

Technical Note

Subsurface GPR imaging of a potential collapse area in urban environments

Yih Jeng*, Chih-Sung Chen

Department of Earth Sciences, National Taiwan Normal University, 88, Sec. 4, Ting-Chou Road, Taipei, 116, Taiwan, ROC

ARTICLE INFO

Article history:

Received 4 January 2012

Received in revised form 12 July 2012

Accepted 19 July 2012

Available online 1 August 2012

Keywords:

GPR

Shallow imaging

Logarithmic transform

EEMD

Sub-component

ABSTRACT

Ground penetrating radar imaging is one of the promising nondestructive and noninvasive methods that have offered new opportunities for mapping the subsurface structures of shallow earth in highly urbanized regions. In this study, we performed the ground penetrating radar survey in a potential collapse urban area. The acquired data were processed through the logarithmic transformed ensemble empirical mode decomposition (EEMD) methodology that reduces the exponential decay of the original data and extracts meaningful images. This method proves successful in imaging the top pavement layers, utilities and voids within approximately 2 m depth. Moreover, the quality of the subsurface image can further be improved by using the sub-component EEMD filter bank. Through a control study followed by the general field survey and direct excavations, we demonstrate the efficiency and quality of this method in mapping shallow structures in an urban area. An interpretation of the cause for the collapse in the study area is also proposed.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Information of shallow earth structures is important for land use in urban environments. Near-surface voids, shallow faults, the boundary between sediment and bedrock, and the subsurface utility infrastructures, among others, are key factors that affect the dweller safety and city development (Harbor, 1999; Alcántara-Ayala, 2002; Jeng et al., 2004; Xu et al., 2010). Because the developments of geomorphic structures in the urban area are proceeding underground or beneath the road surface, it is difficult to locate the position and monitor the change directly from the ground surface. Therefore a competent scheme to acquire knowledge of shallow structures is vital for city planning and hazard prevention. There have been many geophysical methods demonstrating the effectiveness in shallow earth investigation (Arcone et al., 1998; Baker et al., 2003; Kneisel, 2006; Jeng et al., 2007a,b); however, the application in the urban area is still a challenge because of the complicated environments and cultural activities (Jeng, 1995; Mellett, 1995; Schrott and Sass, 2008; Boudreault et al., 2010; Sgarlato et al., 2011).

The study area is a potential collapse site located in the south district of metropolitan Taipei (Figure 1) which is densely populated. To gain the necessary subsurface information for the assessment of potential hazardous events, a pilot study using GPR system was carried out in this area. With antenna frequencies varying from 12.5 MHz to 2 GHz in general, ground penetrating radar (GPR) system is a high frequency electromagnetic device for near-subsurface sounding and structure

evaluation. In addition, it is an instrument particularly useful for carrying out shallow survey in urban environments due to its nondestructive nature and capability of providing high resolution shallow subsurface profile. Despite these advantages, GPR data require special processing techniques to reveal signals in complex urban environments. Some standard techniques borrowed from seismic data processing are applied routinely in the GPR data processing for nondestructive evaluation of structures or shallow subsurface investigation. However, the pavements and buried utilities in urban environments will resist the penetrating of GPR energy and degrade the data quality to the extent that standard data processing efforts may not be useful. Besides, if the subsurface consists of numerous reflecting events interfering each other, the analysis and interpretation of the data can be very complicated and the success of GPR survey will be limited (Guangyou and Pipan, 2003; Theune et al., 2006). In fact, a basic problem hidden in this matter is that the data attributes of the GPR system are basically different from that of seismic data; a processing algorithm to enhance or extract interesting events in seismic data may not be suitable for GPR.

In view of the above consideration, we propose a processing scheme which is efficient in enhancing the signal of the acquired GPR data and eliminating spurious components lacking of physical meaning. In fact, the proposed method is a nonlinear filtering technique, the ensemble empirical mode decomposition (EEMD) with the aid of logarithmic transform. The EEMD method has been demonstrated very effective in extracting signals from noisy data (Wu and Huang, 2009; Lin and Jeng, 2010). Chen and Jeng (2011) described the logarithmic transformed EEMD extensively and successfully applied it to a geologic field example. However, there are some arguments raised on applying the logarithmic transformed EEMD algorithm to field GPR data. For example, the multi-mode distribution of the decomposed component and the

* Corresponding author. Tel.: +886 2 77346416; fax: +886 2 29333315.

E-mail address: geofv001@ntnu.edu.tw (Y. Jeng).

