DESIGN AND FABRICATION OF LOW COST CARDIOPULMONARY RESUCITATION DEVICE

Submitted by

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Abstract

Cardiac arrest is very common nowadays. Sudden heart attack is a condition where the heart suddenly stops beating causing a significant decrease in blood flow to the brain. The first step in medical point of view is for a patient experiencing sudden heart attack is Cardiopulmonary Resuscitation (CPR).Moreover, compression rate needed for CPR process is far beyond for humans to provide manually. So, there is intense need of mechanical device which can perform resuscitation. Cardiopulmonary resuscitation device is used to augment the blood flow and maintain hemodynamic cycle of human body. CPR device is proposed to meet the effective and unique blood flow mechanism, feedback system. In term of effective and unique blood flow mechanism design and fabrication of low cost cardiopulmonary resuscitation device based on principle of CPR and two concepts. It is combined Sterno-Thoracic Cardiopulmonary Resuscitation. The "cardiac pump" generates blood flow by squeezing blood out of the heart as the sternum is depressed. The "thoracic pump" increases intrathoracic pressure due to elastic recoil of ribs. In order to meet the American Heart Association standard guidelines a feedback system has established through closed loop control system, and integration of processing controllers. Specifically, a small HMI (Human machine interface) device has been established to control the whole mechanism which would be used for child, Adults and Senior citizens as a manual intelligence system. Henceforth, feedback system act as backbone for this device.

Keywords: Cardiopulmonary Resuscitation, Closed loop Control System, Human Machine Interface, Cardiac pump, Thoracic pump.

Dedication

We dedicate this thesis to our parents who have been a constant support throughout our journey, and all our teachers who provided us with pertinent knowledge to complete this project.

This thesis is especially dedicated to our honorable Supervisor **Dr. Shahzad Anwar** for always being an ear to our queries and for steering us in the right direction to find the solution to our problems. He has been a strong influence behind this project and has mentored us in the best way possible.

It was very difficult to fabricate such project in low cost, our supervisor has enlightened us in the right direction. So, that we could be able to finish this final year project.

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All praises to Allah Almighty for giving us the strength and know how to be able to continue this project and complete it in time. We are grateful to our parents for always having our back and helping us through thick and thin; the completion of this project would have been impossible without them. We pay our gratitude to our respectable teacher **Dr. Shahzad Anwar**, our supervisor, who has helped us through the entire research and has guided us in the right direction to complete this project.

Nabeel Ahmad Khan Jadoon

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Contents

List of figure:

List of Tables:

List of Acronyms

CPR	Cardiopulmonary Resuscitation
ROSC	Return of Spontaneous Circulation
CPP	Coronary Perfusion Pressure
HBS	Human Body System
ACD	Active Compression Decompression
IAC	Interposed Abdominal Compression
HI	High-Impulse
SCV	Simultaneous Compression & Ventilation
CAD	Computer Aided Design
SC	Senior Citizen
A	Adult
C	Child
HMI	Human Machine Interface

CHAPTER 1: INTRODUCTION

Design and Fabrication of Intelligent Low Cost Cardiopulmonary Resuscitation Device

1.1. Overview

Cardiac arrest is very common nowadays. Sudden cardiac arrest is a condition where the heart unexpectedly stops beating causing a significant decrease in blood flow to the brain and other vital organs. The first step in medical assistance to a patient experiencing sudden cardiac arrest is Cardiopulmonary Resuscitation (CPR). It is an important step because effective CPR can as much as triple the chance of survival. According to UK, survey a 3 lac people died each year due to cardiac arrest and hardly 95% people get the CPR [1]. High quality CPR is difficult to maintain. Ideally a patient would experience about 100 compressions a minute but this is not always attainable.

Generally, the victims of cardiac arrest people do the manual chest compression but for human beings it is hard to compress continuously and efficiently up to 15 minutes. Because, after the cardiac arrest victims have only 15 minutes for the chance of survival. But if human get exhausted and illiterate about how much the force required for compression depth of compression? Then chance of survival will be less. So, there is intense need of Cardiopulmonary Resuscitation device. The necessity to increase the probability of return of spontaneous circulation (ROSC) has led to the development of mechanical devices that perform continuous compressions [2].

1.2. Introduction

In recent surveys of American Heart Association showed that more than 93% died each year due to cardiac arrest and hardly 2.3% out of them get the resuscitation [1]. Concerning this American Heart Association (AHA) proposed the standard CPR guidelines in 2010. These guidelines told that compression rate needed for the patient should be 100 compression/min and depth of compression must be [1, 1.5inches] applied at the rate of 30:2. It means after 30 compression, resuscitator need to provide two ventilation to the cardiac arrest victim. Afterward, based on that guidelines various device have been proposed for resuscitation procedure. Cardiopulmonary Resuscitation is an emergency procedure that combines the chest compression to provide the blood circulation of human body. Based on that principal different research and developments have been proposed and still on work. While process of CPR include Coronary perfusion pressure acts as a reliable measure of predict the return of spontaneous circulation (ROSC). Furthermore, CPP is the difference between aortic the diastolic pressure and right atrial pressure of heart a CPP of 15 mmHg is needed. The rise up in diastolic blood pressure reflects an increase in coronary flow while the highness in mean blood pressure reflects a positive impact on neural function. Leroy in 1829, proposed the method of ventilation using manual chest compressions with movements of hands [2]. Although manual heart compression mechanism was stablished for resuscitation but soon they realized that human could not be able to provide 100compression/min at standard 30:1 ratio [3]. It implied, because human got exhausted and required depth of compression was also main enigma.

Figure 1. 1 : Chest compression by hand

In 1960 the paper by Jude and Knickerbocker described a method that required the little expertise [4]. Due to mechanical devices blood pressure approaches normal pressure. Unfortunately, standard closed-chest cardiopulmonary resuscitation (CPR) generates only 15-30% of the normal cardiac output. Coronary perfusion pressure above 20 mmHg is required to restore blood circulation [5]. Inconsistency of the current CPR technique persuade the investigators to obtain new CPR technique. In concern, there are two the mechanisms of for augmentation of blood flow. The cardiac pump and thoracic pump [6][7] enables the blood flow by compressing the heart and thorax between the sternum. Importantly, coronary perfusion pressure can be enhanced by cardiac pump [8]. On the other hand thorax pump is able to increase the intrathoracic pressure [9][10]. Hence, dual mechanism CPR device has been proposed which had tested and implemented which provides, 100compression/min standard rate of compression and flexible to implement on child’s, Adults and Senior citizens.

