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Developing And Investigation Knee Arthritis Classification Model From Knee X-Ray Image Using Deep Learning Approach

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Declaration

This thesis work is my original work and has not been presented for any other university.

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Approval Sheet

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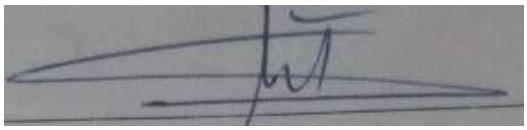
Signature:  Date: 12/20/2021

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Table of Content

Contents

List of figures

List of Tables

Acronyms

ACL …… Anterior Cruciate Ligament

OA……..Osteoarthritis

DICOM ……Digital Imaging and Communications in Medicine

RA……Rheumatoid Arthritis

ReLU …….. Rectified Linear Unit.

GA……Gout Arthritis

Nk…….Normal Knee

JRA …….Juvenile rheumatoid arthritis

IJSP…….International Journal of Signal Processing

ICCPCT….. International Conference on Circuits, Power and Computing Technologies

IP……image processing

PR……..pattern recognition

PET ……..positron emission tomography

SVN……. Support vector machine

CNN…….Convolutional neural network

GLCM…...Gray Level Co-Occurrence Matrix

DTCWT…..Dual tree complex wavelet transform

WHO…….. World health organization

RFC ……..Random forest classifier

OPD -------- Outpatient Department

Abstract

Arthritis is a disease caused by inflammation of joints. It is the primary cause of human impairment. It affects mostly the neck, knee, and palm of hand, elbow, lung, and heart. There are over a hundred various types of arthritis. Osteoarthritis, rheumatoid arthritis, psoriatic arthritis, gout arthritis, and lupus arthritis are among the most common types of arthritis. Physicians use x-ray machines to scan the damaged body of the patient, but it is difficult to determine the types of arthritis So, Imaging processing is required for a more accurate diagnosis of arthritis. As we've seen, earlier research works have only focused on a single type of arthritis.

Now, here we develop a Computer-aided diagnosis (CAD) knee arthritis disease classification model for the most common occurred arthritis diseases namely Osteoarthritis, Rheumatoid arthritis, and gout arthritis. To implement this research work, we collect 665 x-ray images from JUMC, Jimma Aweytu hospital, and Fromsis hospital, then we apply deep learning approach CNN architecture image processing technique to improve the accuracy of the model like image augmentation. We use image normalization like cropping size to 100 by 100, image augmentation from 665 raw x-ray images to 1725 augmented images. Generally, we develop a model that automatically classifies knee arthritis disease. We compare four models Vgg16, ResNet50, DenseNet121, and our custom-developed model KneeArthritisModel by different image sizes 100 x 100, 75 x 75, and 50 x 50. We use the softmax activation function for classification, and the relu activation function for other hidden layers. Our developed model KneeArthritisModel achieves 91% accuracy when we use 100 x100 image size. Our model classifies the arthritis knee x-ray image into four classes of disease as normal knee, osteoarthritis, Rheumatoid arthritis, and gout arthritis.

Keywords: Computer-aided diagnosis (CAD), Osteoarthritis (OA), Gout Arthritis (GA), and Rheumatoid Arthritis (RA), KneeArthritisModel, x-ray image.

Chapter One

Introduction

1.1 Background of the study

Arthritis is normally viewed as a disease caused because of inflamed joints. Inherently, it is not just a single disease rather a collection of medical problems collectively termed as “Arthritis” [1]. Arthritis is a term for a collection of diseases that affect bone joints. This leads to early disability and joint deformities [2]. Arthritis is an inflammatory disease that affects one or more joints in the body and is caused by a variety of reasons, including trauma, infections, autoimmune disorders, idiopathic causes, and other chronic diseases [3]. Arthritis is a disorder in bone joints accompanied by pain swelling and joint deformation. The disease once struck cannot be cured but can be controlled on proper diagnosis and treatment. Radiography of the joint under study is the conventional method used to examine the erosion level caused by arthritis [4].

What exactly is Knee Arthritis? Knee Arthritis is a broad term that refers to a variety of conditions in which the joint surface or cartilage wears out. This surface can deteriorate for a variety of reasons, the source of which is frequently unknown. The knee joint is frequently affected by arthritis. As the articular cartilage wears away, the bone ends rub against one another, causing pain. Arthritis can be caused by a variety of disorders, although the actual reason is often unknown. Osteoarthritis is the most frequent kind of arthritis [5]. Because being overweight puts additional strain on your hips, knees, ankles, and feet, your weight is the single most critical link between nutrition and arthritis.

Symptoms of Knee Arthritis: causes pain and reduced mobility at the knee joint, the cartilages of the joint becomes thinner than the normal knee joint or it may absent totally. There is no space between the knee joint shown on the x-ray but in a normal knee, there is a space between joint cartilages of the knee. The capsule of the arthritic knee is swollen. Due to pain or tiredness, the combination of these factors stiffens the arthritic knee and restricts activities [5]. There are more than 100 types of arthritis disease but the most commonly appear most of the time are the five types of arthritis [6]. These are Osteoarthritis, Rheumatoid arthritis, psoriatic arthritis, gout arthritis, lupus arthritis.

Osteoarthritis (OA) is a joint disease associated with degenerative damage to joint cartilage. More people are suffering from this disease than any other form of arthritis. This is the "wear and tear" that develops as a result of the overuse of joints. It is most commonly associated with old age, although it can also be caused

by joint disease or obesity, which puts additional strain on the joints. WHO report shows that 40% of the world's population will suffer from OA, of which 80% of them have limited motion [7]. The most usually affected appendicular joints are the knees, hips, and hands [8]. Osteoarthritis (OA) is a disease of the joints (commonly knee, hip, hands). When joints lose cartilage, bones grow in an attempt to repair the damage. However, the abnormal growth of bones did not make things better but made them worse. For example, a bone might grow misaligned, causing pain in the joint and restricting movement. Your bodily functions are affected by OA, particularly your ability to use your joints [9].

Gout Arthritis (GA) is a type of arthritis most of the time is caused by crystals created by the high amount of uric acid that builds up in the joints. It commonly affects the big toe and knee, although it can also affect other joints. Even without treatment, the attack will last 3 to 10 days. It may take months or years for you to have another, but over time, the attacks can become more frequent. They can also last longer. If gout is not treated in time, it can affect the joints and kidneys. One of the conditions that can causes gout is your body is making more uric acid.

Rheumatoid Arthritis (RA) is a complex and progressive autoimmune disease that affects people of different ethnic backgrounds all over the world. The specific cause of RA is unknown. Some experts agree that after being infected with bacteria or viruses, the immune system becomes "confused" and begins to attack the joints [6]. This type of arthritis occurs when the body's defensive system malfunctions. The natural immunity of the individual secretes antibodies and fight against his/her healthy tissue. It affects the joints and bones (especially those in the hands and feet), as well as internal organs and systems. Scientists believe that two-body chemicals related to inflammation, tumor necrosis factor (TNF), and interleukin 1 trigger other parts of the immune system in rheumatoid arthritis. Drugs that block TNF, interleukin 1, and interleukin 6 can improve symptoms and prevent joint damage. Symptoms can appear gradually or suddenly. They are usually more severe than osteoarthritis. Rheumatoid arthritis is a chronic autoimmune illness that affects between 0.5 - 1% of the global population [10]. In Ethiopia According to the latest WHO data published in 2018, 185 people died with rheumatoid arthritis accounting for 0.03 percent of all deaths [11]. There is no cure for RA. However, early and aggressive treatment can help prevent further joint damage and promote relief.

Psoriatic Arthritis: Psoriatic arthritis, this type of arthritis disease have inflammation of the skin (psoriasis) and the joints (arthritis). Psoriasis causes raised, red, white, irregular scaly areas on inflamed skin. It usually affects the tips of the elbows and knees, the scalp, the belly button, and the skin around the genital or anus

area. Only 10% to 30% of persons who have psoriasis will develop psoriatic arthritis [6]. The symptoms of gouty arthritis are severe joint pain: It can appear in the big toe, but it can also appear in the ankle, knee, elbow, wrist, or finger. Discomfort: Even after severe pain subsides, your joints will still be sore. Inflammation and redness - Joints become red, swollen, and tender. Difficult to move: Your joints will be stiff.

Arthritis cannot be easily identified from each other because of similar symptoms of each arthritis type. Pain, redness, heat, swelling in the joints, difficulty moving, fever, weight loss, breathing problems, and rash or itch are all symptoms of arthritis. To diagnosis, the disease the doctor may ask you about your medical history give you a physical exam, take samples for a laboratory test, and take x-rays. As scientists agree that, still the cause of arthritis disease is not known. To treat the patient from pain and control from further damage of joints and repair the damaged joint via surgery. A medical history, physical examination, and an x-ray of the affected joint are used by doctors to diagnose knee arthritis. A reduction of joint space and the growth of bone spurs can be seen on the x-ray in the case of arthritis in the knees, however, there is no blood test available. Health care services are unlike any other, it is a high-priority industry, and people want the best possible care and services, regardless of the cost. Even though it consumed a large portion of the budget, it didn't meet the social expectation. Medical experts are usually the ones who interpret medical data. Subjectivity, image complexity, significant variations among interpreters, and weariness limit human image interpretation. Deep learning is already giving promising high-accuracy solutions for medical imaging, following its success in other real-world applications. And it is predicted to be a major pathway for future applications. Therefore, there is a need for automation of the Arthritis identification and classification model using the image-processing technique and we prefer CNN, because CNN is accurate in medical image classification [13], in this study the convolutional neural network (CNN) algorithm is used [12]. Image processing is now a day rapidly growing technology. In addition, it is applied to varieties of problems like health sector services for accurate identification and classification of disease diagnosis and other problems.

Now, in our research work, we had designed a model only for the main types of arthritis identification investigation model to classify the above-listed types of arthritis using image processing techniques and a convolutional neural network algorithm. Osteoarthritis (OA), Gout Arthritis (GA), and Rheumatoid Arthritis (RA) is among the most frequent types of arthritis. Now, as we explore still, there is no research work conducted to identify and classify these listed above arthritis diseases.

1.2 Motivation

The main motivational reason for developing this diagnosis model is to overcome the critical challenges faced by radiologists and doctors during the examination of arthritis disease. Misdiagnosis of diseases is caused by a shortage of a qualified/experienced radiologist, the symptoms of each type of arthritis are very similar and the investigation is time-consuming and tedious. Some patients treat their pain wrongly. Because of misdiagnosis of the disease, so after a time their pain is not changed rather it increases and starts to damage their joint. Due to this reason some patients believe this is a gift of God and they cannot believe by medication. And the victims of the disease complain to God, claiming that it is a spirit of bad luck and that they are prone to injury, pain, and other health complications until they die. So, as an academic staff member of Health Informatics, and an educated scholar, we want to contribute to this work and lay the good base work for my future academic research and this research area. Due to this reason, we are highly interested to conduct this research work.

1.3 Statement of the Problem

Arthritis is one of the most frequent health issues that people face all around the world [13]. A person suffering from arthritis faces a considerable risk of early impairment and joint abnormalities. The damage to the joints might be minimized by early diagnosis and treatment of Arthritis. Many therapeutic approaches are now widely available for the diagnosis of this disease. The analysis depends heavily on imaging of the damaged joints [2]. Arthritis is a condition in which one or more joints swell and become tender. The main symptoms of arthritis are joint pain and stiffness, which typically worsen with age. The most prevalent arthritis diseases include osteoarthritis, rheumatoid arthritis, reactive arthritis, gout, and lupus arthritis.

Osteoarthritis (OA) is the most common joint disease, affecting 10 to 15% of adults globally and causing chronic pain and disorders [14]. Rheumatoid arthritis (RA) is a common autoimmune disease that affects 0.5–1% of the world's population [10]. Now in Ethiopia, there is no clear figure of the patient’s statistical information but the issue is a series and affects many adults and exposed too many socio-economic problems and it exposes to disability of different body’s joint and unable to function.

The disease is identified by observing progressive degradation of the articular cartilage causing severe discomfort accompanied by pain and loss of mobility [1]. The problem is to identify the Arthritis disease from this joint cartilage x-ray images of the patients because of the difficulty of manual reading of the x-ray image captured and also to classify which types of arthritis are from most common arthritis. But this manual

identification of arthritis from x-ray images is not that much enough accurate, so an image processing technique is needed to increase this accuracy of identifying the arthritis disease. And save the patients from the pain of the disease, risky life, and family economy expense, in general, it rescues the country's economy. Because the disease is a lifelong disease, so their family is exposed to too many economic expenses.

Many researchers have been conducted many research works to detect Arthritis disease using image processing, machine learning, and deep learning Techniques. But those research works only focus on a single arthritis disease [15] and also they use a small number of dataset size up to 15 images [16], [17] these 15 images may not give all the features of the diseases, so it may not give accurate decision for medical image classification because feature extraction is vital for image processing so during medical diagnosis decision it gives the false result and also same researches did the status level of the patients as early symptoms, moderate, and worst stage [13], so here in our study we develop a model which detects and classifies multi arthritis disease. The most fundamental question we address in this research is as folows:

I. Which image size is better to improve performance and computational time?
II. Which CNN model classifies better than other models?
III. To what extent the model works in Arthritis detection and classification?

