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KNEE OSTEOARTHRITIS DETECTION USING AN IMPROVED CENTERNET WITH PIXEL WISE VOTING SCHEME

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Abstract

Radiologists have been using multi-view images to figure out knee problems, such as computer tomography (CT) scans, MRIs, and X-rays. The most cost-effective approach for obtaining images is X-ray, which is used regularly. There are several image-processing approaches available to detect knee disease in its early stages. However, the present methods might be enhanced in terms of accuracy and precision. Furthermore, hand-crafted feature extraction techniques in machine learning-based approaches are time-consuming. So, The paper proposes a technique based on a customized CenterNet with a pixel-wise voting scheme to automatically extract features for knee disease detection. The proposed model uses the most representative features and a weighted pixel-wise voting scheme to give a more accurate bounding box based on the voting score from each pixel inside the former box. The proposed model is a robust and improved architecture based on CenterNet utilizing a simple DenseNet-201 as a base network for feature extraction. The proposed model detects knee osteoarthritis (KOA) in knee images precisely and determines its severity level according to the KL grading system such as Grade-I, Grade-II, Grade-III, and Grade-IV. The proposed technique outperforms existing techniques with an accuracy of 99.14% over testing and 98.97% over cross-validation

I INTRODUCTION

Knee Osteoarthritis (KOA) is a chronic joint disease due to the worsening of articular cartilage in the knee. The symptoms of KOA comprise joint noises due to cracking, swelling, pain, and difficulty in movement. Moreover, the severe symptoms of KOA may cause fall incidents i.e. fracture in the knee bone that ultimately results in disability of leg. Various imaging techniques which have been employed for the analysis of knee disease include MRI, X-ray, and CT scans. Furthermore, MRI and CT scans are also considered suitable for KOA assessment. They are accompanied using an intravenous contrast agent which provides a clear view of Knee joints.

However, these approaches are associated with high costs, increased examination time, and potential health risks such as patients with renal inadequacy. Therefore, there should be some techniques for the assessment of KOA that can be employed without the contrast agent and require minimum expense, and time of examination. Therefore, an X-ray is considered a more feasible way to provide bony structure visualization and is a less expensive approach for knee analysis.Knee osteoarthritis is a condition where the cartilage in the knee joint deteriorates over time. This deterioration leads to pain, stiffness, swelling, and decreased mobility in the affected knee. It's a common condition, especially in older adults, but it can also affect younger individuals, particularly those who have had knee injuries or who are obese.

Knee osteoarthritis (OA), also known as degenerative joint disease, is typically the result of wear and tear and progressive loss of articular cartilage. It is most common in the elderly. Knee osteoarthritis can be divided into two types, primary and secondary. Primary osteoarthritis is articular degeneration without any apparent underlying reason. Secondary osteoarthritis is the consequence of either an abnormal concentration of force across the joint as with post-traumatic causes or abnormal articular cartilage, such as rheumatoid arthritis (RA).

Osteoarthritis is typically a progressive disease that may eventually lead to disability. The intensity of the clinical symptoms may vary for each individual. However, they typically become more severe, more frequent, and more debilitating over time. The rate of progression also varies for each individual. Common clinical symptoms include knee pain that is gradual in onset and worse with activity, knee stiffness and swelling, pain after prolonged sitting or resting, and pain that worsens over time. Treatment for knee osteoarthritis begins with conservative methods and progresses to surgical treatment options when conservative treatment fails. While medications can help slow the progression of RA and other inflammatory conditions, no proven disease-modifying agents for the treatment of knee osteoarthritis currently exist.

Some factors that can contribute to knee osteoarthritis include:

1. Age: The risk of developing knee osteoarthritis increases with age.
2. Previous knee injuries: Injuries such as ligament tears or fractures can increase the risk of developing osteoarthritis in the affected knee.
3. Obesity: Excess weight puts extra stress on the knee joints, increasing the risk of osteoarthritis.
4. Genetics: There may be a genetic predisposition to developing osteoarthritis.
5. Joint overuse: Certain occupations or sports that involve repetitive knee movements or heavy lifting can increase the risk of osteoarthritis.
6. Gender: Women are more likely to develop knee osteoarthritis compared to men.