CHAPTER 2: LITERATURE REVIEW

2.1. Concept of blood flow during Chest compression

A primary goal of CPR is to maintain and restore tissue perfusion to as normal a level as possible during resuscitation. Blood flow generated by current standard CPR technique is not enough to maintain viability of vital organs. This limitation of current CPR technique is largely responsible for the universally low resuscitation rates seen both in and out of the hospital. To increase blood flow to vital organs during cardiac arrest, man investigators have tried to develop better CPR techniques [11][12]. To develop new CPR technique, it is essential to understand the mechanism of blood flow by external chest compression.

2.1.1. Two Different Theories for Blood Flow

Although the different techniques were developed and kept simple for blood flow but there are controversial one's. The mechanism of blood flow effectively and efficiently can be achieved if rescuers and investigators are well aware about the process of blood flow. ROSC and CPP term are used and fit in process as well to maintain the POBF (process of blood flow). Two different theories have been proposed to explain that why blood flow is generated during external chest compression and how. These are "cardio pump" and "Thoracic pump" . Human body system (HBS) is magnificent system created by God. Its body parts and organs itself act as the mechanical devices as follows[13][14].

2.1.2. Heart as Cardio Pump

Heart act as a mechanical pump in the cardiac pump mechanism. During compression systole both the ventricles are squeezed between the sternum and the spine. The aortic and pulmonic valve open by the increased ventricular pressure when the atrioventricular valves are closed, and then forward blood flow occurs. During compression diastole, the heart expands and refills by its own elasticity and blood enters the chambers. The mode of coronary flow and cerebral flow are similar to that of intact circulation.[15]

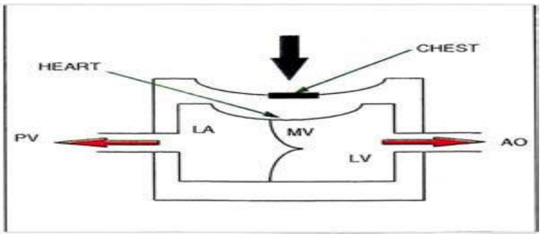


Figure 2. 1 Cardiac pump mechanism

2.1.3. Thorax as pump

Thoracic pump mechanism occurs in the relaxation phase. one factors are included for this mechanism that is ribs elasticity. According to the "thoracic pump" mechanism, increases in the intrathoracic pressure during external chest compression generates blood flow from the intrathoracic to the extra thoracic regions. Closure of the jugular vein valve at the thoracic outlet and the larger capacity of veins relative to arteries also facilitates generation of a pressure gradient between the intrathoracic and extra thoracic cavities[16][17]. During the relaxation phase of chest compression, venous return occurs because venous pressure is relatively higher than intrathoracic pressure that is negative pressure. Some blood flows retrograde from extra thoracic to intrathoracic arteries perfused the coronary arteries [18][19]. Therefore, the thorax itself behaves as a pump; the heart behaves as only a passive conduit in the "thoracic pump' mechanism.

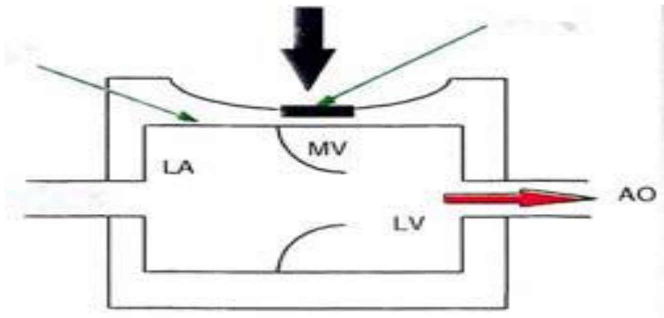


Figure 2. 2 Thoracic Pump Mechanism

Although certain theories are explained, but yet there were problems regarding blood flow generation. Investigators were not obvious about the effective blood flow. For this several tests on animals were conducted to ensure the blood flow generation. Based on that experimentation two different concepts were explained. Several investigators have tried the major mechanism of blood flow during precordial compression.

2.2. Two Different Concepts

These concepts are duration of compression and compression rate.

2.2.1. Compression Rate

Using chronically instrumented dogs, Maier et al [20] demonstrated that the magnitude of blood flow generated by external chest compression is determined by the compression rate, but not by the duration of compression. They interpreted these finding to indicate that direct cardiac compression is the cause of flow because stroke volume should be determined by the amount of cardiac deformation and prolonged compression after ejection will have no effect on stroke volume.

2.2.2. Compression Duration

On the other hand, Halpern et al [21] demonstrated that prolongation of the compression duration increased blood flow during external chest compression in discrete species of animal model. They insisted that flow will be relatively constant due to decrease in the size of the vessels leaving the thorax by increased intrathoracic pressure, and it should be dependent on the duration of compression per cycle rather than the rate of compression.

Further research is going to improve the performance of CPR devices through the adaptation of the compression shape, depth and frequency depending on the individual characteristics of the patient and response throughout the resuscitation procedure. Based on that research many mechanical devices were developed as follows.

2.3. History of Mechanical Devices:

Many CPR devices and techniques have been introduced since it was realized that standard CPR cannot generate adequate blood flow to vital organs. Advantages of using devices during CPR are improvement in blood flow to vital organs, standardization of CPR technique, and reduction in rescuer fatigue. Some of these devices are. The Thumper(Automatic Resuscitator), the Cardiac Press, the Active Compression-Decompression Device (Ambo Cardio pump) , Vest CPR, Resuscitation Apparatus, and the Weightlessness Device.

2.3.1. The Thumper

The most widely used device for performing CPR is the Thumper or Automatic Resuscitator. This device can provide mechanical external chest compression or ventilations during CPR. The device is designed as a plunger mounted on a backboard. It is a time pressure cycled ventilation is delivered every five compressions using a 50% cycle duration length. The plunger's depth of compression on the sternum can be adjusted by the rescuer from 1. 5 to 2 inches (3.9 to 5 cm).The main disadvantage of Thumper is its costs. The advantages are its size, lightweight, and consistent performance of CPR for prolonged periods of time, making it particularly valuable during transport. Because the Thumper does standard CPR, the technique itself does not improve blood flow or survival compare to standard CPR.[22]

Figure 2. 3 The thumper device

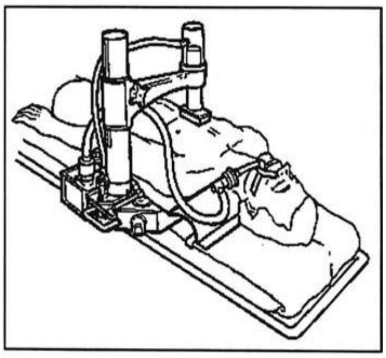


Figure 2. 4 The thumper device

2.3.2. Cardiac Press

The Cardiac Press is a simple, inexpensive device. The device has a hinged arm that makes chest compression easier. The down stroke of the device can be controlled to compress the sternum between 1. 5 and 2 inches. The device can be applied very quickly. It is also lightweight, easy to assemble, and very compact for storage. The two disadvantages of this device are that the compressor head often changes position, and certain components of the device can become loose resulting in inadequate chest compression. Therefore, the device always needs monitoring to make sure compressions are adequate and the compressor head is centered.[23]