1.4 Objectives

1.4.1 General objective

The main objective of our research is to develop and investigate a model that detects and classifies Arthritis disease using a deep learning approach image processing technique.

1.4.2 Specific Objectives

I. To explore more works on arthritis.
II. To prepare a dataset of Arthritis x-ray images.
III. To compare three different image sizes
IV. To design a deep CNN model that automatically detects Arthritis disease.
V. To evaluate the performance of the trained model using evaluation metrics.

1.5 Scope and limitations of the study

Our research works scope is only focused on designing a model to classify knee Arthritis (osteoarthritis, rheumatoid Arthritis, and Gout Arthritis), using image processing techniques. So here the limitation of this research work is only focused on these three types of arthritis. So, here is the limitation, because there are many other types of arthritis disease. But we only apply already suspected patients by the physician. All knee joint diseases and all types of Arthritis are not covered by our research work.

1.6 Application of Results

An increasing healthcare cost has threatened many countries' financial health, and the effort needed to care for their nation, and it affects the development of one country. The economic development of the country is highly related to healthcare status. Therefore, to overcome the above-stated issue improving healthcare facilities and giving accurate diagnosis methodology for the patient is vital. The disease of Arthritis requires quality healthcare service and accurate diagnosis tools due to the nature of the disease. This is the reason, why we conduct this research work. So, the beneficiaries of the research works are all stockholders of the community like Patients, Physicians (Radiologists, Doctors...), Patient families, Country /community, and Researchers who also got the academic reward.

1.7 Ethical Consideration

Confidentiality of the patient's information/x-ray image was ensured during the data collection, preparation, and analysis time and interview of domain experts (physicians) all medical information's are secured and confidential used only for this research purpose. We have an official letter from our faculty and acceptance confirmation signature with titer from the medical directors of the hospital.

1.8 Organization of the Thesis Work

The following is how the rest of this thesis work is organized. Chapter 2 reviews related work on the disease of Arthritis and its diagnosis mechanism related to imaging technology. In chapter 3 we describe and state the methodologies and algorithms of the proposed thesis work to implement the proposed research work. Chapter 4, experimentation and model result discussion: In this chapter, we experiment and apply analysis techniques stated under chapter 3, the dataset used, tool installation and experiment result in discussion for reason out the conclusion of the experiment result. Chapter 5, in this chapter, we briefly state the conclusion and future works of this thesis for future interested researchers of this area.

Chapter Two

Literature Review

2.1 Deep Learning for Image Classification

Deep learning, in particular Convolutional Neural Networks (CNN), is a validated image representation and classification technique for medical image analysis and applications [18]. Our human brain accepts external stimuli, processes the information, and then generates the output. Multiple neurons develop a complex network as the task becomes more difficult, transmitting information back and forth [19]. It is clear that deep learning has already led to improved accuracy of computer-aided detection and segmentation in medical image processing. However, further improvements are needed to reach the accuracy bar set by experienced clinicians [18]. Recently, deep learning is emerging as a leading machine learning tool in computer vision and begins attracting considerable attention in medical imaging [18].

CNN classification is accurate when the image format is .JPEG. JPEG format contains less color information and data capacity than the DICOM format. But SVM and ANN accuracy decreased with the loss of data from DICOM to JPEG formats [12] , whereas CNN increases the accuracy.

Convolutional Neural Networks (CNN) is the current state-of-art architecture for the image classification task [20]. A Convolutional Neural Network (CNN, or ConvNet) is a special type of multi-layer neural network that is meant to recognize visual patterns from pixel images with minimal preprocessing [21]. Convolutional Neural Networks (CNN) becomes one of the most appealing approaches recently and has been an ultimate factor in a variety of recent successes and challenging applications related to machine learning applications such as challenge ImageNet object detection, image classification, and Face recognition [22]. Because of this reason, we choose CNN as our model for this challenging task of medical image classification. One popular application of these convolutional networks is image classification. Image classification is defined as the task of entering an image into a model built using a specific algorithm, which generates the category or probability of the category to which the image belongs. There is a big difference between how we perceive images and how the machine (computer) perceives the same image. For us, we can visualize images and characterize them based on color and size. On the other hand, for the machine, you can only see numbers. The numbers you see are called pixels. Each pixel has a value between 0 and 255. Therefore, using these values, the machine needs some preprocessing steps to derive some specific patterns

or features to distinguish one image from another. Convolutional neural networks help us build algorithms that can derive specific patterns from images [23]. In deep learning, the convolutional neural network is a type of deep neural network that is mainly used for visual images [24].

2.2 Classification

Image classification is the process of predicting a particular class or label of what is defined by a set of data points. Image classification is a subset of deep learning that solves classification problems that assign labels to the entire image. Especially nowadays it is applicable in many sensitive areas including medical diagnosis to classify a specific class of diseases.

Classification Algorithms: we use a Convolutional neural network (CNN), it is the latest Algorithm now day's many medical image-processing problems are implemented using this deep learning Algorithm. Why? Because: CNN is semi-supervised and supervised so, image is unsupervised and classification is supervised so, CNN is appropriate for our research work. Deep learning methods, especially Convolutional Neural Network (CNN), has increased and improved the performance of image processing and understanding. Convolutional Neural Networks (CNN) are very common now especially in the image classification tasks as CNN's have better classification accuracy than other techniques available in image classification [25]. The performance of real-time image classification based on deep learning achieves good results because of the training style, and features that are used and extracted from the input image [26]. The convolutional neural network (CNN) [27] is a classic model produced by the combination of deep learning and image-processing technology. The main idea is to use spatial relative relationships to reduce the number of parameters and share the weights of feature mapping at different positions of the preceding layer network to improve training performance. CNN consists of an input layer, an output layer, and several hidden layers [28]. Each layer in the hidden layer performs a specific operation, such as convolution, pooling, and activation. The input layer is connected to the input image, and the number of neurons in this layer is the pixel of the input image. The middle convolutional layer performs feature extraction on the input data through a convolution operation to obtain a feature map [29]. Because of this, we use CNN for our classification problem. Convolutional Neural Network (CNN) is an anticipatory neural network with a deep learning function. Its structure consists of an input layer, a convolutional layer, a pooling layer, a fully connected layer, and an output layer [30]. Its feature learning process includes extracting and classifying low-level to high-level features. The network can perform two-dimensional graphs of displacement, scale, and other invariant forms of stress. During training, it can be learned implicitly from the training data and can be learned in parallel, so in the field of image

detection classifiers, there are many applications. As their name suggests, ConvNets apply convolutional filters to compute image features that are useful for classification

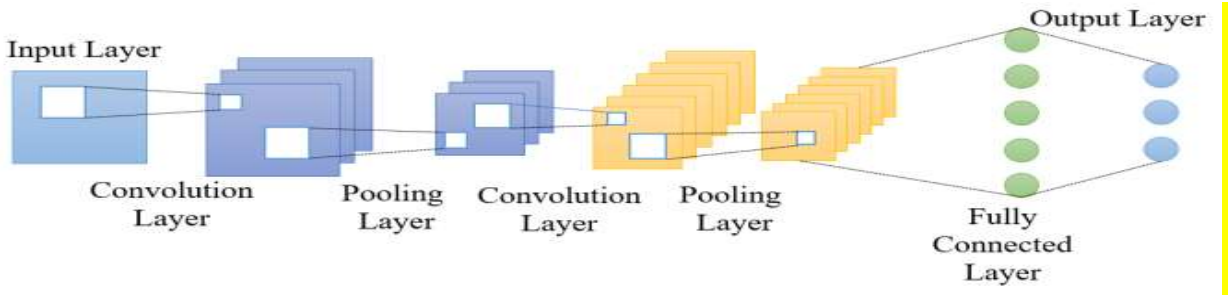

Figure: 3. 1 Basic architecture of CNN

They are a special architecture of artificial neural networks (ANN) proposed by Yann LeCunn in 1998 [31]. The convolutional neural network consists of two parts. The first part consists of a convolutional layer and a pooling layer, in which the main feature extraction process is carried out. In the second part, the fully connected layer and the dense layer perform several non-linear transformations on the extracted features to serve as the classifying part. The convolutional neural network model contains several types of layers, such as [31].

I. Input Layer
II. Convolutional Layer
III. Pooling Layer
IV. Fully Connected Layer
V. Output Layer
VI. Activation Functions

Input layer: As the name suggests, this layer feeds the input image to the CNN model. According to our requirements, we can reshape the image into different sizes. The input raw data set can be directly input to the input layer. One image is inputted by its pixel value into the input layer.

The convolutional layer: This layer is the most important layer, which consists of a filter of fixed size (also called a nucleus). The mathematical operation of convolution is performed between the input image and the filter. This is the stage where most of the basic features (such as sharp edges and curves) are extracted from the image, which is why this layer is also called a feature extractor layer. Convolutional layer: This is the first layer of CNN is the convolution layer. Also known as the up-sampling layer that is to extracts features

from the input data. Each convolutional layer has its convolutional kernel and different convolutional kernels extract different features from the input data. CNN aims to learn very deep features of the image via convolution operation so that the model is capable of identifying the invariant features from raw image data.

Pooling Layer: After performing the convolution operation, we perform the Pooling operation. This is also called downsampling, in which the spatial volume of the image is reduced. For example, if we perform a pooling operation with a step size of two on an image with a size of 56 × 56, the image size is reduced to 28 × 28, which will be reduced to half the original size. Its main function is to finish the second extraction of the feature data followed by the convolution layer. Under normal conditions, the CNN architecture contains at least two convolutional layers and two down-sampling layers respectively.

The Fully Connected (FC) layer is found before the final classification output of the CNN Architecture. These layers are used to flatten the results before classification takes place. It involves various biases, weights, and neurons. Adding an FC layer before classification will produce an N-dimensional vector, where N is the multiple classes from which the model should select a class. Fully connected layer: All the feature maps are connected as input. In general, the nodes of the neurons in the later layer are connected to the nodes of the neurons in the previous layer, but the nodes in each layer are disconnected. This layer integrates and normalizes the abstracted features of the previous convolutions to yield a probability for various conditions.

Output layer: Finally, the output layer consists of tags that are mainly encoded by the one-hot encoding method. Output layer: The number of neurons in this layer is set according to the required conditions. If the classification is required. Activation functions: These activation functions are the core of any convolutional neural network model [31]. These functions are used to determine the output of the neural network. In short, it determines whether a particular neuron should fire ("fired") or may not be fired. They are usually non-linear functions performed on the input signal. Then the transformed output is sent as input to the next layer of neurons. It is the third layer is the activation layer applied after the convolution layer. This layer is used to increase the non-linearity of CNN. The main task of any activation function in any neural network-based model is to map the input to the output, where the input value is obtained by calculating the weighted sum of the neuron's input and further adding bias with it (if there is a bias) [32].

There are many activation functions, such as Sigmoid, ReLU, Leaky ReLU, TanH, and Softmax. Among many activation functions, we use ReLU and softmax activation functions. Because ReLU for input layer with single input and single output classification problems and softmax for multiple input with multiple output classification problems. We understand that applying an activation function during forward

propagation adds an extra step to each layer. Now the question is, can we do without an activation function if the activation function adds so much complexity? Consider a neural network that doesn't have any activation functions. In that situation, each neuron will just use the weights and biases to execute a linear change on the inputs. Although linear transformations make neural networks easier to understand, they also make them less strong and unable to learn complicated patterns from input [19]. So, the answer is no, because of this reason.

In the deep learning area, the ReLU function is a non-linear activation function that has gained popularity. Rectified Linear Unit (ReLU) is an abbreviation for Rectified Linear Unit [33]. The key benefit of employing the ReLU function over other activation functions is that it does not simultaneously stimulate all of the neurons. Because activation function adds complicity of the transformation. This implies that the neurons will only be deactivated if the linear transformation's result is less than 0. The outcome for negative input values is zero, indicating that the neuron is not stimulated. The ReLU function is considerably more computationally efficient than the other activation function since only a small number of neurons are stimulated. Multiple sigmoids are frequently used to define the Softmax function. We know that sigmoid returns values ranging from 0 to 1, which can be interpreted as probabilities of a data point belonging to a specific class. For multiclass classification issues, the softmax function can be employed. The easiest way to define a model is by using the sequential model, which allows easy creation of a linear stack of layers. The following example shows the creation of a simple sequential custom model. Model with one layer followed by activation. The layer would have 10 neurons and would receive input with 15 neurons and be activated with the ReLU activation function.

```
from keras.models import Sequential
from keras.layers import Dense, Activation
model = Sequential()
model.add(Dense(10, input_dim=15))
model.add(Activation('relu'))
```

Layer: A layer in the DNN is defined as a group of neurons or a logically separated group in a hierarchical network structure. As DL became more and more popular, there were several experiments conducted with network architectures to improve performance for a variety of use cases. Dense Layer is a regular DNN layer that connects every neuron in the defined layer to every neuron in the previous layer. For instance, if Layer 1 has 5 neurons and Layer 2 (dense layer) has 3 neurons, the total number of connections between Layer 1

and Layer 2 would be 15 (5 × 3). Since it accommodates every possible connection between the layers, it is called a “dense” layer. Keras offers the dense layer with the following default parameters.

```
keras.layers.Dense(units, activation=None, use_bias=True,
kernel_initializer='glorot_uniform',
bias_initializer='zeros',
kernel_regularizer=None,
bias_regularizer=None,
activity_regularizer=None,
kernel_constraint=None,
bias_constraint=None)
```

It offers a lot of customization for any given layer. We can specify the number of units (i.e., neurons for the layer), the activation type, the type initialization for kernel and bias, and other constraints. Most often, we just use parameters like units and activation. The rest can be left to the defaults for simplicity.

