International Journal of Computer Engineering in Research Trends

Multidisciplinary, Open Access, Peer-Reviewed and fully refereed

Research Paper | Volume-8, Issue-12, 2021 Regular Edition | E-ISSN: 2349-7084

Prediction of Knee Osteoarthritis Using Deep Learning

*P. SIVA

Department of Computer Science and Engineering, Matrusri Engineering College, Hyderabad, Telangana, India.

Email ID: sivap@matrusri.edu.in

Available online at: http://www.ijcert.org

Received: 09/12/2021, Revised: 21/12/2021, Accepted: 28/12/2021, Published: 30/12/2021

Abstract: Knee osteoarthritis (OA) is a disease that increases in incidence and prevalence with advancing age, resulting in symptomatic knee OA in those over the age of 60, around 10 per cent of men and 13 per cent of women. Knee osteoarthritis (OA) is a chronic degenerative joint disease characterized by cartilage loss and changes in bones underneath it, causing pain and functional disability. The main clinical symptoms of knee. OA are pain and stiffness, particularly after activity, leading to reduced mobility and quality of life, and eventually resulting in knee replacement surgery. OA is one of the leading causes of global disability in people aged 65 and older, and its burden is likely to increase in the future with the ageing of the population and rise in obesity worldwide. OA is mainly diagnosed in clinical studies by means of medical images. X-ray imaging creates pictures of the inside of your body. The images show the parts of your body in different shades of black and white. This is because different tissues absorb different amounts of radiation. Calcium in bones absorbs x-rays the most, so bones look white. The typical symptoms of KOA include pain, stiffness, decreased joint range of motion, and gait dysfunctions, which worsen in accordance with an increase in the disease progression. OA is mainly diagnosed through medical images. It can be predicted using x-ray or mri images. The primary goal of this project was to develop an automated classification model fr Knee Osteoarthritis, based on the Kellgren-Lawrence(KL) grading system, using radiographic imaging and obtain satisfactory results for further diagnosis.

Keywords: — Knee osteoarthritis, MRI, KOA, Progression.

---

1. Introduction

Knee Osteoarthritis (KOA) is one of the most common degenerative diseases affecting elderly people in the world, it can limit the mobility of a person affecting daily life activities and even causing early retirement predicts that this type of degenerative joint disease disorder will affect at least 130 million people across the world by 2050, of whom 40 million will be severely disabled by this condition [1]. Moreover, when the disease is at the last stage the only treatment is a total knee replacement. So, it is recommended to identify Knee Osteoarthritis at first stages to avoid knee this medical procedure. Osteoarthritis (OA) is the result–and the observable status–of inflammatory processes in a joint leading to functional and anatomical impairments. The resulting status often shows irreversible damage to the joint cartilage and the surrounding bone structures. The knees are the most commonly affected joints in the human body and knee.

Osteoarthritis (KOA) is more prevalent in females aged 60 years or more compared to males of the same age (13% vs 10%). Severity of KOA amongst females with more than 55 years of age is higher compared to their male counterparts and the severity of KOA is higher compared to other types of OA. Approximately one in every six patients consult with a general practitioner in their first year of an OA episode. The incidence of KOA has a positive association with age and weight and the prevalence is more common in younger age groups, particularly those who have obesity problems [2].

Swelling, joint pain, and stiffness are the prominent symptoms among others, such as restrictions in movement including walking, stair climbing, and bending. The symptoms worsen over time and elderly patients are affected more frequently than patients in other age groups. The presence of OA in the knee reduces activity in daily life and eventually leads to disability, which can incur high costs related to loss in productivity. It is estimated that functional impairment of the knee and the hip are the eleventh highest disability factors contributing to considerable socio-economic burden with an estimated cost per patient per year of approximately 19,000 Euro. The estimated prevalence of disability due to arthritis is expected to reach 11.6 million individuals by 10 the year 2020, which is greater than the estimated risk of disability attributable to cardiovascular diseases or any other medical condition [3].

In a review of possible risk factors of KOA, Heidari concluded that age, obesity, gender (i.e., female), repetitive knee trauma and kneeling are the most common risk factors for KOA. The common symptoms include pain, functional impairment, swelling and stiffness. The severity of KOA and the pain status is measured based on the Kellgren and Lawrence (KL) scale of 0 to 4 by visual inspection of the knee X-ray images [4].

