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Fuzzy Logic-Based System for Stress Detection

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Abstract:

In this paper, a fuzzy logic-based system is developed for stress detection. This system provides an efficient method for finding the stress levels among individuals. This system uses multiple symptoms and parameters such as age, heart rate, skin conductance, respiratory rate, voice pitch, body temperature and blood pressure. The system understands these input parameters and classify individual's state of stress. The objective of this work is to study and review the existing systems for stress levels among individuals and develop a novel fuzzy logic-based system for the same. The fuzzy logic approach offers several advantages over conventional systems by accommodating the uncertainty and variability inherent in stress responses. It is capable of handling overlapping symptoms and subtle changes in physiological and emotional states, making it more accurate and responsive. The effectiveness of the system is found through performance evaluation in terms of accuracy.

Keywords: Fuzzy system, Stress detection, Physiological signals, Fuzzy logic

1. Introduction

Classification and assessment of stress is one of the prominent areas of research. Fuzzy logic-based system is the powerful tool in addressing the challenges related to stress evaluation. In (Bulbul's, 2022) research work, different types of membership functions are considered to increase the performance of the system. With this, system is able to achieve more accuracy. Similarly, (Putro, 2016) investigates physiological responses to stress, applying fuzzy logic to interpret intricate bio-signals. (Yagci's, 2022) a master's thesis also considered fuzzy-logic based systems for stress management in an effective way. In this thesis, authors have also explored various applications where fuzzy logic is useful and have promising results. Additionally, (Dobbins and Fairclough, 2019) investigated into real-time stress detection, using fuzzy rule-based systems to monitor stress during activities such as commuter driving. Together, these studies underscore the versatility and effectiveness of fuzzy logic in both the theoretical understanding and practical implementation of stress detection and management.

2. Literature Review

In this section, the various studies based on fuzzy logic-based development and applications in stress detection are explored.The key findings are mentioned below:

(Fajrin, et al., 2024)first explained the different challenges which are being faced during the research carried out for stress detection. Even there are challenges due to complexity and variations in the

physiological parameters. To deal with these challenges, authors developed a fuzzy logic-based system for accurate diagnosis of stress levels. Several physiological factors are being used in this work for better performance. The model's reliability is improved by using mainly two parameters which are blood pressure and body temperature.

The study by (de Santos Sierra et al., 2011)designed a system using fuzzy logic and physiological signals for stress detection. The physiological parameters which are mainly being considered in this work are heart rate, skin temperature and electrodermal activities. The authors showed the impact of these considered physiological parameters on the stress level detection, which is better as compared to considering individual parameter. This work has achieved promising results in stress detection among humans.

(Zalabarria et al., 2017)developed a fuzzy logic-based system for detection of acute stress episodes and chronic stress patterns. In this work, the different parameters which are being used, are heart rate variability, respiratory patterns and skin conductance. The authors showed that their approach to stress detection is helpful in providing accurate performance.

The research work by (El-Samahy et al., 2015) is based on designing a fuzzy-logic based system for managing the mental stress among individuals. The parameters used in this work are heart rate and skin conductance. This work also suggests relaxation techniques and feedbacks to the users. Thus, the mental well-being among individuals is improved with this kind of system. This system is also helpful in high pressure work situations.

(Mokhayeri& Akbarzadeh-T, 2011)developed a soft computing-based system for mental stress detection in real time situations. It is a novel approach based on physiological signals in identifying stress levels. This work is more focused towards the use of fuzzy logic, neural networks and genetic algorithms for analysing physiological data such as heart rate and skin conductance. The author showed the better values in performance by using the soft computing techniques.

(Uma and Rama, 2020) made use of parameters such as heart rate, blood pressure and skin temperature for classification of stress levels among individuals. In this work, these parameters are converted into linguistic terms such as low, moderate and high during the fuzzification phase. The main aim of this work is to deal with subjective nature of stress and its modelling using machine learning techniques. This work is reliable and adaptive for the stress detection.