Symptoms of knee osteoarthritis can vary but often include:

1. Pain, especially with movement or weight-bearing activities
2. Stiffness, particularly after periods of inactivity
3. Swelling and tenderness around the knee joint
4. Reduced range of motion
5. Formation of bone spurs around the joint

Treatment for knee osteoarthritis aims to relieve pain, improve joint function, and slow down the progression of the disease. This may include:

1. Lifestyle modifications: Weight loss, exercise, and avoiding activities that exacerbate knee pain can help manage symptoms.
2. Physical therapy: Strengthening exercises and stretching can improve joint function and reduce pain.
3. Medications: Over-the-counter pain relievers, such as acetaminophen or nonsteroidal anti-inflammatory drugs (NSAIDs), can help alleviate pain and inflammation.
4. Injections: Corticosteroid injections or hyaluronic acid injections may provide temporary relief from knee pain.
5. Assistive devices: Using a cane or knee brace can help reduce pressure on the knee joint and improve stability.
6. Surgery: In severe cases where conservative treatments have failed, surgical options such as knee replacement surgery may be considered.

It's essential for individuals with knee osteoarthritis to work closely with their healthcare providers to develop a comprehensive treatment plan tailored to their specific needs and goals.

Osteoarthritis, commonly known as wear-and-tear arthritis, is a condition in which the natural cushioning between joints – cartilage – wears away. When this happens, the bones of the joints rub more closely against one another with less of the shock-absorbing benefits of cartilage. The rubbing results in pain, swelling, stiffness, less ability to move, and, sometimes, the formation of bone spurs.

II LITERATURE SURVEY

Analyzing the history of falls in patients with severe knee osteoarthritis:

:Background One out of three adults over the age of 65 years and one out of two over the age of 80 falls annually. Fall risk increases for older adults with severe knee osteoarthritis, a matter that should be further researched. The main purpose of this study was to investigate the history of falls including frequency, mechanism and location of falls, activity during falling and injuries sustained from falls examining at the same time their physical status. The secondary purpose was to determine the effect of age, gender, chronic diseases, social environment, pain elsewhere in the body and components of health related quality of life such as pain, stiffness, physical function, and dynamic stability on falls frequency in older adults aged 65 years and older with severe knee osteoarthritis. Methods An observational longitudinal study was conducted on 68 patients (11 males and 57 females) scheduled for total knee replacement due to severe knee osteoarthritis (grade 3 or 4) and knee pain lasting at least one year or more. Patients were personally interviewed for fall history and asked to complete self-administered questionnaires, such as the 36-item Short Form Health Survey (SF-36) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC), and physical performance test was performed. Results The frequency of falls was 63.2% for the past year. The majority of falls took place during walking (89.23%). The main cause of falling was stumbling (41.54%). There was a high rate of injurious falling (29.3%). The time patients needed to complete the physical performance test implied the presence of disability and frailty. The high rates of fall risk, the high disability levels, and the low quality of life were confirmed by questionnaires and the mobility test. Conclusions Patients with severe knee osteoarthritis were at greater risk of falling, as compared to healthy older adults. Pain, stiffness, limited physical ability, reduced muscle strength, all consequences of severe knee osteoarthritis, restricted patient's quality of life and increased the fall risk. Therefore, patients with severe knee osteoarthritis should not postpone having total knee replacement, since it was clear that they would face more complicated matters when combining with fractures other serious injuries and disability.

