A Survey on Morphological Assessment of Knee Articular Cartilage from MR Images

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Abstract- **Nowadays, articular disorders and musculoskeletal diseases are one of the major health issues and attack usually the older generations. The human knee joint is commonly infected by osteoarthritis (OA) disease. OA can affect the joints of the spine, fingers, thumbs, hips, knees, and toes, but it is most prevalent in the knee and hip joints. Here we are concentrating only on Knee joints. Knee Osteoarthritis is a serious, excruciating & potentially life-threatening joint disease, may lead to permanent disability. It can be detected by measuring changes in knee internal tissues such as cartilage, meniscus and Subchondral Cartilage. For detecting knee osteoarthritis, Magnetic Resonance Imaging is performed to obtain a detailed picture of knee joint and change are measured from MR images. MRI is a test that uses powerful magnets, radio waves, and a make to comprehensive pictures inside our body.**

The main objective is to develop a fully automated non-contrast MRI application for detection and Segmentation of knee bones. The proposed approach is based on Convolution Neural Network to achieve a robust and perfect segmentation of even highly pathological knee structures.

Key Words- **Osteoarthritis (OA), MR Images, Cartilage, knee segmentation,**

1. INTRODUCTION

In recent years Knee Osteoarthritis, not only seen in aging people but also found in the younger generation (30%-40%). OA is a degenerative disease that is the basic genesis of chronic disability. It is a highly widespread joint disease, causing pain and disorder in the older generation, and it can be associated with progressive degeneration of the diarthrodial joint tissue. For exact detection of knee osteoarthritis, Cartilage Segmentation is required. Segmentation of Cartilage from MR Images is time taking when compared with manual segmentation and also issue with correctness. An automatic segmentation is required for consistent and accurate detection of osteoarthritis. The Figure 1a and 1b show the anterior and posterior view of the knee and its pars.

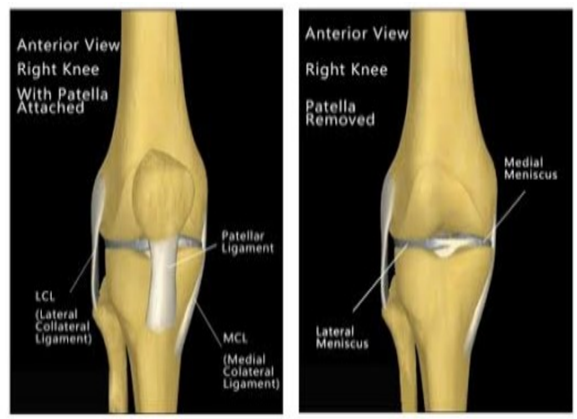

Fig 1a. Frontal view of the knee

Fig 1b. Posterior view of the knee

Hence we found a solution to this problem by using deep learning based approach can resolve the problem of automatic segmentation of subchondral Cartilage from MR Images.

2. LITERATURE REVIEW

Maxim D. Ryzhkov et al. [1], Gives the basic knowledge about the problems faced with knee cartilage segmentation, and to provide us a critical view of the related methods given in the literature in the past years. In this paper, several methods and techniques have been introduced. In semi-automatic methods, the user assists the algorithm to find the initial address for cartilage segmentation. In automatic methods, the initialization is basically done by initially finding the adjoining bones. Cartilage extraction can be done in many different ways. Edge detection method can achieve high accuracy when there is a plain surface at the cartilage and tissues. By recent survey, literature suggest that semi and fully automatic segmentation algorithms have a potential to become the standard technique for the quantification of cartilage surface and volume.

P.Dodin et al. (2010) [2], presented an algorithm that segments human knee cartilage from 3D MRI automatically without the human interventions. They allowed continuous observation of human's osteoarthritis in the knee joint. Depending on the surface of the bone, the technique resample the MRI and uses texture analysis to find the exterior surface of the cartilage. This technique gives the quantification, not only the global cartilage volume but also gives the femur's upper part and tibia's lower part individually. Hence in the previous systems, techniques used for cartilage segmentation did not allow segmentation of knee cartilage into individual surfaces and also they were not tested and validated for complex cartilage a structure that normally occurs in the human suffering from OA. In the new method, they described the major problems have been identified and developed an automatic technique which gives the accurate volume of cartilage with minimum error.