(Salazar-Ramirez et al., 2018) presented an enhanced fuzzy algorithm for stress detection among individuals. The use of advanced signal processing techniques is also made in this research work. A combination of enhanced fuzzy algorithm and advanced signal processing techniques resulted in better accuracy and reliability for stress detection. The physiological signals used in this work are heart rate, respiratory rate and skin conductance. In physiological data, there were some issues such as noise and variability. To deal with these issues, the techniques such as wavelet transforms and PCA are sued in this work.

(Gulhane et al., 2011)presented a method for stress detection using voice characteristics. Basically, this system is designed for stress detection among university students. The reason for using voice characteristics is that the exam stress is always reflected in the speech pattern of a person. This

system is collecting speech of a student before and after the viva voce examination. The features considered in this work are loudness, fundamental frequency, zero crossing rate and power spectral density. Further for the classification, the fuzzy logic is used in this work.

(Cantara & Ceniza, 2016)developed a system for stress level detection during computer usage. It helps the users in managing their screen time. For the development of this model, the authors conducted many interviews in the pre development phases for the purpose of data collection and in the post-development phases, the students and faculty of the universities participated as respondents. For the testing purpose, heart rate sensors and galvanic skin response sensors are used. The whole work is based on fuzzy logic and this work achieves accuracy of 72%.

(Airij, 2015)designed a human stress detection device for autistic children. Autistic children, who may experience tantrums or seizure activities without visible symptoms, can benefit from early detection of rising stress levels. The device serves as a valuable tool for parents and healthcare providers to anticipate and manage potential harmful behaviours in such children.The results showed that the prototype was able to measure stress levels with high accuracy and efficiency, regardless of the participants' age or gender.

3. Methodology

The first step for development of fuzzy logic-based system for stress detection is to collect the data. The data is collected from various experts in medical domain and with their expertise, the input and output parameters are finalized. These input and output parameters are shown in Table I.

Table 1 Input and Output parameters

S No.	Parameter	Title
1	Input	Age
2	Input	Heart Rate
3	Input	Skin Conductance
4	Input	Respiratory Rate
5	Input	Systolic Blood Pressure
6	Input	Diastolic Blood Pressure
7	Input	Voice Pitch
8	Input	Body Temperature
9	Output	Stress Level

The input parameter age is having four linguistic terms which are children, young adults, middle aged adults and older adults. Similarly, for heart rate, the terms considered are normal elevated and extremely elevated. For skin conductance, the terms are low, moderate and high. The respiratory rate is divided into four categories which are low, normal, moderateand high respiratory rate. The systolic and diastolic blood pressure has classes such as low, normal, high and very high. The voice pitch is divided into three terms such as low, moderate and severe. The body temperature also has three classes i.e. Low, moderate and high. The output parameter stress levels considered in this work are relaxed, mild stress, moderate stress and severe stress. These terms are shown in Table II.

Table II Categories of Input and Output Parameters

S No.	Title of Parameter	Type	Categories
1	Age	Input	Children, young adults, middle aged adults, older adults
2	Heart Rate	Input	Normal, elevated, extremely elevated
3	Skin Conductance	Input	Low, moderate, high
4	Respiratory Rate	Input	Low, normal, moderate, high
5	Systolic Blood Pressure	Input	Low, normal, high, very high
6	Diastolic Blood Pressure	Input	Low, normal, high, very high
7	Voice Pitch	Input	Low, moderate, severe
8	Body Temperature	Input	Low, moderate, high
9	Stress Level	Output	Relaxed, mild stress, moderate stress and severe stress

A sample of membership functions for the input parameters are shown with the help of figure Iand figure II. The developed fuzzy logic-based system is having eight inputs and one output. Its structure is shown in figure III. This research work is based on Mamdani fuzzy model.

