SIMULATION AND VISUALIZATION OF INSAR TIME SERIES ANALYSIS DATA

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1. INTRODUCTION

The processing possibilities associated with using multiple coherent SAR observations acquired over time have been explored and extensively documented in the literature. Most of these techniques involve defining a model of the interferometric phase measurements that include some parametric scatterer motion, a spatial model of the atmospheric delay, scatterer elevation above the terrain, and elevation error. Using an iterative process these parameters are estimated. This paper will describe new tools that assist in the fundamental understanding of various algorithmic components and provide deeper insight into the phenomenology associated with these multi-observational datasets.

2. COHERENT TIME SERIES DATA

Coherent time-series of SAR data have been used over the past decade to measure displacement signals, particularly those associated with slow scatterer motions of targets in built-up areas. PSInSAR, in particular, has been demonstrated by many groups to be a very sensitive and capable approach. Essentially through the use of many observations, which can in some sense be considered redundant, iterative approaches are brought to bear on estimating modeled unknowns consistent with the observed SAR data. For instance, given a linear model of motion, in theory only two observations are required to estimate each target's phase slope. The more measurements that are made, the better the linear motion (i.e. phase slope) can be estimated (a result readily analyzed in the software discussed here). Furthermore, the PSInSAR technique, introduced by TRE in 2001, further exploits redundancy to estimate and correct for modeled "contamination" signals in the data series [1]. Atmospheric delays associated with each data set are estimated, scatterer heights of each permanent scatterer are corrected and the SAR sensor locations may be refined.

A challenge in developing such an approach is the complicated and sometimes non-intuitive interaction between the various modeled parameters and the data. This is further complicated by the sensitivity of phase unwrapping errors to phase estimation errors. Under some circumstances, the estimation process can identify solutions that are locally optimum within the parameter space but globally incorrect. In order to insure high quality results, a full characterization of the estimation process is required. This may be done analytically or through simulation. In this presentation we will describe tools developed by the authors that allow us to understand the characteristics of the estimation process implemented in our Interferometric Time-Series Analysis (ITSA) approach to permanent scatterer interferometry

3. SIMULATION

A complex SAR image simulator has been developed that allows the user to specify a SAR system and its geometry as well as scene contents. The scene is defined by multiple point targets (many per resolution cell) of varying cross-sections and polarimetric properties (scattering matrix) located in three dimensions (i.e. accounting for terrain and/or structures). A spatially variant atmosphere may also be included to simulate atmospheric delay. The targets can have a velocity associated with them to simulate target motion. This motion may be steady or random, and is designed to simulate the kinds of motions that are of interest for SAR interferometric applications. For each simulation in a particular temporal series, one may cause any target to remain coherent, loose coherence, or become incoherent. Using this simulator, we can simulate a wide variety of interferometric SAR data time series with complete control of the parameters including SAR sensor location, atmospheric delays, height model, multiple scattering as well as polarimetric effects. By processing this data one can assess the fidelity of the algorithms used.

We have developed a tool to assist in analyzing our ITSA analysis software. In the following example a couple of thousand "permanent scatterers" were dispersed throughout a simulated scene and observed 20 times from various coherent locations over some time period. The tool allows us to use the input to the simulator and the output from our ITSA software to assess performance of the algorithm. Figure 1 shows an example of the output windows.

4. ITSA VIEWER

A viewer that allows us to visualize the temporal and spatial information available in the ITSA results (real data or simulated data) has also been developed. Using this viewer, one may display a background SAR image, and the permanent points which have been detected by the ITSA software as shown in Figure 2. These points may be colored according to either the target's linear motion rate extracted by the software, or the elevation error correction applied during the ITSA run. Each point may be selected to view the time versus motion data associated with that point, including the raw phase information, the processed phase information and the best-fit line to the data if it is a permanent point. The goodness of fit and correlation for each point is also plotted versus test elevation errors. These plots have characteristic shapes near the best height-error values for good points, which are a function of the spatial baseline distributions. These characteristic shapes can be seen in lower coherence points in the scene, and suggest a new way to identify permanent points in SAR imagery, as shown in Figure 3. This figure also shows another point that exhibits two characteristic peaks in the dQ plot, suggesting two “dominant” scatterers within one pixel at different heights.