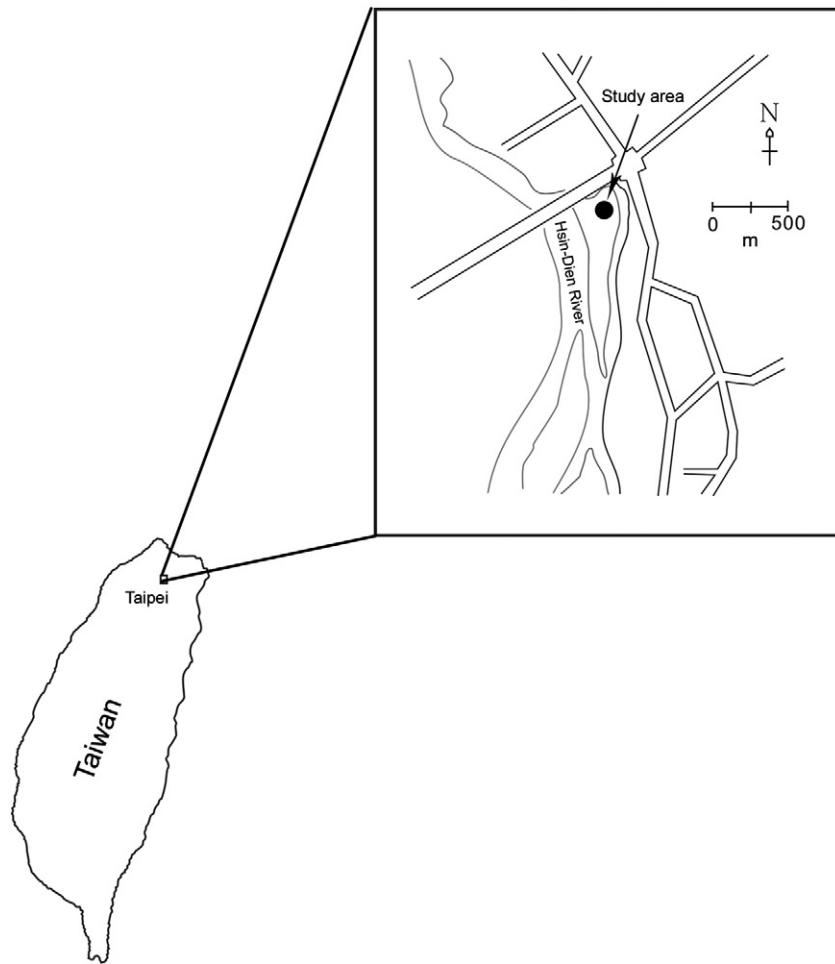


Fig. 1. Map of Taiwan with the location of the study area.

recognition of target information are still noticeable issues, and they may become serious problems in urban environments due to the data complexity and abundance of artificial noises. To deal with the difficulties, we propose a refining procedure, the sub-component EEMD filter bank for acquiring better results.

In addition to processing scheme, the data collection strategy is also critical in urban geomorphic investigation. The GPR system and field acquisition parameters should be carefully selected based on the environment of survey sites. To assure the quality of data interpretation, we performed a control study prior to the general field survey for the purpose of identifying reflection patterns in this area.

The results of the field survey are displayed in a 3D view using 2D profile. Excavation results are also presented to verify the data interpretation derived from this new processing scheme. This study thus provides an insight into the geomorphologic problem of a potential collapse area with a special view to a renovated GPR data processing procedure, incorporating the logarithmic transformed EEMD method and the sub-component EEMD filter bank into the data processing sequence, which should benefit the GPR technique in urban geomorphologic study.

2. Methods

2.1. GPR instrumentation

Subsurface profiling with GPR is similar to that of seismic exploration; the difference is that GPR energy is electromagnetic energy instead of acoustic energy. As the radar wave is transmitted into the subsurface, reflection and refraction response to subsurface discontinuities (Davis

and Annan, 1989; Fisher et al., 1992; Neal, 2004). In contrast to seismic, the discontinuities are electrical properties (mainly the relative dielectric permittivity), not elastic parameter discontinuities. Because the energy emitted by the transmitter is not confined to propagate downward, the first energy to arrive at the receiver is the direct air wave which travels directly from the transmitter to the receiver through the air. This is also called antenna's direct coupling. So the direct coupling is usually used as a marker to perform depth calculation. The next arrival is the direct ground wave. It travels directly from the transmitter to the receiver through the ground surface. The following arrivals are the reflections from the electrical discontinuities in a sequence from shallow to deep. Of course, an appropriate GPR system should be selected to ensure the possibility of reaching the target depth with arrivals of acceptable resolution. As a common knowledge of geophysics, the penetrating depth of GPR waves is related to the antenna frequencies; the lower the frequency, the deeper the radar wave penetrates. Both low and high antenna frequencies have different advantages and shortcomings. For shallow geomorphic survey, antenna frequencies approximately between 200 MHz and 500 MHz are appropriate to acquire data from less than 1 m depth to about 8 m depth with satisfactory resolution. Some cautions should be taken when changing the antenna frequency. In higher frequency (approximately greater than 300 MHz) systems, the antennas are relatively small and can be shielded in an antenna housing to keep away from unwanted electromagnetic energy. In contrast to high frequency antenna, it is impractical to shield the lower frequency antennas due to their larger dimensions. Thus, fiber optic cables should be used to avoid the environmental electromagnetic noise. Although the unshielded GPR system is more difficult to work with, it still has advantages over the shielded system in collecting data for

Download English Version:

<https://daneshyari.com/en/article/6448017>

Download Persian Version:

<https://daneshyari.com/article/6448017>

[Daneshyari.com](https://daneshyari.com)