FPGA-based smart chair recognition system using flex sensors

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***Abstract*—Sitting is the most common status of modern human beings. Many people are sitting with bad posture which may lead to postural pain. Especially for people with short term-disabilities, sitting in the right posture is very important. In this research, we propose a posture recognition system on an office chair that can categorize different health-related sitting postures to prevent harm from bad sitting postures. The smart chair system consists of an array of five flex sensors integrated into a FPGA board. The output of the system is the classification result of the sitting posture. In this paper, several health-related sitting postures are selected. The sitting postures are: 1-sit straight; 2-left recline; 3-right recline; 4-lounge;5-lean backward; 6-cross left leg; 7-cross right leg. The proposed reconfigurable framework will be integrated as part of smart ambient assisted living with user-centered health monitoring system.**

***Index Terms*—Smart Chair, Recognition System Using Flex Sensors, Basys 3 Board, FPGA board.**

I. Introduction

People are sitting on an average of 13 hours a day. Bad sitting postures may bring health problems like postural pain, especially for those whose job requires a prolonged period of sitting, such as students [2]. However, improper sitting for a long time may increase the risk of obesity and metabolic diseases. Moreover, it may cause musculoskeletal disorders such as back pain with deteriorating lung function, low back pain, or injury [1], [3]. A smart chair solution in terms of sensing and processing for sitting posture recognition is proposed to address the earlier-mentioned problems. In this research, we propose a posture recognition system on an office chair that can categorize different health-related sitting postures to prevent harm from bad sitting postures. The smart chair system consists of an array of 5 sensors integrated into an FPGA board; The output of the system is the classification result of the sitting posture. This project will use flex sensors which will work in the voltage divider rule, and the sensor readings will be applied to the XADC ports of the FPGA Board which will be programmed to convert the values to bit information. The values will be quantified with respect to the maximum and minimum limits. Then these values will be used to classify the sitting posture as healthy or unhealthy. Figure 1 shows the block level overview of the proposed framework.

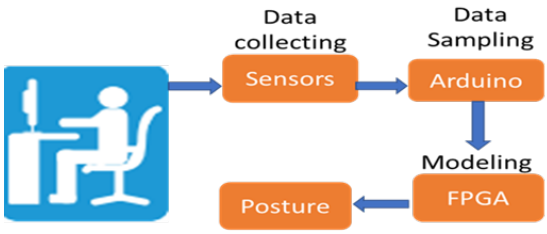

Fig. 1. System block of the sitting postures recognition system

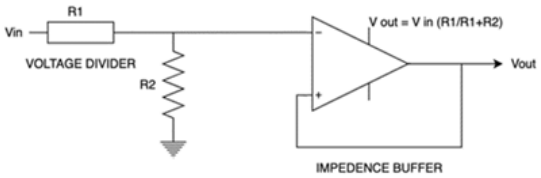

Fig. 2. Circuit for flex sensor

The main idea of our project is to focus more on creating a practical smart chair system for *sitting* posture detection. The RTL (register transfer level) design to our system follows a two-step process, combinational and sequential designs. The first step is to figure out the current sitting posture and the second step is to convert that posture as a sitting pattern using the sensor circuit. We assigned 5 registers on FPGA board and test each register signal if it received "1" which means the person on the chair and "0" when there is no pressure on the sensor.

II. Broad Perspective of the Proposed Framework

The smart chair recognition system has 5 flex sensors integrated into a microcontroller, Arduino, which is then connected to a FPGA board. A flex sensor works in the principle of the voltage division rule. A flex sensor is a bend sensor that is a variable resistor, and its value depends upon the pressure applied to it. Whenever pressure is applied to the sensor, the resistance value of the sensor is changed and so is the voltage output. For reflecting this change in digital form

