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# A Review of Recent Methods in Early Detection of Knee Osteoarthritis

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## Abstract:

Arthritis is the most common condition generally affecting patients over the age of 65. The occurrence of osteoarthritis increases with age and its influence signifies a growing burden on health care. The knee arthritis is the most commonly affected arthritis when compared to hands and hips. In order to reduce its effects and enable early treatment early diagnosis of knee osteoarthritis is necessary. The early diagnosis is possible by implementing the advanced methods of image processing techniques using MRI (Magnetic Resonance Imaging) images. There has been much advancement in the early diagnosis of knee osteoarthritis by analyzing the MRI images. This paper presents a review on these recent advancements in the methods of early diagnosis of knee osteoarthritis. It also presents the possible improvements that can be made on these methodologies.

*Keywords*-— **Knee Osteoarthritis, MRI, Segmentation.**

## 1. Introduction and Background

Osteoarthritis (OA) also known as degenerative joint disease or osteoarthrosis, is nothing but a degradation of joints that occurs because of mechanical abnormalities [1], including subchondral bone and articular cartilage. The symptoms for this may include tenderness, stiffness, locking and few times an effusion. The loss of cartilage will be due to few causes like hereditary, metabolic, developmental and mechanical deficits. When bone suffers from lack of protection from cartilage it may get damaged easily. As a result of reduced movement secondary to pain, regional muscles may atrophy, and ligaments may become more lax [2]. The Subcommittee on Osteoarthritis of the American College of Rheumatology Diagnostic and Therapeutic Criteria Committee defines osteoarthritis (OA) as "A heterogeneous group of conditions that lead to joint symptoms and signs which are associated with defective integrity of articular cartilage, in addition to related changes in the underlying bone at the joint margins" [3]. Worldwide, osteoarthritis (OA) is known to be the 4th highest leading cause of disability. Many times this type of disability burden is a reason to the contribution of the hips or the knees [4]. It is considered as one of the most frequently occurring cause of pain, disability in elders and also loss of functioning. It is sometimes responsible for complete hip replacement (THR) with enormous medical costs.

### 1.1 Early diagnosis

Osteoarthritis (OA) is such a type of disease which is not easy to define and diagnose. It is the most general joint disorder in the world. The evidence of Radiographic of OA occurs for the ages above 65 years and also about 80% of those aged over 75 years [5]. The disability weight assigned to hip or knee osteoarthritis in 'Global Burden of Disease' studies typically range from 0.10 to 0.15 [4]. In view of the significant disability weight associated with OA, it is important to diagnose the disease early and reliably.

## 2. A review of the recent improvements in OA detection methodologies

There have been improvements in detection of OA knees by automatic segmentation and quantitative analysis of MRI images of knee [6] [7] [8] [9]. The Fripp et al. method include automatic segmentation of the bones in an MRI using the extraction of the expected bone-cartilage interface (BCI), a three-dimensional active shape model and cartilage segmentation from the BCI using a deformable model that uses particular patient tissue estimation, localization and a thickness variation model. The method has been compared by them with the three state of the art methods such as a modified semi-automatic watershed algorithm, tissue classification, and nonrigid registration (B-spline based free form deformation). Their method attained an average Dice similarity coefficient (DSC) of (0.83, 0.83, 0.85) for the (patellar, tibial, femoral) cartilages, while tissue classifier obtained DSC of (0.82, 0.81, 0.86) and nonrigid registration obtained DSC of (0.73, 0.79, 0.76). The obtained average DSC for all the cartilages using a semi-automatic watershed algorithm (0.90) was somewhat greater than this approach (0.89), but unlike this approach segmentation is performed as a separate object for each cartilage. The effectiveness of this method for quantitative analysis was evaluated using thickness and volume measures with absolute Laplacian thickness difference of (0.13, 0.24, 0.12) and a median volume difference error of (5.92, 4.65, 5.69) mm.

