ABSTRACT

Knee injuries and impairments are common throughout the world, demanding effective rehabilitation treatments to improve patient recovery and lower healthcare expenses. This project focuses upon design of an innovative knee rehabilitation robotic system controlled by Artificial Intelligence (AI) . The suggested knee rehabilitation robot uses effective artificial intelligence algorithms to provide personalized and adaptable therapy to each patient. Knee problems are a common and debilitating condition that can affect people of all ages. Early detection and intervention is essential for preventing further damage to the knee joint. However, current methods for detecting and predicting knee problems are often invasive or expensive. In this research, a novel approach to the detection and prediction of knee problems is carried and used for curing knee problems. Our approach uses a combination of X-rays and machine learning algorithms to monitor the knee Oestoriartis severity. This allows us to identify early signs of knee problems, such as inflammation and changes in joint mechanics. A mechanism that can be attached to the knee to help in the rehabilitation process will be developed. This mechanism provides feedback on the user's movements and helps to correct any imbalances. This mechanism can help to speed up the rehabilitation d reduce the risk of further injury. Our approach has the potential to revolutionize the way that knee problems are detected and treated. Our approach is non-invasive, affordable, and easy to use. We believe that this approach could have a significant impact on the lives of people with knee problems.

Keywords: Knee rehabilitation, AI, Rehabilitation robots, Exoskeleton.

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CHAPTER 1

INTRODUCTION

1.1 knee rehabilitation

A recent survey has shown lakhs of knee replacement patients are seeking knee rehabilitation. The conventional method is limited and inexperienced. The need for highly professional and flexible availability is in high demand. The design aims to create a robot that assists patients undergoing rehabilitation. The main objective is to provide an effective design that is a portable and effective mechanical design that can accommodate an intelligent control system to manage rehabilitation procedures.

The major purchaser of the assistive robot will be knee replacement patients. Although the age gap is diverse, the 40+ age group has a significant number of patients. Firstly, the knee replacement procedure is done to reduce pain and improve mobility which enables better quality of life. The knee replacement is not a normal procedure as it has stages. First, the surgery is performed by a doctor examining the patient's condition and provides an ideal time for rehabilitation. After the surgery for about 3 weeks, the patient is kept under monitoring and the patient is made to perform rehabilitation exercises. The patient is discharged after the rehabilitation procedure is successfully completed.

After or in 3 weeks the pain reduction should result in the easier movement for performing regular movements and daily tasks. The usage of assistive devices goes on decreasing as the patient has become accustomed. It takes around 3 months of post-surgery according to the patient's pace of recovery progress. At this time the daily routine is a breeze but heavy exercise is avoided. The patient has to be extra careful when it comes to tasks as a concentrated force may cause rupture or damage to the knee joint. It is advised that the rehabilitation exercise should be performed after 6 weeks of surgery and within 24 weeks with constant consultation with doctors and professional physiotherapists, the rehabilitation exercise is constantly changed with the pace of the patient and recovery process.what happens when a person omits physical therapy and leaves it to natural healing The main effect will be that the healing time is increased. Normally the healing period is 6-12 months. This will affect the patient's daily life. The injuries can't be overlooked as a person's joints are not accustomed to various movements. The new joint and supporting muscle injuries are common in this case which can trigger a revision surgery.

Since the introduction of robots, the availability for knee rehabilitation systems is highly in demand. Robots are more efficient and feasible for knee therapy because they can perform repetitive activities without becoming tired, unlike a physiotherapist. Rehab may consist in a range of six to twenty- four weeks, depending on the patient's pace. Since standing and sleeping positions limit mobility and flexibility along with consideration of various age groups, this system aims to develop an aid robot that can operate comfortably in the sitting position. Using active feedback from the muscle and the motors, the robot will have accurate control over every angle and direction of actuation it performs. It is necessary that the exercises are carried out safely with precision and to avoid the wear and tear of patients ligament and joints. By a proper systematic robotic framework with high precision and accuracy, physiotherapy can be performed effortlessly and it is possible to monitor the patient's health, and recovery rate as well as assured safety. The patients will be free to complete the rehabilitation process at their convenience once they adopt and optimize the robotic system. There are numerous available designs that lack or do not consider medical advice from doctors or therapists. A visit to a rehabilitation facility and getting advice and qualitative information from qualified medical professionals there, give us an advantage over other rehabilitation robots. More than 754,000 knee replacements were carried out in 2017, according to the Agency for Health Care Research and Quality. Since 2010, there have been 2 million more records added. About 8 million people have had knee replacements in the United States alone. The number of professionals available is 5-15% of the patients. The system aims to take away or reduce some of the discomforts that come with the process of recovery.

To determine the prerequisites for efficient knee rehabilitation, semi- structured surveys with orthopedic surgeons and physiotherapists as well as on-site observations in hospitals were used to study the clinical pathways for knee replacement intervention. The design and evaluation of an interactive home-based rehabilitation visualization system used by a wide variety of ages to undertake rehabilitation in the home following knee replacement surgery.

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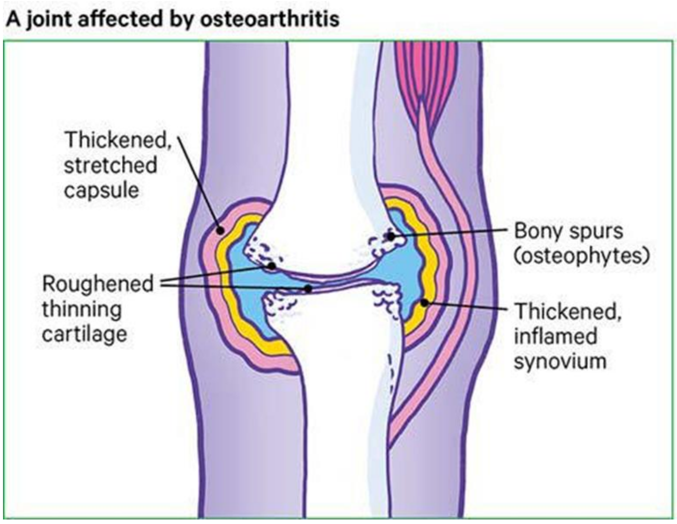
Different types of robots for rehabilitation are classified, the robots have been classified into three categories according to their operative mode: Continuous Passive Motion (CPM) machines & Therapeutic Exercise Machines (TEM); Gait-training Robots; Exoskeletons.[9] The rehabilitation robots are divided into assistive and therapy robots. There are minute differences between the two robots. Assistance robots help in daily life movement by giving assistance whereas therapy robots help in recovery from an injury. This project mainly focuses on the therapy robot.