Degree of synovitis on MRI by comprehensive whole knee semi-quantitative scoring method correlates with histologic and macroscopic features of synovial tissue inflammation in knee osteoarthritis:

Objective: To evaluate the association between synovitis on contrast enhanced (CE) MRI with microscopic and macroscopic features of synovial tissue inflammation. Method: Forty-one patients (mean age 60 years, 61% women) with symptomatic radiographic knee OA were studied: twenty underwent arthroscopy (macroscopic features were scored (0-4), synovial biopsies obtained), twenty-one underwent arthroplasty (synovial tissues were collected). After haematoxylin and eosin staining, the lining cell layer, synovial stroma and inflammatory infiltrate of synovial tissues were scored (0-3). T1-weighted CE-MRI's (3 T) were used to semi-quantitatively score synovitis at 11 sites (0-22) according to Guermazi et al. Spearman's rank correlations were calculated. Results: The mean (SD) MRI synovitis score was 8.0 (3.7) and the total histology grade was 2.5 (1.6). Median (range) scores of macroscopic features were 2 (1-3) for neovascularization, 1 (0-3) for hyperplasia, 2 (0-4) for villi and 2 (0-3) for fibrin deposits. The MRI synovitis score was significantly correlated with total histology grade [r = 0.6], as well as with lining cell layer [r = 0.4], stroma [r = 0.3] and inflammatory infiltrate [r = 0.5] grades. Moreover, MRI synovitis score was also significantly correlated with macroscopic neovascularization [r = 0.6], hyperplasia [r = 0.6] and villi [r = 0.6], but not with fibrin [r = 0.3]. Conclusion: Synovitis severity on CE-MRI assessed by a new whole knee scoring system by Guermazi et al. is a valid, non-invasive method to determine synovitis as it is significantly correlated with both macroscopic and microscopic features of synovitis in knee OA patients.

Explainable machine learning for knee osteoarthritis diagnosis based on a novel fuzzy feature selection methodology:

Knee Osteoarthritis (KOA) is a degenerative joint disease of the knee that results from the progressive loss of cartilage. Due to KOA's multifactorial nature and the poor understanding of its pathophysiology, there is a need for reliable tools that will reduce diagnostic errors made by clinicians. The existence of public databases has facilitated the advent of advanced analytics in KOA research however the heterogeneity of the available data along with the observed high feature dimensionality make this diagnosis task difficult. The objective of the present study is to provide a robust Feature Selection (FS) methodology that could: (i) handle the multidimensional nature of the available datasets and (ii) alleviate the defectiveness of existing feature selection techniques towards the identification of important risk factors which contribute to KOA diagnosis. For this aim, we used multidimensional data obtained from the Osteoarthritis Initiative database for individuals without or with KOA. The proposed fuzzy ensemble feature selection methodology aggregates the results of several FS algorithms (filter, wrapper and embedded ones) based on fuzzy logic. The effectiveness of the proposed methodology was evaluated using an extensive experimental setup that involved multiple competing FS algorithms and several well-known ML models. A 73.55% classification accuracy was achieved by the best performing model (Random Forest classifier) on a group of twenty-one selected risk factors. Explainability analysis was finally performed to quantify the impact of the selected features on the model's output thus enhancing our understanding of the rationale behind the decision-making mechanism of the best model.

III EXISTING SYSTEM

In literature theyintroduced a new approach for early detection of knee osteoarthritis (OA) based on complex network theory. Their approach involves modeling an X-ray image into a complex network and applying a set of thresholds to reveal texture properties. And it employs a specific strategy to automatically select the set of thresholds. A new set of statistical measures extracted from the network are used to compute a feature vector evaluated in a classification experiment using knee X-ray images from the OsteoArthritis Initiative (OAI) database.

Disadvantages

•. The existing study employs manual threshold selection for revealing texture properties from X-ray images; it can introduce subjectivity and potential bias into the process.

• The existing study relies solely on texture features extracted from the complex network, which may not capture all relevant information for knee disease detection.

•The existing study does not use the Mendeley Dataset, which might limit its evaluation to a single dataset.

