A Study on Estimation of Degeneracy in Both Hard and Soft Tissue Region Using Medical Imaging

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Abstract: Multimodal medical imaging (X-Ray, CAT, MRI), functional imaging (fMRI, SPECT, PET) and other diagnostic modalities as biomedical signals EEG, ECG, MEG are increasingly being used by the clinicians to obtain an 'integrated view' for therapy planning. The objective of present work has taken two avenues (1) understanding of human brain (2) study of bone diseases and estimation of bone erosion process from osteoporosis. The paper is mainly based on development of improved image processing methodologies for understanding of human brain firstly from (a) quantitative study of degenerative disease like Alzheimer's disease secondly (b) to distinguish malignancy from benignancy and to find the 'malignancy / benignancy index' which accurately furnishes an estimation of the degree of malignant transformation or malignant potential of a space occupying lesion. Thirdly (c) to study neuro- plasticity related to cortical change and to find the correlation between the neuro- plasticity and the degenerative Alzheimer's diseases. The hard tissue degeneracy has been estimated using conventional radiographs. An attempt has been made to detect the *nature and grade* of bone erosion process in *osteoporosis* using *mathematical approach of shape theory* [3],[4],[5],[7]. The aim of work is primarily to develop the software package based on image processing techniques which will be cost effective and will be economic from the aspect of clinical diagnosis.

I. Introduction :

In present paper some experiments have been carried out in order to find out the degeneracy in both soft and hard tissue regions using different modality medical imaging appropriate for certain specific diseases in either soft or hard tissue regions. Author has concentrated in analyzing different brain tumors obtained from CT and MR modalities in two basic groups of tumors (a) the non – cancerous benign tumor and (b) cancerous malignant lesions. From the experiment a malignancy / benignancy index has been computed to find the tendency of the growth towards benign lesion or towards malignant lesion . The required knowledge base is modeled by correlating the image characteristics and tumor biology. In another experiment a quantitative measure has been accomplished using computational technique to determine the prognosis of degenerative diseases like Alzheimer's disease and the neuronal plasticity of human brain using CT and MR images of section of human brain. In another phase of work the quantitative measure of hard tissue degeneracy has been carried out by an investigation of a class of metabolic bone diseases called osteoporosis, very common bone disorder resulting a major disability using radiographic image modality for diagnostics and therapeutic planning. A methodology is proposed depending upon the mathematical theory of shape to compute (a) an erosion factor for different cases of osteoporosis (b) a gradation of the disease so that doctor make quantitative assessment and decide if the disorder can be treated conservatively or surgically.

II Human Brain Understanding : Using Knowledge Based Approach Degeneracy, Malignancy and Neuro Plasticity

It is now becoming evident that the brain structure is subject to continual change in general morphology of both of its fundamental unit (neuron) and glial cells – and changes in various messengers related to both neural and glial function. It is therefore appearing that the 'understanding of brain' and its relation to behavior requires an understanding of the brain in its environment which can be described as an 'Ecological analysis of the brain' internally and externally. The paper is also concerned to the understanding of human brain from quantitative study of degenerative disease like Alzheimer's disease (AD), Malignant / benign growth of tissue region in human brain and neuroplasticity related to cortical change. Many works [1], [2] have reported the correlation between the neuroplasticity and the degenerative Alzheimer's diseases. The Alzheimer's disease attacks neuroplastic process , the capacity to store new information affected by Alzheimer's diseases. Alzheimer's disease is characterized by neuro degeneration also. A central factor in Alzheimer's disease is ApoloipoProteinE which is produced by glial cells and accounts for at least 50% of the Alzheimer's disease that occurs between 60 -80 years of age. APOE plays a central role in cerebral cholesterol transport. Recent evidence has shown that cholesterol metabolism in Alzheimer causation which also support the neuroplastic hypothesis of

