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工学博士学位论文

# 基于变换编码和分布式编码的谱带排序优化的卫星图像通信方法

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Dissertation for the Doctoral Degree in Engineering

# SATELLITE IMAGES COMMUNICATION SCHEMES WITH BAND ORDERING OPTIMIZATION BASED ON TRANSFORM CODING AND DISTRIBUTED CODING

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# 摘 要

目前，遥感中心提供越来越多的地球表面可用卫星图像。一方面，卫星图像提供大量信息，每一张图像大小在几十兆字节到千兆字节范围之间，图像压缩可以有效的减少存储的需求。另一方面，目前，全球定位系统提供用户的位置和信息。因此，使用卫星导航已成为生活中不可或缺的一部分，同时，传输这些卫星图像成了一个巨大的挑战。此外，高光谱图像已经在独立的陆地地图服务，以及政府和军事活动等各种各样遥感项目得到了广泛应用。考虑到高光谱卫星图像中的一些频带受到卫星和地面站之间的大气以及信道噪声的干扰，我们将同一个高光谱图像的不同版本进行联合处理，以获得更高的图像质量。因此，研究高光谱卫星图像通信方案以提高接收图像的质量成为了新的研究热点。

本文提供了卫星图像通讯的有效方法。在通信系统中，由两部分组成；压缩和传输。本文的第一部分介绍了两个卫星使用小波变换和速率控制卫星图像的图像压缩方法。第一个压缩方法是基于从原始卫星图像众多相关联的频带中去除一些小波子带。被分解的子带由使用带之间的相关系数决定,然后重建解码器从最相关的子带到那些被删除的子带。这种方法减少了高质量卫星图像的储存大小。来自ETM的多频谱图像。实验结果表明，该方法将平均多光谱图像质量提高了3-11dB。第二个压缩方法介绍了一个立足于码率控制的卫星图像有损压缩的简单方法，该方法的目标是减少植物特征的影响。这个压缩技术是基于一个新的速率控制方案的植被组(即。组包含最重要的乐队,植被特征提取)编码比特率高于其余组。该研究是在几个卫星图像上进行的，来自ETM的多频谱图像；通过飞船可见分光仪采集的多频谱遥感图像。在所有实验结果中，传统的压缩方法对卫星图像的植被特征表现出更大的影响。此外，所提出的方法对植被特征影响较小。 这些结果验证了所提方法的有效性。

第二部分介绍了两个无线通信构架，卫星传感图像问题中解决大量接收端情况下的无线编码和基于SoftCast和分布式编码。本文将这些框架进行了扩展，用来解决多波段的遥感图像问题。第一个通讯方法，称为HyperCast，使用一个集群转换的方法。这种方法将高光谱图像波段分成组,然后采用变换从每组删除冗

余信息。随后，传输能量将根据他们的能量分布直接分配到量化数据上，无需FEC的参与。HyperCast分别在LineCast，SoftCast-3D和传统框架上广播PSNR增益高达6.98dB，3.48dB和6.14dB。第二种通讯方法是基于DWT和分布式信源编码实现的。小波变换之前，高光谱的预处理是进行两步波段订购和规范化。对DWT操作，我们进行一个三级划分，每个频谱图像划分为10个小波子带，其中9个子带是图像的细节描述。最后的一个级别（LL-LL-LL）为图像的近似描述。对于LL-LL-LL子带，我们采用了基于信源分布式编码的培基编码技术来提高压缩效率，同时降低编码复杂度。小波分解后细节和陪集值传播类似于前面的方案没有FEC。广播中的实验结果表明，该方案分别比LineCast，SoftCast-3D和常规框架提高了6.91dB，3.00dB和5.63dB 平均图像质量。此外，所提出的方案比所有最先进的方案具有较少的编码时间。最后，此通信方案提出了高效的排序算法来提高压缩性能。与平均PSNR上没有频带排序高达1.30dB的情况相比，所提出的频带排序算法具有更好的性能。

