A Novel Framework For 3D Bone Femur Segmentation And Analysis For Osteoporosis Analysis

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Abstract—Femur bone is the thigh bone and is the longest and the strongest bone of human body. Exposure to sun and hence Vitamin D is reducing for in the urban population by every passing day which is leading to more and more cases of Osteoporosis. An Osteoporosis is reduction in the bone mass density which is difficult to be detected in the early stage from the X-Ray imaging. With Advancement of 3D imaging, more and more structural analysis of the pelvis and femur bones are becoming popular. However, there is still a huge scope of research in this area as no concrete framework is being available for 3D femur bone analysis. In this paper we present a unique method of Osteoporosis analysis by evaluating the variation in the bone mass from the segmented 3D femur bone scan model. Results shows that the proposed technique is 94.3% accurate in diagnosing osteoporosis.

Index Terms—Osteoporosis, Graph cut, 3D segmentation, Femur Bone

I. INTRODUCTION

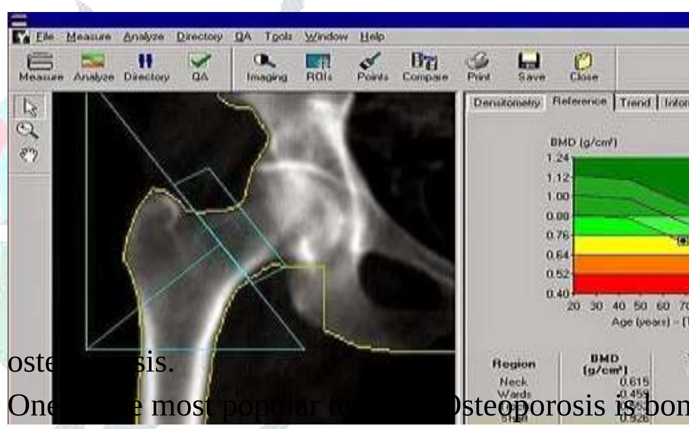
The Femur bone is the thigh bone of the body. A typical X-Ray Femur bone is shown in figure 1.

Figure 1: Typical Femur X-Ray of Male(L) and Female(R)

Figure 2: LEDE Femur

As basic structure of the bone is 3D, it is extremely difficult to find the anomalies in the bone in the 2D image, particularly for bone mass loss like Osteoporosis. A typical low energy Dual Energy Xray Femur analysis is shown in Figure 2.

As Femur is the strongest bone of the human body, it is a popular choice along with spine to analyze Osteoporosis. This method analyzes the change in the BMD across different bone segments and then by comparing them, a physician can easily identify or diagnose for the diseases and problems associated with loss of Bone Mass.



oste sis.

One e most popular t Osteoporosis is bone mineral density (BMD) test which is based on detecting low mass in the bones. Dexa-Scan or dual-energy X-ray absorptiometry is also a popular clinical test choice for

Figure 2: Typical Dexa Femur Analysis of Femur Bone

Figure 3: Typical X-Ray Analysis of Femur Bone

The other method involves analysis of traditional X-ray.
Though it is often used when there is a fracture caused by Osteoporosis as shown in figure 3.

Latest development in the 3D imaging, particularly has lead to an entirely new perspective of the analysis of the bones and muscles. 3D bone imaging is acquired by 3D bone Scan.

The test includes using a very small amount of a radioactive drug called a radiopharmaceutical which acts as a dye or bone strain. Bone scans are becoming popular particularly in the diagnosis of bone metabolism, which is essentially the process that leads to breaking down of bones and recreation of the same. A bone scan is also used to view and analyze long to short term abnormal metabolic bone activity like the case of Osteoporosis.

As the dye spreads through patient's body, the bone's cells gradually navigate to areas of low density. The injected dye tracers the damaged areas by following the cells and collect in spots of bone damage.

3D bone structure can be reconstructed from both MRI as well as from CT scan images. A typical Femur bone 3D with Osteoporosis is shown in figure 4.

