



Identification of Knee Osteoarthritis Disease using Convolutional Neural Networks

S Muni Ratnam^{1*}, D Ragulamma², P Tejaswani³,
G Swathi⁴, K Vijayalakshmi⁵

¹⁻⁵ Department of ECE , Aditya College of Engineering , Madanapalle, Andhra Pradesh, India

* Corresponding Author : S. Muni Ratnam ; smredt@gmail.com

Abstract: Knee Osteoarthritis (KOA), commonly referred to as degenerative joint disease of the knee, is usually caused by articular cartilage gradually losing its structure due to wear and stress. Worldwide, patients with osteoarthritis (OA), especially those with knee OA, have significant disability as a result of this most frequent form of arthritis. Osteoarthritis (OA) is a prevalent degenerative musculoskeletal condition. This illness impacts about 5% of the global population. Arthritis (OA) most commonly affects the knee, where articular cartilage at the ends of bones permanently deteriorates. Over time, the condition known as knee osteoarthritis (OA) worsens and affects the whole knee joint. Despite their time-consuming nature and sensitivity to user variable, manual diagnosis, segmentation, and annotation of knee joints are still employed in clinical practice to diagnose osteoarthritis. The proposed system effectively detects knee osteoarthritis in the MRI images in which median filter is used in the image pre-processing to reduce the noise, Fuzzy C- Means algorithm is used image segmentation, Fuzzy C-Means algorithm is used for segmentation and Convolutional Neural Network (CNN) is used for disease identification. Contrast, Homogeneity, Energy, Entropy and Correlation features were extracted from the Region of Interest (ROI) of the segmented image for training and testing the CNN classifier. MATLAB (R2021a) software were used to implement the proposed system or method. The performance parameters sensitivity, specificity, accuracy, and precision of the proposed system are obtained as 94.19%, 92.60%, 95.77%, and 93.4%, respectively.

Keywords: MRI, CNN, FCM, ROI, DL, AI, ML, MATLAB .

1. Introduction

World wide currently, 344 million people worldwide are suffering from arthritis, an often debilitating disease with the average life span ever-increasing, people will likely work longer, even well into their 60s and 70s, leading to two-thirds of the working population being afflicted by arthritis. Osteoarthritis, fifty percent of patients are suffering from arthritis, is degenerative joint disease that can cause severe pain and hinder people from everyday activities such as working, gardening and playing with grandchildren. This research paper provides the background information necessary to understand this disease, discusses the problems with current treatments, and offers a novel solution of intra-articular injections of the derivative of hyaluronic acid costs, and return social activity to those suffering with osteoarthritis.

The knee joint is a type of synovial joint one in which the ends of two bones are free moving, joined only by connecting ligaments and a fluid filled cavity called the synovial space. The bones are the femur, tibia, fibula, and

patella are the major ligaments and tendons – the anterior cruciate ligament, collateral ligament, and patella tendon – and the meniscal and articular cartilage are shown in the figure 1. Medical Artificial intelligence has advanced recently, resulting in fully automated workflows that frequently outperform human capabilities. Modern neural networks are capable of identifying items in photos and categorising them into thousands of groups quicker and with greater accuracy than humans. Drive automobiles across cities autonomously and translate documents between several languages. They were trained on tens of thousands or even millions of data samples in the majority of these instances. In the domain of medical image processing, where data sets are frequently somewhat smaller, neural networks have also demonstrated remarkable results. Even while the same methods can be used, there are frequently new obstacles to overcome. The practice of producing visual representations of the interior structures concealed by the skin and bones is known as medical imaging. Through this technology, the inside of the body can be seen for the purposes of clinical diagnosis and medical intervention. This area of biological imaging includes radiology, which makes use of



imaging modalities like computed tomography (CT), ultrasound, magnetic resonance imaging (MRI), and X-rays. One of the most prevalent types of arthritis, osteoarthritis primarily affects women, the overweight, and the elderly. The joint ailment known as osteoarthritis (OA) mostly affects cartilage. The protective connective tissue that envelops the ends of the bones in a joint is called cartilage. Bones in a joint can glide more easily and are kept from rubbing against one another by healthy cartilage. The top layer of cartilage deteriorates and wears away in osteoarthritis. This makes it possible for the bones to chafe against one another. It frequently affects the knee, hip,

spine, and foot joints. Swelling, tenderness, inflammation, stiffness, etc., in a greater number of joints are caused by a disorder in the knee, arthritis, which causes osteoarthritis due to the aging effect. The aged people normally or commonly effected by arthritis. Arthritis is due to different causes, and for osteoarthritis, treatment is the most prevalent. Nearly 237 million people globally are affected by osteoarthritis. Arthritis cannot be cured, but early detection can help with prevention.

