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A Fuzzy Logic Model for Stress Assessment

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Abstract: Stress is a universal concept that concerns people of all ages, from young to old, and even all living things. It is important to detect it to protect itself from the negative effects of stress, which is intertwined with human life, or to benefit from its existence. In this study, a model based on fuzzy logic techniques which are some of the sub-branches of artificial intelligence has been developed using photographs containing facial expressions to assess the stress levels of individuals. Basically, the difference between two photographs of the individual was used in the model. Various fuzzy logic techniques which are Fuzzy C-Means (FCM) clustering, Adaptive Neuro-Fuzzy Inference System (ANFIS) and Fuzzy Inference System (FIS) are used in proposed cascade model. In the result of the model, the stress level of the individuals was included in one of the “None”, “Low”, “Moderate” and “High” levels. The fuzzy model correctly assessed approximately 70% of the dataset used.

Keywords: Artificial intelligence, fuzzy logic techniques, fuzzy inference system, image processing, stress assessment

I. INTRODUCTION

Individuals face many events during their lives. The human body reacts to all kinds of physiological, biological, psychological, sociological or environmental events and changes that the individual encounters [1]. This reaction of the body in the face of unexpected conditions was named by Hans Selye, one of the many scientists working on it. Hans Selye defined stress as “the nonspecific response of the body to any demand” [2].

Since human’s perspectives on events are not the same, their reactions may not be the same [3]. Therefore, the stress levels of individuals can be different. In order to minimize the damage caused by stress, which is an inseparable part of life, the first step is to determine the stress level of the person [4]. For this purpose, stress scales developed by scientists appear as common tools used to measure the stress level of an individual [5]. Besides, studies have been carried out to determine and predict stress level with many different methods such as artificial intelligence [6], machine learning [7], image processing [8], neural network [9].

In view of the fact that the various symptoms and effects of stress on people, many different variables can be mentioned to determine stress. The data obtained from behavioural manifestation, physiological signal, physical features, emotional manifestation, facial expression, and voice recognition are used in studies related with stress [10]. These can be data which encountered in many studies, require various equipment to measure (electrocardiogram (EEG), electrodermal activity, respiration, humidity, and heart rate variability, speech), are obtained using thermal images (respiratory rate, skin temperature and blood flow), are obtained from pictures and videos [10,11].

A stress recognition method that uses facial images and does not require body-contact sensors was proposed in a study [12]. The features procured from the videos in the dataset that was used in the study, were used as input for the support vector machine and genetic algorithm techniques used in the study.

In another paper authors stated that the measurements like digital signals (galvanic skin response, blood volume, pupil dilation, and skin temperature), physiological signals, and visual features (eye closure, head movement) were intrusive and less comfortable even though these measurements are used in many studies on stress detection [7]. Instead, they proposed a method based on the change in eyebrow coordinates by using videos taken from the front while the person is working in front of the computer.

A study, which was published in 2019, was mentioned that researchers have proven that stress level deduction can be made using heart rate, humidity response, temperature response and fuzzy logic algorithm [10]. In another study published in the same year considering the importance of real-time stress, a framework which monitors negative emotional stress instantly and warns the person to take a break when a certain threshold level is exceeded was proposed. The proposed framework detects stress using three facial expressions, anger, sadness, and fear which are sensitive to negative emotional stress [13].

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In a recently published study, authors have developed a decision tool to determine a person's stress level using fuzzy inference system. They have used sensors to get body temperature and blood pressure as inputs. Results compared to depression, anxiety, and stress scales 42 (DASS 42), a psychological stress measuring instrument. The system has 74% achievement percentage [14].

Many studies and research on it reveal the importance of determining stress and stress level. Determining the stress level, which is thought to be of increasing importance in the near future, has already become a necessity today. It is very important to develop a method suitable for daily life and the factors affecting stress, when assessing the level of stress that has taken such a place in human life. The aim of this paper is basically to assess the stress level of individuals using images containing facial expressions.

The sections of this paper are organized as follows: In Section 1 the motivation of stress assessment and some studies in literature are introduced. Section 2 provides explanation of stress concept detailly. Section 3 described proposed cascade method and used dataset.

