

Optical Flow-based Algorithm Analyses to Detect Human Emotion from Eye Movement-Image Data

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Abstract— One of the popular methods for the recognition of human emotions such as happiness, sadness, and surprise is based on the deformation of facial features. Motion vectors that show these deformations can be specified by the optical flow. In this method, for detecting emotions, the resulted set of motion vectors is compared with a standard deformation template caused by human emotional changes. In this paper, a new method is introduced to compute the quantity of likeness to make decisions based on the importance of obtained vectors from an optical flow approach. The current study uses a feature point tracking technique separately applied to the five facial image regions (eyebrows, eyes, and mouth) to capture basic emotions. Moreover, this research will be focusing on eye movement regions. For finding the vectors, one of the efficient optical flow methods is using the pre-experiment as explained further below.

Index Terms— Human Emotion; Eye Movement features; Optical flow; Motion vectors.

1. INTRODUCTION

One of the responses to human emotional stimuli is facial features. Recognizing facial features is one of the ongoing works within the face-processing vicinity of study. The facial expression contains a plethora of information about human emotion and plays an important role in human communication. According to psychology research, there are at least six emotions that are universally associated with spectacular facial expressions. [1], [2]. Note that a variety of other emotions and their combinations have also been explored, but they remain unproven as universally identifiable. Happiness, sadness, surprise, fear, anger, and disgust are the six most common emotions. In Figure 1, six human face images, decided on from [3], representing every one of those feelings, are shown.

For intelligent and natural human-computer interaction, it is essential to recognize facial expressions automatically. Various techniques have been developed for automatic facial expression recognition, which differs in the kind of

data used. (still images vs. video sequences), feature extraction methods used, and classifiers used.

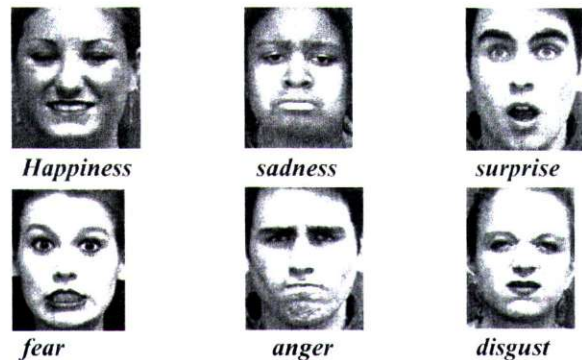


Figure 1. Six images with six universal facial expressions were selected from [2].

Edwards, Hong, et al. [2], [4], [5] delivered nonetheless picture to understand facial expressions. Facial expression reputation from the nonetheless picture has much less precision with admire to video series due to the fact an unmarried picture gives tons much fewer records than a chain of photos for expression reputation processing. The benefit of the use of a chain of photos over an unmarried picture is proven with the aid of using Bassili suggests this truth and concludes that the facial features become extra appropriately identified from dynamic photos than from an unmarried static picture [6].

Thus, the purpose of this has a look is to become aware of which facial capabilities are deformed while those facial expressions occurred. Besides, the extent of the depth of the facial feature may be identified. By detecting the motion of facial capabilities, and focusing on eye movements, the depth of the emotional kingdom may be measured. In this paper, the optical flow set of rules is used to song facial characteristic deformation for three primary facial expressions (neutral, happy, sad). Section 2 describes the study's technique used in this have a look and is accompanied with the aid of using a dialogue of

consequences and evaluation in Section 3. Finally, the conclusions are drawn.

One of the most important advantages of our method is that it is not necessary to determine exact facial feature locations and only the approximate values are sufficient. The proposed optical flow-based movement data processing method applies the Horn Schunck optical flow algorithm to train the eye movement behavior image dataset.

II. RESEARCH OBJECTIVES

The objective of this research was to induce human emotions in individuals to determine if specific facial movements could be detected and analysed by the optical flow technique. This analysis is in the form of motion vector plots. The procedure ascertains if specific emotions can be defined as a set of facial movements which are common to most people when they experience a particular emotion. 'Emotion vector maps' would then be established for specific emotions such as neutral, happy, sad and shock.

