DESIGN OF PASSIVE CONTROLLED IOT BASED SMART CPM FOR LOWER LIMB

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Declaration

I certify that this research work titled *"Design of Passive Controlled IOT Based Smart CPM For Lower Limb"* is my own work. The work has not been presented elsewhere for assessment. The material used from other sources in this work has been properly acknowledged and referenced.

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Copyright Statement

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I am grateful to Almighty Allah for granting me this opportunity and making me able enough to complete this research. I am in debt to my parents for being the source of this great opportunity.

Thank you to my supervisor, Dr. Asim Waris for the patience, guidance, and endless support throughout my research phase. I am extremely grateful that he took me as a student and continued to have faith in me over the years.

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I dedicate my dissertation work to my family and friends.

A special feeling of gratitude for my loving Mom.

I want to thank my friends & office colleagues who have supported me throughout this period.

Abstract

Muscle strength and range of motion in the knee joint are impacted following total knee replacement and anterior cruciate ligament surgery. As a result, the goal of this research is to design a rehabilitative device to improve knee joint muscle strength and range of motion. The global population of people with mobility disorders is growing, which increases the demand for rehabilitation and physiotherapy devices. Automated assistive tools and devices have shown to be extremely effective and necessary in the treatment of physical injuries and impairments. Physiotherapists might use android technology to remotely set the degrees of flexion/extension, the pace of movement, and duration. The Android application will also save the patient's exercise history and can convey the patient's input about his condition's progress to the physiotherapist.

The normal active knee range of motion is as follows: Knee Flexion ROM: 135 deg (completely bent), Knee Extension ROM: 0 degrees (totally straight). External Knee Rotation ROM: 30-40 deg, Internal Knee Rotation ROM: 10deg Normal passive knee ROM is as follows: Passive Knee Flexion ROM: up to 150deg, depending on leg size - the limit is the calf pushing towards the back of the thigh, Passive knee extension range of motion (ROM): up to 10deg hyperextension is deemed typical.

Key Words: Continuous Passive Motion Device, android technology, speed, angle, history, feedback mechanism, range of motion, knee joint disorders

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List of Abbreviations

CPM- Continuous Passive Motion

ROM- Range of Motion

PWM- Pulse Width Modulation

ACL- Anterior Cruciate Ligament

RPM- Revolutions Per Minute

UI- User Interface

TKR- Total Knee Replacement

Chapter 1: Introduction

According to VON RIEMKE, CPM was explained in these words in 1926," all joint affections should be moved. Movement should begin on the first day, should be very slow, and as much as possible it should be continuous" [1].

The concept of CPM was invented by Salter by performing a series of experiments on a rabbit in 1960 along with another scientist Field. They presented that restricted movement of a rabbit's knee joint under incessant compression, provided by either a compression method or forced position, leads to pressure necrosis of the cartilage. The injurious effects of immobilization on the articular cartilage of rabbit knee were reported by Salter et al in 1965 and the resultant abrasion was termed as "obliterate degeneration of articular cartilage". Salter also believed that "The relative place of rest and motion is considerably less controversial based on experimental investigation than based on clinical empiricism" [1]. He also argued as static life for joints is unhealthy and random movement is robust for normal and damaged joints, then perhaps continuous motion for sure would be better. The patient is not able to move his or her joint continuously and because of the fatigue of skeletal muscles, his opinion was that for a motion to be continuous, it would also have to be acquiescent.

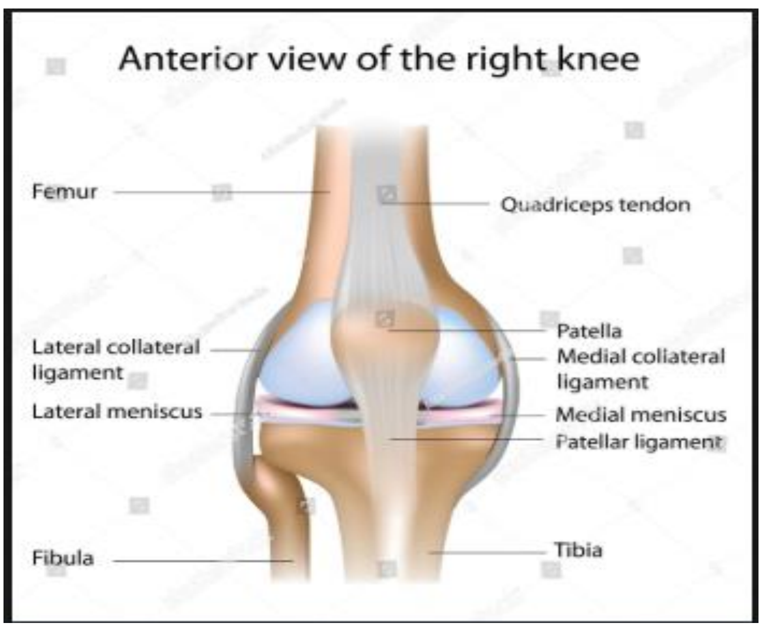


Figure 1: Anterior View of Right Knee

1.1. Background:

Initial development and research on CPM were started based on upgrading the cure and resurgence of articular tissues by allowing the movement of joints. However, the foremost medical use of CPM nowadays is to elude arthrofibrosis in those joints that are susceptible to stiffness after shock or surgical treatments.

Intriguingly, CPM discovered its utmost clinical use in rehabilitation succeeding total knee arthroplasty. To understand the importance of CPM in maintaining a joint range of motion after surgery or trauma, the pathophysiology of joint stiffness must be known.

1.2. Pathophysiology of Joint Stiffness:

Stiffness in joints evolved after any joint injury or surgery and is a consequence of four-stage processes i.e., bleeding, edema, granulation tissue, and fibrosis. The preliminary two stages of stiffness i.e., bleeding and edema can be treated by applying Continuous passive motion (CPM) properly which helps to remove blood as well as edema fluid from the joint and periarticular tissues which conserves the natural periarticular soft tissue compliance. Therefore, the full motion of CPM is efficacious when provided instantly after surgery thus avoiding any increase in stiffness [2].

The four stages of stiffness are bleeding, edema, granulation tissue, and fibrosis.