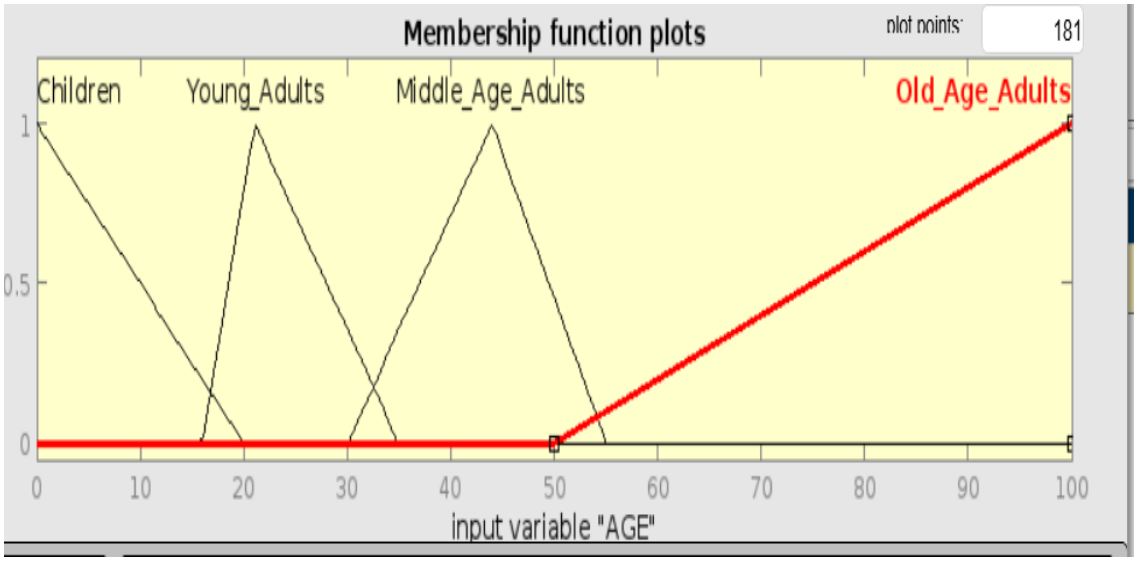

Fig I Membership functions for 'age'

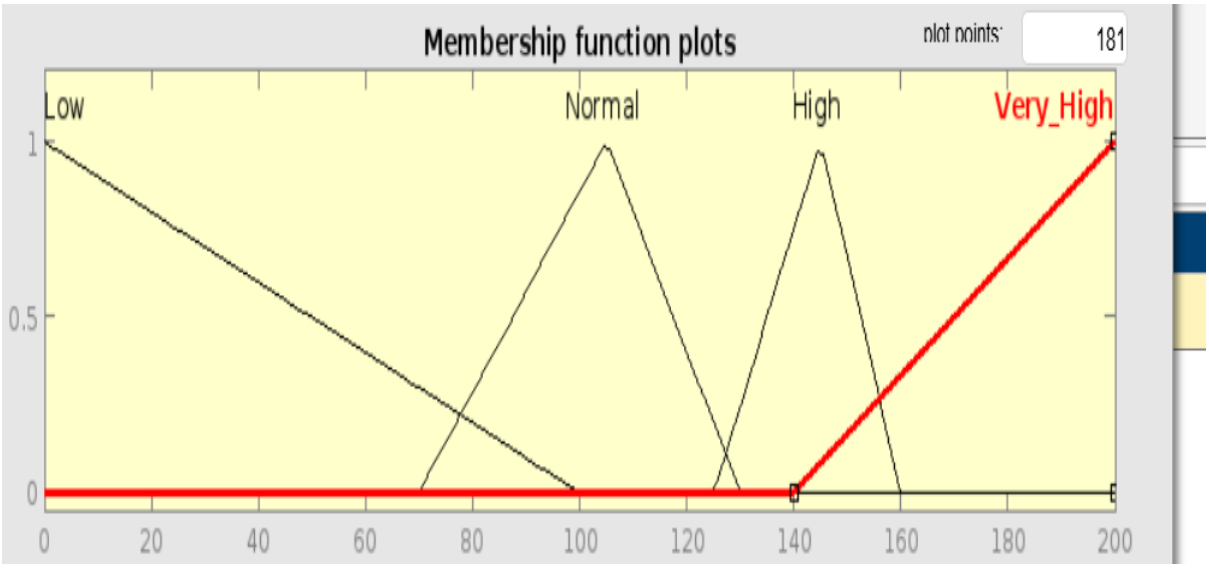

Fig II Membership functions for 'Systolic blood pressure'

