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The Development of Ground Penetrating Radar (GPR) Data Processing

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II. THE PRINCIPLES AND SIGNAL MEASUREMENT OF GPR

Applications for wireless communication systems vary greatly. For example, the GPR is used for non-destructive testing and evaluation (NDT) or civil engineering in the field of geology and archaeology. In this context, the GPR is used to detect and map subsurface structures, such as pipelines, utilities, and archaeological features. The GPR transmits electromagnetic waves into the ground and receives the reflected signals. These signals are then processed to create images of the subsurface.

The GPR system consists of a transmitter, a receiver, and a signal processing unit. The transmitter generates electromagnetic waves, which are directed into the ground. The waves propagate through the ground and are reflected from subsurface structures. The receiver then detects the reflected waves and sends them to the signal processing unit, where they are analyzed to create an image of the subsurface.

The signal processing unit is responsible for processing the reflected waves to create a usable image. This process involves several steps, including filtering, amplification, and calibration. The filtered and amplified signals are then used to create an image of the subsurface.

In practice, the problem of low-electric loss is not as common as was thought to be. An environment with high GPR signal power lasts for many days with a combination of polar materials. In many cases, the GPR works conceptually simple. Its aim is to measure the amplitude of signal and time after excitation.
The core of the GPR system is a time management unit which regulates the signal generating and detects signal echo as shown in Fig. 1. Most of GPR is works in time domain so that to synthesize time domain responses, frequency domain is used.

![Block diagram of GPR](image)

Fig. 1. Block diagram of GPR [3].

Characterization of radar systems is a complex assignment because there are many problems that affect the operation and use of the system. Electronic instrumentation factors that govern the characterization of GPR are signal generation, signal processing, signal capture methods, dynamic range, performance factors, center frequency and bandwidth, support, and portability. The antenna converts the electrical signal from and to the electromagnetic field. 

![Diagram showing Δt](image)

Fig. 2. Transmitter blanking that occurs because overlapping between direct signal and reflected signal [3].

\[ \Delta t = \frac{\text{Direct signal path} - \text{Reflected signal path}}{V} \]

\[ \Delta t = \frac{\Delta \text{Length}}{V} \]

Fig. 3. Transmitter blanking that occurs because overlapping between two reflected signals that have a similar path length [3].

The GPR system has to record the data with an accuracy of time which less than 10 ps for 10,000 ns duration [3]. Bandwidth measurement depends on the application and is directly related to resolution. The resolution of two topics related to "transmitter blanking" and "target separation" is illustrated in Fig. 2 and Fig. 3.

The transmitter blanking is caused by the inability of the receiver to detect the signal until the transmitter has finished transmitting. Transmitter blanking occurs when the direct-signal from the transmitting antenna that propagates to the receiving antenna overlaps with reflected signals from objects below the surface.

This is bandwidth and dynamic range problem. The transmitter source usually emits a very large signal, and if the receiver is near the cassing transmitter in GPR, the receiver will see a very large direct signal transmitted. If this signal is large enough, the electronic receiver will be excess and will not receive the reflected signal. The duration of signal propagation time changes inversely with bandwidth. Resolution length \( \Delta r \) related to bandwidth is

III. THE CONCEPT OF GPR DATA PROCESSING DEVELOPMENT

This study aims to develop a GPR data processing, which is expected to be used freely. The development phase of GPR data processing is briefly explained in the Fig. 4.

![Diagram showing data processing stages](image)

Fig. 4. GPR data processing and analysis steps as explain in [3].

As explained in [3], the editing and rubber-banding phases are the stages of preparing survey GPR data that will be processed. Information about the frequency used, the distance between lines, the number of lines, the number of traces, the type of file used and the others are things that must be known from the beginning so that the data processing in the next step is not wrong. The dewow phase is the stage that aims to eliminate the low frequency and DC bias in the data. Wow is a noise that has a very low frequency value, this occurs due to an electronic instrument saturated by the value of large amplitude of direct waves and air waves. Dewowing is a vital step as it reduces the data to a mean zero level and, therefore, allows positive-negative colour filling to be used in the recorded traces [3]. If done with incorrectly way, the data will be decayed and the low frequency component will distort the spectrum from trace data. This incorrectly processed data will affect to the next data processing stage. If this process is done manually step by step, it is better to eliminate the DC component first and then implement the filter. The dewow concept can be seen in Fig. 5.
process is deforming which aims to eliminate noise and DC bias components. Fig. 9 presents the GPR data profile after the deforming process, while Fig. 10 and Fig. 11 present the signal amplitude ratio before and after deforming process.

