Performance Comparison Between Multi-Class and Sequential Binary Classification Neural Networks for Knee Osteoporosis and Osteopenia X-Ray Classification

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Abstract

Osteoporosis and osteopenia are prevalent skeletal disorders that increase fracture risk and require early, accurate diagnosis. The fractures caused by undiagnosed osteoporosis and osteopenia have high mortality rates, especially in older adults, for whom lifestyle factors and hormonal decline can lead to thinner and more porous bones. While DEXA remains the industry standard, access to screening may be limited in certain settings. The automated analysis of routinely acquired radiographs may provide a more efficient approach for early risk identification.

This study developed a machine learning model for the automated classification of knee X-ray images into three categories: normal, osteopenia, and osteoporosis. A total of 2,142 images (714 per category) were sourced from a public dataset. The data was divided using a 90/10 train-to-test split. Images were preprocessed and analyzed, with a subset undergoing resizing and rotational augmentation. Seventeen supervised learning algorithms, all utilizing random initialization without pre-trained weights, were applied for multi-class classification. To determine the optimal framework, the researchers compared two approaches: binary regression and multiple regression.

Ultimately, binary regression achieved a higher accuracy score compared to multiple regression. Multiple regression recorded an average accuracy of 70.21%. Utilizing DenseNet201 resulted in the highest overall performance, achieving a peak classification accuracy of 79.34%. These findings suggest that the developed framework holds potential as a computer-aided diagnostic tool to support early and automated screening in medical image analysis.

Keywords**:** *Osteoporosis, Osteopenia, Random initialization, DenseNet201*