American Journal of Biomedical Science & Research

www.biomedgrid.com

ISSN: 2642-1747

Research Article

Detection of Osteoarthritis by Applying MATLAB Algorithms on X-Rays Image

Aqsa Bibi, Khadija Khan, Javeria Noor, Faraz Akram, Mehrab Fayyaz and Jawwad Sami Ur Rahman*

Department of Biomedical Engineering, Riphah International University, Islamabad, Pakistan

***Corresponding author:** Jawwad Sami Ur Rahman, Department of Biomedical Engineering, Riphah International University, Islamabad, Pakistan.

To Cite This Article: *Aqsa Bibi, Khadija Khan, Javeria Noor, Faraz Akram, Mehrab Fayyaz and Jawwad Sami Ur Rahman*. Detection of Osteoarthritis by Applying MATLAB Algorithms on X-Rays Image. Am J Biomed Sci & Res. 2024 24(3) AJBSR.MS.ID.003209,* DOI: 10.34297/AJBSR.2024.24.003209

Received: October 16, 2024; **Published:** October 23, 2024

Abstract

Osteoarthritis (OA) is a common degenerative joint disease that is characterized by the gradual deterioration of cartilage. It commonly results in excruciating pain and impairment. Establishing a convincing management and treatment strategy requires early identification as a crucial component. The purpose of this research is to enhance the identification of osteoarthritis from knee radiography x-rays images by presenting an innovative approach that makes use of image processing methods. We conducted research that included the transformation of images to grayscale, which was then followed by an analysis of the histogram to investigate the intensity distributions of the images and calculation of precise Joint Space Width (JSW). This whole process was carried out with the assistance of MATLAB-based algorithms. As a consequence, the use of a thresholding method was successful in differentiating the affected tissue area and separating it from the surrounding tissue, which may be indicative of osteoarthritis. Radiologists and other medical service professionals who are specialists in the early detection and evaluation of osteoarthritis will have access to an accurate determination that is more open and quantitative technique, which provides a promising improvement to the present symptomatic works performed. Image processing has the potential to be used in medical diagnostics, as shown by the results, which reveal a strong capability for highlighting fundamental aspects associated with the ailment.

Keywords: Osteoarthritis, Median filtering, Image processing, Joint space width, MATLAB algorithm, X-ray imaging

Introduction

Osteoarthritis (OA) is the most prevalent type of joint disease worldwide affecting up to 9.6% of men and 18% of women over 60. It is a persistent joint illness that is characterized by the progressive degeneration of ligaments as shown in Figure 1. This condition can affect small, medium, and large joints but mostly affects knees, hips, spine and hand joints [1]. Although in terms of a painful disease, the knee is most frequently affected. Knee Osteoarthritis (KOA) is a disease which results from the wearing of the articular cartilage in between the knee joints. The disease affects more than 250,000 individuals worldwide and ranks among the 50 most common diseases. Due to the fact that it is one of the largest and most complex joints in the human body, the knee joint is particularly vulnerable to the pressures and wear that are associated with osteoarthritis [2]. There are a number of factors that contribute to the deterioration of joint ligaments and the progression of Osteoarthritis (OA), including ageing, obesity, past injuries, and heredity. These factors make this defenselessness even more severe (Figure 1).

Despite being a very prevalent ailment, OA can be challenging to diagnose. When it comes to clinical practice, the diagnosis of knee osteoarthritis is often based on a combination of clinical evaluation, patient history, and radiographic examination [3]. Radiography remains the primary imaging modality in clinical practice for the diagnosis and follow-up of OA. Today, radiography is still the modality of choice to confirm a structural diagnosis of OA and to monitor its progression due to its accessibility, cost-effectiveness, and the ability to visualize changes in joint space and bone architecture that are associated with the disease. In radiographic terms, osteoarthritis may be recognized from other conditions by characteristics such as the narrowing of joint spaces, the development of subchondral sclerosis, the formation of osteophytes, and changes in bone structure [4]. One of them, known as Joint Space Narrowing (JSN), is particularly noteworthy since it has a direct correlation with the deterioration of cartilage. A precise calculation of the Joint Space Width (JSW) on knee X-rays is necessary for the diagnosis of Osteoarthritis (OA), the evaluation of the severity of the condition, and the monitoring of the course of the illness [5].