2.3.3. Ambo Cardio Pump

Active Compression-Decompression CPR (ACD-CPR) is similar to Standard CPR, but it also provides negative intrathoracic pressure during the relaxation phase. ACD CPR is performed with a device called the Ambo Cardio-Pump. This device consist of following important parts:

" A neoprene suction cup, a plastic circular handle with an undercut hand grip, and ,a force gauge." The gauge can be calibrated to a fixed depth, which usually is similar to standard

CPR (1. 5 to 2 inches). To ensure proper function by the operator, the decompression force is also measured up to -30 Ib by the gauge. The device is positioned at mid sternum level in alignment with the nipples. The mechanisms of ACD-CPR is not completely understood. Some believe that ACD-CPR might work by a mechanism similar to the thoracic pump. During active compression, air is fills the chest, causing it to increase the intrathoracic pressure. Negative intrathoracic pressure is produced by active decompression causing greater venous return. This device is still being tested clinically, but preliminary results suggest no dramatic increase in blood flow. Further tests are needed.

Figure 2. 5 Ambu Cardio pump

2.3.4. The Auto pulse

The Auto Pulse was introduced in 2004. It is designed as a pneumatic vest and it has a load-distributing band attached to a short back board. The band is connected to a mechanism that can shorten the band under force in a rhythmic fashion such that the band squeezes the entire chest with each cycle. An experimental study has shown an improvement in hemodynamics compared to mechanical chest compressions with a piston but later clinical studies have had conflicting results. Studies have shown injuries due to CPR with the Auto pulse™ although the incidence of injuries is not evidently clear [24]

Figure 2. 6 Auto-pulse Device

2.3.5. The LUCAS Device

Two models of LUCAS™ have been developed. The first model was the LUCAS™ 1 Chest Compression System which was a pneumatic gas-driven device. As of early 2010, this was replaced by the LUCAS™ 2 Chest Compression System which is powered electrically. Both devices achieve mechanical chest compressions at a constant rate of 100 per minute and to a fixed depth of 4– 5 cm by means of a piston that has a 50% duty cycle, with the added feature of a suction cup that may assist the chest back to neutral position. This is also very good device and flexible but the main disadvantages of this device are: It is not applicable to different age of patients. Its compression depth is fixed and more important design issue and operating issue as well.

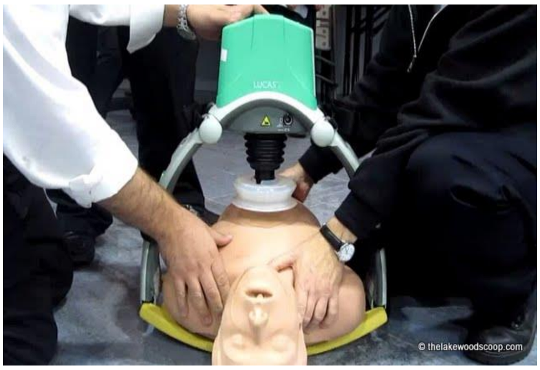


Figure 2. 7 Lucas Device

2.4. New Techniques to Augment Blood Flow

There have been many trials to develop new CPR techniques which can generate higher blood flow to vital organs by modifying standard CPR technique. Some of these techniques are; Simultaneous Compression and Ventilation (SCV-CPR), High-Impulse External Chest Compression (HI-CPR) and Interposed Abdominal Compression (lAC-CPR).

2.4.1. Simultaneous Compression and Ventilation (SCV-CPR)

Simultaneous chest compression and ventilation (SCV-CPR) is a technique in which ventilation is performed simultaneously with every compression. This technique produces a forward blood flow by acting as a "thoracic pump" mechanism [25] in which a pressure gradient is formed between the intrathoracic and extra thoracic structures. In animal models, SCV-CPR improves cerebral flow and systolic pressure. A device which provides simultaneous chest compression and ventilation was introduced and clinically tested in the

1980s. An improvement in survival rate in one study was discovered with SCV-CPR in comparison to standard CPR, but the result could not be reproduced at other testing sites.[26]

2.4.2. High Impulse External Chest Compression (HI-CPR)

This technique, which was introduced by Maier et al is very similar to standard CPR. The only difference is that the compression rate is performed at a higher rate. (120 to 150 compressions /minute) [27]. Ventilation with this technique remains at 12 breaths /minute the same as with Standard CPR. Some investigators have reported that high-impulse CPR improves aortic pressure, cardiac output, and myocardial perfusion pressure in animal models, but clinical studies on this technique have yet to be done.

2.4.3. Interposed Abdominal Compression (IAC-CPR)

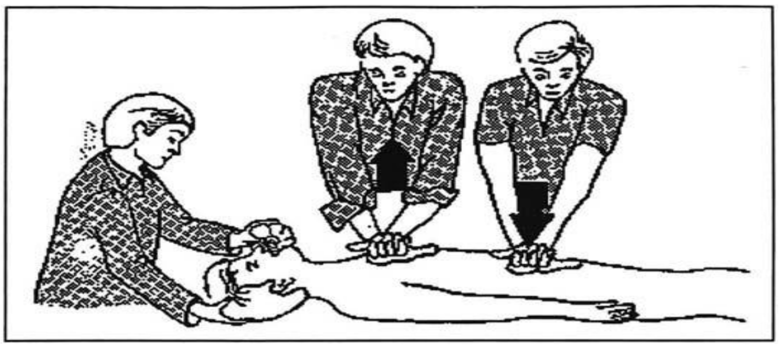


Figure 2. 8 Interposed Abdominal Compression

Another name for interposed abdominal compression (IAC)-CPR is abdominal counter pulsation CPR. This technique requires two more rescuers to provide compression to the chest and to the abdominal region close to the umbilicus. During the relaxation phase of chest compression in standard CPR, the second rescuer provides compression to the abdominal region. The rate that the compression is applied is 80 to 100 compressions / minute, which is the same as for chest compression. The amount of compression force to apply is still in question. Some researchers have measured the abdominal compression pressure as 20 to 150 mmHg by different measuring gauges but there is as yet no established guideline.

CHAPTER 3: METHODOLOGY

3.1. Simultaneous Sterno-Thoracic CPR: (SST-CPR)

Simultaneous Sterno thoracic CPR is the dual induction mechanism in which Heart act as cardiac pump and thorax cavity act as thoracic pump. This mechanism is introduced in device to enhance the augmentation of blood flow and hemodynamic cycle of human body. In device piston and constricting belts are used to achieve the process. In this regard, SST-CPR should increase the intrathoracic pressure with simultaneous compression of heart producing a rapid increase in blood flow.

