Knee Osteoarthritis Grading using Osteo HR Net Model

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Abstract

Knee Osteoarthritis (OA) is a fatal joint condition affecting the lives of many people around the world. This deadly joint disorder is determined by inflexibility of joints, severity and poor functioning of joints. One of the common risk factors of the disability include age. And these are detected by assessing visible syndromes, clinical data and also through many joint examining reports such as Magnetic Resonance Imaging (MRI), radiography reports and computed tomography images. These imaging tests show the disease progression and provide information about the internal structure of our body. However, the traditional way of treatment is difficult as identifying the disorder at an early stage is impractical. Handling this dispute, a deep learning-based model is proposed to assess the severity of Osteoarthritis in scales of Kellgren and Lawrence (KL) grades automatically. The main novelty of the proposed model is that it is based on the combination of a top-most current deep learning models which is the called High Resolution Network (HRNet) and an attention module called CBAM(Convolutional Block Attention Module), which records multiple resolution representations of knee joint X-ray images. This proposed model is referred to as OsteoHRNet in this paper. This model is a convolutional neural network (CNN) which maintains high-scale representational features. Our proposed framework attained an accuracy of 71.74% and mean absolute error (MAE) of 0.31 with the Osteoarthritis Initiative (OAI) dataset which contains train, test and validation sets of five grades ranging from 0 to 4. This proposed framework gains best remarks over the existing models.

Keywords: 1.Knee X-ray, 2.OA, 3.High resolution Net, 4.CBAM, 5.KL grades, 6.Osteo HRNet.

I. INTRODUCTION

Knee osteoarthritis is a very familiar joint disability generally induced due to collapse of the articular cartilage in the middle of the knee joints and thus leaving the knee bones in contact which leads to brushing upon each other. It is very common to happen in the middle of the joints of the knee. It evolves from a set of aspects like another disease, injury, age, hereditary, obesity, stress, infections, trauma, gender and other factors. The rigidity and pain in the joints start to be poor mainly due to stringent work and stress in contrast to other forms of arthritis where actions and exercising enhance the syndromes. This may also prolong weakness, abnormality and reduced functioning of joints. Moreover, due to the break-down of the cartilage, the gap enclosed with the knee joint increases which directs to the growth of knee OA. Radiographic examining, MRI, and CT images helps in finding the deformities in the joint and detects knee OA's severity state. But in today's world, conventional method of medication for knee OA is not feasible as it is highly crucial to detect it at an early stage where the loss could be reduced or completely reversed.

The basic grade definitions for the KL scale are Grade 0: no pathology is present; Grade 1: Potential osteophytic lipping and improbable joint space narrowing; Grade 2: obvious osteophytes and possible restriction of the joint space; Grade 3: Multiple, moderate osteophytes, obvious narrowing of the joint space, some sclerosis, and possible deformity of the bony end; Grade 4: considerable joint space narrowing, extensive sclerosis, and obvious deformity of bone ends. The effectiveness of OA is calculated in the aspects of the KL grading scale which is a progressive grade scale ranging from 0 to 4. And the severity increases gradually from grade 0 to grade 4.

Deep learning is an information-driven method of offering network training. The High-resolution network tends to predict the knee OA severity using the KL grades. OsteoHRNet proved better performance over the existing works, represented with the high-resolution features.

II. RELATED WORK

Many models have been proposed and built for assessing Knee OA severity over the last few years. Some recent approaches have raised to develop the frameworks particular to knee OA provided with the data had in the knee X-rays. DenseNet and VGG are the pretrained existing best published works. DenseNet is a kind of CNN that uses dense connections among the layers, often called Dense Blocks, where we join the layers directly with one another. It was specially designed to enhance the performance degraded due to gradients in high-level neural networks. The densenet-161 model is very large and the representations of every layer are sliced with the earlier layer, and the information is duplicated many times. Moreover, it needs much time for training as it uses several smaller convolutions in the network, which runs slower on GPU than compact large convolution. VGG-19 is also a type of convolutional neural network trained with many images from the ImageNet. The network is 19 layers deep. Therefore, the model has trained with high feature visualizations for a large set of images. But, it has so many weight parameters and requires more time for training. However, performance of the existing methods is in shortage of accuracy and other evaluation metrics.