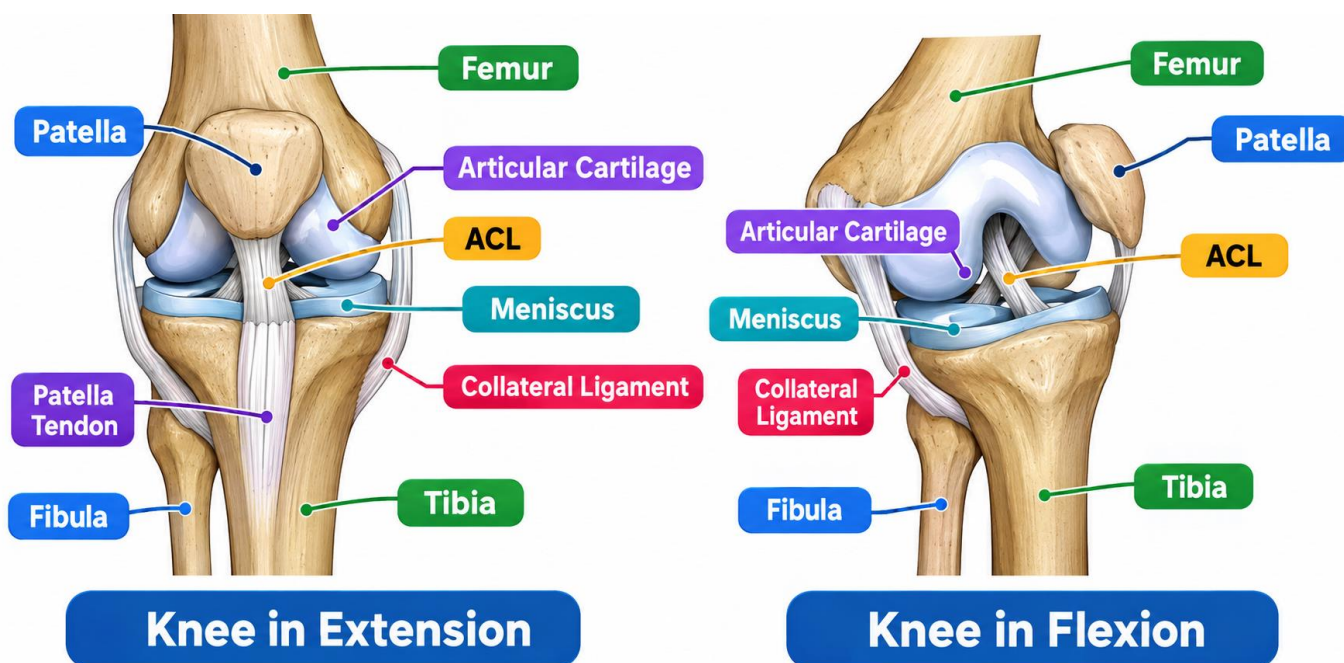


Figure. 1 The major bones, ligaments, and cartilage of the human knee extended (left) and bent (right)

The motivation behind the knee osteoarthritis detection and severity prediction project lies in the need for early diagnosis and effective management of this prevalent condition. Knee osteoarthritis affects peoples' life individually and can be enhanced with help of advanced technology and predictive models. Early detection of knee osteoarthritis allows for timely interventions, potentially slowing its progression and improving patient outcomes. By predicting the severity of the condition, healthcare providers can tailor treatments, optimize care plans, and alleviate pain more effectively. Addressing Diagnostic Challenges Conventional diagnostic methods for knee osteoarthritis often rely on subjective assessments, leading to variations in diagnosis and treatment.

