Journal of Physiotherapy & Physical Rehabilitation

Abdallah and Elmarakby, Physiother Rehabil 2016, 1:2
DOI: 10.4172/2573-0312.1000106

Research Aricle

OMICS International

Improved Training for Physical and Respiratory Therapists using System-on-Chip Technology

Abdallah M[1*] and Elmarakby A[2]

[1]*College of Engineering, Physical Therapy Department, SUNY Poly, USA*

[2]*Physical Therapy Department, Utica College, Utica, NY*

[*]**Corresponding author:** Abdallah M, College of Engineering, Physical Therapy Department, SUNY Poly, USA, Tel: 3157927544; E-mail: abdallm@sunyit.edu

Received date: January 27, 2016; **Accepted date**: April 8, 2016; **Published date**: April 15, 2016

Abstract

Postural drainage is also known as bronchial drainage. It is a passive technique in which a patient is placed in different positions that allow gravity to assist with the drainage of secretions from the different broncho-pulmonary segments of the lungs. The objective of this paper is to develop a smart mannequin that can be used to train physical therapists and respiratory therapists to master the postural drainage and percussion techniques. Different types of sensors are placed on the mannequin to guide and ease the training process. The proposed smart mannequin has achieved an acceptable satisfaction rate.

Keywords: Postural drainage; Sensors; FPGA

Introduction

Postural drainage and percussion are chest physical therapy techniques which are used by a licensed Physical Therapist (PT) to loosen and dislodge the sticky secretions accumulated in the lungs as a result of certain chest diseases which will then be expelled out of the body by coughing.

The human body has two lungs, the right lung contains ten segments and the left lung has nine segments. As a result of certain chest diseases, excessive secretions accumulate in the lung segments which interfere with the normal lung functions and should be removed by chest physical therapy techniques to prevent serious pulmonary complications. Each segment has to be placed in a specific position in order to be drained. After determining the segment of the lung to be treated by auscultation (e.g. hearing moist rales which are generated because of accumulation of secretions in the airways), the patient is positioned in the appropriate position that is designed to drain this lung segment, this position should be maintained for 5 to 10 minutes as shown in Figure 1. A PT should perform an appropriate percussion technique in a certain area. The patient should be encouraged to take deep breaths and cough after each position to get rid of the drained secretions. After having the secretions removed from the lung segment, a cough is stimulated to expel the secretions out of the body, and the adventitious lung sounds are no longer heard on the treated lobe [1]. The physical therapists and respiratory therapists need to be well trained in order to master all the postural drainage positions and the percussion technique to achieve an effective and successful treatment.

A traditional mannequin (dummy) without any capabilities is used. The goal here is to outfit a mannequin, shown in Figure 2, with pressure and flex sensors to simulate a patient.

The mannequin would be moved into certain positions and the user/PT then percusses on the pressure sensors which send that info back to a controller that uses the information as input for a program [2,3].

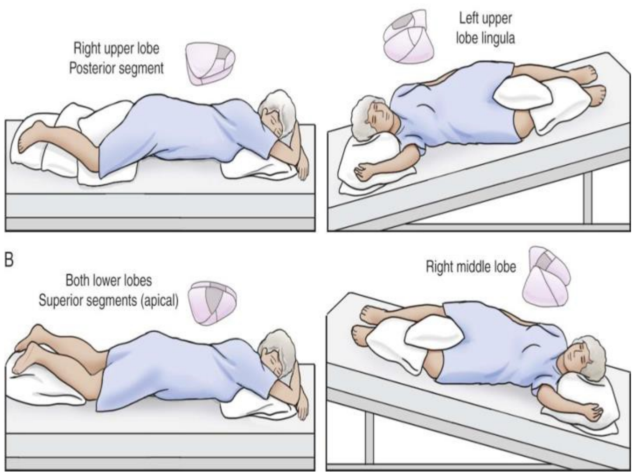

Figure 1: Postural drainage positions.

Figure 2: An example of the mannequin.

To the best of the authors' knowledge and based on an extensive literate review, no such mannequin exits to train PT on the postural drainage and percussion techniques. Other mannequins are utilized for other purposes such as intensive care setting [4] or improving the cardiorespiratory clinical skills [5].

Design Methodology

Several pressure sensors will be placed on the mannequin each corresponding to the specified locations mentioned in a Chest Percussion Physical Therapy guide [6]. These sensors run on two pins, one for ground and the other for signal. They are meant to be wired in conjunction with an Op-Amp to boost the signal they transmit. The change of positions of the mannequin would be monitored by flex sensors, also amplified, on the limbs and door switches on the head and shoulders. The flex sensors would handle hip, knee, and other body contortions while the door switches were meant for closing a contact between the shoulder and the head. Different sensors were used in this phase of the research as shown in Figure 3.