**关键词：**有损压缩；变换编码；速率控制；多谱带排序；遥感图像通信；分布式编码

# Abstract

Remote sensing centers have currently more and more available satellite images of the earth surface. The satellite images produce large volumes of information, and each image may have a size that ranges from tens of megabytes to a gigabyte. So, compression can help to reduce the huge storage requirements needed. On the other hand, global positioning systems (GPS) provide the locations and information for users. Therefore, using satellites for navigation has become an indispensable part of modern life and the transmission of these satellite images have become one of the greatest challenges. Moreover, hyperspectral images have been used in a wide range of applications and remote sensing projects ranging from independent land mapping services to government and military activities. Some bands of the hyperspectral satellite image are corrupted by noise due to the atmosphere and the channel noise between the satellite and the ground station. Therefore, when we have more than one version of the same hyperspectral image, we can combine theme to achieve the best image quality. Thus, the need for development of new communication schemes for hyperspectral satellite image becomes more and more imperative to improve the quality of the received images.

This work is focused on the efficient communication schemes of the satellite imagery. In the communication system, there are two different parts; compression and transmission. The first part of this thesis introduces two lossy compression techniques using wavelet transform and rate control for satellite images. The first compression technique is based on removing some wavelet sub-bands from the most correlated bands. The removed sub-bands are determined using the correlation coefficients between bands and then they are reconstructed at the decoder from the most correlated sub-bands with them. This method reduces the size of storage of satellite images while keeping high-quality reconstruction. Enhanced Thematic

Mapper plus (ETM+) satellite multispectral images are used for evaluation. Simulation results demonstrate that the proposed method improves the average multispectral image quality by 0.5dB to 9dB. The second compression technique introduces a simple trend for lossy compression of satellite images based on rate control aiming at decreasing the impact on vegetation features. This compression technique is based on a new rate control scheme in which the vegetation group (i.e., group containing the most significant bands for vegetation feature extraction) is encoded at a higher bit rate than that of the remaining group. The study is performed on several satellite images, where multispectral images are selected from an ETM+ satellite, and hyperspectral images are selected from an Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) satellite. In all simulation results, the traditional compression methods exhibit more effects on the vegetation features of satellite images. Besides, the proposed method has a less impact on vegetation features. These results validate the effectiveness of the proposed method.

The second part of this thesis introduces two wireless communications schemes for broadcasting high resolution satellite images to a large number of receivers based on SoftCast and distributed coding. These schemes are extended to deal with the hyperspectral satellite images. The first communication scheme, called HyperCast, uses a clustering transformation approach. This approach divides the hyperspectral image bands into groups, and then employs the transforms to remove the redundant information from each group. After that, the transmission power is directly allocated to the transformed data according to their distributions and magnitudes without forward error correction (FEC). These data are transformed by Hadamard matrix and transmitted over a dense constellation. HyperCast achieves in broadcasting a PSNR gains up to 6.98dB, 3.48dB and 6.14dB over LineCast, SoftCast-3D, and the conventional framework, respectively. The second communication scheme is based on wavelet transform and distributed source coding

(DSC). Before wavelet transform, the pre-processing is performed in two steps which are hyperspectral band ordering and normalization. In the wavelet transform, the DWT with three-level decomposition is used to divide each hyperspectral image band into ten wavelet sub-bands; nine of them are the details and the last LL-LL-LL is an approximation version of the band. Coset coding based on DSC is used for the LL-LL-LL sub-band to achieve high compression efficiency and low encoding complexity. The detail wavelet sub-bands and the coset values are transmitted as in the previous proposed scheme without FEC. Experimental results on broadcasting demonstrate that the proposed scheme improves the average image quality by 6.91dB, 3.00dB and 5.63dB over LineCast, SoftCast-3D, and the conventional framework, respectively. In addition, the proposed scheme has less encoding time than all state-of-the-art schemes. Finally, the proposed communication schemes present efficient hyperspectral band ordering algorithms based on the correlation coefficients and absolute differences between bands to improve the compression performance. The proposed band ordering algorithms achieve better performance as compared to the case of no band ordering up to 1.30dB on average PSNR.

**Keywords:** Lossy compression; Transforms coding; Rate control; Hyperspectral band ordering; Satellite image communication; Distributed coding.