Head movement analysis in lie detection

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***Abstract*—This document presents a study regarding the potential of head movement in lie detection. The potential was analyzed using a non-invasive technique that detects the head movement out of video. In the literature there is a lot of information regarding lie indicators and for this reason we made a short review of them. Application was built in order to detect the head movement and head position by performing a frame-to-frame analysis on a color video stream. Tests were performed on a group of ten volunteers and the results confirmed the theory. A correlation was made between head movement/ position and lie detection. Although the results confirmed the theory they are not concluding because this information cannot be used without other additional information from the other information channels like voice, words, gaze and so on. User must correlate the responses of the suspects with the response of the application in order to decide what the verdict is.**

Keywords— lie; detection; position; face; detection; head; movement;

I. INTRODUCTION

In verbal and non-verbal communication there will be a lot of situations when we are going to tell a lie or we are going to be lied. Robert Feldman [1] discovered in his studies that 60% of the persons that took part at his studies lied at least once in the first 10 minutes of the interaction.

When the stake is high or when the people are put under pressure or when their integrity depends on their answers, the lies will be more present. For these reasons lie detectors were introduced in the police interrogatories. The results offered by the lie detectors were admitted as evidence in trials because of the scientific principles that stand behind lie detections. Scientists and psychologists discovered that some physical parameters modify when people lie. These parameters include blood pressure, pulse or temperature. As the detection methods evolved, the criminals protection methods also evolved and they were able to control these parameters. Not to mention the fact that there can exist erroneous reading because the suspects can become nervous just by knowing that they are monitored.

The new studies in psychology made by DePaulo, Ekman, Vrij and others confirmed the fact that there are also other modifications that take place in the exterior and that can be monitored.

In this paper we summarized a few lies indicators that were discovered in their studies and based on which we started our work. Parameters like pupil dilation, head movement, blinking rate, gaze direction, temperature and voice pitch are controlled by the subconscious mind and that's why they are harder to control and manipulate.

We know that there are two types of communication: verbal and non-verbal. We must also analyze what is said and also which are the gestures, facial expressions and other body reactions. Also, we concentrate on the nonverbal communication and we propose a noninvasive lie detection technique in order to eliminate the erroneous readings of the invasive technique.

We analyzed the information channel regarding the head movement/direction and its potential in lie detection. The algorithm for detecting head movement and head direction was implemented and initial tests from video input were performed with 10 volunteers. Preliminary results show that this information channel holds potential in helping with lie detection.

The next part of this paper is structured as follows: chapter two presents a brief literature review of lie indicators as it were discovered by the scientists, chapter three presents the algorithm of detecting head movement and head direction, preliminary results are presented in chapter four and finally the conclusions can be found in chapter five.

II. LIE INDICATORS

There are a lot of studies in this field but we will present only those that are relevant for our project. As Paul Ekman said "There is no element that can be considered a universal lie indicator. There are no gestures, no facial expressions or muscular tensions that individually, independent of the context, to show that a person is lying" [2].

Another authority in the domain of lie detection, Bella DePaulo, shares the same opinion when she says that the verbal and behavioral indicators have a "problematic associations, they are correlating with the lies but not perfectly"[3].

A cue to lie detection is an increase in the blinking rate. The normal blinking rate is of 20 times / minute, but it can increase by four or five times when a person is under stress. This rate also intensifies when the mental activity increases. When people tell lies their mental activity intensifies because they are looking for answers to a problem. Vrij proved that there are also times when liars have a normal blinking rate [4].

One of the most relevant studies in this domain was made by DePaulo [5] which tried to found out if people behave differently when they are lying over the situation in which they are telling the truth. There were 1338 participants at this study and were identified 158 indicators. In the following list we enumerate the lie indicators that are of interest for this project:

- **Visual contact:** the speaker looks into the other persons eyes with a fix gaze;
- **Gaze dodge:** the speaker dodges his gaze from the interlocutor;
- **Gaze changing:** into the direction of the interlocutor gaze's direction;
- **Voice amplitude:** the intensity, amplitude or the strength of the voice modifies;
- **Voice frequency:** the voice pitch is higher than the fundamental frequency of the voice;
- **Pupil dilation:** the pupil dilates;
- **Blinking rate:** increases;
- **Blinking delay:** from the moment the question is asked and until an answer is provided the blinking is more delayed than when the persons are telling the truth;
- **Change of temperature at the face level:** the skin gets red if the temperature increases or it gets white is the temperature decreases.

In Sorjoo's book [8] we find out a few more details about the gaze direction and its relationship with lies. The cues are:

- When a suspect remembers something he will look up and to the left;
- When a suspect is making a story in his mind he will look up and to the right;
- If a suspects looks straight to the left, that means that he remembers something that was said;
- If the suspect looks straight to the right then it means that he is inventing some sounds in his mind, for example a conversation.