III. PROPOSED SYSTEM

Knee Osteoarthritis has been one of the most common diseases now-a-days, especially among the people who are aged above 45 years. The common way of diagnosis of the Knee Osteoarthritis is through x-rays of the joints of the knees. For every patient who is suffering with the knee pain and take x-rays cannot have the access to the high-end treatment from various private hospitals. It has become very difficult for middle-class and lower middle-class people to take treatment or even just to consult an experienced doctor. So, a system is proposed where HR net algorithm is integrated with an attention module called CBAM, Convolutional Block Attention Module to detect the stages of Knee Osteoarthritis stated as 0,1,2,3,4 at an increasing rate of severity from 0 to 4 considering all the 5 stages.

A. Dataset

The dataset is also vital in achieving reliable findings or estimations. A dataset featuring fewer null data values and less impure data is better suited for feeding classification models. Training the models necessitates considering all conceivable approaches to the problem. This dataset consists of train, validation and test datasets of different scales ranging from grade 0 to grade 4. From grade 0 to grade 4 severity of knee OA gradually increases. These are knee X-ray images which are considered to predict the severity of Osteoarthritis. In any Machine Learning techniques, the data sets that are being used for the prediction has to be divided into training and testing.

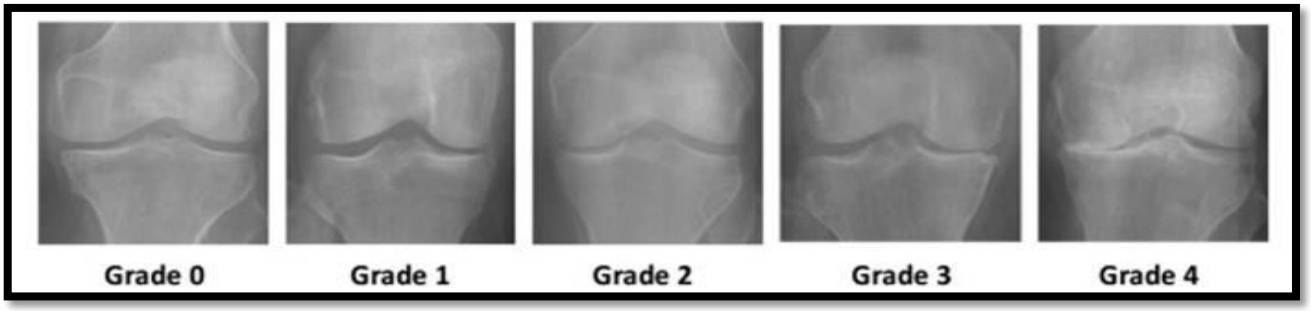

Fig. 1. Dataset with Kellgren-Lawrence Grading

B. High-Resolution Network

An innovative and ground-breaking multi-resolution deep CNN called the High-Resolution Network (HRNet) strives to retain, across the network, high-resolution feature representations are available. It begins with a sequence of two-dimension convolutions and then incorporates streams of high-to-low resolution to create the successive stages. The streams are then combined in various resolutions that operate simultaneously to exchange data. The main key ideas to be considered regarding the High-Resolution Network, compared to the previous works are maintaining high resolution, parallel connection between the subnets and repeated multi-scale fusion.

