# CHAPTER 5

# CONCLUSION

The evaluation of bone quality plays a very important role in the diagnosis of bone disorders and can improve the prediction rate of fracture risk. Bone mineral density is considered clinically essential in explaining the mechanical variability of bone. However, it has long been acknowledged that the role of bone structure is as important in the determination of bone quality as bone mineral density (Roque et al 2013). Digital radiography is a widely available imaging modality that has the potential to reflect bone microarchitecture. The 3D microarchitecture of trabecular bone is indirectly visualized in a two-dimensional X-ray projection. The trabecular bone orientation and density are heterogeneous, and thus the projected pattern shows considerable variations in different regions of the radiographic projection. The differences in orientation of the trabecular bone micro-architecture in different regions of the femur can be visualized and quantified through anisotropy analysis.

The bone anisotropy could provide important diagnostic and prognostic information about the structural integrity of trabecular bone (Chappard 2005, Keaveny et al 2001). In this work, characterization of anisotropic trabecular architecture in femur bone images is carried out using spectral and spatial methods. The compressive and tensile strength regions are delineated from the femur radiographic images using Singh index method. The qualitative analysis is performed on the delineated images to derive apparent porosity. Apparent porosity, which is the key representative of the trabecular architecture, is calculated as the ratio of void area to total area (Christopher & Ramakrishnan 2008).

The anisotropy values are determined using various spectral methods which include wavelets, Gabor wavelet, quaternion wavelets and quaternion Hilbert transform and multiscale spatial methods which include structure tensor, lacunarity and succolarity. The parameters derived from the transformed images and using spatial methods are correlated with apparent porosity. The most significant twenty two parameters from all the above analyses are selected using principal component analysis. The significant parameters derived from compressive and tensile strength regions are given as inputs to extreme learning machines classifier.

Results show that the anisotropy values derived from energy of Haar and Gabor wavelets, second and third phase components of quaternion wavelet transform and directional information of quaternion Hilbert transform are found to be distinct for normal and abnormal samples with high statistical significance. It is also found that variations in the values of kurtosis and skewness extracted from directional information of QHT are highly statistically significant for both compressive and tensile regions. The fractional anisotropy derived from structure tensor analysis show distinct difference in tensile region. These values are high for normal samples in both the regions as their elemental structures are highly orientated. They are found to be low in abnormals as trabeculae may be more widely separated and less connected leading to isotropic distribution.

It is also observed that the lacunarity values correlate well with the apparent porosity. Hence heterogeneity in patterns can be reliably measured using lacunarity method as it could capture the gray level variations in an image. It is also shown that succolarity values of orientation (I) are found to be clustered for low values of porosity for normal images of compressive region. Orientation (IV) shows high succolarity values compared to other orientations in tensile region. It is also found that the values of succolarity are varying linearly with apparent porosity for abnormal images. This could be attributed to the anisotropic nature of trabecular patterns.

The spectral and spatial analyses generate 219 parameters and the most 22 significant features are selected for each strength regions using principal component analysis. These significant parameters derived are given as inputs to extreme learning machines. The classification accuracy is found to be high in compressive region for all the activation functions. The sine and RBF activation function yield high and stable accuracy for compressive and tensile regions respectively. These investigations demonstrate that architectural anisotropy analysis is able to differentiate normal and abnormal samples. It appears that the region specific architectural analysis could be a useful index in quantifying trabecular structure of femur bone from planar radiographic images. This automated analysis can be used to enhance the diagnosis without much human intervention, which would be useful for mass screening of osteoporosis and bone mass disorders.