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Research Article

Computerized Method for Osteoporotic Texture Separation from Mandibular Bones Observed in Digital Orthopantomogram Using Unsupervised Machine Learning Technique

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Abstract

Objectives: Digital Orthopantomogram (OPG) is recommended in various dental treatments as it provide excellent image quality with the low radiation dose. These OPG images can also be used for osteoporosis symptoms detections and its prediction using computerized image processing and machine learning algorithms. This paper showcases machine learning unsupervised neural network algorithm using Self Organizing Map to find and cluster statistical features extracted from mandible bone. Input to this machine learning computer program is digital Orthopantomogram (OPG). These features are useful for prediction of systemic disease osteoporosis. Amongst various unsupervised learning methods, neural network is a preferred image analysis tool and Self Organizing Maps and Adaptive Resonant Theory are commonly used unsupervised neural network learning algorithms.

Methods/Analysis: Digital OPG images are used as input for the algorithm explained in this paper. Statistical features are extracted from these images to form a feature vector. The feature vector with four dimensions is input to SOM. SOM maps this four-dimensional feature vector to two dimensions. This paper studies algorithm unsupervised learning using SOM.

Findings: Feature vector generation is fully automatic for image data which is digital dental OPG image. Combination of four GLCM statistical features contrast, correlation, energy, homogeneity for the four angles viz., 00, 450, 900 and 1350 are given as input to SOM and its behavior is observed. Analysis findings show that features at 1350 gave averaging results.

Keywords: *Orthopantomograph (OPG); Mandible; Unsupervised Learning; Self-Organized Map; Feature Extraction*

Abbreviations

OPG: Orthopantomogram; ANN: Artificial Neural Network; SOFM: Self-Organizing Feature Map; SOM: Self-Organizing Map; ART: Adaptive Resonance Theory; GLCM: Gray Level Co-occurrence Matrix; GSOM: Growing Self Organizing Map

Introduction

Early detection of systemic diseases like osteoporosis is useful in its prevention than taking treatment after diagnosis, as, such systemic diseases affects entire body. These disease symptoms can be observed from dental X-rays like Orthopantomograph (OPG) and are helpful for early detection or prediction. Structural and statistical features extracted from these medical images help to find patterns and classify these patterns as diseased and non-diseased [1-4]. Amongst various pattern classification methods, Artificial Neural Network

(ANN) is a preferred machine learning technique as it supports both supervised and unsupervised learning. For image analysis, commonly used supervised artificial neural networks are feed forward ANN, multilayer perceptron ANN, back propagation ANN and unsupervised artificial neural networks are Self-Organizing Feature Map (SOFM) or Self-Organizing Map (SOM) and Adaptive Resonance Theory (ART). In supervised learning desired pattern is available to guide classification of patterns. This desired pattern is also named as a teacher or a class label. When such teacher or class label is not available, the learning process is called as unsupervised learning and classification is termed as clustering.

This research paper demonstrates a clustering technique SOM to give a class label to statistical features of mandible bone extracted from OPG image. Input to the algorithm presented in this paper is a feature vector formed from four statistical measures namely contrast, correlation, energy and homogeneity of Gray Level Co-occurrence Matrix (GLCM). This research will be useful in future to extract osteoporotic symptoms from mandible bone.

Upuli Gunasinghe., *et al.* [1] used Growing Self Organizing Map (GSOM) to address the problem of missing input information. They used hierarchically organized GSOMs incorporated with Bayesian networks to handle missing input values. Model was applied on the zoo dataset consisting of 16 animal features like hair, features, fins, egg, milk, etc. The animals had been separated into five clusters according to their groups as mammals, birds, fish, insects and amphibians. Missing information in input is also predicted based on the existing information. The paper clearly stated input vector parameters and their values. Proposed research in this paper is based on features extracted from digital OPG image and is a totally different area.