II. STRESS

Stress is a universal concept that concerns people of all ages, from young to old, and even all living things. The earliest known date for the use of the word stress is the 14th century. Stress, which was thought to have no programmatic focus in the 14th century, was used to mean hardship or adversity [15].

The works, that laid the groundwork for the stress definition, of scientists have begun to gain momentum at the beginning of the 20th century. Hans Selye is one of the scientists working on stress whose popularity has increased in the 20th century in the medical world, especially in branches such as physiology and psychology, and perhaps the most important of them on the grounds that he defined stress for the first time in its current meaning.

He used the term stress in his first monograph which is named “Stress” published in Montreal in 1950 [16, 17]. In his study, he explained stress “is the interaction between damage and defense, just as in physics tension or pressure represents the interplay between a force and the resistance offered to it” from a biological perspective [18]. In the result of Selye’s studies, the final version of his stress definition is “the nonspecific response of the body to any demand” [2].

In addition to Selye, many scientists in the medical world were working on this subject. James S. House [19], Menaghan and Mullan, [20], Lazarus and Folkman [21], Thomas Holmes and Richard Rahe [22] and lots of other scientists have defined stress in different ways in line with their fields of expertise. Scientists who define stress albeit with different approaches, have started to develop ideas about what stress is as well as how to cope with it, manage it and prevent the excess, in time. The first step to minimize the damage caused by stress, to cope with it and to manage it is to determine the stress level of the person [4].

The symptoms of stress are used for detecting the presence of stress and determining the level of it using. As it gives instant information, the change in facial expression caused by stress is one of the most important signs of the presence of stress. Facial expressions are a very easy and fast source of stress symptoms, as they can be understood simply by looking at the face of the person with whom are communicating without resorting to any medical method. Faced with a negative and distressing situation, the individual reacts such as squinting, wrinkles on the forehead, bending of the face, and stretching the lips [23].

One of the most important indicators of stress is asymmetric lip and eyebrow movements [24]. Mouth shape, lip deformation, lip corner puller, lip pressor are shown as stress-related facial feature types [25]. An obvious change is observed in the eyebrows. Although eyebrow movements do not have a universal pattern, the change in an individual’s eyebrows is a symptom used to detect the presence of stress [7].

Stress manifests itself in and around the eye in various ways, such as blinking frequency, eye aperture, eyelid response, and pupil size variation [25]. The pupils of the stressed individual are observed to dilate compared to their normal state [26].

Facial expressions, which are one of the important symptoms of stress, also give important information about the emotion of the individual. According to Ekman and Friesen, there are six universal emotions such as anger, happiness, fear, surprise, disgust and sadness. These emotions have basic facial expressions of universal nature that are easily recognizable in many different cultures [27]. There is an intertwined structure between stress and emotions. However,

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stress may not be clearly noticeable under every emotion. The psychological aspect of stress is mostly composed of negative emotions such as fear, anxiety and anger [28].

III. MODEL

The system is presented in this paper has a cascade structure as shown in Fig. 1 All these stages are structured on the basis of comparing two photographs of the individual, one of which is known to belong to neutral state. For this purpose, the eyebrow, eye, forehead, and mouth regions that are frequently used in stress determination have been determined using some photographs in the dataset described in detail in Subsection 3.1. The data based on the difference between the first picture, which is the neutral state of the individual (considered as stress-free), and the photograph intended to determine the stress level was used to determine the parameters for the membership functions of the input variables in the FIS and ANFIS model. All operations shown in Fig. 1 were performed using the R2018b version of the MATLAB program. In addition, the hardware used in this paper is a Lenovo IdeaPad 3 15IML05 (Intel Core i5-10th generation processor, 8 GB RAM) model personal computer.