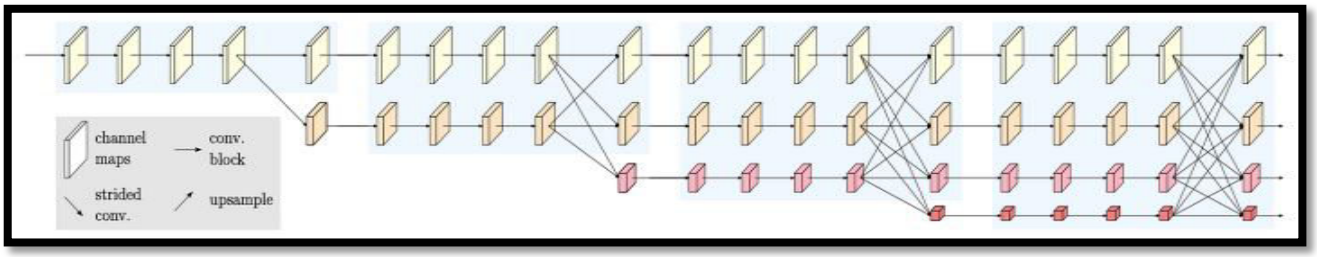

Fig. 2. High-Resolution Network

HRNet often creates credible multi-resolution depictions with solid spatial sensitivity. The intermediary forms from multi-resolution streams were fused using parallel connections as opposed to serial and recurring fusion, which is how it was accomplished. The network may then acquire more strongly connected and semantically solid spatial information as a consequence. This prompts us to include HRNet in image processing procedure of the sample X-Rays of knee, that lack such advanced spatial characteristics.

C. Working of HRNet Algorithm

The High-Resolution network shows more accuracy when compared to the previous models like VGG19 and Densenet161 models. HRNet's parallel technique allows it to maintain high resolution over the whole neural network, resulting in a more exact representation. Other methods combine low resolution and adequately and accurately high -resolution representations. Multi-resolution is repeated by HRNet and conceptually enhances high resolution to low resolution forms.

In pixel and area labelling challenges, strong high-resolution representations are critical. This can be achieved by developing our models using the high-resolution network. So, to process the knee osteo-arthritis x-ray images for better understanding and better focus on the affected area, we can use the high -resolution network.

In several machine learning fields in computer vision, HRNet is cutting-edge. The authors altered the traditional convolution design, which used a serial technique, to an architecture with parallel working mechanism with numerous group convolutions. This design enables high resolutions while improving accuracy and contextual connectivity. HRNet is semantically and spatially precise for the models we build.

D. Convolutional Block Attention Module

The CBAM is an attention module for convolutional neural networks. CBAM is composed of two consecutive sub-modules known as the Spatial Attention Module (SAM) and the Channel Attention Module (CAM), that are used in that sequence. CBAM is used as a layer in every convolutional block of a CNN model. It accepts a tensor containing the feature mappings from the preceding convolutional layer and refines it using channel attention and CAM. Following that, the refined tensor is sent to SAM, which applies spatial attention, giving feature maps which are refined as output.

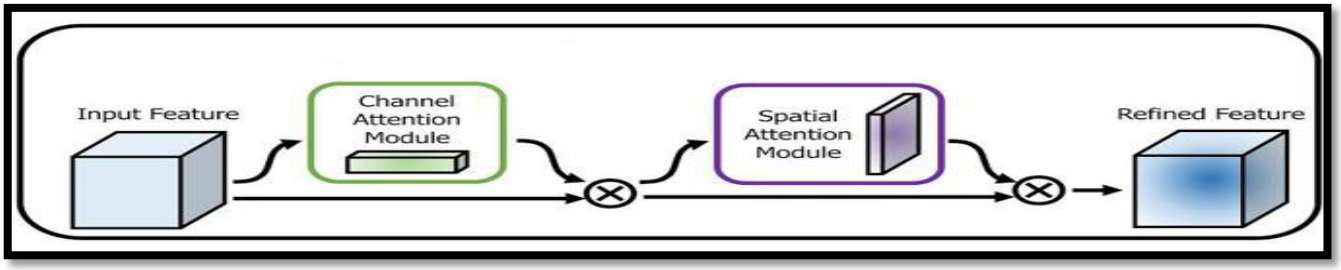

Fig. 3. Convolutional Block Attention Module

III. IMPLEMENTATION

In addition to the HRNet algorithm, to increase the accuracy and reliability about the prediction of the grading of x-rays, an attention mechanism, called Convolutional Block Attention Module (CBAM) is integrated to the High-Resolution network. The combined infrastructure can be termed as OsteoHRNet.

A. OsteoHRNet

The OsteoHRNet model is a way more efficient model which can predict the grades of the Knee Osteoarthritis disorder with more accuracy compared to the previous models introduced for the prediction of the same.

