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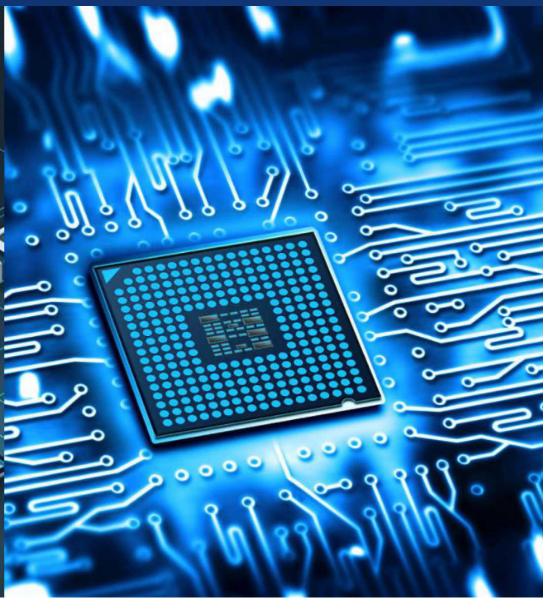


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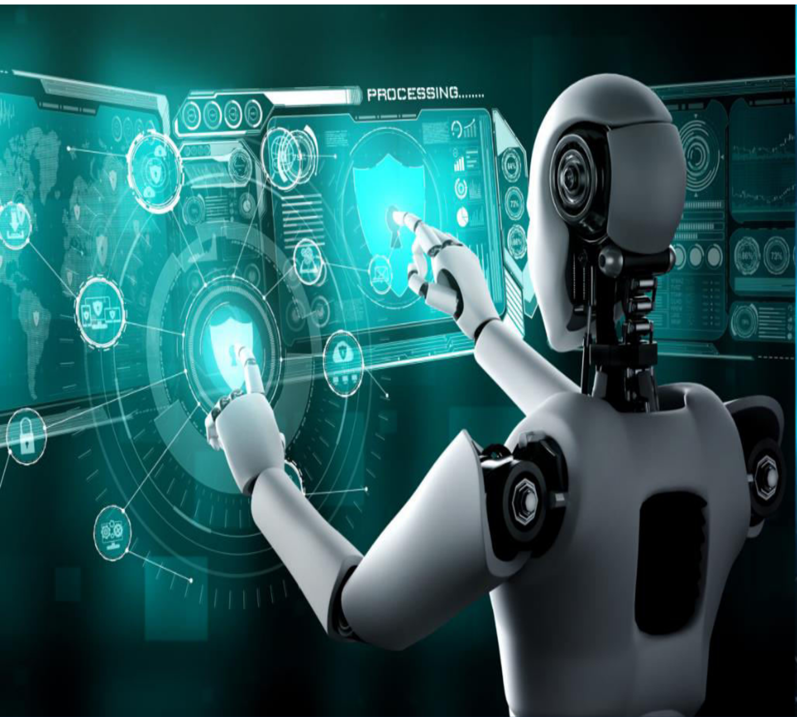

