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Research Paper

Limb flexion-extension counter using IR proximity sensor

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Abstract

People belonging to different age groups who suffered fractures, temporary limb paralysis, paraplegia and monoplegia and various stages of hypertension (High BP) need to carry out physiotherapy to regain motor control in the limb(s). So this limb flexion extension counter can assist the subject to exercise properly and independently recover with ease. This device will help to monitor parameters such as heart rate, temperature and limb flexion-extension counts. This device can detect the skin temperature while doing exercises using LM35 temperature sensor. The instrument has Arduino UNO as its microcontroller and four sensors mainly an IR heart rate sensor, LM35 temperature sensor, IR proximity sensor for limb flexion-extension counter. A cuff pressure sensor used for measuring the pressure applied to the cuff. The cuff is inflated and fixed the sensors to the upper arm. On flexing the lower arm, the IR proximity sensor generates a light output denoting a count which is displayed in the LCD display. The heart rate sensor and temperature sensor is used for assessing the subject's vital parameters while exercising. In conclusion doing more exercise causes rise in heart rate and if it goes beyond 90-100 beats per minute exercising should be stopped.

Keywords: Limb Flexion-Extension; Physiotherapy.

1. Introduction

There has been massive improvements in the field of physiotherapy. With the introduction of thermal and ultrasound diathermy specific improvements has been seen in making the life of individuals better. People who need to undergo physiotherapy are basically people belonging to various age groups recovering from fractures, limb surgeries, temporary limb paralysis and paraplegia etc. The parameters of vital importance to be monitored during exercising are heart rate and temperature. During exercising depending on the number of counts generated produces slight variations in temperature. The movement of limbs is in linear bidirectional motion thus excess body movement is not involved which in turn reduces interferences [2]. The microcontroller is used as an interface for connecting the other sensors which are a flexion-extension counter, a cuff pressure sensor, a heart rate/ pulse rate sensor and a temperature sensor. The main objective of this device is to help a subject to independently carry out his own exercises which are constrained to limb flexion and extension and to monitor one's vital parameters so that by avoiding the physiotherapist, the subject can himself chalk out his own routine and keep monitoring his progress independently. To be cost effective and efficient is of utmost importance as people should be able to accept this device and be able to use it. [3]. The age groups taken into consideration are mostly adults aged above 40 and also senior citizens (>60 years old). People having various stages of BP (normal, Hypertension, Stage 1, Stage 2). The hypertension BP ranges from 120-139 systolic and 80-89 diastolic and the number of counts is set 8-10. For stage 1 hypertension BP the heart rate increase above 90 bpm and systolic range is 130-149 and diastolic is 90-99, so count is decreased to 6-9. For Stage 2 hypertension systolic range is 160 and above and diastolic is 100 or higher, count is set at 5-8 to avoid increasing the heart rate.

2. Literature review

[1] proposed a context aware technology for self- monitoring once critical parameters and its importance for home and workplace environments and provides independency to the subject making them non dependable on others. [2] shows the various functions provided by wearable sensors and feedback straps which helped them to collect information regarding EMG and in various positions only constrained to upper extremity. In this the ELM algorithm used provided instant feedback obtained from the EMG signals and forwarded it to the strap. [3] used an experimental tool for showing the application of Pascal's law during dynamic compression of the muscle. Here they used strain gauges to measure the strain generated during application of muscle along the muscular tibialis anterior and took readings at 50,100,150 and 200 mg of Hg. The result obtained showed that the transducer inflation pressure was almost equal to that of the pressure of the leg. [4] used RULA or Rapid Upper Limb Assessment technique for assessing diseases related to upper limbs and its various implications upon postures such as sitting, standing etc. It also assesses the load taken by an individual. A code is generated which helps to minimise the risks of injury.

2.1. Materials & methods

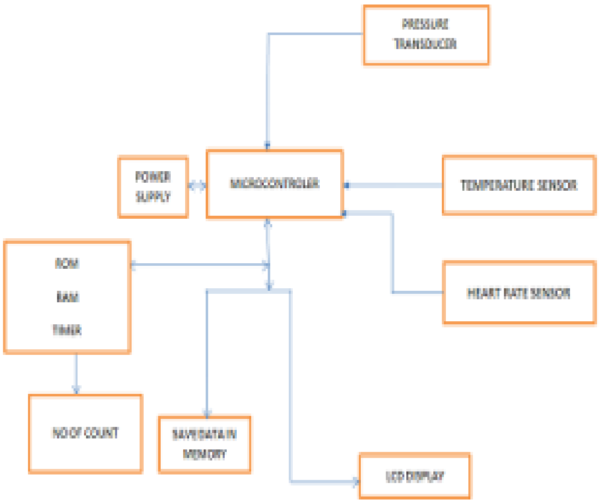

Fig. 1: Shows the Limb Flexion-Extension Counter Block Diagram.