Figure 1: Normal knee and Osteoarthritis knee.

Cartilage degeneration and other skeletal changes can be examined radiographically and quantified using the semi-quantitative grading scale known as the KL scale, Ahlbäck classification and knee osteoarthritis grading system. Manual diagnosis of this disease usually involves observing X-ray images of the knee area and classifying it under five grades using the widely accepted KL system. This requires the physician's expertise, suitable experience, and a lot of time, and even after that the diagnosis can be prone to errors. Also, the manual evaluation of Joint Space Width (JSW) and other osteoarthritic traits may be subjective, laborious, and dependent on the expertise of the radiologist [6]. This is even though X-ray imaging has its benefits. In the process of examining X-ray images, the variation that occurs between eyewitnesses further complicates the process of determining and evaluating osteoarthritis [7]. These limitations bring to light the need to increase the number of approaches that are goal- oriented, reproducible, and automated in the radiographic evaluation of Osteoarthritis (OA). In the field of clinical or medical imaging, the approach of digital image processing and improvements in artificial intelligence have opened up new avenues for improving imaging diagnostic accuracy [8].

Recently, automated image analysis frameworks have been increasingly used to assist radiologists in improving the accuracy and efficiency of clinical judgements. This shift in utilization has occurred in recent times. Through the use of contemporary computations, these frameworks are able to differentiate, quantify, and interpret the radiological signs of osteoarthritis that are present in knee X-ray images [9]. By automating the detection of crucial traits, such as JSW, these innovations not only reduce the subjectivity associated with human estimates, but they also enable the treatment of massive datasets, which in turn helps clinical preliminary studies and epidemiological investigations that cover a wide range of circumstances.

Since, osteoarthritis significantly impacts the quality of life, this disease has received considerable attention in the recent past in terms of diagnosis and cure. Significant efforts have been made in the last few years to improve imaging and image analysis methods for the diagnosis of osteoarthritis with emphasis on methods used to evaluate cartilage and JSW. In [10] *Deny, et al.,* used pre-processed MRI scans and analyzed scans with Canny and LoG edge detection techniques for sharp variations. The method was based on the assessment of cartilage thickness, which is an important diagnostic criterion in osteoarthritis. Thickness is derived from pixel differences at the edges and JSW is compared to control mean values (5.7mm for males and 4.8mm for females) to differentiate osteoarthritic knees from normal knees. In [11] *Bharodiya, et al.,* Described anenhanced approach for edge detection in human X-ray images based on Gaussian filter and statistical range. The Gaussian filter is used in image pre-processing and the enhancement aspect, while the statistical range computes the delta between the highest and lowest pixel present in each division of the 3 by 3 image matrix. These techniques operate in harmony when used in recognizing edges in X-ray images. Furthermore, the authors compared their method with the four recent edge detection algorithms.

Another study conducted by *Bharodiya, et al.,* in [12] the authors aimed at designing an intelligent algorithm known as WODJSW to help orthopedicians to measure JSW extracted from wrist X-ray images automatically. The algorithm includes steps such as inserting the X-ray image, detecting ROI, edge detection, vector height measurement, converted MM, comparing JSW with standard wrist joint width and diagnosis. The authors validated the algorithm using the wrist X-ray images and obtained a significant diagnostic accuracy. In [13] *Saleem, et al.,* proposed a computer vision system that helps the radiologists in diagnosing the osteoarthritis from the X-ray images of knee. The system employs different image processing techniques to increase image quality and, at the same time, it identifies the knee region using template matching algorithm. JSW is then computed and compared with standard values for classification. On a big dataset of knee X-ray, their method proved to be effective in osteoarthritis detection.