This rehabilitation exercise using the lower limb rehabilitation robot should be performed on the hip joint and on the knee joint simultaneously and should be performed separately on the ankle joint, The robot uses linear motion mechanisms in which the robot lifts and lowers the legs by kinematic interpretation, also the System has a servo motor and its driver as an actuator, force/torque sensor and its controller for measurement of force data that come from therapist and patient and a data acquisition card for analog to digital-digital to analog conversion. And the force sensor is attached to a device for pushing up the calf and thigh, measuring the pushing force, similarly, in the design [5] a similar actuation process is considered with the lower limb rehabilitation robot should be performed simultaneously on the hip and knee joints, and separately on the ankle joint. The robot implements linear motion mechanisms, in which the robot lifts and lowers the legs via kinematic interpretation, and the force sensor is attached to a device for pushing up the calf and thigh, measuring the pushing force in addition to the weight of the lower limb.[6]

1.2 Knee Osteoarthritis and CNN model:

Knee osteoarthritis is a degenerative joint disease characterized by the gradual breakdown of the cartilage in the knee joint. Cartilage is the smooth, slippery tissue that cushions the ends of the bones and allows for smooth joint movement. As the cartilage wears down over time, the bones can rub against each other, leading to pain, stiffness, and other symptoms.



The development of knee osteoarthritis can be influenced by several factors, including:

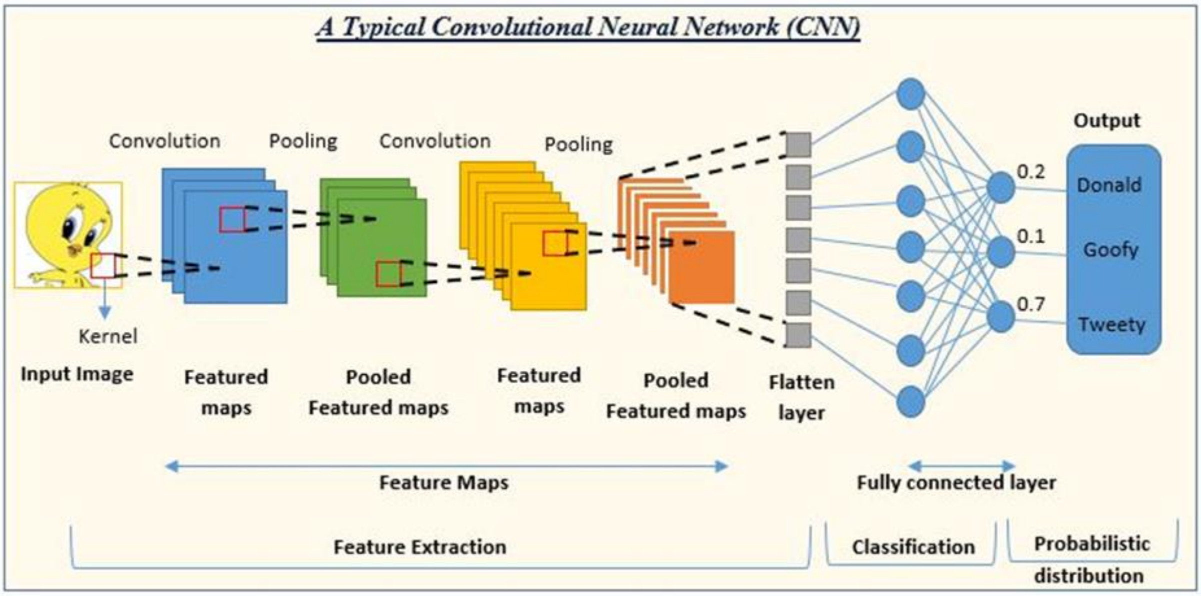
Aging: The risk of knee OA increases with age.

Genetics: Some individuals may have a genetic predisposition to the condition.

Joint Overuse or Injury: Previous knee injuries or excessive stress on the knees can contribute to OA.

Obesity: Excess weight can place increased stress on the knee joints.

Joint Misalignment: Abnormal joint alignment can lead to uneven wear and tear on the cartilage.



Input Layer: This layer represents the raw input data, which is typically an image or a volume of images. The input layer has dimensions corresponding to the dimensions of the input data, such as the width, height, and number of color channels (e.g., RGB channels for color images).

Convolutional Layers: Convolutional layers are the core building blocks of CNNs. These layers apply convolution operations to the input data, which involves sliding a small filter (also known as a kernel) over the input to extract features. Each convolution operation produces a feature map that highlights different aspects of the input. Convolutional layers can have multiple filters to detect various features. The depth of these layers increases as you move deeper into the network.

Activation Layers: After each convolution operation, an activation function is applied to introduce non-linearity into the network. The Rectified Linear Unit (ReLU) activation function is commonly used, which replaces negative values with zero and keeps positive values unchanged.

Pooling Layers: Pooling layers are used to downsample the spatial dimensions of the feature maps, reducing the computational load and making the network more invariant to small translations and variations in the input. Max-pooling is a common technique where the maximum value in a small region of the feature map is retained while discarding the rest.

Fully Connected (FC) Layers: These layers are typically located at the network's end. They flatten the feature maps from the previous layers into a one-dimensional vector and connect each element of this vector to every neuron in the layer. FC layers are used for making final predictions, such as classifying objects in an image.

Output Layer: The output layer provides the final predictions of the CNN. The number of neurons in the output layer depends on the specific task the network is designed for. For example, in image classification, the output layer might have one neuron per class for a softmax classification.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Knee rehabilitation robots have been developed to assist patients with knee injuries, surgeries, or disabilities to regain their mobility and strength. In recent years, there has been a growing interest in the development of these devices due to their potential benefits, including improving patient outcomes and reducing healthcare costs.

Rehabilitation robotic systems designed with insufficient knowledge of joint motions can disrupt or even damage human joints. As a result, when designing a rehabilitation robot, physiological bio-joint kinematics should be considered accurately.

Knee joint is considered as the largest joint among the joints in the human body, which joins the thigh and leg to perform gait for the individual. The knee consists of a modified hinge joint, which allows the individual to perform flexion, extension and a minute rotation. The knee is one among the most vulnerable joints, because it has to sustain greater amount of stress while performing ADLs like lifting heavy weights, acrobatic activities such as running, climbing, jumping [1] Due to improper postures while performing ADLs could lead to knee ligament tear, progressively could lead to knee pain. Besides, aging, degenerative joint diseases and motor accidents are also considered for knee dysfunction/pain, which reduces the range of motion (RoM) for the knee, and which in turn affects the stride length of the individual. In order to reduce pain and increase RoM for the knee, individuals opt for manual physical therapy, which is also a recommended procedure for the post-surgery patients by doctors. The major drawback of this procedure is that, due to increase in knee pain casualties the demand is not met. Besides, the physician needs experience to perform therapy to suffice the pain. As this process is a manual process performed by a physician, the effectiveness of the therapy session might not be as per the patient requirement. Nevertheless, the patient has to wait for the therapy, which is a time taking process. Due to these demerits in manual therapy, the development of assistive/therapy devices for rehabilitation applications has gained a lot of interest. Because these assistive/therapy devices can perform repetitive tasks very effectively [2], [3].