3.2. Device

CPR device incorporated with both components of "Cardiac" and "Sterno" pumps. In describing this device, a general and detailed description are presented, which included all aspects (dimensions, weight, materials and mechanism) which had to be considered and understood in developing this device.

3.2.1. General description

The CPR device consist of two main parts. The first part is Piston which depresses sternum. While second part is Belt around the thorax and cause it to compress when piston push down the sternum. The sternal piston is circular shaped solid cylinder. The anterior end of belt is mounted to roller over the cylinder. The belt passes through rollers inside the housing unit that surrounds the sternal piston. This housing is mounted on the supporting frame. The supporting frame has 4 legs which can be adjusted horizontally. When the sternal piston is pushed down, it depresses the sternum and pulls on the chest compression strap, thus applying direct force to the sternum (cardiac pump) circumferential force to the thoracic cage (thoracic pump).

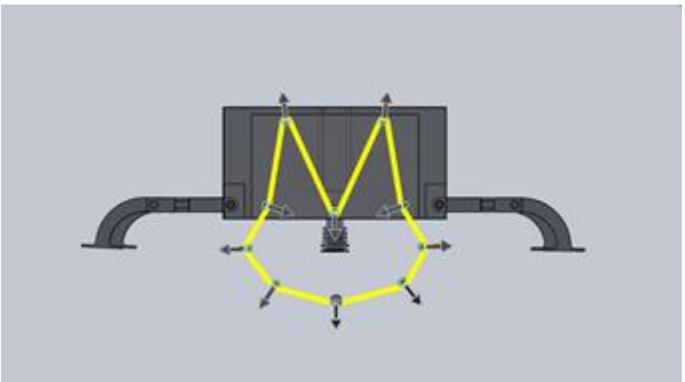


Figure 3. 1 CPR Device

3.2.2. Detailed Description

A Computer Aided Design software (Solid works) was used to develop a preliminary concept of Sterno-Thoracic CPR device. This software helped in designing a solid model and in allowing us to create many upgrades of the model prototype to get the final design. The device is composed of five different components: Belt, Piston, Supporting legs, Rollers and Housing frame. The general dimensions are shown in Table.

Table 3. 1: Description of Size and Material of CPR Device

COMPONENTS	DIMENSIONS L x W x H (inches)	NO	MATERIALS
PISTON CYLINDER	13L x 0.5d 10 x 2 x 2	2 2	ALUMINIUM
FRAME	16 x 5 x 8	1	ALUMINIUM
BELT	20lx4x0.5	1	POLYESTER
ROLLER	5L x 0.5d	4	METAL ROD
SUPPORTING LEGS	20Lx0.5d	4	IRON

The purpose of the belt is to augment the “thoracic pump” mechanism. The length of the belt is according to human chest size which can be adjusted. The belt thickness is 2mm (0.0508 inches) and the width of the belt is 3 inches. the belt was chosen of such material which allow elastic ability before the piston start compressing the chest.

The piston which stimulate the “cardiac pump” mechanism, is designed to provide three different depth of compression (for Adult, Old ages and Child). The size of depth is 2 inches 1.5 inches and 1 inch respectively. The piston also hangs up belt. When the piston travels down, the belt are pulled down on each side and providing a reduction in circumferential length. To keep the piston aligned, there are grooves in the base of the housing frame to guide the belt attach over the rollers. The piston is designed to provide compression at the sternum. The dimensions of the bottom half of the piston are designed to fit for sternal compression.

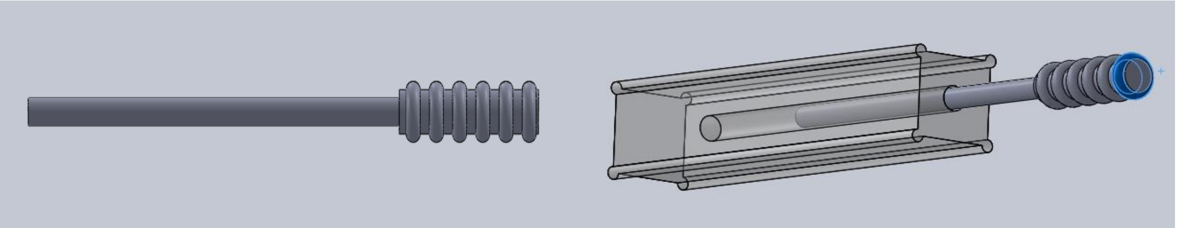


Figure 3. 2 Piston & Cylinder

These frame is designed to house the piston and provide space for the belt to attach to piston via rollers.. The lower rollers is adjustable to provide a tight fit against the thorax. The top roller is fixed to provide a suitable height to the thorax.

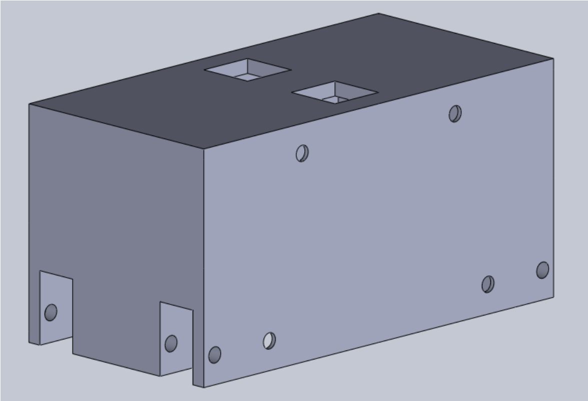


Figure 3. 3 Housing Frame

The rollers are the kind of rod and roller bearings at both end, that reduce friction between moving parts. Belt is passes over the rollers, attached to the piston which stimulate the "thoracic pump" mechanism. When sternal piston is pushed down it depresses the sternum and pulls on the chest compression straps (Belt) thus direct force apply to the sternum and circumferential force to the thoracic cage (thoracic pump).

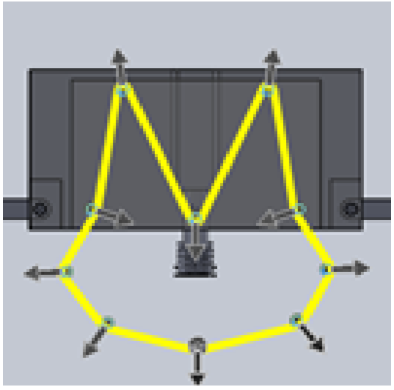


Figure 3. 4 Belt over the rollers

The supporting legs are designed to hold all the structure, consist of four 4 legs. It is adjustable for different height and width. Each legs has 2 degree of freedom.