Considering the impact of KOA on disability and the subsequent unavoidable economic burden, there is a need to quantify the severity of KOA during the early stages of development. KOA severity level helps in determining appropriate treatment decisions and for the monitoring of disease progression. The classical way of quantifying KOA severity is by inspection of X-ray images of the knee by a radiologist who then grades the images according to the KL scale (from 0 for "healthy" up to 4 for "severe" stage) [5]. This approach suffers from high levels of subjectivity as there is no gold standard grading system: the semi-quantitative nature of the KL grading scale creates ambiguity, thus giving rise to disagreements between raters. Recently, several researchers have used these resources to develop an automatic approach for quantifying KOA severity by analyzing X-ray images. Although there have been multiple attempts to quantify KOA severity based on an automated analysis of X-ray images, so far there has been no attempt to build a predictive model [6].

1.1 Existing Systems

The project began with the analysis of models and procedures that already exist to perform this activity. There were many ways to predict the disease using x-rays, MRI's that mainly used machine learning techniques and body mass index. However, precise and reproducible quantitative measurements from MRI scans are burdensome because of the knee's anatomy and morphology, as well as the complexity of MR imaging. It can take a reader up to six hours to manually segment through 3-dimensional (3D) knee MRI sequence. The exisiting method lacks sufficient accuracy and reliability to detect small cartilage changes due to the structure and morphology of the knee. Operators who use cartilage segmentation software often need extensive training which further contributes to the time and cost.

1.2 Proposed Systems

The proposed uses x-ray images to predict the knee osteoarthritis, besides it also provides the severity of the disease. Here KL Grading system is used to classify the image based on their features. The model is trained by providing images of five different stages. The model is trained in such a way that based the patterns and features in x-ray images it will predict the disease. Previously we don't used technique to know the severity instead we only have techniques to predict whether the disease is there or not.

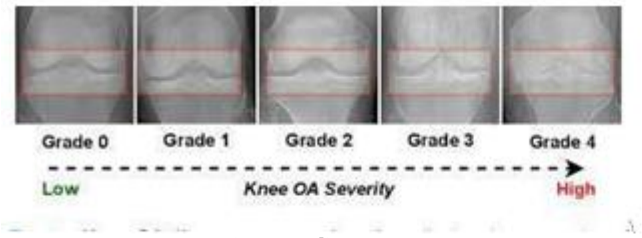

Fig. 1 Grading System

2. Literature Survey

A research paper on "A Novel Hybrid Approach Based on Deep CNN Features to Detect Knee Osteoarthritis" Deep Learning performs nonlinear transformation hierarchy-wise. Convolutional Neural Network (CNN) has deep architecture in a feed-forward manner on which learning can be applied. Each layer in CNN can see the features and show high variance .During the testing phase of the deep convolutional network, it runs in the forward direction, and all layers are distinguished. The main characteristic of deep CNN is to perform each possible match among images. There are convolutional layers that linearize manifolds while pooling layers collapse them. At the output, layer size depends upon the stride. The filter is for sharpening the image [7].

A recent American Orthopaedic Society for Sports Medicine/National Institutes of Health U-13 multidisciplinary conference focused on post-joint injury OA described advantages for studying meniscus-injured and anterior cruciate ligament (ACL)-injured cohorts. These cohorts represent populations that do not meet the classic radiographic or clinical criteria for OA [8] . Rather, subjects have joint pathologies placing them at risk for accelerated OA development. These populations offer opportunities to define and treat pre-OA conditions. The acute ACL and meniscal injury populations are well suited for bench-to-bedside translational studies of new treatment strategies because they are more similar to popular animal models of pre-clinical OA such as ACL transection and meniscus injury than the more heterogeneous older human cohorts with established multi-site OA traditionally used to evaluate potential disease-modifying treatments [9] .

The diagnostic criteria of knee OA consist of a combination of pain, clinical and radiological findings. While pain is a key symptom, it is highly elusive and difficult to reliably quantify [10] .Radiographs in turn, correlate with number of symptoms but there is a considerable discordance between radiographic findings and clinical presentation that is not fully understood . Using MRI has been showing some promises, but most orthopedic surgeons still rely on standard weight bearing radiographs. The Kellgren & Lawrence (KL) OA classification is a widely used grading system. By measuring joint space 13 narrowing, osteophytic formations, subchondral sclerosis and then grading the severity from 0 to 4, radiologists would be able to assess the severity of the disease which could hint the surgeon as to further management. Improving the reliability and reproducibility of these interpretations could thus be hugely beneficial [11].

