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Road (line) Smoothing by SCMS and Circle Window Methods

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Abstract: *In the feature extraction methods, the features have noise like spikes or ridges and gaps. These affect the accuracy. This paper aims to remove the connected noise (ridges) and gap filling in between the two points of roads extracted by an index Normalized Difference Asphalt Road Index (NDARI).The extracted roads from the methodology have connected noise like spikes. This connected noise can remove or smooth by a Subspace Constrained Mean Shift (SCMS) algorithm is a non-parametric and Circle Window method. By using these methods, roads (line) features smoothed and shown in the experimental results.*

Keywords: Landsat-8, Remote Sensing, Mathematical Morphology, Mean Shift, Kernel Density Estimation, Gap Filling, Sub-space Constrained Mean Shift.

I. INTRODUCTION

The road feature extraction from remote sensing (RS) images is a typical task and is one of the most research topics around the world researches. It is very useful for map updating, urban planning, and so forth. Road feature extraction from RS (digital) images and enhance (smooth and gap-fill) of extracted road features has been an active research topic for more than a decade.

In S.L.K.Reddy and C.V.Rao *et.al* [1] proposed an index based road feature extraction from the LANDSAT-8 OLI images. The road features extracted by using the NDARI index with Markov Random Fields (MRF) model. After extracting the road features from the NDARI index [1], the roads have noise i.e., like ridges or spikes or commission errors. Also observed that the gaps in between the roads occur mainly due to the Trees, Buildings besides of roads because of the reflectance of concrete is very high than asphalt. These gaps are not able to connect without any knowledge, because of the roads doesn't have any defined structure.

To remove or smooth the noise in the images various methods are proposed [2], [3]. By using Mathematical Morphology (MM) i.e., opening, closing, thinning, and pruning operators can remove the very little noise. In MM, operators require to define the structuring element (SE) size and shape. To define the size and shape of the SE is difficult, due to Low Resolution (LR) image has less road width (1 pixel).Due to this, when we apply MM on these type of images, few roads may miss the width of 1-pixel road. However, this method produces the ridges or spurs and also less the smoothness of roads.

In literature, to remove the noise, the regression model method is used. The linear regression model is not applicable for this type (Low Resolution) of application [2]. Miao, Shi, Zhang, *et al.* [3] proposed a method to get the centerline by MARS (Multivariate Adaptive Regression Splines). It is a piecewise (multiple) linear functions. In the piecewise linear function requires several start and endpoints of the nonlinear line. Tensor Voting (TV) [8] method was used to eliminate the gaps in VHR images by finding the endpoints of road direction and gap length. Ghassabeh *et.al* [4] has theoretically given analysis on the convergence of Mean Shift (MS) and Subspace Constrained Mean Shift (SCMS). These two algorithms are mainly used to move the data point's locations. Comaniciu and Meer *et.al* [5] proposed a method to compute the recursive mean shift based on kernel regression. SCMS is a nonparametric, iterative algorithm that has recently been proposed to find principle curves and surfaces based on a new definition by Ozertem and Erdogmus *et.al* [6]. SCMS is a generalization of the MS algorithm [5] that iteratively finds probability density function (PDF) from the estimated data samples in the local subspace. [4] applied to synthetic data and now we are using real-time images. i.e., to remove the connected noise problem, a method SCMS (Subspace constrained mean shift) is selected to get the centerline from data points.

Here, SCMS is used to smooth or to get the centerline from noisy points. The SCMS method projects all of the input data points to the closest ridge of the probability density function (PDF) generated by the Kernel Density Estimation (KDE) [7]. It is a non-parametric technique for density estimation in which a known density function (kernel is Gaussian) is averaged across the data points to create a smooth approximation. A KDE is a generalization of histograms to define density estimates in any dimension that are smooth. With a kernel such as the Gaussian kernel, a KDE requires a single user parameter bandwidth. By given the bandwidth, KDE is uniquely determined and which can take complex non-convex shapes.

One more method is used to smooth the image by using the circle window method. This is based on MM. In this, gaps are connected without morphological operators like Dilation, Erosion. At the endpoints if each line, create a circle and where two endpoint circles are met, those gaps only connect.

II. SUB-SPACE CONSTRAINED MEAN SHIFT (SCMS)

The SCMS algorithm starts from a probability distribution to form a finite data set and forms a kernel density estimate f^ based on data. Let the given data set with d-dimensional and the kernel density estimate with kernel K and bandwidth parameter h is given by

$$\hat{f}(x) = \frac{1}{n}\sum_{i=1}^{n} k\left(\frac{x-x_i}{h}\right) \qquad (1)$$

where n is the number of data samples, h is the bandwidth parameter is initialized by the user. K is the kernel function. Some kernel functions are defined in Table 1. An iteration of SCMS evaluate the MS [5] vector m(x) as