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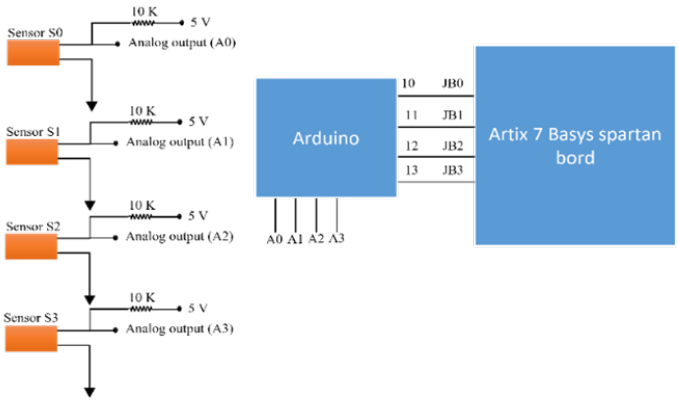

Fig. 3. Circuit Diagram for our proposed system

S0	S1	S2	S3	Output Status
0	0	0	0	No one sitting on the chair
1	0	0	0	The back is not on the chair
1	0	1	0	Justified the top of your back
1	1	0	0	Justified the bottom of your back
1	1	1	0	Good posture
1	1	1	1	Good posture

TABLE I
TRUTH TABLE OF THE POSTURE MONITORING SYSTEM

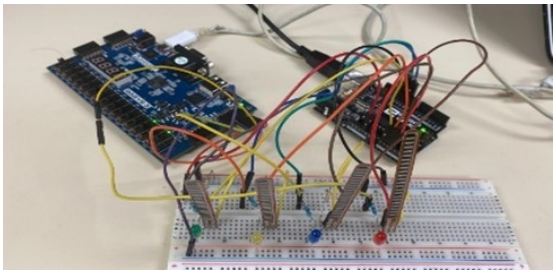

Fig. 4. Proposed system using Basys3 board and flex sensors

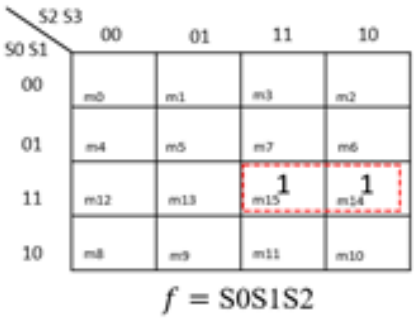

Fig. 5. Good posture states

(1's and 0's), the sensor is integrated with Arduino Uno. The Arduino is programmed to convert analog voltage to digital form. The digital outputs from all the sensors are connected to the FPGA board. Among our 5 sensors, one will be attached at the base of the chair, one at each arm position, and two of them at the back. The sensor on the base of the chair will be assigned as an enable input of our gate, since the system should turn on just when there is someone sits on the chair. This sensor along with other sensors will be used to define the posture of people in the chair. And the FPGA board will be used to classify good and bad postures which would help to differentiate the posture as suitable and unsuitable as per health requirement.

III. System Level Modeling of the Smart Chair

Arduino is used to convert the analog signals from the sensors for digital signals which are the input of FPGA board. For the main test, the body pressure distribution was measured from the sensors, the classification of data divided for three general categories, good posture, no body sitting on the chair and justify your back. FPGA is used for exploring sitting postures instantaneously, which can enhance the calculation time and power consumption of the hardware in order to classify sitting postures in real-world settings.

Primary state of our system (S0) takes the signal from bottom sensor on the chair which provide "1" if there is a person sitting on the chair or '0' if there is no input of the sensor. Moreover, S3 considered the state of sensor 4 which is on the chair arms, these sensors do not have effect on the health care of the person so that we considered them as a don't care logic. The top back sensor is shown in S1 state and S2 represents the bottom back sensor.

Table I shows the states and its interpretation in posture detection. The following K-Map analysis is an example that shows the output of FPGA for different status:

A. State 1. "Good posture"

This state is obtained when the person sits on the chair with a proper alignment and their back is straight resting on the chair. The interpretation is shown in figure 5. Our proposed system is presented in fig. 4, 10 K-ohm resistance has been added with sensor in serial combination. The Arduino and FPGA are connected via I2C.

IV. Conclusions and Future Research

A FPGA based smart chair was built using Basys 3 board. The smart chair recognition system consists of 5 sensors which helps it to identify the good and bad sitting posture. Furthermore, as future research, it can be developed for monitoring and assisting short-term disabilities by adding pattern recognition features.

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