1.2.1. Stage 1: Bleeding:

The earliest stage that transpires instantaneously after articular surgery or trauma is triggered by bleeding which leads to enlargement of the joint capsule and puffiness of the periarticular tissues. The maximum potential volume of the capsule to move to a certain angle varies and is specific for each joint present in the body. For example, the knee joint's capsule can flex approximately to an angle of 35 degrees, and the elbow joint can flex to about 80 degrees. Flexion and extension of a joint further than its maximum limit when the joints or the periarticular tissues are swollen; results in tremendously high hydrostatic pressures inside the joint and the tissues consequently leading to excruciating pain and an increase in opposition to the movement.

Therefore, straightaway after damage or surgical procedure of a joint, it is preferred to grip the joint at the point of supreme articular volume to curtail sore broadening of the joint capsule and the pressure within the articular hematoma [1][2].

1.2.2. Stage 2: Edema:

In a few hours, the next stage of stiffness is experienced which is very much the same but progresses at a slower pace. The occurrence is because of edema that is instigated by inflammatory mediators; the source being dead cells and platelets. These mediators make the surrounding blood vessels expand in diameter and perforate which causes the plasma to leak, which ultimately results in the swelling of specific tissues that also makes them lose their acquiescence. Pain is caused when physically moving the surrounding joint primarily due to the swollen and now fewer concurrent tissues. The main reason for swelling and less compliance at this stage is caused by fluid accumulation. This is followed by fluid replacement by extracellular matrix deposition, a transition that occurs in the next two stages [2].

1.2.3. Stage 3: Granulation Tissues:

The third stage is characterized by the formation of granulation tissue around the joints occurring after a few days of trauma or surgery. Granulation tissue being vascularized and arranged slackly, have properties that lie amongst a well-structured blood clot and an unattached areolar fibrous tissue. This stiffness caused formerly by liquid retention increases owing to the deposition of a dense extracellular medium.

1.2.4. Stage 4: Fibrosis:

Fibrosis is the last stage which results in dense, rigid scar tissue and the maturity of granulation tissue. This scar tissue in its extracellular matrix has an increased concentration of collagen type 1 fiber.

1.3. Principles of CPM Application:

Continuous Passive Motion is a device that provides movement to human limbs and attachment joints as a method for rehabilitation and physiotherapy. This device is self-contained and does not require a constant push to offer mobility. This type of latent movement aids in the reduction of joint rigidity. CPM is useful in the first few days following injury or surgery to reduce joint hemarthrosis and periarticular edema.

During the initial days after injury or surgery, CPM is beneficial mainly to diminish joint hemarthrosis; a condition characterized by severe bleeding in joint spaces and periarticular edema; furthermore, CPM has been discovered to escalate the evacuation of a hemarthrosis. During joint effusion, knee motion beyond its maximum range results in a surge in pressure within the articular tissues which intensifies with an increase in effusion.

CPM generates instability in intra-articular pressure thus quickening the removal of hemarthrosis. Moreover, CPM also averts any further buildup of edema in the soft tissues of knee joints by efficient removal of blood and fluid from the surrounding areas of the joint. Hence CPM shows supreme advantage in the first two stages of joint stiffness [1].

CPM is least effectual in the second last stage of stiffness and completely ineffective in the last. The use of splints is encouraged in the granulation stage to cure the continuous widening of the periarticular tissues. While the last stage might be treated either by extensive and strong splinting or surgery.

1.4. Problem Statement

Having complete knee range of motion (ROM) is important for daily function. The knee must be able to bend and straighten for us to walk and run, support our body weight, manage our balance, and act as a shock absorber for our body. When knee mobility is restricted, it causes discomfort, affects function, and puts us at risk for knee injury. When we talk about knee range of motion, we are referring to the amount of mobility at the knee. The primary motions of the knee are flexion and extension, or knee bending and straightening.

1.5. Objectives

The knee joints are one of the most highly loaded moveable joints in the human body, allowing very complicated movements that allow human mobility to occur unhindered. Knee stiffness is caused by a variety of reconstructive surgeries, including knee replacement, ACL repair, and other knee joint problems. During the first phase of rehabilitation following a soft tissue surgical operation or trauma, continuous passive motion (CPM) devices are employed. Controlling post-operative discomfort, reducing inflammation, providing passive mobility in a specific plane of movement, and protecting the mending repair or tissue are the aims of phase 1 rehabilitation. However, the current device only performs one type of typical flexion and extension exercise using android application which has option for both doctors & patients.

1.6. Thesis overview

In this thesis, chapter 1 includes the introduction and explanation of the problem along with a proposed solution. Chapter 2 includes the work that has been done in the same or related entity. Chapter 3 provides information about the materials and methods used for this study. Chapter 4 includes the results obtained from the proposed study. Chapter 5 consists of the discussions of obtained results and finally a conclusion of this whole work. Chapter 6 enlists all the sources from where the material has been obtained and properly referenced.

Chapter 2: Literature Review

Continuous passive motion is used to move an extremity by an externally applied force without active contraction of the muscles of the respective extremity to accelerate healing. It aims to boost recovery by decreasing soft tissue stiffness, increasing ROM, and preventing the development of adhesions. This technique has been clinically applied for the rehabilitation of the knee following various conditions like total knee arthroplasty, knee osteoarthritis, anterior cruciate ligament surgery, and posterior cruciate ligament surgery. It has also been reported in the treatment of knee flexion contractures, knee sepsis, effusion, and intra-articular fractures of the knee [2].

Numerous factors have been taken into consideration to examine the effectiveness of knee CPM like pain, edema following an injury, joint range of motion, and joint effusions. The variable primarily evaluated in most of the research studies includes the range of motion, to examine the effectiveness of CPM.

There are three types of design of knee CPM devices; anatomical, free linkage, and non-anatomical. The anatomical design is the most widely used and moves the joint through the natural motion by supporting the joint and adjacent proximal structures, by minimizing the level of stress on the joint. The free linkage design does not support the unstable joint but produces motion by gripping the proximal and distal parts. The non-anatomical design does not mimic the natural joint motion and is thus not recommended for fragile joints following surgeries [3].