Figure 3: Different sensors on the mannequin.

State-of-the-art technology was utilized to design and build the proposed smart mannequin. Field Programmable Gate Arrays (FPGA) and microcontrollers such as Arduino were used. Both the flex and the pressure switches will feedback to the Arduino microprocessor which is a center connection between the sensors and the FPGA. When the pressure sensors are hit in the right location and in the right mechanism, the microprocessor Soundboard is actuated turning on the speaker which releases a “cough sound”. A cough sound means that the secretions in the lung segment under treatment has been cleared.

Certain Arduino codes were used to translate the pressure sensor’s analog output to a digital input for the FPGA. When the pressure sensors are hit, pin 2 on the Adafruit Soundboard is actuated turning on the speaker which releases a cough sound.

Design

One of the first challenges was determining the specific positions used by the Chest Physical Therapy (CPT) to treat each lung segment and exact sites of percussion and for how long both should be maintained in order to clear the secretion.

Based on Chest Percussion Physical Therapy guide [6], the hands need to be cupped and that the pressures involved in CPT are to be firm not excessive (painful). The force applied to the chest wall from each hand should be equal. The smart mannequin should be able to determine these conditions and only generates results (cough sound) if the percussion is done correctly.

All treated areas should be percussed at a steady rhythm. The rate of the percussion should be from 100-480 times per minutes [7]. The flex and pressure sensors were distributed across the areas that represent the lungs lobes (upper left and right and lower left and right). The information collected by the these sensors indicates the correctness of the percussion technique regarding its location, amount of pressure, and duration.

In order to condition the analog signal, the signals from the FlexForce sensors would be sent to an Arduino Uno board on the analog input pins after the signal was amplified by a MCP6004 op-amp. A program was written to convert the analog signal into a digital (1 or 0) suitable for the Altera FPGA DE2 board.

The next challenge faced was the placement of the extremities (arms and legs) in various positions required for treatment. With respect to the arms, it was only necessary to have the arms either raised or lowered to be in the proper position. The most efficient way to measure the positions of the arms was achieved by using simple magnetic door switches to decide if the arms are in the proper positions. The legs presented another challenge as the joints of each leg should be placed into different angels as presented in Table 1. The Arduino Uno board was used after the signal was amplified by a CM 358 op-amp into a binary condition. Once in binary, it was transferred to the Altera FPGA DE2 board. Two sensors were placed at the knees to detect angel of knee bending. An example of the treatment process is presented in Table 1. As shown, if all these steps are performed in the exact order and maintained for the preprogrammed/preset length of time, the cough sound should be initiated which indicates the correct treatment technique.

Finally, the position of the torso needed to be addressed. The same flex sensors were used to address torso condition. The signals were amplified, conditioned, and connected to the Altera FPGA DE2 board. The angles assessed by the flex sensors were calibrated in the same way.

Conditions to be met		
1	If left hip is bent 135° and right hip is bent 135° and left knee is bent 180° and right knee is bent 180°	Then hit left top front p.s.
		Then hit right top front p.s.
2	If left hip is bent 90° and right hip is bent 90° and left knee is bent 90° and right knee is bent 90° and left arm at side and righ t arm at side	Then hit left top back p.s.
		Then hit right top back p.s.
3	If left hip is bent 135° and right hip is bent 135° and left knee is bent 135° and right knee is bent 135°	Then hit left top front p.s.
		Then hit right top front p.s.

Citation: Abdallah M, Elmarakby A (2016) Improved Training for Physical and Respiratory Therapists using System-on-Chip Technology. Physiother Rehabil 1: 106. doi:10.4172/2573-0312.1000106

4	If left hip is bent 180° and right hip is bent 180° and left knee is bent 180° and right knee is bent 135°	Then hit right top front p.s.
5	If left hip is bent 180° and right hip is bent 180° and left knee is bent 135° and right knee is bent 180°	Then hit left top front p.s.
6	If left arm up and right arm down and left hip is bent 180° and right hip is bent 90° and left knee is bent 180° and right knee is bent 90°	Then hit right top front p.s.
7	If left arm down and right arm up and left hip is bent 90° and right hip is bent 180° and left knee is bent 90° and right knee is bent 180°	Then hit left top front p.s.
8	If left hip is bent 135° and right hip is bent 135° and left knee is bent 135° and right knee is bent 135°	Then hit left top back p.s.
		Then hit right top back p.s.

Table 1: Postural drainage and percussion treatment procedure.

Wiring up Sensor Circuits

Two op-amp chips are implanted on a breadboard connected to a power supply Proto-Board. The Pressure and flex sensors are connected to their respective op-amps as shown in Figure 4.