After applying the HRNet algorithm, at the end we apply the CBAM to it, for better analysis of the KL grade classification of given x-ray input image. CBAM focuses only on the required and mandatory areas which are to be aimed for better results.

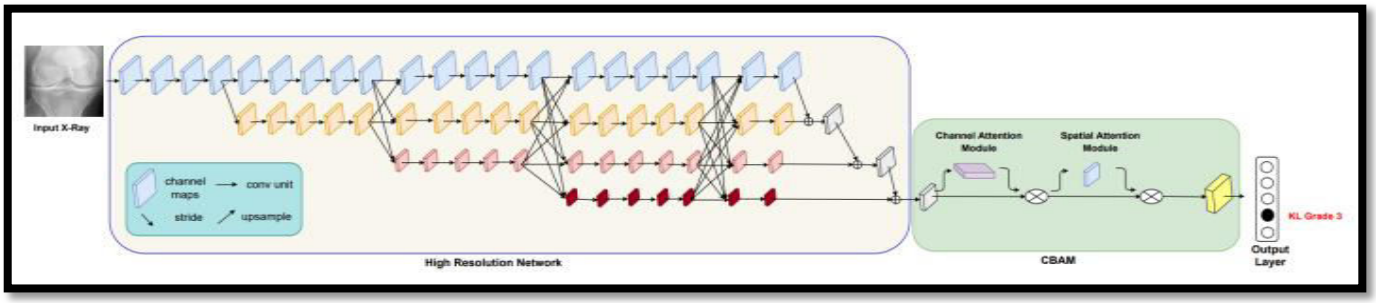

Fig. 4. Osteo HRNet

B. Implementation process

First, the dataset should be divided into training and testing set. Then the HRNet algorithm is to be considered and applied to the training dataset, the output of hrnet is integrated with the validation set. Now, the CBAM is applied at the end to enhance the accuracy of the results.

The final output classification is obtained by checking with the testing data and the evaluation results are obtained. We import many packages and modules for implementing HRNet and CBAM integration as OsteoHRNet. One of the open-source libraries we use mainly is the tensorflow in this implementation of the model. It is used for object detection. We use TensorFlow to create our own machine learning model customized according to our own requirements, in this case a model to predict the severity of the knee osteoarthritis.

Keras is an interface available in python to make the implementation of artificial neural networks easier to build various models. It is an open-source framework which made our work easier to create different architectures convenient to the user requirements.

CBAM involves both the modules spatial and also the channel to get better focus on the x-ray images. In any CNN model, pooling is done to minimize the dimensions of the input feature maps by using different methods. In this model, we use the average and max pooling methods for effective results as every other CNN model generally use. Then the convolution layer output is obtained.

IV. EVALUATION DETAILS

After dividing the dataset into different grades according to the severity of the disorder, we give them numbering from 0 to 4 to differentiate the severity levels for easier classification at later stages of the model.
We build this model with 25 epoches and the whole model is termed as HRNet-CBAM classifer, also the OsteoHRNet model.