Most knee CPM devices commonly control three variables which include the speed at which the joint should be moved, duration and angle of flexion, and extension of the knee. Some devices provide some additional features like auto/manual mode, EMG analysis for pain detection, and pause durations to facilitate the stretching of muscles. The majority of these devices comprise two major components, a mechanical device in which the leg is secured and an electronic device for controlling the mechanical device. The controller can either be hand-held or fixed on a desktop or incorporated into the CPM unit. Recent knee CPM devices involve the use of an android application to control the CPM unit. Smart CPM devices are majorly considered for this paper.

Alireza and farm in their paper describe the design of a knee CPM device with a user graphical interface, programmed using JAVA and Android operating systems. This interface is connected to the main CPM unit via Bluetooth module (HC-05). Different parameters can be controlled by this interface like speed, duration, range of motion, etc. The commands issued by the user are carried to the microcontroller (ATmega2560). PWM signals are then sent from the microcontroller to the motor to move the device. All of the relevant data like speed, time, etc. can then be recorded on the android phone. The motor is driven by a driver. A stepper motor with a torque of 22N/m with 1.8degree/step resolution is used in this design [3][4]. The mechanical structure is first designed in the solid works software. A ball screw is used and some parameters like maximum and minimum linear velocity of the lead screw and rotational speed of the knee are obtained by later analysis using the ADAMS software. A controller is designed using MATLAB-SIMULINK.

Japan and Sumet in their paper again propose a smart CPM device that is light, portable, can be customized according to patient needs, and has a friendly user interface. LCD is used as an interface for the user to enter different parameter values like speed, time, and starting and ending knee angle. These commands are then sent to the microcontroller. The microcontroller then generates PWM signals to drive the motor through a driver. The output from the encoder gives information about the knee angle. In addition, two safety sensors are activated when entered range of motion is achieved and the movement is stopped by the microcontroller. An original point sensor ensures that the device reaches its starting point after the required movement. This device is distinct from the other devices in that it comprises three modes; auto, manual, and setting mode. By operating the manual mode patient's optimum value of the previously mentioned parameters can be found. These parameter values are inputted into the setting mode and then the machine automatically operates on these values. Furthermore, in case of any inconvenience and pain, the unit can be halted at any time. The mechanical structure of this device is designed on solid works software using a slider crank mechanism. The torque needed to drive the CPM unit is also calculated.

Some developed another slightly different knee CPM device with Phuntsok. This device has additional two modes, intermittent and progressive. Intermittent is a warm-up mode that operates for five and stops at any selected 3 angles for 2 seconds. Progressive mode on the other hand pain mode such that when the patients feel pain, the device stops and returns to its original point. A current sensor measures the current from the motor via the motor driver and is used for the progressive mode. When the current increases from a certain value then the device halts. Additionally, a gearbox is used with the motor to increase torque [4].

Another device proposed by Michael and Aulia takes a different approach to detecting a patient's limit in either flexion or extension. The DC motor with the load works at 4-5 V. The motor continues to extend the leg. When the patient's limit is reached, the patient resists further extension thus increasing the load on the motor and leading to a decrease in the voltage of the motor. This decrease when reaches the value of 3V or less then the motor changes its direction and the leg go into flexion. In this design, the input is directly given to the microcontroller which in turn drives the motor through an H-bridge. An ADC is connected to the feedback which outputs the motor voltage to the microcontroller. In addition, there is a switch which when pressed also halts the device completely and can be used in any situation of emergency. The mechanical structure consists of a motor, ball, and lead screw and coupling. The Coupling connects the motor to the ball screw. The clockwise rotation of the motor rotates the lead screw which in turn linearly moves the ball screw. This leads to the extension of the leg. The Resistance of the leg to the extension beyond its limit provides resistance to the lead screw which in turn decreases the RPM of the motor and results in the decrease of motor voltage. This motor voltage hence corresponds to patient pain. The microcontroller is programmed in the assembly language.

Pneumatic muscle actuators are used in a paper by Xiao Li and Hong Xia to achieve smooth continuous passive motion and an active resistance motion that is yielding and adaptive. The system design comprises pneumatic and electrical devices. The pneumatic part mainly consists of an air supply, joint drivers, and control valves. Joint drivers further comprise pneumatic muscle actuators, chain wheels, and brackets. Compressed air is used in these actuators to generate smooth motion. Control units are present in an electrical device. In addition, the working principles of these actuators are described in this paper in detail [3].

Chapter 3: Methodology

CPM is a technique in which the leg of a patient is moved passively without any input from his muscles. This is done to increase the joint's range of motion and remove stiffness. Various joints are subjected to CPM following surgery for example knee, elbow, etc. However, this device is designed solely for knee joints.

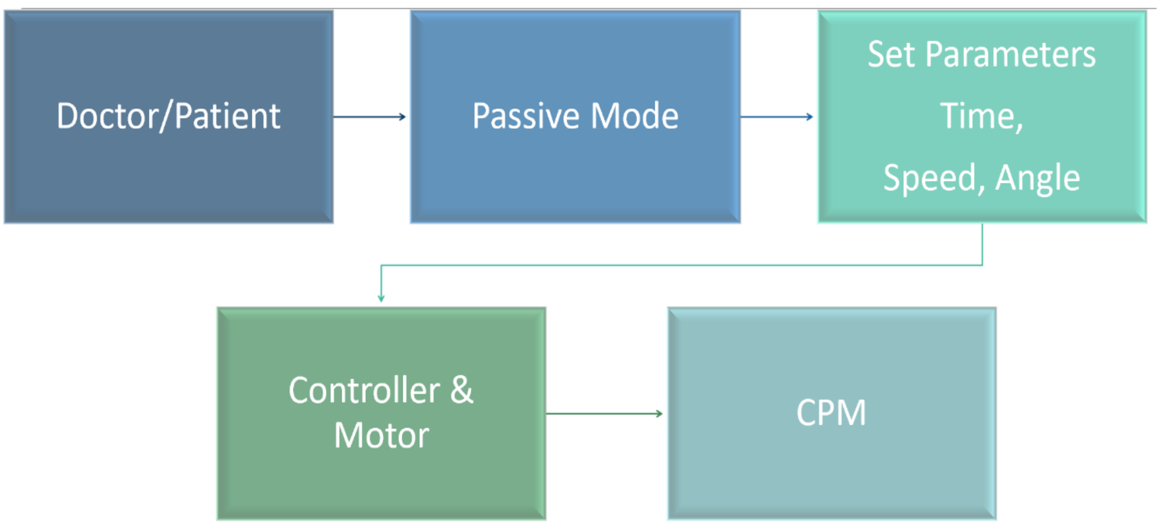


Figure 2: Block Diagram of the CPM Machine

3.1. Subparts of the Project:

There are three sub-parts of this device which when integrated lead to an efficient device that minimizes effort on both sides i-e the doctor and the patient, enlisted as follows:

- Mechanical design
- Electronic design
- Android design

By interfacing all of these parts with one another the CPM device functions properly and effectively, revolutionizing the use of traditional CPM devices.