Deep learning-based solutions have the potential to provide objective, reproducible, and consistent evaluations, addressing these diagnostic challenges the availability of vast amounts of medical imaging data, such as MRIs, presents an opportunity to leverage deep learning techniques for comprehensive and accurate

analysis. CNNs, known for their proficiency in image analysis, can extract intricate patterns and features that might elude human perception, adaptive, and robust compression techniques with broad applicability and significant impact across various domains.

2. Related Works

Serpil Aslan [1] has implemented a deep learning based hybrid model which can identify the knee arthritis disease at the initial stage and suggest the treatment also. In this study of research, three types of Convolutional Neural Network (CNN) deep learning models has been used and features were extracted from the image and combined and enhance by using these deep learning models effectively. The redundancy in the features was effectively removed with the help of Neighbouring Component Analysis (NCA) and the size reduction method. Six different deep learning classifiers were employed for feature map optimization with help of Neighbouring Component Analysis (NCA) and implemented method have achieved

highest accuracy performance.

Yashas C *et al.* [2] have developed system using Convolutional Neural Network (CNN) with multi layers and it is trained by extracting features from images. Convolutional layer was used to extract the features, pooling layer was used to reduce the dimensions of the features and fully connected layer was used for decision making or classification. X-ray images were used in this research work, these images were converted into grey scale images and then image feature were extracted for training and testing of the classifier.

Mrs. CH. Lakshmi Kumar *et al.* [3] have developed the system with help of python as programming and Django framework is included. The researchers have used 1650 digital X-ray images which were collected from premier hospitals and also from diagnostic centers also in the data set. The deep convolutional neural network was used in this study of work which was trained by extracting featured automatically and target evaluated by using Kellgren and Lawrence grades in the given X-ray and the prediction accuracy is low.

Ms. Shabnam Kumari *et.al* [4] developed the system using the VGG16 model in order to enhance the workflow efficacy of clinic and reduce the drawbacks of the traditional techniques. The researchers have used a novel quantitative approach to increase the diagnostics methods for predicting severity of osteoarthritis and also for identifying its early changes to give a significant barrier for clinic and they used less number of data sets in the training and testing phases.

Dr. V. Vijay Kishore1 *et.al* [5] suggested deep learning approach which contains five layers for extracting features, reducing the features' dimensions, training and testing and they have used x-ray images in this research work with VGG16 & SoftMax. The Kellgren – Lawrence approach were used with two deep convolutional neural networks. Two data sets were used in this proposed system such that contain 1650 different knee x-ray images. The sets consists of 514 healthy, 477 doubtful, 232 mild, 221 moderate and 206 severe case of knee osteoarthritis images. The implemented system have classified or identified and predicted the severity of knee osteoarthritis with accuracy of 95 percent.

Kumuda D K *et al.* [6] have proposed a methodology which has classified Knee osteoarthritis for diagnosis and provided the severity of the problems with help of different subgroups of control participants. They have demonstrated by defining subgroups such as gender, age and obesity. They have implemented a system to evaluate the performance of the deep neural network and other soft computing techniques, and the majority of these

techniques effectively classified the input data with good accuracy.

Dr. Shaik Mahaboob Basha *et al.* [7]. Have used MobileNet's deep learning and transfer learning techniques to perform the classification of whether a person has a doubtful, minimal, moderate, or severe infection or is healthy. Since proper treatment will be possible with the help of our suggested method, proper classification is crucial and the precision & effectiveness of diagnosing and treating knee osteoarthritis are low.

Hamad Sajaan Almansour *et al.* [8] have implemented a system based on a convolutional neural network to identify knee osteoarthritis in five types by using x-ray images. The results of implemented method was compared with two pre-trained transfer learning models i.e Xception and Inception ResNet V2. The performance were evaluated by using precision, recall, F1 score and accuracy.

D. Kiruthika *et al.* [9] have implemented an automated detection system with help of joint shape and modified fully connected neural network. The image texture features were used to classify healthy and affected knee osteoarthritis images. The implemented detection system were trained with 8000 knee radiographs images and tested with 3500 images. Image fusion techniques were used to improve the performance of the classifier.

