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***Abstract*—We proposed in this paper, an emotional recognition system based on physiological signals. We adopt the seven basic emotions that are: neutral, joy, sadness, fear, anger, disgust and surprise. An experiment was conducted to verify the feasibility of the proposed system. This experience has allowed us to acquire EEG signals and to create an emotional database. For this, we used the Emotiv EPOC headset. Thereafter, we choose the fuzzy logic techniques to classify the EEG signals and to analyze the results.**

***Keywords*-emotion recognition system; EEG; fuzzy logic;**

I. INTRODUCTION

Today, the world of the smart devices such as the personalized digital interactive TV is a fast developing area with well established and proven research concepts [1], [2], [3]. The future interactive TV should be designed to learn for itself and to prioritize the available programs for the final viewer according to the accepted knowledge. The interactive TV represents a challenging problem. The purpose of the interactive TV is to satisfy the user needs in a considerable time. This requires the authentication of the user and the identification of his preferences (favorite channels, programs, dates, etc). A key component of this interaction is its ability to continually detect and recognize the user face, and even his expression, and therefore understand his internal emotional state. Given the previously mentioned requirements, we propose in our work, a cognitive emotion analysis system that identifies the user and his emotional state in real time to satisfy his needs. Figure 1 shows our proposed system. The system identifies the person via a video camera and follows continuously his emotional state through his face and his physiological state detected from an EEG headset. According to the user's state, the system reacts based on the user preferences stored in its database[27]. In this paper, we focused in the emotion recognition part from physiological state.

This paper is organized as follows. In Section II, the related work is introduced. Then, we describe in section III, the emotion recognition system using a EEG signals and we present also a Fuzzy logic classification technique. We present concluding remarks in section IV.

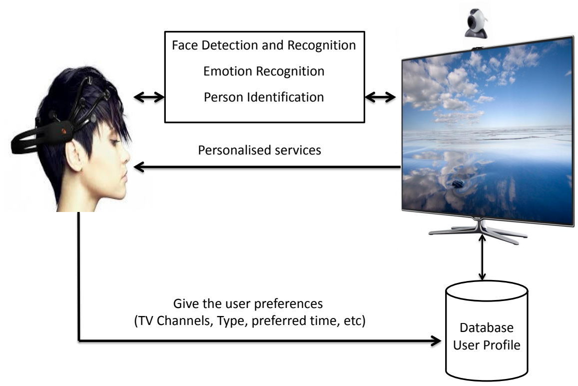


Figure 1. System overview

II. RELATED WORK

Emotional information can be conveyed by a wide-range of multimodal emotion signals. In emotion detection for Human Computer Interaction, all of the emotional signals can be combined into four types. In the process of emotion detection, fusion refers to combining and integrating all incoming single modalities into one representation of the emotion expressed by the user. We presented in the following the emotion detection systems using physiological systems.

A. Brain computer interface

A Brain Computer Interface (BCI) is a system that makes persons communicate with external world only by thinking without relying on muscular or nervous activity [4]. Figure 2 illustrates the functionality of a BCI starting by monitoring the user's brain activity which is conveyed into brain signals processed to obtain features grouped into vector called "feature vector". The mapping of the latter, results into commands to be executed by the system that displays feedback to the user in order to fine-tune or modulate his brain activity. In order to measure brain manifestations, many sensing technologies were introduced such as Functional Magnetic Resonance Imaging (FMRI), Positron Emission Tomography (PET), and Functional Near-Infrared Brain Monitoring (FNIBM). Because of its high time resolution, noninvasiveness, ease of acquisition, and cost effectiveness, the electroencephalogram (EEG) is the preferred brain monitoring method in current BCIs.

