# Detection of Osteoporosis in X-Ray image data

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**Abstract** – This thesis approaches the problem of detecting osteoporosis on X-ray images of different patients by means of machine learning. Osteoporosis has become one of the western world's most imminent conditions [1] for elderly people, both male and female, as it causes a reduction in bone strength thus leading to a higher risk of broken bones [2]. While effective treatment is still largely unknown, early detection of osteoporosis can help prevent or at least delay the disease by means of a proper diet, adequate exercises, medications and also lifestyle changes [3]. In many cases osteoporosis first comes to the patient's notice when a minor injury, like a fall, causes a fracture. This however indicates an advanced stage of the disease, in which prevention or retardation efforts are ineffective. The necessity for early detection is obvious, yet current methods for detection are solely applicable if there is reasonable suspicion that the patient in fact suffers from the disease. The standard detection method entails high radiation exposure, while other methods include the analysis of bone samples thus requiring bone biopsy. An IEEE-ISBI Challenge for Bone Texture Characterization has been issued in 2014 with the goal to accurately classify osteoporotic cases from healthy controls on 2D bone radiograph images [4]. The overall 174 images, of which the labels of 116 images are known and which are equally divided in osteoporotic and healthy cases, show the microarchitecture of the bone and are to be used to train a classifier. The degree of similarity between images of osteoporotic patients and healthy control subjects is very high, in fact too high for humans to be able to distinguish between them. Thus, it represents a very challenging task for a machine learning program.

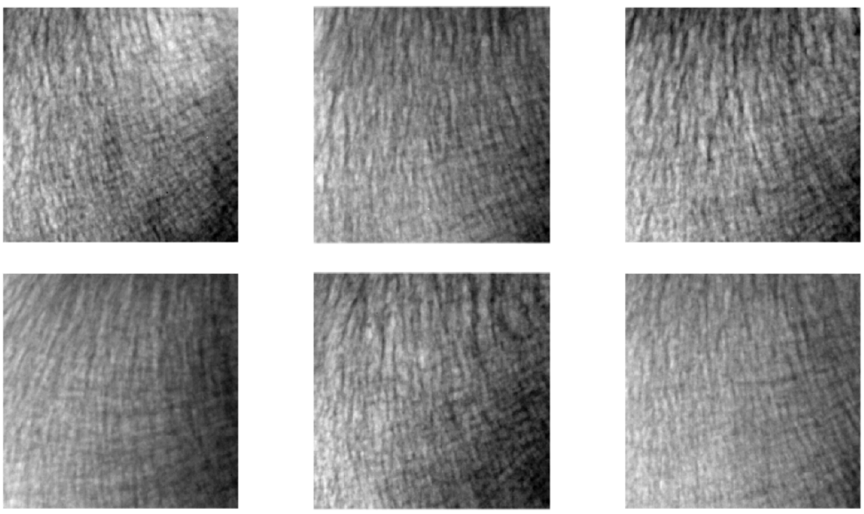

*Fig.1: Samples of available X-ray images. Top row shows images of control subjects, bottom row of osteoporotic patients*

In this thesis, a Support Vector Machine (SVM) is used to obtain a classification of the images. A SVM is a deterministic binary linear classifier, which attempts to separate training data in the feature space into two classes by constructing a hyperplane that separates the feature vectors maximally. The SVM is trained on up to 13 different features (single- or multidimensional) with an almost 300 dimensional feature vector. The features include texture based features like Gabor filters, Haralick features, Law's Texture Energy Filter, Segmentation-based Fractal Texture Analysis (SFTA) and Local Binary Patterns (LBP), but also features related to Phase Congruency (PC), a measure based on local phase information in the frequency domain using Gabor Wavelets. [5] The features include phase symmetry average, average curvature and mean contrast of the PC images. Additionally, statistics based measures like Hu Moments, histograms of gradients and entropy are used.

As some features contain more information than others they are more viable to separate images belonging to osteoporotic patients and to the healthy control group. It is favorable to use only those highly relevant features, therefore the technique *Simulated Annealing* [6] is used to sensibly choose an adequate number of features, which are best to divide the training set into separable classes. Simulated Annealing is a probabilistic approach to a discreet optimization problem which aims at finding the global optimum in a large search space by iteratively considering new feature combinations similar to the currently selected combination, examining if the results are better than previous results, and if so continuing with the new combination. However additionally, combinations with worse results can be accepted to overcome local optima. Acceptance of worse results occurs with a certain probability which decreases over time to ensure that increasingly better results are achieved. With the features obtained by Simulated Annealing the SVM is trained and optimized over the kernel size and the box constraint.

At this stage of the thesis, an accuracy of 79.3% is achieved with the described technique. This represents an improvement of over 10% compared to the best results presented in March 2014 by the official challenge, in which the best accuracy was 65.5% [4]. This enhanced result is most likely due to the expansive feature selection described above. It is reasonable to assume that a more extensive search for best features and optimization of the SVM will yield even better results, thus supporting the attempt for automation of early osteoporosis detection. If reliable automatic detection of osteoporosis by means of analyzing X-ray images with little computational effort was possible, it would be a substantial progress in fighting osteoporosis. Earlier detection could prevent or at least delay the condition and it would not imply additional burdens for the patients since the X-ray images are necessary in any case for other purposes. Even if the automatic detection just yielded correct results in a distinct majority of the cases, supplementary examinations like the standard dual-energy X-ray absorptiometry [7] could be issued if there was a significant possibility for the condition. Therefore, reliable detection of osteoporosis in bone radiograph images by employing a framework that combines feature extraction, feature selection and classification is crucial.

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