Figure 4: A CT Reconstructed Femur Bone with Osteoporosis

Though the reconstruction and modelling of 3D femur structure has become immensely robust and popular, their analysis still lacks the amount of research to help in automatic computer aided diagnosis of the same. This is partially due to current cost of the 3D modelling as well as the availability of the sensors.

A Typical 3D model of a lower male body part and corresponding model of the Femur bone is shown in figure 5. Due to advancement of CAD technologies, it is now possible of synthesizing and constructing 3D models purely in the software and then analyzing them through the analysis engine. Complex anatomical, physiological and pathological problems can be reconstructed in 3D view.

As creating such models and changing them through texture and shape change tools is cost effective, several medical imaging analysis in 3D image relies on 3D synthesized image analysis.

Figure 5: A Typical lower body part 3D(left) and Femur bone (Right)

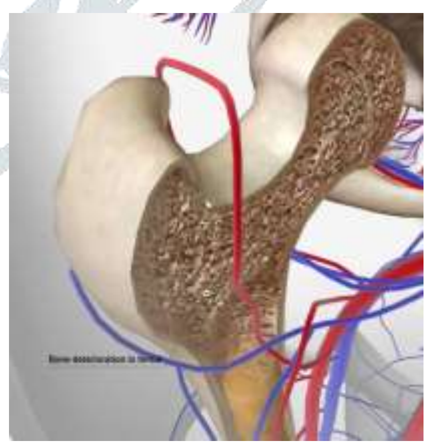


Figure 5: A Typical Osteoporosis bone 3D model.

The variation if the bone mass in the case of Osteoporosis can be seen in figure 5.

It is clear from the diagram that in order to analyze such variations, it is essential to segment the parts of the 3D structure followed by the texture analysis of the structure. A Texture analysis of a 3D image is referred to as extracting 2D color features from the 3D texture model.

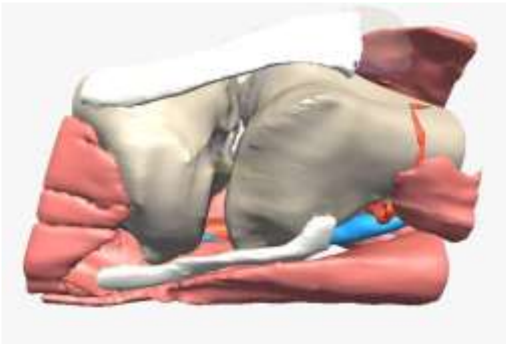


Figure 6: Detailed Bone Anatomy of the Hip and Femur

It is evident from figure 6 that a bone and muscle 3D may contain several other parts and extracting and analysing the bone part from the rest of 3D artifacts, particularly for the bone 3D is both computationally as well as technically extremely challenging. In order to develop and validate the segmentation method, we use CT scan imaging. Before we elaborate the proposed technique we explain in brief past research works in this direction in next section.

II. Related Work

The increase in fracture risk associated with hip fractures is independent of, and additive to, bone mineral density (BMD) measurement. Therefore, having information about hip fractures in conjunction with BMD allows clinicians to better assess fracture risk and select appropriate therapies [12]. Because only one third of hip fractures found on radiographs are clinically diagnosed, imaging is necessary for their detection. This has required radiographs which are usually not obtained in the course of clinical evaluation of osteoporosis. Further, even when hip fractures are present on radiographs, they are often not recognized by the reporting radiologist and do not lead to the diagnosis and appropriate treatment of osteoporosis [13]. Recognition of the importance of vertebral fractures for osteoporosis care, coupled with the realization that they are often not clinically apparent, has led to the development of hip fracture assessment (HFA).