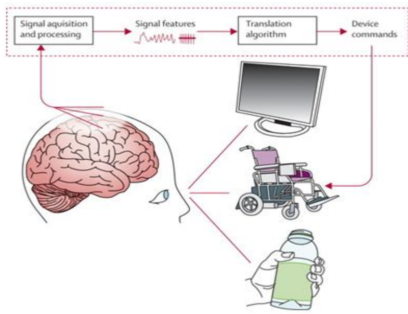


Figure 2. Functional model of a BCI

B. Applications

In EEG, user's mental activities appear as distinctive patterns. Recognized by BCI, those are mapped into commands which are associated with certain actions. In literature, five standard EEG bands are defined, mainly: delta (up to 4 Hz), theta (4Hz-8Hz), alpha (8Hz-13Hz) beta (13Hz-30Hz) and gamma (30Hz-100Hz). Each of them is more prominent in different situations (e.g. delta band is more prominent when a person is sleepy, alpha when he is conscious, etc). The current field of applications of EEG-based BCI systems is very wide and ranges from wheelchair navigation [5], evaluation of Brain-Computer Interface to categorize human emotional response [6], assessment of cognitive loads [7] to neurofeedback training for children with attention deficit disorders [8].

C. Emotion

1) Definition: Emotions consist of multiple components that may include intentions, action tendencies, appraisals, other cognitions, central and peripheral changes in physiology, and subjective feelings. Emotions are not directly observable, but are inferred from expressive behavior, self-report, physiological indicators, and context [9].

2) Emotion types: Discrete emotions could be divided into: basic set (core set) and secondary set depending on the action tendencies [10], [11]. Some other theories argue that emotions could be better measured as differing in degree on dimensions. The well known dimensional models are the pleasure-arousal (pleasure for pleasantness to a given emotional state and arousal for physiological activation) [12] and the approach avoidance (tendencies to approach or avoid the stimuli) [13]. Note that pleasure-arousal dimension is used in this article in line with many researches.

3) Emotion induction protocol: To elicit emotions, many standard strategies such as films, pictures, sound and odors were adopted. Other methods like autobiographic recall, social interactions are also used. The induction protocol developed in this project is based on social interaction [14]. It requested that the behavior of others will affect our own emotional state. Little work in computer tried to induce emotions. For example, in MIT Media Lab, Picard, Healey and Vyzas [15] used pictures to induce a set of emotions include happiness, sadness, anger, fear, disgust, surprise, neutrality, etc. In addition, [16] used the results found by Gross and Levenson [17] to induce sadness, anger, surprise, fear, frustration, and fun. As it was already mentioned, emotions play a fundamental role in cognitive processes; Estrada Isen, and Young [18] found that emotions positive can increase intrinsic motivation. In order to measure emotions, the used methods are either objective or subjective. The subjective methods consist of questionnaire, adjective checklists and pictorial tools such as Activation-Deactivation Check List (AD-ACL) Positive and Negative Affect Schedule (PANAS) and Self Assessment. Mankini (SAM). Objective methods use physiological manifestations derived from emotions such as brainwave activity, heart rate, facial expression, vocal properties and others. Our present work aims to induce the emotional state of the individual to assess. This evaluation will be useful later to define a user profile containing different emotional states as well as the corresponding values recorded. This work will be presented in the next section.

III. Present work

For measuring the emotions, we must measure the three components of the emotion:

1) The cognitive component (what we feel): Self report of the subject using Self report instruments such as surveys, SAM, etc.
2) The behavioral component: Facial expression such as FACS, EMG, etc.
3) The physiological component (cardiac rhythm, physiological signals, respiration).

In this part, we focus on the physiological component especially the EEG signals. The figure below (Figure 3) lists the steps to be done to recognize the emotions by analysis of EEG signals.

The first step consists in the recording of EEG signals, then the processing of these signals by applying the fft and the band pass filter. The following step consists on the extraction of the emotion features, followed by the classification by fuzzy logic techniques and finally, the analysis phase. We are trying to establish a protocol for induction of emotions by the recording of EEG signals. In particular, we examine the possibility of inducing complex emotions and we lean for that on the dimensional approach of emotions [19]. This approach proposes to model the emotions from the following three dimensions: arousal, valence, and dominance.