The mechanical design comprises the mechanical assembly on which the patient puts his leg and that assembly is driven by the rest of the subparts. Mechanical assembly is designed using various design software. No novelty is brought while designing the mechanical assembly. Major innovation lies in the other two sub-parts.

The electronic design facilitates the connection of the mechanical design to the android device whether it be a tablet or a smartphone. This design involves motor and motor controllers, the microcontroller, and the Bluetooth module, which receives serial data from the android application, and necessary programming is done in Arduino to control the motor.

The third sub-part is the android application which is the main user interface. The doctor and patient both will be operating the machine using an application. This application can be used inside as well as outside of hospital premises thus aiding in long-range doctor-patient interaction. Android is interfaced with the electronic sub-part thus completing the device. This application gives control of speed, angle, and time thus rehabilitating at your own pace.

3.2. Android Development:

3.1.1. Conceptual Design:

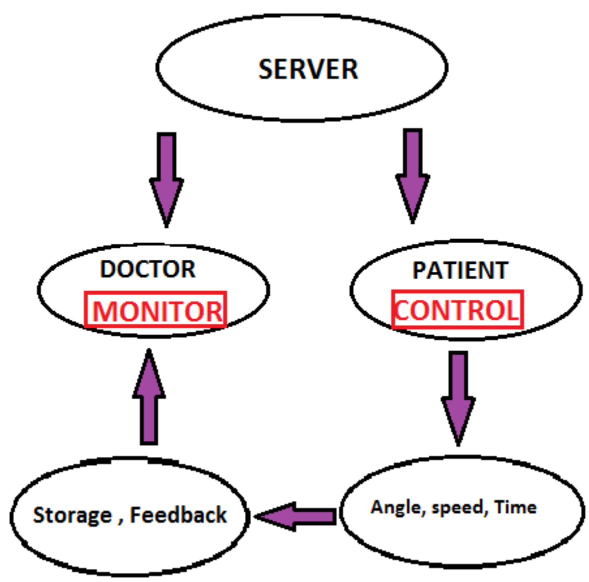


Figure 3: Conceptual Design

Many software's are used for doing Android Programming to make an Android Application. For example, Eclipse, Adobe Flash (Flash/AIR), Android studio, etc.

The Software used in this project to develop the android app is ANDROID STUDIO.

3.1.2. Choice of Android Studio:

The software used for the development of android applications here is Android Studio. **Android Studio** is the IDE for android application development.

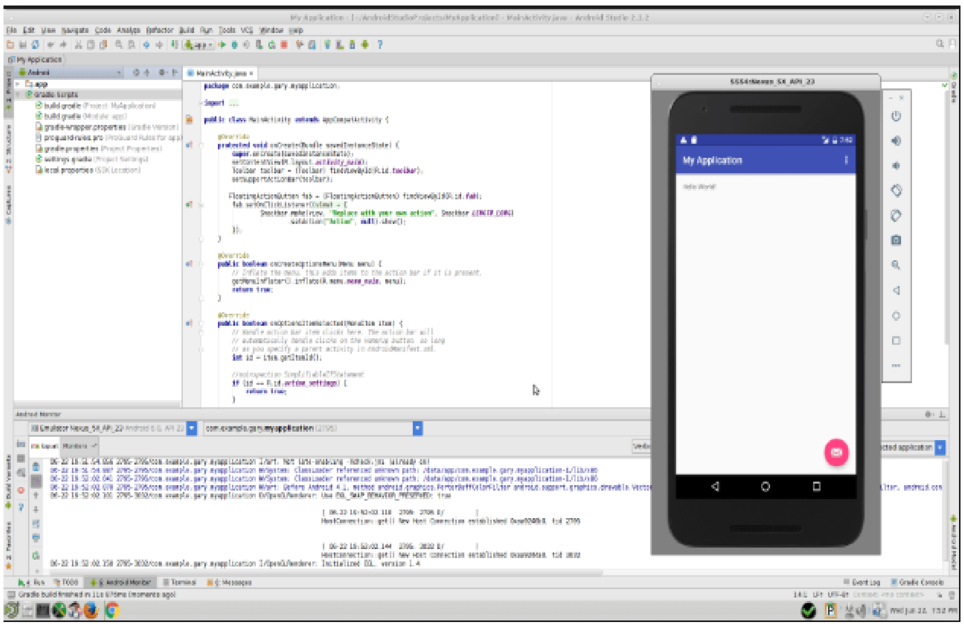


Figure 4: Android Studio UI

Android studio has many advantages over other software. Some of them are listed as follows:

- **Faster Coding:**

In Android studio, one can quickly make changes to your application without restarting or building your APK again. Furthermore, it offers a more efficient code editor and then uses a more advanced form of code completion. The emulator is much more efficient in that it allows your application to be easily tested on various devices like tablets, smartphones, wearable devices, etc. Various hardware features can be easily incorporated into the application like GPS location.

- **Efficient Building:**

Building a project doesn’t need the integration of various projects as one can easily build everything in one project and various teams can be synchronized on a single project. An application developed on android studio can be used on a variety of platforms like tablets. Android wear devices etc.

- **Versatile Integration:**

You can easily connect to firebase and cloud and incorporate different features like notifications, Analytics, etc. A debugger allows you to debug your c or C++ code and java code at the same time.

- **Drag-and-Drop Editor:**

In Android Studio, the editor can be used to create customized layouts just by dragging and dropping various views which then automatically adapt to your screen size.