According to a recent study, 80% of people over the age of 65 have radiographic KOA inthe USA . It is expected that the ratio will increase in the future. Another study has stated that KOA affects more than 21 million people in the USA . In Indonesia, 65% of total arthritis cases are knee osteoarthritis . In Asia, it is also increasing day by day. According to a recent study conducted in Pakistan, 28% of the urban and 25% of the rural population is affected by knee osteoarthritis . Clinically, along with medication, KOA is cured by exercise, weight loss, walking aids, heat and ice treatment, and physiotherapy as non-invasive methods and acupuncture, intra-articular injection, and surgical procedures as invasive methods of treatment [12].

In a research done on Knee osteoarthritis is a big data problem in terms of data complexity, heterogeneity and size as it has been commonly considered in the literature. Machine Learning has attracted significant interest from the scientific community to cope with the aforementioned challenges and thus lead to new automated pre- or post-treatment solutions that utilize data from the greatest possible variety of sources. Knee Osteoarthritis (KOA) is a degenerative disease of the knee joint and the most common form of arthritis causing pain, mobility limitation, affecting independence and quality of life in millions of people [13] .

There is no known cure for KOA, but there are several medical, biological and environmental risk factors, both modifiable and non-modifiable, that are known to be involved in the development and progression of the disease [14]. The aforementioned data characterizing KOA are high-dimensional, heterogeneous and the limited number of simple logistic regression models are not capable of handling large numbers of risk factors and most importantly, any interactions between environmental and other medical and biological factors. Furthermore, they cannot identify the tendency of a healthy subject to show signs of the disease and its progression based on patient outcomes. Despite that, the power and importance of correct study design should not be 14 underestimated. In the well-designed study even "simple" analysis can give trustful results. These significant short- falls in OA risk prediction models require a completely different model-ling and computational approach to the problem [15].

In a research about Segmentation of the Cartilage in the Rib Cage in 3D MRI, Yolanda H. Noorda stated that Cartilage segmentation of the rib cage in MRI is a relatively unexplored topic, since it has never served a purpose. Nowadays, new techniques for treatment of tumors in abdominal organs are in development, that require automatic monitoring of the treatment. MR-guided HIFU (High Intensity Focused Ultrasound) is an example of such a technique. An ultrasound transducer is used to create a heating focus at a tumor, such that the tumor tissue coagulates. The temperature is monitored by MR-thermometry. To use this technique for ablation of tumors in the liver, the ultrasound beam needs to propagate through the intercostal space, to prevent painful heating of the ribs. Therefore, the location of the ribs should be known during treatment. Since the liver is partially covered by the cartilage of the rib cage, automatic cartilage segmentation in MR images is required. The rib cage consists of bone and cartilage. The first seven ribs are attached to the sternum by the costal cartilage. The 8th, 9th, and 10th ribs join with the costal cartilage of the 7th rib. The floating ribs are not attached to the costal cartilage [16].

3. System analysis

3.1 Proposed Methodology

We adopt the (new preactivated) residual network (ResNet) as our image model. The identity mapping in ResNet significantly improves the network generalization ability. There are many architecture variants of ResNet. We adopt the wide ResNet (WRN) which has shown better performance and higher efficiency with much less layers. It also offers scalability of the network (number of parameters) by adjusting a widen factor (i.e., the channel of feature maps) and depth. Transferring learning is widely used

in medical image classification. Beside WRN, we also use and compare a ResNet18 which is pretrained on the ImageNet dataset. We extract the output of the layer before average pooling as our image representation, denoted as V with dimension C*G. The input image size is 224 × 224, so G = 14*14 depends on the widening factor.

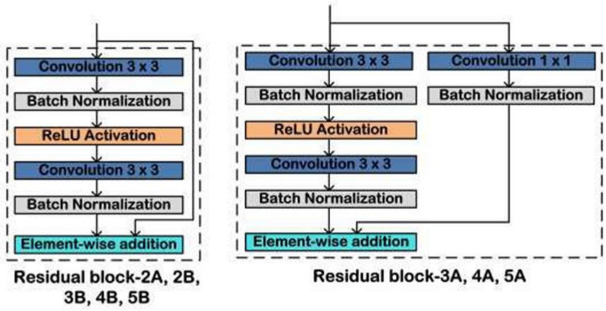

Fig. 2 Typical residual block used in ResNet18 CNN model.