III. RELATED WORK

Another technique utilized by many scientists is primarily based totally on optical flow. Yacoob and Davis [7] used optical flow to track the movement of brows, eyes, nose, and mouth. In their technique, they used a research desk to categorize six fashionable facial expressions, which we brought earlier. Barlett et al. [1], [8], [9] blended optical flow and predominant factor evaluation expressions.

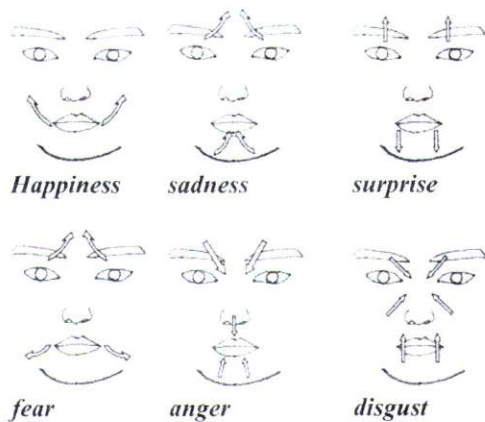


Figure 2. The cues for facial expression as suggested by Bassili [8].

Furthermore, in this research, we use photo sequences of expressive human faces to estimate optical flows accurately, allowing us to grasp human emotions. In this procedure, the face is segmented into 6 sections based on its facial capabilities and deformation following a difficult and approximate recognition of the locations of facial features. Then, using Gautama and Vanhulle's [8] optical glide set of rules, the picture motions of facial capabilities

are recognized, and the movement vectors are extracted by evaluation of the vector set. This assessment is completed by describing the deformation caused by the expression of emotions on the face.

Besides that, supply vectors are a collection of vectors that show movement and distortion in the face as a result of emotional representation. To obtain supply vectors, a set of facial pictures is chosen whose movement vectors properly represent facial traits, similar to Bassili's explanation [2], [8] [10]. Then the incorrect vectors are deleted, and a couple of vector perspectives and their surroundings are saved for the rest. Figure 3 shows an example of supply vectors that were utilized to detect happiness in a happy face. Because of the entry picture sequences, six frames of the image of a happy smile are programmed in this situation. The vectors are then created, and their miles are displayed inside the rest of the image. The vectors are then produced and it is shown in the remaining picture. This method is administered for all simple feelings.



Figure 3. An instance of source vectors [11].

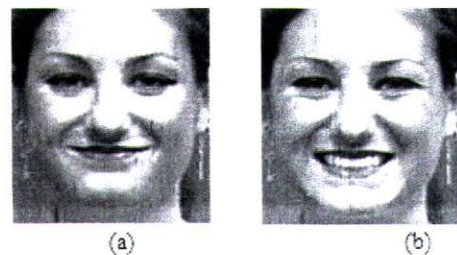


Figure 4. Two different cases of happiness are used for happiness [11].

Note that emotions have different forms in different. Also, for some emotions, it is possible to have more than one form in one person. An example is the two forms of happiness in one person's face shown in Figure 4.

IV. OUR WORK

In this study, video data of our experiments database is used, which comprises three basic facial expressions. The database provides videos of subjects with audio-video interleaved (avi.) file format. All videos display the sequences of facial expressions in frontal face view. The facial expression video consists of approximately about 80 to 100 frames per second with a length of 4 seconds in 640 x 480 resolutions. The image sequences of the database begin with the neutral state to the highest intensity level and then back to the neutral state of expression, refer to Figure 5. Facial expression is repeated with other human emotion which is happy and sad. The intensity of facial feature deformation is measured using optical flow. For this research, we focused on the eye section.