Alzheimer's diseases. In order for brain understanding from the neuroplasticity related to cortical change and neurogenesis - a quantitative measure using computational technique is required to determine the prognosis of degenerative diseases like Alzheimer's disease and the neuronal plasticity of human brain. In order to measure the degree of prognosis of the AD patients methodologies have been developed based on 'shape theoretic approach'. The ROI of different modalities of images are brought to same plane by appropriate transformation. Where one set of landmarks can be mapped onto the other for a closed match. Using a Taylor series expansion the co-ordinate transformation can be expressed as a polynomial series. The series can be split up into two parts, an affine part and a non-linear part. The point is that the co-ordinate transformation is in some sense a measure of `shape difference' or the `shape difference' can be characterized via the co-ordinate transformation. Let x_i, y_i and x'_i, y'_i, be the two sets of landmarks for i = 1, 2... n. Landmarks are some conspicuous features of the structures that indicate some events marking some stage or stages in the development of the structure and they are invariant under translation, rotation and scaling. In present problem the landmark points are detected on a chosen concavity as the point of maximum curvature by convex hull method [4]. The transformation considered can be expressed as, $x_i' = a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 xy + a_5 y^2 +$ …….and $y_i' = b_0 + b_1 x + b_2 y + b_3 x^2 + b_4 xy + b_5 y^2 +$ …….. The measure of goodness of matching depends on the selection of control points and their mapping by fitting a function. Control points are features located in the input image and whose location in the final output is known. A measure of goodness of fit (GOF) is achieved by the process of minimization of an error factor. Here an error matrix termed as `error factor e' is defined which is deduced from the difference between the predicted value and the actual value and which is in a sense a distance measure between the corresponding landmark or in other words a measure of shape difference [3],[5],[11]. For each chosen concavity the best matching is searched by computing the error terms for each case $e = [(\partial x_m)^2 + (\partial y_m)^2]^{1/2}$ … where, $\partial x_m = x'_m - x_m$ and $\partial y_m = y'_m - y_m$.
The measure of mismatch of the ROI of different modality images which is medical feature for the AD patient indicates the prognosis of the disease.

The approach for tumor classification has been developed using the medical investigation which predicts that the benign lesion grow uniformly and the nodule is approximately circular, contour is well defined whereas the malignant lesion grows fast , non –uniformly and the contour of the lesion is irregular in nature. If the growth of the tumor is assumed to be spherical in nature considering a known regular geometry a degree of mismatch between the contours [10],[12] of different tumor lesions and the `spherical model' may be computed. A shape similarity / dissimilarity measure μ between the contours of the `model' and the tumor lesions may indicate the low grade benignancy or high grade malignancy of tumors. The low grade homogeneous benign glioma are usually smooth masses with single radius where as malignant transformation have multiple protrusions [6],[4],[7],[8]. The concept of symmetry analysis of shape is utilized to classify the tumors mainly in two broad categories benign and malignant transformations. A shape of a contour is described on the basis of its structural features using chain code representation. The descriptors of the shape are information preserving. So that it is possible to reconstruct any reasonable information of the shape from the descriptors. In classification of tumors the idea of shape similarity measure is implemented by minimization of distance function D between the contours of tumor lesions and the model. These measurements give the indication of benignancy or malignancy of tumor lesions from a coarse to a finer grading and will be helpful to the medical practitioners for preoperative diagnostic planning considering the condition of the patient.

IV RESULTS : : This section includes some results for classification of CNS (central nervous system) tumors appearing in brain detected from CT and MR images

Case	Measure of μ	Tendency of Tumor growth	Nature of of tumo	Grade of Benignancy
I	0.72	Benign	Intracranial Cyst	Grade 3
II	0.59	Benign	Primary Neoplasm	Grade 5
III	0.56	Benign	Glioma	Grade 5
IV	0.41	Malignant	Primary Neoplasm	-
V	0.65	Benign	edema effect	Grade 4