The shape of the proximal femur has been demonstrated to be important in the occurrence of the femoral neck. J.S. Gregory et al proposed a new method called active shape modeling (ASM) to quantify the morphology of the femur. A proportion of hip fracture risk not captured by BMD may be due to the geometric proportions of the femoral neck. The retrospective study, show that ASM is a promising technique for describing these and, in the future, may provide a fast, automated method for analyzing the gross morphology of the hip from radiographs or, potentially, imaging DXA [13]. Bone mass is an important determinant of resistance to fractures. Whether bone mineral density (BMD) in subjects with a fracture of the proximal femur (hip fracture) is different from that of age-matched controls is still debated. T. Chevalley et al measured BMD of the femoral neck (FN) as we as femoral shaft (FS) on the opposite side to the fracture by dual photon absorptiometry. These studies indicate that women and men with a recent hip fracture following moderate trauma has lower BMD values at the levels of the FN and FS as compared with elderly non fractured controls [14]. To differentiate changes in trabecular and cortical bone density at a skeletal site bearing body weight. S. Prevrhal et al proposed a retrospective study to develop and characterize two new regions of interest (ROIs) for DXA at the hip, one focusing on cortical and other for trabecular bone [15]. Magnetic resonance imaging (MRI) is a promising medical imaging technique that is used to assess femoral neck cortical geometry. S.L. Manske et al analysed the lateral edge of the femoral head and extended medially to the lesser trochanter of the femoral neck region and they found that MRI measures of the femoral neck cortical bone geometry are highly associated with failure load of the proximal femur [16]. In BMD testing, unilateral hip analysis measurements have been the clinical standard for diagnosis and treatment classification for postmenopausal women at risk of osteoporosis. R.E. Cole et al introduced Dual-femur DXA measurement technique which allows rapid BMD scanning.

If both hips in one acquisition, eliminating time consuming repositioning of the patient and minimizing the patient's exposure to radiation [17]-[18]. The primary compressive strength components of human femur trabecular bone are qualitatively assessed using image processing and wavelet analysis. S. Sangeetha et al proposed wavelet based qualitative assessment of femur bone strength using digital x-ray images. The normal and abnormal femur has comprehensively analysed using haar wavelet at 4th level decomposition and results were highly correlated for abnormal samples [19].

III. Proposed Technique

a) Segmentation

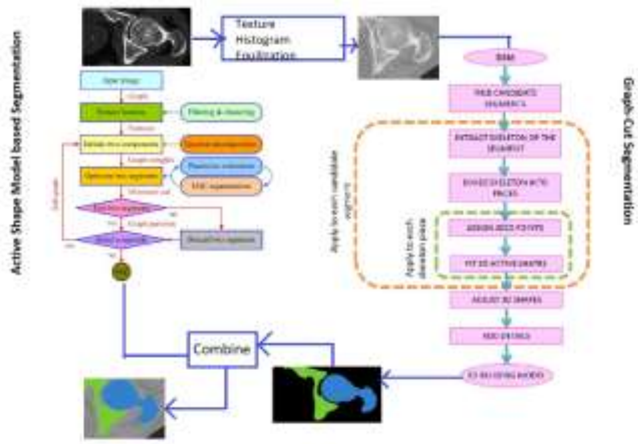


Figure 7:Proposed Segmentation Algorithm

Proposed technique is explained in Figure 7. We combine active shape model with that of graph cut segmentation techniques to extract the exact bone area. The Active shape model first extract the features of the image. We use a combination of Gabor, GLCM and Counterlet features that represents the texture properties of the images. Then the feature set is clustered using k-Means clustering for two clusters. The most significant cluster is considered to be the bone area. Further the image is considered as a chunk of small blocks and the features of the main cluster is searched in the blocks. If the block satisfies the features, then it is considered to be the part of the bone area. This process is continued till the feature differentials in the total selected bone area and the non-bone area doesn't vary any more. This is called an active shape model because in each iteration the shape of the area is changed till finally the entire structure is marked. Once it is marked, a mask is generated out of this area.

The drawback of this technique is that, this is mainly a 2D segmentation approach. The technique is applied on the texture mask of the 3D CT images. However, this method is incapable of segmenting the 3D area. We therefore use a graph cut technique to perform the 3D segmentation. Graphcut assumes the 3D image to be a superset of several polygons and calculates energy in each of the polygons. Then the method creates an active path combining all the polygons with minimum energy differential. Once the polygons are selected, the active graph offers a 3D structure. We use Eigen vectors for defining the energy structure.