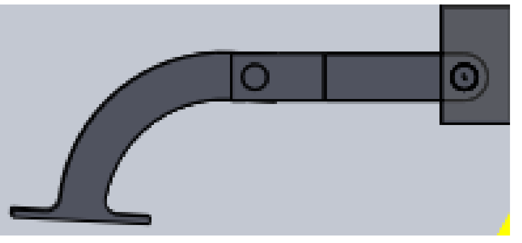


Figure 3. 5 Supporting Leg

CHAPTER 4: FABRICATION

In this chapter we will study in detail about the mechanical design and assembling of device includes part wise detail drawing in Solid work. While, fabricating CPR device CAD design and specification are kept in mind. These drawing can be used for parts manufacturing as well as assembly of part. The main part of this device is compression mechanism. This mechanism has dc motor assembly with the disc plate, slider and piston rod. When motor rotates, the assembly converts the rotational motion into the linear motion of rod.

Other components of the device are upper assembly, electronic housing, supporting legs, rollers, tappers and HMI feedback system. Part wise description are given below

4.1. Compression Mechanism

Compression mechanism contain following parts

4.1.1. Piston Rod

Piston rod is 8 inches long, made of Teflon (Polytetrafluoroethylene) bearing force of 125lb, centered at the middle of assembly. It non-sticky and electrically insulated material.

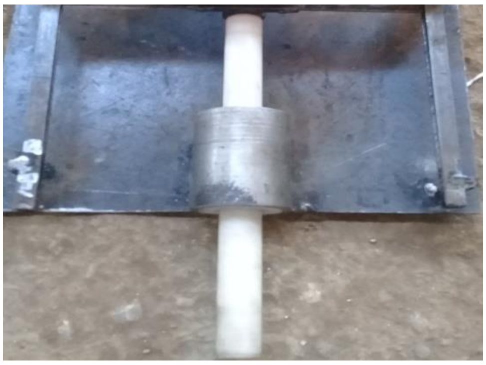


Figure 4. 1 Piston Rod

4.1.2. Rotating Disc and Slider

The rotating disc is of 4 inches in diameter, made up of aluminum, centered at the middle and joined with the slider through screw and roller. The slider is 5 inches long , provide space to move as disc rotates. The slider also aligns the disc motion in vertical direction.

Figure 4. 2 Disc and Slider

4.1.3. 12 volts DC Motor

Dc motor is electrical device used to operate the compression mechanism. The motor power calculations are according to our required specification.

P=W/t

W=Pxt

W=F.V.t

W=F.S (force required 125 lbs, S=1 inch)

W=125 lbs x 1 inch

W=125(4.4 N) x 1 (2.54x 10^-3)

W=21 J

P=21 J / 0.5 sec

P=42 watts (required power)

Motor output power

P=VI

P=12x6

P=72 watts

4.2. Housing Unit

CPR Housing unit is made up of Aluminum sheet of 2mm thickness. It covers the compression mechanism and electronics components. Supporting legs are attached for the holding the assembly at specific height of 20 inches.

4.2.1. Electronic Housing

It is space for placing the electronic components, feedback system(HMI), power supply.

Figure 4. 3 Electronic Housing

4.2.2. Supporting legs:

Supporting legs are made up of iron (Fe) durability 200Newton Force , cubical in shape, hold the entire assembly at specific height of 20 inches. It is adjustable by tapper at every leg.

Figure 4. 4 Supporting legs

4.2.3. Belt and Rollers

A belt is a flexible band or strap, made of heavy cloth and worn around the waist of the person. The belt passes through the rollers and is connected through the piston rod. The rollers are 12 inches long and made of stainless steel. The bearings are fitted at the ends of roller, which helps the rollers to move freely under the load during compression.

Figure 4. 5 Roller

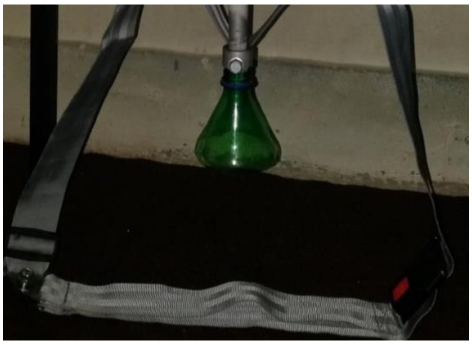


Figure 4. 6 Belt Assembly

Regarding methodology of the device, all housing assemblies, outer structures and internal parts are selected according to required criteria and economical point of view. Henceforth, there durability and strength are enough to maintain and provide the required compression rate and depth of compression.

Chapter 5: Results

5.1: Fuzzy Logic Implementation on Cardiopulmonary Resuscitation Device.

Fuzzy logic implementation has been performed on device to obtain the effective and accurate results, which are in form of piston compression rate and compression depth control, using the age factor (of Adults, Child and Senior Citizens) as our input for the device.

5.1.1. Fuzzy Logic Control

Fuzzy logic is soft computing technique used in control of machines [28]. The term "fuzzy" indicates the human approximation that can deal with concepts of artificial intelligence and soft computing .Fuzzy logic has the significance that problem is more understandable by humans. Human experience and knowledge base can be used in the design of the controller. This makes it a lot easier to handle tasks that are performed by humans. Input/output listing of device for fuzzy logic control were: Age as primarily factor input, and Compression depth and rate as output variable.

5.1.2. Fuzzy Logic MATLAB Tool Box

Fuzzy logic Tool box comprises of different compositional rule used for the problem. In our case, it is Mamdani rule of composition for Fuzzification and centroid method for Defuzzify the results. It contain inputs, outputs membership functions and real time graph assessment according to human expertise which have been implemented.

5.2. Procedure for Fuzzy Logic Implementation.

- Knowledge Base
- Input and Output Listing.
- Membership function definition.
- Rule of Inference (Fuzzification)
- Centroid Method (Defuzzification).

5.2.1. Fuzzy Logic Controller Design.

5.2.1.1. Knowledge Base

According to European Heart Resuscitation Council and American Heart Association Guidelines 2010, they have defined the certain criteria needed for that device, using these guidelines and knowledge we have implemented the procedure as follows.

- ✓ If input =Child is selected, then output=Child Compression and Depth rate should be provided.
- ✓ If input= Adult is selected, then output= Adult Compression and Depth rate should be provided.
- ✓ If input =Senior Citizen is selected, then output= its respective compression and depth rate should be selected.

Input/ Outputs Listing:

We have 3 Inputs primarily age factor for Childs, Adults and Senior Citizens and 2 Outputs piston compression rate and depth rate.