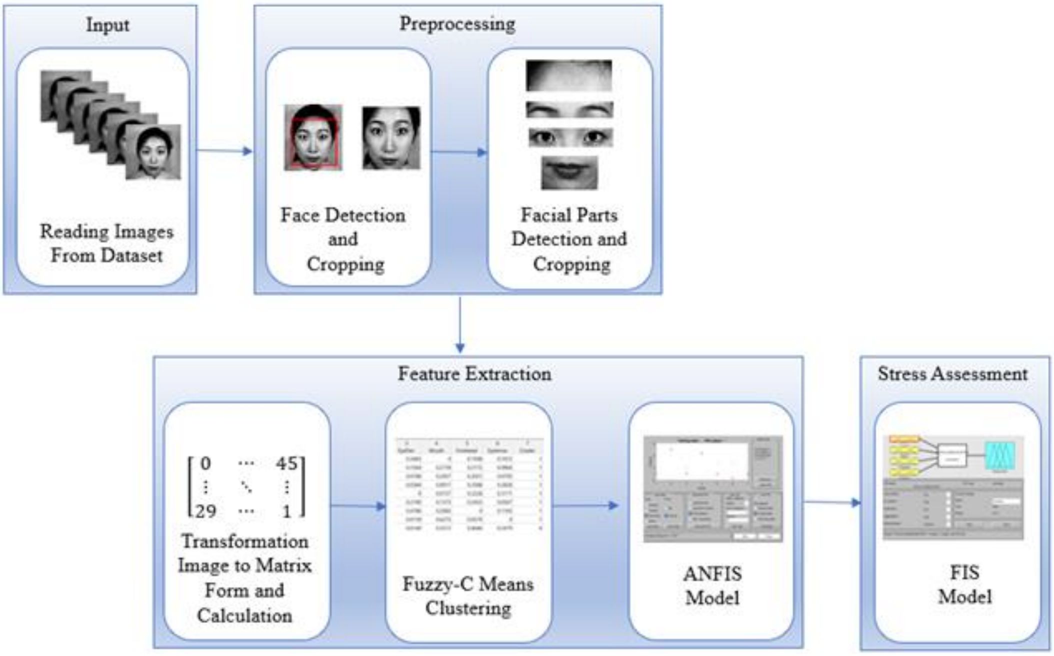

Fig. 1 Stages of the proposed framework for stress assessment

A. Dataset

The Japanese Female Facial Expression (JAFFE) Database was used for the model due to reasons such that each image is the same size, the eyebrow, forehead, eye and mouth areas to be used for the model are obvious and clear, not using any accessories (hats, glasses, etc.) and make-up, composing of the photographs facial expressions containing six basic emotions and neutral states, labeling of photos according to the emotional state they reflect. At the same time, the fact that it has been used in many studies aiming to determine stress has increased the reliability that the dataset is suitable for the model.

The preferred JAFFE dataset for this paper was developed by Michael J. Lyons, Miyuki Kamachi, and Jiro Gyoba in 1998 [29]. The entire dataset consists of images containing seven different facial expressions of Japanese female subjects. Images are in ".tiff" format and have 256x256 pixel resolution. The photos have been tagged based on the statements of the expressor. While labelling, happiness, sadness, surprise, anger, disgust, fear and neutral are abbreviated as "HA", "SA", "SU", "AN", "DI", "FE", "NE" respectively. Participants were identified with the initials of their names (KA, KL, KM, KR, MK, NA, NM, TM, UY, YM). In Fig. 2, samples containing a photograph of neutral, sadness, anger, and fear facial expression of the same participant are given with their labels.

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Fig. 2 Sample images in the JAFFE dataset

Although the JAFFE dataset includes seven different emotions, the images labelled SA, AN and FE in the dataset were used in this model based on the relationship between negative emotions and stress. In addition, since the model made an inference by comparing two images of the individual, images containing the neutral state of the individual were also needed.

B. Preprocessing and Feature Extraction

While choosing the facial parts to be used in the model, the parts of the individual that undergo the most changes during stress are preferred. These are the eye pair area, mouth area, forehead and eyebrows. Firstly, face detection from photos is needed to determine these facial parts.

In the face detection phase of the study, a detector based on the Viola-Jones algorithm was first created in MATLAB. Using this detector, the facial regions in the images were detected. After the detection of the face the framed face region was cropped. In the next steps, the model uses cropped form of images detected face region. In this way, while detecting the facial parts, the system has reached the most accurate result more easily and quickly by using the cropped photo.

