KCCA) was used to learn the correlation between the LG vector and the semantic vector [23]. In 2007, Sebe *et al.* evaluated different machine learning algorithms to recognize spontaneous expressions where subjects are showing their natural facial expressions [24]. And in the same year, Kotsia and Pitas attained very high recognition rates with six basic expressions and then worked with occlusions [25-26]. More research was also conducted in facial micro-expressions, among which [27-29].

III. MATERIALS AND METHODS

The proposed lie detection system using facial micro-expressions is composed of a hardware part and a software part. A high speed camera is used to capture the face which is then divided to specific regions. For testing this approach, a new dataset of facial micro-expressions, is created and manually tagged as a ground truth.

A. Materials

The hardware components used in the system consist of a high speed camera with its accessories, a laptop to see the results, and an NI Embedded Vision System (EVS) (National Instruments, TX, USA). Figure 1 depicts the hardware setup of the lie detection system developed in this study.

As for the software, the detection algorithm was programmed with NI LabVIEW™ (National Instruments, TX, USA) and the IMAQ vision system that is integrated with the LabVIEW™.

Figure 1. The lie detection system using facial micro-expressions hardware.

The high speed camera is the most important component in the system. In order to detect a facial micro expression, which takes 1/25 of a second, a minimum of ten frames per second needs to be captured and analyzed. The camera used in the study captures 25 frames per second. In the settings of Figure 1, the camera lens needs to have a focal length between 50 mm and 180 mm in order to get the best quality. The lens employed has a focal length of 90 mm offering the desired sharpness. The camera and the lens were mounted on a tripod facing the subject's face at a distance of two meters. In order to minimize reflections and shadows, a light gray background is used ensuring the capture of pre-filtered video.

High speed computing is needed by the lie detection system because the camera is capturing a video with a high number of frames per second to be able to detect micro-expressions. The EVS is a high-performance, multi-core processor running a real-time LabVIEW™ Operating System dedicated to process the frames captured by the camera at extremely high speeds. It is a dedicated computer system that can be programmed with LabVIEW™ and can run independently in industrial environments. The laptop connected to the EVS in the developed lie detection system is used only as an output screen to show the results of the processing made by the EVS.

B. Methods

The hardware setup is the first stage in the method used to detect facial micro-expressions and therefore, infer that the interviewed individual is lying or telling the truth. Figure 2 summarizes the steps of the lie detection system using facial micro-expressions.

In preparing the subject for interview, his/her face should always be facing the camera in order to detect all possible muscle changes. The rotation of the individual's head may lead to a miss prediction. That is why; prior to shooting, these restrictions should be applied.

After capturing the interview, the EVS, containing the LabVIEW™ program, starts processing the captured video. First the video is converted into a sequence of frames for analysis. Second, geometric-based dynamic templates on specific parts of the face (such as the eyes, the mouth, the cheeks, etc.) are used for marking key features of the expression.

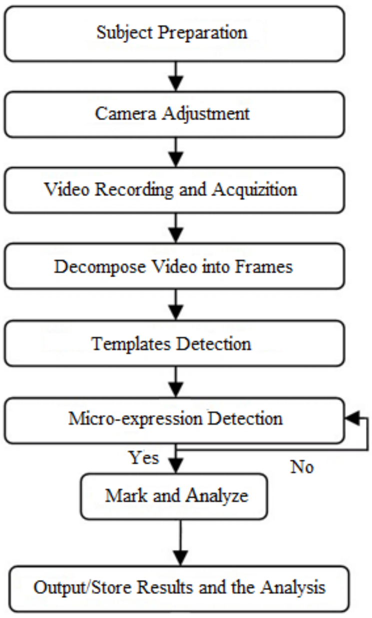

Figure 2. The steps used in the method of the lie detection system.

The program starts by reading one frame at a time and simultaneously processing the extracted frame by two parallel loops. The first loop plays back the video on the computer screen. While the second loop inputs the frame into a vision assistant block that saves the frame as image into an already specified path, and then, processes the saved image according to predefined templates. The templates are predefined using the NI IMAQ Vision Assistant and represent the following areas on the face: the left and right edges of both eyebrows, the left and right edges of the eyes, the left and right edges of the mouth, and the cheeks. When templates are detected, the program measures nine different distances between center points of the templates, such as the horizontal length of the mouth. Then these different distances are individually saved into separate arrays. Figure 3 shows the templates detected on the face of a subject, and Figure 4 shows the corresponding distances of lines detected on the face. The total arrays referring to all sets of points are compared according to preprogrammed rules derived from the emotion's muscle descriptions equivalents in Table I.

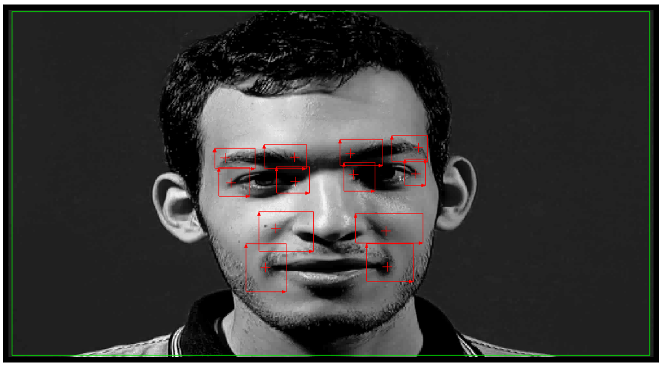

Figure 3. Templates detection on the face of a subject.

Figure 4. Distances shown on the face of a subject.