5.2.2. Fuzzy Sets For IO'S

- ▶ Listing all of Inputs and outputs needed for device

Inputs: Primarily(Age Factor)

Table 5. 1 Fuzzy Logic Inputs Specification

Patients	Fuzzy sets	Range of Functions
Senior citizen	Fuzzy set:SC= {x1, µsc(x1)}	Range: x1 € [38<x1<=70] , µsc € [0, 1]
Adult:	Fuzzy set:SC= {x2, µA(x1)}	Range: x2 € [18<x2<=40] , µA € [0, 1]
Child:	Fuzzy set: SC= {x3, µA(x1)}	Range: x3 € [10<x3<=20] , µc € [0, 1]

5.2.2.1 Outputs

There are two outputs going to be control for different age of patients of Cardiac arrest. Piston Compressions and Depth or Distance.

Table 5. 2 : **Fuzzy logic output specifications**

Input Factor	Depth of Compression	Compression Rate
Child	0.8 to 0.95 inches	70-85compression/min
Adult	1.20 to 1.50 inches	105-120 compression/min
Senior Citizen	0.92 to 1.15 inches	80-110

5.3. Membership Functions for Inputs/outputs

In fuzzy logic design, membership function is basically the possibility of occurring that event which lies between [0 1]. It requires inputs and outputs graph needed to be define in fuzzy logic MATLAB toolbox.

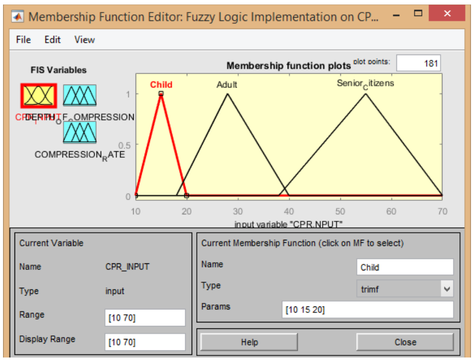
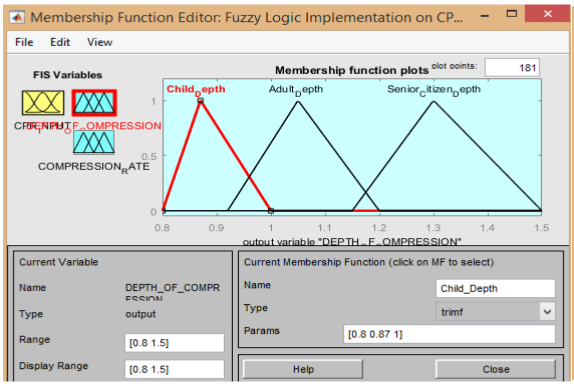


Figure 5. 1 Input membership functions of MATLAB



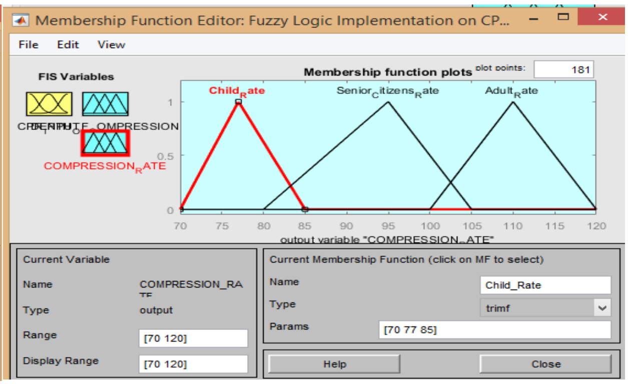


Figure 5. 2: Membership function for output

5.4. Fuzzification process

In order to fuzzify the problem, we have used the mamdani rule of composition. Which select the MIN and MAX combination means, intersection and union respectively. Moreover, for rule of composition another term also used, which is Inference Engine. This engine match the required rule to be executed first and fired the that rule to obtain the result.

Regarding fuzzy process for CPR machine, three rules have been defined for three types of patients. Importantly, there must be intersection between the inputs so that human approximation and soft computing method can be implemented. These values are linguistic.

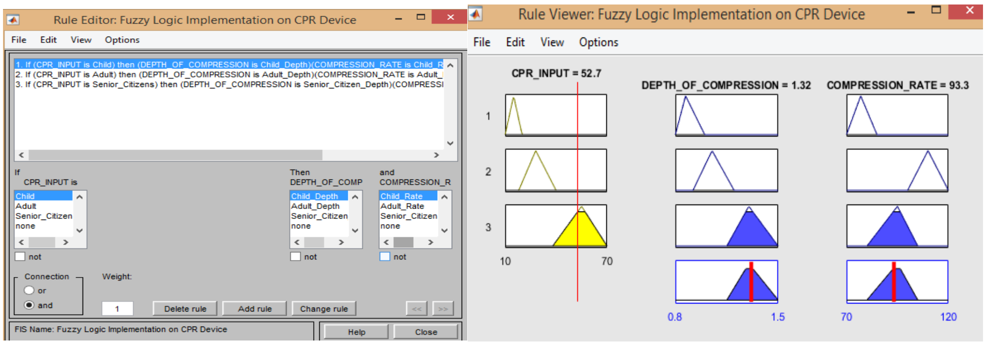


Figure 5. 3: Fuzzification process on MATLAB

5.5. Defuzzification process

This is the most important phase to obtain the real result in form of crisp values. Crisp are those value which are either “true” or “false” . We have used the centroid method to defuzzify the output membership number for obtaining the pre-requisites. Particularly, MATLAB result shown, is same as the actual one.

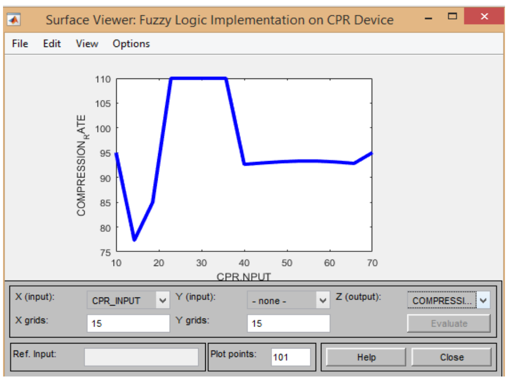


Figure 5. 4 : Compression Rate

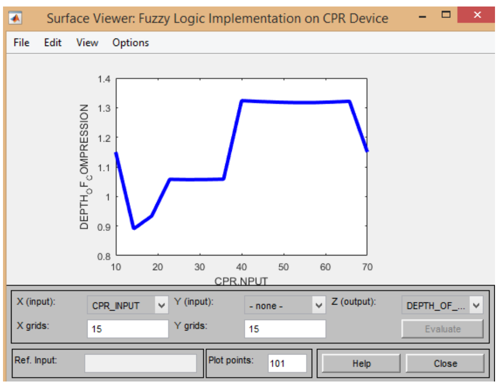


Figure 5. 5: Depth Rate

CHAPTER 6: CONCLUSION

Cardiopulmonary Resuscitation is an emergency procedure which is successfully implemented using dual mechanism theory on this device. While performing compression rate and depth of compression this device could be control easily through feedback system attached to this device. A small HMI shows the real time input needed for different type of patients. Furthermore, compression rate and depth of compression is already calculated and feed into the device so that successful resuscitation can be implemented. Hence, its dual mechanism theory augment the blood flow more than other devices. For instances, LUCAS CPR device, Zoll CPR device. This device has many immense advantages in hospitals, ambulances and first aid services.

