3D ANALYSIS OF SCATTERING EFFECTS BASED ON RAY TRACING TECHNIQUES

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High resolution SAR images, as they are provided by TerraSAR-X or Cosmo SkyMed, offer new possibilities to localize and analyze scattering effects showing up at man-made objects. As the relevance of deterministic scattering effects becomes more dominant compared to stochastic effects, an increased number of time-coherent scatterers can be distinguished in urban areas [1], e.g. appearing as linear or areal structures at buildings [2]. Nevertheless, visual interpretation of the nature of scatterers and their geometrical layout in the SAR image is still challenging due to foreshortening and overlay effects. To this end, the decision was made to develop simulation tools based on ray tracing techniques in order to approximate the reflection behavior of radar signals at man-made objects [3]. In this paper we present an enhanced version of our simulator offering new tools for analyzing scattering effects in three dimensions: on the one hand by localizing backscattering areas in the three-dimensional object space, on the other hand by capturing scattering effects in azimuth, range and elevation direction.

So far, several simulation approaches have been published focusing either on *geometrical* or on *radiometrical* correctness. Franceschetti et al. developed SARAS for obtaining images of high radiometric quality and enhanced their approach for describing multiple bounce effects at buildings that are approximated by box models [4]. Concentrating on the geometrical part, Balz used rasterization methods provided by programmable graphics cards to create single bounce SAR images in real time [5]. Hammer et al. developed a simulator using ray tracing techniques for obtaining artificial SAR images [6].

Our simulator is also based on ray tracing techniques and is in particular designed to create SAR reflectivity maps of complex urban environments by illuminating multi-body 3D scenes by a virtual SAR sensor [3]. Virtual rays, which are used for approximating the SAR signal, are sent in reverse direction through object space and reflection contributions are evaluated for each intersection point detected in the model scene. Arbitrary multiple reflections can thus be simulated in reasonable time. Each reflection type (single, double, …) is assigned to a separate image layerwhich strongly supports the geometrical analysis of bright features appearing in high resolution SAR images.

Two significant enhancements included in the existing simulation toolbox will be presented in this paper:

1.) The former version of our simulator delivers the simulation result in SAR slant-range geometry. Now, the scatterers are additionally localized in object space: while rays are traced along their path through the model scene, 3D coordinates of intersection points are detected at object surfaces. Since it is known, which surfaces will finally contribute to strong scattering effects in the reflectivity map, also the inverse way can be followed, i.e. starting at features in the artificial image and ending at the 3D model space. Thus, areas causing reflection effects like dihedral or trihedral scattering can be identified and marked within the model scene used for the simulation.

2.) Tomographic analysis: In our approach, both the imaging SAR system and effects occuring during post-processing are modeled by approximating the imaging SAR system by means of an orthographic camera and a cylindrical light source. By using the camera's image axis pointing in elevation direction, also tomographic analysis is feasable which has proven to be helpful for distinuishing several scatterers within one resolution cell [7] [8] [9]. Hence, potentials of the simulator have been evaluated with respect to the separation of scattering mechanisms in three dimensions. In this paper, reflectivity maps will be generated in the azimuth-range plane followed by the localization of scatterers in elevation direction.

Results of both enhancements will be shown and discussed for chosen test sites, for which 3D models, high-resolution TerraSAR-X images as well as ground-truth data is available,

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