$$m(x) = \frac{\sum_{i=1}^{n} x_i g\left(\left\|\frac{x-x_i}{h}\right\|^2\right)}{\sum_{i=1}^{n} g\left(\left\|\frac{x-x_i}{h}\right\|^2\right)} - x \qquad (2)$$

where $g(x) = -K'(x)$

SCMS algorithm projects the MS update onto the orthogonal subspace spanned by the largest Eigenvectors (V) corresponding to the largest Eigenvalues of the inverse covariance matrix given by

$$y = VV^T m(x) \qquad (3)$$

The inverse covariance matrix of PDF estimate at that point given by

$$\Sigma\ (x)^{-1} = -\hat{H}(x)\hat{f}(x)^{-1} + \nabla\hat{f}(x)\nabla\hat{f}(x)^T\nabla\hat{f}(x)^{-2} \qquad (4)$$

Where H(x) is a Hessian matrix, $\nabla\hat{f}(x)$ is a gradient of PDF estimate at x and T represents the Transpose.

The gradient and Hessian matrices for KDE are

$$g(x) = \hat{f}(x)^{-1}\nabla\hat{f}(x)^T$$
$$H(x) = -\hat{f}(x)^{-2}\nabla\hat{f}(x)^T\nabla\hat{f}(x) + \hat{f}(x)^{-1}\nabla^2\hat{f}(x) \qquad (5)$$

The summarized steps of the SCMS algorithm are given in Algorithm 1.

Algorithm 1: Subspace Constrained Mean Shift

1) Initialize number of iterations (j) and Bandwidth (h)
2) Evaluate Mean Shift update m(x) for an iteration using eq.no. 2.
3) Compute Gradient, Hessian, and local inverse covariance matrix using eq.no. 4.
4) Perform Eigen decomposition on the local inverse covariance matrix.
5) Project the mean shift update onto the orthogonal Subspace spanned by the largest eigenvectors corresponding Eigenvalues of the inverse covariance.

As in [4], [6], stopping rule not taken by us, because in real-time application to set the stop parameter is more critical than fixing the number of iterations. And also bandwidth parameter h selection problem some more detail in [5] for the SCMS algorithm. Small values of bandwidth h lead to very spiky estimates (i.e., is not that much smoothing) and large bandwidth h leads to over smoothing.

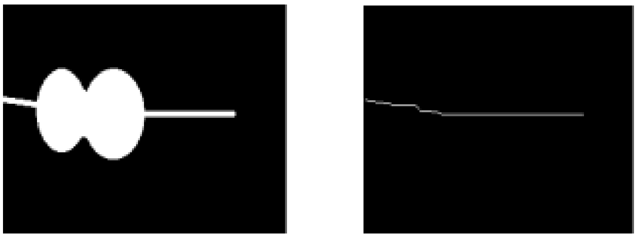
SCMS able to smooth the image but the location of the pixel position and junctions are moving away from the original. Also, it is time consumable.

Gaps Filling by Circle Window

In this paper, presents a method to connect the gaps in-between road points based on finding all endpoints of roads, at every endpoint creates a circle with a defined radius. This method needs to define the gap (pixel difference between two endpoints). Here, where two endpoints of circles are connected only considered and remain removed. When a circle is thinned by Morphological operations it forms only dot (center point). If two circles are connected and then morphological thin operation forms a line between two center points of circles. The example of the presented method shown in Figure 1. In this Figure 1(a) shows the two circle are placed at points of line and are in connected. By the thinning method it connected as shown Figure 1(b). The summarized steps of Linking are based on the circle window method in Algorithm-2.

Algorithm 2: Circle Window method for Linking

1) Hierarchically select the road has a gap only.
2) Detect the endpoints of the hierarchically selected road and observe the gap between the points and fix the radius of the circle.
3) Now, create a circle at every endpoint of the road with an observed gap length radius.
4) Select the Where two endpoints of circles are connected based on area.
5) Apply the Morphological thinning
6) Repeat steps1 to 5 until where the gaps need to connect.



(a) (b)

Figure 1: Example of circle widow method (a) At two end points placed circles. (b) Morphological Thin Operation creates a line

III.EXPERIMENTAL RESULTS

The methodology of smoothing and gap filling performed on LANDSAT-8 OLI images. Here, the road features extracted from OLI images using NDARI and MRF [1]. In the result, observed that the extracted roads have connected noise like ridges and gaps in-between. To remove or smooth the road features, SCMS is used. To fill the gaps in-between roads, circle window method used.

In Figure 2, shows the original image of OLI, which covers the area of Hyderabad, India. The roads extracted by [1] shown in Figure 3. Here, observed that the roads have noise like ridges.

