NSST-based feature descriptors for remote sensing and bio-medical image retrieval

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Hilly Gohain Baruah

Registration No. TZ167096 of 2016

Department of Electronics and Communication Engineering

School of Engineering, Tezpur University

Tezpur, Assam, India - 784028

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Chapter 6

Conclusions and Future scope

In this chapter, we summarize the key contributions made in this thesis. We also provide a few potential areas of research that might be explored in future.

6.1 Concluding remarks

The main focus area of this research has been to develop NSST based feature descriptors which extract discriminative features for retrieval of RS and biomedical images. The conclusions drawn from each contributing chapters are presented below.

- In chapter 3, two NSST-based image feature descriptors that use statistical modeling of NSST coefficients for RS images are proposed. In the first descriptor, the four parameter SNIG distribution is shown to provide best fit to the highly non-Gaussian statistics of NSST coefficients of RS images. An EM type of algorithm is considered for ML estimation of SNIG parameters. The final feature vector is constructed using the SNIG parameters estimated from the NSST detail subbands, and the mean and standard deviation estimated from the NSST approximation subband. For PatternNet dataset, the NSST-SNIG descriptor is found to obtain improvement of [ANMRR,MAP] values over to LBP, Granulometry, Gabor L, Gabor RGB, and FV by [6.99,5.10]%, [21.90,115.89]%, [25.02,80.83]%,[6.99,18.80]% and [16.05,63.91]% respectively.

  In this next work, through KS test and log histogram plots it has been shown that the 2-state LM distribution best approximates the statistics of NSST detail subband coefficients of RS images when compared to SNIG, BKF and laplacian pdf's. An EM algorithm is used to estimate the parameters of LM distribution. Mean and standard deviation from approximation subband are extracted. These statistical features are fused together to construct the global NSSTds features. Further we extend the existing LTP to 3D-LTP concept by utilizing the spatial RGB planes. Through this, we encode both color features and local intensity variations across RGB planes. This 3D-LTP features are finally fused together to increase the effectiveness of the feature descriptor for RSIR. This fused feature NSSTds-3DLTP with both global and local features is demonstrated to perform better in comparison to other state of the art hand crafted descriptors. For PatternNet dataset, the NSSTds-3DLTP showed improvement of retrieval performance in terms of [MAP,ANMRR] compared to Gabor RGB, Granulometry, LBP, FV, VLAD, and MRELBP by [32.79, 10.34]%, [141.30, 24.72]%, [17.47, 10.34]%, [83.20, 19.07]%, [21.56, 3.60]%, and [19.30,0.48]% respectively.

- In chapter 4, two NSST domain texture feature descriptors that use bit-plane decomposition in transform domain are introduced for the retrieval of biomedical images. The class of existing local descriptors such as LBP fails to catch very fine image details which greatly affects its retrieval performance. The spatial domain bit-plane decomposition based image descriptors have shown good results in this dimension. In the first work, we have attempted to investigate the bit-plane decomposition and encoding concept in NSST domain for biomedical image retrieval in order to improve its discriminative power of features. Due to the sensitivity of NSST coefficients w.r.t the local variations, the spatial domain feature extraction schemes cannot be implemented directly in the transform domain. Therefore, we apply the bit-plane decomposition directly on image NSST coefficients after the addition of non-linearity followed by smoothing(also normalizing it in the range of [0-255])over the coefficients in order to overcome the sensitivity issues. Then we have extended the existing spatial domain LBP-DAP in NSST domain which encodes the combination of 'centre-neighbor' and 'neighbor-neighbor' dissimilarity association and using an 'adder' before being encoded to a value. Afterwards, the NSST-LBPDAP is computed by comparing this encoded value to the corresponding centre pixel energy reference value. This NSST-LBPDAP implementation showed encouraging results for, NEMA-CT, TCIA-CT and YORK-MRI in terms of % ARP and % ARR. For TCIA-CT dataset (top match 30 images), NSST-LBPDAP outperforms LDEP, LWP, LBDP, LBDISP, LBPDAP, LB-

PANDP, and CSLBCOP in terms of [ARP,ARR]% by [20.7677,15.9942]%, [18.7406, 13.4646]%, [11.6347,8.6615]%, [3.2564,2.5456]%, [1.1106,0.1441]%, and [4.20,1.23]% respectively. The encouraging extension of spatial LBPDAP to NSST-LBPDAP exhibits high feature dimension which is required to be addressed in case of transform domain bit-plane encoding schemes.