3.3. Android Versions:

Android versions (*codenames*) are used to describe the various updates for the open-source Android mobile operating system. Android versions are developed under dessert-inspired codenames, with each new version arriving in alphabetical order with new enhancements and improvements to the Android SDK. The following are the versions of Android OS:

- Android 1.6. Donut.
- Android 2.1. Eclair.
- Android 2.2. Froyo.
- Android 2.3. Gingerbread.
- Android 3.0. Honeycomb.
- Android 4.0. Ice Cream Sandwich.
- Android 4.1. Jellybean.
- Android 4.4. KitKat
- Android 7.0 Nougat

The Android version used to develop the application is Oreo.

3.4. Android Programming:

3.4.1. Some Basic Commands:

- Textview( )
- Edittext( )
- Imageview( )
- ImageButton( )
- Padding
- Margin
- Background
- Color

3.4.2. Layouts:

The following layouts were used in the designing of the user Interfaces of the application:

- Linear Layout
- Relative Layout
- Scroll View

3.4.3. Java Basics Used:

Java is a popular high-level programming language developed by Sun Microsystems now owned by Oracle. Java incorporates many of the powerful features of those powerful languages like c and C++. We use java for android backend programming because it is easy to learn and understand and it is platform independent.

➢ **Core Features**

Java is an object-oriented programming language meaning everything is done using concepts like class, object, inheritance, and polymorphism. Core Features that are being used in Android Development are Polymorphism, Inheritance, and Abstraction.

➢ **Inheritance**

It is the first feature that is used excessively. In Android Development we have multiple activities in our application. Each activity is a Class that extends another class named App Compact

Activity. By inheritance we use, or access or override methods and attributes written in Parent Classes in our Child Class.

- **Polymorphism:**

It is a concept where after inheritance we can override methods in our child class. By overriding, we can redefine the same method previously defined in our parent class to match our needs. The most common methods that we override in our activities after extending the Parent class are on Create, on Destroy, on Create Options, on Stop, on Start, and so on.

- **Abstraction:**

It is a class in which methods are only declared but not defined. This class is also called Interface. Later we can implement these interfaces in our classes to set Event Listeners. We can use the keyword “implements” to implement an interface. The most common interface that we use in Android Development is View on Click Listener which forces us to implement all the methods declared in this Interface.

3.5. Mechanical Design:

3.5.1. Choice of Design:

Most of this project's innovation lies in android interfacing with the mechanical design and innovating the mechanical design was not part of the project. However, choosing a design to be made was a requirement therefore the most common design currently used now of knee CPM machines was made on Solid Works and designed in real-time.

The design used for this project is of Phoenix Company depicted below:

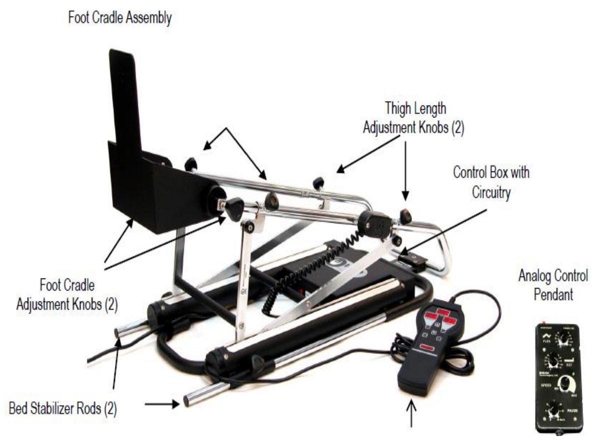


Figure 5: Commercial Design of CPM Machines

It operates on a slider mechanism such that when the patient places his leg or shank on the machine, the slider moves forward and backward due to the rotation of the motor clockwise and anticlockwise. When the slider moves forward and backward so does the leg of the patient but up to a certain degree that is decided by the doctor and controlled via the remote. Using a remote tells us that the machine can be controlled up to a limited distance. Mostly electronic sliders are used in these machines.

3.5.2. Ball and Screw Assembly:

Ball and screw assembly is used to flex and extend the leg mostly in commercial machines. A ball and screw are a mechanism of a shaft and ball bearings that converts rotational motion into linear motion. So, the ball bearings move linearly on the shaft when the shaft rotates. However, our design is different and doesn't use a ball and screw assembly to move the slider forward. We used chain and pulley assembly to flex and extend the leg.

Figure 6: Ball and Screw

3.6. Project Design:

In this project, the CPM machine is almost similar to the above design with a few exceptions to make the design more economical. The following are the distinguishing features of the device:

3.6.1. Choice of Material:

In this project most of the material selected for manufacturing is Aluminum. It is selected as it's very cheap and also its machining is comparatively easier than steel or iron. Also, aluminum can be easily painted. For some parts box iron is used instead of solid iron as young's modulus of box iron is more than solid iron therefore solid iron is more susceptible to breaking.

3.6.2. Chain and Pulley Assembly:

Chain and pulley assembly uses a chain that is put over a pulley and moves over the pulley to move the slider forward and backward. One side of the chain is put over the pulley while the other is wrapped on a gear assembly that is assembled with the geared dc motor. To reduce friction greasing is done.

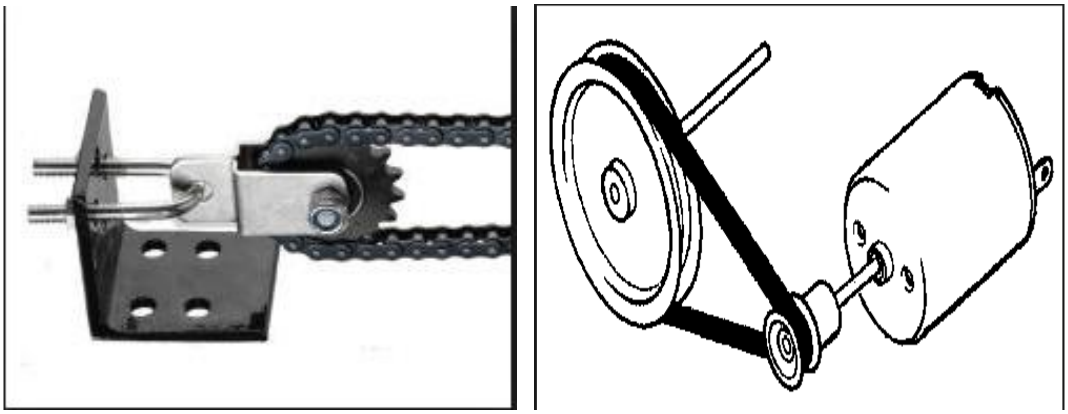


Figure 7: Chain and Pulley

A shaft is used to fix the pulley. Chain locks are used to lock the chain on the pulley. Furthermore, there is a sliding block that moves forward and backward on the sliding rod when the chain moves on the pulley. The chain and pulley are mounted on the bottom chassis. The chain and pulley assembly used in this project comprise the following parts:

