Detection of buried human bodies using ground-penetrating radar method

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Abstract. Indonesia is a country that often experiences natural disasters as it is a meeting point of several tectonic plates. When a natural disaster occurs, most of the time the evacuation team having some trouble finding the buried victims underground. The Ground-Penetrating Radar (GPR) method is one of the solutions for this problem. GPR or also called georadar is a geophysical method that is used to investigate conditions under the earth’s surface using electromagnetic waves. This study aims to detect buried human bodies underground using the GPR method to increase the effectiveness and efficiency of natural disaster victims by doing a simulation measurement. It took place in one of the public cemeteries in Jakarta, Indonesia passing two graves with corpses buried around three years before the survey. GPR measurements were conducted using Geoscanners AKULA A9000+ Antenna GCB 3070 to detect the buried human bodies underground. The GPR data then processed using MATLAB based program called matGPR. A series of adjustments and filters such as signal position adjustment, remove DC, mean filter, inverse amplitude decay, remove global background, and Karhunen-Loeve (KL) filter have been applied to the data. The result of data processing shows amplitude contrasts which are suspected to be the buried corpses. Further research can be conducted to investigate the buried victims from landslides, earthquakes, and other natural disasters.

1. Introduction

Indonesia is known as a remarkable country with a lot of islands, placed between the vast Pacific and Indian Oceans, rich with astonishing natural environments and resources along the regions. Despite its beauty, Indonesia also lies across the Pacific Ring of Fire which is the center of some active volcanoes, located in between tectonic plates and had intense tropical rain along the year, which makes this country prone to devastating natural disasters such as volcano eruption, earthquake, tsunami, and landslide [1]. As stated by BNPB, there were more than 3,397 natural disasters that occurred in 2018 and 3,662 natural disasters occurred in 2019 [2] which threaten Indonesian people and the environment. These natural disasters caused severe destruction and a huge number of victims. Unfortunately, conventional methods for investigation are still often used by the evacuation team to locate the buried victims underground. These conventional methods were taking a long time in the process and most of the time left some buried victims unfound [3].
The Ground-Penetrating Radar (GPR) method is a well-known geophysical method that transmits electromagnetic waves from antennas into the subsurface and measures the travel time between when the radar waves are sent and when they are back to the receiver [4]. As the radar waves are transmitted through some mediums to the buried target underground, their velocity will vary depends on the physical characteristics of the medium in the subsurface [5]. Experiments to detect buried human bodies using the GPR method have been done by Damiata et al. that able to detect the presence of human skeletal inside a grave [6], and Widodo et al. that able to estimated human bodies in the subsurface using georadar method at local graveyard [7]. All experiments mentioned before are using the same principle, which is based on the value of the magnetic permeability and the electric permittivity from the human objects with the environments around them [3]. This study aims to detect buried human bodies underground using the GPR method to increase the efficiency of natural disaster victims evacuation by doing a simulation in one of the public cemeteries.

2. Methodology

2.1. Data Acquisition
GPR measurements in this study were conducted in Jakarta, Indonesia using Geoscanners AKULA A9000+ Antenna GCB3070 with 700 MHz of frequency. This tool was based on the GPR method principle, which transmitting radar waves into the target medium in the subsurface and then these waves are reflected back to the receiver. Various kinds of objects can be detected and recorded in the GPR program from the reflection results. There are 3 acquisition lines (Line 1, 2, and 3) which are passing 2 graves as shown in the survey acquisition design (Fig. 1) with corpses buried around three years before the survey.

![Figure 1. Survey acquisition design.](image)

2.2. Data Processing
The acquired GPR raw data were processed using MATLAB based program called matGPR. A series of adjustments and filters as explained below were applied to increase the interpretability of the GPR profiles. Fig. 2 shows the flowchart of data processing.

![Figure 2. Data processing flowchart.](image)
2.2.1. **Signal Position Adjustment.** This correction is necessary because the tool used in this study did not directly touch the ground, so all traces need to be adjusted to a time zero position before doing the processing procedure further. This point usually is when the first negative peak of the georadar trace is noticed [8].

2.2.2. **Remove DC.** DC component from each trace of the GPR profiles needs to be removed [8].

2.2.3. **Mean Filter.** Mean filtering is applied to decrease the spatial intensity derivatives which occurred in the GPR profiles and generally acts as a lowpass frequency filter [8].

2.2.4. **Inverse Amplitude Decay.** Data amplification by the Inverse Amplitude Decay applies an empirical gain function, which exactly compensates the mean or median attenuation observed in a 2-D GPR radargram [8].

2.2.5. **Remove Global Background.** Background removal is used to remove the ringing in the GPR data. Some noises in the data usually appear to have a similar amplitude along the same acquisition line, this filter will also be able to remove the effect of that occurrence [9].

2.2.6. **Karhunen-Loeve (KL) Filter.** This filter has similarities with Fourier transforms which the coefficients needed to transform are taken directly from the GPR data. It reconstructs the initial GPR data with the main component which increases the lateral coherency and decreases the noise [10].

