TERRAIN CLASSIFICATION BY USING A LARGE SET OF SYNTHETIC APERTURE RADAR IMAGES AND MODIFIED FRACTAL SIGNATURE METHOD

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Abstract

In this paper a large dataset of satellite Synthetic Aperture Radar (SAR) Images from Capella's SAR mode satellite constellation system is analyzed by using the Modified Fractal Signature Method, for terrain classification. Four (4) types of terrain are considered (urban, mountain, rural and sea), and our numerical results show a good classification between them. Furthermore, nonlinear regression models are used to our results, showing also satisfactory differentiation between the four (4) terrain types.

1. INTRODUCTION

In this paper we obtained a large number of SAR satellite images from Capella's SAR mode satellite constellation system for classification purposes. Namely, we chose four (4) types for terrain classification, which are the following: urban, mountain, rural and sea. The classification is performed by using a well – known in the literature fractal technique, namely the Modified Fractal Signature (MFS) Method [1-9]. Namely, compared to Ref. [9], the main advantage here is that we used a very large number of SAR images, that is 100 images for each type of terrain (400 SAR images), which we consider as an important advantage as compared to [9].

2. SAR DATA PRESENTATION USED IN THIS WORK

In this work we used SAR images obtained by the Capella X-SAR Earth observation satellite constellation system [10], collecting high-resolution X-band synthetic aperture radar images, with spatial resolution less than 1 m. The constellation operates at an altitude of 485-525 km. We used 'Single Look Complex' (SLC) images, which are free offered data [10], containing both the amplitude and phase of the radar signal. The SLC SAR images are available in GeoTIFF format, which means georeferenced TIFF images. The SAR used frequency band is at X-band (9.4 – 9.9 GHz).

The dataset consists of:

1. 100 SAR images for mountainous regions.
2. 100 SAR images for urban regions.
3. 100 SAR images for rural regions.
4. 100 SAR images for sea regions.

GeoTIFF images collected from Capella's SAR mode satellite constellation, which offer spatial resolution less than 1m and well-defined area coverage. Below follow four (4) representative images from the dataset.

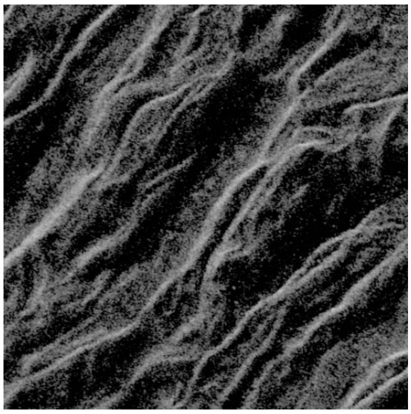

Fig. 1. SAR image mountainous region

Fig. 2. SAR image urban region

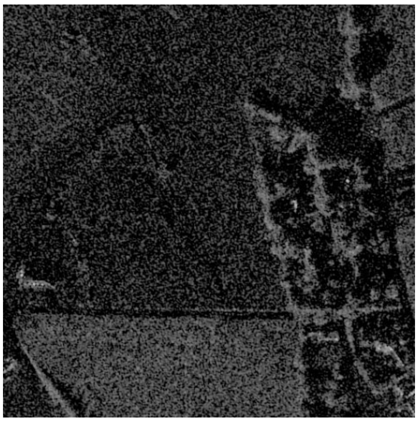

Fig. 3. SAR image rural region

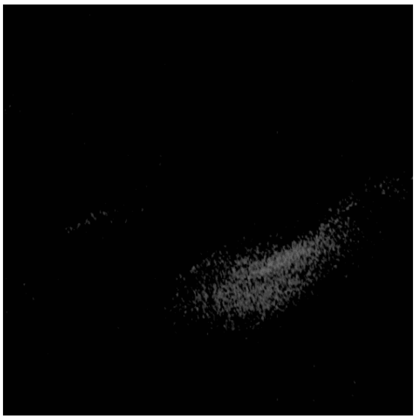

Fig. 4. SAR image sea region

Each one of the 400 SLC SAR images has 500 x 500 pixels size resolution and the amplitude magnitude of each one of these images is in the range 0 to 256.

3. MODIFIED FRACTAL SIGNATURE (MFS) METHOD USED IN OUR WORK

In this paper we are using the MFS fractal method, as we also did in Ref. [9] [see also Refs. [3], [4]], but here with the very important advantage using a very large number of real spaceborne SAR data.