- Chain
- Pulley
- Pillars
- Shaft
- Chain locks
- Sliding blocks
- Sliding rod
- Bearings
- Bushes.

3.6.3. Motor Assembly:

The motor assembly in the project is used to hold the motor in place when the slider moves backward and forward thus the chain rolls over the gear assembly attached to the motor. This is also mounted on the bottom chassis. The following components are used to produce a robust motor assembly on the design:

- Motor
- Spacer
- Clamps
- Limiting switches
- Power adapter
- Control board/ microcontroller
- H bridge circuit

Figure 8: Motor Assembly

3.6.4. Chassis:

Chasis is the framework of any device and the chassis of the CPM device is the bottom framework that has the following components:

- Bottom frame
- Fixed pivot studs
- SS large pins
- Base plate

- Stopper

3.7. 5.3 Main Structure:

The main structure is the overall framework of the device excluding the bottom framework. It has the following components:

- Main frame
- Rotating pivot studs
- Small pins
- Large pins
- U frame
- Leg supporting bed.

3.7.1. Fasteners:

Screws are an important part of any design as they ensure the integrity of the design screws of the following diameter is used in the project:

Internal Locks (8mm & 10mm)

M3X8 Csk (+)

M3X16 Pan Head

M3X12 Pan Head (+)

M3 Plain Washer

M4 Cut Washer

Plain washers are used so that the screw head doesn’t too deep into the structure while cut washers are used to minimize vibrations and are therefore used on moving structures, not on static ones.

3.7.2. Paint:

To paint the device, which is mostly composed of aluminum, a coating of lead oxide is done on the entire machine. After coating it with lead oxide, it was painted white.

3.7.3. Mechanical Design on Solid Works:

The mechanical design of the solid works is shown below

Figure 9: Mechanical Design

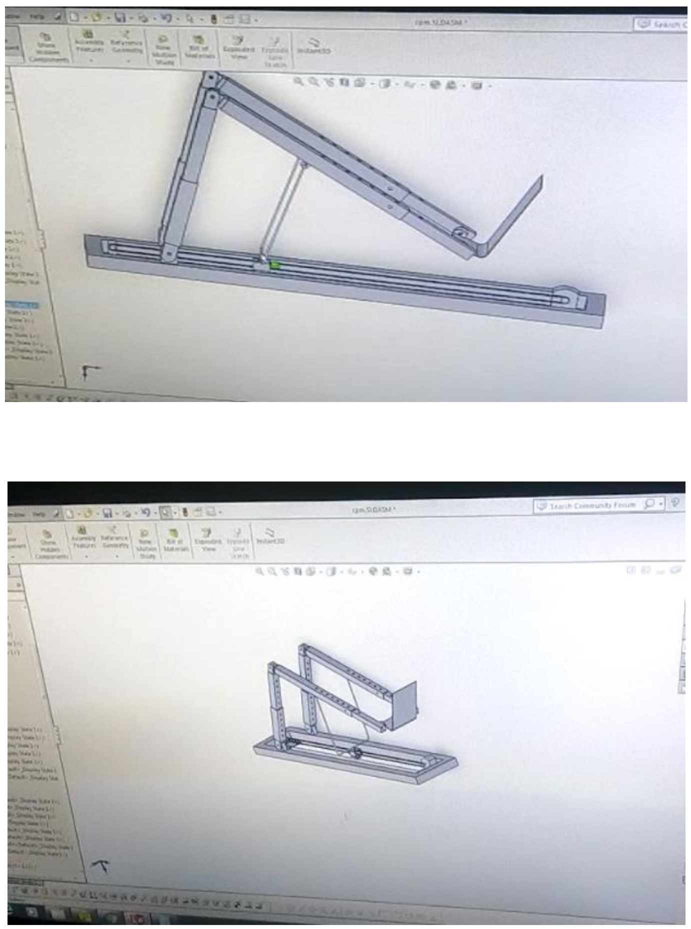
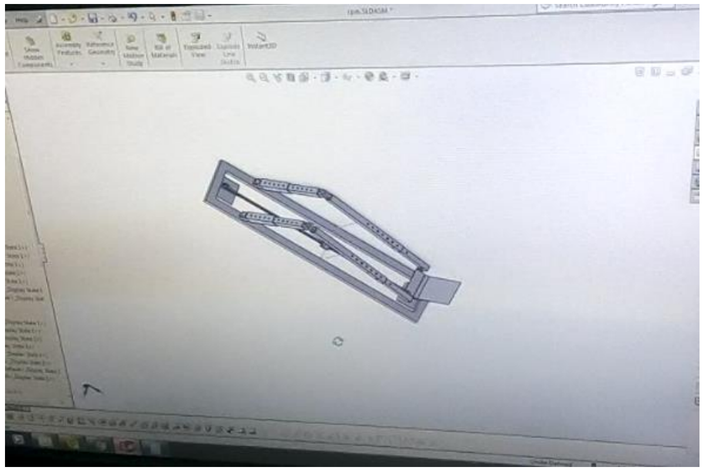


Figure 10: CPM Design on Solid Works



Chapter 4: Results

The CPM machine starts working following the user-selected parameters as soon as it was turned on and Android communication was established by pairing the device's Bluetooth with a smartphone.

Android application’s working was also checked by creating different Login Id’s for doctors and patients and checking the storage capacity of patient’s history, sending this data as well as patient’s remarks through a Wi-Fi connection to the doctor thereby ensuring the functionality of the app.