OPG is a panoramic x-ray recommended while planning treatment of dental diseases. Literature available shows that OPG images are useful indicatives of systemic disease symptoms like osteoporosis, carotid artery calcification, etc. These findings are interesting for patients and dental surgeons with no additional cost. Various image processing and machine learning tools have been used to extract systemic disease symptoms form digital OPG images [2]. In 1996, five specimens of human maxillary alveolar bones were progressively decalcified and radiographs of each specimen were digitized. Bony regions of interest were selected from the density-corrected images of each specimen. An association was found to be consistent between calcium loss and entropy. There was moderate level of association between calcium loss and energy. In those days, they were very important findings, where research was carried out on specimens which were decalcified manually. The proposed research works on real time data.

MS Kavitha., *et al.* in their research [3] confirmed that, the mandible width is a good measure to identify osteoporosis in postmenopausal women. They used support vector machine in their algorithm to measure osteoporosis which is a supervised method of learning. In the proposed algorithm, learning method is unsupervised.

The research in paper [4], demonstrate combination of supervised and unsupervised methods to reduce limitations of both the methods. According to the paper, the fusion model inherit common defect from both supervise and unsupervised methods. Proposed algorithm in this paper use unsupervised method to study dental data.

Noor Elaiza., *et al.* in [5] focused image processing methods for edge detection. The study used histogram approximation method to identify cortical bone outline from for hand bone. This paper was useful to understand image processing methods for edge detection. The proposed algorithm in this paper use simple thresholding technique and novel strip method for mandible edge detection which is explained in our previous research papers [6,7].

Akira Asano., *et al.* used mathematical morphology to extract trabecular structures of mandible. This paper focused various image processing methods used while analyzing mandible bone. The proposed algorithm use simple thresholding method along with morphological operations to extract mandible from lower jaw [8].

The Self-Organizing Map developed by Professor Kohonen [9] is based on unsupervised competitive ANN. High dimensional patterns are input to SOM and output is a lower dimensional pattern. Here, learning occurs by finding the best matching neurons at output space. First, the network identifies the winning neuron. Then the weights of the winning neuron and the other neurons in its neighborhood are moved closer to the input vector at each learning step using the SOM learning function. The weights of winning neurons are altered proportional to the learning rate [8]. In the proposed algorithm, training of SOM is done for feature vector of four dimensions and it is reduced to two dimensions. SOM training is done using neural network toolbox of MatLab.

Following sections of in this paper present, the module wise explanation of proposed algorithm, results and conclusions.

Materials and Methods

Proposed algorithm uses digital dental panoramic x-ray as an input image. Using algorithms mentioned in [6,7], four statistical GLCM features are extracted. Strip algorithm is applied on 138 digital images. 8 OPG images gave error. 120 images showed separated mandible. Amongst 120 images good quality 75 images were selected for feature extraction. Features extracted at various angles from these images are stored in Excel sheet. Block diagram of these algorithms is shown in figure 1.

