The thesis reports four new computerized methods for Bone Age Assessment (BAA), to estimate the bone age of a child from his/her hand wrist radiograph. BAA is very significant in the area of pediatrics, especially in relation to endocrinological problems and growth disorders. Based on the skeletal development of the left-hand wrist, bone age is assessed and compared with the chronological age. A remarkable difference between the two is an indication of growth abnormalities. This practice is used in the management and diagnosis of endocrine disorders and also in monitoring the therapeutic effect of treatment. The main clinical methods for skeletal bone age estimation are the Greulich and Pyle (GP) method and the Tanner and Whitehouse (TW) method. GP is an atlas matching method while TW is a score assigning method. TW method is more accurate of the two. It is technically feasible to automate BAA and much research has been undertaken to computerize the TW method. This research is undertaken to develop new promising techniques for computerized BAA with improved accuracy, specificity, precision, and recall. The objectives of the research are to study the existing techniques available for BAA, to develop new convex hull approach for BAA from carpal bones, to propose new feature ratio approach for BAA from carpal and radius bones, to develop new decision tree approach for BAA from radius and ulna bones, to propose new Hausdorff distance approach for BAA from the Epiphysis/ Metaphysis Region of Interest (EMROI) of phalangeal bones, to analyze and compare the performance of
the proposed four BAA methods using Partitioning technique and to optimize the performance of BAA by the proposed four BAA approaches.

The existing BAA suffered from the drawbacks of not utilizing all the seven carpal bones in BAA, not taking into account all the stages of the bones (Class A to Class J), not considering the fusion of EMROI bones, and reduced accuracy and precision of classification. The four new approaches for BAA developed and reported in this thesis address the problems in the existing BAA. The proposed convex hull approach estimates bone age by extracting three geometric features from the convex hull of each bone, based on which the input image is classified into one of the ten skeletal bone age classes. The feature ratio approach developed is an efficient method combining the features from the carpal bones and radius wrist bone. Two feature ratios, namely (Carpal Region of Interest Ratio) CROI-Ratio and (Radius Region of Interest Ratio) RROI-Ratio are computed, based on which the final age class is determined. The proposed decision tree approach is a proficient method for BAA from the radius and ulna wrist bones. The existing methods that use radius and ulna bones for BAA fail in the extreme cases (initial classes A and B and final classes I and J). But the proposed method succeeds in estimating the bone age for the entire age range of 0 – 10 years. From the radius and ulna bones, 11 epiphyseal features are extracted and fed into the proposed new decision tree classifier (different for male and female cases), which outputs the final bone age class to which the radiograph belongs. The proposed Hausdorff distance approach estimates the bone age from EMROI joints, by constructing the feature vector
FnewBoneStage of 15 features from each EMROI and finally estimating the bone age by calculating the Hausdorff distance between the features extracted from the test image and the stored $F_{\text{new BoneStage}}$ feature vector. The existing BAA method using EMROI does not take into account the extent of fusion of the epiphysis and metaphysis, which is overcome in the proposed Hausdorff distance approach by introducing a new feature named MED. For all the four new approaches proposed, the dataset used for BAA consists of 220 images (110 male and 110 female images). The dataset is organized into three partitions, by varying the number of images used for training and the number of images used for testing. Partition I consists of 120 train images and 100 test images, Partition II consists of 160 train images and 60 test images, while Partition III consists of 180 train images and 40 test images. The standard age classes used in all approaches are Class A to Class J. The input to the system is a radiograph image of size 200 X 300 pixels and the output is the age class (Class A – Class J) to which the image is classified into. The performance of the four proposed approaches is measured in terms of four metrics, precision, recall, specificity and accuracy. Partition III yields results nearest to 100% for all the four performance metrics, for all the four proposed approaches. Partition II scores 100% in all the metrics, for the convex hull approach. For Partition I, the convex hull approach obtained 98.5% accuracy, 99% specificity, 93% precision and 92% recall. The proposed feature ratio approach exhibited 99% accuracy, 99% specificity, 95% precision and 94% recall for Partition II, and 98% accuracy, 99% specificity, 90% precision and 90% recall for Partition I. The proposed decision tree approach produced 99% accuracy, 100% specificity, 92% precision and 93% recall for
Partition II and 98% accuracy, 99% specificity, 90% precision and 91% recall for Partition I. The proposed Hausdorff distance approach showed 99.5% accuracy, 99% specificity, 95% precision and 94% recall results for Partition II, and 98% accuracy, 99% specificity, 88% precision and 90% recall for Partition I. From the literature and based on the suggestions from radiologists, it is resolved that a difference of one year in age (for example, if the radiologist classified it as B and the proposed BAA method classified it as C), can be taken as correct classification because the error of one year in a bone age system is clinically negligible.

By introducing a tolerance limit, ToL = \pm 1\text{year}, all the four proposed methods achieved 100% in all the performance metrics, for the partitions I and II. Thus all the four proposed systems have achieved nearing 100% success rate for all the three partitions. The proposed new BAA approaches have been proved to be more efficient than the existing methods for the age group of 0-10 years for both male and female cases, when validated with the results obtained from two radiologists.

The significance of the research is worthy in the fields of pediatric radiology and pediatric endocrinology. The former is benefited by the research in terms of reduced human intervention, minimized intra and inter rater variability and the ease of automation. The latter is profited by more accurate results of BAA there by improving the diagnosis and treatment of growth disorders.