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论文与技术报告

基于稀疏表示的THz信号分类方法

李静, 谢维信, 裴继红

西安电子科技大学电子工程学院

摘要：

基于几何代数的太赫兹时域光谱(Terahertz time domain spectroscopy，THz-TDS)信号分析的研究表明：THz信号可表示为几何代数结构下的实矢量，同类THz信号矢量位于与其物质相对应的二维特征子空间中，并且在研究同厚度目标样品或菲涅耳损耗可忽略的情况下，同类THz信号矢量间具有线性相关的特性。THz信号矢量可以用已知同类的信号矢量的线性组合来表示。在此基础上，本文从信号的稀疏表示方法出发，采用已知THz信号矢量构建冗余字典，对THz信号矢量进行基于冗余字典的稀疏表示，并将THz信号分类问题描述为线性方程组的求稀疏解问题。本文提出了基于稀疏表示的THz信号分类方法。该方法首先基于已知类别的THz信号矢量构建冗余字典，然后对待分类信号运用最小化l1方法来求解线性方程组中的系数，最后根据稀疏系数来确定该信号矢量的类别标识。本文详细讨论了该方法中的每个步骤：基于THz信号矢量的几何分布和代数结构特性，提出了冗余字典的优化构建方法；通过引入噪声因素，对信号分类问题的线性方程组模型进行了修正；在确定类别标识的问题上分别提出了以最大系数和最小残差作为分类依据的方法。实验验证了本文方法的可行性和有效性。

关键词： 太赫兹时域光谱信号；稀疏表示；压缩感知；几何代数

THz-TDS Signal Classification via Sparse Repressentation

LI Jing, XIE Wei-Xin, PEI Ji-Hong

School of Electronic Engineering, Xidian University, Xi’an

Abstract:

It is demonstrated by the THz-TDS (terahertz time domain spectroscopy) signal analysis based on geometric algebra that: THz signals can be represented as real vectors under the framework of the geometric algebra, vectors corresponding to the same substance belong to the intrinsic 2-dimensional feature subspace of that substance, and especially when the samples studied are of the same thickness value or when the Fresnel loss can be neglected, vectors of the same substance are linearly dependent to each other. Vectors of THz signals can be represented as a linear combination of the signal vectors correspondingly from the same class. Based on that, from the view of the signal sparse representation, THz signal vectors can be represented in an overcomplete dictionary whose base elements are the “known” signal vectors themselves. Such that, the signal classification can be modeled as the problem of finding the optimal sparse solution to linear equations. A signal classification method via the sparse representation is presented. In the method, an overcomplete dictionary is constructed using the “known” THz signal vectors. And for one test signal, the optimal sparse coefficients of the linear equations are obtained efficiently via the l1-mininmization. Finally, the class of the test sample is determined based on the coefficients. Each step of the method is discussed in detail: an optimal construction method of the overcomplete dictionary is developed based on the geometrical distribution and the algebraic structure properties of signal vectors, the model of the signal classification is modified to account for possibly noise, and the test sample is classified using the criterion of either the maximized coefficient or the minimized residual. Feasibility and effectiveness of the method is confirmed by experiments presented.

Keywords: THz-TDS sparse representation compressive sensing geometric algebra

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通讯作者:

作者简介:

作者Email: lijingsz@szu.edu.cn

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