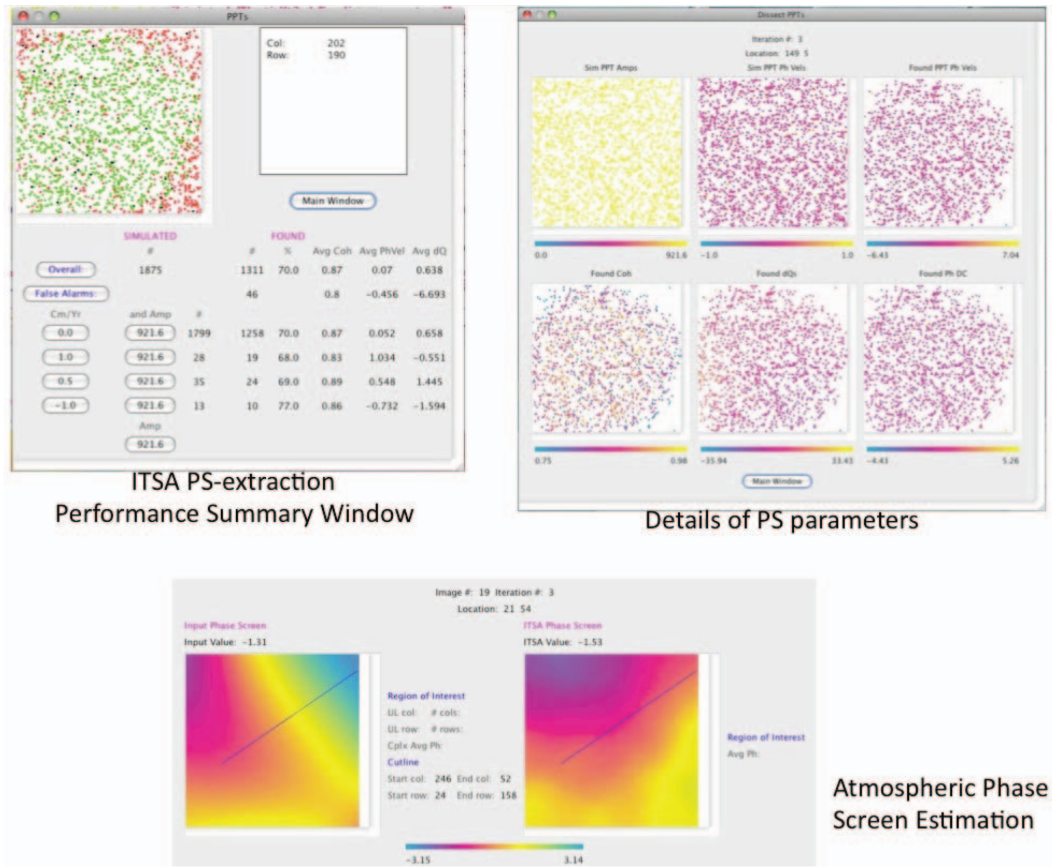

Figure 1 Three window of the ITSA simulator viewer and analysis tool.

4. SUMMARY

The complex nature of PSInSAR algorithms makes access to a simulator and visualization tool essential to understanding the nature and characteristics of the processing algorithms. We present two such tools that indeed augment our understanding of this particular algorithm’s implementation, and suggest new methods for identifying PS points as well as making algorithmic improvements. Such tools would be valuable to all researchers in this field.

Figure 2 Overview of the ITSA Viewer main window.

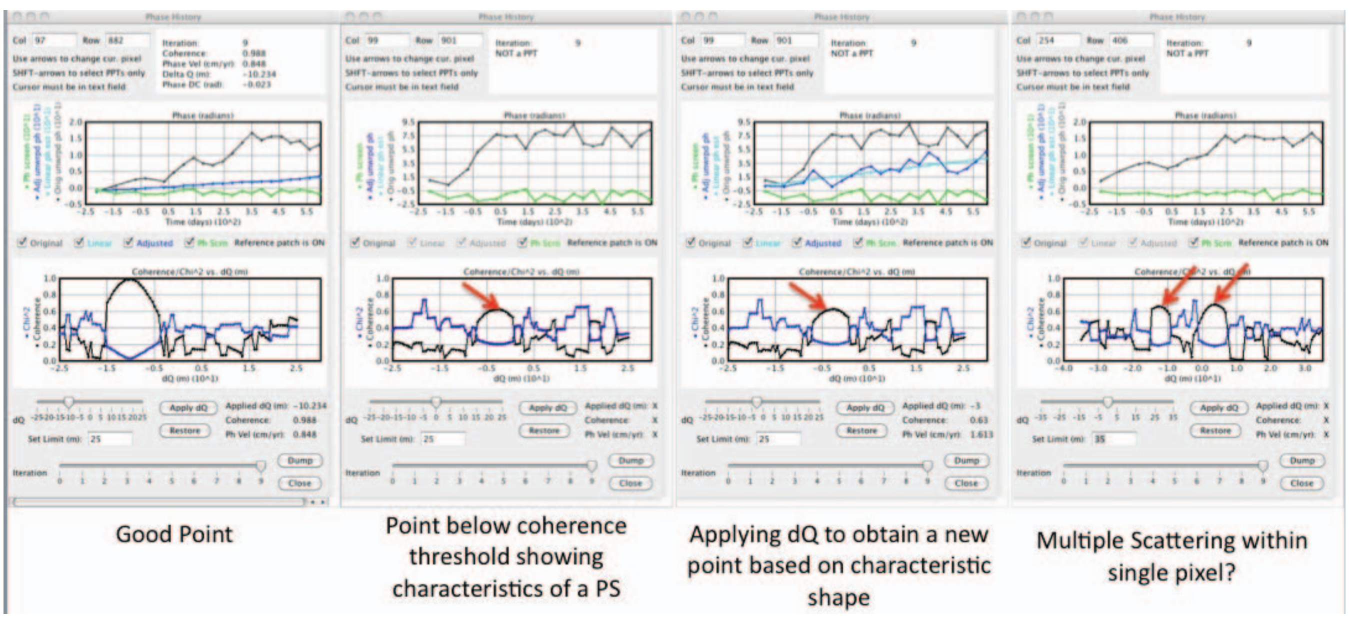

Figure 3 Plot of a "good" point detected, one below the coherence threshold and then the result of forcing the appropriate dQ as seen in the dQ plot, and (right) evidence of multiple PS's within a single pixel.

5. REFERENCES

[1] A. Ferretti, C. Prati, F. Roca, "Permanent Scatterers in SAR Interferometry," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 39, No. 1, pp 8-20, 2001.