国防科技图书出版基金

SAR图像统计建模：模型及应用

Statistical Modeling of SAR Images: Models & Applications

高贵 时公涛 匡纲要 程江华 编著

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National Defense Industry Press

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图书在版编目(CIP)数据

SAR图像统计建模:模型及应用/高贵等编著.—北京:国防工业出版社,2013.8

ISBN 978-7-118-08945-5

Ⅰ.①S... Ⅱ.①高... Ⅲ.①遥感图象—数字图象处理 Ⅳ.①TP751.1

中国版本图书馆CIP数据核字(2013)第170858号

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国防工业出版社出版发行

(北京市海淀区紫竹院南路23号 邮政编码100048)

北京嘉恒彩色印刷责任有限公司

新华书店经售

*

开本 710×1000 1/16 **印张** 12½ **字数** 240千字

2013年8月第1版第1次印刷 **印数** 1—2500册 **定价** 50.00元

(本书如有印装错误,我社负责调换)

国防书店:(010)88540777 发行邮购:(010)88540776

发行传真:(010)88540755 发行业务:(010)88540717

致 读 者

本书由国防科技图书出版基金资助出版。

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Foreword

Spaceborne and airborne synthetic aperture radar (SAR) sensors have been intensively applied to map, monitor and analyze the Earth: new operational modes increase the flexibility of SAR sensors that are now able to obtain microwave 2-D images as well as 3-D interferometry products within a wide range of space and time resolution and coverage. However, the SAR data processing is challenging due to the changing properties of targets (such as vehicles, ships and buildings) and terrains for the electromagnetic waves with various bands, views, polarimetric modes and configurations. Hence, the definition of new techniques and algorithms for SAR data usage as well as assessment of existing methods for SAR products exploitation are required.

Statistical modeling of SAR images is one of the basic problems of SAR image interpretation. It involves several fields such as pattern recognition, image processing, signal analysis, probability theory, and electromagnetic scattering characteristics analysis of targets etc. At present, one of the major strategies of SAR image interpretation is to use the methods of classical statistical pattern recognition which are based on Bayesian theory. To utilize these methods for SAR image interpretation, a proper statistical distribution must be adopted to model SAR image data.

Main purpose of this book is to discuss detailedly the models and applications of statistical models for single channel and multi-channel SAR images. We summarize and emphasize especially the new developing models based on our work. Meanwhile, some important applications employing these developing models, such as detection, terrain classification, etc., are also reported in this book to assess these statistical models. We expect this book could bring some positive aspects for influencing the forthcoming SAR interpretation. Moreover, this book also provides an index for the researchers, as well as to advance the exploitation of their data for monitoring applications.

We would like to thank Dr. Xianxiang Qin for his contribution to the materials included in this book. We appreciate the editors of publication for their efforts and works. This book could not have been completed without their significant contributions. Meanwhile, many thanks must be given to several free website for their downloading service of data.

Dr. Gui Gao
National University of Defense Technology
Changsha, June 14, 2013

Contents

Chapter 1 Overview for Statistical Modeling of SAR Images

1.1 Introduction

Statistical modeling of SAR images is one of the basic problems of SAR image interpretation. It involves several fields such as pattern recognition, image processing, signal analysis, probability theory, and electromagnetic scattering characteristics analysis of targets etc. [1]. Generally speaking, statistical modeling of SAR images falls into the category of computer modeling and simulation. At present, one of the major strategies of SAR image interpretation is to use the methods of classical statistical pattern recognition which are based on Bayesian Theory and can reach a theoretically optimal solution[1,2]. To utilize these methods for SAR image interpretation, a proper statistical distribution must be adopted to model SAR image data[1,2]. Therefore, in the past ten years, statistical modeling of SAR image has become an active research field[1].

Statistical modeling is of great value in SAR image applications. Firstly, it leads to an in-depth comprehension of terrain scattering mechanism. Secondly, it can guide the research of speckle suppression[8-14], edge detection[15], segmentation[1,19-21], classification[16-18,99], target detection and recognition[3-7, 27,31], for SAR images, etc. Finally, combining statistical model with ISAR target database can simulate various SAR images with variable parameters of aspect, terrain content, region position and SCR (signal to clutter ratio), so statistical modeling can provide numerous data for developing robust algorithms of SAR image interpretation[22].

The research on statistical modeling of SAR images may be traced back to the 1970's. With the acquisition of the first SAR image in the U. S. , analysis of

the real SAR data directly promoted the development of statistical modeling techniques. The speckle model of SAR images, proposed by Arsenault[23] in 1976, is the origin of these techniques, which established the theoretical foundation of the later researches. In 1981, Ward[24] presented the product model of SAR images, which took the speckle model as a special case. As a landmark of the development of statistical modeling, the product model simplified the analysis of modeling. Since then, many scholars joined this research area and many statistical models of SAR images had been developed.