Building upon the previous advancements, the proposed research aims to further enhance the automation and accuracy of osteoarthritis detection. The purpose of this work is to propose a complete technique that makes use of digital image processing in order to differentiate and assess Joint Space Width (JSW) in knee X-ray imaging. The ultimate goal is to provide a reliable tool for the diagnosis and monitoring of osteoarthritis. For the purpose of precisely measuring the joint space width from radiography images, the suggested technique combines the most recent calculations for image preprocessing, edge detection, and area of interest (ROI) analysis. The feasibility of the method is shown by a series of experiments, which demonstrate a high level of exactness and consistency in comparison to the traditional manual estimates. The remaining parts of this article are aligned in the following manner: In the second section, the approach is broken down into its component parts, which include image preprocessing procedures, edge detection computations, and JSW estimation algorithms. In the third section, the findings are discussed, with an emphasis placed on the benefits and possible uses of the automated system in clinical environments. The work is brought to a close with a review of the results and a discussion of potential future research topics in Section 4.

Methodology

Acquiring and Pre-Processing of X-ray Images

JSW, which stands for joint space width, is an important factor to consider while observing the progression of osteoarthritis in the extremities [14]. The approach for acquiring and preprocessing X-ray images of knee osteoarthritis is a crucial component of the research, which makes use of knee X-ray images received from a clinical database. MATLAB was chosen because of its ability to handle high-goal pi, which guarantees a detailed study of joint designs [15]. These images are in a digital format that lends themselves well to being handled in MATLAB. Each and every X-ray image is first converted to grayscale before being processed further. By taking this enhancement step, the complexity of the information is reduced without sacrificing the key data that is necessary for accurate analysis. Following this, a median filter is applied to each image in order to enhance image quality and reduce the amount of noise that is there, the flow of methodology is shown in Figure 1.

This stage of sorting is quite important since it helps to smooth out the overall image while also safeguarding the margins of knee structures, which are particularly important for the studies that will follow. CLAHE, which stands for contrast-limited adaptive histogram equalization [16], is finally being carried out in order to make the joint spaces inside the knee more specific and easier to dissect as shown in Figure 2. This approach profoundly upgrades the differentiation of the X-ray image, specifically working on the perceivability of subtle differences in tissue thickness within the joint space, consequently working with more precise Joint Space Width (JSW) estimates in the succeeding phases of the research. The imagen enhancement for the easier dissection of the joint spaces inside the knee, after the application of CLAHE, can be observed in Figure 3 (Figures 2,3).

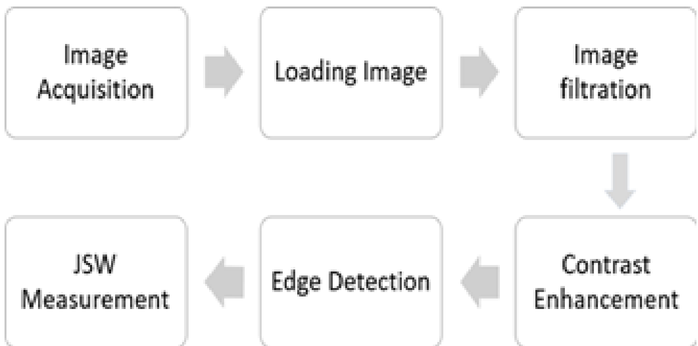

Figure 2: Process flow diagram of methodology.