4. System Design

In this process we define the system architecture, modules used, interfaces used, and data for a system to satisfy specified requirements. Systems design could be seen as the application of systems theory to the development of the product. The design phase helps to produce the overall design of the software. The goal of this phase is to figure out the different modules that can be used for the given system to achieve its goal with the greatest possible accuracy and efficiency. The system design contains details about each of the modules being used along with the way they interact with the other modules and help produce the output. The output of the design process is a description of the software architecture.

4.1 System Architecture Design

The architecture of a large-scale service will have a high level of complexity. It can have several micro services deployed running in conjunction with each other in a distributed environment. The comprehensive architecture of a service that involves several different components is called the system architecture The system architecture design shows us the relationship between the different components being used. They are usually created for gaining a deep understanding of how the different components work with each other to achieve the goals that were set to be achieved by the project.

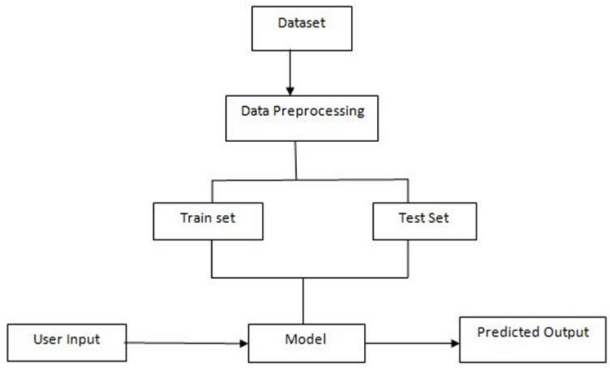

Fig. 3 System Architecture Design

4.2 Data Flow Diagram

A data-flow diagram is a way of representing the flow of data of a process or a system (usually an information system). The data flow diagram also helps us to monitor what data we are feeding to a given component of the program and what output data it generates after processing. A data-flow diagram doesn't have any control flow as there are no decision statements or loops. The data flow diagram is just a graphical representation of the flow of data through the information system. The Data Flow Diagram is very useful in understanding a system and can be efficiently used during analysis. The data flow diagram helps us to represent the functions and processes that capture, manipulate, and store the data in a graphical format. It also shows how the data flows between the various modules of the system. This visual representation is easy to understand and makes it easy for the user and system designer to communicate with each other using the design process. It also helps us to 20 find any lapses in security where the data flow is compromised.

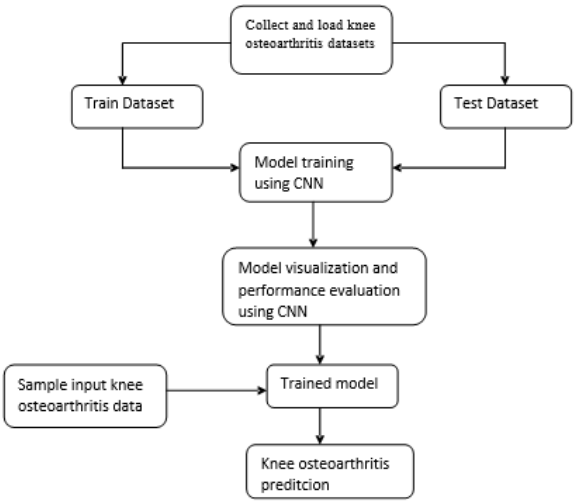

Fig. 4 Data Flow Diagram

4.3 Flow Chart

A flowchart is a diagrammatic representation of an algorithm, workflow, or process. Their flowchart has certain shape conventions to represent certain operations that are followed during the drawing process. This diagrammatic representation gives us the solution for the given problem. Flowcharts are used in analyzing, designing, documenting, or managing a process or program in various fields.
A flowchart is a graphical representation of steps followed in completing a given task. It originated from computer science as a tool for representing algorithms and programming logic but had extended to use in all other kinds of processes. Nowadays flowcharts play a major role during the design and assessment process. They help the designers to visualize the complex steps of an algorithm into a simple diagram of the flow chart. The flow chart can be used to illustrate the implementation of the project pictorially.