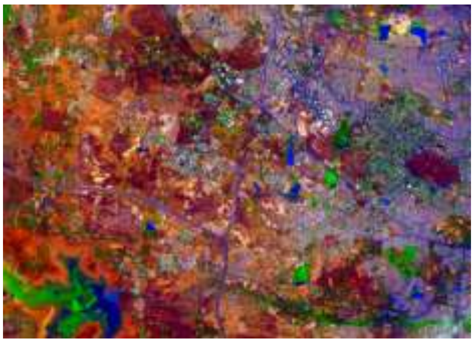


Figure 2: LANDSAT-8 OLI image (B752) [1]

Figure 3: Road extracted using NDARI and MRF model [1]

These ridges are smoothed by using the SCMS algorithm. In this, the BW is selected manually as 5 as shown in Figure 4. Here, observed that the smoothness of roads is improved but the roads are shifted from the original coordinates. Due to the Mean Shift works, where the density of points is high, there the points in that radius will shift. For this, manually taken BW as 5 and this also shifts the points from the original location as shown in Figure 5.

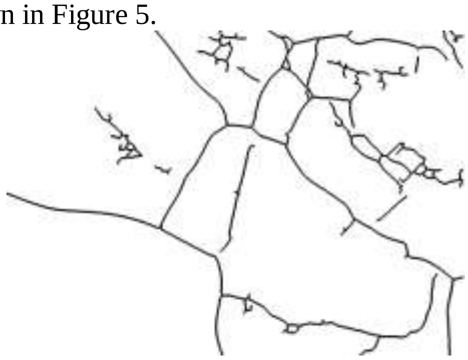


Figure 4: Smoothed by using SCMS with BW is 5

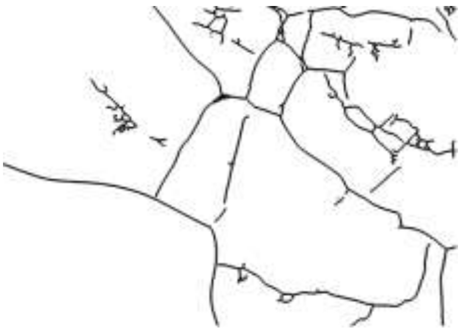


Figure 5: Smoothed by using SCMS with automatic BW

In Figure 5 and 6, observed that gaps are increased due to the mean shift of the points based on the density. Also, the lines are deviating from the original location, this leads to False Negative. This affects the accuracy. The accuracy details of the methods SCMS with selected BW, with automatic BW and Circle Window given in Table-I. For the measuring the accuracies of these methods, the roads features are converted from the raster to vector. The extracted roads in Figure 3, used as reference for the evaluating these methods to get the accuracy. That is, the roads smoothed by the methods should be match with original. The evaluated results presented with Precision, Recall and Accuracy in Table 1.

The vector line layer of reference is buffer with 30 meters and the layers of smoothed methods are used as line layer only. The smooth methods of line vector are overlaid on the reference of the buffer layer. Where the line coincides with buffer is treated as True Positive and line not in the buffer area treated as False Positive. Due to this precision is very less and affects the accuracy.

Table 1: Accuracies of the Methods

	SCMS with BW 5	SCMS with automatic BW	Circle Window
Recall	91.30	91.66	97.01
Precision	60.00	62.85	98.20
Accuracy	72.41	74.56	97.60

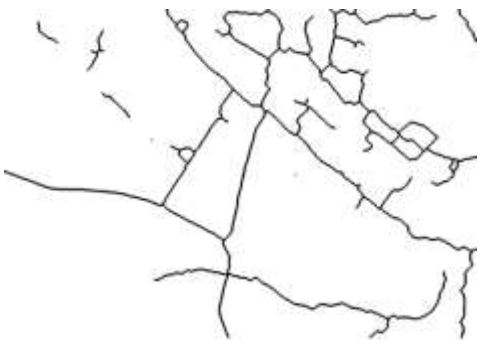


Figure 6: Smoothed and Gap filled by using Circle Window

The Circle Window method is used to connect the gaps in-between the road features and as well as smooth the roads or lines as shown in Fig 6. The proposed Circle Window method smoothes the line and connects the gaps based on the defined radius of the circle. Here defined radius of the circle is 5. That is the 5-pixels gap in-between points are connected. Here, observed that the roads connected and smoothed. Also, observed that, two lines in parallel with endpoints are very near i.e., within the defined circle radius makes a centerline of two parallel lines. The spurs were also removed by the morphological operation with a length of 5 pixels.

The SCMS method is a more complex and time consumable algorithm. The circle window method is simple to apply and reliable. The SCMS and Circle window codes were generated in python and performed on the Workstation (Z840) with 16GB RAM.

IV. CONCLUSION

In this paper, to smooth road features extracted by the NDARI index, used SCMS and proposed Circle Window method. The SCMS is works based on the density of pixels where it placed and moves towards there. This depends on the bandwidth (i.e., defined or automatic) and also time consumable (hours). The proposed method Circle window smoothes the road or lines as wells as fill the gaps in between the two points. This method of accuracy depends on the selected radius of the circle. It is easy to apply and less time (within a minute).

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Conflict of Interest: *Authors confirm there is no conflict of interest.*

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