Fig 1 working is Power supply of +5-8 V is given as biasing voltage to the microcontroller. The Pressure transducer measures the cuff pressure applied by the cuff and the temperature sensor LM35 is placed below the cuff to measure the variable change in temperature.[12] A heart rate sensor is used for measuring the heart rate of the subject by using plethysmography principle.[11] The microcontroller used here is ARDUINO UNO used for interfacing all the signals and carries out signal conversion techniques and sends the electrical signal to the display and memory unit (RAM and ROM) for storage. The IR proximity sensor counts the number of counts generated by the limb, sends it to the microcontroller and finally is directed to the LCD display where the number of counts, heart rate, and temperature and cuff pressure is shown for the user to observe. The function of each block in the block diagram is explained as follows:

2.2. Pressure transducer

The pressure transducer measures the pressure generated by the cuff and is converted to electrical signal to be read by the microcontroller. The sensor is ARDUINO based pressure sensor as shown in Fig 2. It has a small piezo crystal attached to the probes; so change in dimension upon receiving the pressure generated via the cuff causes the pressure signal to be converted to electric signal. This principle is known as piezoelectric effect.

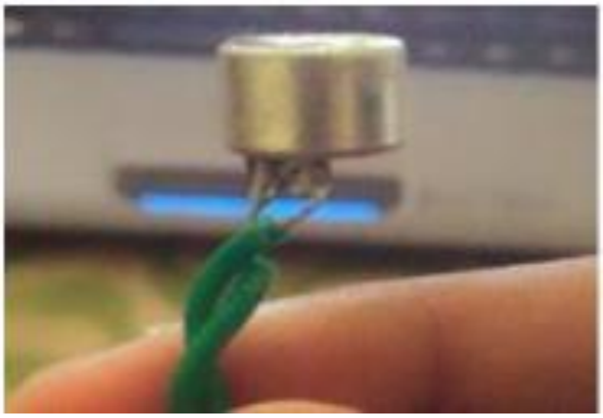

Fig. 2: Cuff Pressure Sensor.

2.3 Temperature sensor

The sensor used is LM35 as shown in Fig. 3 which is placed inside the cuff or measuring body temperature and has a temperature range between -55ºC and +150ºC. Operating voltage is around +5V-+8V.

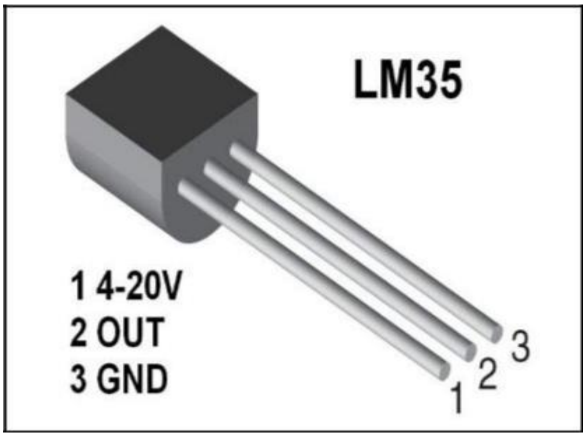

Fig. 3: Temperature Sensor LM35.

2.4. Heart rate sensor

This sensor shown in Fig. 4 is used for measuring the heart rate of the subject using IR plethysmography principle. It has a receiver on one end and a transmitter on the other end. So when biasing voltage of +5V is applied the IR light goes through the skin and reaches the receiver which is converted into electrical signal thus showing the final reading in the form of numbers in display

Fig. 4: Heart Rate Sensor SEN-11574.

2.5. IR proximity sensor

This sensor works using IR radiation which is an IR emitter and a photodiode placed side by side as shown in Fig. 5 the number of times the signal is obstructed generates the count of flexion and extension. When no signal is returning to the receiver which is placed alongside the transmitter, it denotes no obstruction in its proximity and if there is any obstruction then the signal is received by the receiver and is shown by the emission of red light.

Fig. 5: IR Proximity Sensor.

2.6. 16x2 alphanumeric LCD display

Fig. 6 is a 16x2 Alphanumeric Display. The signal from all the sensors is channelled through the microcontroller to this display board where the heart rate, number of counts, temperature and cuff pressure are shown. Operating voltage is around +4-5V. The display is integrated with the microcontroller, so the relay information is transferred directly to the display.

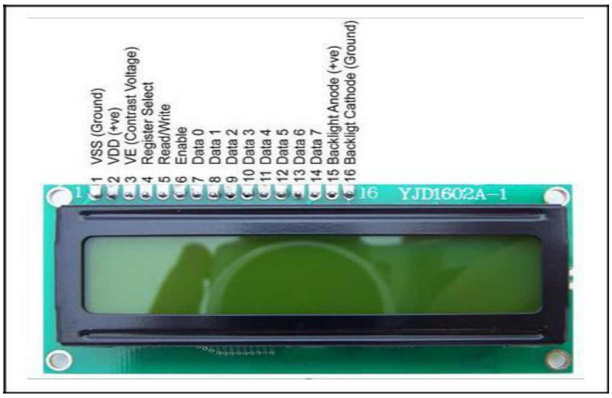

Fig. 6: LCD Alphanumeric Display HD44780.