The organization will provide the doctor's registration information. This implies that the application may only be accessed by doctors who have registered with the firm. Each physician will have a unique login ID. He would create their login IDs and register his patients after that. The patient may utilize the program to execute his workout by selecting the duration, speed, and angle from the parameters UI as directed by the doctor once he has logged in.

Following that, the program will save the patient's medical history because it has a one-month data storage limit. When necessary, it can also be transmitted to the doctor over an Internet connection. Additionally, the patient can give the doctor comments on his condition. A complete android application was created.

4.1. Sign Up:

This is the first display page of the application. This page is to create a new account for the user. Once the account is created doctor simply has to log in to the account. This page is created using Android Studio software and the programming is done in XML. We used a linear layout for creating this page because it is a very simplest and most common method for creating android application pages. To set the width and height of the text we used the WRAPE CONTENT and MATCH PARENT command.

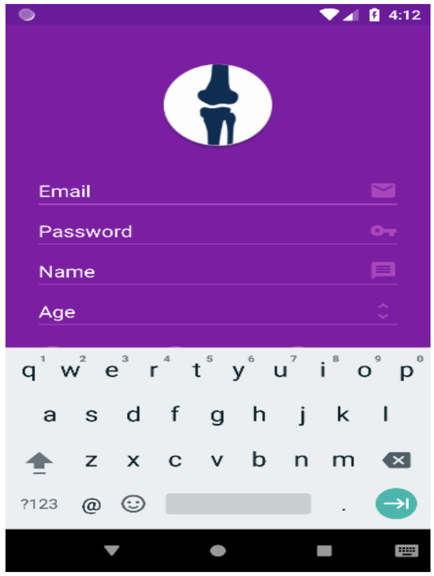


Figure 11: Sign Up Page

4.2. Sign In:

This page is to log in to the email that is already created. If the account of the user is not created yet we can create it by clicking on CREATE ONE. This page is also designed in Android studio and the programming is done in XML using a linear layout. Email and Password are simply created using the Edit text command whereas login is created using the Button command. WRAP CONTENT and MATCH PARENT commands are used to set the height and width of the text.

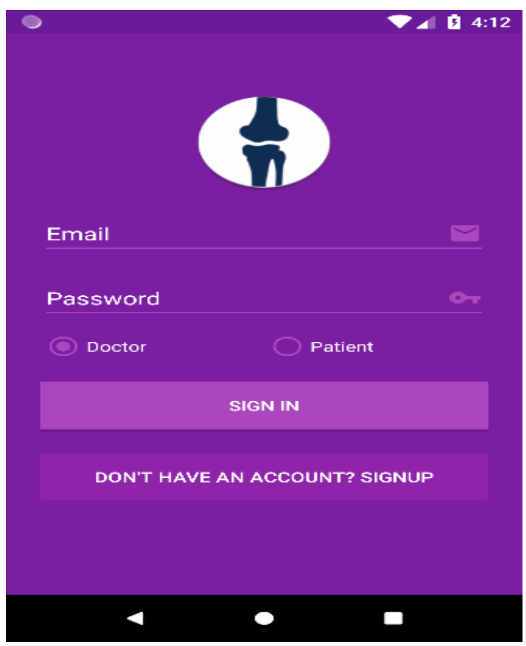


Figure 12: Sign-In Page

4.3. Doctor Main Menu:

This is a setting page of our android application which includes Sound settings. We can click on and off buttons according to our needs. This page is also designed in android studio using a linear layout and WRAP CONTENT, MATCH PARENT commands are used to adjust the height and size of the text. The space between the border and the content is done using the Padding command.

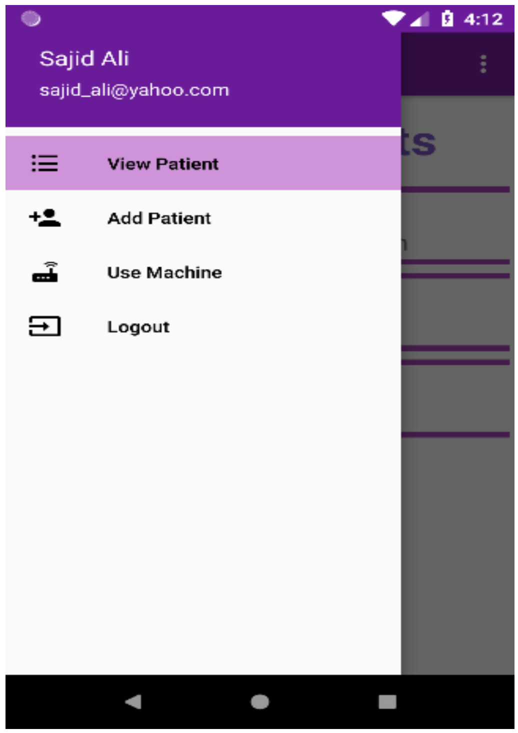


Figure 13: Doctor Main Menu Page

4.4. Register Patient:

A doctor can register his new Patient by filling in the patient's details as shown in the image. Different edit view and text view commands are used to create this page. Buttons and images are also used to modify the explanation of the page.

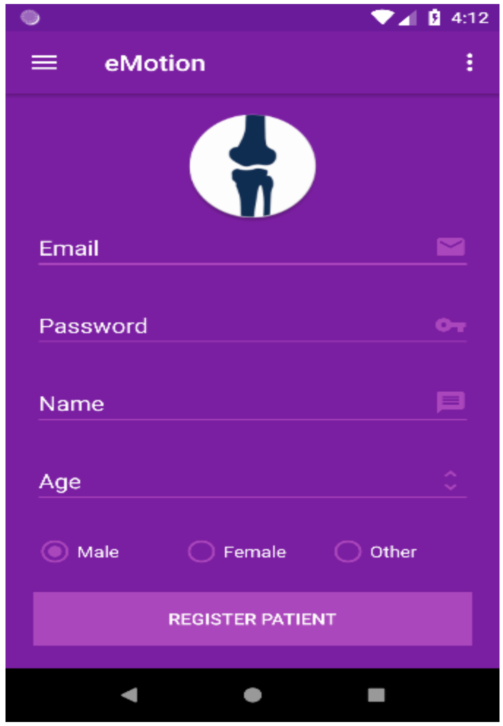


Figure 14: Register patient Page

4.5. Settings:

This is the main activity page of our android application. This includes different parameters i.e.: Angle (Flexion or Extension); Duration and Speed. These parameters will be adjusted by the doctor who is operating the device for a certain time. This page is designed in android studio and its programming is done in XML. We used a linear layout for its design and inserted buttons using the drag-and-drop method. The height and size are adjusted using WRAP CONTENT, MATCH PARENT. The space between the border and the content is done using the Padding command.