Numerous mechanisms are developed for the knee rehabilitation devices. Among which a 4-bar mechanism is generally considered as the common mechanism for the knee rehabilitation as shown in figure 1 [4].

A knee rehabilitation robotic system is a type of medical device that aids in the recovery of patients following knee injuries or surgeries. It makes use of advanced robotics technology to provide patients with personalized therapy that can help them recover. A robotic system with exoskeleton like [1] consists of the design and control of a knee rehabilitation robot with a parallel mechanism. For robot-assisted rehabilitation, a novel knee exoskeleton system is introduced that allows the knee joint's rotation as well as transitional movements. Similarly, in [3] proposed a developed robotic knee exoskeleton for gait rehabilitation, which can provide assistance to patients with knee injuries or disabilities. The authors evaluated the robot's performance in terms of gait analysis and energy consumption and concluded that the robot could effectively assist patients in gait rehabilitation. The robot is capable of providing various training modes to help patients with different knee conditions. The authors evaluated the robot's performance using numerical simulations and experimental tests. Also, in [2] This study proposed a lower limb rehabilitation robot for ankle and knee joints. It consists of a gait training-based motor control system, the authors designed and validated the robot's hardware and software, and conducted a pilot clinical trial with five patients. They concluded that the robot could effectively assist patients in knee rehabilitation. The results demonstrate that the 3-RRP planar parallel robot is flexible and adaptive as claimed and a good candidate to aid with knee rehabilitation exercises. It is typically attached to a patient's leg and programmed to move in a specific pattern designed to strengthen the knee joint and surrounding muscles.

Meanwhile on the other hand it has been observed that some systems offer highly individualized therapy because it can modify its movements to meet each patient's unique needs. Compared to using conventional therapy techniques, this can help individuals recover more quickly and with better results. Patients and therapists obtain real-time feedback from the system as well, enabling them to monitor progress and make changes as needed as done in [4] which proposed a knee rehabilitation robot with biofeedback, which provides visual and auditory feedback to patients during the rehabilitation process. The researchers obtained the robot's effectiveness in a clinical trial with ten patients and concluded that the robot could significantly improve patients' knee flexion and extension to limit the motion and attain ease to the patient while performing the exercises [9] This study proposes a wearable knee rehabilitation robot with hybrid actuation which can assist patients in walking, stair climbing, and other activities of daily living. The authors evaluated the robot's performance in terms of motion tracking, force transmission, and energy cconsumptionand concluded that the robot could provide safe and effective knee rehabilitation. A robotic knee rehabilitation system offers highly individualized therapy because it can modify its movements to meet each patient's unique needs. Compared to using conventional therapy techniques, this can help individuals recover more quickly and with better results. Patients and therapists obtain real-time feedback from the system as well, enabling them to monitor progress and make changes as needed. Overall, robotic systems for knee rehabilitation are a promising technology that can help increase the efficacy and effectiveness of knee rehabilitation therapy. Although they are still fairly new and not yet widely accessible, it is likely that as technology advances, they will become increasingly typical in hospitals and rehabilitation facilities all over the world.Lead-screw drives are often used in high-performance systems because they provide a. high stiffness and an inherent drive reduction. They are readily preloaded to have no backlash. But the carriage position of the motor can be controlled very rapidly, and it can deviate from that desired due to form errors.[5] Structural analysis aids in determining the long-term performance of existing structures. It can be used to analyze the structural status, detect any degradation or damage, and determine the need for maintenance or repair using procedures such as structural health monitoring and non-destructive testing.[21] Structural analysis is critical for assuring the safety, dependability, and optimal functioning of structures while taking assessment of risks, conformity, environmental effect, and innovation into account. It is critical in the fields of engineering; this proactive strategy protects the structural lifetime and operating efficiency. The ANSYS study has been inspired by the static and dynamic analysis of the spindle, the static analysis it considers parameters such as material of the spindle, bearing span, Morse taper. The dynamic analysis has been performed corresponding to the optimized static model and modal shapes are obtained.[4]

The knee osteoarthritis (KOA) detection and prediction of total knee arthroplasty(TKA) is predicted by taking the data from the web and taking the KOA and TKA dataset and by using densenet dense net neural network architecture and deep siameses CNN network which achieved highest of 66% accuracy.[23] The MRI images were taken and EfcientNet-B0 network was used to predict the KOA availability which had 2 outputs and predicted with an accuracy of 70%, the images went through multiple preprocessing steps to convert the MRI to color norm.[24] . The different machine learning algorithms are compared, and the advantages and disadvantages are given clearly.[25] The image prediction is given while using only classification, which achieved 61% whereas the highest of 71.9 achieved by using PA and LAT channels which other combinations are also given[26].

2.2 Research Gap

Based on the literature survey conducted, Robots designed specifically for knee rehabilitation hold great promise in aiding patients' recuperation from knee operations and traumas. Nevertheless, in order to properly utilize the possibilities of these gadgets, a number of study limitations still remain.

The design of robots that can deliver more individualized and efficient rehabilitation therapy is one research gap. The majority of today's robots are made to offer generic activities that can help a variety of patients. All patients, however, have different needs and requirements. Thus, it's critical to customize the rehabilitation program to meet those demands. Scientists are attempting to create robots that can evaluate the unique requirements of every patient and create a customized rehabilitation program using artificial intelligence (AI).