Since the 1990's, with the coming forth of a series of airborne or space-borne SAR platforms, the acquisition of SAR data is no longer a problem. Due to the urgent demands for analyzing and interpreting the obtained image data, statistical modeling has drawn much attention and become an active research area.

In recent years, many famous research organizations are doing research on SAR statistical modeling[25], and great progress has been made. According to the collected literatures, from 1986 to 2004, there are more than 100 papers dealing with SAR statistical modeling published in some famous journals such as *IEEE-AES*, *IEEE-IP*, *IEEE-GRS*, and *IEE*, etc. and in some international conferences such as SPIE and IGARSS. The related papers, which use SAR statistical model for the purpose of segmentation, speckle suppression, classification and target detection and recognition, are uncountable. Much creative research has been made. Proc. Oliver, an English scholar, published his monograph *Understanding Synthetic Aperture Radar Images* in 1998[1]. The book includes 14 chapters, two of which discuss the statistical modeling technology. It summarizes related techniques on SAR statistical modeling before 1997. After 1997, literatures on SAR statistical modeling can be seen in the famous journals almost every year. The most attractive achievement among them is the statistical modeling on extremely heterogeneous region of SAR images proposed by Frery[25] who works in Brazil. The originate ideas are introduced that SAR image can be divided into homogeneous regions, heterogeneous regions and extremely heterogeneous regions according to their contents for the purpose of statistical modeling. Further more, statistical modeling of SAR images is taken as one of the main

contents in more than 20 doctors' dissertations of UMI and in the research reports from Belgium Royal Military Academe. While numerous statistical distributions have been proposed to model SAR image data, we are unaware of any surveys on this particular topic. It is necessary to categorize and evaluate these models and relevant issues.

The main contribution of this survey is the classification and evaluation of the statistical models of SAR images existed currently. The vital and latest contributions have been covered also. The survey is organized as follows. Section 1.2 illustrates the classification and the research contents of statistical modeling. In Section 1.3, current statistical models are discussed in detail. The relationship of them and their limitations in applications are pointed out. Major conclusions and developing trends of statistical modeling are also presented. We conclude the survey in the final section.

1.2 Model Classification and Research Contents

According to the modeling process, the statistical models of SAR images can be divided into two categories[2,44,45,72,77]: parametric models and nonparametric models. When dealing with a parametric model, several known probability distributions of SAR imagery are given at first. Usually, the parameters of these distributions are unknown and have to be estimated according to the real image data. Finally, by using some certain metrics, the optimal distribution is chosen as the statistical model of the image. While handling a nonparametric model, no distributions have to be assumed, and the optimal distribution is obtained in a way of data-driven of image data. The merit of the nonparametric models is that they make the process of statistical modeling more flexible and can fit the real data more accurate.

Since nonparametric modeling involves complex computation as well as numerous data, it is usually time-consuming and cannot satisfy the requirements of various applications[44]. Consequently, parametric modeling is intensively studied. The process of parametric modeling can be described in brief as to choose an

appropriate one from several given statistical distributions for the image to be modeled. The process is shown in Fig. 1. 1. According to Fig. 1. 1, the process of parametric modeling consists of: (1) analyzing several known statistical distribution models; (2) parameter estimation: estimating the parameters of different distribution; (3) goodness-of-fit tests: assessing the accuracy of the given models fitting to the real data.

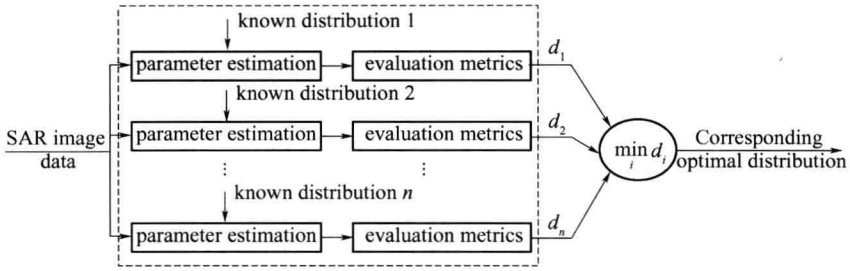

Fig. 1. 1 A general flow chart of parametric modeling

1. 2. 1 Parameter estimation

Several strategies have been proposed in the literature to deal with parameter estimation[45]. The two most frequently used methods are probably the "method of moments" (MoM)[1,173,99], and the maximum-likelihood (ML) methodology[27,72,95]. Recently, the method of log-cumulants (MoLC) is also included as a possible parameter estimation approach[8,99,108].

1. 2. 2 Goodness-of-fit tests

A number of methods for quantitatively assessing the validity of statistical models in light of sample data have been developed over the last hundred years. Many of these methods place the problem in a statistical hypothesis testing framework, pitting a null-hypothesis H_0 , an assertion that the data were not generated according to the model, against an alternative hypothesis H_1 , an assertion that they are not. The methods are then implemented by computing some statistic of the random observations that has a known distribution if H_0 were true. Values of this quantity close to zero are interpreted as evidence that H_0