The combination phase, the 3D structure is flattened and is superimposed with the 2D structure produced by active shape model. The resultant 3D structure is mapped back to the 3D CT image in order to extract the final segmented image.

a) Feature Extraction and Classification

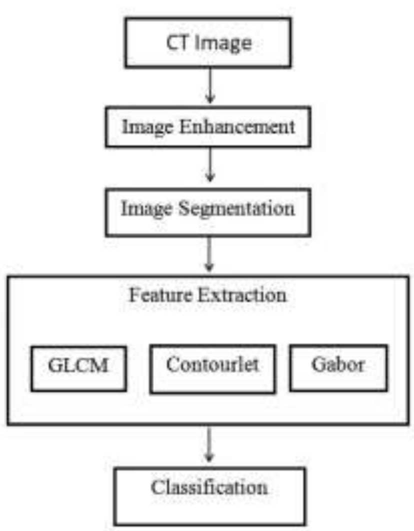


Figure 8: Proposed Classification Framework

For the classification purpose we flatten the segmented 3D image containing only the bone structure and extract feature vector set as explained in the previous subsection. The feature vector set is then used for the machine learning.

The images are grouped into two main categories: patients with Osteoporosis and normal patients. The normal patient CT image also contained fractured images.

This classes are further divided into training and testing method. Training set feature vector with the classes is used to train support vector machine and the testing set is used for evaluation of the technique.

Results are compared with various segmentation techniques rather than standard approach of validating results with different classifiers and feature sets. This is because past literature reveals that the selected feature vectors are the most optimal features for medical images. Also SVM has been identified as the best technique for binary classification. The results are presented in detail in the next section.

IV. Results

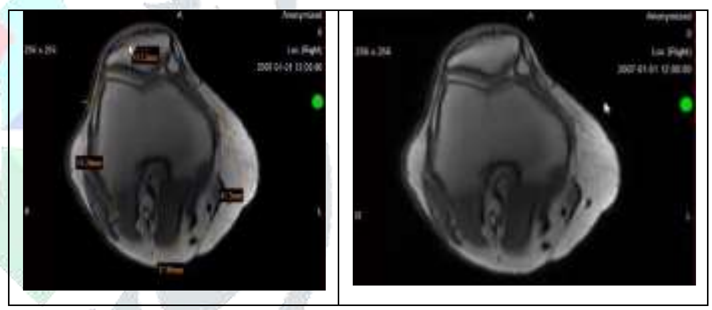


Figure 9: Sample Data Set

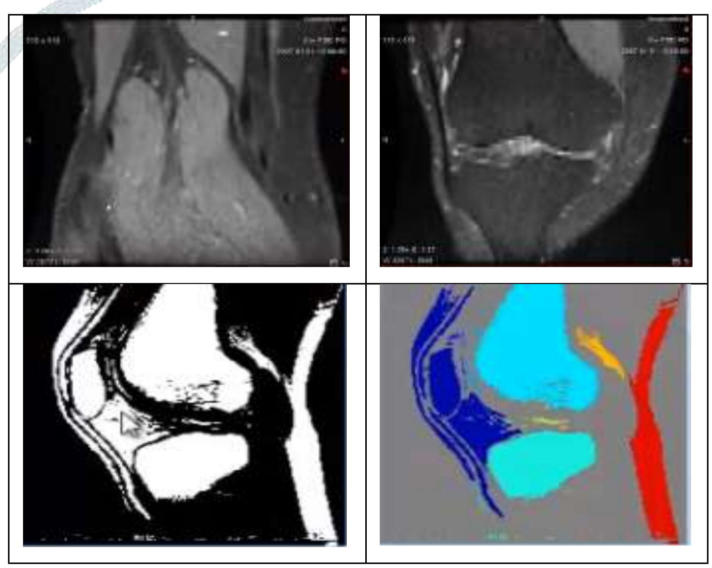


Figure 10: Result of Proposed Segmentation.