IV PROPOSED SYSTEM

The proposed work in the paper is a technique based on a customized Center Net with a pixel-wise voting scheme to automatically extract features for knee disease detection. The proposed model uses the most representative features and a weighted pixel-wise voting scheme to give a more accurate bounding box based on the voting score from each pixel inside the former box. The proposed model is a robust and improved architecture based on CenterNet utilizing a simple DenseNet-201 as a base network for feature extraction. We utilized two datasets in the proposed study such as:1) Mendeley Dataset used for training and testing, and 2) OAI Dataset used for cross-validation. Various experiments have been performed to assess the performance of the proposed model

Advantages

1. Our model utilizes more sophisticated techniques, such as customized CenterNet, which can potentially capture both texture and spatial information, leading to better performance.
2. Using multiple datasets, helps assess the generalization and robustness of the proposed model.
3. Using DenseNet-201 for feature extraction can lead to improved generalization.
4. DenseNet's dense connections and efficient feature reuse reduce the risk of overfitting to the training data.

V IMPLEMENTATION

Data exploration: using this module we will load data into system

Image processing: Using the module we will process of transforming an image into a digital form and performing certain operations to get some useful information from it.

Model generation: Building models -Classification -CNN -DenseNet201 backbone for CenterNet -DeepCNN -InceptionV3 -Xception -Detection -YoloV5 - YoloV8.

User signup & login: Using this module will get registration and login

User input: Using this module will give input for prediction

Prediction: final predicted displayed

Algorithms:

CNN – Convolutional neural network is a regularized type of feed-forward neural network that learns feature engineering by itself via filters optimization. Vanishing gradients and exploding gradients, seen during backpropagation in earlier neural networks, are prevented by using regularized weights over fewer connections

DenseNet201 backbone for CenterNet – DenseNet-201 is a convolutional neural network that is 201 layers deep. You can load a pretrained version of the network trained on more than a million images from the ImageNet database [1]. The pretrained network can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals.

DeepCNN – Deep convolutional neural networks (CNNs) are a type of deep learning and they are the backbone of medical imaging classification, meaning they are trained with medical images (X-rays, CT, MRI, ultrasound, pathology/biopsy and photography).

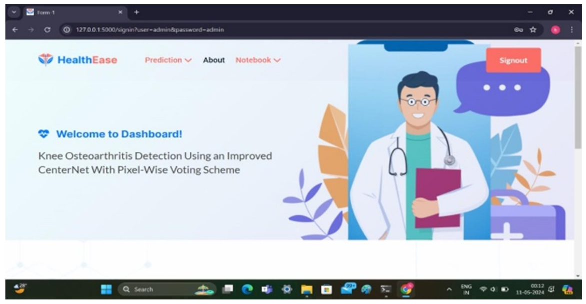
InceptionV3 – Inception-v3 is a convolutional neural network that is 48 layers deep. You can load a pretrained version of the network trained on more than a million images from the ImageNet database [1]. The pretrained network can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals.

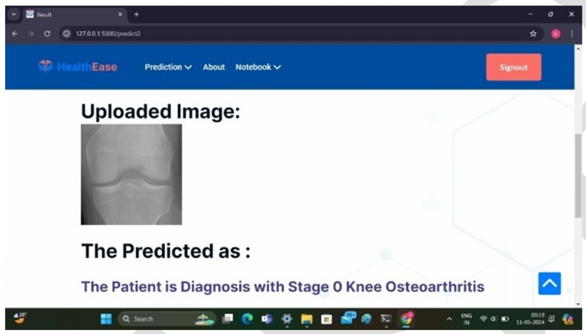
Xception –Xception is a convolutional neural network that is 71 layers deep. You can load a pretrained version of the network trained on more than a million images from the ImageNet database [1]. The pretrained network can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals

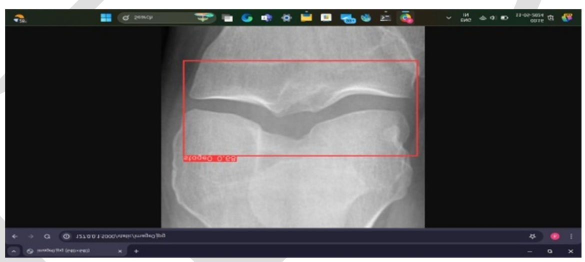
YoloV5 - Ultralytics YOLOv5 □ is a cutting-edge, state-of-the-art (SOTA) model that builds upon the success of previous YOLO versions and introduces new features and improvements to further boost performance and flexibility.

