URBAN AREAS CHARACTERIZATION FROM POLARIMETRIC SAR IMAGES USING HIDDEN MARKOV MODEL

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1. INTRODUCTION

Analysis of buildings in urban areas using high-resolution Synthetic Aperture Radar (SAR) images has received a lot of attentions in recent years. Exploiting multi-apect characteristics of buildings can help to improve detection accuracy. Look-angle dependency is a common effect in SAR images since radar scattering is often highly dependent on the object-sensor orientation. Sub-aperture analysis is an efficient tool to deal with this problem. It sacrifices resolution to obtain more spectral details. Multiple sub-apertures sample wave physics from several aspects of scatterers. They are equivalent to images acquired at sequential periods. Polarimetric SAR data provide additional features for investigating the statistical behaviors of sub-apertures.

Sub-apertures are not independent because spectrum of some scatterers might span the whole aperture and sub-apertures describe continuous aspects of scatterers. In order to obtain an accurate building detection, the temporal variation of sub-aperture characteristics should be modelled. This kind of problem is well described by state space models. Hidden Markov Model (HMM) is a statistical model in which sequential data are assumed to be a Markov process, i.e. the next prediction only depends on the most recent observation. HMM is an extension of a mixture model and the choice of mixture component for each observations depends on the state of the previous observation. The multi-aspect data can be represented by several discrete states, each corresponding to a range of look angles over which the scattering physics is relatively stationary. Once we have determined the state parameters from the observation data, HMM can be used to perform further recognition tasks.

This paper models the directional behaviors of building reflections using HMM. It models the temporal and spectral variations along sequential sub-apertures. The model is expected to improve building detection accuracy and reveal the multi-aspect characteristics of buildings. Building signature in a SAR image is a function of radar look angle and building alignment. The sub-apertures implicitly view buildings from several angles. Each sub-aperture samples physics from a state, which is dictated by building structures and corresponding SAR aperture. For buildings with a specific alignment angle, sub-apertures with same orientation angle are supposed to be identically distributed. We also analyze coherent scatterers using HMM. Coherent scatterers may have different characteristics in several sub-apertures. We investigate the evolution of coherent scatterers' responses throughout all the sub-apertures. Our contribution is an initial modelling of multi-aspect correspondence between buildings and SAR geometry.

2. RELATED WORK

Current models for urban area characterization treat sub-apertures as i.i.d. data. Ignorance of interdependency will fail to exploit the sequential patterns in the data. Polarimetric stationarity [1] exploited the variation of polarimetric properties with respect to azimuth look angle in vegetation areas. Look-angle dependency was modeled in maximum-likelihood detection. The generated stationarity map revealed variation process happening in successive sub-apertures. However, the indicator did not consider how polarimetric features in neighboring sub-apertures evolved.

HMM was used to model multi-aspect tactical target detection in [2]. The authors generated feature vectors using matching persuits based on physical and scattering models. Only two HMMs were trained for clutter and interested vehicles, respectively, since there were not many targets in training images. Nonetheless, they obtained promising detection results.

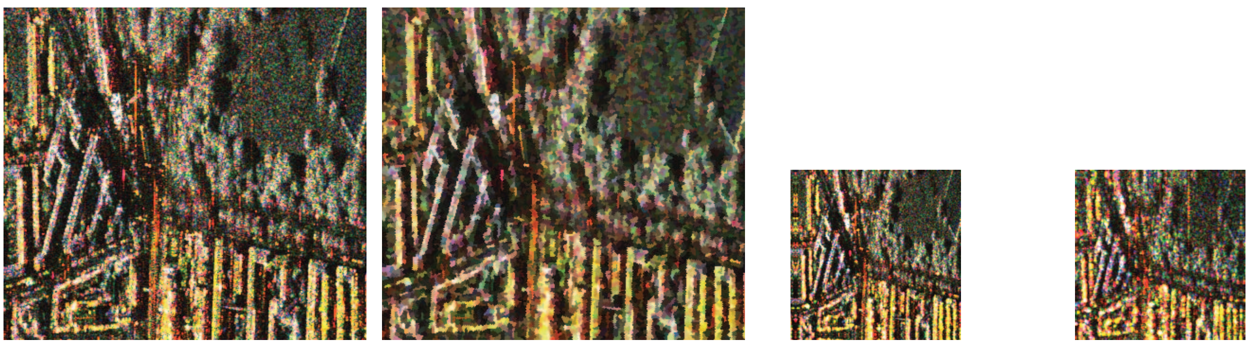
3. FRAMEWORK

We propose a building detection framework using multiple HMMs. The first stage is to apply watershed segmentation and wavelet packet decomposition. Behaviors of segments in sub-apertures are then modelled by the HMMs.

We use watershed segmentation in order to build the analysis on the level of super-pixel (a collection of neighboring pixels) rather than pixel. Statistics computed in a super-pixel are more stable. The spatial support provided by patches allows us to extract rich features, e.g. intensity, polarimetric cues, textures and geometric cues, for object detection. Watershed segmentation is preferable here because it produces nearly equal-sized patches and almost true boundaries. The feature used in the segmentation is the log intensity of SAR span image. An example of the segmentation is shown in Fig.1.

In order to generate sub-aperture data, SAR data are usually transformed into azimuth spectral domain. Then the image spectrum is split into several equally sized intervals. The inverse Fourier transform of them result in sub-apertures [1]. In this paper, instead, we use wavelet packet to recursively divide the whole frequency band. Each resulted band contains partial contents of the whole aperture, therefore is analogous to sub-aperture but not identical. An example of wavelet packet decomposition is shown in Fig.1. The high-pass and low-pass filters in wavelet framework are able to perform flexible decomposition and perfect reconstruction. Wavelet transform has advantages over Fourier transform for representing functions that have discontinuities and sharp peaks. It can accurately decompose and reconstruct finite, non-periodic and non-stationary signals. Therefore we are able to extract more accurate components at different frequency scales.

Since the appearances of buildings are different approximately according to their alignment angles, we discretize the alignment angles and design a HMM for each angle. Several HMMs are also designed for other object types. HMM can have flexible state-transition structures. We parse buildings into a set of states. In each state we assume that scattering physics is varying slowly. In the training stage, we manually draw boundaries to get the alignment angle of buildings. The labeled buildings are used to train the layover HMMs. For a HMM of another object, we randomly select some regions of the object type to train it. In the testing stage, a region is associated with the object type for which the corresponding HMM outputs the highest probability.



(a) (b) (c) (d)

Fig. 1. (a) An EMISAR image, (b) watershed segmentation, (c)(d) two of the components of single-level wavelet packet decomposition.

4. REFERENCES

[1] L. Ferro-Famil, A. Reigber, E. Pottier, and W.M. Boerner, "Scene characterization using subaperture polarimetric sar data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 41, no. 10, pp. 2264–2276, Oct. 2003.

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