Figure 5. Facial Expression Sequences for Happy Expression

Optical flow [12] is the estimation of an object's perceived motion between an observer and the scene. The optical flow allows for the measuring of motion between two image frames. The images of a subject's face with the facial points serve as the optical flow's input. Two video frames are extracted each time the optical flow function is run, which are then utilised to measure the object's motion. Equation 1, which is the optical flow restricted, must be solved to construct the optical flow between two images.

$$I_x u + I_y v + I_t = 0 \quad (1)$$

where:

I_x , I_y and I_t are the spatiotemporal image brightness derivatives u is the horizontal optical flow and v is the vertical optical flow

The video of facial expressions from our database is converted to grayscale format in the first phase. The purpose of converting RGB video to grayscale is to eliminate superfluous pixels when extracting data. In addition, converting to grayscale helps simplify a lot of the calculations in the next step. Because of its ability to measure motion between two video frames, optical flow for video is computed. Before that, the video background was removed first to extract all the noises in the video data.

At the same time, two video frames are used, one of which is the subject's initial state, which is the neutral face, and the other is a non-neutral facial expression with a different level of expression strength. Help to observe the movements of the facial characteristics by focusing on a region of interest (ROI). For example, the ROI of gaze is used to assess human task performance [13]–[16]. To assess the amplitude of optical flow, the segmentation process, which divides the face into numerous ROIs, must be completed. (1) the area around the eyes and brows, (2) the cheeks, and (3) the lips. Furthermore, for this study, we

will concentrate on one essential area: the eyes and brows. Figure 6 depicts the subject segmentation in this study.

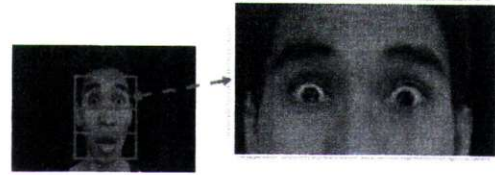


Figure 6. Segmentation of subjects in this research.

The magnitude of each facial feature is measured by computing the displacement of the initial position and previous position for each frame using Equation 2.

$$\tilde{v} = \sqrt{(x_i - x)^2 + (y_i + y)^2} \quad (2)$$

Finally, the facial expression in the video is analysed. The framework can be shown in Figure 7.



Figure 7. The facial expressions analysis framework

V. MOTION VECTORS COMPUTATIONS USING OPTICAL FLOW TECHNIQUES

Optical flow shows how a photograph changes as a result of movement over some time. Higher-degree processing that can solve movement issues requires the calculation of optical flow. Calculating optical flow can be done in a variety of ways. Barron et al. [8], [17], [18] examined nine distinct strategies, serving as a consultant for a variety of approaches, including differential, matching, energy-based, and phase-based ones. They tested these algorithms on a variety of popular photo sequences.

The optical flow method [19], [20] is an important method for evaluating movement photographs and has a wide range of applications in system vision and image processing. The movement subject of optical flow calculated can be used to assess the motion statistics of facial characteristics. The Horn-Schunck optical flow set of rules is a dense optical flow subject based entirely on grayscale consistency assumptions. The optical flow computations may be incorrect if the brightness isn't always invariant or if a movement item is deformed. Non-inflexible movement includes facial movement. Using the traditional optical flow approach will invariably result in a flawed optical flow subject, which will have an impact on the popularity rate of face features.

In this paper, based on the extended optical flow constraint equation, a novel approach for estimating facial expression change detection based on Horn and Schunck optical flow is presented. The approach is used to calculate

the optical flow field of facial expression sequences. The experiment results show that the performance of this approach is better than the normal method [21], [22]. On top of that, we propose an optical flow method for moving images because the characteristics of optical flow are quite robust to abrupt movement [23], [24]. Previous research has used optical flow because it enables the extraction of velocity and angle. Hence this technique will calculate the displacement and density of intensity in each frame in the movement video. The Horn-Schunck algorithm (HS) is one of the classical algorithms in an optical flow due to its reasonable performance and simplicity of the algorithm.

Previous research [25] has compared differential optical flow fields from Horn-Schunck, Lucas Kanade and Brox’s warping techniques. The Horn-Schunck set of rules objectives for higher smoothing impact with the aid of using presenting denser fields as compared to others. Within the big variety of item displacements, it offers steady fields of optical flow. However, the fields are very touchy to mistakes derived from the sort of their neighboring points [22]. Therefore, we use Horn and Schunck method to estimate the optical flow wished in our set of rules.