Dropout Layer: The dropout layer in DL helps reduce overfitting by introducing regularization and generalization capabilities into the model. In the literal sense, the dropout layer drops out a few neurons or sets them to 0 and reduces computation in the training process. The loss function is an evaluation metric of a model that helps a network understand whether it is learning in the right direction. And also there are other layers to build a custom model using sequential model activation function, pooling layer, and convolution layer clearly explained above section.

2.3 Transfer learning

Now, we decide to use the same popular pre-trained CNN models for the following reason, the first one is due to limited input x-ray dataset size in the context of deep learning, secondly, save the training time and avoid huge computational power/resources required to train the model. Transfer learning consists of taking features learned on one problem, and leveraging them on a new, similar problem. Transfer learning is typically used for tasks where the dataset contains insufficient data to train a full-scale model from scratch. In the context of deep learning, the most common manifestation of transfer learning is as follows:

I. Layers from a previously trained model are used.
II. Freeze them to prevent information contained from being destroyed during future training rounds.

III. On top of the frozen layers, add some new, trainable layers.

IV. They'll figure out how to turn old features into predictions on a new dataset.

V. On your dataset, train the new layers.

2.4 Medical Imaging modalities

Computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), X-ray, and ultrasound imaging are the most common types of medical imaging utilized in clinics. Image segmentation is a well-known subject in computer vision research that has recently exploded in popularity in the field of image understanding. We use in our experiment black x-ray images as default grayscale x-ray images.

2.5 Image processing

Firstly an image is defined as a two-dimensional function f(x, y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) [34]. When x, y, and the intensity values of f are all finite discrete quantities we call the image a digital image [34]. Image processing begins with the display of images on a computer screen and the storage of images on hard drives or other media for later processing. We may use image processing to process and interpret all data as if it were being processed in the human brain. There are more than 100 image formats with different applications like jpeg, gif, png, etc are used for photographic images, on the other hand for formats like DICOM, nifti, analyze avw are used in medical imaging [35]. As a computer-based technology, image processing is becoming increasingly significant in many aspects of our daily life.

Image processing is divided into two categories: image filtering and image warping. Image filtering alters the range (or pixel values) of an image, causing the colors to shift without affecting the pixel locations, whereas image warping alters the domain (or pixel positions), causing points to be mapped to other points without changing the colors. Acquisition, preprocessing, segmentation, feature extraction, and classification are all steps in image processing. The quantity of samples and gray levels in a picture has a significant influence on its quality the more of these two factors there are, the better the image will be [36].

2.6 Medical background of Arthritis and General Overview of recent work

Here in chapter two as we introduce in the thesis organization section, we describe the disease of arthritis from their scientific perspective and related research works of the scientific community. Moreover, what is

arthritis disease and their case, treatment, diagnosis mechanism with their accuracy of identification of the diseases, also we reviewed WHO worldwide statistical reports. In addition, we visit many resource materials and websites, individual medical blogs also included in this chapter like books, scientific published research works, and conference papers and bibliography of the Arthritis disease affected community reports also revised. Additionally, the arthritis disease and medical imaging technology's contribution and their accuracy of detection, as well as classification of each Arthritis disease, have been also reviewed. Finally, we compare and contrast related research works in Arthritis related works accuracy with their algorithms, methods as well as the number of datasets used in their study. Because, our research work is conducted in image processing so, the above list of activities were have been covered during our study.

2.6.1 Arthritis Imaging and Diagnoses

The condition can affect every joint in the body, but it is most common in the knee, hands, and elbow. Your doctor may propose X-ray imaging procedures to obtain images of the patient's affected joints. Cartilage loss is shown by a narrowing of the area between the bones in your joint, which is not visible on X-ray images. Magnetic resonance imaging (MRI) is another option. It produces comprehensive images of bone and soft tissues, including cartilage, using radio waves and a strong magnetic field. Although an MRI is not usually required to diagnose osteoarthritis, it can be useful in some particular conditions [37].

In recent years, deep learning architectures have been widely utilized to classify biomedical images to aid clinicians in the diagnosis and therapeutic management of patients with various health issues [38]. Deep learning frameworks-based automation tools can change every stage of the medical imaging workflow, from image acquisition to interpretation and analysis. One of the most common areas where these techniques are applied is knee MR image classification for different types of Anterior Cruciate Ligament (ACL) tears [38]. The identification and treatment of ACL tears can help patients avoid further joint degeneration, and decrease the progression of later knee arthritis if they are addressed quickly and appropriately.

X-ray imaging is a type of electromagnetic imaging that involves passing an X-ray beam produced by an X-ray tube through the body. Some of the X-ray beam's energy is absorbed in the body. This is referred to as X-ray beam attenuation. On the opposite side of the body, detectors or films capture the attenuated X-rays, yielding a clinical image after passing through a digital computerized system. In traditional x-ray imaging, a filter covers the radiographic film, reducing the number of dispersed x-rays that could trigger a chemical reaction. Because of the silver atoms radiography, areas exposed to ionizing radiation appear darker on the film when treated, producing a single 2D image.

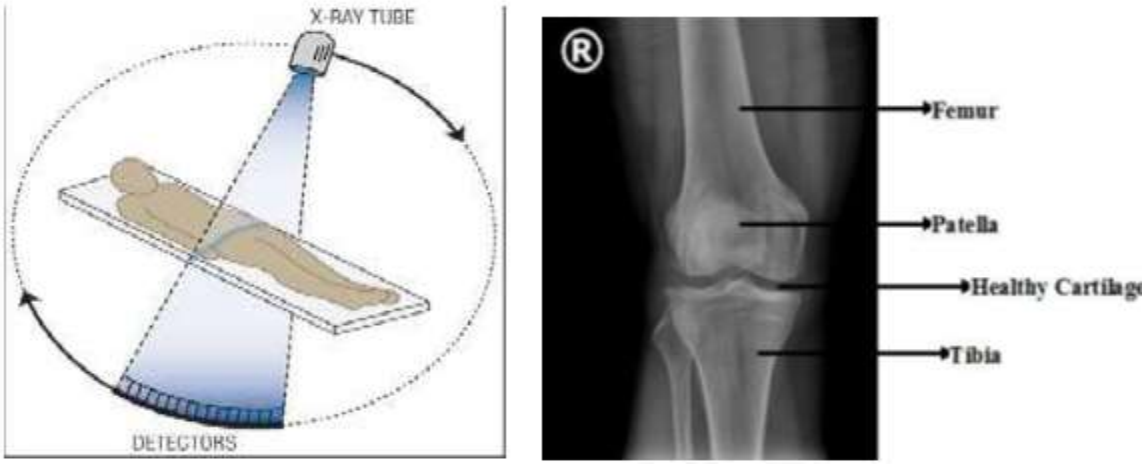

Figure: 2. 1 X-ray imaging modality

2.6.2 Understanding joints

A joint is the meeting point of two bones. The joints allow various sections of the body to move and be flexible. Cartilage is a tough tissue that covers the ends of bones to support them. Synovial fluid is a little amount of viscous fluid that flows between the cartilages of two bones. This lubricates the joint, allowing for uninterrupted movement between the bones. The joint capsule, cartilage, synovial fluid, and the joint itself are all included within the synovium, which is a connective tissue that surrounds a joint. Consider how a door opens and closes when thinking about the knee joint. Unlike a door, however, the knee has a little more flexibility to enable movement patterns that go beyond the front-to-back motion of a hinge. The patella, commonly known as the kneecap, is a protective bony cover that links the femur (thighbone) and the tibia (shinbone) in the knee joint. The knee is a synovial joint that can be affected by a number of pathogens. The knee can straighten (extend) to 0 degrees and can flex (bend) to about 135 degrees [39].

2.7 Arthritis diseases

The term arthritis is often used to refer to any condition that affects the joints, even though joint inflammation is a symptom or indicator rather than a specific diagnosis. Joints are places where two bones meet, such as your elbow or knee. In some diseases in which arthritis occurs, other organs, such as your eyes, heart, or skin, can also be affected [40]. Between 2010 and 2012, 52.5 million adults (22.7 percent of the total adult population) in the United States had doctor-diagnosed arthritis, with 22.7 million (9.8%) having arthritis-related activity impairments By 2040 [41] the number of people in the United States with doctor-diagnosed

arthritis is anticipated to increase by 49 percent to 78.4 million (or 25.9% of all adults), while the number of people with arthritis-related activity limits is expected to increase by 52 percent to 34.6 million (11.4 percent of all adults) [41].

Figure: 2. 2 Knee joint anatomical Structure

2.7.1 Osteoarthritis

Osteoarthritis (also known as OA) is a chronic inflammatory disease. In addition, it results in joint discomfort, swelling, stiffness, and loss of function. It is hard to diagnose in the early stages [42]. Damaged joints can make every movement from bending to lifting painful and uncomfortable [43]. Some people call it a degenerative joint disease or "wear and tear" arthritis. Osteoarthritis is a disease that causes the structures of the joints to degenerate. The joint space narrows when the articular cartilage wears out or deteriorates (i.e the space between the ends of bones in a joint). The hands, hips, and knees are the most frequently affected areas. The cartilage within a joint begins to break down, and the underlying bone changes as a result of OA. These alterations typically take time to appear and worsen. Pain, stiffness, and swelling are all symptoms of OA. It can also result in impaired function and incapacity some persons are unable to do everyday duties or jobs [44]. Damage or degradation of joint cartilage between bones causes OA. The most prevalent risk factor for OA is joint injury or overuse, such as knee bending and repetitive stress on a joint, which can damage a joint and raise the risk of OA in that joint. People's chances of acquiring OA rise as they get older. Women are more likely than males to develop OA after the age of **50**. Obesity Weight increase stresses joints, particularly weight-bearing joints like the hips and knees. Genetics People who have a family history of OA

are more likely to get the condition. Hand OA patients are more likely to acquire knee OA. Race Some Asian populations are less likely to develop OA [44]. Any joint particularly weight-bearing may be affected. The hips, knees, shoulders, hands, wrists, and spine are frequently involved. Features of osteoarthritis include but are not limited to:

I. Osteophyte formation: osteophytes are spurs of compact bone that form at joint margins.
II. Joint space narrowing: cartilage loss eventually leads to non-uniform joint space narrowing.
III. Loose bodies: results from the separation of cartilages and osteophytes.

Figure: 2. 3: Sample OA X-ray Image and When the OA reaches its severe stage

The condition of the knee is so bad because the joint space is severely narrowed with the total destruction of the cartilage, the knee is swollen and painful with more osteophytes and the bone is rubbing against the bone and no cartilage left, there is no cushion, and nothing to absorb the shock of the weight, As we see in the below image. So the condition becomes very painful. Because the patient is walking on their bone there will be decreased mobility, decrease activity, and the patient will have an inferior quality of life. In this case, surgery with a total knee replacement is the best option for the patient.

[45]

Figure: 2. 4 Knee Arthritis Image similarity

2.7.2 Gout Arthritis

The most prevalent type of inflammatory arthritis is gout. Gout is caused by the buildup of monosodium urate crystals in and around bone joints, and around 50 % of patients' apparent, radiographic alterations occur 6-8 years after the initial attack, so these changes are dependent on where the urate crystals are deposited [46]. This uric acid crystal is built in two main mechanisms firstly by excessive urate production and the second one has diminished urate clearance. Without treatment, it can cause permanent bone, joint, and tissue damage, as well as other serious health problems. It can affect almost anyone the elderly, younger adults, athletes, and in some cases, children with obesity, diabetes, or kidney disease. People suffering from Gout experience excruciating pain in the affected area, even covering the foot with a blanket could be too painful. Active gout flare-ups with intense swelling and redness would require oral medications dispensed by your doctor or rheumatologist. With a history of gout, your podiatrist will be able to help you to prevent long-term joint damage. A doctor would order a blood test if he suspects that your joint pain is from gout. Attacks are typically acute onset, can be recurrent, and initially mono articular (affecting only one joint). In dealing with this arthritic condition. Gouty attacks are caused by uric acid crystals forming within a joint. Gout can be treated by a rheumatologist with the right drugs. Many people, however, are unaware that gout is more than just a case of crystals producing chronic inflammation. Gout can harm the bones permanently, causing joint degeneration and damage. If joint damage has already occurred, drugs will not be enough to address the condition. There may even be secondary musculoskeletal symptoms in other places of the body as a result of a gout-affected joint.