A new methodology uses Volumetric Appearance Models using minimum message length principle. This has been claimed to achieve a major enhancement in accuracy of segmentation [9]. They have suggested a technique using the minimum message length principle for refining the correspondences and segmentations by constructing a volumetric appearance model. The study on 12 subjects with the results is presented by them and the suggested method achieved better accuracy of segmentation compared to the approach of surface active appearance model. It also reduced the measurement variations in cartilage thickness for key regions. They have used the same images of the 12 subjects obtained from scanners of different vendors and also showed the possibility of multi-centre trials. In their study, they use Active Appearance Models (surface AAMs) for locating (segment) the bone surfaces and create anatomical correspondence among images. They use the NIH OAI study protocol for the Siemens scanner and developed near-equivalent protocols for GE and philips scanners in association with the vendors. Their approach involves using surface AAMs for automatic segmentation of tibia and femur in the multivendor study images. Around 160 volunteer's knee images were used for construction of volumetric AM from an osteoarthritis initiative. The mean bone shapes from both the models was registered by using iterative closest point alignment and the closest point on the volumetric AM mean shape to each point on the surface AAM mean shape was determined. One-to-many points mapping was used for defined region boundaries to propagate volumetric AM mean shape to the surface AAM mean shape. The advantage in their method lies in the fact that the volumetric appearance model uses the minimum message length principle. Their method can also detect disease progression whereas traditional measures of cartilage loss were not able to do so. Their approach is also attractive in so far as it uses Multi-Vendor Image Acquisition.

Yin et al. proposed a technique for concurrent segmentation of several interacting surfaces which belongs to numerous interacting objects, called LOGISMOS- "layered optimal graph image segmentation of multiple objects and surfaces". The method is based on the algorithmic integration of several spatial inter-relationships in a particular n-dimensional graph, followed by graph optimization that gives a global optimal solution. They show the LOGISMOS technique's performance and utility on a cartilage and bone segmentation in the knee joint. Even though trained on only nine example images, the LOGISMOS scheme attained good performance. It is judged by considering the leave-one-out test for DSC values of 0.80 ± 0.04, 0.84 ± 0.04 and 0.80 ± 0.04 for the tibial, femoral and patellar cartilage regions, respectively. These are good DSC values, considering the narrow-sheet character of the cartilage regions. Likewise, they have obtained low signed mean cartilage thickness errors when compared to a manually-traced independent standard in 60 randomly chosen 3-D MR image datasets from the Osteoarthritis initiative database— 0.05 ± 0.23, 0.11 ± 0.24 and 0.03 ± 0.17 mm for the tibial, femoral and patellar cartilage thickness, respectively. The average signed surface positioning errors for the six identified surfaces varies from 0.04 ± 0.12 mm to 0.16 ± 0.22 mm. The suggested framework LOGIMOS gives accurate and robust knee joint bone and cartilage segmentation of patella, femur and tibia [10].

Shah et al. suggested a method of implementing segmentation, visualization methods to differentiate the knee cartilage and analyze in a simple manner. They used semi-automatic scheme based on Bezier splines and canny edge detection. The smoothing of images is performed by enhancing the cartilage edges using anisotropic diffusion. Shape-based interpolation on segmented cartilage is performed to get isotropic voxels. The artificial matching points at different slices are used for MRI registration. Cartilage analysis is performed by finding its volume and thickness. Articular cartilage visualization provides an additional tool to characterize it for quantification purposes. Their approach is a Semi-Automatic, Bezier Spline based Canny Edge Detection approach using a log filter. The approach uses a Shape Based Interpolation algorithm to determine Cartilage Thickness. Euclidean distances have been used for cartilage thickness. The advantage of this method is that it used simple interpolation technique instead of complex shape based interpolation methods. The results obtained for cartilage visualization and quantification are comparable with earlier works. The usage of canny edge detection method along with LoG filter improves the edge detection since all the false edges are removed.