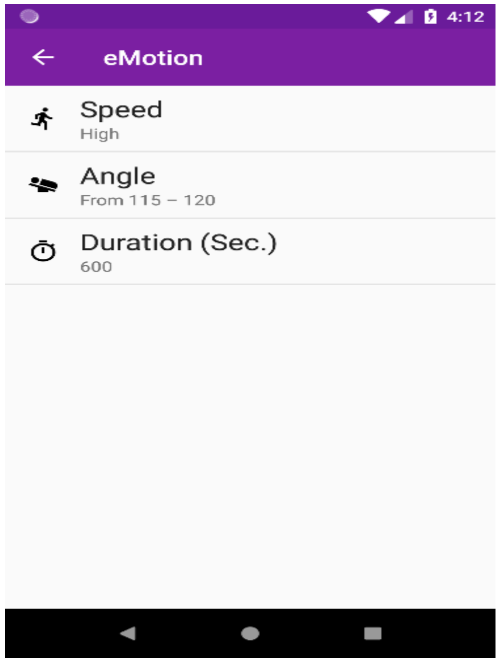


Figure 15: Settings Page

4.6. List of Patients:

The doctor can view the List of his patients by simply selecting the view patient option from the drawer. From the list, he can view any of the particular patient's details. Each patient is assigned an id which is shown as a number on the left side of the page.

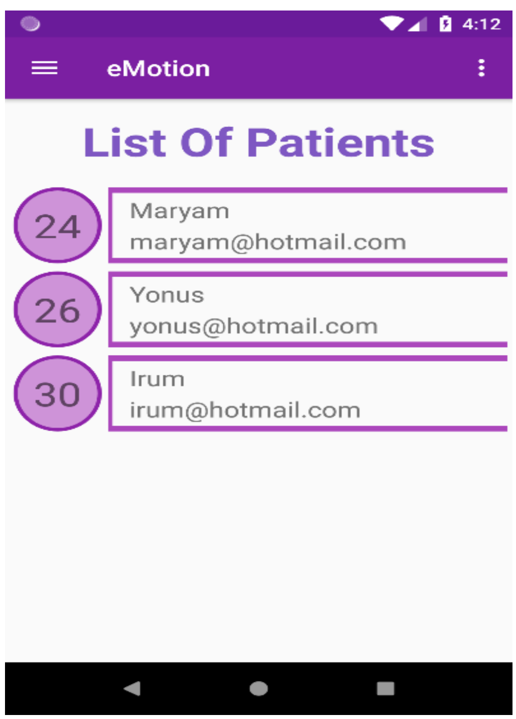


Figure 16: Patient List Page

4.7. Use Machine:

The machine is operated by using Bluetooth connectivity. First of all, the Bluetooth is turned on by clicking the ON/OFF option. Then the device to be connected is searched by the search devices option. Once the devices are found and connected, the data is sent by the start option. The data sent is then used to drive the machine.

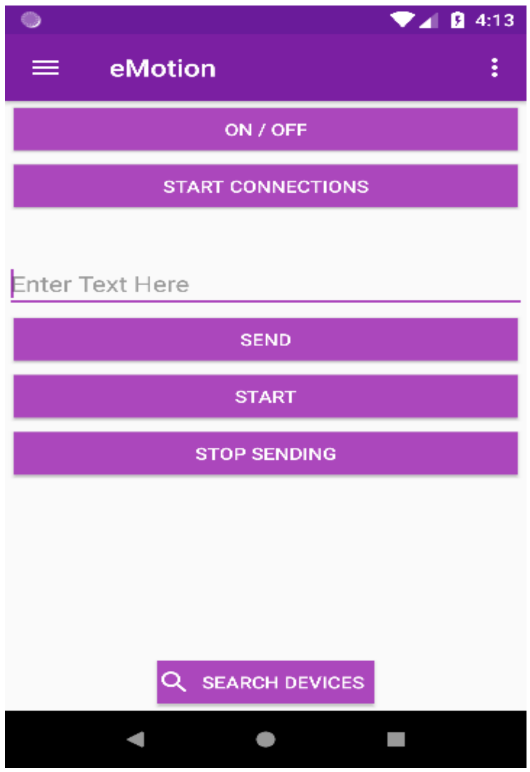


Figure 17: Use Machine Page

4.8. View Patient:

This page includes a Patient's details i.e.: Name, Age, Weight, and Gender. The information entered here will be saved and it will help the doctor to assess the patient. This page is created using Linear Layout. The height and size are adjusted using WRAPE CONTENT, MATCH PARENT. The space between the border and the content is done using the Padding command.

Figure 18: View Patient

Chapter 5: Discussions

5.1. Conclusion

At the knee joint, most functional activities require up to 120 degrees of knee flexion.Normal active knee range of motion is: Knee Flexion ROM: 135^{o} i.e. fully bent, Knee Extension ROM: 0^{o} i.e. fully straight, Internal Knee Rotation ROM: 10^{o}, External Knee Rotation ROM: 30-40^{o} , Normal passive knee ROM is: Passive Knee Flexion ROM: up to 150^{o}, depending on the size of the leg – the limit is the calf pushing onto the back of the thigh, Passive Knee Extension ROM: up to 10^{o} hyperextension is considered normal.

The development of a continuous passive motion device is significant for patients' recovery from total knee replacement surgery. The major goal of the study was to improve knee range of motion by combining android technology and CPM. An android-controlled CPM device is built, which controls the device's speed, angle, and time length, maintains the patient's device usage history, and provides input from the patient to the doctor using android technology. IoT based technology helps the doctor to evaluate the patient range of motion ROM remotely after signing in the application.

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