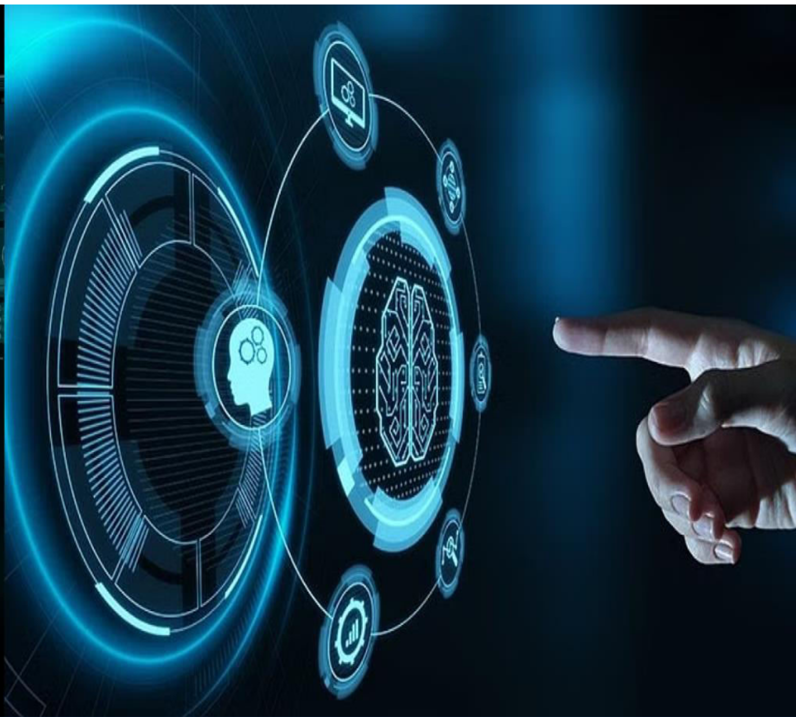

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Knee Osteoarthritis Detection and Severity Classification using Deep Learning

Harshitha S[1], Prajwal R[2], Prajwal C G[3], Rajath B G[4], Rajath H M[5]

Assistant Professor, Department of Computer Science and Engineering, Malnad College of Engineering, Hassan, Karnataka, India[1]

Department of Computer Science and Engineering, Malnad College of Engineering, Hassan, Karnataka, India[2]

Department of Computer Science and Engineering, Malnad College of Engineering, Hassan, Karnataka, India[3]

Department of Computer Science and Engineering, Malnad College of Engineering, Hassan, Karnataka, India[4]

Department of Computer Science and Engineering, Malnad College of Engineering, Hassan, Karnataka, India[5]

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 for Knee Osteoarthritis, based on the Kellgren-Lawrence(KL) grading system, using radiographic imaging and obtain satisfactory results for further diagnosis.

KEYWORDS: Knee Osteoarthritis, Deep Learning, Inception, Xception, ResNet, Severity Classification, Medical Imaging, Web Application, Healthcare AI

I. INTRODUCTION

Knee Osteoarthritis (KOA) is a prevalent degenerative disease that significantly impacts the elderly population worldwide. It often restricts mobility, interfering with daily activities and, in severe cases, can even lead to early retirement. Projections indicate that by 2050, approximately 130 million people globally will suffer from this condition, with 40 million experiencing severe disabilities. At its advanced stages, the only viable treatment option for KOA is total knee replacement. Therefore, early identification and management of KOA are essential to avoid invasive medical interventions. Osteoarthritis (OA) is characterized by inflammatory processes within the joints, resulting in both functional and structural impairments. Over time, these processes can cause irreversible damage to joint cartilage and surrounding bone structures. The knees are the most commonly affected joints in the body. KOA is particularly prevalent among women aged 60 and above, with rates at 13% compared to 10% in men of the same age group. Additionally, women over 55 years tend to experience more severe KOA compared to men. KOA is also the most severe among different types of OA. Risk factors for KOA include age, obesity, female gender, repetitive knee trauma, and activities such as prolonged kneeling. Symptoms often include joint pain, swelling, stiffness, and restrictions in movement, such as difficulty walking, climbing stairs, or bending. These symptoms tend to worsen with time, disproportionately affecting older adults and individuals with obesity. As the disease progresses, it can lead to significant disability, reducing the ability to perform daily tasks and contributing to a substantial socio-economic

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burden. Globally, the functional impairment caused by OA in the knee and hip ranks as the eleventh highest disability factor. It is estimated that KOA-related disability incurs an annual cost of approximately $9000 per patient, with productivity losses being a significant contributor. By 2026, an estimated 15.6 million individuals were expected to experience disability due to arthritis, surpassing the disability risks associated with cardiovascular diseases and other medical conditions.