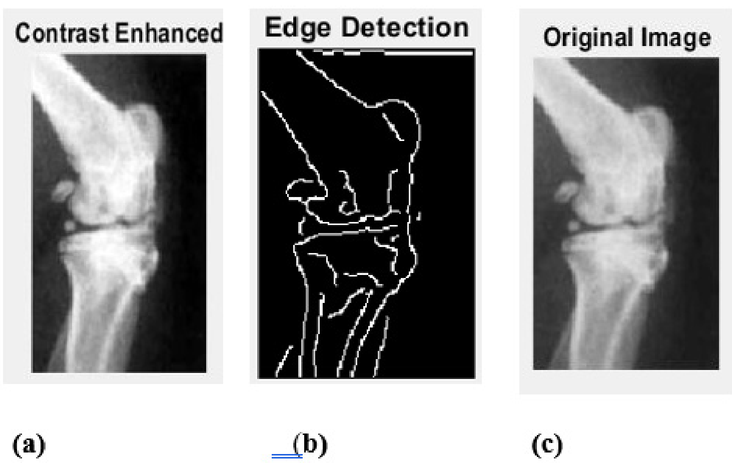

Figure 3(a): Original image, (b) contrast enhanced and (c) edge detected image of knee.

Determination of Joint Space Width (JSW)

The vertical distance between the tibial plateau and the border of the femur on either side is the unit of measurement for the joint space width [17], as shown in Figure 3. The medial side of the human knee joint has a normal joint space width of 5.15 millimeters, whereas the lateral side has a normal joint space width of 5.9 millimeters [18]. Edge recognition is an essential component in the process of determining the Joint Space Width (JSW) since it depicts the restrictions that are placed on the tibiofemoral joint [19]. It is for this reason that the canny edge detector is used because of its capacity to effectively capture sharp edges while simultaneously minimizing the impact of disturbance. MATLAB's edge capability, which is specifically built to recognize edges in light of ideally set limitations in order to ensure precision, is used in the execution of this procedure. Immediately after the edge detection process, the Region of Interest (ROI) is mapped out, with the knee joint area being the primary focus of attention [20]. If the underlying organization of the research is taken into consideration, the ROI may be characterized either physically or by automated procedures. Detailed research is taken into account by this specific center, which is essential for accurate JSW assessment. Within the ROI, the JSW itself is assessed by determining the shortest distance that exists between the margins of the femur and tibia bones that have been detected [21]. These measurements are made easier by the extensive image processing toolbox that MATLAB provides, which provides JSW values in pixels on the screen. The significance of this process lies in the fact that it has a direct impact on the findings and evaluations that are ultimately obtained about osteoarthritis. This process guarantees that the measurements are correct and can be replicated. As can be observed, in Figure 3a, which is the original image, its contrast is enhanced by applying CLAHE which is shown in Figure 3b, finally, the edges are detected through canny edge detection as shown in Figure 3c. The JSW can be observed inside the red box as shown in Figure 4 (Figure 4).

Figure 4: Red box indicating the JSW.

Implementations

All of the procedures that are included in this investigation are meticulously carried out in MATLAB, which takes use of its powerful image processing capabilities. In order to achieve the highest possible level of efficiency and precision, the contents have been meticulously adjusted, with a significant emphasis placed on ensuring that they can be reproduced in clinical settings. In light of the fact that the ability to replicate findings in a variety of situations provides a basis for clinical study and application, this perspective is of significant importance. For the purpose of enhancing the robustness of the framework, extensive iterative testing and advancement were directed. During these iterations, the feedback that was gathered from the preliminary stages served as a source of information [22]. This feedback provided insights into the practical issues that the image analysis algorithms faced and how well they performed under different settings. The automated procedure has been completely developed to satisfy the high standards that are needed for clinical diagnostics. This has been accomplished by continuously developing our approaches in light of really accurate information and explanations from professional experts. Due to the fact that this iterative approach works on the framework's exactness as well as its unshakable quality, it has become a significant tool for radiologists and doctors to obtain correct and speedy inspection of knee X-ray images for the purpose of detecting osteoarthritis.