In [20], the authors projected the emotions on the

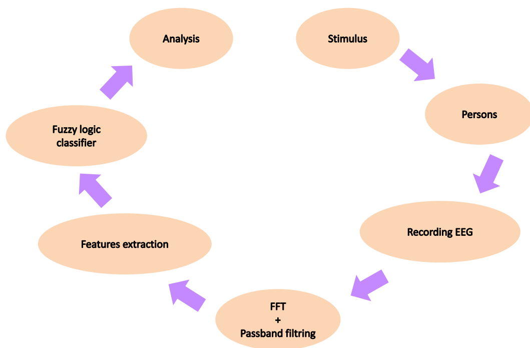


Figure 3. Overview of the recognition system of signals EEG

plan arousal, valence, control and favorability as follow:

- Valence: How positive is this situation?
- Control: To what extent can you influence the situation ? (if desired)
- Arousal: How active/aroused are you in this situation?
- Favorability: How this situation is favorable for you?

In our work, we retained the following emotions: anger, surprise, disgust, sadness, joy, fear, and neutral. We believe that the valence will include the notion of favorability, and we will use the plan composed of three variables arousal, valence and dominance or control. The interpretation of these emotions leads us to a finer recognition of emotional states in our future research.

A. *Emotion experience*

1) Data acquisition: For acquiring the EEG Data, we used the Emotiv EPOC headset containing 14 electrodes (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8 and AF4) and 2 reference electrodes (Figure 4). These electrodes are placed according to the standard layout of the 10-20 system. This system refers to the spacing of the electrodes varying from 10 or 20% according to the morphology of the individual.

2) Collection of the personal information of subjects: Each subject must fill the form of personal information described below (Figure 5). In addition, the subjects were asked to collect the necessary information needed to create the stimuli that may trigger an emotion for each subject.

3) Emotion induction protocol: After defining the retained emotions for this study, we have created a scenario for each emotions. These scenarios are believed to cause the expected emotional reactions[21,22].

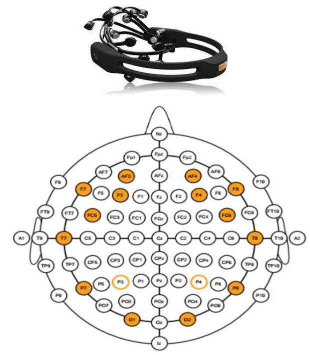
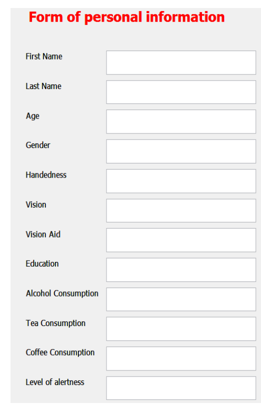


Figure 4. Emotiv EPOC Headset



Form of personal information

First Name
Last Name
Age
Gender
Handedness
Vision
Vision Aid
Education
Alcohol Consumption
Tea Consumption
Coffee Consumption
Level of alertness

Figure 5. Personal information Form

- Neutral : it is induced by the introduction of neutral images (such as GAPED Geneva Affective PicturE Database[23]).
- Joy : it is induced by an imagination of a dream that can be happen in the future, or by the introduction of a video sequence triggering joy in the subject (match, song, show,...).
- Sadness : it is induced by a bibliographic reminder that made the subject by recalling an unhappy memory.
- Fear : it is induced by the introduction of a video sequence (film, etc).
- Anger : it is induced by a social interaction between two or more persons.
- Disgust : it is induced by the introduction of a video sequence showing a disgusting act.
- Surprise : it is induced by the introduction of a video sequence containing a surprise.

4) Self report tools of emotional state: For evaluating the emotional state of each subject, we used the Geneva Emotion Wheel[24](Figure 6).
This wheel propose 20 different emotions ordered circularly on the next sheet of response.