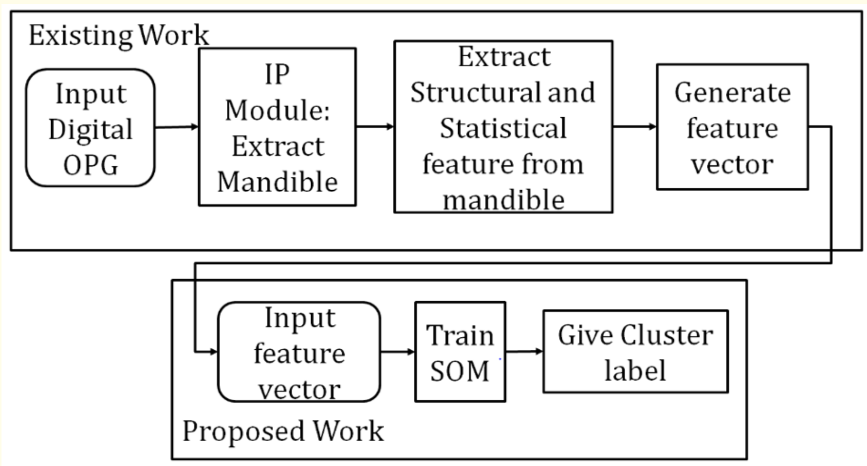

Figure 1: *Block Diagram of a System.*

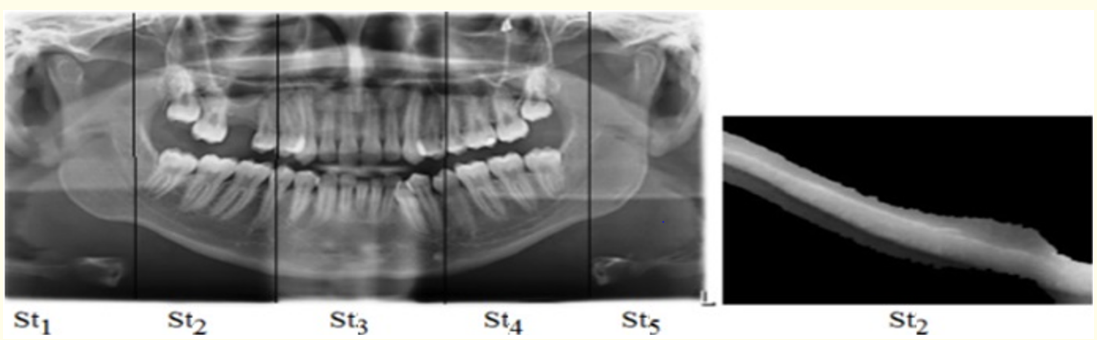

Figure 2: *(a) OPG image separated in five strips. (b) Extracted mandible bone in strip St2.*

Steps followed for this work are as follows: Input is a colored. JPG image of digital dental OPG. Fully automatic novel strip algorithm [6] is used to separate mandible bone from lower jaw. As shown in figure 2a, strip St2 and St4 carry useful information. St1, St5 and St3 are not considered in the algorithm as these strips show shadows of spinal cord which are, as good as, noises or unwanted data for mandible separation work. Strip St2 is considered in further algorithms. Figure 2b shows mandible bone extracted as an out of strip algorithm. This mandible is used to extract statistical GLCM features taken at four angles viz. 00, 450, 900, 1350 [7].

Figure 1 also is the block diagram of existing work, which includes input, SOM training and clustering blocks. Coding is carried out in MatLab 7 using Neural Network toolbox. Four statistical texture features namely contrast, correlation, energy, homogeneity for the four angles viz., 00, 450, 900 and 1350. These statistical and structural features form a feature vector which is given as input to SOM. Training of SOM is done using 75 images with 500 epochs. Training for every angle is carried out separately. Training for all features taken together is also carried out. Observations are noted and discussed in results.

Results and Discussion

The proposed algorithm for unsupervised learning using SOM, is tested on 75 OPG images obtained from practicing dental professionals. For majority of the images, image sizes in pixel are 2440 x 1292 or more. Pixel resolution is 235 dpi with 24-bit depth. Observations on training SOM at various angles are mentioned in table 1.

Cluster label	0^0	45^0	90^0	135^0	Same class label observed in all angles	All angles taken together
Cluster label 1	27	46	39	30	15	30
Cluster label 2	48	29	36	45	21	45

Table 1: *Count of cluster label for various options.*

It is observed that, for all the angles, out of 75 images, 15 images belonged to class label 1 category and 21 images belonged to class label 2 category. This means, around 50% images showed same results for all the angles viz. 00, 450, 900, 1350. This implies that for around 50% data, class labels are not matching and GLCM statistical features at various angles provide different information. When all the angles are taken together as input to SOM, input is a 16-dimensional feature vector. 16-dimensional data is also input to SOM and observations are noted down which are mentioned in the table 1. It can be observed from the table that the results of all angles taken together are same as results of angle 1350. Thus, features at 1350 are very important as compared to other three angles and they give averaging features.

Conclusion

SOM training was carried out on 75 images with four statistical features taken at different angles. The proposed algorithm for feature extraction and clustering is fully automatic. Feature vector is of dimension four. Using SOM dimensionality of input vector is reduced from four to two. It can be concluded that GLCM statistical features at different angles gave different results. When features of all angles are combined, all the results appear to be same as those of angle 1350. This implies that information at angle 1350 gives average information of all the features.

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