Results

The consequences of this study show the viability of the automated image processing framework created in MATLAB for distinguishing and estimating Joint Space Width (JSW) in knee X-ray image as a demonstrative device for osteoarthritis. Through near examination against physically explained images by radiologists, the automated framework showed high accuracy and unwavering quality in JSW estimation. In Figure 4 the sample x-ray images of knee with osteoarthritis are shown, A total of two different kinds of knees, namely arthritic and non-arthritic knees, are included in the dataset (Figure 5).

In our study, the canny edge detector and Gaussian filter played essential parts in the image preprocessing stage, empowering exact discovery of Joint Space Width (JSW) and the determination of osteoarthritis. Sample X-Ray images of knee osteoarthritis are shown in Figure 5.

Application of Median Filter

Through the use of the median filter, the nature of the knee X-ray image was significantly improved [23]. This was accomplished by clearing out the noise without obscuring crucial anatomical characteristics. The image is convolved with a median filter of 3x3, which results in a significant reduction in image noise. In order to prepare images for edge identification, it is essential to remove artifacts. This is because removal of unnecessary noise reduces the likelihood of recognizing deceptive edges that are caused by noise. In the programme that we developed, the filter settings were carefully selected to allow for a range of adjustments. The upgraded filter was able to effectively pre-arrange images for more precise edge detection, which is essential for the future stages of measuring JSW. The original image after the application of the median filter has been filtered out from noise as shown in Figure 6 (Figure 6).

Figure 5: Sample X-Ray images of knee osteoarthritis.

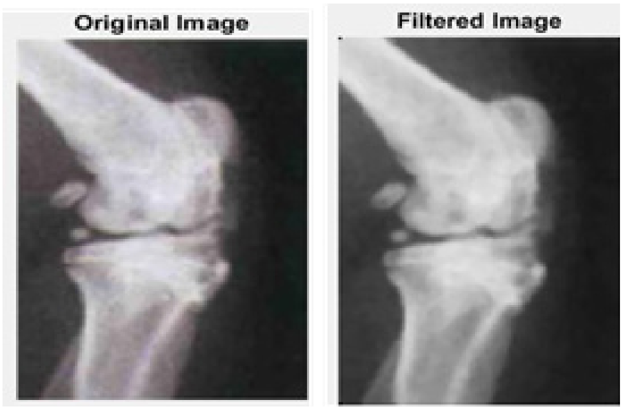

Figure 6: Original image and image after applying median filter.

Canny Edge Detection Technique

A huge number of edges in images were identified using the canny edge identifier, which was selected due to its effectiveness and feasibility in this endeavor [24]. In order to identify a large number of edges in images, this computation is performed in a few stages. In the beginning, the image that has been filtered by the median filter is smoothed in order to lessen the effect of any artefacts that have not been totally eliminated by the underlying separating [25]. At this point, non-maximum suppression is performed in order to thin down the edges. This ensures that the output that is produced has thin lines, which makes it simpler to analyze and precisely calculate distances. Taking this step is important for accurately determining the JSW because determining the exact edge area is necessary in order to estimate the minimal distances that exist between the edges of the femur and the tibia bones. Among the most recent developments are twofold thresholding and edge tracking by hysteresis, both of which distinguish true edges from deceptive up- sides. Setting two thresholds allows for the possibility of powerless edges being considered in the case that they are related with regions of strength for with [26]. This, in turn, reduces the likelihood of deceptive edges occurring as a result of tumult or variations within the image. This strategic move proved to be effective, as seen by the sharpness and clarity of the knee joint margins in the image that was processed, which resulted in more trustworthy JSW calculations. Thus, edges of the knee joints have been highlighted and identified through canny edge detection as shown in Figure 7 (Figure 7).