The magnetic door sensors required no additional circuitry, thus they were able to be directly hooked up to the FPGA. The magnetic door sensors worked perfectly when the circuit was closed via touching the contacts together. The Flex sensors also worked perfectly when being bent in any direction. Finally, the pressure sensors detected the proper percussion technique.

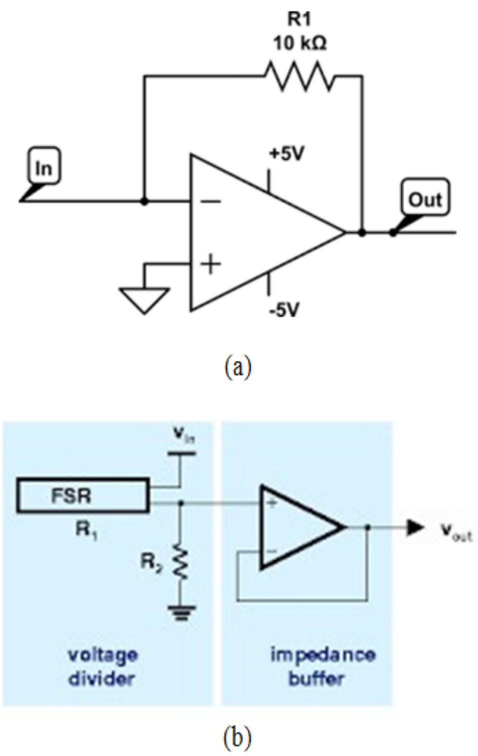

Figure 4: Pressure sensors (a) and flex sensors (b) schematic diagrams.

Coding

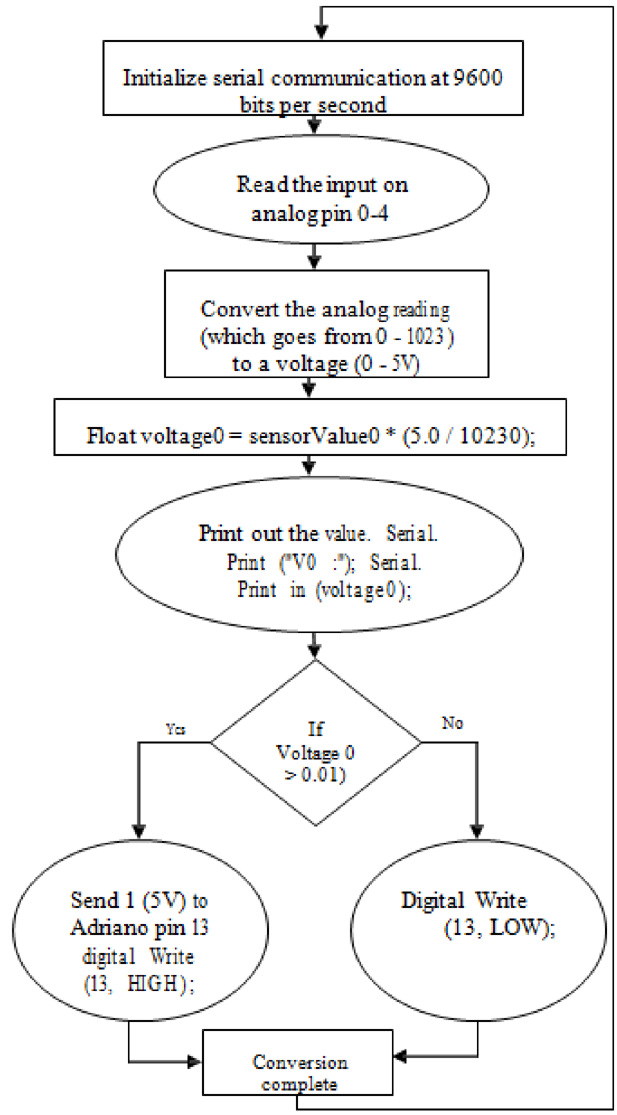

Figure 5: Flow chart converting sensor analog outputs to digital.

The main code for the FPGA was written using flags for each position and percussion technique.

The final challenge to be addressed from a coding and electronic sense was the calibration of the sensors to be read by the Arduino microcontroller. The flex sensors needed to be bent to the positions listed in Table 1 and measurements of the signal output were detected. The code of the Arduino was then attenuated to this positions to output an (on or off) states.

Another issue encountered was the output voltage of the op-amp connected to the pressure sensors. The output voltage has a -1V reference voltage. A relay was used in order to change the -1v reference voltage and allow the successful reading of the op-amp output by the Arduino microcontroller. The Arduino code for converting the analog input signals from the pressure sensors to digital outputs for the FPGA is presented in Figure 5.