VI. METHODOLOGY

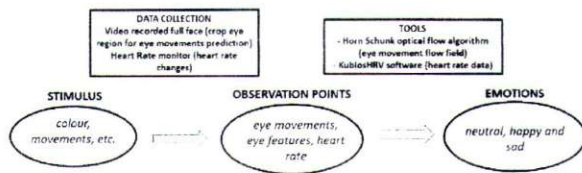


Figure 8: Underlying Model

Figure 8 above shows an underlying model for the whole research process. In the first step, heart rate data, and eye movement video are preprocessed to remove artifacts. Next the human eye movement flow field is calculated from the processed eye movement data. Horn Schunck optical flow algorithm was chosen to extract the eye movement flow field. Finally, three fusion strategies are explored to improve the performance of the proposed emotion prediction algorithm.

A. Data Acquisition

For the image acquisition phase, an experimental paradigm is designed to acquire the emotional eye movement signals. The first video clip displayed is “Happy” which is a comedy video in which a group of minions plays themselves happy with the music and it happens in a clear background area which triggers a happy feeling. The second video on the list is “Neutral” which the video shows peaceful and beautiful scenery in a short film. The third video displayed is “Sad” in which is a single mother crying badly after losing her daughter. The fourth video displayed is “Shock” which emphasizes fighting and gunshot during World War I.

B. Preprocessing

During this phase, the entire human eye movement image will be extracted and stored in file “.net” using the Matlab software. Preprocessing converts the input video into individual frames that is suitable for further processing. The format used in processing the video file is “.avi”.

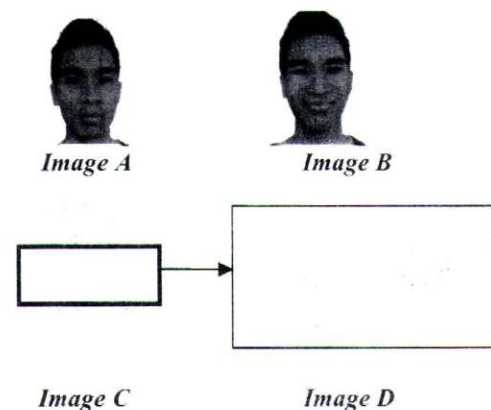
C. Feature Extraction

Then, for human eye movement data, the Horn Schunck optical flow will be applied to extract the velocity-based features. This application was made based on MATLAB software. The details of this application are described below.

1) Optical Flow

The method chosen for the analysis of facial expressions was the optical flow technique. This method involved assessing the magnitude and direction of facial motion. In recent years, the optical flow has emerged as a useful tool in the analysis and tracking of motion features in video sequences. The traditional approach assumes the motion between two image frames at the pixel level. The motion of an object in three dimensions (3D) is projected into a two-dimensional (2D) plane. It is assumed the type of motion sought is distributed over a sequence of several neighboring frames. In practice, this assumption is reasonable as the motion is gradually spread out across several frames. Although the large motion of vehicles and human beings is easier to detect, the morphological deformation of a human body organ is harder to capture.

For this work, it was assumed there is a brightness constancy across neighboring video frames. Hence the brightness of neighboring image pixels does not change over time. Therefore, in Figure 7 an example of an optical flow analysis can be seen, where the ‘neutral face’ seen in image A is compared to an image of the ‘expressive face’ (image B) creating a vector map (quiver diagram) - Image C. The arrows are ‘flow vectors’, with their length being proportional to the velocity of the expression.



The base ‘neutral face’ image A on the left is compared to the ‘happy face’ image B and the vector map image C is created. Image D is an enlarged portion of the complete

vector map, or flow field diagram, showing individual vectors, which are too difficult to see in image C.

VII. EXPERIMENTAL PROCESS

A. Stimuli

An experimental paradigm is designed (as shown in Figure 10) to acquire the emotional eye movement signals. Each trial starts with a presentation of the word “begin” displayed on the screen to prompt playing movie clip, followed by a short warning tone “beep”. Afterward, three different emotional movie clips with a duration of 60 s are displayed. When the movie clip ends, the subject is allowed to relax for 15 s to attenuate the current induced emotion. Then repeated with different movie clips.