T.P Ann Thabitha *et al.* [10] have developed proposed system which extracted profound features from medical images to classify normal and OA affected images. The researchers developed a system such that redundancy features were effectively reduced to improve the accuracy of the detection or classification. In this research work, large number of Magnetic Resonance Images (MRI) images were considered for identification or classification knee osteoarthritis by using the deep learning convolution neural network. The implemented method were extracted features for training and testing the classifier and evaluated with help of sensitivity, specificity and accuracy.

3. Research Methodology

The primary objectives of this research include the development and implementation of a Convolutional Neural Network (CNN) based system for knee osteoarthritis utilizing clinical data and medical imaging. Our methodology involves the extraction of pertinent features from diverse datasets, encompassing patient medical history, diagnostic assessments, and imaging modalities. The CNN model is trained to classify different severity levels of knee osteoarthritis and predict the progression of the disease. Feature selection and model optimization

techniques are employed to enhance the CNNs' performance, ensuring its robustness and accuracy.

Magnetic Resonance Image (MRI): MRI is a non-invasive imaging technology that produces three dimensional detailed anatomical images without the use of damaging radiation [11]. It is often used for disease detection, diagnosis, and treatment monitoring. X-ray and Computer Tomography (CT) images differs with Magnetic Resonance Images (MRI) which is not using effecting ionizing radiation. MRI imaging system can clearly view the information in the various parts of human body without damaging the cells. This is main reason MRI images used in the detection of knee Osteoarthritis [12].

The Features such as contrast, energy, entropy, homogeneity and correlation which are used to capture textural patterns indicative of osteoarthritis severity. The Features of Region of Interest (ROI) are computed by using Grey-Level Co-occurrence Matrix (GLCM) in the MATLAB [13].

Texture features are extracted using Grey Level Co-occurrence Matrix and the GLCM function characterizes the texture of an image by calculating how often pairs of the pixels with specific values and in a specified spatial relation occur in an image[14].

Contrast: It is measure of the intensity contrast between two pixels and it is calculated by using equation (1)

$$\alpha_c = \sum_{i,j} (|i - j|^2) x(i, j) \quad (1)$$

Energy: It is measure of the sum of the squared elements and it is calculated by using the equation (2)

$$\alpha_E = \sum_{i,j} (x_{ij})^2 \quad (2)$$

Homogeneity: It is measure of the closeness and distribution between the pixels and it is calculated by using equation (3)

$$\alpha_H = \sum_{i,j} \frac{x(i, j)}{1 + |i - j|} \quad (3)$$

Correlation: It measures the similarities between the pixels and it is calculated by using the equation (4)

$$\alpha_{CR} = \sum_{i,j} \frac{(i - m_{1i})(j - m_{1j})x_{ij}}{\sigma_i \sigma_j} \quad (4)$$

Entropy: Measure the randomness of intensity levels and it is calculated using equation (5)

$$\alpha_{Et} = \sum_{i,j} x_{ij} \log_2 \left(\frac{1}{x_{ij}} \right) \quad (5)$$

The performance identification of the classifier is computed with help of a 2x2 contingency table as shown in the table 1.

Table. 1 Contingency table with 2x2 for the presence and absence of Knee Osteoarthritis

Classifier output	Actual input		Total
	Present	Absent	
Present	True Positive	False Positive	All test Positive
Absent	False Negative	True Negative	All test Negative
Total	Total Actual Presences	Total Actual Absences	Total

True Positive (TP) which represents hits, **True Negative (TN)** which represents number of correct rejections, **False Positive (FP)** which specifies number of false alarm, and **False Negative (FN)** which specifies the number of misses of the classifier and these are used to measure the performance of the classifier.

True Positive (TP) = the classifiers' output which is positive in the presence of positive input and it is correct identification or detection.

True Negative (TN) = the classifiers' output which is negative in the presence of the positive input and it is correct rejection.

False Positive (FP) = the classifiers' output which is positive in the absence of the positive input and it is incorrect identification or detection.

False Negative (FN) = the classifiers' output which is negative in the presence of positive input and it is incorrect rejection.

Based on the above four outputs, the following performance evaluation of classifier is evaluated.