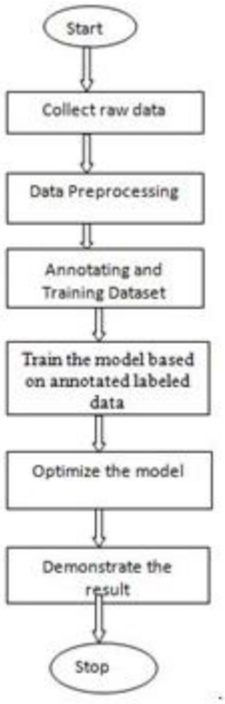

Fig. 5 Flow Chart

5. Implementation

1. Acquiring the dataset
2. Preprocessing
3. Feature extraction
4. Model building
5. Detection

5.1 Acquiring the dataset

The dataset which is collected from Kaggle is taken into consideration. The dataset contains knee X-ray data for both knee joint detection and knee KL grading. The Grade descriptions are
Grade 0: (Healthy): Healthy knee image.
Grade 1 (Doubtful): Doubtful joint narrowing with possible osteophytic lipping
Grade 2 (Minimal): Definite presence of osteophytes and possible joint space narrowing

Grade 3 (Moderate): Multiple osteophytes, definite joint space narrowing, with mild
sclerosis.
Grade 4 (Severe): Large osteophytes, significant joint narrowing, and severe sclerosis.

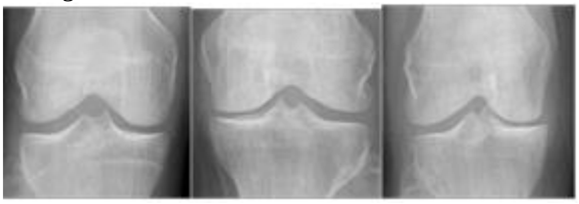

Fig. 6 Healthy Knee, Doubtful and Minimal

Fig. 7 Moderate and Serve

5.2 Preprocessing

After collecting the dataset, we remove the noise from dataset and divided the dataset into training and testing dataset and then performed actions accordingly. The process starts with importing necessary packages such as numpy, pytorch, flask, matplotlib, pillow, torchvision, numpy which the construction of the argument to parse the arguments takes place.

5.3 Feature Extraction

A common technique shared by all three approaches is bounding box regression, which handles the object's location and size separately. The bounding box is a rectangle that tightly covers one object. Each object's location and size are determined by the center coordinates of its bounding box. For our task, each knee joint's visual structure is clear, but its position and size are difficult to detect. Bounding box regression boosts segmentation performance and minimizes the human effort in designing a sophisticated extraction system.

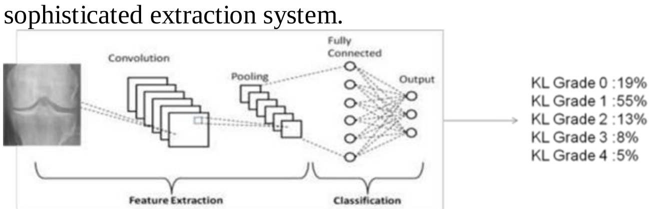

Fig. 8 Feature Extraction

5.4 Model Building

The model is trained with Residual Neural Network at first but the accuracy is not as expected we again trained the model using Efficient Net deep learning architecture, the improved the efficiency of the model.

5.5 Detection

The model is trained in such a way to classify the given input image into desired category. Here, the x-ray image is taken as input, the model analyses the input by extracting the features. The model classifies the given image accordingly and predict the grade of disease.

Fig. 9 Grading System

6. Testing

Software testing is an examination directed to furnish partners with data about the nature of the product item or administration under test. Programming testing can likewise give a target, free perspective on the product to permit the business to acknowledge and comprehend the dangers of programming usage. Test procedures incorporate the way toward executing a program or application with the purpose of discovering programming bugs (mistakes or different deformities) and checking that the product item is fit for use. As the quantity of potential tests for even straightforward programming segments is for all intents and purposes interminable, all product testing utilizes some methodology to choose tests that are doable for the accessible time and assets.