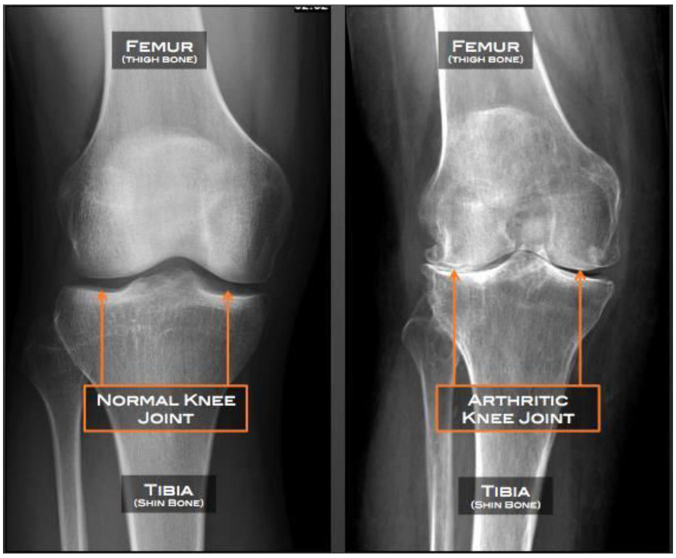

Fig.1 Normal knee joint and Osteoarthritis knee joint

The severity of KOA is typically assessed using the Kellgren and Lawrence (KL) scale, which ranges from 0 (indicating a healthy knee) to 4 (representing severe OA), based on visual inspection of knee X-rays. However, this traditional method is subject to high variability due to its semi-quantitative nature, leading to inconsistencies between evaluators. Given the profound impact of KOA on individuals and society, early-stage severity assessment is crucial for timely and effective intervention. Automated approaches to analyse X-ray images are emerging as a promising solution to overcome the limitations of subjective grading. Despite considerable progress in developing automated methods for quantifying KOA severity, efforts to build a predictive model remain limited. Developing such models can significantly aid in accurate diagnosis, monitoring disease progression, and making informed treatment decisions.

II. 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 existing 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.

III. RELATED WORK

The work is done [1] for classification to evaluate the effect of additional patient information on the prediction of the DL model for KOA severity. Two types of experiments were performed. First, only imaging information was used; in the second experiment, image data and clinical information were input. They used a private dataset of 3464 training images, 386 validation images, and 516 testing images. A CNN was developed with the six Squeeze and Excitation ResNet (SE-ResNet) modules. Their obtained AUCs with only image data for KL grades 0-4 are 0.91, 0.80, 0.69, 0.86, and 0.96. For DL with image data and patient information obtained, AUCs for KL grades 0-4 are 0.97, 0.85, 0.75, 0.86, and 0.95. It has been reported that KL grade 2 is the most complex and confusing to predict for the DL model. They observed that patient information improved the AUC for each stage

In study, [2], 25873 training images, 7779 validation images, and 5941 testing images are taken from the OAI dataset. Left and right Knee joints are localized using U-Net. Demographic information, i.e., age, gender, BMI, is fed to the DenseNet. Their method achieved sensitivity results for four levels of OA are normal 83.7%, mild 70.2%, moderate 68.9% Severe 86.0%, and Specificity normal 86.1%, mild 83.8% moderate 97.1%, and severe 99.1%. They have eliminated the KL1 doubtful grade. Moreover, their internal radiologists highlight the inter-observer reliability of KL classification varies from 0.51 to 0.89. It has also been observed that these wrong classifications are mainly made for adjacent KL grades.

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 [3].

In a research [4] 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 © 2021, IJCERT All Rights Reserved 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

A recent American Orthopedic 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. 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.

In 2018 Abdelbasset Brahima et al. used a circular Fourier filter to pre-process the X-ray in the Fourier domain. The data is then subjected to a unique normalization approach based on modeling that predicts multivariate linear regression (MLR) to decrease the variations in OA and healthy persons. To reduce dimensionality, an independent component analysis (ICA) technique is applied at the feature selection/extraction step. Finally, for the classification challenge, Naive Bayes and random forest classifiers are utilized. The findings demonstrate that the suggested approach has an 82.98 % predictive classification performance for OA detection[5].