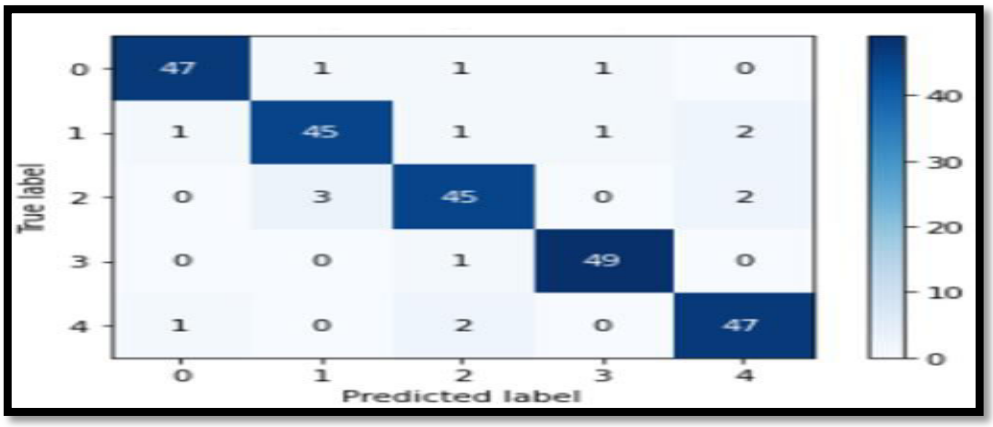

Fig. 5. Confusion matrix of the model

After the preprocessing and dividing the images according to their grades, we need to perform dataset segregation into training as well as testing datasets. Training data made up 70% of the total data, and test data made up 30%. We need to train the model with the training dataset.
After training completion, we need to test the model using the testing dataset. For the OsteoHRNet model's construction, Python is used to assess the accuracy of the proposed model, and the outputs are as following.:

	precision	recall	f1-score	support
0	0.96	0.94	0.95	50
1	0.92	0.90	0.91	50
2	0.90	0.90	0.90	50
3	0.96	0.98	0.97	50
4	0.92	0.94	0.93	50
accuracy			0.93	250
macro avg	0.93	0.93	0.93	250
weighted avg	0.93	0.93	0.93	250

Fig. 6. Classification report

According to the plot above, classification 0, 1, 2, 3, 4 are correctly classified as 96%, 92%, 90%, 96%, 92% respectively and the final total accuracy is approximately 93%, showing that the OsteoHRNet model is satisfactory and way better than any other proposed previous models.

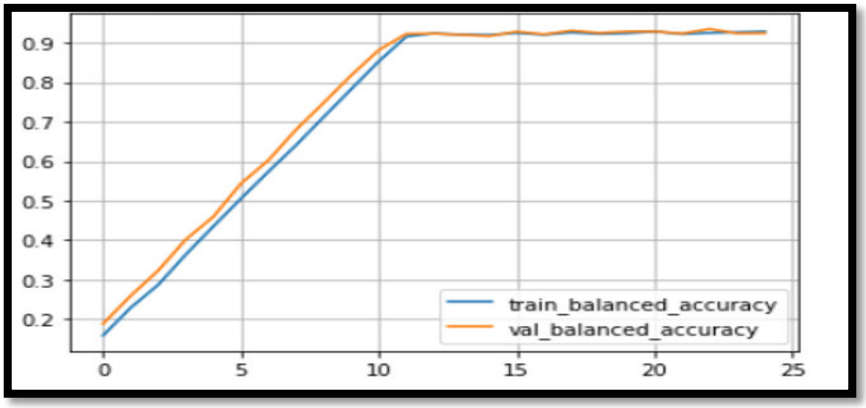

Fig. 7. Graph showing trained and testing data accuracy comparison

From this plot, it can be seen that the accuracy is almost same for the testing and training data sets. Further we used this model to create a web application which takes an x-ray image as an input and gives the grade of KL classification to which it belongs.

V. CONCLUSION AND FUTURESCOPE

The proposed system greatly enhanced he intermediary retrieved characteristics, allowing X-rays with similarities across classes and changes within classes to be identified better. Because of the OsteoHRNet model's capacity to preserve the characteristics with HR across the system and record dependable space characteristics, this suggested network performed extraordinarily well and achieved considerable improvements over previously proposed techniques. The algorithm and the system proposed has gradually learnt the resilient properties on each element of the neural framework. As a result, it has been established that every element of this system adds to the final knee Osteo-Arthritis KL grade prediction.

OsteoHRNet has made easier for predicting the grade of the osteo arthritis from the give data set images of the joints in the form of x-rays. This model will help the doctors or healthcare workers to analyze the condition of the patient when they are not available for the patients for proper diagnosis. The designed web application also helps the patients to get a better view of their health condition without consulting the doctor and then decide to consult the doctor or not according to the grade of the knee x-ray analyzed for the given input.

The model developed in this paper is a web page for only one disease i.e., the Knee Osteoarthritis. In further works, we can build a hospital management system or a disease prediction system which consists of prediction of various other disorders as well for early and easy diagnosis for the doctors and patients.

