Ph.D. Thesis

Studies on Advanced and Effective Technology for Deformation Monitoring and Imaging by GB-SAR

(GB−SAR による変位計測とイメージングのための新しく効率的な技術に関する研究)

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Summary

All across the world, people are facing a wealth of new and challenging environmental problems every day. These problems are not only natural disasters such as earthquake, typhoon, volcanic eruptions and tsunami, but also include human impact on the environment. Like the collapse of civil engineering structure such as building, bridge and tunnel. In recent years, Ground Based Synthetic Aperture Radar (GB-SAR) has been studied as a potential method of environmental monitoring and disaster mitigation. Essentially, GB-SAR operates in the same principle as air- and space-borne SAR. GB-SAR can takes a measurement with much less time than other techniques over a widespread area at a higher spatial resolution. Furthermore, interferometric techniques can be applied by repeatedly scanning the scene in order to detect very small changes.

In this thesis, the principle of GB-SAR and interferometry technique were briefly reviewed. The GB-SAR measurement for displacement estimation by interferometry technique were carried out for the demonstration. The displacement of the trihedral corner reflector was correctly estimated by interferometry technique. Moreover, the GB-SAR interferometry technique was used to monitoring Arato-zawa post landslide which located at Kurihara city, Miyagi prefecture Japan. Two long term observations were carried out. Displacement maps of each period and each month are obtained and large displacement changed caused by snow are observed. These GB-SAR results have been useful for the interpretation of long-term stability of this post landslide.

In GB-SAR measurement, the information cannot be extracted from all pixels within the area under study; due to decorrelation phenomena, only a limited number of pixels along the whole dataset are useful. The detection of high-quality scatter has thus become an important topic with a wide range of applications for GB-SAR monitoring. These pixels called coherent scatterers. In this thesis, an extend work to select coherent scatterer from single dataset with full-spatial resolution is discussed. The sub-images were generated by interleaved pick out the data along frequency direction of each azimuth acquisition point. The main advantage is keep the resolution of sub-images and finally full resolution coherent scatterer's map will be obtained. The limitation is shortened the observation range involved in the reduction of frequency points of sub-spectrum. The performance of the proposed method has been evaluated using real GB-SAR data acquired in both urban and nature areas. The coherence scatterer maps selected by the proposed method were compared with the so-called classical approach (dispersion of amplitude method). Both methods produce similar coherent scatterer maps, and the trihedral corner reflectors that were placed in both urban and natural settings were successfully selected by the proposed approach. However, coherent scatterers with short temporal characteristics were successfully selected by the proposed approach and were missed during long term observations.

Accurate image is very important for all radar instruments. In this thesis, I proposed an efficient and accurate GB-SAR imaging algorithm. The mathematical formation of this algorithm and the optimal focusing condition are given in this thesis. This proposed algorithm is a kind of modify diffraction stacking method and focused reflectivity map into a polar format. The key point of this algorithm is that the spatial frequency along linear rail could be optimal represent at certain rotated angle fractional Fourier transform. This property makes only 1-D fractional Fourier transform is required for azimuth compression. Before applying this algorithm, 1-D IFFT is needed to transform the raw data into time domain signal. Then the optimal rotated angle for each range should calculated. After that, 1-D FrFT should applied with a certain rotated angle for each range. Finally, the polar format GB-SAR image is obtained. Both numerical simulations and GB-SAR experiments show that the quality of the imagery obtained with proposed approach is perfectly comparable to that of well-known diffraction stacking, no matter near- or far-field. Moreover our approach has the lower computational cost, which is an important request for GB-SAR applications. The numerical simulations have shown that the algorithm can be used with ultrawideband and high frequency GB-SAR system with excellent results.

Moreover, a new way to reconstructed GB-SAR image by compressive sensing in fractional Fourier domain was proposed. The reconstructed images were compared with that in Fourier domain. The simulation and experiment results demonstrated that to reconstructed GB-SAR image by compressive sensing in fractional Fourier domain shows better performance than that in Fourier domain, especially for sampled in spatial domain.

Last, the potential study about deformation monitoring by polarimetric GB-SAR is shown and two main issues were discussed. One is full polarimetic analysis for target identification during GB-SAR monitoring. This analysis can help us to clearly identify where deformed is and what kind of deform is. It is very useful tool when we have a complicated monitoring environment. Another aspect is use full polarimetric information for deformation monitoring. Both are validated by measurements and reasonable results are obtained.

Keywords: ground based synthetic aperture radar (GB-SAR); interferometry; remote sensing; environmental monitoring; coherent scatterers; fractional Fourier transform (FrFT); imaging; compressive sensing; polarimetric analysis; deformation monitoring; displacement; scattering matrix.

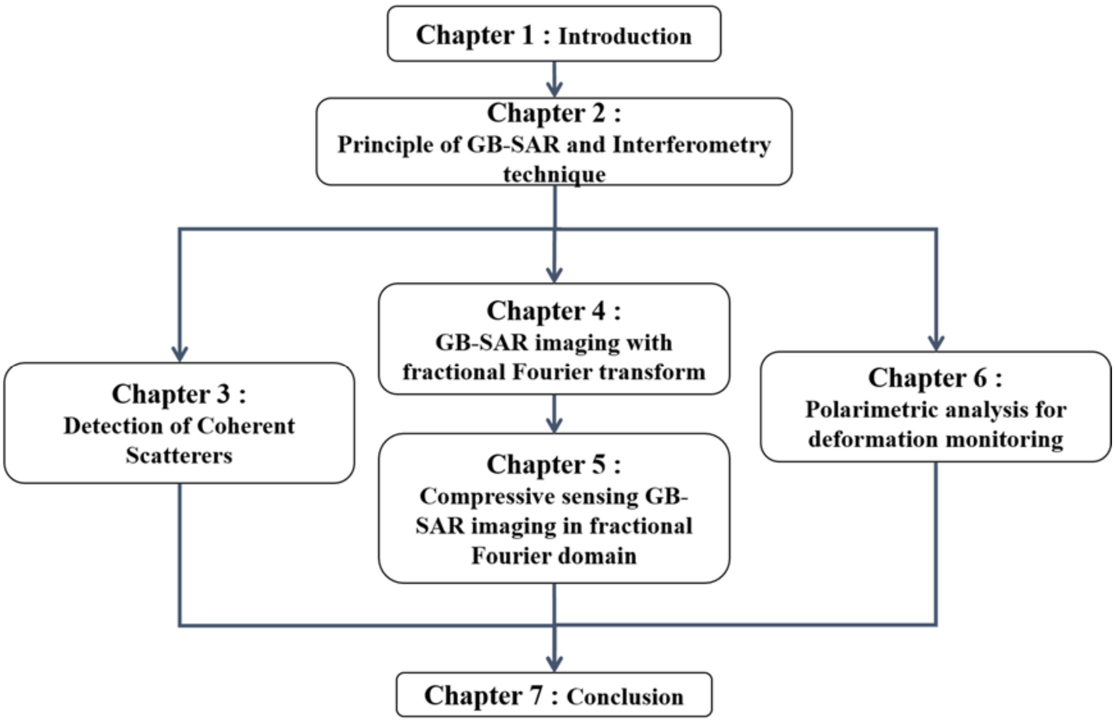

Figure 1 Structure of this thesis.