6.1 Sample dataset of Doubtful

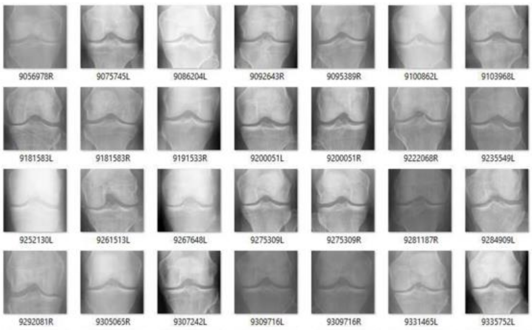

Fig. 10 x-rays of doubtful

6.2 Sample dataset of Helathy

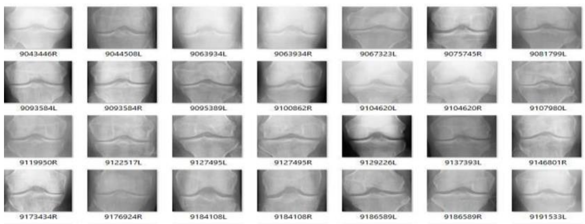

Fig. 11 X-rays of Healthy

6.3 Sample dataset of Minimal

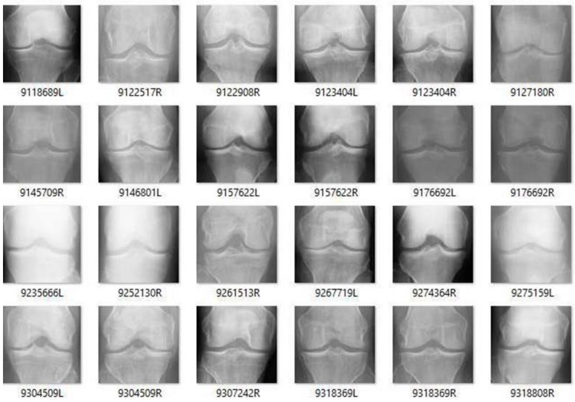

Fig. 12 X-rays of minimal

6.4 Sample dataset of Moderate

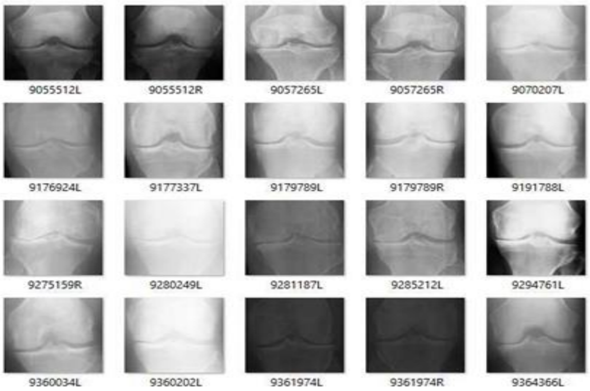

Fig. 13 X-rays of Moderate

6.5 Sample dataset of Serve

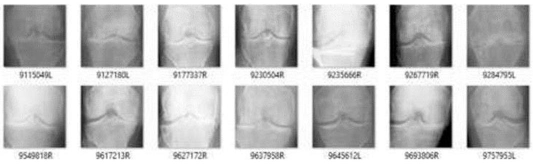

Fig. 14 X-rays of Serve

7. Results

After the code is run and model is trained, we give the image as input which the model needs to analyze and classify. The model analyses and predicts the severity of the knee.

