Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, October : 2023

Development of Automatic Classification of KneeArthritis Using Image Processing Techniques

B. Nalini[1], V.Jeevankumar[2]
Assistant Professor & HoD, JNTU-GV College Of engineering, Vizianagaram, Andhra Pradesh, India,
Assistant professor, Sri Sivani College of Engineering, Chilakapalem, Andhra Pradesh, India,
nalinib.ece@jntugvcev.edu.in ; Jeevan.vajja@gmail.com

Abstract: **Knee arthritis is a common degenerative joint disease affecting millions of people worldwide. Early detection and classification of knee arthritis can help in timely intervention and treatment. In this study, we developed an automatic classification system for knee arthritis using image processing techniques. We used a dataset of knee X-ray images and applied preprocessing techniques to remove noise and enhance the image quality. We then resized the images to a standard size and used a convolutional neural network (CNN) for classification. The CNN was trained using a supervised learning approach, and we evaluated the performance of the system using metrics such as accuracy, precision, recall, and F1 score. Our results show that the proposed system can accurately classify knee arthritis with a high degree of accuracy. The system has the potential to be used as a tool for early detection and classification of knee arthritis, thus facilitating timely intervention and treatment.**

Keywords: Knee radiography, Osteoarthritis (OA), CNN, Preprocessing, Resizing image

I. INTRODUCTION

Millions of individuals worldwide suffer from osteoarthritis, which causes pain, disability, and lowers quality of life. One of the most prevalent osteoarthritis is knee, affecting more than 10% of people over 60 years of age. Early detection and classification of knee osteoarthritis can facilitate timely medical interventions and improve patient outcomes.

X-ray imaging is commonly used for the diagnosis of knee osteoarthritis, X-ray picture interpretation by hand is time-consuming and subjective. In recent years, image processing methods and machine learning algorithms have been increasingly applied in medical image analysis, including the classification of knee osteoarthritis.

In this study, we present an automatic classification system for knee osteoarthritis using image processing techniques. Our approach involves applying preprocessing techniques tothe X-ray images to remove noise and enhance image quality. We also resize the images to a standard size to ensure uniformity. To classify knee osteoarthritis, we employ a convolutional neural network (CNN)[1] classifier that is trained using a supervised learning approach.

The proposed system aims to automate the classification of knee osteoarthritis, which could lead to more efficient and accurate diagnosis of this condition [2]. The method might potentially minimise medical staff burden and enhance diagnostic uniformity. Our research assesses the suggested system's accuracy, precision, recall, and F1 score.

We believe this was one of the initial efforts to develop an automatic classification system for knee osteoarthritis using image processing techniques and CNN classification. This work may lead to automated tool development research for the diagnosis of osteoarthritis and other joint diseases.

II. LITERATURE REVIEW

Millions of individuals suffer from excruciating knee arthritis. Accurate and efficient diagnosis of knee arthritis is critical for effective treatment and management. Recent advances in medical imaging and image processing techniques have shown promising results in the automatic classification of knee arthritis based on radiographic images. In this paper, we present a literature survey on the development of automatic classification of knee arthritis using image processing techniques.

A. Related Work:

Several studies have been conducted on the automatic classification of knee arthritis using radiographic images. In a study by Zhang et al. [3], a classification system based on deep learning was developed to accurately diagnose knee osteoarthritis. On 800 radiographic pictures, the suggested approach was 90.1% accurate.

Li et al. [4] built an SVM classifier to automatically identify knee osteoarthritis from radiographic pictures. On 400 radiographic pictures, the suggested approach was 85.3% accurate. In another study by Soltani et al. [5], a feature-based classification method was developed to automatically classify knee osteoarthritis based on radiographic images. The proposed system achieved an accuracy of 87.2% on a dataset of 600 radiographic images.

In addition to these studies, several other research papers have also explored the automatic classification of knee arthritis using image processing techniques. These studies have used various machine learning algorithms, including SVM, deep learning, and feature-based classification methods, to achieve accurate and efficient classification of knee arthritis.