Also, it was observed that many of the systems in the existing models on the market consume a large amount of space and power to generate the ideal motion of actuation for knee rehabilitation procedures. It is crucial that the exercises are performed safely with high precision and accuracy. In systems like roller belts [14], At the same time, some systems require a large area for setup and provide inefficient results of the rehabilitation process due to improper framework, which turns out to be less suitable for some patients [17]. Also, quite a number of models are expensive, highly complex, and difficult to set up for personal use (they require a physiotherapist to perform). The slippage of the motors is crucial; energy losses and accuracy are affected by this factor. To be an Ideal rehabilitation robot, the slippage should be minimal, to be precise. Moreover, the implementation of a proper algorithm is necessary to provide efficient rehabilitation procedure to the patient, which can be achieved by predicting the need for rehabilitation. In addition, research has to be done in the field of integrating cutting-edge technology like machine learning and AI to customize rehabilitation exercises according to physiological data and real-time patient feedback. In addition to advancing the area of knee rehabilitation robotics, filling these research gaps will help build better patient-centered, efficacious rehabilitation procedures that may be applied widely. The models of AI had limited data and classified the availability of KOA or need for TKA. The models have multiple hidden layers to accurately predict, which increases computation power. [23]

2.3 Objective

Giving patients an easy and cost-effective way to rehab their knees at home is the primary objective of the knee rehabilitation mechanism. This would spare patients from having to make the sometimes expensive and time-consuming trip to the physical therapy center for rehabilitation. Additionally, patients would be able to recover their injured knees at their own pace and convenience with a precise, affordable, and portable knee rehabilitation mechanism. This system emphasizes limiting flaws like excessive power consumption and slippage and focusing on compactness, high precision, fewer mechanical parts, and accuracy. Also, the proposed system will be able to be operated easily without the need for a physiotherapist to perform the rehabilitation exercises.

The research aims to achieve the following objectives

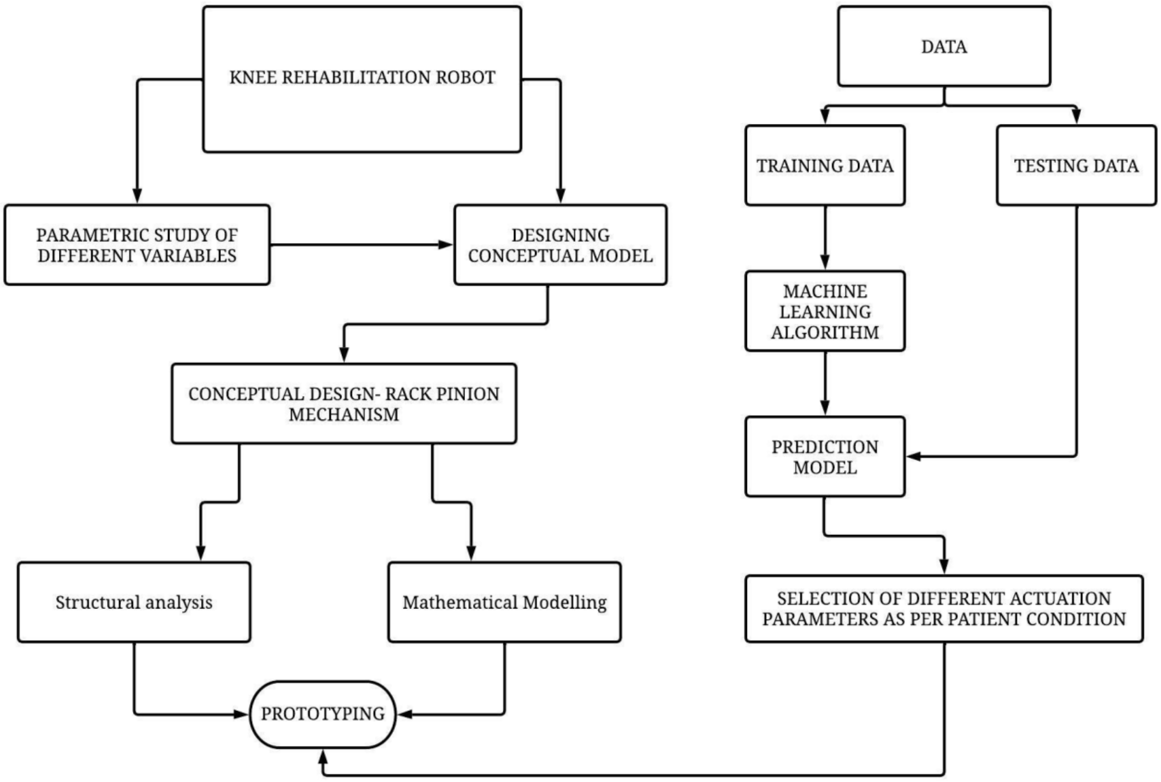
- Prediction of knee abnormalities using AI algorithms
- Design and simulation of the model
- Analysis of the model
- Fabrication of real-time model

The robotic system's main objective is to provide accurate control and minimal mechanical components, which provide an efficient and effective robotic system along with the prediction of severity of rehab pprocedures.After analyzing the data, the maximum and ideal distance for foot movement, as well as the angle for knee extension, are taken into account for ease of movement of the knee, which reduces and limits the pain to the patient during the extension and retraction process during the rehabilitation procedure.