Swamy et al. have applied image processing methods on magnetic resonance images (MRI) of knees. In this, they have used thresholding, histogram equalization, Canny edge detection scheme and region of interest (ROI) processing. Using this, they have segmented cartilage from tibia, femur and menisci. The method of visualization of knee cartilage suggested by them is semiautomatic. The quantification of cartilage thickness is also performed for both normal and osteoarthritis. The results presented by them are useful in the study of development of OA and for therapeutic judgments [8]. In this approach, grayscale image from RGB MRI images is obtained, a histogram is plotted to know the gray level of the image, a contrast stretching operation is carried out for enhanced view of the anatomical boundaries and appropriate masks are built by fixing the points on ROI polygon. Finally, using the Canny edge detection method, the femur and tibia boundaries are obtained. The advantage of such an approach is that it is semi automatic while its disadvantage lies in the fact that it can only work on 2D images.

Pang et al. presented a new segmentation algorithm which is active contour-based that includes combination of both local region based technique and external force field ideas in a consistent manner. The method not only has a large capture variety as it is common with curve evolution methods based on static force fields like the vector field convolution (VFC) and gradient vector flow (GVF) scheme, but also can distinguish small details as local region based techniques do. The feasibility of their algorithm is shown on both synthetic images as well as real knee MRI images where the aim is to find the femur and tibia as part of a larger osteoarthritis problem of image analysis [11].

The active contour-based segmentation algorithm used by them combine local region based schemes and external force field ideas in a consistent manner. It includes two-step method where the bone region of the knee is found and the same is used as mask for segmentation. The advantage of their scheme is that it can identify weak edges located in near proximity. They also propose a hybrid model based on both local region information and edge information for image segmentation. The said method combines local region-based forces and external vector field which is characterized by a large capture range and the facility to identify local details, such as weak edges. The approach has a large capture range seen in curve evolution methods based on static force fields like the vector field convolution (VFC) and the gradient vector flow (GVF) methods, and can distinguish small details with local region based methods capture.

Jia Hui Ho et al., have developed semi-automatic anterior cruciate ligament (ACL) segmentation to facilitate ACL injury diagnosis. It is the most commonly diagnosed injury among the ligaments which preserves knee joint structural integrity. The MRI images are used to assess this injury due to recent development in clinical imaging technology. But, the visual assessment of these images need manual tracing of chosen boundary structures using software which is frequently time consuming. Such interpretation also depends on past experience and opinion of radiologist. Hence they have proposed a semiautomatic ACL segmentation using both active contour and morphological operations. ACL's unique shape and orientation within MRI images is considered for segmentation. The proposed method segmented 111 PD-weighted images. The accuracy of the system is measured by using the parameters such as sensitivity, specificity and Dice coefficient. The proposed method was capable of achieving an overall specificity, sensitivity and Dice coefficient of 99.4 % ± 0.3 %, 43.3 % ± 14.0 %, and 0.381 ± 0.091 respectively. This indicates that the images segmented from both proposed and manual segmentation method is 38.1% similar. Even though these values indicate low performance, the results presented in this study did prove its feasibility in providing an objective and reproducible ACL segmentation. Thus, with essential enhancements implemented, this method can be clinically deployed to assist diagnosis of ACL injury [12].

## 3. PROPOSAL ON POSSIBLE IMPROVEMENTS ON THE ABOVE METHODOLOGIES

We propose to build a fuzzy logic/neural network based intelligent system for the early detection of Knee Osteoarthritis. The method to be developed by us will take inputs from the works cited above, and will integrate them seamlessly in a fuzzy logic/neural network based intelligent model.

## 4. Conclusion

The most common condition that occurs in aged people is knee osteoarthritis. The early detection of this condition enables early treatment with better results. This paper discusses different image processing methods that are employed for early diagnosis of osteoarthritis and also possible improvements that can be made for the available methods.

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