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TENSOR BASED MEAN-SHIFT POLSAR IMAGE ENHANCEMENT

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MEAN-SHIFT FILTERING

Modes of probability density function (pdf) could be used to define classes or clusters. The mean-shift approach uses a local estimation of the pdf and moves every data points toward the modes. At a data point, we can estimate the local pdf by using a Gaussian kernel. The data point x is moved in the direction of higher density or in the direction of gradient assent. For a point $\boldsymbol{x}$, the mean $\boldsymbol{m}$ of surrounding points weighted by a Gaussian kernel is calculated. The direction is given by the difference between $\boldsymbol{x}$ and $\boldsymbol{m}$, $-(\boldsymbol{m}-\boldsymbol{x})$.

An advantage of the mean-shift technique is that both radiometric (D_r) and spatial (D_s) information could be used in the weighted mean calculation. The spatial distance between pixels is used with a Gaussian weighting function. All the useful information is integrated into the weight $W_{i,j}$ between the window central pixel $\boldsymbol{i}$ and the neighbor pixel $\boldsymbol{j}$.

$$W_{i,j} = EXP\left\{-D_r(Z_i,Z_j)^2 \Big/ H_r^2 - D_s(p_i,p_j)^2 \Big/ H_s^2\right\}$$

where H_r is the radiometric scaling factor. p_i is the position of pixel $\boldsymbol{i}$, $p_i = (x_i,y_i)^t$. D_s is a circular Gaussian weighting function and H_s is the spatial scaling factor.

In a homogeneous area, multi-look PolSAR covariance or coherency pixel values Z_i could be viewed as draw from a Wishart distributed population. The likelihood ratio statistic is generally used to evaluate if two pixel values belong to the same population. It could also be used to evaluate the similarity between two pixels and to define a pixel distance, . For the Wishart distribution, the measure uses the log of the covariance matrix determinants,

$$D_r(Z_i,Z_j)^2 = 2\ln\left|(Z_i+Z_j)/2\right| - \ln\left|Z_i\right| - \ln\left|Z_j\right| .$$

New radiometric pixel value Z_i is obtained from the weighted mean of neighbor pixels Z_j, $\sum Z_j W_{i,j} \Big/ \sum W_{i,j}$. At each iteration, the image smoothing is improved. Contours are well preserved because pixels on one side are dissimilar to pixels on the other side. To improve contour preservation, we examine how other contextual information can be integrated into the weight calculation.

POSITION TENSOR

Standard image filtering uses only the pixel position, D_s, to define the weight. The mean-shift filtering uses D_r and D_s. The spatial and radiometric dimensions are used to calculate the weights and both informations can be updated. As the radiometric value, the pixel position can be moved toward its window mean. Iteratively moving the pixel positions will change the pixel distances and the weight values. The updating of the pixel radiometric values Z_i will be affected.

The mean-shift approach allows the integration of others features. We are particularly interested in using the weights to define new attributes. The multi-look coherency or covariance matrix can be view as a tensor value calculated from one-look backscatter vectors. We propose to use the weight to define a spatial 2x2 covariance matrix or tensor, $\Sigma_{s,i}$

$$\Sigma_{s,i} = \sum W_{i,j}\,(p_j - p_i)(p_j - p_i)^t \Big/ \sum W_{i,j}$$

The tensor captures edge or orientation information. For example, for a pixel on a road, its neighbours that are similar and have a large weight value will be located along the road. If the weights are considered, the neighbour dispersion will follow the orientation of the road. The tensor orientation could now be used in the inter-pixel distance D_s with the use of the Mahalanobis measure.

Furthermore, the spatial tensor can be added as new feature dimensions to the pixel values and the distance between tensors can be included into weight calculation. The S1 similarity measure of Garcia (BMC Evolutionary Biology 2012, 12:222) is used to evaluate the distances between tensor matrices. As the other data dimensions, the spatial tensor is also moved toward its mean.

Good results are obtained from a polarimetric SAR image of Mer Bleu area, near Ottawa. We have important noise reduction and smoothing inside fields, while edges and small targets are well preserved. We have more important smoothing than the Lee Sigma filter. We get finer grain and better detail resolution. Results for San Fransisco and Oberfaffenhofen images will also be presented.