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一种基于图像增强的地下管线 **GPR B-scan** 预处理方法

摘要

探地雷达（GPR）已被证明是一种有效的无损检测地下管线的方法，然而，现有的自动化方法在从 B-scan 中分割目标双曲线方面表现不佳，尤其是在非理想野外条件下识别较细的管线时效果有限。本文提出了一种用于 B-scan 预处理的自动化算法流程。该流程包含三个核心步骤：地面反射条带消除算法（GRRA）、基于数据作用力的增强算法（DGFE），以及基于扩张的局部定阈和分割算法（DLTS）构成的全局–局部定阈方法。首先，算法利用基于快速傅里叶变换的频域滤波器和空间滤波器对原始 B-scan 进行处理，去除干扰性的地面反射条带。鉴于目标双曲线、多次波和背景之间的强度差异较小，引入 DGFE 以增强双曲线的主体结构，使其从噪声中更可辨别。最后，采用一种混合定阈法从灰度图像中提取目标双曲线，主要使用 DLTS 方法，通过扩张和局部定阈完成双曲线的完整分割。实验表明，该模型在实地实验中获取的 B-scan 数据上实现了快速且有效的处理表现。

关键词

探地雷达（GPR）；地下管线；图像增强；定阈；双曲线分割

Abstract

Ground-penetrating radar (GPR) has been proven effective for detecting subsurface pipes in a nondestructive way, typically with manual processing and decision-making. However, existing automatic models for segmenting target hyperbolas from B-scans perform inadequately, particularly for thin pipes buried under suboptimal field conditions. In this paper, an automatic model for B-scan preprocessing is proposed to assist in interpreting B-scans with small-scale hyperbolas that attenuate along the time axis. The model includes a ground reflection removal algorithm (GRRA), the data gravitational force enhancement (DGFE) method, and a global–local thresholding technique consisting of dilation-based local thresholding and segmentation (DLTS). First, a frequency-domain filter based on the fast Fourier transform and a spatial filter are applied to the raw B-scan to remove obstructive ground reflection strips. Owing to the minimal intensity differences among the target hyperbola, multiples, and background, the DGFE enhancement approach is introduced to amplify the main body of the hyperbola, distinguishing it from the noise. Finally, the target hyperbola is extracted from the grayscale image by an integrated thresholding approach. The approach initially employs global thresholding to eliminate all information except part of the hyperbola, followed by DLTS, which uses a dilation operation with local thresholding to fully segment the hyperbola. The proposed model is demonstrated to be fast and effective through implementation on B-scans from a database acquired in a field experiment.

Keywords

ground penetrating radar (GPR); underground pipes; image enhancement; thresholding; hyperbola segmentation

Author: 史, 政一

Co-authors: Prof. 黄, 弘 (清华大学安全科学学院); Mr 马, 翰超 (清华大学安全科学学院)

Presenter: 史, 政一

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