Just like in face detection, facial parts other than the eyebrow were basically obtained using the detector. The eye pair parts were detected directly but different methods were used in addition while detecting the mouth and forehead area. The mouth area was basically detected using the same detector. However, “Mouth” classification model of the detector was insufficient to detect the mouth region in the images. For this reason, improvement studies have been carried out so that the model can give clear and proper results.

In the forehead detection, a detector was created likewise previous facial parts detection. However, this detector does not have a classification model developed to detect the forehead region from the image. So, a custom classifier was trained to use the detector. Fig. 3 illustrates the stages of detector training. The newly created detector detected all forehead regions in the dataset using generated classifier.

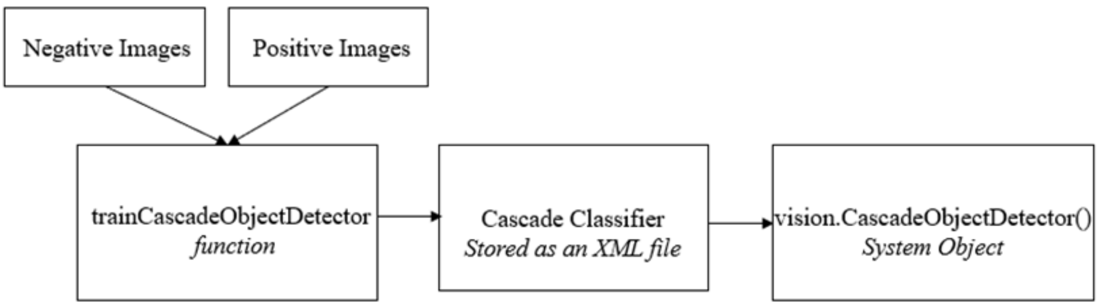

Fig. 3 Detector training stages

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In the first stage of eyebrow detection, the "Image Labeler" application was used. The labelling rectangle containing the eyebrows were cropped. By detecting the eyebrow regions, the facial parts that need to be determined from the images are completed. Fig. 4 contains samples of detected and cropped face and all facial parts.

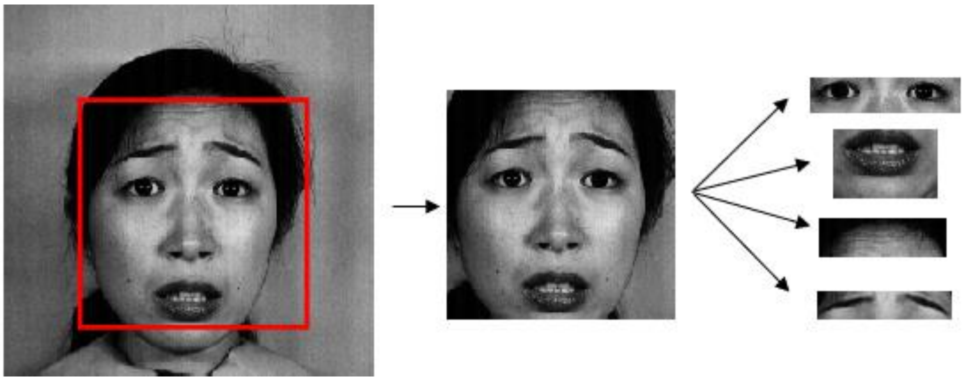

Fig. 4 Sample of face and facial parts detection and cropping

The proposed model in this paper used as input the numerical values by comparing the photographs taken in the neutral, neutral (pose 2), fear, anger, and sadness state of the individual. The matrices of the images were needed to get these numerical values. So, the matrices of each facial parts getting from neutral state-neutral state (pose 2), neutral state-fear, neutral state-anger, neutral state-sadness images were subtracted each other in own. Thus, difference matrices were obtained. The next operation on the matrices is to find the mean of the difference matrices consisting of the elements taken their absolute value. Finding the mean of the matrices is important both to find the mean change in two different images of the individual and to convert the matrix to a single real number. In the next step, normalization was performed on the data to scale the data in a common range.

The first fuzzy technique used in the model is FCM clustering. The dataset used in the application does not contain information about the stress levels of individuals. In other words, the output values of the systems developed in this study are not yet known. By contrast, the system needs both input and output values for the training of the ANFIS model. Therefore, before the system was built it was deemed appropriate to divide the dataset into four clusters, using the FCM cluster method.