Another cue to lie detection is when a suspect presents an affirmative situation, but it shakes its head in a disapproval manner and the other way around [5].

These are all the cues that are of interest in this project and on which we centered our research and development work. For this paper and application we choose a holistic approach because we are only monitoring head movement.

III. Algorithm Implementation

In the literature there are various methods presented for detecting the face, facial signs or head movement, by using computer vision [9], [10], [11]. Using a holistic approach, most of this methods can be applied to the hole head or face and there are others that can be applied only to specific regions of interests (ROI) like eyes or mouth. Despite the fact that the holistic approach offers a complete picture, there are cases when facial features are located in specific regions. In this case a local approach will offer more detailed and distinguishable information.

We developed our Windows Forms application (Figure 1) using Visual Studio 2013, a .NET technology and C# as programming language. As reference library we used EMGU CV [12]. Emgu CV is a cross platform .NET wrapper to the OpenCV image processing library. It allows OpenCV functions to be called from .NET compatible languages such as C# or VB. The wrapper can be compiled by Visual Studio, Unity and others and it can run on Windows, Linux, iOS or Android.

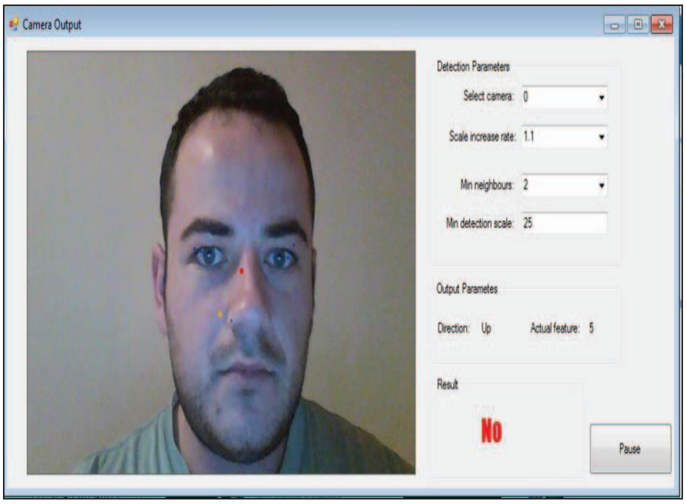

Fig. 1 Windows Form application running

Our algorithm detects and estimates head movements from a color video with a predefined resolution and frame rate. For a better understanding please follow the next pseudo code:

```
Begin
    Variables initializations
Function SelectCamera()
    If capture is not created
        {Create capture; /*start capturing video frames from camera in order to be processed*/
        Call function InitializeFaceTracking(); /*call the function that analyses the frame one by one and send the frame as parameter*/} Else {throw error}
    End if
End function SelectCamera()
Function InitializeFaceTracking()
    Declare new Harr object;
    Convert the frame to a gray frame;
    Detect face by calling .DetectHaarCascade; /*method from the library*/
    If face is detected then
        {Enlarge and restrict the search features;
        Allocate proper working images;
```

```
                Detecting good features that will be tracked
                in following frames;
                Features computed on a different
                coordinate system are shifted to their
                original location;
                Computing convex hull by calling the
                method .ConvexHull;
                referenceCentroid is FindCentroid(hull);
/*The reference centroid will be computed by FindCentroid
function that takes as parameter the computed convex hull
*/}
Else {throw error}
        End if
    End function InitializeFaceTracking()

    /*Below are the function used for computing
parameters*/
    Function FindCentroid()
        Add the first point at the end of the array
        Find the centroid
        Divide by 6 times the polygon's area
                If the values are negative{ the polygon is
        oriented counterclockwise so reverse the signs} Else
                {leave it the same}
    End Function FindCentroid()

    Function Application_Idle()
        If next frame is Not Null and face is detected then
                {ComputeSparseOpticalFlow()
                ComputeMotionFromSparseOpticalFlow()
                Display result
                Updating actual frames and features with
        the new ones} Else{throw error}
        End if
    End Function Application_Idle()

    Function ComputeSparseOpticalFlow()
        Compute optical flow using pyramidal Lukas Kanade
Method
        Draw tracked features
    End function ComputeSparseOpticalFlow()

    Function ComputeMotionFromSparseOpticalFlow()
        Perform mathematical operations
    End funct. ComputeMotionFromSparseOpticalFlow()
    END
```