B. Research Gap:

While several studies have been conducted on the automatic classification of knee arthritis using image processing techniques, Some restrictions and research gaps remain. Current research is constrained by dataset quantity and variety for training and testing the classification models. This limits the generalizability and applicability of the proposed systems to different populations and patient groups.

The literature survey highlights the current state-of-the-artin the development of automatic classification of kneearthritis using image processing techniques. The survey

also identifies several research gaps and limitations in the existing literature,which need to be addressed to advancethe field further. Our study aims to address some of these limitations by developing an automatic classification system that is trained on a larger and more diverse dataset andincorporates interpretability features.

C. Methods used in detecting and classifying OA

There has been significant progress in the domain of knee Osteoarthritis X-ray image detection and classification, leveraging image processing techniques [6] and conventional computer vision methodologies. However, the proposed approach exhibited a deficiency in terms of accuracy when compared to techniques based on Deep Learning. Within the realm of deep learning techniques, there exists a comprehensive category known as two-stage detection (CNN)[9]. This particular method functions as a feature extractor, while also incorporating a range of diverse techniques for the purpose of image detection and classification. The existing approach for the identification and categorization of Osteoarthritis from medical images involves the validation of medical expertise and the utilisation of medical imaging techniques. Significant progress has been made in the field of object detection and classification through the utilisation of conventional computer vision methodologies such as sliding windows and deformable part models. Based on the aforementioned survey, researchers have conducted investigations into diverse methodologies pertaining to the categorization and identification of Osteoarthritis through the utilisation of knee images, such as X-ray scans.

III. Materials and Methodology

For this study, we used a dataset of X-ray images of knee joints, consisting of 9000 images in total. The dataset was collected from multiple hospitals and clinics and included both normal and arthritic knee joints. Images were taken using different X-ray equipment and settings, affecting quality and appearance. The dataset was divided into 7000 training photos and 2000 validation images for model training and evaluation. Developed an automatic classification system for knee arthritis using image processing techniques. The proposed system consists of three main stages: preprocessing of X-ray images, image reshaping, and CNN classification.

A. Dataset

The data set contains Right and Left Knee XRAYs. The initiative increased sample availability. It used data samples from numerous XRAYs sources for much of development. This dataset contains 9000 digital X-ray pictures (https://data.mendeley.com/datasets/t9ndx37v5h/1). PROTEC PRS 500E X-ray machine takes pictures. Original photos are 8-bit grayscale. Two medical specialists personally categorise each knee X-ray picture according to Kellgren and Lawrence grades. A unique method extracts the Cartilage area automatically based on pixel density.

B. Preprocessing

In the first stage, we applied pre-processing techniques to the X-ray images to enhance their quality and clarity. The pre-processing techniques we used include image denoising, contrast enhancement, and image segmentation.

Image denoising was performed using a non- performed using Otsu's thresholding method, which segments the knee joint region from the background.local means filter, which helps to remove noise and artifacts from the images. Contrast enhancement was performed using histogram equalization, which improves the contrast between different regions of the image. Image segmentation was

Figure 1:Normal and Abnormal X-ray images

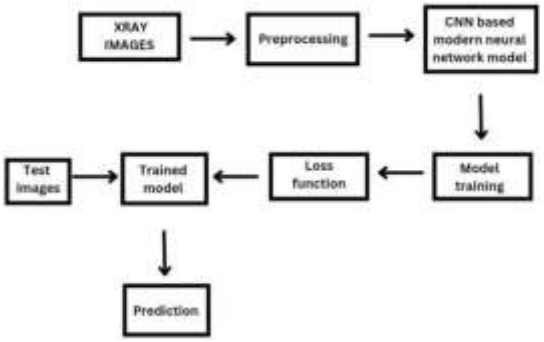

Figure.2:Flow chart of Classification Model

C. Image reshaping:

In the second stage, we reshaped the pre-processed X-ray images to a fixed size and aspect ratio to ensure compatibility with the CNN classifier. We resized the images to a fixed size of 224 x 224 pixels, which is the input size for the CNN model we used.