The ANFIS model is trained using the relationship between the known outputs of the data used. Therefore, the user must give the outputs to the system before the training starts. The model consists of four inputs consisting of "Eyepair", "Mouth", "Forehead", "Eyebrow", and one output. The normalized values and the result of FCM clustering were used as inputs and output in the ANFIS model, respectively. In Fig. 5, the structure of ANFIS consisting of 4 inputs, 1 output and 256 rules is given.

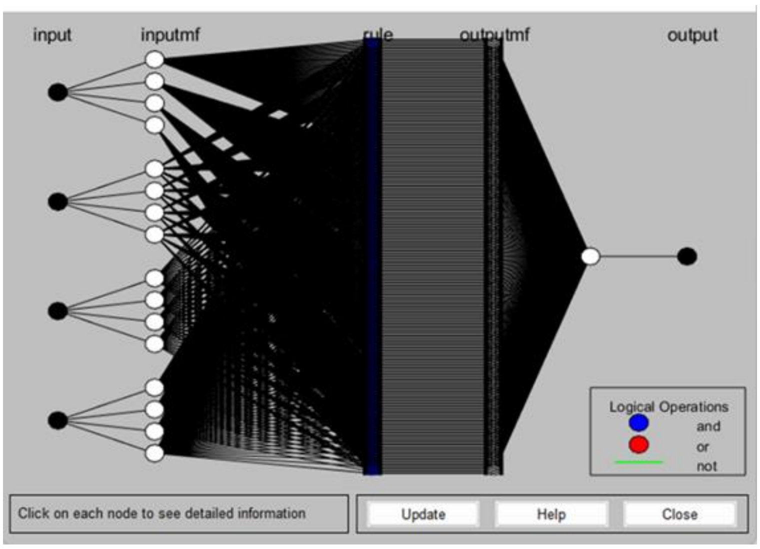

Fig. 5 The structure of ANFIS model

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The result of ANFIS is the same as the result found by the FCM algorithm. As a result, it can be said that the ANFIS model makes a correct inference for this data. The cluster of all inputs in the dataset belonged to was determined.

C. Stress Assessment

The last fuzzy technique used for stress assessment is FIS. Although FIS is similar to the ANFIS model they differ from each other in basic points such as the application used, ranges and rules entry. First, input and output variables must be added into the FIS. Just like in the ANFIS model, the FIS has four inputs and one output as seen in Fig. 6.

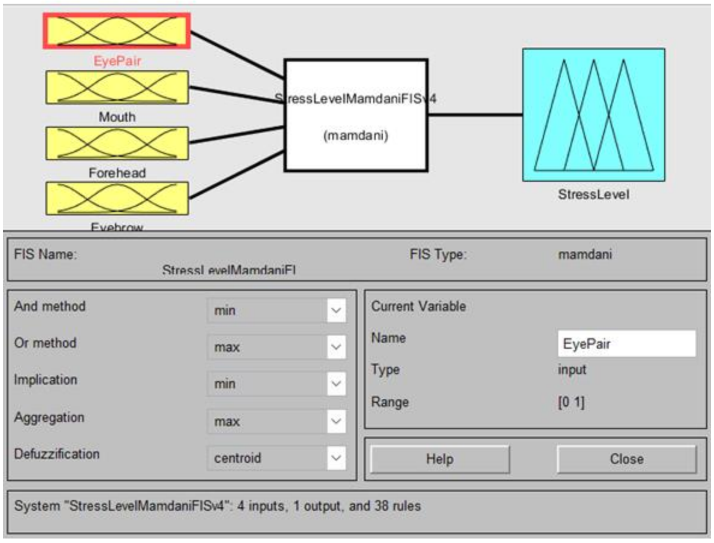
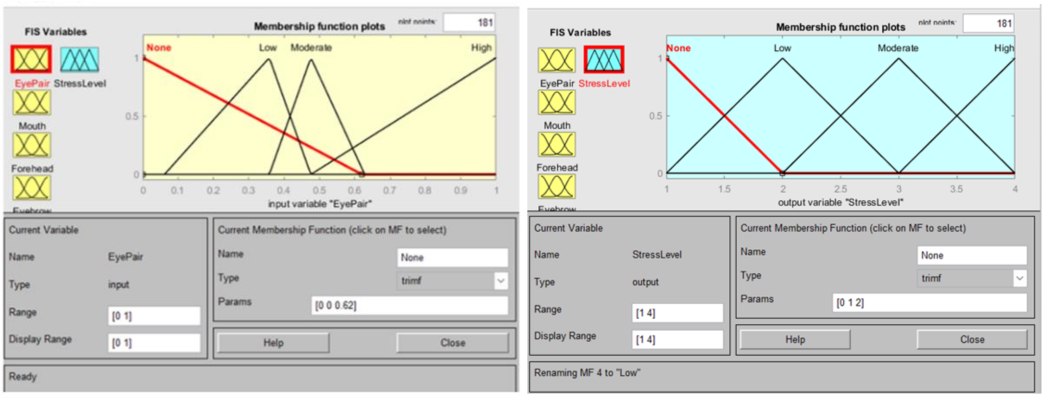