Integration

The final stage was to integrate the mannequin, code, and sensors. The pressure sensors needed to be attached in such a way as not to interfere with their sensing. A major non- electrical challenge faced was connecting the sensors to the body of the CPT dummy because the self-adhesive pads of the magnetic sensors were not strong enough to remain attached through use. This problem was addressed by the use of Hot Melt Glue which worked as intended.

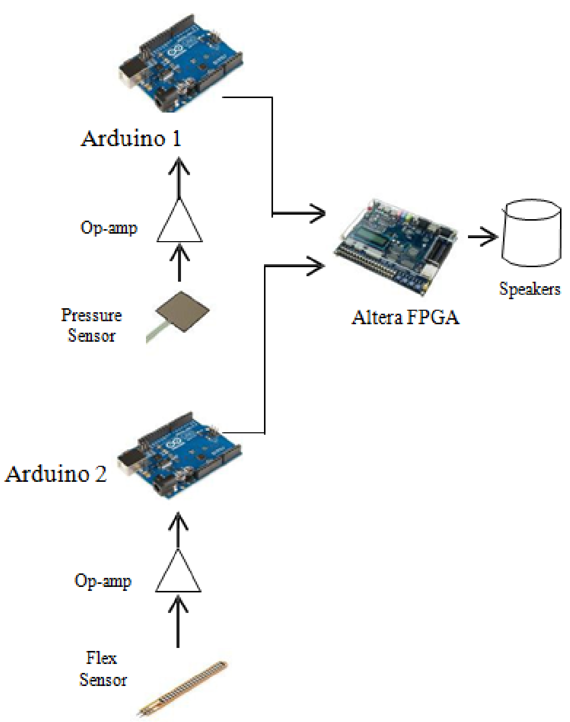

Figure 6: Smart mannequin overall structure.

The smart mannequin consists of three main components. An Arduino microcontroller is connected to the pressure sensors, another Arduino microcontroller connected to the flex sensors, and an Altera FPGA connected to both Arduino microcontrollers and the speaker as shown in Figure 6.

Testing

To verify the functionality of the smart mannequin, three positions were tested. The mannequin successfully functions in the following three positions; 1) the first position with arms along the sides and body level. 2) The left arm stretched along the head with the body level. 3) The right arm stretched along the head and the body level.

After placing the smart mannequin in the treatment procedure and applying body percussion within a predetermined time, a cough sound was heard indicating a successful treatment technique.

Conclusion

This research paper presents a new system to train physical therapists and respiratory therapists to master postural drainage and percussion techniques which are used clinically to loosen and dislodge the sticky secretions in the lungs which will then be removed by coughing in patients with certain chest diseases. A smart mannequin was designed, developed, and tested to facilitate the training process for therapists to master the techniques without dealing with human beings or real patients. Arduino microcontroller and Altera FPGA are utilized to develop the proposed smart mannequin. Two types of sensors were used. Flex sensors were used to determine the proper angels of the limbs and the torso required for placing the smart mannequin in the correct positions for postural drainage. Pressure sensors were used to verify whether the therapist applies the correct percussion techniques in terms of the force and duration. The initiation of the cough sound by the smart mannequin and the disappearance of the adventitious lung sounds would be used as evidence of applying the correct postural drainage and percussion treatment techniques. The mannequin is not yet utilized in the curriculum. However, five PT students and three licensed PT are invited to try the proposed smart mannequin. Four out of five students believe that the proposed mannequin is an efficient way of training. The fifth student reported that he believes that he should get training on real human patient.

References

1. Frownfelter D (1987) Postural drainage: Chest physical therapy and pulmonary rehabilitation (2nd edn.) Year Book Medical Publishers, Chicago.
2. Frownfelter, D, Dean E (2012) Cardiovascular and Pulmonary Physical Therapy: Evidence to Practice (5th edn.) MO : Elsevier, Missouri.
3. (2016) Basic KERi Manikin.
4. Michael J, Shoemaker (2009) Use of High Fidelity Human Simulation to Teach Physical Therapist Decision-Making Skills for the Intensive Care Setting. Cardiopulm Phys Ther J 20: 13-18.
5. Jones A (2011) Use of a Human Patient Simulator to Improve Physiot therapy Cardiorespiratory clinical skills. The Journal of Allied Health Sciences and Practice 9: 1-11.
6. Evans R (2009) How to do Chest The Emily Center Phoenix Children's Hospital.
7. Emile PC (1982) Percussion and Vibration: Chest Physics therapy in the intensive care unit (2nd edn.) Williams and Wilkens, Baltimore.