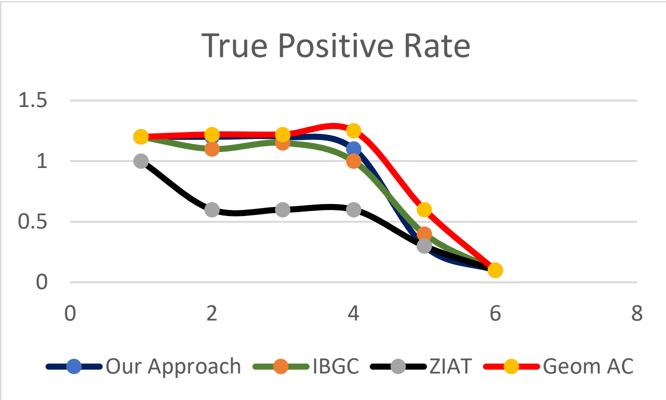


Figure 11: True positive comparison of present and proposed system

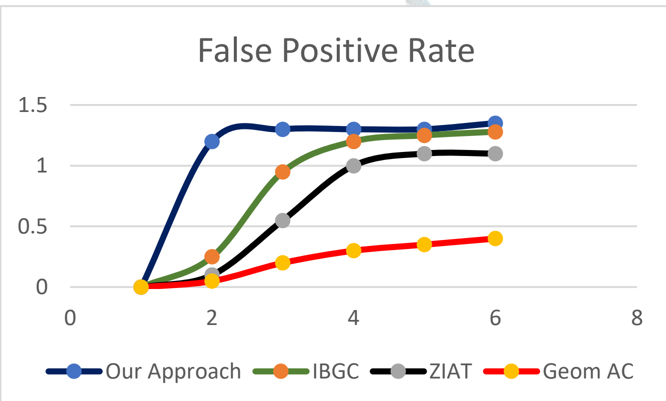


Figure 12: False Positive Comparison of present and proposed system

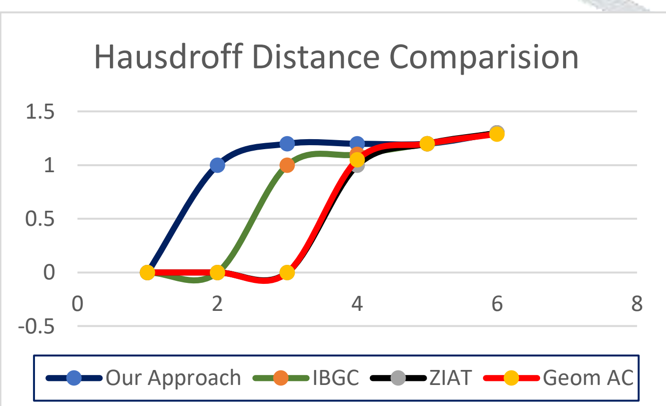


Figure 13: Hausdroff Distance comparison of present and proposed system

It can be seen from the results 10,11 and 12 that proposed system performs better than the other state of art in terms of segmentation and classification both. For all the techniques same feature vector set and classification method is being used.

V. Conclusion

Osteoporosis is identified as one of the fastest concerning bone diseases in India. Due to lack of early prognosis systems, early detection and treatment is difficult. However, it is established that if detected early, the diseases is curable. Though it is easy for human eyes to detect fractures and other traits in both X-Ray as well as in CT images, it is not easy for human eyes to mark micro-structural changes in the bone. Therefore machine learning based technique for Bone Osteoporosis detection is one of the most feasible areas. Pas research has not produced a comprehensive framework for this. Further 2D and 3D techniques are being studied in isolation. In this work we firstly bridge the gap between the 2D and 3D medical pelvic section images and propose a unique hybrid segmentation technique. We further use the segmented bone area to extract features and classify the data into probable osteoporosis or normal sample using support vector machine classification. Results show that the proposed technique offers better segmentation as well as the classification accuracy with acceptable false positive. The method can be further improved by using other texture descriptors like fractal or LBP and ABLP features and convolution Neural network.

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