Figure: 2. 5 Sample patient Gout X-ray image

2.7.3 Rheumatoid Arthritis

The inflammation of the synovial membrane of the joints is the beginning of this disease. Rheumatoid arthritis (RA) is a complex and progressive autoimmune disease that affects people of different ethnic backgrounds all over the world. It was classified by the world health organization (WHO) as the disease with the greatest social impact [47]. RA is a chronic inflammatory disease that causes severe joint pain, swelling, damage, and disability, eventually leading to joint destruction and function loss. The immune system attacks joints destroy cartilage and bone, cardiovascular disorders are a complication of RA, primarily due to systemic inflammation and dyslipidemia. In Rheumatoid Arthritis as the disease progresses, it results in the reduced physical activity level of the patient [48]. Rheumatoid arthritis (RA) is an autoimmune disease in which the body's immune system attacks the joints, causing them to worsen. RA commonly affects the hands, knees, ankles, feet, hips, and spine in a symmetrical pattern. Shoulders, elbows, and biceps Joint swelling, pain, stiffness, and deformity are all symptoms of RA. In addition, it also affects tissues and organs, like the heart, skin, and lungs, and so on.

Figure: 2. 6 Sample RA X-ray Image Arthritis disease Related works

As we explored, there is no classification work is done for the proposed work, but there are other works like classification of common arthritis and classification of the stages of a single arthritis presence or absence. Here below we reviewed these types of previous works related to our work.

2.8 Related work

Arthritis Identification from Multiple Regions by X-Ray Image Processing: in this paper, the author tries to distinguish between the two types of arthritis. The author uses a classification technique using x-ray image processing technique namely Osteoarthritis (OA) and Rheumatoid Arthritis (RA) the classification is done using differentiation of properties and boundaries using MatLab tool in SVM Classifier and the researchers use 60 images of RA, OA, and normal individuals. However, the author considers only two types of arthritis not including other similar Arthritis types and they did not clearly state the results of the experiment in terms of accuracy [49].

Block-Based Texture Analysis Approach for Knee Osteoarthritis Identification Using SVM, in this paper, the Author collects 20 normal subjects and 20 patients X-ray images of knee joints from diagnosed with Osteoarthritis (OA). These images were divided into blocks and a texture analysis algorithm was applied for statistical feature extraction. Finally, classification is done using the Support Vector Machine (SVM) Classifier for decision-making. Results indicate that: firstly, X-ray images can be useful for detecting patients with the disease, Secondly, the extracted texture features are good to describe image information about

Osteoarthritis, finally, the extracted features and classifiers used have assisted them to differentiate between normal subjects and patients with OA are the Skewness, Kurtosis Standard Deviation, and Energy. The accuracy of an algorithm for affected subjects is 86.67% whereas for normal knee images it is 80%. The algorithm is tested for test images, which are, not included for training where for affected subjects accuracy is 80% whereas for normal knee images it is 60% [42].

Classification of Rheumatoid Arthritis Based on Image Processing Technique, in this paper the author tries to classify the stages of Rheumatoid arthritis as normal abnormal and Severe stage in this paper the author uses 60 x-ray images in three classes using SVM classifier got 92% accuracy for normal 70% for RA abnormal and for sever stages accuracy got 100%, but their dataset size is not that much enough to train all features each class of the x-ray image. So, the accuracy of the result may degrade due to this reason [48].

Statistical Feature-Based Classification Arthritis in Knee X-Ray Images Using Local Binary Pattern, in this paper, the author tries to classify the status of the knee joint where the knee is normal, abnormal, and the level of abnormality either medium or worst. Now the author classifies the image in two ways first normal and abnormal and in the second classification medium or worst using KNN and Bayesian Classifier algorithms using 50 X-ray images of 15 normal knee x-ray, from 35 abnormal, 19 medium knee x-ray, and 16 worst knee x-ray images. Finally, the author got for KNN classifier (71.43, 91.43, 93.75, and 99.74) % and Bayes classifier (66.67, 96.14, 87.50, and 89.57) % respectively for normal, abnormal, medium, and worst knee joint space classification accuracy. Now the problem is still dataset size is small and not that much enough to train the model [2]. **Classification and Assessment of Hand Arthritis Stage using Support Vector Machine**, in this paper the main goal of the research is to classify and categorize the stages of hand arthritis of the patient to determine finger width along the finger center-line, finger joint coordinates, and from these anatomical fiduciary points to measure other Features. These include finger spacing, size of the hand, location and size of joints, length of fingers, angulation of fingers, angular deviation at joints, identification of Heberden nodes, and identification of Bouchard nodes of hand. The work is done using machine learning as stage classifier uses finger border detection, developed curvature analysis, principal components analysis, support vector machine, and K-nearest neighbor algorithms [13]. The author uses a total number of 40 finger images of PIP joints and 40 images of DIP joints, finally, the author got DIP and PIP (77.5%) for multiple classification accuracy and (92%, 97%) for binary classification accuracy respectively. **Detection of Osteoarthritis using Knee X-Ray Image Analyses: A Machine Vision-based Approach** [15], in this paper, the author used the Active contour segmentation technique to segment the part of the knee X-ray image used by the random forest classifier to diagnose the condition utilizing a variety of

features such as statistical, first four movements, texture, and shape. As input datasets, the author employed 200 knee X-ray images acquired from various hospitals and diagnostic facilities. Individual joints are classified into five classes by the author: grade 0, grade 1, grade 2, grade 3, and grade 4. The categorization is based on the severity of the condition. Finally, the Author receives a score of 87.92 percent correctness.

Dual tree wavelet transform-based watershed Algorithm for image segmentation in hand radiographs of Arthritis and classification using BPN neural network [17], this paper includes: The author's goal was to automatically segment RA patients' hand arthritis radiography images using a dual-tree complex wavelet-based watershed algorithm. The author used a gray level co-occurrence matrix for feature extraction and backpropagation neural networks for the classification of two classes, normal and abnormal, with a sensitivity of 78% and 75% as specificity and accuracy of 77%.

Generally, in the previous work, we got the following research gaps:

I. As we saw, the proposed study does not employ the image processing technique.
II. Same related works are not stated their experimental output/result in terms of accuracy.
III. Almost all works use a small dataset size even starting from 15 x-ray images for their classification then their accuracy and performance are not as such as enough.
IV. Most works are only focused on a single arthritis stage/severity classification.

Finally, we, try to summarize the related works based on feature extraction algorithms used, classification algorithm, dataset size, Accuracy and, their limitation. International Journal of Signal Processing, Image Processing, and Pattern Recognition.

Title and Author	Publisher and publishe date	Classifier Algorithm	Dataset size	Accuracy (%)	Limitations/weakness
Arthritis Identification from Multiple Regions by X-Ray Image Processing, Hunza et, al	2017,IJSP, IP,and PR	VM	60 x-r image for two cla	---not state	They use a small number of the dataset, due to this the accuracy may be lower than expected
Block-Based Texture Analysis Approach For Knee Osteoarthritis Identification Using SVM Dattatray Ishwar, et, al	2015, IEEE	SVM	20, 20 for a two-class total of 40 images	86.67% for affected 80% for normal and for test(80%,60% respectively	The author uses a very small dataset, so the accuracy may degrade for this reason.
Classification of Rheumatoid Arthritis Based on Image Processing Technique Kale S. et al	2019, Springer Natu Singapore	SVM	60 x-ray images three class	92%,70%and 100% for normal, abnormal and saver stages respectively	Here, the author did no consider the effect of dataset size because dataset determinant factor for deep learnin accuracy.
Statistical Feature Based Classification of Arthritis in Knee X-Ray Images Using Local bina pattern Dr. VRajini, et al	2013, ICCPCT	KNN and Baye	50 images for 4 classes 15,19, 16 x-ray images for normal medium and worst class respectively	(71.43, 91.43, 93.7 and 99.74) % and f Bayes classifier (66.67, 96.14, 87.5 and 89.57) % for norm abnormal, medium, and worst respectively	The author tries to classify the knee joint space status into 3 classes, but the author did not tell anything about the disease of the Knee.

Classification and Assessment of Hand Arthritis Stage using Support Vector Machine Farhad, Et al	2019, EEE	SVM, finger border detection, KNN	40 images for 2 classes Of osteoarthritis and inflammatory arthritis	For Binary DIP a PIP(92%,97%) respectively and multiple classificatio types they got 77.5% accuracy	The limitation of this paper is they use a small dataset size, And they did not subdivide further which types of inflammatory arthritis.
Detection of Osteoarthritis using Kn X-Ray Image Analyses A Machine Vision-base Approach, Shivanand S. Et al	IJCA 2016	RFC	200x-ray images for classes	The author gets 87.92 % accuracy	The limitation of this work is, the author uses only RFC no other comparative classifiers are used in addition to the small data set. In addition, the author didn't sure the suspected knee is affected by OA or not.

Table 2. 1 Short representation of related works

2.9 Summary

In this chapter we covered the basics of Arthritis disease type, and their medication in medical imaging technology. Although addressing all related works is difficult, the important literature is provided in this chapter. The majority of the literature presented is the support of automatic knee arthritis diagnosis and classification, which is the main goal of this work. We attempted to fill the gap in this thesis work by reviewing the literature as well we can.

Chapter Three

Methods and Algorithms

3. Introduction

In this chapter, we discussed dataset preparation, choosing appropriate tools, appropriate deep learning algorithms for the proposed problem, and hardware devices (computers).

3.1 Arthritis x-ray Image analysis and labeling

Arthritis is a bone-related disabling disorder. The field is very diverse and it is difficult to classify the types of arthritis through imaging alone. The image processing techniques are thus used to better contemplate the differences and devise a possible diagnostic tool [49]. An x-ray is one of the most common procedures to diagnose arthritis. On an x-ray, arthritis is clearly visible, and doctors frequently utilize the x-ray result to confirm it. Tissues, organs, and other biological structures can be imaged with the use of an x-ray. Because arthritis on x-ray assists in acquiring clear images of the affected area, it is a relatively reliable tool used by physicians to diagnose arthritis. A radiology department is responsible for all x-ray tests. An x-ray machine will send the beam via an x-ray tube for ionizing radiation. The x-ray machine's energy will flow through the body component that is being examined. Following the passage of energy through a bodily part, the part of the body is imaged using a digital camera or film. The bones along with various other dense areas will be showing up as lighter shades of grey to white. There are some areas, which do not absorb the radiation and these areas will appear as a dark grey to black color [50].

3.2 Arthritis x-ray Feature Extraction

Because bones are visible on X-rays, X-ray imaging is the most extensively utilized imaging technique in arthritis. It is also the most cost-effective approach to detect arthritis from several modalities. A radiologist manually computes the principal feature in observing extremity and advancement of joint space narrowing (cartilage loss) on knee x-rays. Such investigations require the analysis of a professional radiologist's x-ray image, which is a difficult and time-consuming task [51].

3.3 Research design

In our work, we follow experimental research design is a systematic research study in which the researcher manipulates and controls is testing to understand the causal process. It is used for the researchers for identifying and observe which powerful tool the diagnostic of the results is vital. In our research work, we

use an experimental method for model building, analysis, and prototype development and testing of our model. We try many experiments for each variable like changing the Convolutional neural network models architecture and recording the results or performances of this result and doing again another experiment until we got efficient performance results by comparing the previous one. Next conduct another experiment by changing the image size of the x-ray image with three different sizes. To achieve our research work we follow experimental research. The method that we apply basic processes of image processing technique looks like the following Architecture.