In 2021 Albert Swiecicki et al. created a method for automated deep learning that assesses knee osteoarthritis severity according to the KL grading system by combining the Lateral (LAT) and Posterior-Anterior (PA) views of knee X-ray. For the assessment of OA in the knee, an unique deep learning-based technique was used in two steps : (1) detection of joints of the knee in X-ray using faster R-CNN. and (2) classification using multi-input CNN for the Two inputs image (LAT, PA). The result of the model is 71.90 % multi-class accuracy [6]

A deep learning paper about KOA was published in 2021 by Jean Baptiste Schiratti and Remy Dubious, the goal of the study was to help or support radiologists in their tough task of determining the stage of knee osteoarthritis. This is

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because radiologists are prone to human errors that can have disastrous effects, especially when it comes to matters of health. For the same reasons, numerous academics from throughout the globe have published articles on KOA [7]
The use of a deep learning system to identify knee osteoarthritis was suggested by A. Swiecicki [8]. On the MOST dataset, the application had an accuracy of 71.90 %. The region of interest in images from X-rays was found using the Region Proposal Network method. Then, to anticipate entity limitations, the Region Proposal Network and Visual Geometry Group16 convolutional networks were used.

IV. METHODOLOGY

In this section, we explain the methods clearly to show the details of the phases

4.1 Normalization and Knee Joint Detection

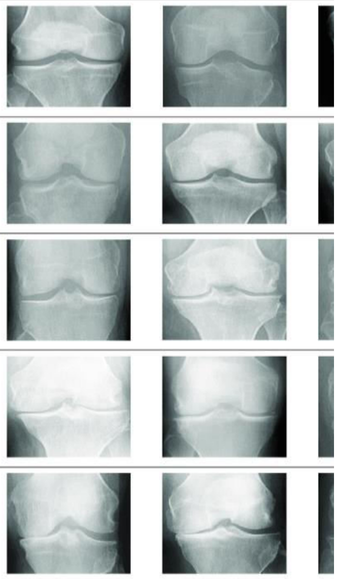
To increase the accuracy of the classification results, normalization of image intensity and dimensions is implemented before entering data into the convolutional neural network. In this study, we used CLAHE as a method for normalizing image intensity and cropping to 400 x 100 pixels at the center of the knee joint on both the right and left knee to normalize the image dimensions. The purpose of cropping is to get a suitable Region of Interest (ROI).

4.2 Data Collection

The Osteoarthritis Initiative (OAI) was the only publicly available dataset used in this investigation [9]. For every class, examples and standards are shown in Figure . There are 8253 photos of knee OA in the sample. According to the Kellgren-Lawrence (KL) categorization, which is based on the descriptions of medical experts, the dataset is classified into five classes.

Table -1

Class	Total Images	Sample X-ray Images
(Healthy)	3857	
(Doubtful)	1770	
(Minimal)	2578	
Moderate)	1286	
(Severe)	295	



4.3 Data Preprocessing

The input knee X-ray image is initially checked for the proper quality and then it is smoothened with anisotropic filter. All the input images are resized into 256 × 256 for the standardization of all the four categories of KOA

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4.4 Residual Network (ResNet)

ResNet, [11] that is comparatively shallow, has proven to perform better for image recognition tasks and won ILSVRC 2015. The ResNet-34 involves over 21 million trainable parameters and overcomes the problem of vanishing or exploding gradients by adding auxiliary connections. These connections help maintain a constant flow of information throughout the network and reduce computational costs.

4.5 Feature Extraction

A common technique shared by all three approaches is bounding box regression, which addresses the object's location and size independently. A bounding box is a rectangle that tightly encapsulates a single object. The location and size of each object are defined by the center coordinates of its bounding box. In our task, while the visual structure of each knee joint is distinct, accurately determining its position and size poses a challenge. Bounding box regression enhances segmentation performance and reduces the need for extensive manual effort in designing a complex extraction system.

4.6 Detection

The model is designed to classify the input image into the desired category. In this case, an X-ray image is provided as input, and the model analyzes it by extracting relevant features. Based on this analysis, the model classifies the image and predicts the disease grade.

V. 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.

5.1 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.