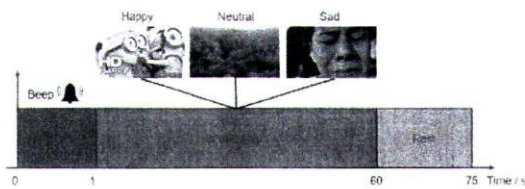


Figure 10. The experimental paradigm of each trial. The horizontal axis indicates the duration of the experiment.

B. Subject

For experiment work, 10 healthy subjects (five females and five males, aged 24 ± 1) are involved to seat about 40 cm in front of the screen. Stereo loudspeakers are located on the desktop, and the sound volume is empirically initialized to a reasonable level. Before the experiment, all subjects have informed of the purpose and the procedure of the experiments and arranged to preview 2–3 stimuli to be familiar with the experimental environment and instrument. Besides, they will be asked whether the conditions such as distance between subject and screen, the volume, the indoor temperature, etc., are comfortable. If not, the setting will be adjusted according to the subject’s feedback.

C. Laboratory Set-up

The experiment was conducted in the air-conditioned laboratory. Simultaneously, the previous system tracks the eye movements using the PC’s webcam only. The system is fully automated initialization, and the process of choosing the needed parameters is fully automated too. Tests were carried out on a 14-inch screen. A Logitech HD webcam was used to record the image at a resolution of 1920×1080 pixels with a frame frequency of 15 frames per second, with the lens facing a chair positioned approximately 40cm in front of the screen.

D. Experimental Process

A total of 10 healthy subjects, most-watched 5 short films each. The participants were seated on a chair approximately 40cm away from the screen, directly facing

it, and instructed to look at the computer’s screen. This process assisted in determining the link between emotion and associated physiological changes. The participants were given the remote control and instructed to adjust the volume at any time to a comfortable level during the films. The cameras were then turned on, the film started and the researcher left the room. The short films were shown in a random sequence to negate the order effect. The initial seven films were chosen randomly.

VIII. RESULTS AND DISCUSSION

Figure 11 depicts the result of applying our algorithm to the image sequences. The left column shows the facial expression and other cells show the numbers of suitable vectors earned for each of the emotions. One of the properties of this method is that it is not determined an emotion absolutely but shows the amount of similarity it has with every basic emotion. Also, our algorithm can determine facial expression with only a few numbers of frames in an image sequence (three or four frames). It means that even if most of the frames are lost, this method can still work.

Moreover, to make result for flow vectors in the flow field more clearly, t value in Equation 3 is created which is value of maximum optical flow minus the minimum value optical flow for all images sequences from each videos of experiments. Hence, t value for every frame in all experiments was calculated and the highest value of the frames was selected as the reference image.

$$t \text{ value} = \text{maximum optical flow} - \text{minimum optical flow} \quad (3)$$

Referring to the Table 1, we can identify the average value represented by every facial expression that is derived from Equation 3. Through this average value, we can make a rough analysis on the optic flow change which occurred with the existence of two frames of facial expression images with different rates. Table 1 shows that human emotion shock has highest optical flow value compared to others human emotion which is neutral, happy and sad. This is also proven in most of the study [26] [27] including this experiment that, when much movement in the face occurred, it will show the highest optical flow value. Table 1 and 2 also shows the results of applying our method only on the first, middle and last frames of the different facial expression image sequence. We show the optical flow field for the full-face of humans and also the optical flow field for eye crop.

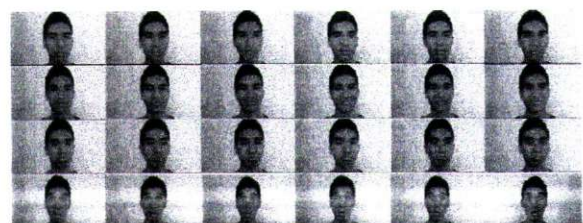


Figure 11. Some instances of emotion representation for neutral, happiness, sadness, and shock respectively.