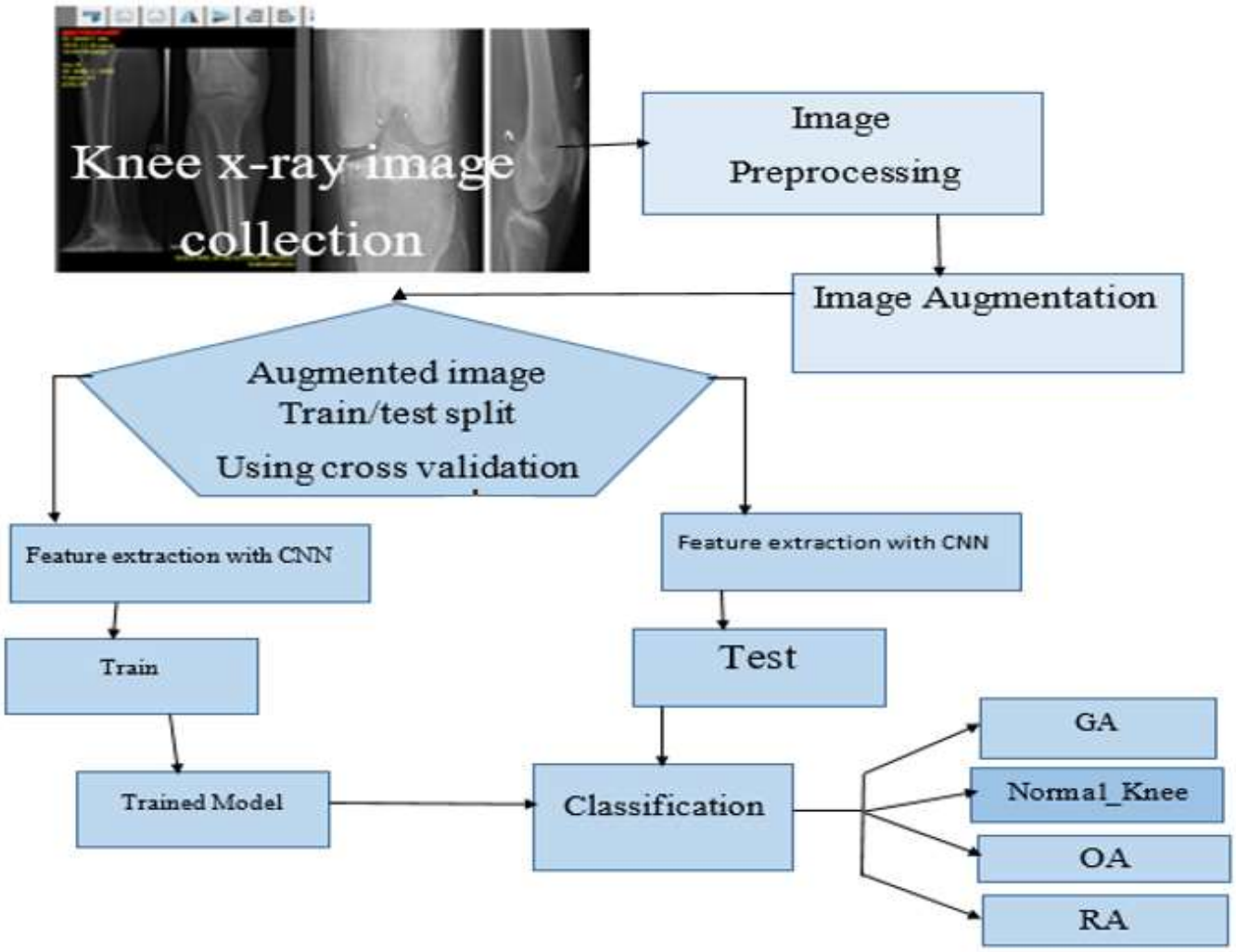

Figure: 3. 2 Block Diagram of the Research work Design

3.4 Image pre-processing

Image preprocessing is a term used to describe operations on images at the most basic level of abstraction, in which both the input and output are intensity images, which are commonly represented by a matrix of

image function values. Image preprocessing techniques are used to improve the quality of acquired images. When compared to traditional classification algorithms, which require hand-engineered filters, CNN's use very little pre-processing. CNN has the advantage of not requiring human interaction in learning filters. CNN is a supervised deep learning method that requires a significant amount of labeled data for training. The model will learn the weights after training, and the classifier's accuracy will improve [52]. Picture filtering, image quality enhancement, normalization, and binarization were the image preprocessing techniques employed in this investigation. Image filtering is used to reduce noise in captured image data. As a result, Gaussian blur may be accomplished with simpler filters for many practical reasons. Because it outperforms other filtering algorithms like mean and median filtering, Gaussian blur filtering was chosen for x-ray image filtering. Smoothing quality enhancer techniques were also used to improve image quality for better understanding. For additional processing and analysis, images were normalized and transformed to black-white space. Conversion is the first stage in color image segmentation. We use the following Image pre-processing steps:

Image Accusation: we decide to gather this patient image from different private/ public hospitals. Image preprocessing: Image pre-processing is a technique to bring out detail that is simply to highlight certain features of interest in an image. The removal of noise, edge enhancement, restoration, resampling, and the soft-focus (blurring) effect are the way to enhance an image presentation.

Feature Extraction: this is the method for creating a new and smaller set of features that captures most of the useful information of raw data. Identifies and gives the main characteristics of each class of arthritis. To identify one another. Features are the information extracted from images in terms of numerical values that are difficult to understand and correlate by a human.

There are several image features, which represent an image for classification/identification systems. Most popular among them are the color, texture, and shape of an image. The most and commonly used color features include color histogram, color moments (CM), color coherence vector (CCV), and color correlogram, etc. Texture Features: The texture is a pattern of local image intensity variations that repeats. The size, shape, density, arrangement, and proportion of an object's constituent parts determine its surface features and appearance. The texture is thought to be used by human visual systems for recognition and interpretation. The pixel values are utilized to create numerical structures that are linked to the image's texture pattern. Shape Features: the shape of an object refers to its physical structure. Shape features are mostly used for finding and matching shapes, recognizing objects, or making measurements of shapes. Moment,

perimeter, area, and orientation are some of the characteristics used for the shape feature extraction technique. The shape of an object is determined by its external boundary abstracting from other properties such as color, content, and material composition, as well as from the object is other spatial properties. Shape features are commonly used in object recognition and shape description. The shape features extraction techniques are classified as region-based and contour-based. The contour methods calculate the feature from the boundary and ignore its interior, while the region methods calculate the feature from the entire region.

3.3.1 Image resizing and cropping

In this section, we resize the captured x-ray image to the appropriate image size focused only on the area of interest of the knee joint where the lesion of the arthritis disease affected area. And we crop the required area of the knee arthritis lesion.

3.3.2 Image augmentation

When we don't have enough data to train a deep learning model, image augmentation is an effective strategy. Learn how to use image augmentation techniques to artificially extend your image dataset. Preparing a single image to many numbers of views by the neural network. When given a large amount of data, a deep learning model usually performs well. The more data we collect, the better the model will perform. The data augmentation approach can help to enrich the data set and improve classification performance [53].

3.3.3 Where do we use Image Augmentation and what is Image Augmentation Techniques

We use image augmentation when we don’t have enough training data to train our model. In such situations, we can create new images out of the existing images, by applying transformations to them. Though these images look similar, they are considered entirely as new images by CNN (Convolutional Neural Network). This will help us to create a larger training dataset and consequently will enable our model to converge more efficiently.

3.3.4 Image Augmentation Techniques

Image rotation is one of the most often employed augmentation techniques. The information on the image remains the same regardless of how it is rotated. Even if you look at it from a different perspective, the image remains the same. As a result, by making many images rotated at different angles, we may use this strategy to enhance the size of our training data. Image Shifting: Image shifting is the next image enhancement approach. We can modify the position of the objects in the image by changing the images, giving the model

additional variation. This could eventually lead to a more generic model. We use the following augmentation techniques and finally we got for RA 117 to 383, GA from 124 to 404 image, Normal_Knee from 220 to 504 and the last class OA from 204 to 472 total of 1763 augmented images for four classes from 665 row image, but to balance the number of images for each class we reduce Normal_Knee from 504 to 488 and OA from 472 to 450. Finally we use 1725 total images for our model. The following fragment of code shows how it works for one class and the other remaining class possess the same step.

image data augmentation fragment code

```
import keras ,cv2, os, glob
from keras.preprocessing.image import ImageDataGenerator, array_to_img, img_to_array, load_img
datagen=ImageDataGenerator(rotation_range=25,width_shift_range=0.5,height_shift_range=0.5, shear_range=0.2,zoom_range=0.2)
i = 0
for batch in datagen.flow_from_directory(
    directory ='C:/Users/hp/Desktop/chung_print/input_image _for_augmentation/',target_size = (100,100),
   save_to_dir = 'C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/RA',
   save_prefix = 'Normal_Knee',save_format = 'JPG'):
    i+=1
    if i>12:
     break
print('C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/RA=',len(os.listdir('C:/Users/hp/Desktop/chung_print/Au
print('C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/GA =',len(os.listdir('C:/Users/hp/Desktop/chung_print/A
print('C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/Normal_knee=',len(os.listdir('C:/Users/hp/Desktop/chung
print('C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/OA =',len(os.listdir('C:/Users/hp/Desktop/chung_print/A

```

```
Found 117 images belonging to 1 classes.
C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/RA= 383
C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/GA = 404
C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/Normal_knee= 504
C:/Users/hp/Desktop/chung_print/Augmented_x_ray_image_dataset/OA = 472
```

Figure: 3. 3 : Image augmentation for each class

Disease category	Before augmentation	After augmentation
RA	117	383
GA	124	404
Normal_Knee	220	488
OA	204	450
Total	665	1725

Table: 3. 1 Image augmentation result

3.5 Methods

The method that we apply in our research work is a Convolutional neural network with three different CNN pre-trained models with transfer learning models namely ResNet50, VGG16, DenseNet121, and custom CNN model KneeArthritisModel. After we train the model with the above three CNN models, then we compare one another and choose the highest accuracy model for our classification problem. The reason why we choose CNN is, because it is already validated image representation and classification technique for medical image analysis and applications [18].

3.5.1 KneeArthritisModel custom CNN model

We develop a model that classifies knee arthritis x-ray images based on CNN-based transfer learning sequential function from the TensorFlow library. We add eight convolution layers, four Maxpooling layers, seven dropout layers, and four dense layers. With different values and Total params and Trainable params: 2,430,932. The overall structure of a DNN is developed using the model object in Keras. This provides a simple way to create a stack of layers by adding new layers one after the other. The easiest way to define a model is by using the sequential model, which allows easy creation of a linear stack of layers by adding a simple sequential model with one layer followed by an activation function [54]. Due to this reason, I made many experiments using a sequential model by passing different parameters.

3.5.2 ResNet50 transfer learning model

Residual Network (ResNet) is a Convolutional Neural Network (CNN) architecture that overcame the "vanishing gradient" problem, making it possible to construct networks with up to thousands of convolutional layers, which outperform shallower networks. To solve complex problems, we mainly stack several additional layers on the deep neural network to improve accuracy and performance. The intuition behind adding layers is that these layers gradually learn more complex features. In our case we feed four class as input and output layer due this reason we apply transfer learning using transfer learning principle.

3.5.3 VGG16 based transfer learning Model

VGG is another CNN architecture, with two versions VGG16 and VGG19 which consists of 16 learned layers including thirteen convolutional layers with a filter size of 3 x 3, five pooling layers that follow some of the convolutional layers, and three fully-connected layers with the final 1000-way softmax which produces a distribution over the 1000 class labels for thousands of image datasets. All learned layers were applied with the ReLU activation function. Now we use the VGG16 CNN model-based transfer learning approach to

reduce the complexity of the network. In our case we feed four class as input and output layer due this reason we apply transfer learning using transfer learning principle.

3.5.4 DenseNet121 based Transfer Learning

DenseNet is a new CNN architecture that achieves State-of-the-art results on classification datasets (CIFAR, SVHN, ImageNet) using fewer parameters. Thanks to its new use of residual it can be deeper than the usual networks and still be easy to optimize. In the DenseNet architecture, each layer is directly connected to all other layers, hence the name Dense Network. For the "L" layer, there are L (L + 1)/2 direct connections. The densenet121 model is part of the DenseNet family of models designed to perform image classification. DenseNet121 has 8,062,504 parameters. To summarize, DenseNet121 has the following layers: 1 (7x7) Convolution, 58 (3x3) Convolution, 61 (1x1) Convolution, 4 AvgPooling, and 1 fully Connected Layer. In our research work we use only the hiden layers wieghts only we remove input and output layer, because the input and output layers are designed for 1000 classes, but in our case we feed four class as input and output layer due this reason we apply transfer learning using transfer learning principle.

3.6 Medical images feature Extraction

Digital image processing is done by acquiring data sets, storing them, and compressing them to initiate processing technology. Depending on the stage and type of arthritis, these features are mild or obvious on x-rays. Therefore, the process is image acquisition, which is used to feed X-ray images and the grayscale conversion/threshold is used to convert the image to grayscale if necessary. Use a threshold function to set the image to binary. Median Filter/Gaussian Filtering is also applied to smooth the image. Classification amongst OA, RA, GA, and normal. Deep convolutional networks (ConvNets). As their name suggests, ConvNets apply convolutional filters to compute image features that are useful for classification, and also the convolutional filter kernel elements are learned from the raw image training data in a supervised fashion [18]. Feature Extraction is Joint location, orientation, circular features, and space detection is done using Image Recognition [49].

3.7 Summary

In this chapter, the design of the CNN-based Arthritis Diseases investigation and Classification model for arthritis disease detection and classification is discussed carefully. The components of the model such as preprocessing, feature extraction, data augmentation, and classification, transfer learning, medical imaging modalities are discussed.

Chapter Four

Experimentation and model result discussion

4.1Experiment setup And Installation / Implementation tool

In deep learning technology, it needs updated hardware and software resources/technology's to run the deep learning algorithm. So, here as we expressed under chapter three section four in our research work we use an HP laptop computer with Intel(R) Core(TM) i5-4210M CPU @ 2.60GHz with a Logical Processor speed of 8.00 GB (7.88 GB usable), and 500GB hard disk capacity with a windows 10 operating system and jupyter Notebook (Anaconda3) and online Google collaboratory with GPU for training the model and spyder (Anaconda3) for web-based application development with many libraries of Keras, pytorch, and TensorFlow.