Fig. 6 Fuzzy Logic Designer

The FIS model does not need to know the output information of the inputs beforehand. Instead, the numbers of membership functions and numerical parameters must be entered into the system. In this model, four membership functions for each input are used. Since the stress level of the images was desired to be divided into four levels, four membership functions were determined for the output, bearing the names of these levels ("None", "Low", "Moderate", "High"). The names and numerical parameters values of the membership functions of the Eyepair input are also given as a sample. The graph (a) in Fig. 7 includes the membership functions and their parameters of this input. The graph (b) in Fig. 7 includes the membership functions and parameters of the output.



(a) (b)

Fig. 7 The Membership Function Editor (a) Membership functions and their parameters of input "eyepair"; (b) membership functions and parameters of the output

The ranges of membership functions of the inputs used in the FIS model are based on the amount of change that occurs in the variables. While determining the ranges, the quantiles of the normalization data were found. The quantiles finding process was carried out in two stages. Firstly, the data were divided into two groups, the data obtained using neutral-neutral (pose 2) images, and the others. While making this distinction, it is assumed that individuals are stress-free in their neutral state, based on the labeling in the dataset. Therefore, the neutral-neutral (pose 2) data gave the range of the

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level at which the change was "None". The smallest value and the largest value of the neutral-neutral (pose 2) data represent the minimum and maximum values for the range, respectively, to be found separately for each variable.

In the next step, the minimum, lower quartile, median and upper quartile values of the array containing all the data obtained from the images of fear, anger and sadness were found. In Fig. 8, the division scheme of the eyepair variable into ranges is given. In this scheme, 0 represents the minimum value of the neutral-neutral (pose 2) data, and 0.62 the maximum value. Thus, the range of the "None" class was found to be [0, 0.62]. The minimum, lower quartile, median and upper quartile values of other data were found to be 0.0613, 0.358, 0.4757, and 0.6281, respectively. Using these values, the range is divided into three classes as "Low", "Moderate" and "High". The ranges of other variables were determined by the same method. Thus, the required ranges for inputs in FIS were obtained.

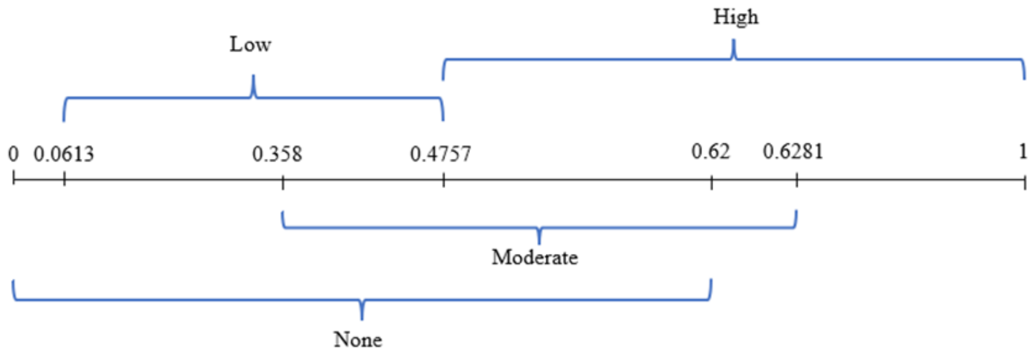

Fig. 8 The ranges of input "eyepair"

The most important tool that defines the behavior of the system is the list of rules added to the system. While creating the rule for the FIS model, the results of the FCM algorithm and the rules obtained as a result of the training of the ANFIS model were taken as reference.