6.1. Future Recommendations

During fabrication of this device , Firstly, there was challenge to overcome weight of this device and secondly the vibrations of motor. Although, weight of this device is being taken into consideration but yet there is need to resize this device. Secondly, compression mechanism used in this device is producing vibration because it produces friction with sliders. To overcome, this effect another mechanism could be proposed so there would not be any vibrations.

Appendix

Code for CPR Device and HMI Configuration:

```
// Learning the basics of adafruits TFT LCD Touch

// adafruit's 2.8" TFT Touch Screen 16bit color 320x240 pixels

// more info at http://www.ladyada.net/products/tfttouchbreakout/#bitmaps

// tested using Arduino IDE 0022 and code base from here https://github.com/adafruit/TFTLCD-Library

// Code by NABEEL AHMAD KHAN JADOON 02/04/2018

#include<SPI.h>        //libraries

#include <Adafruit_TFTLCD.h>

#include <Adafruit_GFX.h>

#include <TouchScreen.h>

int motorI1=52;        //motor pin definition

int motorI2= 50;

int motorpmw= 12;        //pulse width modulation of motor to control speed

int ledSC=48;        // ledsc led A and led C for senior citizen, adult and Childs respectively.

int ledA =46;

int ledC =44;

#define LCD_D0 22

#define LCD_D1 23

#define LCD_D2 24

#define LCD_D3 25        // from D0 to D7 Lcd pin configuration digitals

#define LCD_D4 26

#define LCD_D5 27

#define LCD_D6 28
```

```
#define LCD_D7 29
/* For the 8 data pins:
 Duemilanove/Diecimila/UNO/etc ('168 and '328 chips) microcontoller:
 D0 connects to digital 8
 D1 connects to digital 9
 D2 connects to digital 2
 D3 connects to digital 3
 D4 connects to digital 4
 D5 connects to digital 5
 D6 connects to digital 6
 D7 connects to digital 7
 For Mega's use pins 22 thru 29 (on the double header at the end)
 */
#define YP A3  // must be an analog pin
#define XM A2  // must be an analog pin
#define YM 9   // can be a digital pin
#define XP 8   // can be a digital pin
#define TS_MINX 143
#define TS_MINY 148
#define TS_MAXX 935
#define TS_MAXY 884
//Create the touchscreen object
TouchScreen ts = TouchScreen(XP, YP, XM, YM, 500);  //(data,data,data,data,sensitivity);

//Some of the tft pins
#define LCD_CS A3
#define LCD_CD A2
#define LCD_WR A1
#define LCD_RD A0
```

```
// Optional, used to reset the display
#define LCD_RESET A4
#define REDBAR_MINX 80
#define GREENBAR_MINX 130
#define BLUEBAR_MINX 180
#define BAR_MINY 30
#define BAR_HEIGHT 250
#define BAR_WIDTH 30

//Create the tft object
Adafruit_TFTLCD tft(LCD_CS, LCD_CD, LCD_WR, LCD_RD, LCD_RESET);

// Define some TFT readable colour codes to human readable names
#define BLACK   0x0000
int BLUE = tft.color565(50, 50, 255);
#define DARKBLUE 0x0010
#define VIOLET 0x8888
#define RED     0xF800
#define GREEN   0x07E0
#define CYAN    0x07FF
#define MAGENTA 0xF81F
#define YELLOW  0xFFE0
#define WHITE   0xFFFF
#define GREY   tft.color565(64, 64, 64);
#define GOLD 0xFEA0
#define BROWN 0xA145
#define SILVER 0xC618
#define LIME 0x07E0
void setup() {
```

```
  pinMode(ledSC, OUTPUT);
   pinMode(ledA, OUTPUT);
    pinMode(ledC, OUTPUT);


  pinMode(motorI1, OUTPUT);
  pinMode(motorI2, OUTPUT);
  pinMode (motorpmw, OUTPUT);
//  pinMode( indicator, OUTPUT);


  Serial.begin(9600);  //This turns on serial monitor


  tft.reset(); //clears LCD Ram
  digitalWrite(35, HIGH); //on mega 35 I use this for backlight. pin 10 for Shield i think.. or
//comment out and run backlight pin to 5v
  Serial.print("reading id...");
  delay(500);
  Serial.println(tft.readID(), HEX);
  tft.fillScreen(BLACK);
  tft.begin(0x9341);  // this returns the above results. below you can see how I replaced all this
once i know which one I have...
  //tft.begin(0x9328); //<---Here I bypassed the above. cause I already checked...
 //=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-==--=-=-=-=-=-=-=-=-=-=-==-=-=-=-=-=-=-=-
=-=-=
  tft.setRotation(3); // 3=landscape mode -w- row pins on right...
 homescreen();
}// End of setup
#define MINPRESSURE 10       //check for any touch 0 would mostly be too senitive.
#define MAXPRESSURE 1000
//--Start of loop----------------------------------
void loop(){
```

```
  TSPoint p = ts.getPoint(); //checks touch x/y min-max

  // if you're sharing pins, you'll need to fix the directions of the touchscreen pins!

  //pinMode(XP, OUTPUT);    //normally not needed..when used as defualt setup..

  pinMode(XM, OUTPUT);

  pinMode(YP, OUTPUT);

  //pinMode(YM, OUTPUT);   //normally not needed..when used as defualt setup..

     // turn from 0->1023 to tft.width

    p.x = map(p.x, TS_MINX, TS_MAXX, 0, 240);//default is (240, 0) [default puts touch cord. 0=x/y upper right.

    p.y = map(p.y, TS_MINY, TS_MAXY, 0, 320);//default is (320, 0) [I change these cause i like 0=xy bottom left.

  if (p.z > MINPRESSURE && p.z < MAXPRESSURE) {      //checks IF theres any touch action then continues

else if (p.y > 50 && p.y < 270 && p.x > 180 && p.x < 220) {  //looks for touch within x/y box area of button 1