**R. Data Filtering Process**

- **Deconvolution Process:** In Fig. 6, the deconvolution process is performed to enhance the signal quality. The deconvolution filter is applied to the data to remove the effects of the antenna and the medium. The processed data shows improved signal-to-noise ratio.
- **Time Zero Correction:** In Fig. 7, the time zero correction is applied to remove the delay caused by the propagation of the signal through the medium. The corrected data shows a more accurate representation of the subsurface.
- **Comparison of GPR data:** In Fig. 8, a comparison of GPR data before and after the correction process is shown. The corrected data shows a clearer image of the subsurface structures.

**C. Increasing Gain on Data**

- **Radar Waves:** Radar waves can propagate through the ground, but the signal is attenuated and scattered. The gain on the data enhances the signal-to-noise ratio, allowing for a clearer image of the subsurface.
- **Electromagnetic Wave Propagation:** Electromagnetic waves propagate through the ground, and the gain on the data enhances the signal-to-noise ratio, allowing for a clearer image of the subsurface.

**Fig. 8:** The GPR data image after time zero correction shows a clearer image of the subsurface structures. The corrected data allows for a more accurate interpretation of the subsurface conditions.

After the time zero correction, the signal propagation time is adjusted to remove the delay caused by the medium. This process enhances the signal quality, allowing for a clearer and more accurate image of the subsurface.
can be seen or read is strengthened them by multiplying the signal with a certain amplifier factor. This called as gain the data. There are two methods that used in this study, the first method is to increase the power of signal data with a large factor for signals that originating from the deeper subsurface and multiplying it with a smaller factor for signals coming from the subsurface that are not too deep. This method is called time power amplitude gain correction. With this first method, the GPR data image on the top layer will be a little unclear, but the bottom layer will be strong enough. The other method is to multiply all signals from all layers at various depths with the same specific factors. This method called as automated gain control. The choice of this strengthening data signal power method depends on the type of data or target that wanted to.

Time-power gain (TPGW): In the time power amplitude gain correction method, the signal is amplified along the axis of the two-way propagation time and multiplies each trace with the power of \( t \) (\( t^\alpha \)). If we assume \( \alpha = 1 \), then we increase signal power linearly at each propagation time. If we assume \( \alpha = 2 \), then the power will increase quadratically throughout the propagation time. In this picture below, we use \( \alpha = 2 \).

Fig. 12. Image profile of GPR data after being strengthened by the time power gain method.

Fig. 13. 1D plot for signal trace after being strengthened by the time power gain method.

Fig. 14. Image profile of GPR data after being strengthened by the automated gain control method.

Fig. 15. 1D plot for signal trace after being strengthened by the automated gain control method.

Fig. 16. Profile of GPR data images with two-way travel time converted to depth with velocity = 0.05 m/\( \mu \).
The profile pictures that have been described before, all images are presented in two-way travel time. This two-way travel time can be converted to a depth. To convert the two-way travel time to depth, the speed of the radar signal in the ground needs to be known first. For the speed of electromagnetic waves in the media can be seen in Table I. The speed of propagation used in GPR data is 0.6 m/s. Fig. 16 showing the GPR data profile where two-way travel time is converted to depth.

V. CONCLUSION AND FUTURE WORKS

The goal of this study is to provide a free program to process and visualize the GPR data. This program is still under development. This program in this study follow the phase to processing GPR data as in [3], start with preparing the data, dewow, time zero correction, filtering, deconvolution, velocity analysis, elevation correction, migration and depth conversion. And the result of this phase can be seen at this paper.

Next step of this study is to convert it into freeware program so that this program can use to many other people. Our plan is to convert it into Octave Program.

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