2.7. Arduino uno microcontroller

Fig 7 is an ARDUINO UNO microcontroller board based on the Atmega328. It has 14 digital input output pins of which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button. It's being used because it's cheap and fast in processing and more importantly can incorporate various sensors without going through the process of compiling and burning unlike other microcontrollers.

Fig. 7: Arduino Uno.

2.8. Bulb and pressure cuff

The cuff is same as that of the one used in sphygmomanometer which is tied around the arm of the subject and the bulb is used for inflating the cuff which is simultaneously attached to the pressure sensor. The cuff is placed around the arm of subject and the temperature sensor is placed inside the cuff in direct contact with the skin and the heart rate sensor is placed between the index finger and thumb with the proximity sensor placed above the cuff surface at an angle inclined to the lower arm. To be noted this device is for people suffering from neural dysfunctions, heart disorders and recovering patients from major heart operations and also partial temporary paralysed people. The subject then inflates the cuff to a minimal pressure which is felt by the subject. Then the subject has to raise the lower arm very slowly towards the upper arm (flexion) and when the proximity sensor lightens and an angle is subtended then the arm is extended to its original position (extension). [10] The number of times this process is carried out, the count is generated and shown in display. An inflated cuff tied around an individual would create pressure on the arterial walls but while carrying out flexion and extension of limbs the variations in blood pressure wouldn't be much noticeable [1] since the pressure applied by the cuff is very less.

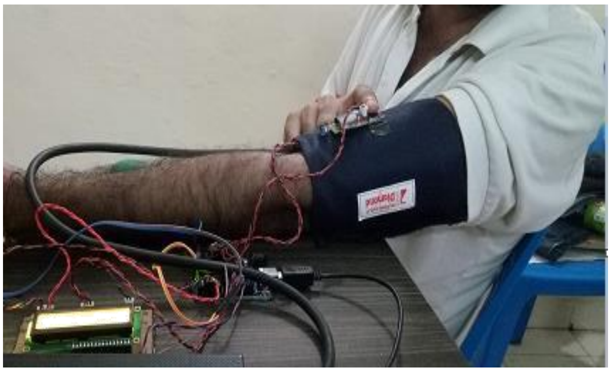

Fig. 8: Extension Movement of Forearm.

Fig. 9: Flexion Movement of Forearm.

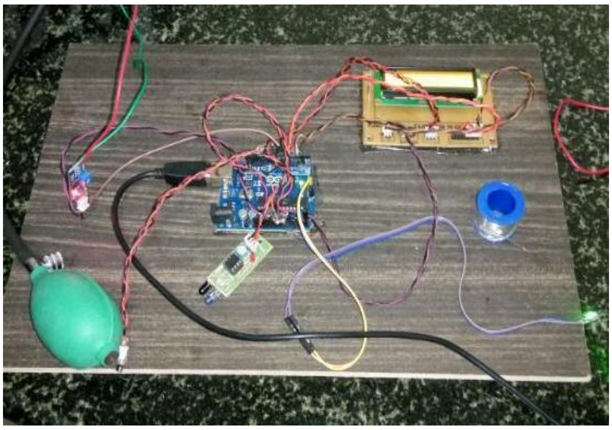

Fig. 10: Limb Flexion-Extension Circuit.

3. Results and discussion

Table 1: Experiment Performed on Different Subject for Various Counts (Different Age Groups)

S. No.	Age	Cuff Pressure (mm of Hg)	Heart Rate (bpm)	Body Temp (oC)	Count
1	25	40	72	34.0	12
2	28	40	73	34.2	12
3	32	40	74	35.5	11
4	30	40	75	35.8	11
5	37	40	77	35.1	10
6	41	40	82	36.2	9
7	44	40	85	36.5	9
8	41	40	90	37.0	8
9	57	40	93	37.2	7
10	65	40	97	37.7	6

From Table 1 we can draw the inference that after conducting the experiment for different counts upon the different subject at constant cuff pressure it was noted that the heart rate increased with increase in temperature and decreased with decreased in temperature. [14] It was also noted that at higher heart rate, the limb flexion-extension count decreased. Thus showing that at elevated heart rate levels the count tends to decrease. This experiment proved to be a success since for individuals who cannot use weights for training found a suitable substitute in the cuff pressure generated thus helping the user to rehabilitate. Individual didn't need any assistance for doing exercises. The cuff deflation rate was kept at 2mm of Hg to avoid progressive arterial damage [9]. The cuff pressure was kept always between 30-50 mm of Hg as it is the standard level for applying cuff pressure.

4. Conclusion

For adults between age group of 20-40 years of age the heart rate was measured to be around 72-80 beats per minute with number of counts ranging from 10-12. With increase in age i.e. above 40-60 years, heart rate is found above 80 beats per minute so the number of counts of limb flexion and extension was seen to be 8-10. Therefore we can conclude by saying that Change in temperature is directly proportional to change in heart rate and results in decrease of limb flexion and extension counts.

5. Acknowledgements
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