CHAPTER 3

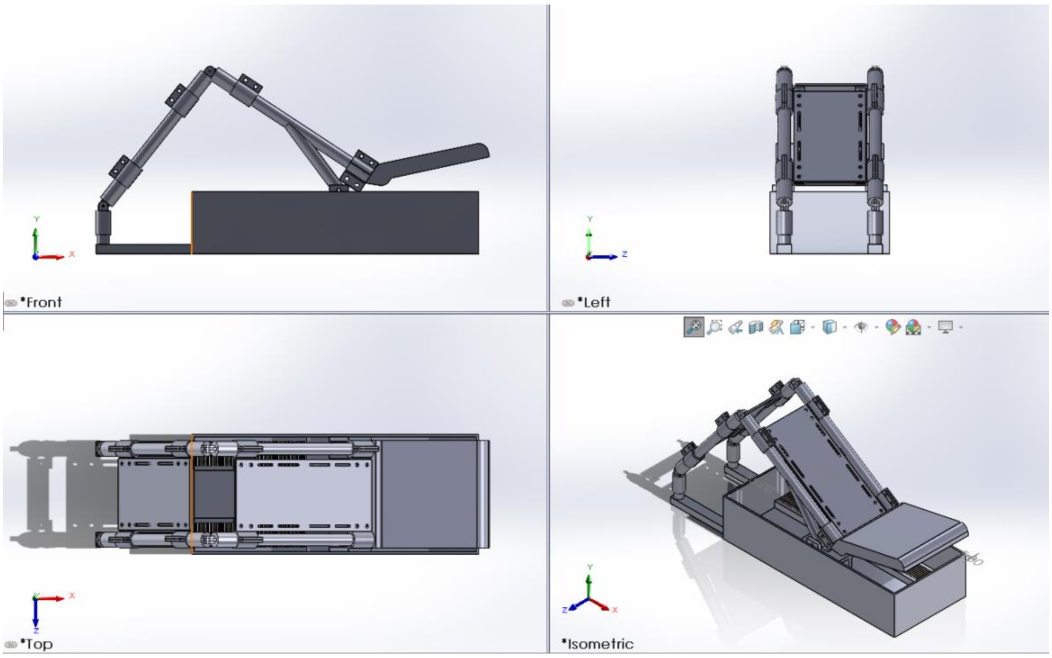
METHODOLOGY

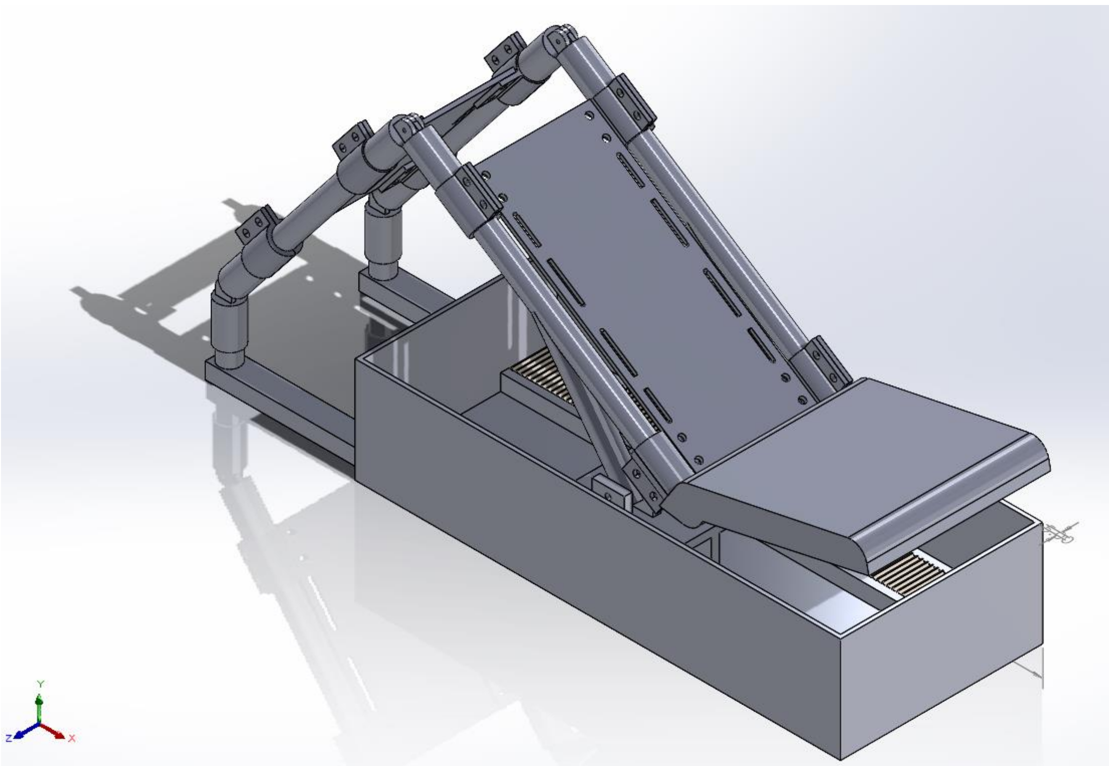
3.1 Flow chart



The preparation of the model is carried out based on the designing of the electro-mechanical model with actuation and transmission mechanism to accurate the knee joint for rehabilitation exercises followed by mathematical modeling of its kinematics and component selection, simultaneously AI model is trained and tested for the prediction of need of rehabilitation for the lower limb knee joint for which data is collected and classified in corellance with machine learning algorithm.

According to a research survey conducted Sitting giat posture provides the knee joint desired flexion although considering the patient condition and safety, sleeping giat mode is considered for the rehabilitation of knee joint as the human body is grounded and will avoid any unwanted and reflex motion of the knee joint. Also minimal actuation will be required to perform the procedure considering minimum power consumption, reducing unnecessary motion of the body.


*Front
*Left
*Top
*Isometric

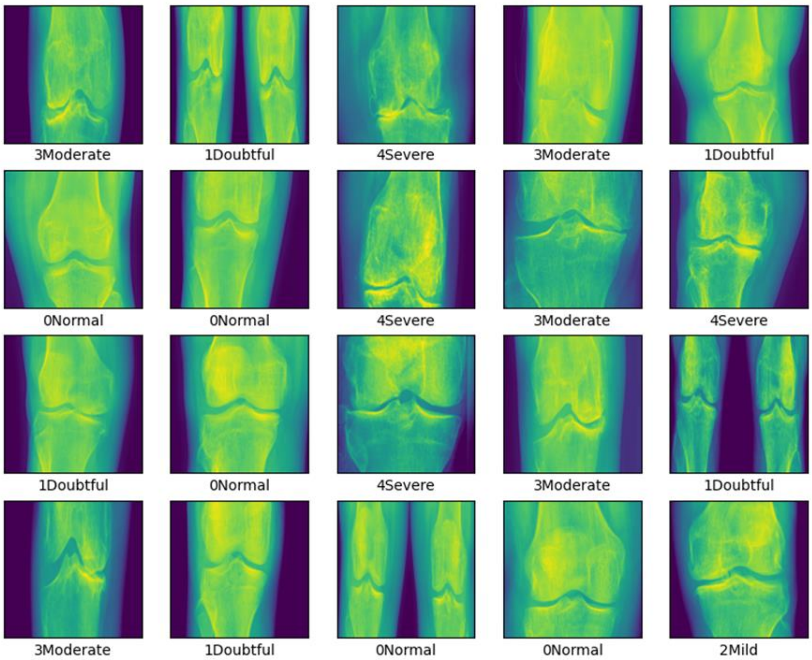


This a CAD based model of the prototype model based on sleeping giat position of the patient which uses rack and pinion mechanism for the actuation of the knee joint. Various links and joints are used to actuate and support the knee joint while performing rehabilitation procedures.The total extension of the slider is 450mm covering 6 flexions in a 60 seconds. The length of the linkages can be customized in accordance with the patient making it feasible to use the machine for distinctive people.

3.2 AI model for prediction

Artificial intelligence can be a valuable tool for assessment and early detection, any medical diagnosis or therapy plan should be confirmed and monitored by a certified healthcare professional. Furthermore, the efficacy and dependability of AI systems for knee rehabilitation evaluation would be determined by the quality of data used for training and validation. The system will become more efficient and accurate by analyzing and presenting results for gait analysis, RoM, Sensors data analysis, and various machine learning models.

3.2.1 Input data:



The X-RAY dataset of knee joint was taken from Kaggle which were derived from OAI website where authentic data was collected and stored in kaggle.The above pictures are the

X-RAY images of different patients overall having different types of seriousness levels coupled with the files and the data is divided into 5 parts from the image “3Moderate", "1Doubtful", "0Normal", "2Mild", "4Severe". The data is then converted into black and white as the image processing is better and more effective. The convolution layers are added to filter the required deference.