Neuro Plasticity and Learning Using Entropy :It is appearing that the 'understanding of the brain' and its relation to behavior requires an understanding of the brain in its environment which can be described as an 'Ecological analysis of the brain' and an 'ecology of the brain' deals with the brain in its environment internal and external. Plasticity mediated competitive learning is an attractive solution from both neurobiological and computational neuroscience point of view. 'Schraudolph and Sejnowski'[1] suggested a model that extend the advantages of simple inhibition to distributed representations by decoupling the competition from the activation vector. In particular the neural plasticity can be defined as the derivative of a logistic activation function and use it as the medium for competition. Considering the binary entropy ; $H(z) = -z \log z - (1-z)\log(1-z)$ …
And considering a well-known approximation of H(z) as , $H(z) \cong 8 e^{-1} z (1- z)$ …
Since plasticity is a logistic node , $f'(y) = (\partial / \partial y) \{1 / 1 + e^{-y}) = z (1-z)$ …is in fact proportional to H(z) – that is a logistic node's plasticity. More general, $\sum f'(y) \propto \sum H(z)$ …and which indicates the how much more information remains to be gained by learning from a particular input.

III. Radiographic Diagnostic Procedure of Bone Erosion Process in Osteoporosis

Present study is based on mathematical theory of shape of bone contour to compute the erosion factor for osteoporosis [9],[13],[14],[15] and a gradation of the diseases. It also helps in quantitative assessment of bone erosion process so that the doctors can access the mode of treatment of osteoporosis. A methodology is proposed depending upon the mathematical theory of shape to compute (a) an erosion factor for different cases of osteoporosis (b) a gradation of the disease so that doctor make some quantitative assessment and decide if the disorder can be treated conservatively or surgically. Attempt has been made for estimation of percentage bone material loss due to osteoporosis and erosion of spine from conventional radiographs. The outline of an eroded vertebra and a non-eroded vertebra for necessary shape analysis has been considered. In case of bone erosion the loss of bone contours occurs [16]. Hence at a micro level the bone erosion is estimated as a function of shape similarity / dissimilarity measure between the contour of an eroded vertebra and a normal one. Using this technique for quantitative analysis the hazards and harmful effects of excessive radiation in human body can be avoided. A '*shape similarity measure* μ' is computed which is giving the '*distance function measure D*' in terms of two string numbers *d1* and *d2* belong to a set between two contours. From the '*shape similarity measure*' the '*degree of bone erosion* ε' is computed as , $\varepsilon = (1 - \mu) / (1 + \mu)$. The erosion factor ε which gives an estimation of bone erosion can be derived from the expression of similarity measure μ. The regions of higher resemblance have a higher degree of shape similarity.

Result : Estimation of Shape Similarity Measure μ, Erosion Factor ε and Grade of Erosion for different patients having osteoporosis

Case	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
D^*	169.6	254.8	35.7	257.9	472.4	135.7	149.8	101.6	71.6	77.3	173.2
μ	0.8	0.52	0.95	0.66	0.4	0.55	0.51	0.61	0.72	0.6	0.7
ε	0.11	0.32	0.02	0.21	0.43	0.29	0.33	0.24	0.16	0.26	0.18

Range of ε values vs the grade of bone erosion

Range of ε values	0.00 - 0.01	0.11 - 0.20	0.21 -0.30	0.31 - 0.40	0.41 – 0.50	0.51 - 0.60	0.61 - 0.70	0.71 -0.8
Grade of erosion	I	II	III	IV	V	VI	VII	VIII

From the conventional radiographs using proposed method it is possible to assess the loss of bone density from the investigation of the radiological change, in respective region where the appearance of more dark region in the vertebra, indicates the less opacity and higher degree of erosion, with a meaningful (acceptable by clinicians) degree of accuracy. Clinicians in general make a guess of the bone density loss from the radiographic features. This new gradation technique proposed will assist the medical practitioners to take more accurate treatment planning by classifying the cases in clinically meaningful grades.

Acknowledgements

The work is part of a project funded by Department of Science and Technology (DST), Govt. of India on Knowledge Based Approach in Bio-Medical Imaging for diagnostic and therapeutic planning.

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