MICROCONTROLLER-BASED HUMAN STRESS DETECTION SYSTEM USING FUZZY LOGIC

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Gratefully dedicated to my family, my mentor and friends. I couldn’t have completed this without you all. Thank you for your love, support and guidance.

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ABSTRACT

This research presents a working prototype of human stress detection device capable of measuring human stress level perhaps also for autistic children. The device records human physiological signals in order to determine the mental stress level. High stress levels may be dangerous especially for certain individuals such as autistic children who are unable to express mounting levels of stress. The autistic children can have frequent tantrums and seizure activities without any visible signs or symptoms, making this device a useful tool for parents and doctors to anticipate any harmful behaviours of autism. This research focuses on the hardware and software development of a low cost microcontroller-based stress detection system prototype. The prototype was designed using Arduino Mega platform and tested with 35 clinical patients. The data from two sensors is fed to the microcontroller using its two analog input pins and the sensor data is sent to the fuzzy logic module which is pre-programmed into the microcontroller for further processing. The output of the prototype is displayed on the LCD module connected to five digital pins of the microcontroller. In addition, three LEDs are connected to three digital pins of the microcontroller which light up in accordance with the stress levels. In order to test the developed system, an experiment was designed which requires subjects to perform mental calculations to solve arithmetic problems. The experiment involves three phases: low stress phase (P-1), medium stress phase (P-2) and high stress phase (P-3). The results showed that the prototype measures the stress levels with high degree of accuracy and efficiency. Apart from that, the results also highlighted that the stress neither depends on age nor gender.

ABSTRAK

Kajian ini membentangkan prototaip alat pengesan tekanan minda manusia yang digunakan untuk mengukur tahap tekanan manusia dan juga untuk kanak-kanak autistik. Peranti berfungsi untuk merakam isyarat fisiologi manusia bagi menentukan kadar tekanan. Tahap tekanan yang tinggi mungkin berbahaya terutamanya untuk individu tertentu seperti kanak-kanak autistik dimana mereka tidak mampu untuk menyatakan dengan jelas perasaan atau tekanan yang dihadapi. Kanak-kanak autistik boleh mempunyai tantrum yang kerap dan bersikap agresif secara drastik tanpa sebarang tanda yang boleh dikesan dengan awal, menjadikan peranti ini alat yang berguna untuk ibu bapa dan doktor untuk menjangka tingkah laku yang berbahaya dari penghidap autisme. Kajian ini memberi tumpuan kepada pembangunan perkakasan dan perisian mikropengawal kos rendah berasaskan prototaip sistem pengesan tekanan. Prototaip ini telah direka menggunakan platform '*Arduino Mega'* dan kemudian diuji dengan 35 orang pesakit klinikal. Data daripada dua sensor disalurkan ke mikropengawal dengan menggunakan dua pin input analog dan data tersebut dihantar ke modul logik kabur (Fuzzy Logic) yang telah diprogramkan dalam mikropengawal untuk proses seterusnya. Output prototaip ini dipaparkan pada modul paparan kristal cecair (LCD) yang disambungkan dengan lima pin digital mikropengawal. Di samping itu, tiga diod pemancar cahaya (LED) disambungkan kepada tiga pin digital mikropengawal yang menyala mengikut tahap tekanan. Bagi menguji prototaip yang dibangunkan, pesakit dikehendaki menyelesaikan masalah aritmetik dengan melakukan teknik pengiraan secara mental atau congak. Eksperimen ini melibatkan tiga fasa iaitu fasa tekanan rendah (P-1), fasa tekanan sederhana (P-2) dan fasa tekanan tinggi (P-3). Keputusan menunjukkan bahawa tahap tekanan dapat diukur dengan tepat dan cekap. Selain itu, kajian ini merumuskan bahawa tekanan tidak bergantung kepada umur atau jantina.

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ANS	-	Autonomic Nervous System
ASD	-	Autism Spectrum Disorder
BVP	-	Blood Volume Pulse
ECG	-	Electrocardiography
EEG	-	Electroencephalography
eFLL	-	Embedded Fuzzy Logic Library
FLM	-	Fuzzy Logic Module
GSR	-	Galvanic Skin Response
LCD	-	Liquid Crystal Display
MRI	-	Magnetic Resonance Imaging
PPG	-	Photoplethysmography
REI	-	Rhythmic Entertainment Intervention
SC	-	Skin Conductance
SDS	-	Stress Detection System
SVM	-	Support Vector Machine

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CHAPTER 1

INTRODUCTION

The present research aims at developing a working prototype in order to detect stress by using Arduino Mega. The device makes use of human physiological signals measured with the help of various electronic sensors, along with a fuzzy logic decision-making system to calculate the stress levels accurately.