3.4 CNN

Model: "sequential_1"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 254, 254, 128)	1280
activation (Activation)	(None, 254, 254, 128)	0
max_pooling2d (MaxPooling2D)	(None, 127, 127, 128)	0
conv2d_1 (Conv2D)	(None, 125, 125, 64)	73792
activation_1 (Activation)	(None, 125, 125, 64)	0
max_pooling2d_1 (MaxPooling2D)	(None, 62, 62, 64)	0
conv2d_2 (Conv2D)	(None, 60, 60, 32)	18464
activation_2 (Activation)	(None, 60, 60, 32)	0
max_pooling2d_2 (MaxPooling2D)	(None, 30, 30, 32)	0
flatten (Flatten)	(None, 28800)	0
dropout (Dropout)	(None, 28800)	0
dense (Dense)	(None, 256)	7373056
dropout_1 (Dropout)	(None, 256)	0
dense_1 (Dense)	(None, 128)	32896
dropout_2 (Dropout)	(None, 128)	0
dense_2 (Dense)	(None, 64)	8256
dense_3 (Dense)	(None, 5)	325

Total params: 7508069 (28.64 MB)
Trainable params: 7508069 (28.64 MB)
Non-trainable params: 0 (0.00 Byte)

The above tables define the layer-by-layer steps proceeding in the deep learning model which was created to identify knee osteoarthritis seriousness in the patient. Firstly, as mentioned the black and white image is subjected to convolution layers and pooling layers. After the Max pooling creates an array of values in a matrix which is then flattened to get an n*1 matrix which gives n inputs that are used for ANN. The ANN here consists of 3 hidden layers with respective perceptron. Finally, after many trials and errors and other factors we have chosen “RELU” as our activation function. Finally, after this whole process, we used “SOFTMAX” activation as we were to choose one out of the five. By taking the probability this is done. The answer is arrived, the data set, activation function, hidden layers, and Epoch play an important factor in the accuracy increase and prediction.

Finally, to train the model we have taken a 100-epoch rate. The test error was minimized and the prediction was done by taking a different image from the other dataset.

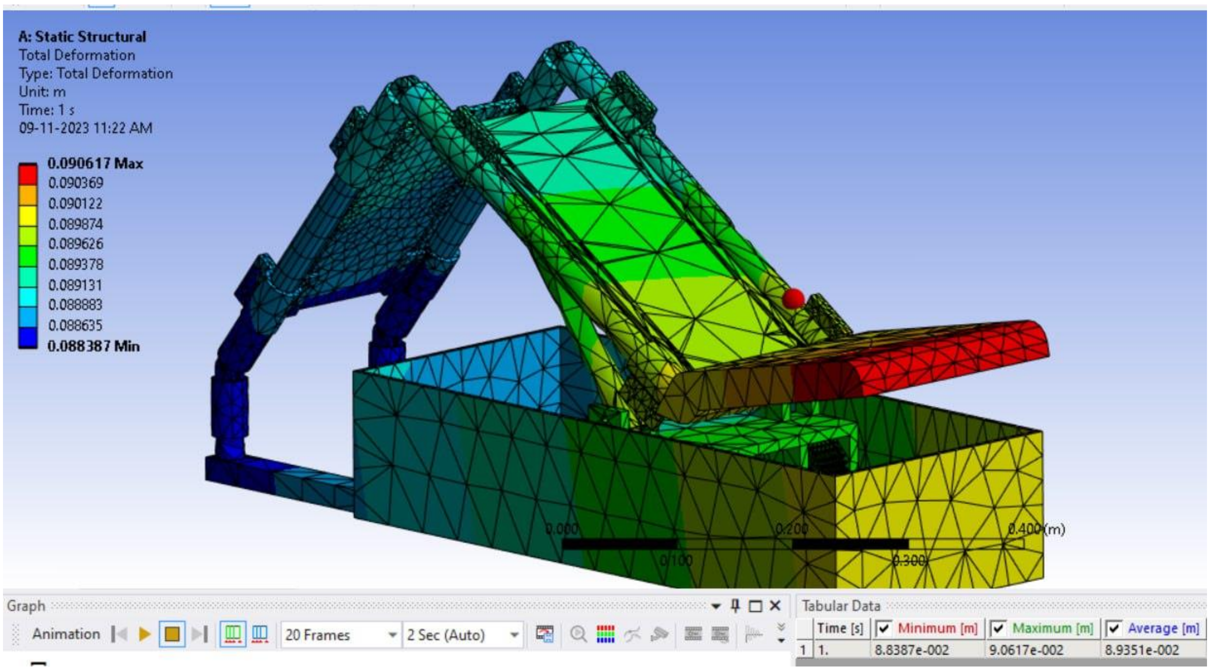
CHAPTER 4
RESULTS AND DISCUSSION

1.1 Structural Analysis

To verify the model the structure analysis is needed to analyze the load and the material loading capacity of the integrated model. The materials are defined by extensive testing along with the statistics of the cost along the manufacturing. PI Thermoplastic, PVC,ABS material and structural steel for joints and hinges is considered for testing [20].

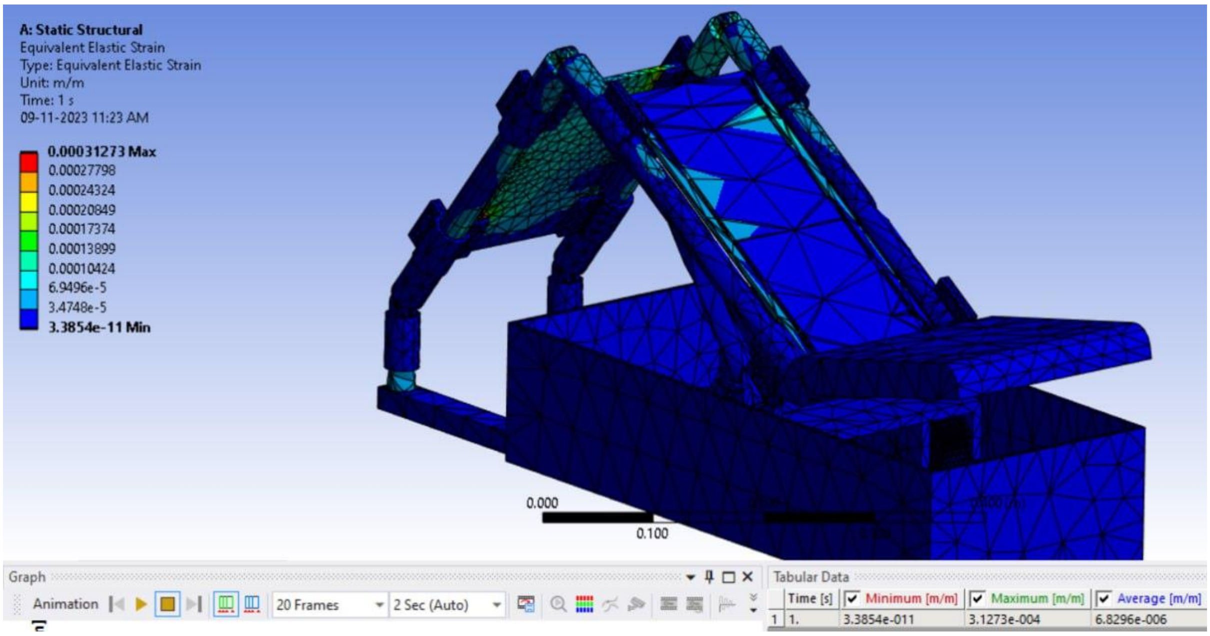
Structural Analysis is carried out to determine the structural integrity of the model. The force applied on the leg supports is 15N, with fix supports applied on the base**.**