3. **Results**

Raw GPR profiles from the acquisition process shown in Fig. 3. These profiles gave initial visualization from the subsurface below. Fig. 3(a) and 3(b) resembled each other because they were taken from Line 1 and 2 which passed both graves, while Fig. 3(c) is from Line 3 which only passed Grave 2 (see Fig. 1). The vertical scan-axis showed the two-way travel time in nanoseconds (ns) and the horizontal axis showed the distance at which the data was recorded in meters (m). It was necessary to process the data before doing interpretation because there were still some noises in the raw GPR profiles.

![Figure 3. Raw GPR profiles of (a) Line 1, (b) Line 2, and (c) Line](image-url)
Data adjustments and filtering was done to increase the interpretability of those raw GPR profiles. Fig. 4(a) shows the signal position adjustment result where the signal had been positioned to time zero because the tool used in this study did not directly touch the ground, caused a gap between the tool and the soil. DC removal process was then applied to the GPR profile. In Fig. 4(b) The radargram contrast seemed to become a bit lower but there was not any significant difference from the step before. The mean spatial filter is applied to remove ringing under the target and makes the radargram in Fig. 4(c) look smoother. Another adjustment applied to the data was the inverse amplitude decay, which generated a significant difference in Fig. 4(d) because the signal had been strengthened. In most cases, some noises have a similar amplitude along the same acquisition line or so-called horizontal banding. A process of filtering called remove global background had been applied to remove the horizontal banding and the result is shown in Fig. 4(e). The last filter applied to the data is the Karhunen-Loeve (KL) filter. Fig. 4(f) shows the final result where the noise had been reduced and the lateral coherency had been increased before continuing to the interpretation process.

**Figure 4.** Data processing results of representative GPR profile (Line 1), involve (a) Signal position adjustment, (b) Remove DC, (c) Mean filter, (d) Inverse amplitude decay, (e) Remove global background, and (f) Karhunen-Loeve filter.

4. Discussion
Final radargrams from the Karhunen-Loeve filter (Fig. 5) were interpreted based on the responses from objects in the subsurface. The amplitude contrast indicated by the blue rectangle within the travel time range of 1.9 – 2.5 ns and the scan-axis range of 1.8 – 2.4 m in Line 1 (Fig. 5a) is suspected as the
location of where the body in Grave 1 is buried. There was also a higher amplitude contrast indicated by the green rectangle within the travel time range of 1.9 – 2.7 ns and the scan-axis range of 2.8 – 3.4 m in Line 1 (Fig. 5a) which is suspected as the location of where the body in Grave 2 was buried. On the upper part of those marked amplitude contrasts in Line 1 (Fig. 5a), there were some random hyperbolic patterns caused by the unconsolidated rock. This soil material was not being compacted and used to bury the body. Two amplitude contrasts were also found in Line 2 (Fig. 5b) with similar positions of travel time and scan-axis ranges compared to Line 1 (Fig. 5a). The amplitude contrast indicated by the green rectangle in Line 1 (Fig. 5a) and Line 2 (Fig. 5b) was higher because the buried corpse in Grave 2 might be younger than Grave 1. The body part of the younger corpse would give a larger contrast with soil compared to the contrast of human bones from the older corpse. It was rather difficult to interpret which amplitude contrast represents the location of the buried body in Line 3 (Fig. 5c), but from the Line 1 and Line 2 results, it could be estimated that the amplitude contrast indicated with a green rectangle was the location of buried body in Grave 2. The lower part of the radargram in Fig. 5 shows a layering pattern from the undisturbed sand which is well consolidated compared to the upper soil. The discontinuities on the radargram profile might be caused by the air from the hole in the subsurface.

Figure 5. Final radargram of (a) Line 1, (b) Line 2, and (c) Line 3. The blue and green rectangles are interpreted as the location of where the bodies are buried because of the strong amplitude contrast presence.
The result from Dewi et al. is similar to the findings described in this study [3]. The significance amplitude contrasts indicated by the rectangles (Fig. 6) are suspected as where the buried bodies are located, while discontinuities caused by the air effect in the subsurface are indicated by red arrows [3]. It helps to prove the hypothesis that the Ground-Penetrating Radar method can be used to detect the buried human objects underground. However, Hammon et al. mentioned that GPR frequencies need to be above 900 MHz to give better resolution for the human body [11]. For that reason, the 700 MHz antenna frequency used in this study might be less effective to detect the buried human bodies but it still depends on what type of soils present in the survey location. The GPR method will perform better in soils that are drier and sandier. It might be required to use lower antenna frequencies to detect the buried human bodies in wetter or clay-rich soils, while higher frequencies might only be possible at shallow depths [11].

![Figure 6. Radargram result from Dewi et al. (2017) [3]](image)

5. Conclusion
The use of the Ground-Penetrating Radar (GPR) method with 700 MHz of antenna frequency can find high amplitude contrast anomalies which are suspected as the location of where the bodies are buried. The amplitude contrast anomaly on Grave 2 is higher because the buried corpse might be younger, which will give a larger contrast with soil compared to the contrast of human bones from the older corpse in Grave 1. Further research using the GPR method can be conducted to investigate the buried victims from landslides, earthquakes, and other natural disasters to make the evacuation process better.

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