JSW Estimation

In the course of our investigation, the calculation of Joint Space Width (JSW) using MATLAB is an essential component in the process of identifying osteoarthritis. Due to the fact that JSW is a crucial indicator of cartilage degradation that is typical of osteoarthritic changes, this quantitative measurement is of the utmost importance [27]. In order to get an accurate calculation of JSW from a knee X-ray image, it is necessary to use sophisticated image processing methods that are carried out in MATLAB. The primary emphasis is placed on accuracy and repeatability. The use of edge detection computations, more specifically the canny edge indicator, is the first step in the interaction. Because of its capacity to accurately depict the boundaries of the femur and tibia bones [28], this calculation was selected after careful consideration. We are able to determine the closest foci between the bones at the knee joint, which are related to the negligible JSW, by clearly identifying these edges from one another. It is for this reason that the MATLAB function edge is used. This function employs a multi-stage computation to differentiate between solid edge slopes while simultaneously restricting noise. Following the characterization of the edges, the computational devices of MATLAB determine the shortest possible distance between the edges that are opposed to one another [29]. This distance calculation, which is lead across a few foci along the differentiated edges, ensures that the JSW is shown in an accurate manner. In most cases, this involves performing several iterations over the pixels that make up the edge-recognized image and use numerical operations in order to record distances. MATLAB's array handling skills and its quick processing of image data matrices contribute to an improvement in the high quality of these estimates, which are consistent and reliable. The most recent JSW values are typically shown in pixels as shown in Figure 8 (Figure 8).

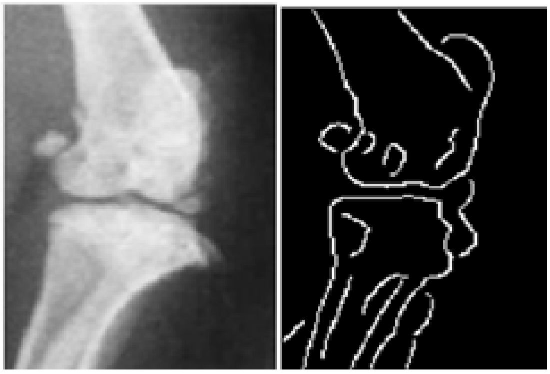

Figure 7: Original and edge detected image of knee osteoarthritis.

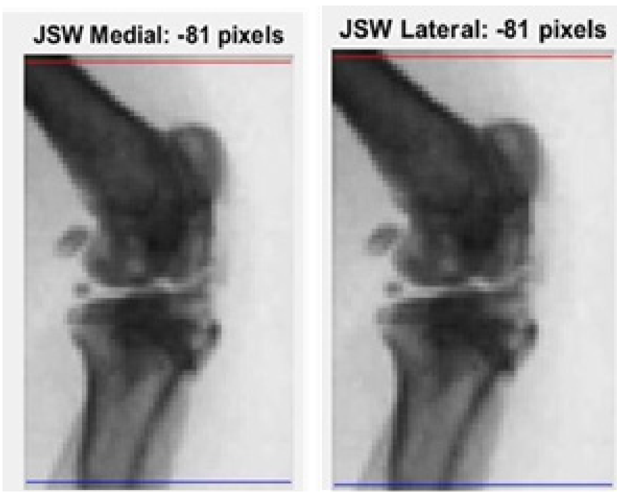

Figure 8: JSW Medial and JSW Lateral.

however, they are capable of being converted entirely to millimeters by making use of alignment information that is specifically established for the X-ray imaging equipment that is being used. Not only is this modification essential for clinical relevance, but it also makes it possible for the automated framework to provide outputs that are significant to clinical professionals.