Secondly, we used the tool S.A.M. " Self-Assessment Manikin "[25], this tool has proved its efficiency in several published works. This is a graphic scale with 3 dimensions:

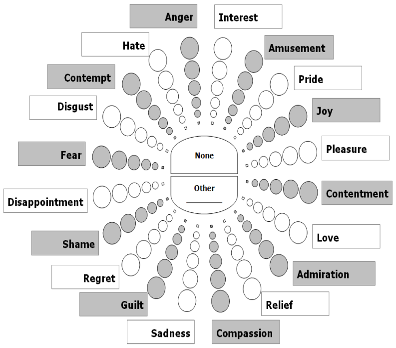


Figure 6. Geneva Emotion Wheel

valence, arousal and dominance(Figure 7). For each dimension, the state of a figurine is graphically declined in nine degrees (5 degrees and 4 intermediates).

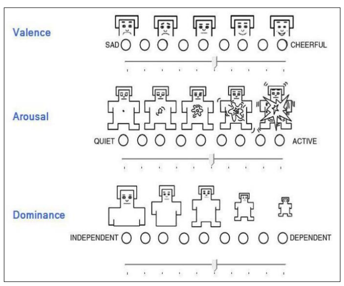


Figure 7. SAM-Scales for valence, arousal and dominance

Finally, we proposed a self report survey composed of the following questions :

- Describe the event that caused your emotional experience.
- Indicate what happened and the consequences of this event for you.
- When does the intensity of your emotion has increased?

5) Sample and procedure: Six subjects whose age between 22 and 61 years constitute the sample of our experience. The sensors for recording electrodermal activity are placed before the start of the emotional experience so that participants can get used. At the end of each test, each subject was asked to fill the emotions Geneva wheel, to specify the degree of scales of SAM and finally to respond to the three questions of the self report survey described above.

B. FFT and Passband filtering

In our case we treated an EEG signal of a duration of 20seconds, that can be find either on the beginning, middle or end of the experience. Firstly, we applied the Fast Fourier Transform on the signal, then a bandpass filtering is applied to extract the desired frequency bands. An EEG signal can contain several rhythms described on the following table: According to our goals, we will need the Alpha (8-13 Hz) and Beta (13-30 Hz) bands which are the most specific

Table I
EEG RHYTHMS

Rhythms	Frequency interval	Location	Reason
Delta	(0-4) Hz	Frontal lobe	Deep sleep
Theta	(4-7) Hz	Median, temporal	Drowsiness and meditation
Alpha	(8-13) Hz	Frontal, occipital	Relaxation and closed eyes
Mu	(8-12) Hz	Central	Controlateral and motor acts
Beta	(13-30) Hz	Frontal, central	Concentration and reflection
Gamma	(30- 100+) Hz	—	Cognitive functions

waves in the search of emotion. We seek the values of these waves in 6 locations in the frontal lobe: AF3, AF4, F3, F4, FC6 et F8, and a location in the parietal lobe : P8.

C. Features extraction

1) Arousal: It is characterized by a high beta power and coherence in the parietal lobe, as well as low alpha activity. Beta waves are associated with a state of alert mind or excited, while alpha waves are more dominant in a state of relaxation. Thus the beta/alpha ratio is a reasonable indicator of the state of excitation of a person(1)

$$Arousal = \alpha(AF3 + AF4 + F3 + F4)/\beta(AF3 + AF4 + F3 + F4) \quad (1)$$

2) Valence: The prefrontal lobe (F3 and F4) plays a crucial role in the regulation of emotion and conscious experience. Inactivation of the left frontal indicates a negative emotion, and even inactivation of the right frontal indicates a positive emotion.
Thus to determine the valence, we compare the levels of activation of the two cortical hemispheres (2).
In addition, other research proved that hemispheric differences tell us about the motivational direction. And as the emotional valence is connected to the motivational leadership, the hemispheric differences we mentioned on the valence state.

$$Valence = \alpha F4/\beta F4 - \alpha F3/\beta F3 [Ramirezetal, 2012] \quad (2)$$

3) Dominance: It is characterized by an increase in the ratio beta / alpha activity in the frontal lobe and an increase in beta activity in the parietal lobe. [26](3)

$$Dominance = (\beta FC6/\alpha FC6) + (\beta F8/\alpha F8) + (\beta P8/\alpha P8) \quad (3)$$

To extract the emotion features arousal, valence and dominance, we presented the following algorithm.