4.2 Data Source and Data collection Techniques

To achieve our research work, we have to collect patients' x-ray images from different private and public hospitals and also. From Jimma university medical center (JUMC), Fromsis hospital (FH), Jimma Awetu Primary hospital (JAPH). The data is collected starting from (March 2019 – August 2021). Then we apply different image processing techniques to feed for the suitable image classification algorithm. Because more than 70% of the information is transmitted by image or video, to extract useful information from these images and video data, computer vision emerged as the times require [55].

4.2.1 Dataset preparation

The first step in data science is data collection from a primary source like a data source site and other secondary data sources like a scientific repository, previous research on the same or related areas, and so on. Here in this step; after we collected the required x-ray image from respective data sources like private and public hospitals and other sources the first one is Kaggle, now these images are not appropriate for machine learning, so we converted them into the appropriate format. We convert the x-ray images (.Dcm) to (.JPG) image format using DcmToJpg converter open-source software. Again we use (ren *.jpg *.png) command on 'notepad++' text editor software with (.bat) file extension to convert the (.jpg) image to Portable Network Graphics (PNG) format (.png) image extension format. In addition, we appalled different image preparation techniques, like image cropping and other techniques to ready for image processing techniques. CNNs have the advantage of requiring less pre-processing than other image classification algorithms [56].

4.3 Model Building

Now, today there are many imaging technologies applied for diagnosis medical diagnosis process. These technologies are built by many years of the trial of imaging technology, now here we use the following values. And also we use to experiment with our model and select the most build effective diagnosis model, we do many experiments in different directions like changing color mode, training epoch size, batch size, and dropout values, and other input values. Below is a brief explanation of these values.

4.3.1 Parameters and Hyper Parameters in the model

Parameters are artifacts collectively used to design a network, and they have a huge impact on the model's learning process and its end performance. These parameters cannot be trained. Hyperparameters are the parameters that define a model's holistic structure and thus the learning process. We can also relate hyperparameters as the Meta parameter for a model. It differs from a Model's actual parameters, which it learns during the training process (say, the model weights). we need to tune them with different approaches to get improved performance. Hyperparameters are set before training like, Number of Neurons in a Layer, Number of Layers, Number of Epochs

Batch Size: Parts from all datasets are to be visited at a time. Using a moderate batch size always helps achieve a smoother learning process for the model. A batch size of 32 or 64, irrespective of the dataset size and the number of samples, will deliver a smooth learning curve in most cases.
Learning Rate: The learning rate is defined in the context of the optimization algorithm. A positive fraction determines the step of learning of the network neurons. It defines the length of each step or, in simple terms, how large the updates to the weights in each iteration can be made.
Dropout: It is a mechanism of regularization of the training to overcome overfitting. Hyperparameters and the value assigned are explained in the following table.

No	Hyper parameters	Values
1	Number of epoch	25
2	Batch size	32
3	Learning rate	0.0001
4	Dropout	0.1 ,02, 04, 04, and 0.5
5	Activation function	Relu, and Softmax

Table: 4. 1 Hyperparameters and the value assigned

4.3.2 Dataset splitting

In our study, we have collected 665 Arthritis x-ray images and we augment the dataset up to 1725 images to increase the dataset and the distribution of the data is splited by using 80% training and 20% dataset splitting technique for the test from the total dataset using a holdout dataset splitting technique. From 1725 total augmented images we use 1725*0.80 for training 1380 images for training and 1725* 0.2 for testing the model 345 images.

4.4 Identification of effective CNN model for medical image processing

The first thing is that you need your data to be in a matrix. The CNN model learns in short parts by sliding a smaller matrix through a data matrix. It then applies what it has learned to produce a new data matrix, from which you can either have the model go through the new matrix to learn more or set up a function to classify the data. How does this translate to images? Images are made up of pixels, each of which has a Red, Green, and Blue value that may be converted into a matrix for the CNN model to learn from it. We try to reduce false positives and increase the recall by close to a hundred percent. The ConvNets are trained to differentiate hard false positives from true positives utilizing a set of 2D (two-dimensional) re-sampled views comprising random translations, rotations, and multi-scale observations around a candidate's center coordinate [18].

4.4.1 KneeArthritisModel result

We develop a model that classifies knee arthritis x-ray images based on CNN-based transfer learning sequential function from the TensorFlow library. We add eight convolution layers, four Maxpooling layers, seven dropout layers, and four dense layers. With different values and Total params and Trainable params: 2,430,932. The overall structure of a DNN is developed using the model object in Keras. This provides a simple way to create a stack of layers by adding new layers one after the other. The easiest way to define a model is by using the sequential model, which allows easy creation of a linear stack of layers by adding a simple sequential model with one layer followed by an activation function [54]. Due to this reason I made many experiments using a sequential model by passing different parameters.

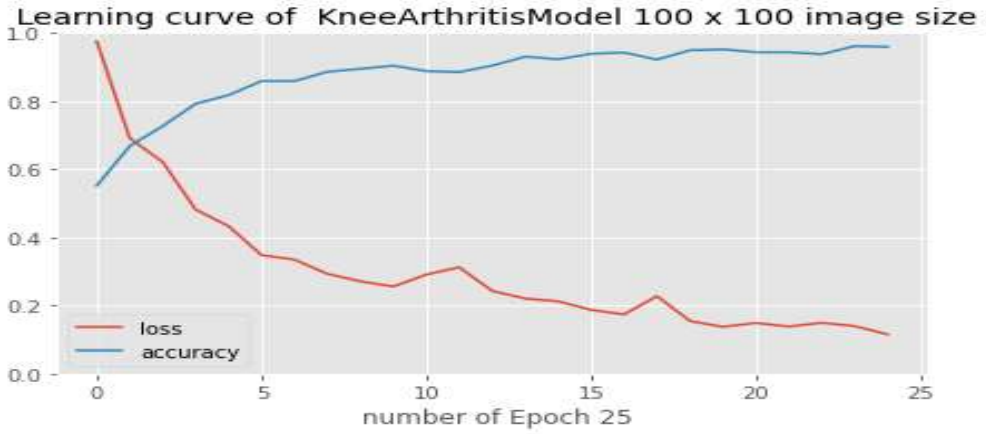

Figure: 4. 1 learning curve for KneeArthritisModel

4.4.2 ResNet50 transfer learning model result

Residual Network (ResNet) is a Convolutional Neural Network (CNN) architecture that overcame the "vanishing gradient" problem, making it possible to construct networks with up to thousands of convolutional layers, which outperform shallower networks. To solve complex problems, we mainly stack several additional layers on the deep neural network to improve accuracy and performance. The intuition behind adding layers is that these layers gradually learn more complex features. For example, in image Recognition, the first layer can learn edge recognition, the second layer can learn texture recognition, and the third layer can learn object recognition as well.

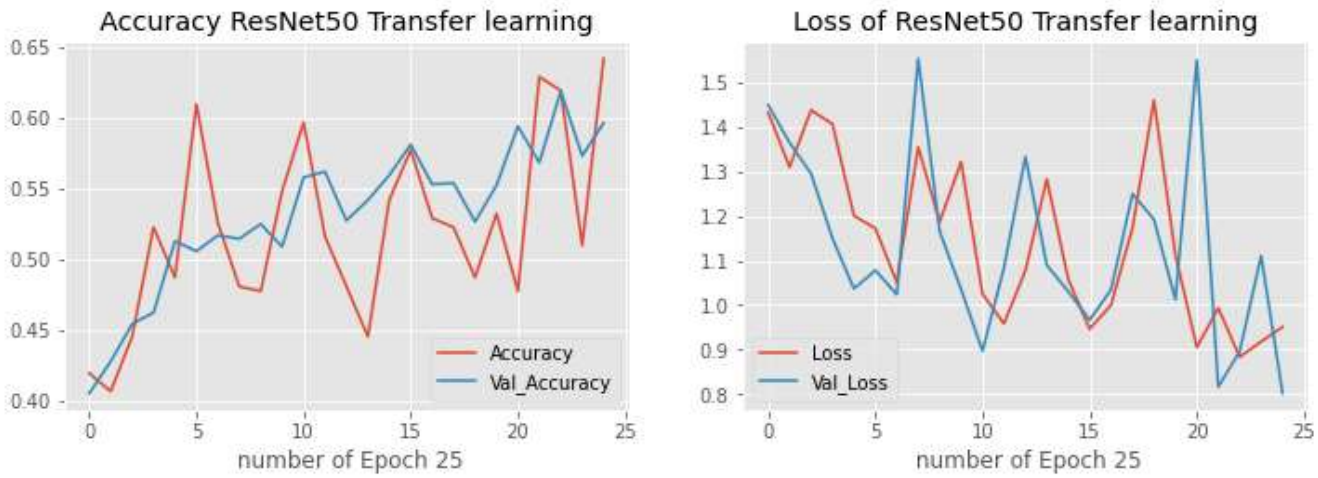

Figure: 4. 2 : Learning Curve for ResNet50

4.4.3 VGG16 based transfer learning Model

VGG is another CNN architecture, with two versions VGG16 and VGG19 which consists of 16 learned layers including thirteen convolutional layers with a filter size of 3 x 3, five pooling layers that follow some of the convolutional layers, and three fully-connected layers with the final 1000-way softmax which produces a distribution over the 1000 class labels for thousands of image datasets. All learned layers were applied with the ReLU activation function. Now we use the VGG16 CNN model-based transfer learning approach to reduce the complexity of the network because we have a limited number of image datasets. And we got the following experimental results. Our experiment result looks like the below figure and the average accuracy of the three folds training accuracy is 75.5% other evaluation metrics are looks like the below figure.

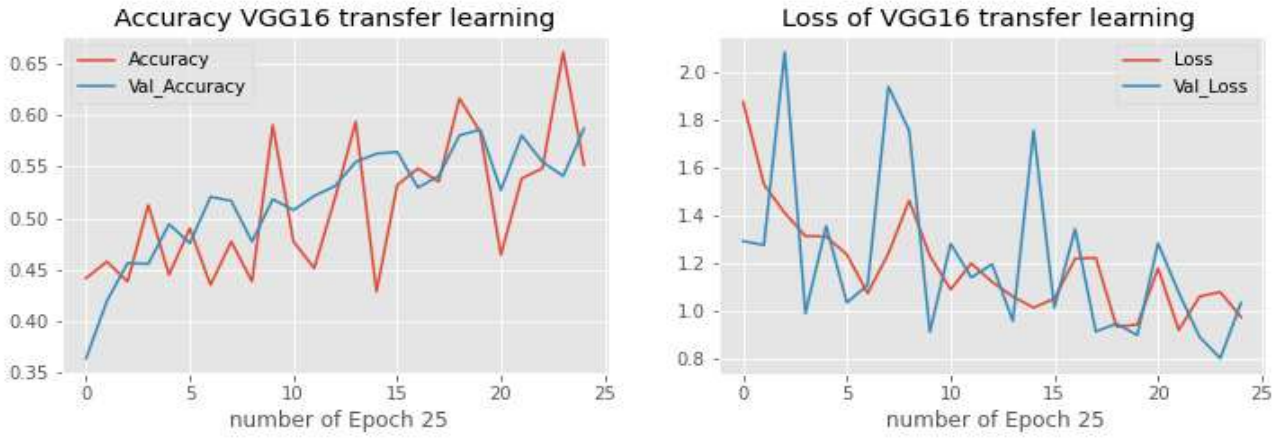

Figure: 4. 3 Learning Curve for VGG16

4.4.4 DenseNet121 based Transfer Learning

DenseNet is a new CNN architecture that achieves State-of-the-art results on classification datasets (CIFAR, SVHN, ImageNet) using fewer parameters. Thanks to its new use of residual it can be deeper than the usual networks and still be easy to optimize. In the DenseNet architecture, each layer is directly connected to all other layers, hence the name Dense Network. For the "L" layer, there are L (L + 1)/2 direct connections. The densenet121 model is part of the DenseNet family of models designed to perform image classification. DenseNet121 has 8,062,504 parameters. To summarize, DenseNet121 has the following layers: 1 (7x7) Convolution, 58 (3x3) Convolution, 61 (1x1) Convolution, 4 AvgPooling, and 1 fully Connected Layer.