Deformation:



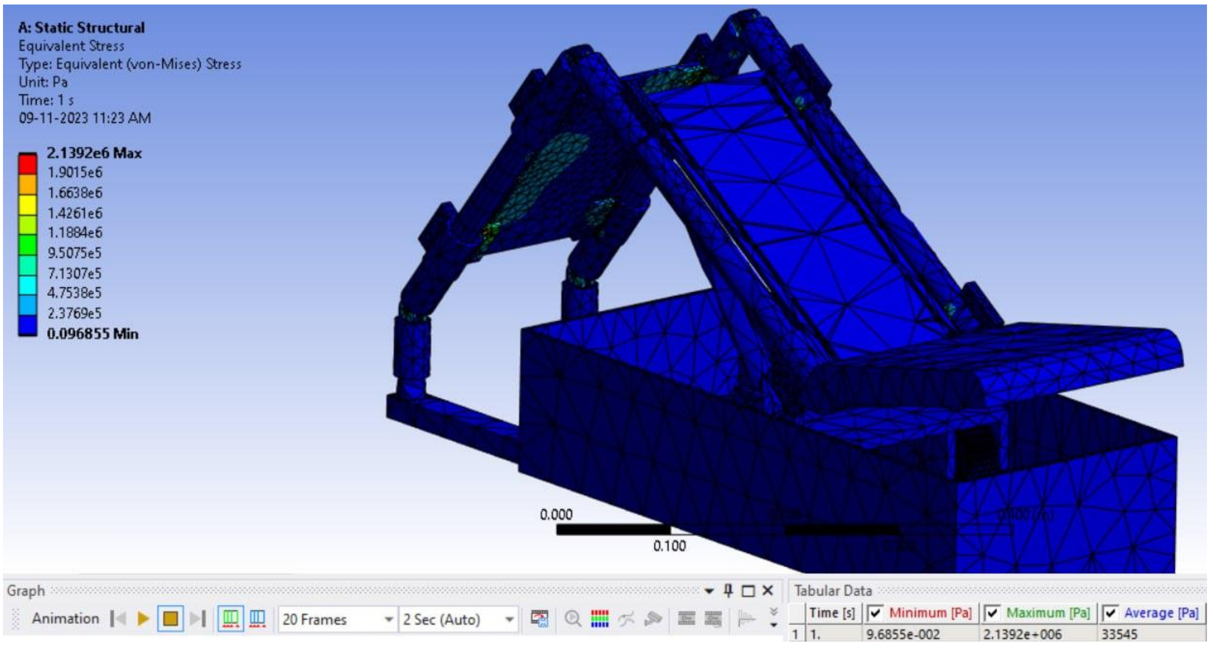
In the Deformation test conducted in ANSYS, a uniform load of 150 N was applied to the test specimen. The analysis revealed that the stress distribution within the material exhibited distinct patterns, with higher stresses concentrated near the footplate. This information is crucial for understanding how materials respond to external forces, which can be invaluable in the design and optimization of structural components. It was observed that maximum deformation was occurring on the

Strain:



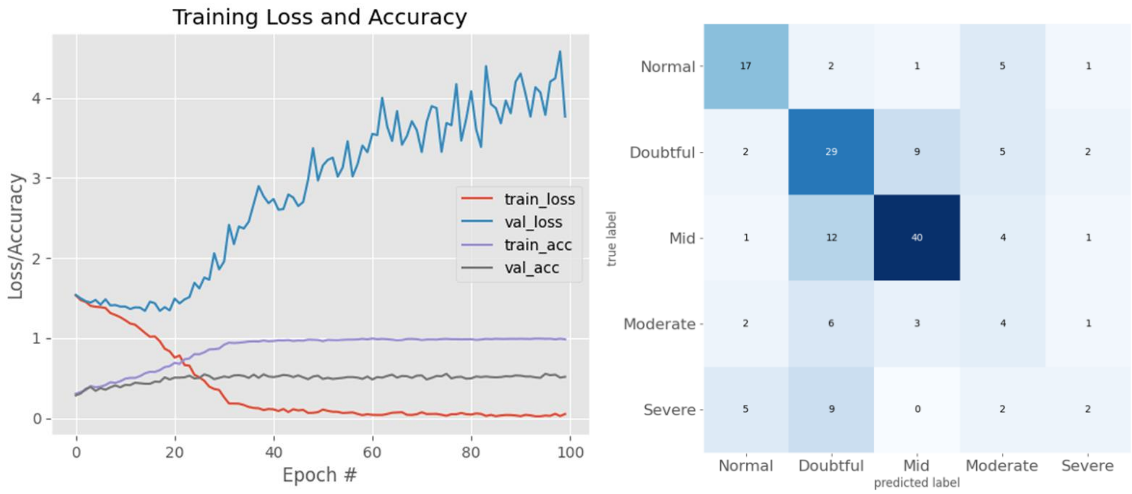
The results obtaining depicts that the load acting on the body is evenly distributed towards the support in extended position considering the maximum load acting on it, although you can see there in some strain occurring to the end on support attached but that might not be a concerning issue as it is almost negligible.

Stress:



Similarly, stress analysis on the model considering the same parameters was carried out to verify compatibility and analyze the model's efficiency. It was observed that the model is able to withstand the load applied, considering safety factors, proving it to be reliable to use.