Performance Evaluation

One of the most fundamental aspects of our research is the validation of automated measures as shown in Figure 8 and findings by comparing them to clinical standards. For the purpose of ensuring the precision and unwavering quality of the automatic approach that was developed for differentiating osteoarthritis, we performed a similar evaluation using a collection of images that were manually associated with annotations. Radiologists have only lately completed their analysis of these images. Among the components of this connection is a definitive evaluation of the automated JSW estimates and the osteoarthritis analysis that was produced by our MATLAB-based image processing approach. Through the process of contrasting these automated results with the explanations provided by the experts, we are able to essentially evaluate the precision of our edge detection calculations and the appropriateness of the

JSW estimate methodologies that were used. In addition, this procedure assists in the identification of any inaccuracies that may exist between the automated framework and the human evaluations. This offers us the opportunity to adjust our calculations so that they are more likely to coincide with clinical impressions. One of the most important goals of this correlation is to perfect the automated process to the point where it can reliably support or even improve the dynamic in clinical settings. This will result in the creation of a device that is not only quick but also robust enough to be utilized in close proximity to the conventional methods that radiologists employ. Thus, osteoarthritis has been detected after applying various image processing techniques which include application of median filter, canny edge detection and estimation of JSW medial and lateral values as shown in Figure 9 (Figure 9).

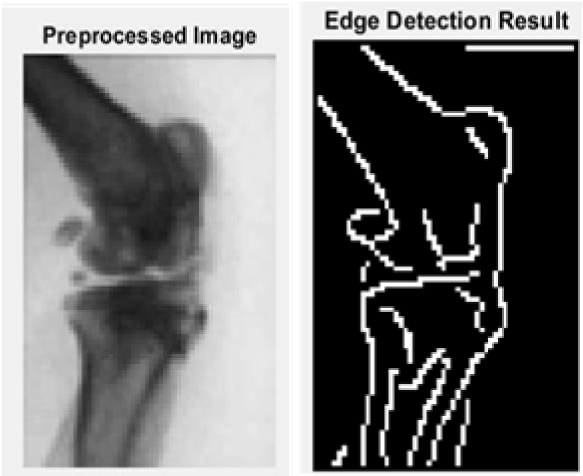

Figure 9(a): Preprocessed image of knee osteoarthritis (b) Edge detected through canny edge detector.

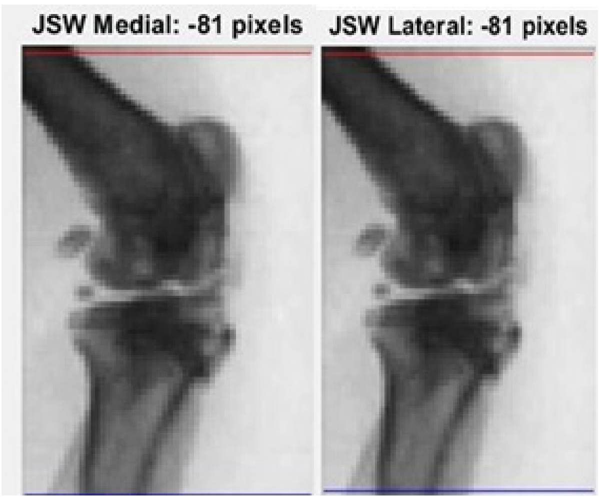

Figure 9(c): JSW medial (d) JSW lateral.

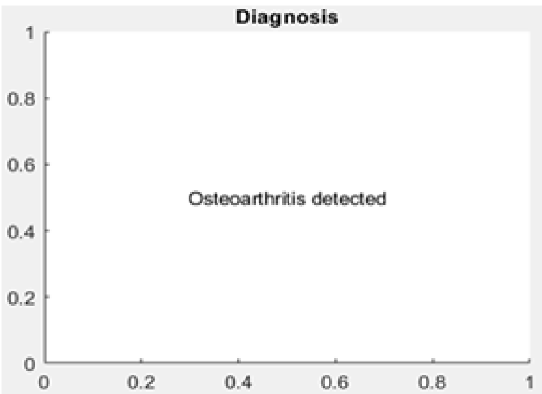

Figure 9e: Result showing Osteoarthritis presence.