           drawHome();

      }

else if (p.y > 2 && p.y < 62 && p.x > 90 && p.x < 130){  //back button

  homescreen();

  }

  else if (p.y > 2 && p.y < 62 && p.x > 180 && p.x < 230){

     digitalWrite(ledSC, LOW);

      digitalWrite(ledC, LOW);

       digitalWrite(ledA, LOW);//STOP

 off();

  Serial.println("off"); }


if (p.y > 100 && p.y < 280 && p.x > 135 && p.x < 175){ // for adults

 digitalWrite(ledSC, LOW);
```

```
  digitalWrite(ledC, LOW)
  digitalWrite(ledA, HIGH);
  Adults();
  Serial.println("adults");
  }
  else if (p.y > 100 && p.y < 280 && p.x > 180 && p.x < 230){   //for child
  digitalWrite(ledSC, LOW);
 digitalWrite(ledA, LOW);
 digitalWrite(ledC, HIGH);
Child();
 Serial.println("child");
  }
    else if (p.y > 100 && p.y < 280 && p.x > 80 && p.x < 120){
     digitalWrite(ledC, LOW);
     digitalWrite(ledA, LOW);
    digitalWrite(ledSC, HIGH);
    SeniorCitizens();
   Serial.println("senior");
  }


  }
}// end of loop



void drawHome()
{
  tft.fillScreen(BLACK);
  tft.drawRoundRect(0, 0, 319, 240, 8,YELLOW);     //Page border
```

```
  tft.fillRoundRect(0, 80, 70, 160, 8, WHITE);
  tft.drawRoundRect(0, 80, 70, 160, 8, WHITE);

  tft.fillRoundRect(100, 190, 180, 40, 8, RED);
  tft.drawRoundRect(100, 190, 180, 40, 8, WHITE);  //child

  tft.fillRoundRect(100, 135,180, 40, 8, RED);   //adult
  tft.drawRoundRect(100, 135, 180, 40, 8, WHITE);

  tft.fillRoundRect(100, 80, 180, 40, 8, RED);
  tft.drawRoundRect(100, 80, 180, 40, 8, WHITE); //SENIOR CITIZEN

  tft.fillRoundRect(2, 90, 60, 50, 8, VIOLET);
  tft.drawRoundRect(2, 90, 60, 50, 8, BLACK); //BACK

    tft.fillRoundRect(2, 180, 60, 50, 8, VIOLET);
    tft.drawRoundRect(2, 180, 60, 50, 8, BLACK); //STOP

  tft.setCursor(40, 10);
  tft.setTextSize(2);
//  tft.setFont();
  tft.setTextColor(WHITE);
  tft.print("Select Type of Patient");
  tft.setCursor(10, 40);
  tft.setTextSize(2);
  tft.setTextColor(LIME);
  tft.print("Providing CPR at 100C/min ");
  tft.setTextSize(2);
  tft.setTextColor(BLACK);
```

```
  tft.setCursor(160, 199);
  tft.print("CHILD");
  tft.setTextSize(2);
  tft.setCursor(160, 145);
  tft.print("ADULT");

  tft.setTextSize(2);
  tft.setCursor(110, 95);
  tft.print("SENIOR CITIZEN");

tft.setTextSize(2);
  tft.setTextColor(WHITE);
  tft.setCursor(7, 108);
  tft.print("BACK");

  tft.setTextSize(2);
  tft.setTextColor(WHITE);
  tft.setCursor(7, 198);
  tft.print("STOP");



}
void homescreen()
   {
  tft.fillScreen(WHITE);
   tft.drawRoundRect(0, 0, 320, 240, 8,CYAN);

 // tft.drawRect(0,0,320,240,MAGENTA);
```

```
 tft.setCursor(10,30);
 tft.setTextColor(BLACK);
 tft.setTextSize(2);
 tft.print("CPR Device HMI Interface");

 tft.setCursor(100,60);
 tft.setTextColor(BLACK);
 tft.setTextSize(2);
 tft.print("Prepared By");

 tft.setCursor(60,90);
 tft.setTextColor(RED);
 tft.setTextSize(2);
tft.print("Nabeel Ahmad Khan");
 tft.setCursor(10,120);
 tft.setTextColor(BLACK);
 tft.setTextSize(2);
tft.print("Supervisor:");



 tft.setCursor(60,150);
 tft.setTextColor(RED);
 tft.setTextSize(2);
tft.print("Dr.Shahzad Anwar");
 tft.fillRect(50,180, 210, 40, BLUE);
 tft.drawRect(50,180,210,40,RED);
 tft.setCursor(68,193);
 tft.setTextColor(CYAN);
 tft.setTextSize(2);
```

```
 tft.print("PROCEDE FOR CPR");
 delay(500);
   /*tft.fillScreen(BLACK);  //Set's LCD Back Ground as Black



 //=-=--Button 1=-=-=-=-=--=--==-=--=-=-=-=-=-=--=-=-=-=--=
 tft.fillRect(25, 150, 250, 30, RED);   //our Rectangle box for Button 1 ( x, y, w, h, color)
 tft.drawRect(25, 150, 250, 30, WHITE);
 tft.setTextSize(2); //Sets all text font size till called again  (Fontsize 1-5) defualt is "1"
 tft.setTextColor(WHITE);  //Sets all text color till called again
 tft.setCursor(100, 155); //sets cursor to start writing text from.. (x, y)
 tft.println("PROCEED FOR CPR");  // Text string to write on lc
 */
 }


void Child()
{ //analogWrite( motorpmw, 120);        //you can change speed of motor max upto 255
 //digitalWrite(motorI1, LOW);
 //digitalWrite(motorI2, HIGH);
//digitalWrite(indicator, LOW);
//delay(1);
analogWrite( motorpmw, 100);  //speed of motor
  digitalWrite(motorI1, HIGH);
 digitalWrite(motorI2, LOW);
 delay(10000);

 analogWrite(motorpmw, 0);
```

```
  delay(4000);



  }
  void SeniorCitizens()
{ //analogWrite( motorpmw, 130);
  //digitalWrite(motorI1, LOW);
  //digitalWrite(motorI2, HIGH);
  //delay(1);
 //digitalWrite(indicator, LOW);
 analogWrite( motorpmw, 110);
    digitalWrite(motorI1, HIGH);
  digitalWrite(motorI2, LOW);
  delay(10000);

  analogWrite(motorpmw, 0);
  delay(4000);

  }
  void Adults()
{ //analogWrite( motorpmw, 140);
  //digitalWrite(motorI1, LOW);
  //digitalWrite(motorI2, HIGH);
 //digitalWrite(indicator, LOW);
 //delay(1);
 analogWrite( motorpmw, 130);
    digitalWrite(motorI1, HIGH);
  digitalWrite(motorI2, LOW);
   delay(10000);
```

```
analogWrite(motorpmw, 0);
delay(4000);


}
void off()
{ analogWrite( motorpmw, 0);
  digitalWrite(motorI1, HIGH);
digitalWrite(motorI2, LOW);
  }
```

///END OF CODE

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