1.1 Project Background

The term “stress” basically refers to the physical reaction of a person in response to an unpleasant/dangerous environmental condition or stimuli [1] as shown in figure 1.1. Over-stress has proven to be one of the major factors contributing to several serious health problems such as high blood pressure, hypertension, cardiovascular diseases and panic attacks [2].

Figure 1.1: Stress response to a stressor (stimuli)

According to a research, stress is categorized into three types namely; *acute stress, episodic acute stress* and *chronic stress* [3]. Acute stress and episodic acute stress do not cause much damage as they are for a short period making people anxious and frightened but are easily treatable [3]. However, on the other hand, the chronic stress lasts longer and causes serious complications depending upon the type of patients [4, 5]. As a result of stress, stress-response hormones such as epinephrine, norepinephrine and cortisol are secreted which can be a contributing factor in cardiac abnormalities[5] along with some other serious complications. Moreover, high levels of stress can cause commonly known mental disorders namely; depression and anxiety[4].

The system proposed in this project can non-invasively detect stress levels in humans through some physiological signals such as skin conductance, temperature, heart rate and blood pressure measured with the help of various electronic sensors.

1.2 Problem Statement

Nowadays, everybody is stressed, however, the type of stress dealt within the very research and complications caused by it are limited to a specific group of people. The children suffering from Autism Spectrum Disorder (ASD) are the focus of study. According to a research, every 1 in 166 births suffers from ASD [6]. Autistic children can have seizures, panic attacks, suicide thoughts, commit homicide and can also be harmful to their surroundings when they are under stress. But there are no visible signs or warnings when under high stress.

Currently, low cost commercial device for detecting stress is not available. Nonetheless, devices to monitor temperature, heart rate and variations in respiration exist. Furthermore, even such high-end devices are devoid of detecting stress on their own. For instance heart rate variation alone is incapable of detecting stress. There is a dire need for a stand-alone device that can detect stress by using a couple of physiological signals and process them further in order to decide whether the person is under stress or not. Such device will possibly help the parents and doctors to anticipate harmful behaviours of autism.

1.3 Research Objective

The objectives of this research are:

1) To study the fuzzy logic and familiarize with embedded fuzzy logic library (eFLL) for Arduino.
2) To interface electronic sensors with Arduino Mega board.
3) To measure physiological signals accurately using electronic sensors.
4) To develop a prototype of human stress detection system.
5) To test the prototype functionality on intended subjects.

1.4 Research Scope

The scope of this research covers development of a human stress detection system prototype consisting of Arduino Mega 2560 microcontroller board, LCD display, pulse sensor, grove GSR sensor and LEDs as indicators. AtMega2560 microcontroller is the main processing unit for the entire system and is programmed using Arduino IDE.

1.5 Research Contributions

Prior research has shown various approaches of stress detection but unfortunately, there is no device available till today which is accurate and low cost. This research aims to develop a prototype of human stress detection system which is capable of accurate measurement of human stress levels at a very low cost.

1.6 Thesis Organization

This thesis consists of six chapters. The first chapter discusses the background, problem statement, intended objectives and the scope of this research.

Chapter 2 includes the literature review focused on techniques, experimental setup, results and drawbacks found in previously built devices for stress detection purpose. In chapter 3, the working principles of the sensors and other components are discussed. Later in chapter 4 the design of the system is discussed in terms of interfacing the sensors, designing output display along with an indicator and designing of the fuzzy logic system. The next chapter presents the results obtained from the developed stress detection prototype and discussion on the results. The problems and challenges faced during this research are also included in chapter 5. Finally, a conclusion of the entire research and some recommendations for future improvements are given in chapter 6.

REFERENCES

[1] D. Carneiro *et al.*, “Multimodal behavioral analysis for non-invasive stress detection,” *Expert Systems with Applications*, vol. 39, no. 18, pp. 13376-13389, Dec 15, 2012.

[2] J. Wijsman *et al.*, “Towards mental stress detection using wearable physiological sensors,” *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 1798-1801, 2011.

[3] J. Bakker, M. Pechenizkiy, and N. Sidorova, “What's Your Current Stress Level? Detection of Stress Patterns from GSR Sensor Data,” pp. 573-580, 2011.

[4] A. Fernandes *et al.*, "Determination of stress using blood pressure and Galvanic Skin Response." pp. 165-168. *International Conference on Communication and Network Technologies (ICCNT).*

[5] G. S. Everly, *et al.*, “A Clinical Guide To The Treatment Of The Human Stress Response,” pp. 3-51, 2013.