4) Features Extraction Algorithm:
- Loading the CSV file
For each data of the signal: (treatment of 20 s of the signal)
- Applying the FFT filter on the signal of electrodes
- Construction of the two pass band filter Alpha and Beta
- Applying the passband filter on the different electrodes
- Computing the values of Arousal, valence and dominance

$$Arousal = \alpha(AF3 + AF4 + F3 + F4)/\beta(AF3 + AF4 + F3 + F4)$$

$$Valence = \alpha F4/\beta F4 - \alpha F3/\beta F3$$
$$Dominance = (\beta FC6/\alpha FC6) + (\beta F8/\alpha F8) + (\beta P8/\alpha P8)$$

End For

- Clustering by fuzzy c-means

5) Projection of emotions in the plan Arousal Valence and Dominance: As a result of the feature extraction phase, we projected seven emotions that are : neutral, joy, sadness, fear, anger, disgust and surprise on the arousal, valence and dominance plan. The results are described in the following figure.

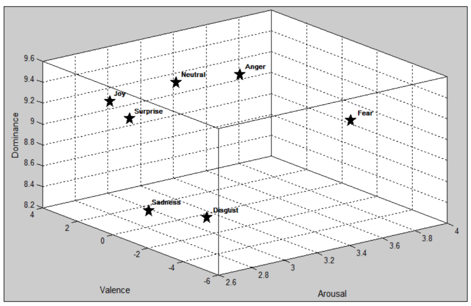


Figure 8. Emotions on the arousal, valence and dominance plan

D. Fuzzy logic classification

In this section, we resort to classify EEG signals. We use the techniques of fuzzy logic. The technique used is that of Mamdani (Figure9).
We have three inputs: *arousal* (Figure 10), *valence* (Figure 11), *dominance* (Figure 12), and the emotion is the output variable.

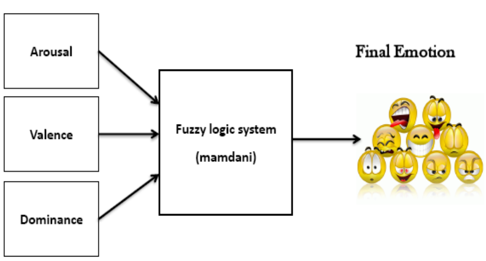


Figure 9. Fuzzy logic system

Each input variable has three membership functions: *Small*, *Medium* and *Large*.

The output "emotion" include 7 fuzzy sets according to the 7 emotions employed in our application : disgust, joy, surprised, sadness, fear, anger and neutral (Figure 13).
We presented in the following, a fuzzy rules.

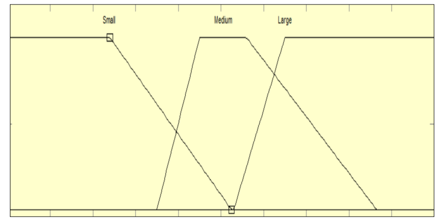


Figure 10. Input variable "Arousal"

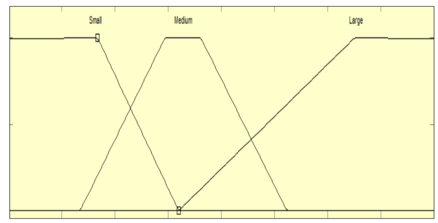


Figure 11. Input variable "Valence"

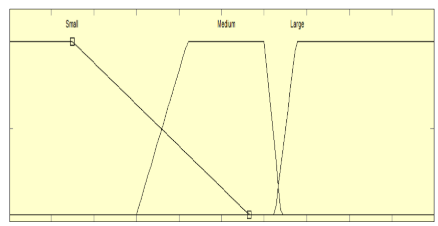


Figure 12. Input variable "Dominance"