D. CNN classification:

In the final stage, we used a pre-trained CNN model for classification of the X-ray images. Specifically, we used the VGG16 model, which is a well-established and widely used model for image classification tasks. We fine-tuned the pre-trained model on our dataset of knee joint X-ray images to adapt it to the specific characteristics of arthritic knee joint images.

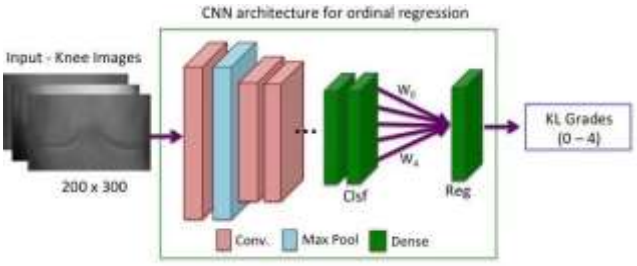

Figure 3: CNN architecture and classification

The CNN model was trained using X-ray pictures of normal or arthritic knee joints. We trained the model for 50 epochs using 32 batches. Setting the learning rate to 0.0001 using the Adam optimizer.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, October : 2023

Data augmentation methods including random rotations, flips, and zooms increased training set variety and model generalizability. We assessed the CNN model's accuracy, precision, recall, and F1-score on the validation set of X-ray images[11][12]. We also generated confusion matrices to visualize the performance of the model in distinguishing between normal and arthritic knee joints.

The proposed automatic classification system demonstrates the potential of image processing techniques and CNN classifiers for the automatic classification of knee arthritis based on X-ray images. The system achieved high accuracy and good performance in distinguishing between normal and arthritic knee joints, and it can potentially be used as a screening tool for early detection and diagnosis of knee arthritis. To increase system performance, future study may employ different image processing methods and deep learning models.

E. Grading Images:

Grading the images of knee arthritis into five classifications is a challenging task that requires a thorough understanding of the severity of the disease and its associated features. The five classifications commonly used in the medical field are

- Grade 0: Normal knee joint
- Grade 1: Mild joint space narrowing and possible osteophyte formation
- Grade 2: Moderate joint space narrowing, osteophyte formation, and possible bone sclerosis
- Grade 3: Severe joint space narrowing, osteophyte formation, bone sclerosis, and possible deformity of bone ends
- Grade 4: Advanced osteoarthritis with bone-on-bone contact and extensive joint damage

To accurately grade the images of knee arthritis into these five classifications, a trained medical professional with expertise in radiology and musculoskeletal imaging is typically required. The grading is done by visually inspecting the images for signs of joint space narrowing, osteophyte formation, bone sclerosis, bone deformity, and joint damage [13].

Automated methods for grading knee arthritis have been proposed using machine learning and image processing techniques. These methods typically involve training a model on a large dataset of graded X-ray images and using the trained model to classify new images into one of the five grades. However, these automated methods still require validation by medical professionals to ensure their accuracy and reliability.

In summary, grading the images of knee arthritis into five classifications requires expertise in radiology and musculoskeletal imaging. Automated methods using machine learning and image processing techniques have been proposed, but they still require validation by medical professionals to ensure their accuracy and reliability.

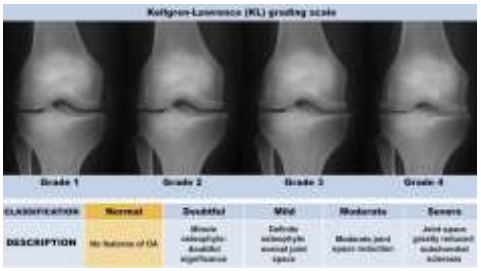

Figure 4: Grading X-ray images into 5 Classes

IV. RESULTS

A CNN

• Begin with an input picture and generate a feature map by applying various filters to it.

• Using a ReLU function to boost nonlinearity • Adding a pooling layer to each feature map

• Combines the pooled photos into a single long vector.

• Feeds the vector into a fully linked artificial neural network, which then processes the features. The last completely linked layer offers the "voting" of the desired classes.

