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博 士 学 位 论 文

小波变换在光谱和多光谱图像的应用与研究

Research and Application of Wavelet Transform on

Spectroscopy and Multi-spectral Image

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## 摘要

本论文分为两部分：小波变换在光谱定量分析与多光谱图像的应用。

小波分析技术是新近出现的数学方法，近年来，在光谱分析得到广泛的应用。本论文介绍小波变换和多分辨分析的原理和方法，并将其应用于光谱信号的噪声去除、有用信息的提取等方面，取得良好效果。

将小波变换技术应用于 MS-3100 多光谱图像的近红外通道 (Ir) 图像的边缘特征提取。同时，将盲解卷积恢复技术结合小波变换的边界提取技术，在一定程度上抑制了模糊图像恢复时产生的振铃效应。

本论文具体的主要研究内容和结果如下：

- (1) 在小波变换阈值去噪技术中，一般分为硬阈值与软阈值技术两种方法，硬阈值技术会造成重构信号的振荡，软阈值技术会造成重构信号与真实信号的偏差。针对这一缺陷，本论文提出了提升阈值法，在此方法中，利用一可变参数对不同信号的特点自适应地进行阈值调节。同时，在小波变换去噪技术中，其它参数（如小波函数、分解层数、阈值估计函数）对去噪质量都有一定的影响。针对这种情况，本论文提出用模拟退火算法 (Simulated Annealing Algorithm, SAA) 来优化这些参数，并将提出的算法应用于奶粉的可见-近红外光谱中。结果表明，与其它参数的去噪结果相比，模拟退火算法寻找到的这些参数即是最优的参数。
- (2) 针对在小波包变换 (WPT) 产生的频带混乱问题，在不改变 WPT 原算法的基础上，本论文提出了解决频带混乱问题的新算法。并将新算法应用于近红外光谱的小波包分解中，使其在小波包分解域的物理意义清晰化。
- (3) 在小波包分解域中，不同的子频带对模型的贡献是不同的。因此，本论文提出利用 SAA 对其寻优，寻找出对模型贡献最大的子带频。提出的方法应用于月桂酸成分预测的红外光谱和机油分类的可见-近红外光谱中，用偏最小二乘回归 (PLS) 建立模型，相比于用全光谱建立的模型，月桂酸的成分预测均方根误差分别从 7.9557 提高到 6.6787，机油分类的成分预测均方根误差从 0.2383 提高到 0.1031。
- (4) 针对无信息去除算法 (UVE) 阈值选择的随机性和主观性，提出了改进

无信息去除算法 (IUVE), 即用 SAA 来寻找最优阈值。同样地将 IUVE 应用于月挂酸成分预测的红外光谱和机油分类的可见-近红外光谱中, 也用偏最小二乘回归 (PLS) 建立模型, 相比于传统的 UVE, 月挂酸的成分预测均方根误差分别从 7.3171 提高到 7.0171, 机油分类从 0.1044 提高到 0.0991。同时, 根据在小波包分解域中用少数的几个系数就能够表达大部分原始光谱信息的特点, 提出了 WPT 结合 IUVE 的方法, 从而能够得到紧凑而高效的模型。并将此方法应用于月挂酸成分预测的红外光谱和机油分类的可见-近红外光谱中, 相比用原始光谱数据的 IUVE 中, 在没有降低预测均方根误差的前提下, 相应的模型所用的变量数目分别从 319 减少到 164 和 472 减少到 13。

- (5) 在 MS3100 多光谱成像仪的三个图像通道中, Ir 通道图像特别适合用于作物杂草与背景物 (如土壤等) 的区分, 这非常有利于杂草识别。而形状是识别作物与杂草重要的判别之一, 为了把杂草与作物区别, 往往需要对采集的图像进行边缘检测。基于 B 样条小波变换技术的边缘提取算法, 有效地弥补了传统的边缘检测检测算法的不足, 从而提高边缘定位精度。本论文结合多光谱图像技术和 B 样条小波边缘提取技术, 有效地提取作物与杂草的边缘信息。同时, 结合盲解卷积技术与 B 样条小波边缘提取技术, 在一定程度上抑制了图像恢复所产生的振铃效应现象。

**关键词:** 小波变换; 可见-近红外光谱; 无信息去除; 多光谱图像;

## ABSTRACT

The dissertation is divided into two parts: applications of wavelet transform on spectral quantitative analysis and multi-spectral digital image.