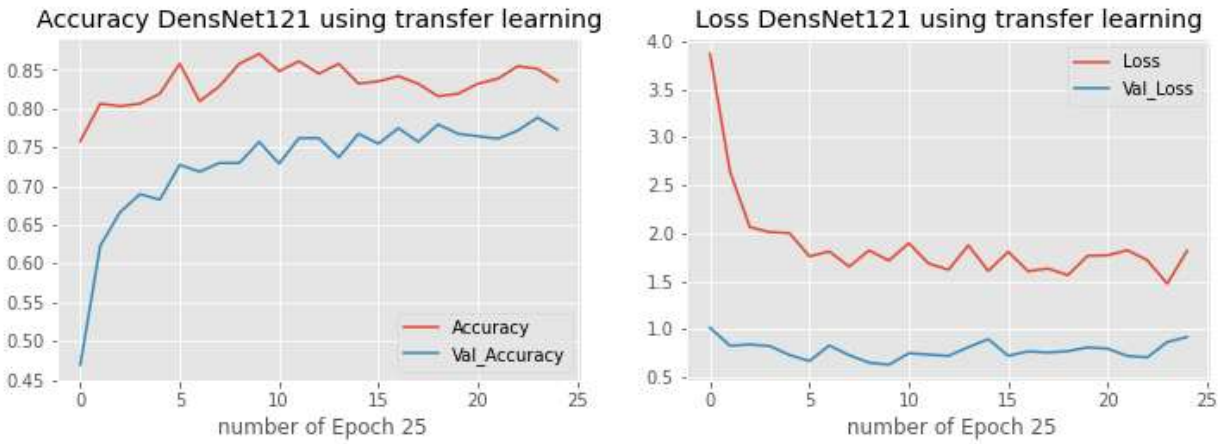

Figure: 4. 4 Learning Curve for DenseNet121 based transfer learning model

4.4.5 The Overall performance of the above list of models experiment result

model	Im e size	Number epoch	C or	Training accuracy %	Validation accuracy %
KneeArthriti Model	10 x 100	25	gr scale	91	65
ResNet50	10 x100	25	gr scale	64	59
VGG16	10 x 100	25	gr scale	72	62
DenseNet12	10 x100	25	gr scale	83	77

Table: 4. 2 Experiment result of each CNN model

From the above experiment of the KneeArthritisModel, ResNet50, VGG16, DenseNet121 models we got the above results KneeArthritisModel achieves high performance, so our appropriate model for our classification problem is KneeArthritisModel with an accuracy of 91%.

4.5 Identification of suitable image size to classify Arthritis disease

Which image size is better to improve performance and computational time? To answer this question we conduct three types of image size and we got different results for each image size presented below diagram. When we train a deep learning convolutional neural network with a custom dataset, it is important to choose the right image size.

4.5.1 For image size 100 by 100 experiment result

When we use image size 100 by 100 for our experiment with the grayscale color channel, we got a training accuracy and validation accuracy of 91%, 65% respectively. And the learning curve of the training looks like the below figure.

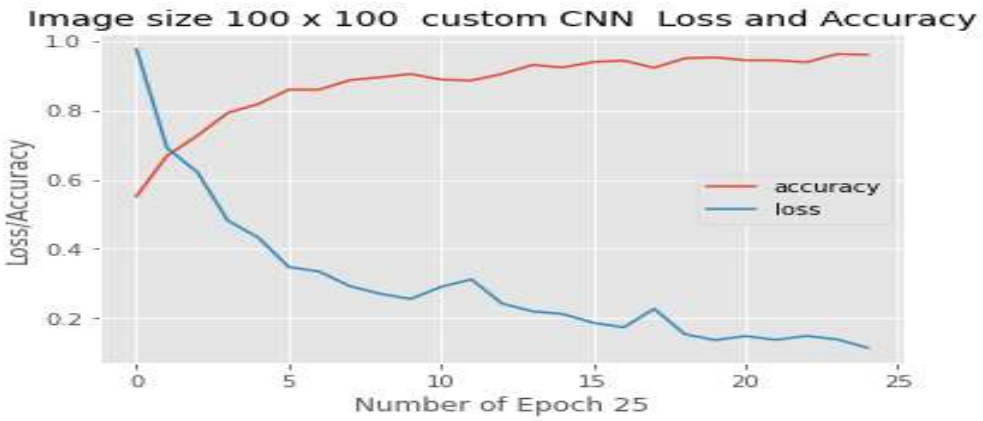

Figure: 4. 5 Learning curve for KneeArthritisModel 100x 100 image size

4.5.2 For image size 75 by 75 experiment result

When we use image size 75 by 75 with gray color channel registers a training and validation accuracy of 87% and 71 % respectively. The learning curve of the training looks like below figure

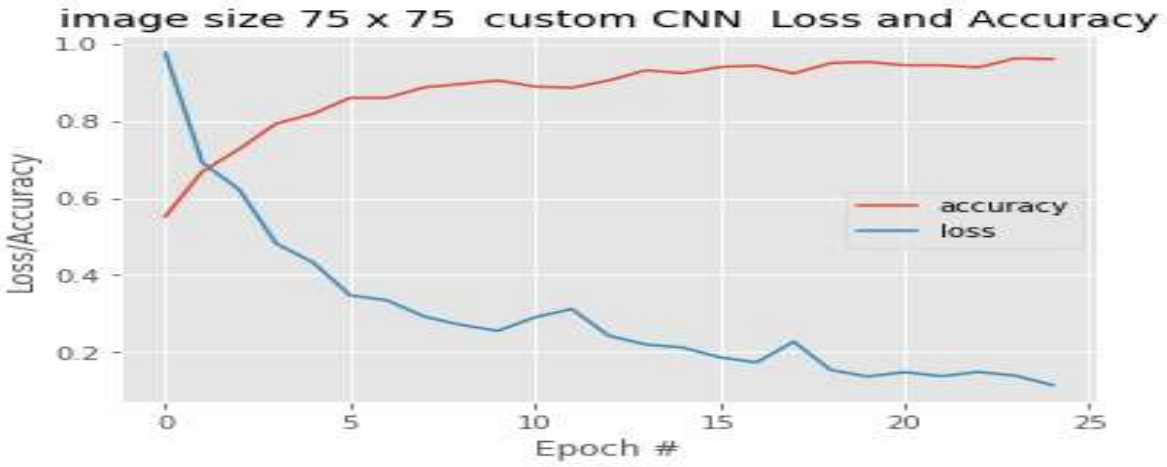

Figure: 4. 6 Learning curve of 75 x 75 image size

4.5.3 For image size 50 by 50 experiment result

When we use image size 50 by 50 with gray color channel registers a training and validation accuracy of 82% and 66 % respectively. The learning curve of the training looks like below figure

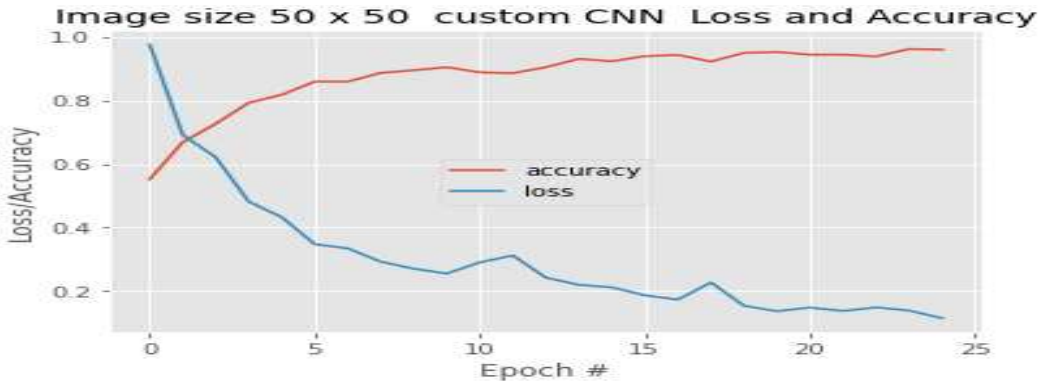

Figure: 4. 7 Learning curve of 50 x 50 image size

Here, the below table is an experiment result of three different image size, we understood that when the image size increases the performance of the model also increase. We achieve the highest accuracy when we use 100 x 100 image size. The problem is when the image size increases the computation time and memory usage increase. In conclusion when the image size increases the mode's accuracy also increases.

Selected Model	Color mode	Image size	Training accuracy in %	Validation accuracy in %
KneeArthritisMod	Grayscal	100 100	91	65
	Grayscal	75 x75	87	71
	Grayscal	50 X5	82	66

Table: 4. 3 Different image size experiment results

Developed model	Color mode	Image size	Correctly classified	Incorrectly classified	Training accuracy in %
KneeArthritisModel	Grayscale	100 x 100	234	111	91

Table: 4. 4 Overall performance of new developed model

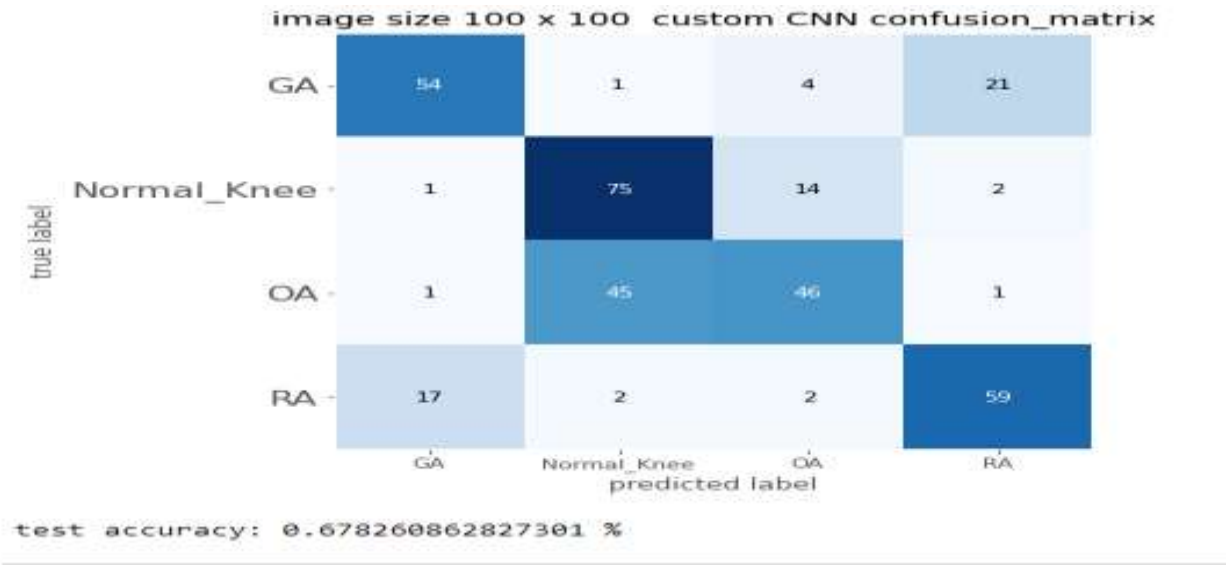

Table: 4. 5 : Final kneeArthritisModel performance result

4.6 Evaluation Metrix

Based on the above training result we evaluate our model using deep learning evaluation techniques. The classification report is described based on the experiment result. Based on deep learning context evaluation measurements' are Precision, recall, F1-score, accuracy. But, in the case of balanced dataset distribution, the overall performance is measured using accuracy. So, we use accuracy for the evaluation of the experiment results model performance. From our experiment the best model which is kneeArthritisModel with 100 x 100 image size achieves 91% accuracy and correctly classifies from 1725 image of 20% test image 1725* 0.20 total 345 test images 245 are correctly classified and 111 images are incorrectly classified Under the discussion section, we clearly discuss the whole discussion of the experiment.

4.7 Discussion and results

In our discussion, we saw in different directions like selected CNN Architecture/model accuracy results comparison, and different image sizes for our experiment using default x-ray image color which is grayscale color. Now, in our experiment, we conduct four types of CNN models for comparison to select the appropriate CNN model for our classification problem. From four models the first one that we developed is KneeArthritisModel gets an accuracy performance measure of 91% training accuracy from ResNet50, DenseNet121, and VGG16 CNN models of the score(64 ,83,72) respectively. And the second experiment is about the size of the image, we take three different image sizes and to select the appropriate image size for our model and we experiment with three image sizes (100 x 100, 75 x 75, and 50 x50) from this experiment

we got an accuracy of 91% highest accuracy for 100 by 100 image size of the selected model KneeArthritisModel

Now, when we summarize our experiment of this discussion, from four experimented models namely ResNet50, VGG16, DenseNet121, and KneeArthritisModel the custom built model is appropriate, from three image size experiment result 100 x 100 image size is appropriate registers the highest accuracy for our classification model 91% accuracy.

4.8 Deployment of the model

After we train our classification model, we deploy the system as a web-based application system using a flask web framework. We install the flask library from the Keras package and use it as a web-based application development framework. To make our model more interactive for end users we develop a user interface platform. We run on the localhost address and port number at 127.0.01:5000 of the user's browser. The user browses the suspected x-ray image from the source and uploads it to the model, then the system predicts the class of the arthritis disease. We put the sample user interfaces of our system.