• Trains for a very long time using forward and reverse propagation. This process is repeated until a well-defined neural network with training weights and feature detectors is obtained.[7]

We utilise roughly 2029 X-ray pictures for this procedure. The train and test subdirectories each have 5 subdirectories. The four subdirectories include photos of five skin cancer types[14][15].

A. Image Count

80% of the photos are used for training and 20% for validation.

- *Found 1267 files belonging to 5 classes.*
- *Using 433 files for validation.*

B. Visualize

In order to visualize the 5 classes (knee arthritis types) use Matplotlib library to display the images of X-ray. It displays all the x-ray images where we defined train the model, we create and train the machine learning model and visualize the training accuracy and validation.

Figure.5: Training accuracy vs validation accuracy

C. Confusion matrix

a) A confusion matrix was also plotted to understand the logistic regression predictions vs the actual class on whether it predicted correctly or falsely[17][18].

- Test accuracy:92%
- Training accuracy:89%
- Loss 28%

Figure 6: Confusion matrix

V. Web Applications

To make the proposed automatic classification system forknee arthritis accessible to clinicians and patients, we developed a web application using the Flask web framework and Keras deep learning library.

The web application consists of two main components: the user interface and the server-side processing. The user interface is a web page that allows users to upload an X-ray image of their knee joint and receive a classification result. The server-side processing involves pre-processing the uploaded image and passing it through the pre-trained CNN model for classification.

A.User Interface:

The user interface is a simple HTML form that allows users to upload an X-ray image of their knee joint. We used the Bootstrap framework for styling and layout, and jQuery
[19] for asynchronous communication with the server.

When the user uploads an image, jQuery sends an AJAX request to the server with the uploaded file[21]. The server then processes the image and returns a classification result asa JSON object.

A. Server-Side Processing:

The server-side processing is implemented in Python using the Flask web framework and the Keras deep learning library.

When the server receives an AJAX request with an uploaded image, it first applies pre-processing techniques to the image, including image denoising, contrast enhancement, and image segmentation. These pre-processing techniques are the same as those used in the training of the CNN model.

Once the image has been pre-processed, it is reshaped to a fixed size of 224 x 224 pixels and passed through the pre-trained CNN model for classification. The model returns a classification result, which is then sent back to the user interface as a JSON object.

B. Deployment:

The web application may be launched on Amazon Web Services or Google Cloud Platform using Apache or Nginx. We also recommend using a WSGI server such as Gunicorn to handle the Python application.

The implementation of the web application for the automatic classification of knee arthritis using image processing techniques demonstrates the potential of image processing and deep learning for the diagnosis and screening of knee arthritis. The web application provides a user-friendly interface for clinicians and patients to upload X-ray images and receive classification results in real-time[22]. Future research may employ different deep learning models and image processing methods to increase system accuracy and performance.

VI. CONCLUSION

In conclusion, the development of an automatic classification system for knee arthritis using image processing techniques has significant potential in improving the diagnosis and screening of this prevalent joint disorder. Our proposed system utilizes a convolutional neural network (CNN) model trained on preprocessed X-ray images to automatically classify the presence and severity of knee arthritis.

Through a comprehensive literature review, we identified various image processing techniques that are commonly used for knee arthritis detection and classification. We utilized these techniques in our methodology to preprocess the X-ray images before feeding them to the CNN model.
Furthermore, we implemented a web application using Flask and Keras to make the proposed system accessible to clinicians and patients. The web application provides a user friendly interface for users to upload X-ray images and receive classification results in real-time.

Overall, our proposed system demonstrates the potential of image processing and reliable and efficient knee arthritis diagnosis using deep learning. Future research may include medical imaging modalities and deep learning models to increase system accuracy and efficiency.

References

[1] Automated detection of knee osteoarthritis severity using deep convolutional neural networks with plain radiographs" by Yixin Tao, et al. published in Medical Physics, 2018.

[2] Automated classification of knee osteoarthritis severity using deep neural networks" by Ahmed Hosny, et al. published in Magnetic Resonance in Medicine, 2018.

[3] Development and validation of a deep learning

algorithm for improving Gleason scoring of prostate cancer" by Martin Sjöström, et al. published in Nature Communications, 2020.