Sensitivity: The ability of the classifier which measures the number positives which are correctly identified. The sensitivity is also called true positive rate or recall. The Sensitivity can be measured by using the equation (6).

$$\text{Sensitivity } \lambda_{SEN} = \frac{TP}{TP + FN} \quad (6)$$

Specificity: The ability of the classifier which measures the number of negatives which are correctly identified. The specificity is also called true negative rate of the classifier. The specificity can be measured by using the equation (7).

$$\text{Specificity } \lambda_{SPE} = \frac{TN}{TN + FP} \quad (7)$$

Accuracy: Correct recognition of the classifier is called 'accuracy'. It is measured using equation (8).

$$\text{Accuracy } \lambda_{ACC} = \frac{TP + TN}{TP + TN + FP + FN} \quad (8)$$

Precision: Precision of a classifier is the probability of positive outcome given that a positive classification results and contrast to the sensitivity of the classifier. This is called Positive Prediction Rate. The formula for PPV is given in equation (9)

$$\text{Precision } \lambda_{PPV} = \frac{TP}{(TP + FP)} \quad (9)$$

4. Experimental Method

The proposed methodology consists of 6 major steps: Input MRI Images, Preprocessing, Image Segmentation, Feature extraction, Classification and Validation as shown in the figure 2:

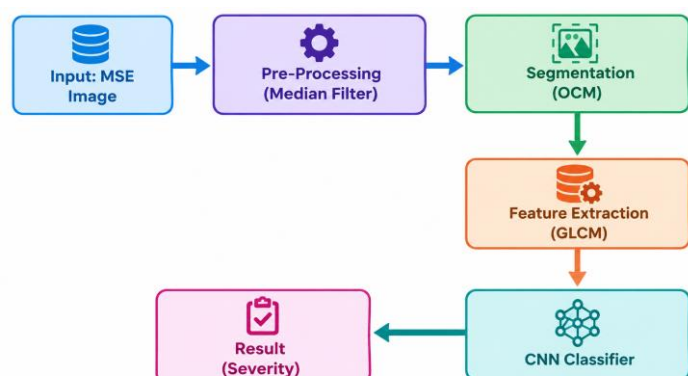


Figure. 2 Block Diagram of Proposed Method

Input MRI Images: Data set consists of training and testing data sets; training data set is used to train the classifier and testing data set is used to test the performance of the classifier. Data set is created by downloading website which are freely available. The training set contains 53 Knee Osteoarthritis images and 66 normal knee images. Testing set contains 36 Knee Osteoarthritis images and 32 normal knee images.

Pre-processing: It is image enhancement technique which improves the appearance of the image by reducing the noise. The Median filter is used in this proposed method in the pre-processing. Median filter is very crucial in the image processing field as it is well known for the preservation of edges during noise removal. The median

filtering is belongs to nonlinear type which can be reduce the noise from images. The median filter works based on replacing each pixel value by replacing the median values of the neighbouring pixels.

FCM Segmentation: Fuzzy C-Means segmentation algorithm is unsupervised image segmentation and does not take in to consideration the local information in the image context [15]. It combines both region and edge features of the image and then merge regions recursively asper the criterion of the maximum fuzzy integral.

The following steps are used in the FCM Segmentation

Step-1: Randomly choose at least two centroids and assign the values.

Step-2: Calculate membership matrix.

Step-3: Calculate the clusters C^k and $C^{(k-1)}$.

Step-4: If $C^{(k-1)} - C^k < \epsilon$ then stop else go to step2.

Morphological operations such as dilation, erosion, opening and closing are used to highlight the segmented region.

Features Extraction: The statistical features such as contrast, energy, homogeneity, correlation and entropy are extracted from the segmented image to train and test the performance the classifier.

Convolutional Neural Network (CNN): A CNN has three layers which are Convolution Layer, Pooling layer and fully connected Layer as shown in the Figure 3:

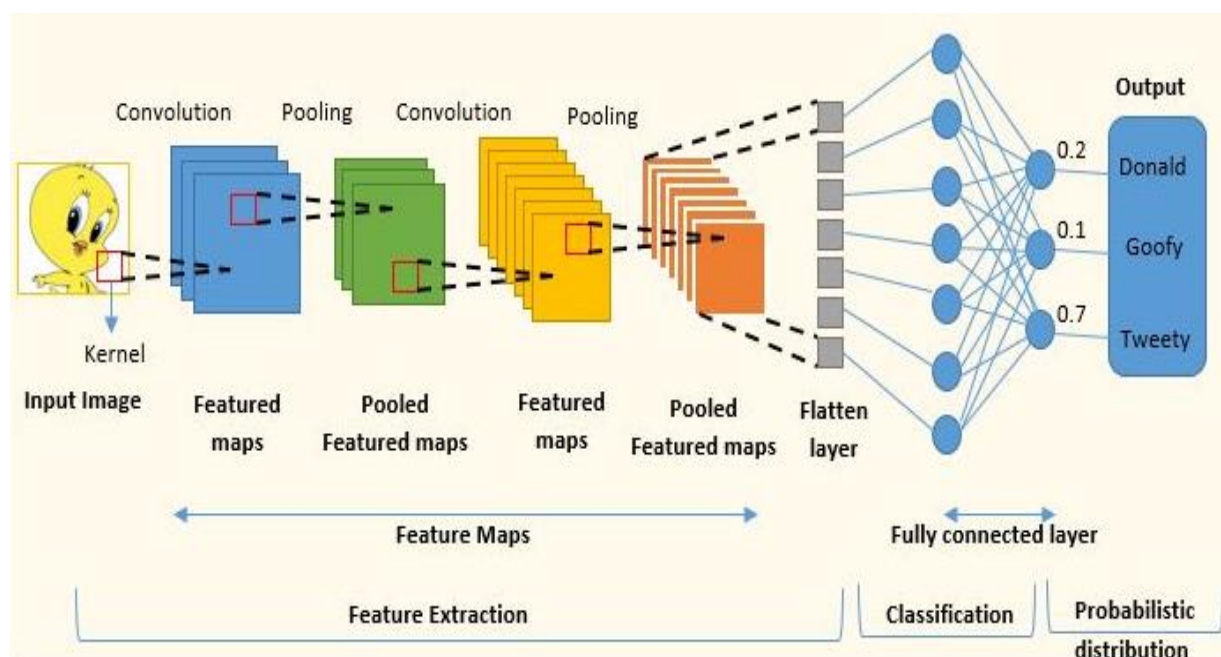


Figure. 3 Convolutional Neural Network (CNN)

The main function of Convolution Layer is to extract features by using Convolution operation. The function of pooling layer is to reduce the dimensions of the feature maps. The role of fully connected layer is to capturing global patterns and relationships in the input image by connecting every neuron from the previous layer to every neuron in this layer. Fully connected layer is trained by the extracted features by using backpropagation algorithm with help of training set and tested by using testing set.

5. Results and Discussion

The proposed method is implemented based on the MATLAB (R2021a) image processing, neural network, fuzzy logic toolboxes of MATLAB are used for experimental analysis. Input MRI image, Median Filtered image and segmented image are shown in Figure 4, Figure 5 and Figure 6 respectively.

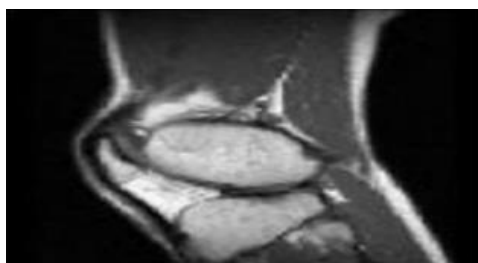


Figure 4. Input 2D MRI image

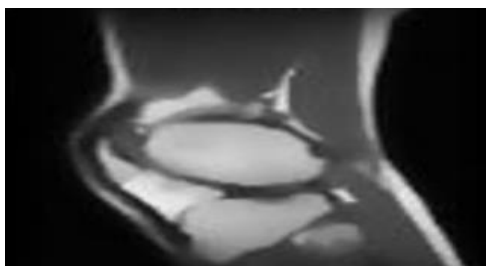


Figure 5. Filtered image

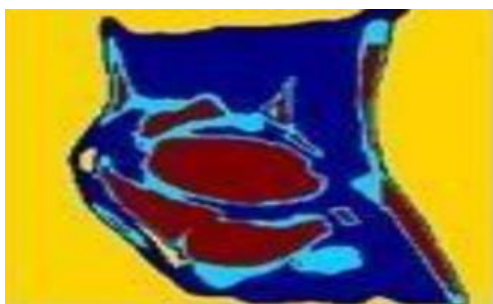


Figure. 6 Segmented Image

The Table. 5 shows the Performance Comparison between Existing system with proposed system and Figure 7. Shows the Graph of Performance Comparison between Existing System and Proposed System.