Meenaz H. Shaikh et al. (2014)[3], introduced new methods Active Shape Models (ASM) which uses the statistical analysis of the structural variation in the 3D objects. The ASM method initiates with average model shape and produces new structure repeatedly depending on the image data. Active Appearance Model (AAM) is a new method developed using both shape and gray level data. AAM is completely depending on assumption that there exists a linear dependency between the shape of the object and intensity pattern surrounding the object vertices. Therefore AAM is not an appropriate method for knee joint segmentation because of its assumptions. Deformable Models gives robustness, boundary gaps and allow integrating boundary elements. Knee joint image segmentation is a very complex task. Segmentation methods for knee can be classified in 3 types manual, semiautomatic and fully automatic. The Manual segmentation is time-consuming and will not give accurate results and we need users for doing manually. To reduce this disadvantages Semiautomatic method is developed, by automating a few steps of processing. Fully automatic methods include advanced and complex processing steps with minimum limitations.

Jianxu Chen et al. (2016)[4], proposed a new Deep Learning(DL) principle for 3D image segmentation. By Combining a Fully Convolutional Network (FCN) and a Recurrent Neural Network(RNN), which are accountable for developing the intra slice and inter slice perspective, separately. They assess in two different 3D biomedical image segmentation implementation, they introduced approach can achieve the state of the art action. They have developed a framework for a new model to convert the higher performance of 2D deep structural design to develop 3D contexts.

CemM.Deniz et al.(2018)[5], proposed a Statistical shape model and deformable model for automatic proximal femur segmentation using MR Image which depends on the Convolution Neural Network (CNN). Initial studies of MRI focused only on particular regions of interest (ROI) such as the femoral neck, femoral head. In recent times, investigation of the whole proximal femur has been used as a way to study the mechanical properties of it, instead of specific sub-regions. The CNN model had reduced the time required for manual segmentation and gives the accurate result.

K.Mori et al. (2013)[6], proposed a method Triplanar Convolutional Neural Network (CNN) for knee cartilage segmentation using MR Image segmentation of skeletal structures in medical images is depends on the study of voxel/pixel categorization. Triplanar 2D CNN's which categorizes voxels from 3D images with high accuracy.MRI slice with segmentation by the method of triplanar CNN result exceeds the result of Radiologists. This method achieves effective DSC, responsiveness, carefulness, and correctness.

Julio-Carballido-Gamio et al. (2013)[7], proposed a new technique for the cartilage of the knee in 3D. Using MR Image visualization tool that is easy to execute and that allows the picture of 3D cartilage thickness map in 1D and 3D. The common indication of Osteoarthritis(OA) of the knee is morphological deterioration of articular cartilage.

The MRI potential to create mentally and examine quantitatively.

Deise M et al. (1999)[8], proposed a method for Quantifying the articular surface, the arrangement of natural and artificial physical feature, and cartilage thickness of human knee joints from MR Image. Well-Organized semi-automated method provides equivalently fine and sometimes superior perfection than manual segmentation.

Gabrielle Blumenkrantz et al. (2007)[9], proposed a method for MR imaging of articular cartilage which is affected by osteoarthritis. They implemented this method by computing cartilage volume, thickness, and the measurement of relaxation times. Also, the delayed uptake of Gadolinium DTPA as a marker of proteoglycan depletion is also reviewed. The major goal of MR images is to detect osteoarthritis at an early stage as much as possible, so that treatment may be given before irremediable morphologic degeneration take place.

M.S.Mallikarjunswamy et al. (2012)[10], proposed a method for knee articular cartilage segmentation, visualization, and quantification for measurement of cartilage thickness which is useful for early determination of disease in osteoarthritis infected patients. They used semi-automatic and automatic techniques for knee thickness measurement in 2D and 3D. They also adopted statistical measures for accuracy detection, precision and validation purpose.

Quan wang et al. (2014) [11], focuses on 3D MR images, where the human knee cartilage segmentation is done in 3D. The technique uses semantic information in the knee joint. Also, they presented a multi-class learning method to segment the femoral, patellar and tibial cartilage. The method uses the spatial contextual constraints between bone and cartilage, and also between different cartilages. For cartilage segmentation, they used fully automatic learning-based voxel classification mechanism.

Carballido-gamio et al. (2004)[12], described a process to succeed in degeneration of articular cartilage and MRI with sub-pixel accuracy. They applied log filter for edge detection after smoothing the knee cartilage. In the detection of OA quantitative data visualization is essential and they presented visualization tools which are very easy to apply and MRI cartilage of knee that allows the representation of 3D cartilage thickness in 1D and 3D.

