Computer Simulation of Synthetic Aperture Radar Data

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Abstract— A computer simulation of SAR data is discussed. A method is outlined for simulating a distributed scene which is capable of modeling SAR data under moderate motion of the radar platform, and a wide range of incidence angles. Arbitrary terrain profiles and reflectivities can be modeled. Interferometric pairs of data can be generated. Inputs and outputs to the simulator and the steps required in the simulation algorithm are outlined.

INTRODUCTION

Brigham Young University has developed several SAR systems, including YSAR [1] and YINSAR [2]. YSAR, a 2GHz SAR, was flown in several locations in Utah and at significant archaeological sites in Israel. YINSAR, a 9.9 GHz interferometric SAR, will be used for numerous applications requiring high resolution digital elevation maps. Both systems are flown on a small aircraft at low altitudes. In the course of the development of these systems an accurate simulation has become necessary for studies in motion compensation and interferometry. The requirements for the simulator are:

1) Accurately account for a wide range of incidence angles.
2) Simulate the turbulence induced motion incurred in a small aircraft.
3) Model the phase and σ^o characteristics of a distributed target.
4) Reasonable computational demands.
5) Generate interferometric image pairs.
6) Account for the antenna pattern in range and azimuth.
7) Simulate the effects of terrain height profile.

SIMULATING A DISTRIBUTED SCENE

The inputs and outputs of the simulator are illustrated in Fig. 1. Dotted lines indicate optional files. The inputs to the simulator are provided in four files. The first file contains the parameters of the SAR system, such as transmit frequency, power, chirp duration and bandwidth, sampling rates, number of points to collect, and several nominal default values: platform velocity and altitude, antenna geometry, and 3dB beam-width. The second file contains a digital elevation and σ^o map of the scene to be simulated. If the σ^o value for each point is not implicitly given, a default value from the SAR parameter file is used. The third file provides the motion of the radar platform, including the roll, pitch, yaw, position and velocity of the aircraft as a function of time. The last input file contains the three dimensional antenna pattern in spherical coordinates. If there is no input file for platform motion or the antenna pattern, the simulator defaults to linear motion and a uniformly illuminated aperture respectively, where the default values are defined in the SAR parameter file.

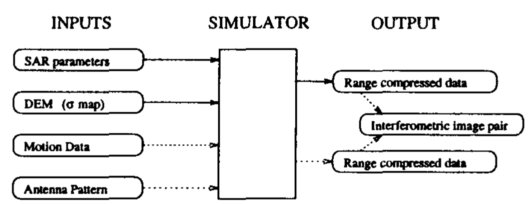

Figure 1: Simulator Inputs and Outputs

The output of the SAR simulator is an ideal range compressed image. The range compressed data can be convolved with the point response of a target to introduce the effects of the range filter. Optionally, the simulator can produce two off-set range compressed images to form an interferometric image pair. The antenna geometry information required for interferometry is found in the SAR parameter file.

The distributed target simulator is designed to provide a realistic simulation. For example, power fall off as a function of range, the incidence angle dependence of σ^o, and speckle can be simulated. Speckle is simulated by insuring that the input DEM file resolution is twice that of the theoretical resolution of the final SAR image, so that there are at least two scatters per resolution cell. The simulator does not not attempt to simulate the 'shadowing' effect found in actual SAR images, due to the increased computational demand.

For each azimuth line in the image, the ground scene is transformed to spherical coordinates referenced to the platform center. The justifications for the spherical transformation are:

1) The antenna pattern is naturally in spherical coordinates. Thus weighting the return by the antenna pattern becomes trivial.

2) Using spherical coordinates, the off-set in antenna direction caused by roll, pitch, and yaw are more easily accounted for.
3) The points from the scene that lay in a given range bin are rapidly determined.
4) The dynamic position of the aircraft is simulated.

ALGORITHM FOR SIMULATING A DISTRIBUTED SCENE

An algorithm for simulating range compressed data is illustrated by Fig. 2. Dashed lines indicate steps in the algorithm that are optional, while solid lines indicate required steps . In order to insure that the phase of the returned signal is not determined by the grid spacing of the input DEM, the location of each scatterer in the scene is shifted within a resolution cell by a uniformly distributed random component. Without this step the phase of each return would be deterministic in nature.

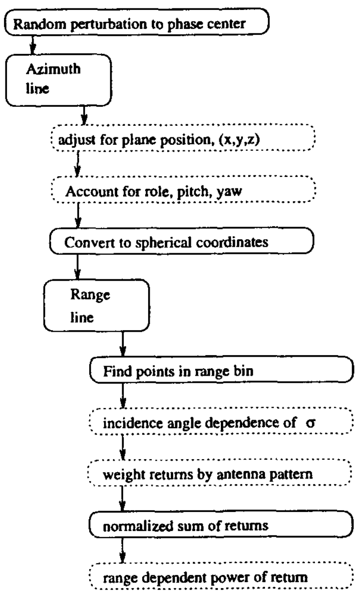

Figure 2: SAR Simulator Flow Diagram

The initial implementation of the algorithm is written in MATLAB for rapid development. The code has not been optimized for speed at this point in development. Implementation of the algorithm in C will result in improvements in the speed of the simulation, and is planned for the realization of the final tool.

SUMMARY AND FUTURE WORK

The simulator algorithm meets the specified requirements. Arbitrary incidence angle, platform motion, and phase characteristics are accurately modeled. Simulation of shadowing will be modeled in the simulator as future needs dictate. The simulator allows for the researcher to evaluate the effects of various compression algorithms, motion of the radar platform, antenna patterns and geometry, ground images and reflectivities, etc independent of one another or combined together. Simulated data will be presented in poster form at the conference.

References

[1] D. G. Thompson, D. V. Arnold, D. G. Long, G. F. Miner, and T. W. Karlinsey. Ysar: A compact, low-cost synthetic aperture radar. In *Proceedings of the 1996 International Geoscience and Remote Sensing Symposium*, pages 1892–1894, Lincoln, Nebraska, May 1996.

[2] Douglas G. Thompson, James S.Bates, David V. Arnold, David G. Long, and Adam E. Robertson. Yinsar: A compact, low-cost interferometric synthetic aperture radar. In *Proceedings of the 1998 International Geoscience and Remote Sensing Symposium*, Seattle, Aug 1998.