Wavelet transform (WT) is a new mathematical method. Recently, it is applied on spectral quantitative analysis extensively. In this thesis, firstly, an introduction of wavelet transform and multi-resolution analysis is presented. Then, WT is applied on spectral noise removal and extraction of useful information, good results are obtained.

The second part in the dissertation is combination of multi-spectral digital image technology and wavelet transform to extract the edge information, and the extracted edge information is applied on the restoration with blind deconvolution, which restrained the ringing artifacts effectively.

The detailed content and the main research results are as followed:

- (1) Wavelet threshold de-noising includes hard- and soft-threshold strategy. The hard-threshold may lead to the oscillation, and soft threshold may cause constant deviations between estimated wavelet coefficients and original signal wavelet coefficients. An improved de-noising method was proposed to solve the defects. According to the characteristics of different signal, a flexible parameter in the improve method was adjusted automatically. Simultaneously, other parameters such as wavelet function, decomposition level and threshold estimation method affects seriously the quality of de-noising. So, the simulated annealing algorithm (SAA) was used to find the optimal parameters. The presented method was applied on visible-near infrared (vis-near) spectra of milk powder. The results showed the obtained parameters by SAA were optimal parameters.
- (2) The new algorithm for frequency derangement of wavelet packet transform (WTP) is presented. The new algorithm has not changed the original algorithm of WTP, and applied on vis-near spectral of glycerol gonolaurate and lubricant, The new algorithm could explain clearly the physical meaning of WTP for spectral.
- (3) In the decomposition domain of WPT, the frequency sub-bands who contribute to the calibration model have different. In this dissertation, SAA was adopted to find

the sub-band who contributes most to model. The proposed method was applied on vis-near spectral of glycerol gonolaurate and lubricant. The model was built by partial least square (PLS) regress. Compared to the model using the whole original spectra, the root mean square error of prediction (RMSEP) of glycerol gonolaurate and lubricant was improved from 7.9557 to 6.6787, and 0.2383 to 0.1031 respectively.

(4) In uninformative variable elimination (UVE) algorithm, the cutoff threshold of UVE is evaluated by adding a noise matrix which size is the same with instrumental response data. The method to evaluate the cutoff is experientially and randomly, and difficult to obtain the optimal cutoff threshold. In this dissertation, the improved UVE (IUVE) was presented. In the IUVE, the SAA was used to find the optimal cutoff threshold, and applied on Vis-near spectral of glycerol gonolaurate and lubricant. Compared to the traditional UVE, RMSEP of gonolaurate and lubricant obtained by IUVE was improved from 7.3171 to 7.0171, and 0.1044 to 0.0991 respectively. Simultaneously, in WPT decomposition domain, only a few coefficients may explain the information of the whole original spectra. If WPT coefficients are used in the IUVE, more parsimonious model should be obtained. The proposed method was applied on the vis-near spectral of glycerol gonolaurate and lubricant. Compared to IUVE, the result indicated that the input variables for calibration model was reduced from 319 to 164 for glycerol gonolaurate, and 472 to 13 for lubricant, and the prediction precision was not compromised.

(5) The three channel of MS3100 multi-spectral imager are green (Gn), near infrared (Ir), and red (Rd). Ir-channel image is particularly suitable for distinction of the crop and background objects (such as soil, etc.), so it is extremely beneficial to weeds recognition. The shape is important feature for distinction of weeds and crops, so the edge information should be extracted in order to recognize the weeds and crops correctly. In the dissertation, integration of B-spline wavelet transform and multi-spectral image technology was used to extract the edge information of multi-spectral image, the results showed the important edge



information is extracted by the proposed method. Finally, the edge information was applied on the blind revolution restoration, and the ringing artifacts.were eliminated effectively.

**Keywords:** Wavelet transform; Vis-NIR; UVE; Multi-image;

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