Archit Raj et al. (2018)[13], proposed Automated Cartilage Segmentation is constituting for enhancing the performance of advanced Knee Osteoarthritis value due to its convoluted 3D structure and developing a knee cartilage. It using the methods is Network Architecture (U-Net), Data and Labels, Training and testing, methods are used.

Han sang Lee et al. (2018)[14], proposed a method for segmentation of knee cartilage from MRI which is based on DSN(Deep Segmentation Networks). It converts the problem of segmentation cartilage into problem segmenting the BCC(Bone Cartilage Complexes) and bones, and they applied2.5D segmentation has three plane result with the majority voting to enhance the segmentation accuracy.

Jurgen Fripp et al. (2007)[15], proposed a scheme for segmentation that is automatically and exactly obtains cartilage segmentation from the healthy human beings. The scheme consists of three phases to automatically and accurately obtain the cartilage segmentation, automatic segmentation of bone, the extraction from the bone cartilage interfaces (BCI) and segmentation of cartilages.

Francois Lauze et al. (2013)[16], proposed Convolutional Neural Network (CNN) using deep learning architecture and recently have been applied successfully for 2D images segmentation tasks. They used CNN for voxel classification in the 3D images. They are also using Triplanar Convolutional Neural Network for the segmentation of cartilage.

Fang Liu et al. (2017)[17], used Deep Convolutional Neural Network(CNN) and three-dimensional(3D) simplex deformable displaying to upgrade the precision and proficiency of cartilage and bone segmentation inside the knee joint. The totally automatic segmentation pipeline was developed by conjoining a semantic division CNN and 3D simplex deformable demonstrating. A CNN strategy called SegNet was associated as the focal point of the segmentation method to perform high assurance pixel-wise multi-class tissue classification. The 3D simplex deformable demonstrating refined the yield from SegNet to spare the general shape and keep up a smooth surface for musculoskeletal structure. The completely automated segmentation technique was tested utilizing an openly accessible knee image data set to contrast and presently utilized best in class division strategies. The completely automated segmentation was additionally assessed on two distinct informational indexes, which incorporate morphological and quantitative MR pictures with various tissue contrasts.

The proposed totally automatic segmentation technique produces good segmentation performance better than the non-automated and semi-automated method of segmentation in the openly accessible knee image data set. The strategy additionally exhibited flexible segmentation performance on both morphological and quantitative musculoskeletal MR images with various tissue contrasts and spatial resolutions.

The examination demonstrates that the combining CNN and 3D deformable displaying approach is reasonable for performing quick and accurate cartilage and bone segmentation inside the knee joint. The CNN has promising potential applications in musculoskeletal imaging.

Berk Norman et al.[18], utilized 2D U-Net Convolutional Neural Network for completely automated segmentation of Cartilage and Meniscus from knee MRI to decide the shape, or structure and relaxometry in contrast and other manual and semi-automated state of art method. In the investigation they have utilized 638 MR imaging volumes from two information associates obtained at 3T: 1) SPGR T1ρ-weighted and 2) 3D twofold reverberate consistent state (3D-DESS) pictures. For the Automatic segmentation, they have utilized a Deep learning model in view of U-Net Convolution Neural Network engineering which naturally portions Cartilage and Meniscus segment.

The Result of the Automatic division is contrasted and the manual division which was performed by specialists and Radiologist, The Performance of Automatic Segmentation was assessed on Dice Coefficient cover with a manual division. The Model created solid Dice coefficients, especially for 3D-DESS pictures, running between 0.770-0.878 on the cartilage compartments and 0.809, 0.753 for parallel and average meniscus, separately. The models average 5 seconds to create the automatic segmentation. Normal relationships between a manual and programmed measurement of T1ρ and T2 esteems were 0.8233 and 0.8603, separately, and 0.9349 and 0.9384 for volume and thickness, individually.

The longitudinal exactness of the automatic technique was equivalent to the manual one. U-Net shows viability and exactness in rapidly producing precise divisions that can be utilized to extract relaxation times and morphologic characterization and values that can be utilized as a part of the observing and determination of OA.

Felicia Aldrin[19], proposed "Mechanized Segmentation of the Meniscus" of a knee from MR images. 3D segmentation of tissues in the knee joint envisions injuries and distortions, empowering Computer-aided finding and treatment arranging of patients with knee issues. Manual segmentation is, nonetheless, tedious and subject to interrater inconstancy, making a characteristic want for strategies empowering automated segmentation.