After capturing the first frame we need to transform it to a grayscale image and then perform face detection. This is done by calling a function trough Emgu, called ".detectHarrCascade", which applies the Viola-Jones algorithm [6]. After the face detection, a local region of interest (ROI) has to be selected with absence or very low local movements in order to measure optimally the head motion. We assumed that the region between the mouth and eyes is the most appropriate region since there is no movement here. This step is done by calling the ".ConvexHull" function. After this step we try to find a centroid by using the convex hull previously computed and we apply the algorithm developed by Flavio Bernardotti [13] which actually consists of mathematical operations. Next step after finding the centroid is the choice of specific reference points, reference points that are located at the four edges of the ROI. A tracker based on Flavio's optical flow algorithm is applied for tracking their position. In the next frame another centroid is computed and the trajectories are computed and analyzed in order to produce the output. Trajectories are scalar computed in horizontal and vertical and also vectorially trough the deviation magnitude. The difference between these two centroids is compared to a threshold and the result is displayed. The method is not very complicated and the results obtained are quite good. There are some problems regarding the reference points that can be lost if foreign object gets into the frame and this leads to erroneous or false readings and problems in detections. In Figure 2 we have a capture from the output of the program where the centroid of the first frame is marked with red and is used as a reference, the centroid of the analyzed frame is marked with orange and is used to compute the actual position of the head. The blue points are the points that are used as references for computing the centroids.

Fig. 2 Display of the two centroids and the detection points.

IV. Results

The above algorithm, as we mentioned earlier on this paper, had been tested in a preliminary manner. With the help of a camera we recorded ten interviews with the collaboration of ten volunteers. On this interviews we've ran our algorithm and tested it's potential. Half of the subjects were asked to lie about a specific task that they had to execute and the others were asked to tell the truth. This interviews were conducted and the results were classified in a system similar to the method presented in the Janet's paper [14]. All of them had to look inside a box where there were some money. The subjects that had to lie had to take the money and put it into his pockets and the others subjects which were telling the truth must leave the money into the box. After the tasks were executed we asked the suspect 10 questions:

1) I know that you have looked into the box. What did you see?
2) How much money was in the box?
3) What did you do with the money?
4) Are you sure that you didn't take the money from the box?
5) Do you have any pockets?
6) When did you use your pockets for the last time?
7) Did you put the money into your pockets?
8) Please describe the content of your pockets.
9) Are you telling the truth about the money location?
10) Have you lied in this interview?

Regarding the head movement we took into consideration the theoretical concepts that tell us how the suspect should act in order to have coordination between what he is saying and how he is moving his head. If he confirms the affirmation, he must move his head in an affirmative way and the other way around.

During the test we discovered that there are various patterns for moving the head during lying and telling the truth. The algorithm should learn these patterns in order to provide reliable data to detect the truth and the lies. The results are presented in Table 1.

TABLE I. RESULT CLASSIFICATION

Interview type	*Deception accuracy(DA)*	*Truth accuracy(TA)*	*Accuracy classification(AC)*
Deceptive	58%(DD)	10%(TD)	34%
Truthful	75%	90%(TT)	82.5%
Total	66.5%	50%	58.25%

Half of the interviews were truthful, containing ten honest answers. The others interviews were deceitful and it contained at least seven deceitful answers and a maximum of three truthful answers. In real life it's possible that a person who lies to tell the truth in some situations. The TT answers were always honest and the classification for DD answers was always deception. We discovered during the tests that a lot of differences between the head movements of those that we've interviewed. Question number five will always generate truthful answers because all the volunteers have pockets. We can notice the fact that at this question all the volunteers have a similar head position, with low or no movement or an affirmative node of the head, this being said we can say that the control question criteria was accomplished. For all the other answers the reactions are different so we cannot follow a certain pattern. For the majority of the volunteers that had to lie we've been able to identify stress and anxiety which lead to a lot of intense and chaotic movements on all the directions. The volunteers that told the truth were very relaxed, and they had a central position of the head with low or no movement.

The results are promising, but they cannot be treated separately from the context. These results will have value only if we use them with the other sources of information to give the final verdict.

V. CONCLUSIONS

This paper presents a preliminary study on specific head movements and direction in order to estimate if a person is lying or telling the truth. This study also conducts a literature review in order to report the most relevant cues to deception and the corresponding methodologies that can be used for the estimation and measurement of such indicators. Following this review, a method for evaluation of the head movement and direction was implemented.

Some potential indicators of lies and truth have been obtained. However, given the limited number of subjects, an extensive test on an larger dataset has to be made in order to validate the results for the algorithm and to draw solid conclusion after comparison with other published methods. This extensive test might also suggest additional calibration of the algorithm.

If we take these results individually and independently from the context, then it cannot be ruled out that the combination of the results might produce strongest indicators of a potential lie or truthful answer.

We are positive and we think that after we study all the information channels with potential in lie detection , like eyes, voice or temperature and we combine all the results we can build an algorithm that is trained to take into account all the parameters and provide a verdict that is genuine.

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