1.2 Prediction result:



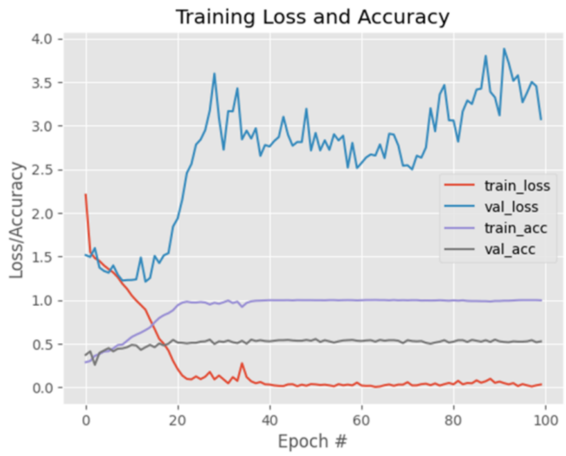
test loss: 3.478864908218384 %

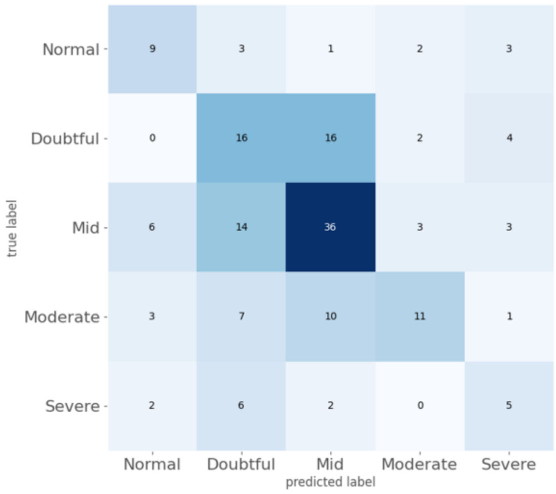
test accuracy: 0.5575757622718811 %

True positive=92 of 162

figure4 Relu activation training model:

The prediction of the Relu model is high from the confusion matrix given. The epoch was 100 and the same deep learning model was used for all predictions. The test loss is less comparative to linear and the leakyRelu. The accuracy of relu is best in CNN model which was a known fact due to it less computation and overcomes the vanishing gradient problem. The problem with leaky relu is over computation and over feature capture which hinders primary objective. Due to the vanishing gradient mentioning the sigmodial,hyperbolic and linear stop at certain training epoch where future training is not possible which can be observed from the table



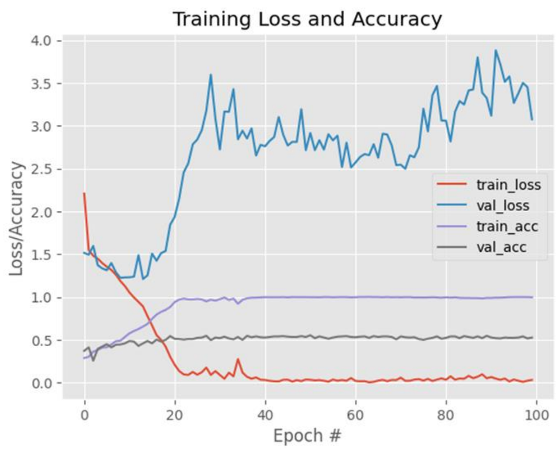


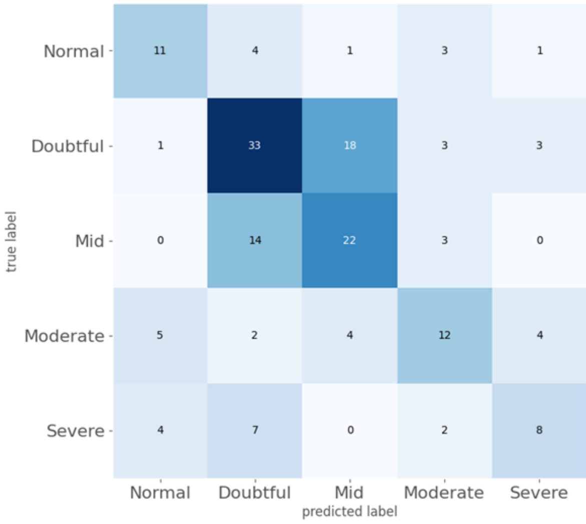
test loss: 3.7095234394073486 %

test accuracy: 0.46666666865348816 %

True positive=77 of 162

Figure 5 Linear activation function:





test loss: 4.584426403045654 %

test accuracy: 0.521212100982666 %

True positive:86 of 162

Figure 7 Leaky Relu activation function:

The comparison between different activation functions and different epoch conditions are given in the table. where we can observe that the relu is the best for image processing of current dataset and model. The linear model fails to make the accuracy of the model understandable as the image data are not always linear classified. The LeakyRelu also shows an increase in accuracy but stops after an accuracy of 0.52%.The test accuracy of 0.56% is the highest achieved from the relu model and can be stabilized to 0.57 after increasing the epoch. the test losses also show the LeakyRelu having the highest increase in test loss.

ADD TABLE NAME

Activation Function	Epoch	Test loss	Test accuracy
Relu	**100**	**3.48**	**0.56**
Relu	**50**	**2.82**	**0.53**
Linear	**100**	**3.71**	**0.47**
Linear	**50**	**3.11**	**0.46**
LeakyRelu	**100**	**4.58**	**0.52**
LeakyRelu	**50**	**3.08**	**0.50**

Chapter 5

Conclusion

The use of AI algorithms in predicting knee rehabilitation robotic systems is a significant advancement in the field of medical technology. AI's predictive skills not only improve the precision and efficacy of rehabilitation regimens, but also contribute to personalized and patient-centered care. The model is created by comparing different activation functions. The difference in accuracy ranges from 2-5% by changing the activation made to choose Relu over linear and leakyrelu. The final accuracy observed was 55% with the deep-learning model. The images chosen—around 169—were validated alone. The epoch rates were taken at 50 and 100. The linear learning rate stopped with 50 epochs but leakyrelu and relu learning rates stopped around 110-130 epochs. The AI-driven knee rehabilitation robotic devices may adapt and modify exercises to specific demands by employing machine learning algorithms to analyze individual patient data. The prediction was done by taking the model and running it in programmed code. The predictions are acute and precise based on the confusion matrices from respective models.As we stand at the crossroads of AI and healthcare, the possibility for revolutionizing knee rehabilitation through predictive technology holds enormous promise for improving patient outcomes and reshaping the healthcare system.

The future of disease prediction is needed as diseases are increasing and technology has reliable methods to predict them. Disease recognition starts with this, and due to the algorithm being open source, it can be combined with other predictions to make a full pledge device where doctors can focus on precise identification rather than a vague search for symptoms. Variable resistance and assistance mechanisms can be incorporated to challenge patients at different stages of their rehabilitation, promoting muscle strength and flexibility. Virtual reality environments are integrated to make exercises for rehabilitation more engaging and interesting, motivating patients to adhere to their rehabilitation programs.

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