Figure 5. 1 : GUI 1 homepage of the system

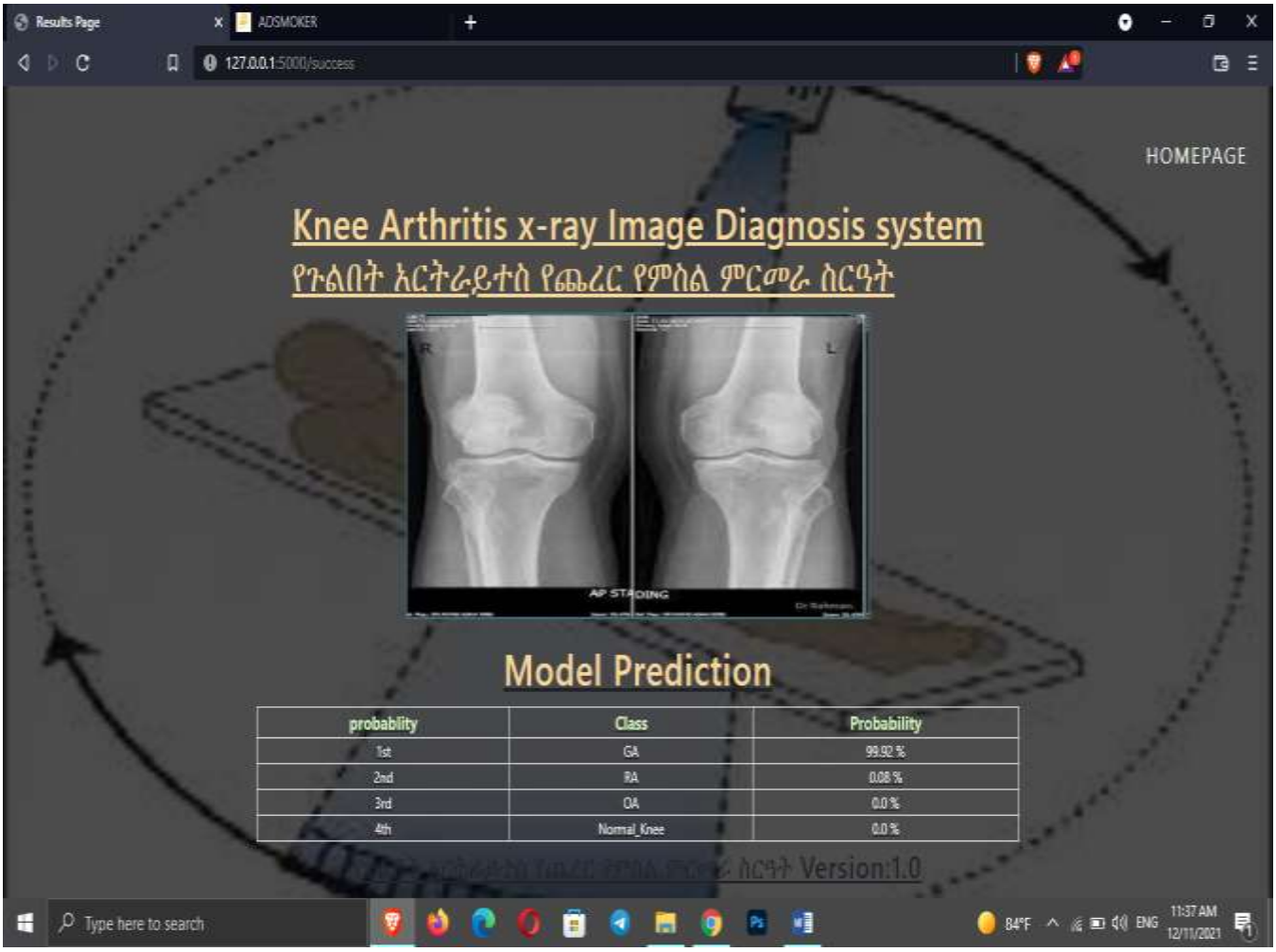

Figure 5. 2 : GUI 2 Classification result page

4.9 Summary

In this Chapter, implementation tools, experimentation based on color, image size, and different CNN models experiments are conducted, and also comparisons of different parameters are discussed. The model's evaluation result of CNN architectures MobileNetV2 and ResNet50 are reviewed and KneeArthritisModel outperforms from ResNet50, VGG16, and DenseNet121 CNN based Model.

Chapter Five

Conclusion and Recommendation

5.1 Conclusion

In conclusion, this area is a new research idea to solve the complex problems of internal medicine diagnosis. Specifically to diagnosis Arthritis diseases, as we explore no published work is done yet, now we try to discover new ideas of diagnosis technology using deep learning approach image processing technique. We use 665 total row preprocessed images before augmentation and after augmentation 1725 images. We consult many radiologists and internal medicine professionals when we were collecting data collection time. This discovery of technology solves the problem of many similarities of Arthritis disease during diagnosis time and medication order for each arthritis type. Specifically, we discover for knee arthritis diseases classification model using knee x-ray images. Now, this model classifies the three most common attack human Arthritis diseases with the reference of the normal human knee x-ray images. To develop this classifier model we use three pre-trained CNN models using transfer learning to compare the developed model namely Vgg16, ResNet50, and DenseNet121, and also we use three different image sizes of the x-ray to compare the model performance for each image size (100, 75, and 50). From the experiment, we register when we use 100 x 100 image size and grayscale color with an accuracy of 91%. This research work helps many stockholders but specifically for radiologists, doctors, and patients, it gives an unmeasurable advantage in terms of time, correct medication, resources, and short-time recovery of the diseases for the patient.

5.2 Thesis Work contribution

As a contribution, we contribute a lot for the area of the health stack holders from the nurse up to specialists, patients, and the patient's family and scientific community by investigating and developing an Arthritis classification model to diagnosis the disease. Next, we collect and prepare a dataset to feed the convolutional neural network to train the model and test the model and also we are ready to publish our research work to the scientific community and also upload our prepared Arthritis dataset for the public repository for future researchers.

5.3 Recommendation for future work

From our experience during the time of conducting this research work, I recommend for future researchers include for their study another arthritis type that is not included in our work. And can also develop another part of the body arthritis disease like neck, elbow and the like parts of arthritis diseases. As much as possible when we increase the dataset size, we got good accuracy and the model's classification performance becomes accurate during real-time testing by end-users. So with a large dataset, depth neural networks like EfficientNet (B0 to B7), and by increasing the number of epoch size of the training model using GPU can achieve and develop a more accurate model.

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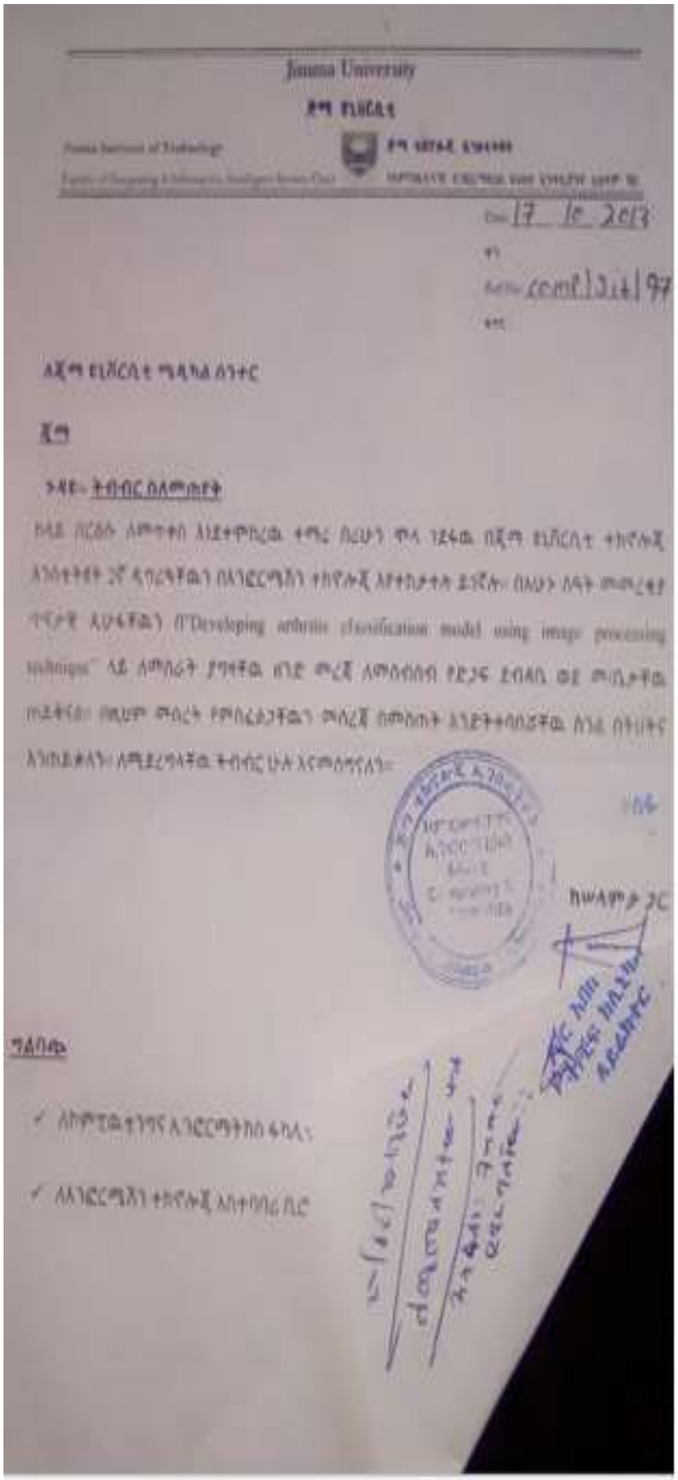
Appendix A: knee x-ray image data collection request and medical data privacy conformation


Jimma University

Date 17 10 2013

Ref No. comp/3it/97

"Developing arthritis classification model using image processing technique"


Jimma University

Date 23/10/2013

Ref No. comp/3it/07

"Developing arthritis classification model using image processing technique"

Appendix B: Custom CNN Build Model Summary

```
Model: "sequential_21"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_74 (Conv2D)           (None, 98, 98, 256)       2560
_________________________________________________________________
activation_56 (Activation)   (None, 98, 98, 256)       0
_________________________________________________________________
max_pooling2d_65 (MaxPooling (None, 49, 49, 256)       0
_________________________________________________________________
conv2d_75 (Conv2D)           (None, 47, 47, 128)       295040
_________________________________________________________________
activation_57 (Activation)   (None, 47, 47, 128)       0
_________________________________________________________________
max_pooling2d_66 (MaxPooling (None, 23, 23, 128)       0
_________________________________________________________________
conv2d_76 (Conv2D)           (None, 21, 21, 64)        73792
_________________________________________________________________
activation_58 (Activation)   (None, 21, 21, 64)        0
_________________________________________________________________
max_pooling2d_67 (MaxPooling (None, 10, 10, 64)        0
_________________________________________________________________
flatten_20 (Flatten)         (None, 6400)              0
_________________________________________________________________
dropout_53 (Dropout)         (None, 6400)              0
_________________________________________________________________
dense_79 (Dense)             (None, 256)               1638656
_________________________________________________________________
dense_80 (Dense)             (None, 128)               32896
_________________________________________________________________
dropout_54 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_81 (Dense)             (None, 32)                4128
_________________________________________________________________
dense_82 (Dense)             (None, 4)                 132
=================================================================
Total params: 2,047,204
Trainable params: 2,047,204
Non-trainable params: 0
```

Appendix C: The fittest grayscale color 100 x 100 image size training output of KneeArthritisModel

```
39/39 [==============================] - 104s 3s/step - loss: 0.5418 - accuracy: 0.7271 - val_loss: 1.0705 - val_accuracy: 0.57
97
Epoch 15/25
39/39 [==============================] - 118s 3s/step - loss: 0.5123 - accuracy: 0.7432 - val_loss: 0.9732 - val_accuracy: 0.57
25
Epoch 16/25
39/39 [==============================] - 115s 3s/step - loss: 0.4558 - accuracy: 0.7939 - val_loss: 1.1414 - val_accuracy: 0.62
32
Epoch 17/25
39/39 [==============================] - 107s 3s/step - loss: 0.3964 - accuracy: 0.8180 - val_loss: 1.2248 - val_accuracy: 0.63
77
Epoch 18/25
39/39 [==============================] - 118s 3s/step - loss: 0.4316 - accuracy: 0.8003 - val_loss: 1.4301 - val_accuracy: 0.64
49
Epoch 19/25
39/39 [==============================] - 128s 3s/step - loss: 0.4572 - accuracy: 0.7955 - val_loss: 1.1174 - val_accuracy: 0.63
77
Epoch 20/25
39/39 [==============================] - 119s 3s/step - loss: 0.3492 - accuracy: 0.8543 - val_loss: 1.3541 - val_accuracy: 0.65
94
Epoch 21/25
39/39 [==============================] - 117s 3s/step - loss: 0.3147 - accuracy: 0.8671 - val_loss: 1.5990 - val_accuracy: 0.63
04
Epoch 22/25
39/39 [==============================] - 124s 3s/step - loss: 0.2844 - accuracy: 0.8937 - val_loss: 1.5233 - val_accuracy: 0.62
32
Epoch 23/25
39/39 [==============================] - 124s 3s/step - loss: 0.2326 - accuracy: 0.9163 - val_loss: 1.5883 - val_accuracy: 0.61
59
Epoch 24/25
39/39 [==============================] - 121s 3s/step - loss: 0.2098 - accuracy: 0.9187 - val_loss: 1.5802 - val_accuracy: 0.69
57
Epoch 25/25
39/39 [==============================] - 129s 3s/step - loss: 0.2124 - accuracy: 0.9114 - val_loss: 1.4259 - val_accuracy: 0.73
19
Time: 0:44:59.445703
```

```
5]: 1 model.save('Arthritis_classification____Arthrits____12___11___2021.h5')
```