References

1. C. Kokkotis, S.Moustakidis, E. Papageorgiou, G. Giakas,and D. Tsaopoulos, "Machine learning in knee osteoarthritis: A review," Osteoarthritis and Cartilage Open, vol. 2, p. 100069, 05 2020.
2. P. Chen, L. Gao, X. Shi, K. Allen, and Y. Lin, "Fully automatic knee osteoarthritis severity grading using deep neural networks with a novel ordinal loss," Computerized Medical Imaging and Graphics, vol. 75, pp.84–92, 2019.
3. M. Gorriz, J. Antony, K. McGuinness, X. Gir o-i-Nieto, and N. O'Connor, "Assessing knee oa severity with cnn attention-based end-to-end architectures," vol. 102, pp. 197–214, 08–10 Jul 2019.
4. B. Zhang, J. Tan, K. Cho, G. Chang, and C. M. Deniz, "Attention-based cnn for kl grade classification: Data from the osteoarthritis initiative,"pp. 731–735, 2020.
5. J. Antony, K. McGuinness, N. E. O'Connor, and K. Moran, "Quantifying radiographic knee osteoarthritis severity using deep convolutional neural networks," pp. 1195–1200. M.
6. J. S. Yadav, S.S., "Deep convolutional neural network based medical image classification for disease diagnosis." J Big Data 6, 113, 2019.

7. Jingdong Wang, Ke Sun, Tianheng Cheng, Borui Jiang, Chaorui Deng, Yang Zhao, Dong Liu, Yadong Mu, Mingkui Tan, Xinggang Wang, Wenyu Liu, and Bin Xiao,"Deep High-Resolution Representation Learning for visual recognition".

8. H. Khalid, M. Hussain, M. A. Al Ghamdi, T. Khalid, K. Khalid,M. A. Khan, K. Fatima, K. Masood, S. H. Almotiri, M. S. Farooq, andA. Ahmed, "A comparative systematic literature review on knee bone reports from mri, x-rays and ct scans using deep learning and machine learning methodologies," Diagnostics, vol. 10, no. 8
9. N. E. O. J. Antony, K. McGuinness and K. Moran, "Automatic detection of knee joints and quantification of knee osteoarthritis severity using convolutional neural networks." 2021.
10. T. J. R. E. L. P. S. S. Tiulpin, A., "Automatic knee osteoarthritis diagnosis from plain radiographs: a deep learning-based approach."Scientific Reports.
11. S. A. A. F. N. D. Kohn, M. D., "Classifications in brief: Kellgrenlawrence classification of osteoarthritis." Clinical orthopaedics and related research, vol. 474(8).
12. Y. Du, et al., A novel method to predict knee osteoarthritis progression on MRI using machine learning methods, IEEE Trans. NanoBioscience 17 (3) 228–236.
13. E. Halilaj, et al., Modeling and predicting osteoarthritis progression: data from the osteoarthritis initiative, Osteoarthritis Cartilage 26 (12)1643–1650.
14. J. Lim, J. Kim, S. Cheon, A deep neural network-based method for early detection of osteoarthritis using statistical data. International journal of environmental research and public health 16 (7)1281.
15. A. Tiulpin, et al., Automatic knee osteoarthritis diagnosis from plain radiographs:a deep learning-based approach, Sci. Rep. 8 (1) (2020) 1727.
16. N. S¸ enKoktas € ¸, et al., A multi-classifier for grading knee osteoarthritis using gait analysis, Pattern Recogn. Lett. 31 (9) (2020) 898–904.
17. L. de Girolamo, E. Kon, G. Filardo et al., "Regenerative approaches for the treatment of early OA," Knee Surgery, Sports Traumatology, Arthroscopy, vol. 24, no. 6, pp. 1826–1835.
18. Antony, J., McGuinness, K., O'Connor, N. E. & Moran, K. Quantifying radiograph Kolenikov, S. &Ángeles, G. The use of discrete data in principal component analysis with applications to socio-economic indices. cpc. Tech. Rep., MEASURE Working Paper No. WP-04-85
19. Antony, J., McGuinness, K., Moran, K. & O'Connor, N. E. Automatic detection of knee joints and quantification of knee osteoarthritis severity using convolutional neural networks. In International Conference on Machine Learning and Data Mining in Pattern Recognition, 376–390 (Springer, 2017)