Every basic expression is interpreted from the AUs in Table I as a combination of changes in the distances stored in the arrays between different frames. The system takes the first element of each array and checks the variation of the distance between the points; each basic expression has specific point measurements and distances combination. For example, during a smile, the mouth's horizontal distance increases and the eyes close a bit. The system then indicates that the expression is joy. The system runs the logic shown in Figure 5 to determine and store the code of the expression detected in another array. The expression codes are shown in Table II.

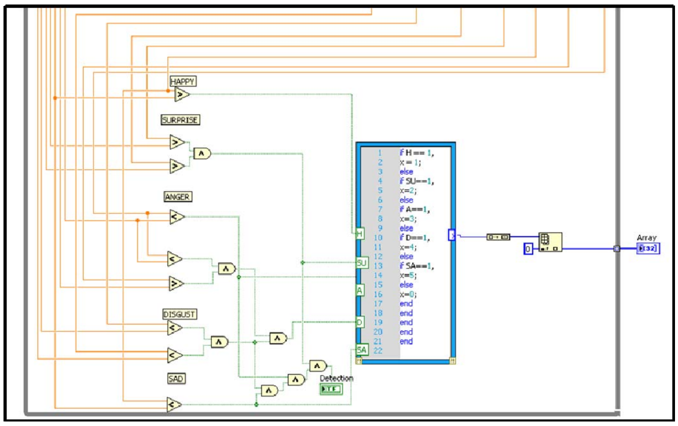

Figure 5. Distances shown on the face of a subject.

TABLE II. EXPRESSION CODES

Expression Code	Expression
0	Not Used
1	Happiness/Joy
2	Surprise
3	Anger
4	Disgust/Contempt
5	Sadness

The program then, iterates over the expression codes in the array and notes the time taken by each expression. If the same expression is repeated less than five times consecutively, it is marked as a micro-expression and a indicator LED is turned on to indicate the presence of a micro-expression. Accordingly, the program can distinguish whether the subject is lying or saying the truth.

IV. Testing and Results

The system was tested on four subjects. The team developed a questionnaire containing seven control questions and eight relevant questions based on [30]. The questions asked during the interview are:

1. *Is your name Sandy Hill? (Control question)*
2. *Are you 43 years old? (Control question)*
3. *Is your cat's name Josie? (Control question)*
4. *Were you born in 1956? (Control question)*
5. *Do you rent a house? (Control question)*
6. *Do you live on Vine Street in Iowa? (Control question)*
7. *Is today (day of week)? (Control question)*
8. *Have you stolen more than four hundred dollars in cash or property from an employer? (Relevant question)*
9. *Based on your personal bias, have you ever committed a negative act against anyone? (Relevant question)*
10. *During a domestic dispute, have you physically harmed a significant other? (Relevant question)*
11. *Prior to your application, did you ever lie to someone in a position of authority? (Relevant question)*
12. *Before this year, did you ever put false information on an official document? (Relevant question)*
13. *Prior to this year, did you ever betray someone who trusted your word? (Relevant question)*
14. *Before this year, did you ever take credit for something you didn't do? (Relevant question)*
15. *Prior to this year, did you ever deceive a family member? (Relevant question)*

Each subject was prepared for the test and then asked the 15 questions while the system is running and showing the results on the GUI front panel. The system, when detecting an certain expression, stores this expression and analyzes it; when it detects a micro-expression on the face of the subject, a green light flashes, indicating the presence of the micro-expression resulting from the subject's attempt to hide the real answer and lie.

Figures 6 and 7 are screenshots taken from the tests showing a lying subject and a truthful one respectively. The results show that expressions and micro-expressions are correctly detected on the face of the four different subjects.

Using the derived template models for classification, the expression recognition accuracy is 85% on a database of five expressions. More work is being done on expanding the database to cover other expressions as well as to increase the accuracy of the system.

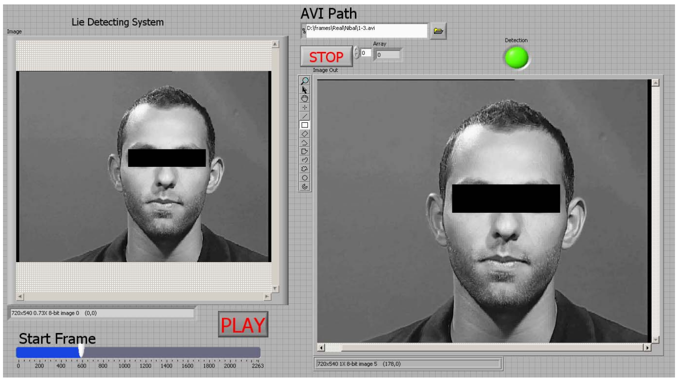

Figure 6. A subject lying (Green LED is ON).

Figure 7. A subject telling the truth (Green LED is OFF).

V. Conclusions and Future Work

The team has derived a mathematical algorithm and implemented a computer vision system capable of detailed analysis of facial expressions within an active and dynamic framework. The purpose of this system is to analyze real facial motion in order to derive the spatial and temporal patterns exhibited by the human face while attempting to lie. The system analyzes facial expressions by observing significant articulations of the subject's face over a sequence of frames extracted from a video. By observing the parameters over a wide range of frames, a parametric representation of the face which could be useful for static analysis of facial expression in other fields of studies was extracted. This motion is then coupled to a physical model by which geometric-based dynamic templates are applied on the facial structure.

Human emotion on the basis of facial micro-expressions is an important topic of research in psychology. It is believed that the developed system can be useful in many areas where psychological interpretation is needed such as in police interrogations, airport and homeland security, employment, and clinical tests.

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