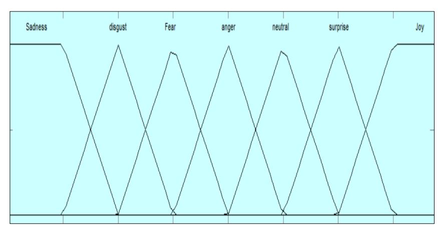


Figure 13. Output variable "emotion"

Fuzzy Rules

The fuzzy rules are presented as follows :

1) *if (arousal is Medium) and (valence is Large) and (dominance is Medium) then (emotion is Joy)*
2) *if (arousal is Medium) and (valence is Large) and (dominance is Medium) then (emotion is Joy)*
3) *if (arousal is Medium) and (valence is Small) and (dominance is Small) then (emotion is Disgust)*
4) *if (arousal is Medium) and (valence is Medium) and (dominance is Medium) then (emotion is Neutral)*
5) *if (arousal is Small) and (valence is Medium) and (dominance is Medium) then (emotion is Surprise)*
6) *if (arousal is Large) and (valence is Medium) and (domi-*

nance is Large) then (emotion is Anger)

7) *if (arousal is Large) and (valence is Small) and (dominance is Large) then (emotion is Anger)*
8) *if (arousal is Small) and (valence is Small) and (dominance is Small) then (emotion is Sadness)*
9) *if (arousal is Medium) and (valence is Medium) and (dominance is Large) then (emotion is Neutral)*
10) *if (arousal is Small) and (valence is Medium) and (dominance is Large) then (emotion is Surprise)*
11) *if (arousal is Large) and (valence is Small) and (dominance is Medium) then (emotion is Fear)*
12) *if (arousal is Small) and (valence is Large) and (dominance is Medium) then (emotion is Surprise)*
13) *if (arousal is Small) and (valence is Large) and (dominance is Large) then (emotion is Surprise)*
14) *if (arousal is Small) and (valence is Small) and (dominance is Medium) then (emotion is Sadness)*

E. Analysis process

To execute the fuzzy classifier, we use the “Fuzzy logic controller” included in the Simulink library (Figure 14). In this application, the Simulink bloc of EEG signals analysis contains a matlab function ***Function1***. The role of this function is to retrieve the file containing the EEG signal, perform the fast Fourier transform on this signal, applying a band-pass filtering to extract the alpha and beta waves of the concerned electrodes, then extract the characteristics of the signal by calculating the valence, arousal and dominance.
The three outputs of this function will be the inputs to the fuzzy logic controller, that will classify the characteristics of the generated signal and generate the emotion of the test subject.

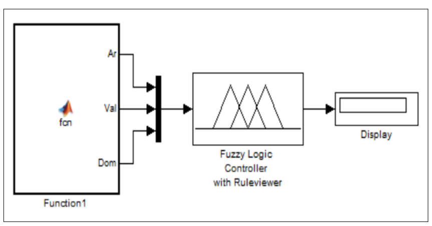


Figure 14. Simulink bloc of EEG signals analysis

Recognition rates

We validated our system on a set of test samples. As a result of the analysis phase, we obtain a rate of recognition favorable for the emotions neutral, joy, sadness and fear. For the emotions anger, disgust and surprise, the rate of recognition is acceptable and susceptible to be improved (Table II).

Table II
EMOTION RECOGNITION RATE

Emotion	Recognition rate
Joy	71,42%
Sadness	71,42%
Anger	64,28%
Fear	78,57%
Neutral	100%
Disgust	64,28%
Surprised	53,57%

IV. CONCLUSION

We proposed in this paper, an emotional recognition system based on physiological signals. We adopt the seven basic emotions that are: neutral, joy, sadness, fear, anger, disgust and surprise. An experiment was conducted to verify the feasibility of the proposed system. This experience has allowed us to acquire EEG signals and to create an emotional database. For this, we used the Emotiv EPOC headset. Thereafter, we choose the fuzzy logic techniques to classify the EEG signals and to analyze the results.

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