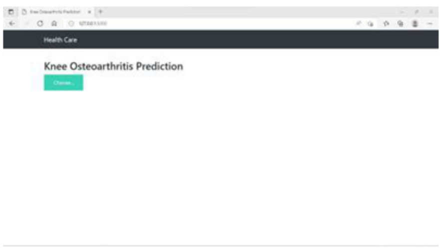

Fig. 15 Output Screen 1

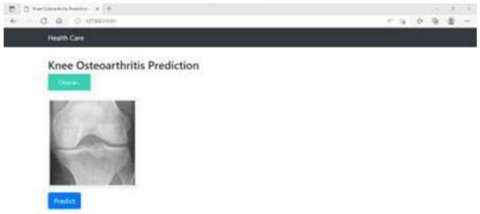

Fig. 16 Output Screen 2

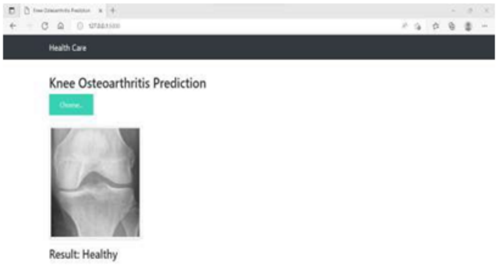

Fig. 17 Output Screen 3

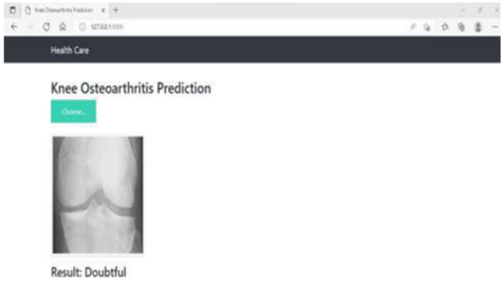

Fig. 18 Output Screen 4

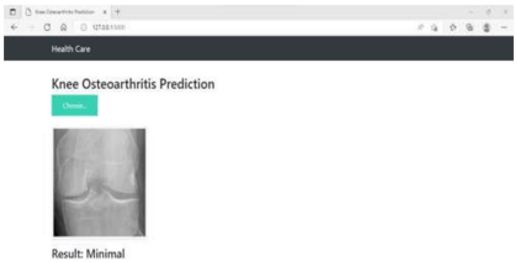

Fig. 19 Output Screen 5

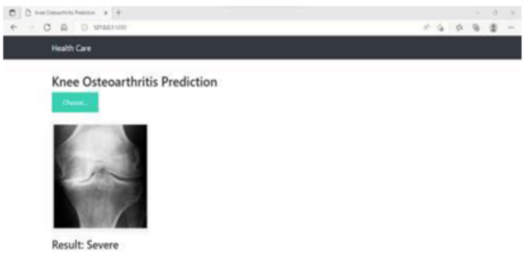

Fig. 20 Output Screen 6

 https://doi.org/10.22362/ijcert/2021/v8/i12/v8i1204

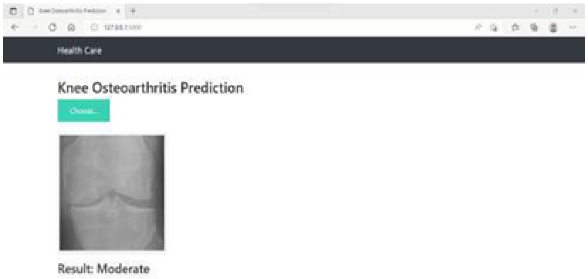

Fig. 21 Output Screen 7

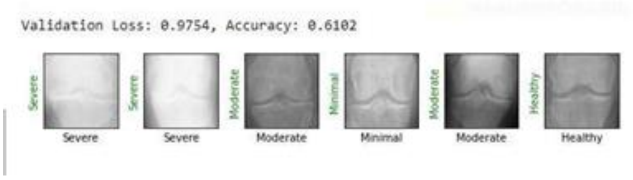

Fig. 22 Accuracy

Fig. 23 Final Results

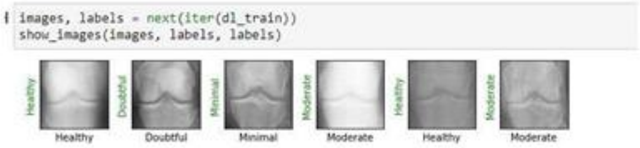

Fig. 24 Training Set

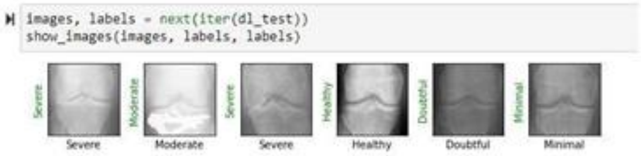

Fig. 25 Testing Set

8. Conclusion and future scope

This system is capable of providing most of the essential features required topredict the knee Osteoarthritis. The proposed approach achieves accuracy i.e., which is much higher than the existing methods, and can predict knee osteoarthritis progression approach using CNN algorithm. Knowing the stage of disease makes the treatment easy and efficient. If the severity is not known and the same kind of treatment given for all stages of patients don't give good result. At present clinicians should manage patients with osteoarthritis with a combination of methods.