5.2 Data Flow Diagram

A data-flow diagram (DFD) is a visual tool used to represent the flow of data within a process or system, typically an information system. It illustrates the input data provided to a component, the processing it undergoes, and the resulting output data. Unlike control flow diagrams, a DFD does not include decision statements or loops, focusing solely on the graphical representation of data movement.

DFDs are highly beneficial for understanding and analysing a system. They graphically depict the functions and processes involved in capturing, manipulating, and storing data, as well as the data flow between different system modules. This clear and intuitive representation facilitates effective communication between users and system designers during the design process. Additionally, DFDs are useful for identifying potential security vulnerabilities where the data flow might be compromised.

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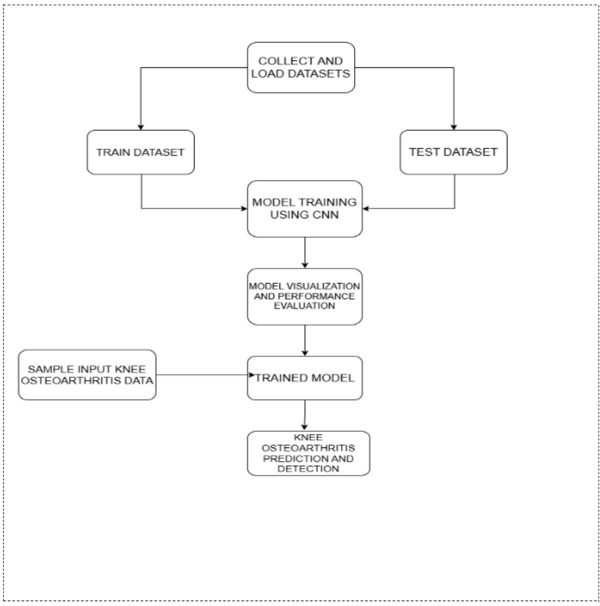

Fig. 2 Data Flow Diagram

VI. CONCLUSION

This system is designed to provide key features essential for predicting knee osteoarthritis (OA). The proposed approach, utilizing a convolutional neural network (CNN) algorithm, achieves significantly higher accuracy than existing methods and effectively predicts the progression of knee osteoarthritis. Identifying the disease stage is crucial for tailoring treatment, as applying the same treatment across all stages often yields suboptimal results. Currently, clinicians manage OA using a combination of methods, but advancements in medical imaging research with CNNs offer promising improvements in diagnosis. In past years, CNN applications in medical imaging have made significant progress, providing great potential in OA diagnosis. With advancements in computational power and increased data availability, 3D deep learning has the potential to revolutionize early detection of knee osteoarthritis. Three-dimensional imaging enables a comprehensive assessment of the knee joint from multiple planes, providing precise information about the subtle progression of the disease. However, developing a robust and generalized 3D CNN for diagnostic applications remains a challenge, not only in terms of model accuracy but also computational efficiency. order the pdf, and are given directions as to how to do so. Although 3D CNN applications are still in the early stages, the development of methods based on MRI data shows promise for a deeper understanding of OA progression, particularly in its early stages. In the future, clinical practice may incorporate automated 3D clinical applications capable of detecting biomarkers and delivering performance comparable to clinical experts in early OA detection. These advancements could transform the early diagnosis and management of knee osteoarthritis.

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In this connection, on behalf of the editors of this report, we would like to extend our appreciations to the authors of the papers under reference for having offered so much detail of their findings and containing so much of the research data, let alone about such fascinating and encouraging ideas. They have been very helpful for our work since they have provided the substantive context and the framework for the development and improvement of the investigation. Their papers show the level of commitment and knowledge that defines this discipline; we have learned from reading their works .Naturally, we appreciate the opportunity to build and build upon their great work .Resources, analysis, and ideas constitute a valuable contribution that has informed this study. It has been a pleasure to have their work as part of our study as it has offered the basis upon which knowledge and direction for enhancements of our research was gotten. The passion with which users provided their input has not only enhanced the knowledge shared here but also made me explore the area further.

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