TABLE I. IMAGE FRAMES WITH OPTICAL FLOW FIELD FOR FULL-FACE


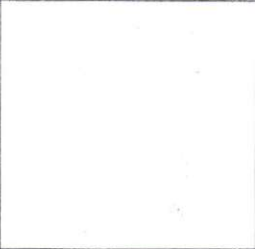






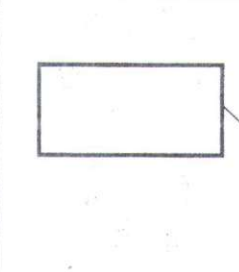

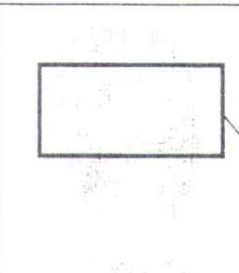

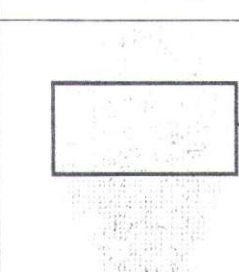

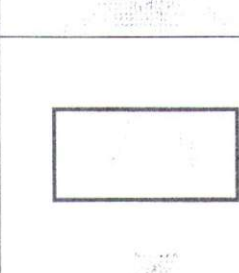

Image Frames	Optical Flow Field (full-face)	t value
 Neutral		+1.083 (lowest value)
 Happy		+1.115 (medium value)
 Sad		+1.113 (medium value)
 Shock		+1.118 (highest value)

TABLE II. OPTICAL FLOW FIELD BETWEEN FULL-FACE AND EYE CROP

Optical Flow Field (full-face)	Optical Flow Field (eye crop)	t value
		+1.090 (lowest value)
		+1.105 (medium value)
		+1.140 (medium value)
		+1.175 (highest value)

The slowness of the optical flow algorithm, the difficulty of the emotion detection in the presence of significant head motion and the problems related to the optical flow techniques, when the light is unfixed, are the most disadvantages of our algorithm.

TABLE III. RESULTS OF AVERAGE VALUE

Human Emotions	t value for Optical Flow Field (full-face)	t value for Optical Flow Field (Eye crop)
Neutral	+1.083	+1.090
Happy	+1.113	+1.105

Sad	+1.115	+1.140
Shock	+1.118	+1.175

In conjunction with values in Table III shows that human emotion 'shock' has highest t value for optical flow field compared to human emotions 'neutral', 'happy', and 'sad'. This proves that human emotion 'shock' has more facial expression movement compared to other human emotions. Meanwhile human emotion 'neutral' has lowest t value for optical flow field compared to human emotions 'neutral', 'happy', and 'sad'.

Both results either t value for optical flow field (full-face) nor t value for optical flow field (eye crop) show that human emotion 'shock' produce the highest value compare to another human emotions given. In addition, the results also show that only a few numbers of image frames (three frames) are sufficient to detect human emotions. These advantages should make a high-performance facial recognition based on optical flow techniques, feasible.

IX. CONCLUSION

In this research, we present an efficient facial expression detection method based on the Horn Schunck optical flow technique for extracting the essential motion vectors and, as a result, determining the faces of various expressions such as neutral, happy, sad, and shock.

For facial expression change detection, we suggested a video-based method based on Horn Schunck optical flows. The performance of our suggested technique for facial expression identification problems has been demonstrated using sequential image frames. Optical flow increases feature extraction, according to the results of the experiments. Furthermore, when compared to other feature extraction methods, optical flow processed sequential facial expression photos can yield a higher recognition rate.

Future work will include the use of more individuals to obtain a greater number of eye movement points, as well as a more detailed investigation of pupil dilation about eyes fixation. Also in our future work, we will further our exploration in physiological changes using human heart rate variability based on facial expression. The results may be combined with this experiment to raise the overall accuracy level.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Tuan Khalisah Tan Zizi @ Tuan Zizi, and Suzaimah Ramli conducted the research, analyzed the data and wrote

the paper. Muslihah Wook, Mohd 'Afizi Mohd Shukran wrote the paper. All authors had approved the final version.

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