Discussion

Previous studies conducted on osteoarthritis detection have a number of drawbacks, particularly with regard to image processing techniques, which include labor and time-consuming manual measurements that are susceptible to partiality and observer variability as these measurements are dependent on the clinician observation and expertise thus are more prone to errors. The limited accuracy of many approaches can be attributed to either insufficient edge detection techniques or a lack of robust automation. Furthermore, methods usually focus on specific factors, such as cartilage thickness, without offering comprehensive diagnostic solutions, thus there is a need to develop such technique which can reduce the time and labor required for manual measurements by automating the process and providing a more efficient diagnostic When using MATLAB to diagnose Osteoarthritis (OA), it will significantly alter the way that medical imaging data are used in clinical settings. This is because MATLAB is capable of performing image processing processes. OA assessment may be made much more accurate and expedient by the use of automated methods, particularly those that make use of Joint Space Width (JSW) measurement and edge identification techniques, as shown by this study. One of the most significant things that we discovered as a result of our research was that the Canny edge detector is capable of accurately characterizing the edges that are present between the femur and the tibia bones. This is an essential component for obtaining precise measurements. The Canny method is superior because it is able to correctly suppress noise while simultaneously locating a large number of lines. In order to get high-quality images that may be used for the purpose of making precise readings, this is of utmost importance. When several fundamental image processing processes have been completed, such as applying a median filter to decrease noise and increase contrast, edge detection performs more effectively. By following these procedures, the image will be prepared for improved edge identification. Considering that human error and lengthy processing periods are major issues with conventional methods of measuring JSW, the manner in which we performed it in our study represents a significant advancement in the field. When this procedure is automated, there is a lower probability of making a mistake, and it is possible to complete more tests in a shorter amount of time. It is now simpler to diagnose osteoarthritis and to give more effective therapies as a result of this. Additionally, since these readings are now automated, it is now feasible to deal with larger volumes of data, which is important in clinical trials and demographic studies that need a large amount of data to be processed. In spite of the fact that the outcomes seem to be favorable, there are a few shortcomings and constraints that need to be taken into consideration. There is a significant relationship between the quality of the images that are sent into the autonomous system and the efficiency with which it operates. It is possible that the system will not be able to accurately locate edges and measure JSW if appropriate X-rays are not taken, if the subject is moved about, or if the image parameters are not adjusted appropriately. It is possible for the Canny edge detector to lose its efficiency when used with images of poorer quality, yet it performs very well in controlled environments. This demonstrates how essential it is for medical imaging techniques to adhere to rigorous adherence criteria. A connection must also be made between this autonomous system and the existing information technology systems for healthcare in order for it to be used in hospitals. This might result in significant changes to the way that healthcare staff are taught and how they do their jobs. Consideration should also be given to the fact that individuals are unique in a variety of ways, such as the fact that their bodies are constructed differently or the presence of other health issues that may alter the Joint Space Width (JSW) and, therefore, the diagnosis of Osteoarthritis (OA). It is recommended that researchers focus on enhancing these image processing approaches in the future so that they are more adaptable and dependable in a variety of imaging scenarios. In addition, machine learning models might be used to make predictions about the progression of osteoarthritis by using JSW measurements and other radiographic characteristics. These kinds of prediction models might make it much simpler for medical professionals to provide individualized care to patients by enabling them to formulate treatment strategies based on how the illness is anticipated to proceed.

Conclusion

As a result, the incorporation of sophisticated image processing techniques into MATLAB for the purpose of detecting and quantifying osteoarthritis represents a significant advancement in the realm of medical imaging. The automation and improvement of these procedures will allow us to get findings that are more accurate, quicker, and reproducible, all of which are extremely significant for the improved management of patients who suffer from osteoarthritis. In the course of our ongoing efforts to enhance and expand these technologies, there are several applications that may be found for them in therapeutic settings. It is possible that this may lead to a future in which the assessment and treatment of osteoarthritis will be based on more data and will be more uniquely customized to each individual patient.

Acknowledgement

None.

Conflict of Interest

None.

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