MODELING HIGH RESOLUTION SAR IMAGES OF URBAN AREAS USING MIXTURE MODELS AND HIDDEN MARKOV MODEL

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1. INTRODUCTION

A distribution of Synthetic Aperture Radar (SAR) amplitude data in urban areas has a heavy tail. Most of the energy, i.e. composed of low radar return from natural areas and shadow regions, concentrates in a tiny portion of the distribution. Some strong backscattering from man-made structures lie in the long tail. The contrast between the clutter and building layover is extremely high. Furthermore, the buildings spans a much bigger extent along the distribution, which results in wide diversity and complexity for building analysis. Various distributions have been proposed for SAR amplitude data, including K-, Weibull, Log-normal, Nakagami-Gamma, generalized Rayleigh, Fisher distribution [1], and so on. Fig. 1 shows four examples of SAR amplitude data fitted by Fisher, Gamma and Log-normal distribution. Fisher distribution is capable of capturing the variations in amplitude distribution. In [1] each object class in an urban area is modeled by a Fisher distribution. However, a single distribution is not enough to describe the variations inside an object class. A more refined model, e.g. a mixture model, is required.

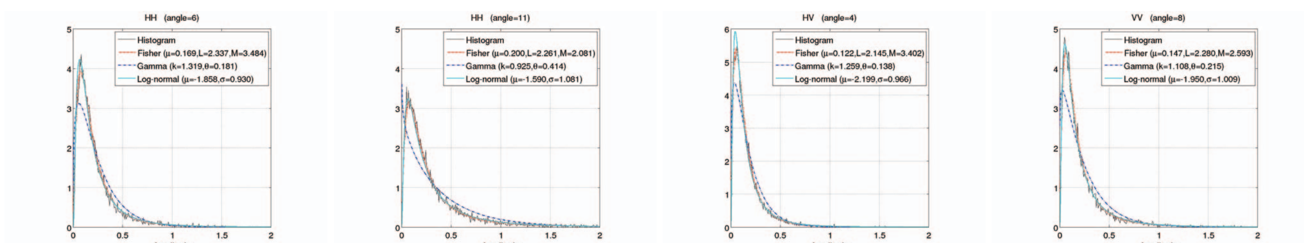

Fig. 1. SAR amplitude data of buildings with different alignment angles fitted using Fisher, Gamma and Log-normal distribution.

Mixture model, e.g. Gaussian Mixture Model (GMM), has been widely applied in various data analyses. K-means clustering is a special case of GMM in which the class assignment is hard rather than probabilistic. Gamma mixture model was proposed in [2] to model high-resolution radar range profiles of ships for automatic recognition. Integration of the prior distribution of Gamma parameters in a Bayesian framework was put forward in [3] for automatic recognition of military ships. The parameters of the Bayesian model are estimated using Markov Chain Monte Carlo (MCMC) technique. Bayesian estimation of mixture parameters through variational inference is promising [4]. Bayesian model is able to solve the problems of preventing overfitting and automatically determining the number of components.

Scatterers in SAR images exhibit high dependence on scatterer-sensor alignment. This phenomenon is prevalent on buildings in urban areas. We apply Hidden Markov Model (HMM) to characterize the dependence and model the variations with respect to building alignment. Buildings in high resolution SAR images of urban areas are studied. Buildings regions are divided into several discrete classes according to their alignment angles. We model the variations of scatterers characteristics throughout the subapertures using HMM.

In [5] we extracted amplitude, log-amplitude, texture, polarimetric features in a HMM framework. GMM was adopted to model the normalized features. In this paper we consider using only amplitude features. We extend the HMM model by modeling the distribution of SAR amplitude data using Gamma mixture, Log-normal mixture and Fisher mixture models, respectively. The performances of the three mixture models are evaluated in object classification tasks.

2. FRAMEWORK

2.1. Mixture Models

Gamma mixture, Log-normal mixture and Fisher mixture models are investigated to model the distribution of a SAR amplitude image. The parameters of Gamma mixture and Log-normal mixture models are estimated by maximum likelihood using expectation-maximization (EM) algorithm. Log-normal mixture is the same as GMM on the logarithm transformation of SAR amplitude data. We use MCMC technique to estimate the parameters of Fisher mixture model. Fig. 2 shows Gamma mixture and Log-normal mixture fitting of a sample square region in a EMISAR polarimetric SAR (PolSAR) image of Copenhagen.

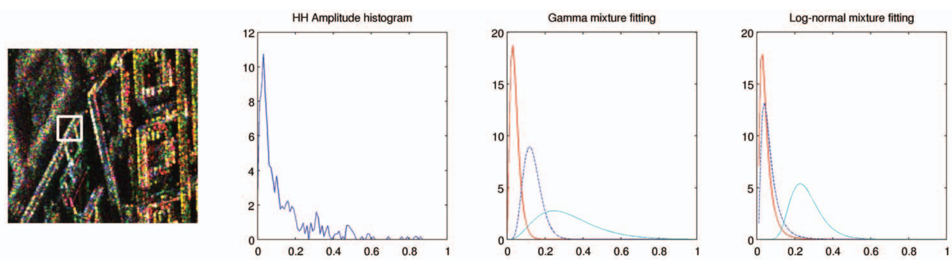

Fig. 2. From left to right: a square region (25 $\times$ 25) in a PolSAR image, HH amplitude histogram of the region, Gamma mixture fitting and Log-normal mixture fitting with 3 components.

2.2. Hidden Markov Model

We use HMMs to interpret the characteristics of different objects in an urban scene, e.g. building, tree and grass. The variations of amplitude distribution along subapertures are modeled by HMMs. HMMs are also capable of characterizing object classes for classification. Special design of HMMs for buildings are considered due to the fact that the polarimetric SAR characteristics of buildings vary according to their alignment angles. We discretize the angle into 10 intervals, each covering 18 degrees. Vertical buildings which are almost parallel to the flight trajectory are defined as the 11th class. A HMM is designed for each alignment angle class. Several HMMs are designed for tree and grass, respectively.

Instead of using GMM, we design Gamma mixture, Log-normal mixture and Fisher mixture models for amplitude features of each object class. The design of HMM on these mixture models is a challenging problem. A component corresponds to a state in a HMM. It represents a stationary sector of amplitude characteristics. Observations are assumed to be sampled from a sequence of states based on a probability distribution function.

The classification capacities of HMMs are validated using testing data. We are particularly interested in the state transition which indicates variations throughout the subapertures. Scatterers on man-made structures tend to change their behaviors along subapertures frequently, whereas coherent scatterers are supposed to have stable characteristics. Therefore, the state transition is expected to play an important role in subaperture analysis.

3. REFERENCES

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