Table. 2 Comparison between Performances of Proposed System with Existing System

Performance Parameter	Existing System (SVM)	Proposed System (CNN)
Sensitivity	91.24%	94.19%
Specificity	88.08%	92.60%
Accuracy	94.4%	95.77%
Precision	89.64%	93.4%

The sensitivity is the ability of the classifier to measure the portion of positives that are correctly identified. This is also called the true positive rate or recall. Specificity is the ability of the classifier to measure the portion of negatives that are correctly identified. It is also called true negative rate. Accuracy is the total correct recognition of the classifier. The positive predictive value or precision of a classification is the probability that a positive outcome given that a positive classification result and it is contrasting to sensitivity.

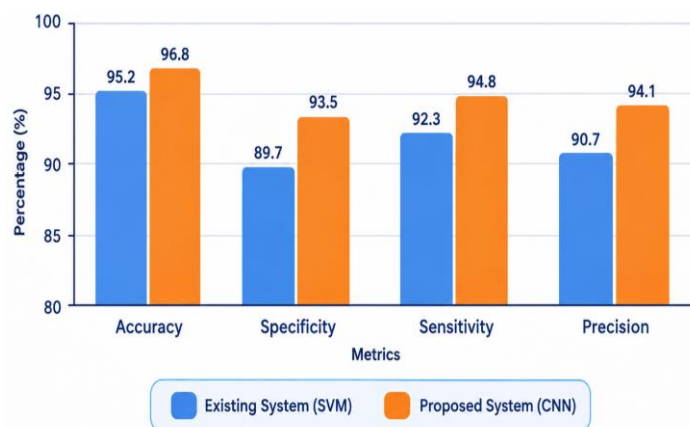


Figure. 7 Graph of Performance Comparison between Existing System and Proposed System

From the Figure 7, it is observed that proposed system developed using Convolutional Neural Network (CNN) gives efficient results in comparison with existing system developed using Support Vector Machine (SVM) because the feature extraction is done effectively in Convolutional Neural Network which is the reason for improvement in performance evaluation measures. The Sensitivity, Specificity, Accuracy and Precision of the proposed system are 94.19%, 92.60%, 95.77% and 93.4% respectively.

6. Conclusion and Future Scope

In this work, we have proposed a system to classify the In this work, we investigated the application of a complete method for the diagnosis and severity prediction of knee osteoarthritis (OA) using MRI input images. A median filter was used for pre-processing, fuzzy C-Means (FCM) was used for segmentation, a gray-level co- occurrence matrix (GLCM) was used for feature extraction, and a convolutional neural network (CNN) classifier was used

for classification in the suggested approach.

The application of Convolutional Neural Network (CNN) in Knee Osteoarthritis (KOA) detection and severity prediction has shown remarkable promise, with an impressive accuracy of 95.77%. The CNN classifier's performance can be enhanced even more by adding bigger and more varied datasets. Adding data from various demographic groups, communities, and imaging modalities can improve the generalizability of the model. Performance could be enhanced by carefully examining hyper parameters and optimizing the CNN architecture. It is possible to experiment with various network topologies, activation functions, and optimization strategies.

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How to Cite:

S Muni Ratnam¹ , D Ragulamma , P Tejaswani , G Swathi , K Vijayalakshmi , " Identification of Knee Osteoarthritis Disease using Convolutional Neural Networks ", *International Journal of Computational Sciences and Engineering Research (IJCSER)* , Volume 1, Issue 4 , pp 82-88, November 2024.

CrossRef DOI: <https://doi.org/10.63328/ijcser-v1ri4p14>

Declaration

Conflicts of Interest: The authors declare no conflict of interest.

Author Contribution: All authors wrote the main manuscript text and also consent to the submission.

Ethical approval: Not applicable.

Consent to Participate: All authors consent to participate.

Funding: Not applicable, and No funding was received

Institutional Review Board Statement: Not applicable.



Informed Consent Statement: Not applicable.

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Acknowledgements

We thank everyone who inspired our work.