IV. RESULTS

The model is ready to use by entering the rules into the system. The results of the model for the first 20 inputs are given in Table 1.

It was determined that the FIS model assessed the stress level of 11 data incorrectly when the FCM cluster results and the FIS outputs were examined. The FIS model, which correctly predicted the stress level of 25 out of 36 data, made a correct assessment for approximately 70% of the dataset.

Other results were obtained when the relationship between the stress levels determined by the FIS model and emotions of individuals was examined. In the neutral state images, the stress level of seven individuals was "None" and the stress level of two individuals was "Low". Since it is known that the individual is stress-free, this result proves that the model successfully detects stress-free individuals. In the fear images, the stress level of four individuals was determined as "Low", the stress level of two individuals as "Moderate", and the stress level of three individuals as "High". Stress level distribution in sad images of individuals is two "None", three "Low", two "Moderate" and two "High". The stress level of five individuals was determined as "Moderate" and the stress level of four individuals as "High" from the images labeled as anger. According to these results, it was concluded that the stress of individuals when they are angry is more than other emotions.

TABLE I THE OUTPUT VALUES OF FIS MODEL

Neutral Image	Sample Image	Output Values	Stress Level
KA.NE1.26	KA.NE2.27	1.3541	None
KL.NE1.155	KL.NE2.156	1.3589	None
KR.NE1.71	KR.NE2.72	1.3686	None
MK.NE1.113	MK.NE2.114	1.3855	None
NA.NE1.199	NA.NE2.200	1.3404	None

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NM.NE1.92	NM.NE2.93	1.3561	None
TM.NE1.177	TM.NE2.178	1.8494	Low
UY.NE1.134	UY.NE2.135	1.3780	None
YM.NE1.49	YM.NE2.50	1.9995	Low
KA.NE1.26	KA.FE1.45	3.5741	High
KL.NE1.155	KL.FE1.174	2.0231	Low
KR.NE1.71	KR.FE1.89	3.6226	High
MK.NE1.113	MK.FE1.131	3.5743	High
NA.NE1.199	NA.FE1.217	1.9622	Low
NM.NE1.92	NM.FE1.110	2.9134	Moderate
TM.NE1.177	TM.FE1.196	2.0179	Low
UY.NE1.134	UY.FE1.152	2.0001	Low
YM.NE1.49	YM.FE1.67	3.3755	Moderate
KA.NE1.26	KA.SA1.33	1.3410	None
NM.NE1.92	NM.NE2.93	1.3561	None

V. CONCLUSION

The results of FIS model were evaluated based on the FCM cluster results. In fact, the techniques used in application are a link in the chain. If examined elaborately, the output values of the inputs must be known beforehand to generate the ANFIS model. In this application, these values were obtained through the FCM cluster. Rules to be added for the FIS model should have a reference. For this, the rules created by the ANFIS model as a result of training were taken as a basis. Briefly, the FCM cluster supports the ANFIS model, and the ANFIS model supports the FIS model.

Some determinations have been made in order to contribute to the future studies of the application developed in this study. The dataset used in the application of this study does not provide information about the stress levels of individuals. Using a dataset containing the stress levels of individuals can add a new dimension to the application. In addition, all the images in the dataset belong to female participants. Developing the model using images of both male and female individuals may provide better results for all individuals regardless of gender. Another determination is related to the number of participants. More images can be obtained for the dataset by increasing the number of participants. The common purpose of all these determinations about the dataset is to optimize the proposed model in this paper. Therefore, in future studies, it is aimed to develop a more comprehensive dataset containing many photographs belong both male and female participants labelled according to their stress levels.

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