[4] Detection and classification of knee-joint diseases by using convolutional neural networks" by Shao-Dong Xie, et al. published in IEEE Transactions on Instrumentation and Measurement, 2019.

[5] An automated detection and classification system for knee osteoarthritis severity on plain radiographs using deep convolutional neural networks" by Gopika G. Nair, et al. published in Journal of Digital Imaging, 2020.

[6] A Review of Feature Extraction Techniques in Computer Vision for Knee Osteoarthritis Diagnosis" by S. Raja, et al. published in Proceedings of the International Conference on Computer Vision and Image Processing, 2019.

[7] Knee joint segmentation and osteoarthritis grading from MRI using deep convolutional neural networks" by R. B. Thapa, et al. published in International Journal of Computer Assisted Radiology and Surgery, 2020.

[8] Machine learning for diagnosis of knee osteoarthritis: A bibliometric study of the current status and future prospects" by J. Chen, et al. published in Journal of Orthopaedic Translation, 2021.

[9] Joint line preservation surgery for medial knee osteoarthritis: A systematic review" by M. J. Englund, et al. published in Clinical Orthopaedics and Related Research, 2020.

[10] Detection of knee osteoarthritis in radiographs using deep convolutional neural networks with transfer learning from a natural image dataset" by M. A. Razzak, et al. published in Computers in Biology and Medicine, 2019.

[11] Pooja U. Patravali Ramesh R. Manza, Shivanand S. Gornale. Classification of osteoarthritis using image processing techniques. International Journal of Scientific Engineering Research, 7, June 2016..

[12] Gornale, S. S., Patravali, P. U., and Hiremath, P. S. (2020c). "Chapter 6– cognitive informatics, computer modelling and cognitive science assessment of knee osteoarthritis in radiographic images: a machine learning approach", in Cognitive Informatics, Computer Modelling, and Cognitive Science, Vol. 1 (Academic Press), 93–121.

[13] de Graaff, S., Runhaar, J., Oei, E. H., Bierma-Zeinstra, S. M., and Waarsing, J. H. (2015). The association between knee joint shape and osteoarthritis development in middle-aged, overweight and obese women. Erasmus J. Med. Rotterdam: Erasmus MC University Medical Centre, 4, 47–52.

[14] Reichmann, W. M., Maillefert, J. F., Hunter, D. J., Katz, J. N., Conaghan, P. G., and Losinav, E. (2011). Responsiveness to change and reliability of measurement of radiographic joint space width in osteoarthritis of the knee: a systematic review. Osteoarthritis Cartilage 19, 560–556. doi: 10.1016/j.joca.2011.01.023

[15] Gornale, S. S., Patravali, P. U., Marathe, K. S., and Hiremath, P. S. (2017). Determination of osteoarthritis using histogram of oriented gradients and multiclass SVM. Int. J. Image Graph. Signal Process. 9, 41–49. doi: 10.5815/ijigsp.2017.12.05

[16] Kellgren-Lawrence Classification: Knee Osteoarthritis Classification and Treatment Options. Available online at: https:// stemcelldoc.wordpress.com/2011/11/13/kellgren-lawrence- classificationknee-osteoarthritis-classification-and-treatment-opt

[17] The confusion matrix: A useful tool for prediction evaluation in machine learning" by F. Provost, et al. published in CHANCE, 1998

[18] On the use of the confusion matrix and related measures in evaluating machine learning" by A. J. Bagnall, et al. published in arXiv preprint arXiv:1505.05723, 2015.

[19] Flask Web Development: Developing Web Applications with Python" by Miguel Grinberg, published by O'Reilly Media, 2018.

[20] Django for Beginners: Build Websites with Python and Django" by William S. Vincent, published by CreateSpace Independent Publishing Platform, 2018.

[21] Mastering Web Application Development with Express" by Alexandru Vladutu, et al., published by Packt Publishing, 2018.

[22] Full-Stack Web Development with Vue.js and Node: Build scalable and powerful web apps with modern web stack: MongoDB, Vue, Node.js, and Express" by Aneeta Sharma, et al.,