CNN in medical imaging research has advanced significantly in recent years and has shown great potential in OA diagnosis. With the expanding availability of advanced computational power and data availability, 3D deep learning may greatly enhance the early diagnosis of knee osteoarthritis. This is significant in osteoarthritis diagnosis since a three-dimensional image allows the assessment of the knee joint from different planes and offers precise information of the disease's modest progression. However, to develop a robust and generalized 3D CNN in diagnostic application is still a challenging task and remains an open research area, not only considering the accuracy of the model but also the computational efficiency. Even though the application of 3D CNN is still in a preliminary phase, we envisioned that the development of 3D CNN methods based on MR images will offer better understanding on the progression of the OA disease, especially on early detection of OA in the knee joint. The future of clinical practice may utilize 3D automated clinical applications to embrace new possibilities, not only to detect biomarkers but also to show excellent performance on par with clinical experts in early detection of OA.

References

[1] Y. Zhang and J. M. Jordan, "Epidemiology of osteoarthritis", Clinics Geriatric Med., vol. 26, no. 3, pp. 355, 2010.

[2] K. D. Brandt, M. Doherty and L. S. Lohmander, Osteoarthritis, Oxford, U.K.:Oxford Univ. Press, pp. 598, 2003.

[3] The burden of musculoskeletal diseases in the United States, Rosemont, IL, USA, 2008.

[4] C. R. Chu, A. A. Williams, C. H. Coyle and M. E. Bowers, "Early diagnosis to enable early treatment of pre-osteoarthritis", Arthritis Res. Therapy, vol. 14, no. 3, pp. 212, 2012.

[5] D. Bhatia, T. Bejarano and M. Novo, "Current interventions in the management of knee osteoarthritis", J. Pharmacy Bioallied Sci., vol. 5, no. 1, pp. 30-38, 2013.

[6] H. Shim, S. Chang, C. Tao, J. H. Wang, C. K. Kwoh and K. T. Bae, "Knee cartilage: Efficient and reproducible segmentation on high-spatial-resolution MR images with the semiautomated graph-cut algorithm method", Radiology, vol. 251, no. 2, pp. 548-565, 2009.

[7] J. L. Jaremko, R. W. T. Cheng, R. G. W. Lambert, A. F. Habib and J. L. Ronsky,"Reliability of an efficient MRI-based method for estimation of knee cartilage volume using surface registration", Osteoarthritis Cartilage, vol. 14, no. 9, pp. 914-922, 2006.

[8] Y. Yin, X. Zhang, R. Williams, X. Wu, D. Anderson and M. Sonka, "LOGISMOS—Layered optimal graph image segmentation of multiple objects and surfaces: Cartilage segmentation in the knee Joint", IEEE Trans. Med. Imag., vol. 29, no. 12, pp. 2023-2037, Dec. 2010.

[9] Abedin, J. et al. (2019) "Predicting knee osteoarthritis severity: comparative modeling based on patient's data and plain X-ray images," Scientific reports, 9(1), p. 5761.

[10] Alexos, A. et al. (2020) "Prediction of pain in knee osteoarthritis patients using machine learning: Data from Osteoarthritis Initiative," in 2020 11th International Conference on Information, Intelligence, Systems and Applications (IISA. IEEE, pp. 1–7).

[11] Bandyopadhyay, S. and Sharma, P. (2016) "Detection of Osteoarthritis using Knee X-Ray Image Analyses: A Machine Vision based Approach." Available at: https://www.semanticscholar.org/paper/b5c55c6c40c389cb203bb654c78b2a3a306ffe4e (Accessed: August 4, 2021).

[12] Bany Muhammad, M. et al. (2019) "Deep ensemble network for quantification and severity assessment of knee osteoarthritis," in 2019 18th IEEE International Conference On Machine Learning And Applications (ICMLA). IEEE, pp. 951–957.

[13] Chen, P. et al. (2019) "Fully automatic knee osteoarthritis severity grading using deep neural networks with a novel ordinal loss," Computerized medical imaging and graphics: the official journal of the Computerized Medical Imaging Society, 75, pp. 84–92.

[14] Chen, T. and Guestrin, C. (2016) "XGBoost: A Scalable Tree Boosting System," arXiv [cs.LG]. Available at: http://arxiv.org/abs/1603.02754 (Accessed: August 10, 2021).

[15] IEEE. Kwon, S. B. et al. (2020) "Machine learning-based automatic classification of knee osteoarthritis severity using gait data and

radiographic images", IEEE access: practical innovations, open solutions, 8, pp. 120597–120603.

[16] " Knee Osteoarthritis pain prediction from X-ray imaging: Data from Osteoarthritis Initiative" Jorge I. Galván-Tejada, Víctor Treviño, José M. Celaya-Padilla, José G. Tamez-Peña.