The main function that we are using here is $F_D(\delta)$

$$F_D = 2 - \frac{\log_2 A_{\delta 1} - \log_2 A_{\delta 2}}{\log_2 \delta_2 - \log_2 \delta_1} \qquad (1)$$

which represents the 'Fractal Dimension' of the SLC SAR image (it is a characteristic function of the image ([3], [4], [8],[11]). Please note here that δ denotes the *resolution* in the image (i.e. δ=1 means maximum resolution of the image, and furthermore as δ increases the resolution of the image is decreasing). For this reason function F_D (δ) is a decreasing function of δ. Note also that δ is the iteration number in this procedure ([3], [4], [8]), that is if F_D was a true fractal surface it would be a constant, i.e. independent of δ. Finally, note that function F_D (δ) in some way gives a measure of the 'roughness' of the surface, and this 'roughness' is increasing with increasing function F_D (δ). Furthermore, note that F_D (δ) is always a monotinically decreasing function of δ ([3], [4], [8]). Finally, in eq. (1) note that A(δ) is the *area* of the blanket corresponding to the real surface (amplitude of the SAR image [see ([3], [4], [8] for details].

4. SAR DATA PROCESSING AND NUMERICAL RESULTS (QUANTITATIVE TERRAIN CLASSIFICATION)

By obtaining 100 GeoTIFF SAR images per terrain class (1. Sea, 2. Rural, 3. Mountain, 4. Urban, as mentioned above), and by calulating the amplitude average for each pixel per SAR image and class, we obtained the following results, where in Fig. 5 we show the fractal dimension function F_D (δ) as a function of resolution (iteration) δ for the whole set of 400 images. Here, we can easily observe the nice quantitative classification between the four (4) types of terrain, which are in good agreement with our expectation (as mentioned in Section 3, above).

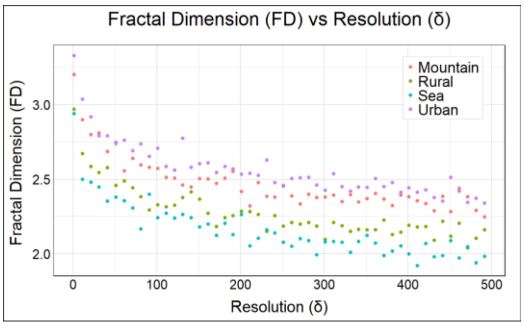

Fig. 5. Fractal dimension F_d as a function of δ (image resolution – iteration) in the MFS method for all chosen terrain classes

In the following two (2) figures we also obtained two types of curve fitting by using nonlinear regression analysis (3rd degree polynomial curve fitting, fig. 6, and logarithmic curve fitting, fig. 7).

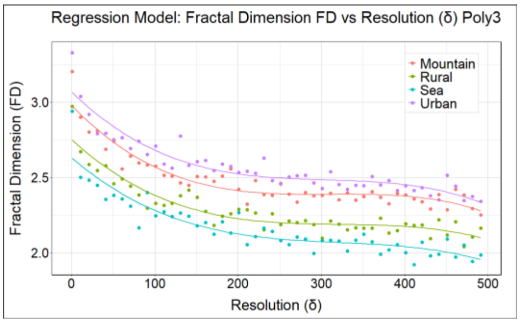

Fig. 6. Polynomial regression (3rd degree) for F_D vs δ

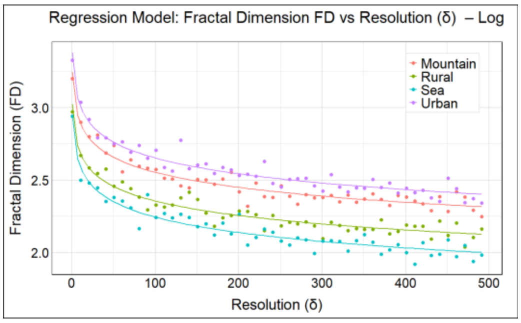

Fig. 7. Logarithmic regression for F_D vs δ

These two (2) figures (Fig. 6 and Fig. 7) show in an even clearer way the excellent classification of the four (4) spaceborne SAR images types (100 images per type).

Finally, please note that all the above quantitative classification processing was developed by using *R-software* (*R-software* is a modern free software environment for statistical computing-programming and graphics).

5. CONCLUSIONS – FUTURE RESEARCH

In this paper we used the MFS fractal method for quantitative terrain classification by using a very large set of spaceborne SAR SLC images. The numerical classification results were very promising.

As future research, we intend to use machine learning techniques (training and testing of real spaceborne SAR data), as well as by using more advanced fractal techniques.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP19676900), which supported this research.

Furthermore, the authors would like to thank Professors N. Ampilova and I. Soloviev for many years discussions and scientific cooperation in the area of fractals.

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