Motivated by NSST-LBPDAP, we introduce a new improved NSST domain bit-plane decomposition based descriptor called NSST-LBNDP. The final 8 bit values obtained after applying normalization on the values (obtained after non-linearity addition and smoothing) are decomposed into 8 bit-planes through bit-plane decomposition. A powerful dissimilarity association between each neighbor and all of its adjacent neighbors is used in each bit-plane with regard to each reference to produce a dissimilarity matrix that is then thresholded, multiplied with the appropriate weights, and added to produce an encoded bit-plane value. The 8 bit-plane encoded values are then all compared to the corresponding reference local energy feature value to produce binary values, which are then added and appropriately weighted to provide the final NSST-LBNDP value. This descriptor obtained good retrieval performance for CT and MRI image datasets considered for experiments. For TCIA-CT dataset, the NSST-LBNDP with moderate dimension shows performance in terms of $[ARP, ARR]\%$ (for top match of 30), is found to be better than LDEP, LWP, LBDP, LBDISP, LBPDAP, LBPANDP, CSLBCoP and Cont.-TrP by [27.93,20.87]%, [24.74,17.33]%, [14.71,11.16]%, [4.78,4.18]%, [2.50,1.68]%, [3.75,2.82]%, [24.05,17.83]% and [5.63,2.78]% respectively.

- In chapter 5, two NSST-based feature descriptors that combine shape and texture features are proposed for biomedical image retrieval. In the first approach, spatial ZM based global shape feature and a powerful NSST domain maximum of subbands local directional edge pattern (MSLDEP) based texture features called ZM-NSST-MSLDEP is introduced. This fused feature descriptor captures both shape and texture details present in biomedical images. ZM features are extracted from the spatial biomedical images. Before extracting the local texture features from the NSST subbands, the nonlinearity followed by smoothing is applied to the NSST subband coefficients, which are then normalized to an 8 bit value. The local texture information is then generated utilizing the directed maximum edge idea from a set of NSST detail subbands available in a scale. In a given scale, with respect to each reference, the edges in a particular direction are computed for each NSST detail subband, and the NSST domain local texture feature value in that direction is obtained based on the magnitude of the maximum to minimum edge distributions of all subbands. The NSST domain local texture feature values at 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° directions are computed at each scale. Local texture details from image NSST approximation subband is captured through simple LBP 'uniform' operator. Two different types of features together effectively minimizes the respective limitations of each other. The NSST-MSLDEP inherit the attributes of both NSST and the effective edge magnitude based features. In NSST-MSLDEP, the edge information in a given direction are computed from each NSST subband present in a scale and then these information are altogether encoded by considering the magnitude of maximum to minimum distribution of edges. This way both the NSST intra and inter-subband details are extracted effectively which supplies improved discriminative features. This fused descriptor showed significantly better retrieval performance in terms of ARP and ARR. For TCIA-CT dataset, at a top match 30 (in terms of [ARP,ARR]%), the % improvement of ZM-NSST-MSLDEP is [29.32,23.37]%, [26.10,19.76]%, [15.96, 13.46]%, [5.92,6.34]%, [3.62, 3.78]%, [25.40,20.27]%, [6.78,4.91]%, [5.97,6.90]% and [2.45,2.78]% over LDEP, LWP, LBDP, LBDISP, LBPDAP, CSLBCoP, Cont.-TrP, LDMaMEP, and LDEBP descriptors respectively.

Inspired by the success of ZM-NSST-MSLDEP, we attempted to form feature descriptor which provides improved retrieval performance with low feature dimension. For that we have modelled the singular values obtained after applying SVD on image NSST detail coefficients with Weibull distribution. The parameters of Weibull distribution is estimated through ML scheme. These parameters together with ZM from spatial image and 'uniform' LBP and mean and standard deviation from image NSST approximation subbands are concatenated together to form the ZM-NSST-SVDw descriptor which obtained better retrieval performance with very low feature dimension. The use of ZM based shape features and discriminative texture features from accurate statistical modeling of image NSST subband singular values provides effective set of features for biomedical image retrieval. For TCIA-CT dataset, at top match of 30, ZM-NSST-SVDw shows improvement over LDEP, LWP, LBDP, LBDISP, LBPDAP, CSLBCoP, Cont.-TrP, LDMaMEP, and LDEBP by a margin of ,[29.79,23.59]%, [26.55,19.98]%, [16.38,13.67]%, [06.30,06.54]%, [03.99,03.98]%, [25.85,20.49]%, [07.16,05.11]%, [06.34,07.10]%, and [02.82,02.97]% in terms of [ARP,ARR]% respectively.

6.2 Future scope of research

The descriptors proposed in this thesis exhibit competitive performance in retrieval but at the same time open the door for new directions which can be explored in future research. These future research directions can be summarized as follows:

- The deep CNN based features have demonstrated excellent advancements in retrieval/classification applications of RS images. The concept of NSST-based local global feature fusion in a deep learning framework with applications to RS images would be interesting to investigate.
- The effective blend of NSST-based handcrafted and deep features in relation to improved biomedical image retrieval/classification is an important field to explore.
- The image NSST subband coefficients exhibit highly non-Gaussian statistics. The univariate models explored in this thesis are quite effective in capturing these statistics. However exploiting the multivariate models in order to capture the image NSST subband statistics could further improve the existing results and would be interesting to investigate.
- Motivated by the powerful characteristics of NSST, the extension of NSST based techniques in a deep learning framework to applications like image denoising, compression artifact removal etc. would be intriguing.