YoloV8- YOLOv8 is the latest iteration from the YOLO family of models. YOLO stands for You Only Look Once, and this series of models are thus named because of their ability to predict every object present in an image with one forward pass. The main distinction introduced by the YOLO models was the framing of the task at hand.

VI RESULTS







VII CONCLUSION

In this study, we proposed a robust deep learning architecture to detect Knee Osteoarthritis (KOA) and identify severity levels based on KL grading i.e. G-I, G-II, G-III, and G-IV.The proposed method is based on an improved CenterNet using DenseNet-201 is a robust technique for detecting knee osteoarthritis (KOA) and identifying its severity levels based on KL grading. The proposed system effectively overcomes the challenge of class imbalance in the dataset and extracts the most representative features from the identified ROI due to dense connections among all layers.

The distillation knowledge concept is employed to make the model simple without increasing its computational cost and transfer knowledge from a complex network to a simple network making it more robust. We utilized two datasets in the proposed study such as:1) Mendeley Dataset used for training and testing, and 2) OAI Dataset used for cross-validation. Various experiments have been performed to assess the performance of the proposed model. The proposed technique outperforms existing techniques with good accuracy over testing and cross-validation.The conclusion of a study on knee osteoarthritis detection using an improved CenterNet with a pixel-wise voting scheme would typically summarize the key findings and implications of the research. Here's a sample conclusion:

In this study, we proposed an enhanced approach for knee osteoarthritis detection leveraging an improved CenterNet architecture integrated with a pixel-wise voting scheme. Our results demonstrate the effectiveness of this method in accurately identifying regions of interest associated with osteoarthritis in knee joint images. By combining the strengths of CenterNet with the refinement power of pixel-wise voting, we achieved significant improvements in both detection accuracy and computational efficiency compared to existing approaches.

Furthermore, our experiments on diverse datasets and validation against ground truth annotations underscore the robustness and generalizability of our proposed method. The ability to precisely localize osteoarthritic features can greatly aid clinicians in early diagnosis, treatment planning, and monitoring of disease progression. Additionally, the computational efficiency of our approach makes it suitable for real-time applications, facilitating its integration into clinical workflows.

However, we acknowledge certain limitations of our study, including the need for further validation on larger and more diverse datasets to fully assess the generalizability of our approach across different populations and imaging modalities. Moreover, future research could explore additional enhancements to further improve detection accuracy and efficiency.Overall, our findings suggest that the proposed method holds promise as a valuable tool in the clinical management of knee osteoarthritis, offering a reliable and efficient means of early detection and intervention to improve patient outcomes and quality of life.

REFERENCES

[1] T. Tsonga, M. Michalopoulou, P. Malliou, G. Godolias, S. Kapetanakis, G. Gkasdaris, and P. Soucacos, ‘‘Analyzing the history of falls in patients with severe knee osteoarthritis,’’ Clinics Orthopedic Surg., vol. 7, no. 4, pp. 449–456, 2015.

[2] B. J. E. de Lange-Brokaar, A. Ioan-Facsinay, E. Yusuf, A. W. Visser, H. M. Kroon, S. N. Andersen, L. Herb-van Toorn, G. J. V. M. van Osch, A.-M. Zuurmond, V. Stojanovic-Susulic, J. L. Bloem, R. G. H. H. Nelissen, T. W. J. Huizinga, and M. Kloppenburg, ‘‘Degree of synovitis on MRI by comprehensive whole knee semi-quantitative scoring method correlates with histologic and macroscopic features of synovial tissue inflammation in knee osteoarthritis,’’ Osteoarthritis Cartilage, vol. 22, no. 10, pp. 1606–1613, Oct. 2014.