[6] A. S. Hamid BehnamA, *et al.*, “Analyses of EEG background activity in autism disorders with fast Fourier transform and short time Fourier measure,” *International Conference on Intelligent and Advanced Systems 2007*, pp. 1240-1244, 2007.

[7] V. J. Madhuri, *et al.*, “Stress Management Using Artificial Intelligence,” *2013 Third International Conference on Advances in Computing and Communications*, pp. 54-57, 2013.

[8] I. Goel, and D. Kumar, “Design and Implementation of Android Based Wearable Smart Locator Band for People with Autism, Dementia, and Alzheimer,” *Advances in Electronics*, vol. 2015, pp. 1-8, 2015.

[9] P. Maureen Grissom, Neuropsychologist Developmental Assessment & Intervention Center Bedford Hills, NY 10507 “Autism Spectrum Disorders,” April 15, 2013.

[10] C. o. R. E. I. Strong Institute, “Autism Case Studies.”

[11] T. Tamura *et al.*, “Wearable Photoplethysmographic Sensors—Past and Present,” *Electronics*, vol. 3, no. 2, pp. 282, 2014.

[12] G. Q. Zhao *et al.*, "A Pervasive Stress Monitoring System Based on Biological Signals," *2013 Ninth International Conference on Intelligent Information Hiding and Multimedia Signal Processing (Iih-Msp 2013)*, pp. 530-534, 2013.

[13] Mohammad S. Sharawi, *et al.*, "Design And Implementation Of A Human Stress Detection System: A Biomechanics Approach," *Proceeding of the 5th International Symposium on Mechatronics and its Applications (ISMA08), Amman, Jordan,*, May 27-29, 2008.

[14] S. K. G. Ashish Patel, Qamar Rehman, M. K. Verma, "Application of Fuzzy Logic in Biomedical Informatics," *Journal of Emerging Trends in Computing and Information Sciences*, vol. 4, pp. 57-62, 1 Jan, 2013.

[15] V. J. Madhuri, M. R. Mohan, and R. Kaavya, "Stress Management Using Artificial Intelligence," *2013 Third International Conference on Advances in Computing and Communications (Icacc 2013)*, pp. 54-57, 2013.

[16] K. R. Ruggeri., "Bayesian networks," *Encyclopedia of Statistics in Quality & Reliability*, 2007.

[17] F.-T. Sun *et al.*, "Activity-Aware Mental Stress Detection Using Physiological Sensors," *Mobile Computing, Applications, and Services*, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering M. Gris and G. Yang, eds., pp. 211-230: Springer Berlin Heidelberg, 2012.

[18] K. D. Tong. S, "Support Vector Machine Active Learning with Applications to Text Classification," *Journal of Machine Learning Research*, pp. 45-66, 2001.

[19] N. C. T. S. Furey, *et al.*, "Support vector machine classification and validation of cancer tissue samples using microarray expression data," vol. 16, pp. 906-914, 2000.

[20] J. Z. J. Zhai *et al.*, "Realization of stress detection using psychophysiological signals for improvement of human-computer interactions," *Proceedings. IEEE SoutheastCon, 2005.*, pp. 415-420, 2005.

[21] A. De Santos Sierra *et al.*, "A stress-detection system based on physiological signals and fuzzy logic," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 10, pp. 4857-4865, 2011.

[22] a. D. S. Sierra, *et al.*, "Two Stress Detection Schemes Based on Physiological Signals for Real-Time Applications," *Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2010 Sixth International Conference on*, pp. 1-4, 2010.

[23] C. K. Feng-Tso Sun, *et al.*, "Activity-Aware Mental Stress Detection Using Physiological Sensors," *Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, pp. 211-230, 2012.

[24] J. Allen, “Photoplethysmography and its application in clinical physiological measurement,” *Physiol Meas*, vol. 28, no. 3, pp. R1-39, Mar, 2007.

[25] S. A. b. S. Noh, “Galvanic Skin Response,” *Final Year Project - UniKL BMI*, 15-July, 2015.

[26] A. Mega, “2560: http://Arduino. cc/en,” *Main/ArduinoBoardMega2560*.

[27] Nokia5110, "PCD 8544, *48 x 84 pixels matrix LCD controller/driver*. Philips”

[28] C. W. Sheng, “Embedded System For Stress-Detection Based On Physiological Signals And Fuzzy Logic”, *Universiti Teknologi Malaysia, Final Year Project Thesis*, 2014.