The advancement of machine learning as of late has drastically enhanced automated segmentation and classification task, settling on it a characteristic decision for the additionally challenging menisci segmentation. The Author proposed, two completely automated machine learning division strategies are implemented and compared for segmentation of the menisci, in particular, Random Forest in view of Haar-like highlights and the deep learning technique 2D U-Net Fully Convolutional Network (FCN). The two strategies were tried and looked at for division of 18 menisci from 3D Magnetic Resonance (MR) images.

The 2D U-Net cascade indicated better outcomes than the Random Forest for segmentation of the menisci, with a mean Dice Similarity Coefficient (DSC) of 75.3% contrasted with 54.4%. Moreover, 2D U-Net cascade was also tested on an extra 28 subjects for single-and multi-class segmentation of distal femur and articular cartilage from 3D MR images. The single-class 2D U-Net course gave insignificantly better outcomes contrasted with the multi-class segmentation with a mean DSC of 95.3% for distal femur and 71.7% for the articular ligament.

With limited training data, the proposed 2D U-Net cascade segmentation technique demonstrates promising outcomes for all the three tissues. The future work proposed to focus on 2D U-Net cascade algorithm. Additionally training on more data and dividing the images for training in separate networks based on properties of the image is suggested.

Alexander Tack et al.[20], proposed a novel method for automatic segmentation of menisci from MR Images. The Model combines Convolution Neural Network and Statistical shape model. The Accuracy of the method is carried out on 88 sample MR Images which was manually segmented. Meniscal volume, tibial coverage were calculated and test for different age people suffering from Osteoarthritis. The proposed method results in 88.3% accuracy.

3. PROPOSED ARCHITECTURE

The Fig.2 shows the proposed architecture for morphological assessment of articular cartilage. We are using Deep Convolutional Networks (DCN), which is proved best when compared with the existing state of art method.

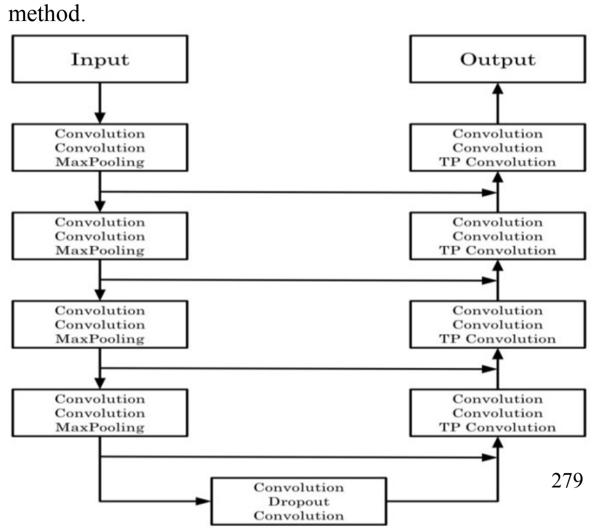

Fig 2. The proposed architecture for the segmentation

In the Fig.2, the design proposed 4 "Down Blocks" on the contracting side that are reflected through 4 "Up Blocks" on the extending side. Each level is associated with the opposite side to share data at the current spatial goals.

A Down Block comprises of 2 convolutional layers each pursued by a RELU activation function, after which A MaxPooling layer parts the width and height of the image. The Up Block appears to be comparative yet includes a transposed convolutional layer to start with to upscale the goals and no Max-Pooling at the end. The Middle Block includes a Dropout layer with an estimation of 0.5, which is encompassed by convolutional layers too. All convolutional layers have 32 channels. The output layer incorporates another convolution that decreases the channels to 1, which represents the segmentation map.

Evaluation:

After training the network result is generated on test Image dataset. The visual result is for evaluating and verifying that segmentation is done in the right way. The results are based on data the network has not been trained with. The architecture was developed using a single segmentation channel that merged cartilage maps.

4. CONCLUSION

In this paper, we discussed different techniques for knee articular cartilage segmentation and drawbacks of the existing techniques. To overcome the drawbacks of existing methods, we are planning to use Deep Learning based Deep Convolution Network (DCN) which enhances the accuracy of cartilage segmentation.

5. FUTURE ENHANCEMENT

The proposed technique is planned for fully automated non-contrast MRI application for detection and segmentation of knee bones.

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