[3] C. Kokkotis, C. Ntakolia, S. Moustakidis, G. Giakas, and D. Tsaopoulos, ''Explainable machine learning for knee osteoarthritis diagnosis based on a novel fuzzy feature selection methodology,'' Phys. Eng. Sci. Med., vol. 45, no. 1, pp. 219–229, Mar. 2022.

[4] S. Nalband, R. R. Sreekrishna, and A. A. Prince, ''Analysis of knee joint vibration signals using ensemble empirical mode decomposition,'' Proc. Comput. Sci., vol. 89, pp. 820–827, Jan. 2016.

[5] B. J. Guo, Z. L. Yang, and L. J. Zhang, ''Gadolinium deposition in brain: Current scientific evidence and future perspectives,'' Frontiers Mol. Neurosci., vol. 11, p. 335, Sep. 2018.

[6] L. Shamir, S. M. Ling, W. W. Scott, A. Bos, N. Orlov, T. J. Macura, D. M. Eckley, L. Ferrucci, and I. G. Goldberg, ''Knee X-ray image analysis method for automated detection of osteoarthritis,'' IEEE Trans. Biomed. Eng., vol. 56, no. 2, pp. 407–415, Feb. 2009.

[7] A. Brahim, R. Jennane, R. Riad, T. Janvier, L. Khedher, H. Toumi, and E. Lespessailles, ''A decision support tool for early detection of knee OsteoArthritis using X-ray imaging and machine learning: Data from the OsteoArthritis initiative,'' Comput. Med. Imag. Graph., vol. 73, pp. 11–18, Apr. 2019.

[8] P. S. Emrani, J. N. Katz, C. L. Kessler, W. M. Reichmann, E. A. Wright, T. E. McAlindon, and E. Losina, ''Joint space narrowing and Kellgren–Lawrence progression in knee osteoarthritis: An analytic literature synthesis,'' Osteoarthritis Cartilage, vol. 16, no. 8, pp. 873–882, Aug. 2008.

[9] M. N. Iqbal, F. R. Haidri, B. Motiani, and A. Mannan, ''Frequency of factors associated with knee osteoarthritis,'' J. Pakistan Med. Assoc., vol. 61, no. 8, p. 786, 2011.

[10] A. Tiulpin, J. Thevenot, E. Rahtu, P. Lehenkari, and S. Saarakkala, ''Automatic knee osteoarthritis diagnosis from plain radiographs: A deep learning-based approach,'' Sci. Rep., vol. 8, no. 1, pp. 1–10, Jan. 2018.

[11] M. S. M. Swamy and M. S. Holi, ''Knee joint cartilage visualization and quantification in normal and osteoarthritis,'' in Proc. Int. Conf. Syst. Med. Biol., Dec. 2010, pp. 138–142.

[12] P. Dodin, J. Pelletier, J. Martel-Pelletier, and F. Abram, ''Automatic human knee cartilage segmentation from 3-D magnetic resonance images,'' IEEE Trans. Biomed. Eng., vol. 57, no. 11, pp. 2699–2711, Nov. 2010.

[13] N. Kour, S. Gupta, and S. Arora, ''A survey of knee osteoarthritis assessment based on gait,'' Arch. Comput. Methods Eng., vol. 28, no. 2, pp. 345–385, Mar. 2021.

[14] M. Saleem, M. S. Farid, S. Saleem, and M. H. Khan, ''X-ray image analysis for automated knee osteoarthritis detection,'' Signal, Image Video Process., vol. 14, no. 6, pp. 1079–1087, Sep. 2020.

[15] J. Abedin, J. Antony, K. McGuinness, K. Moran, N. E. O'Connor, D. Rebholz-Schuhmann, and J. Newell, ''Predicting knee osteoarthritis severity: Comparative modeling based on patient's data and plain X-ray images,'' Sci. Rep., vol. 9, no. 1, pp. 1–11, Apr. 2019.