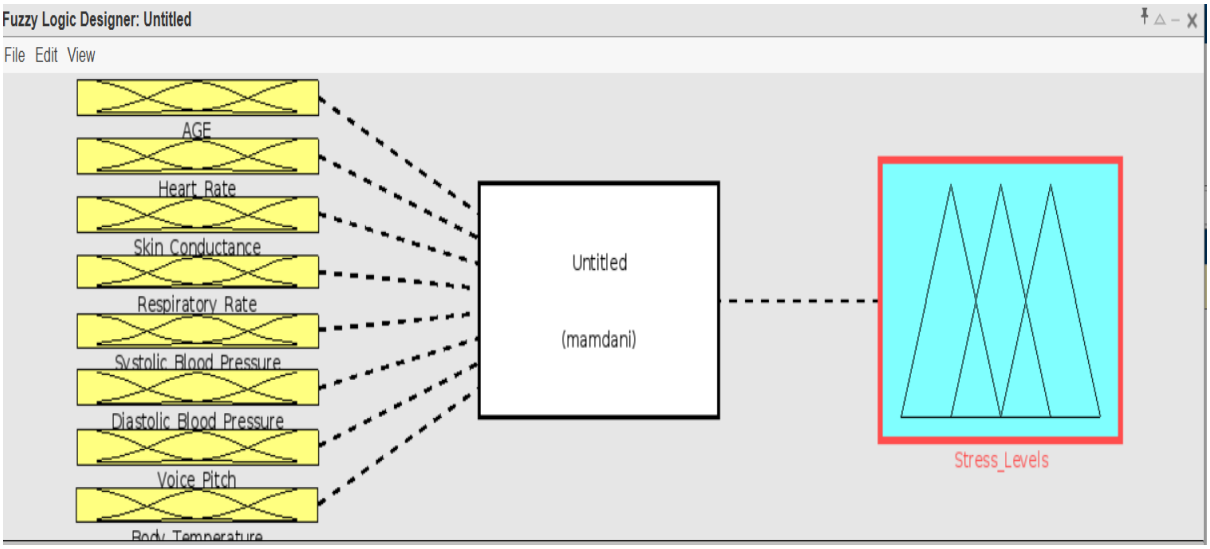

Figure III Structure of developed system

4. Results and Discussion

A total number of 160 patients' data is tested on this developed system. The output from the system is matched with the actual output and then a confusion matrix is generated with the help of data input to this developed system, actual output and the output from this developed system. Further on the basis of true positive rate, false positive rate, true negative rate and false negative rate, the performance of developed system is calculated in terms of accuracy and it is found that the accuracy of the developed system is 91% approximately. This developed system can help the doctor and patient as a supporting tool in the diagnosis of stress level among individuals. Although the doctor's decision will be considered as final but this tool can also give decision as an expert. It can be a useful

tool foe expert regarding the detection of stress levels among humans. This developed fuzzy system can be useful in developing areas, villages and small towns where doctor to patient ratio is very small and patients suffering from stress don't get medical assistant and expert advice.

5. Conclusions

The diagnosis of stress levels among individuals is a very difficult task. There is always a possibility of misdiagnosis which can lead to wrong treatment. In this work, a fuzzy logic-based system is developed for stress level diagnosis among individuals. Only computer systema and software are required to implement this system. It is much useful in areas where there is no hospital or medical experts. This is a very efficient, less time consuming and more accurate method to calculate the stress levels among humans.

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