論 文 の 内 容 の 要 旨

論文題目　Fractional Brownian Motion for Accurate Topographic Mapping in Interferometric Synthetic Aperture Radar Imaging
(干渉型合成開口レーダ・イメージングにおける高精度地形図作成のための非整数ブラウン運動)

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This dissertation presents new research results concerning the use of fractional Brownian motion (fBm) model in accurate topographic mapping using interferometric synthetic aperture radar (InSAR) imaging. Three separate InSAR processing tasks are considered: coregistration of synthetic aperture radar (SAR) images, regularization of topographic maps, and interferogram phase unwrapping.

First, we present an image coregistration method by considering the amplitude of SAR images as fBm surfaces. This allows the estimation of the relative offsets between two SAR images from their local statistics. The method is simple and efficient. It provides accurate image alignment faster than the conventional methods with a comparable accuracy. In particular, the method gives better results for images that show near homogeneous fractal behavior.

Next, we describe a method for correcting errors in topographic maps after phase unwrapping. The method also works as a regularization procedure for InSAR interferograms. For these objectives, we combine SAR imaging geometry and the small perturbation method (SPM) scattering model for fBm surfaces, and derive an InSAR model that relates the phase and amplitude of a complex interferogram. This data model is then applied in a variational procedure to simultaneously remove speckles from the amplitude image and phase noise from the topographic map. Experiments with actual data show that the method considerably improves the accuracy of topographic maps and suppresses noise in the complex interferograms.

Before the discussion of phase unwrapping, we first introduce a new random process called skew fractional Brownian motion (sfBm) as a model for the absolute phase data in InSAR imaging. This model displays the anisotropic behavior of the phase data and the skewness of their gradients. We verify the model by developing an sfBm estimator to estimate the fBm parameters of the surface from the absolute phase. Experimental results using simulated data and actual topography suggest the suitability of sfBm to model phase data obtained in InSAR imaging.

Last, we propose a method for InSAR phase unwrapping based on sfBm model. The proposed method looks for the most likely unwrapped phase under the presence of additive phase noise. By treating this as a global optimization problem, we develop a simple heuristic procedure in order to find the solution. Experimental results with actual InSAR data show the effectiveness of the approach as well as its ability to unwrap images that are difficult to unwrap using other phase unwrapping algorithms.