Arduino-based soil structure detector using geophone

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Abstract. Because of technology development, the needs for energy are increasing. Earth provide energy source by means of oil, gas and coal, buried beneath ground soil. A tool that can detect soil structure and material before drilling is needed. Each material has a different density; the difference in density produces a back effect. Geophones can be used to detect differences in material that is below the surface of the ground. This is done by carrying out artificial vibrations and receiving these vibrations with the geophone. To measure the vibrations that will be captured by the geophone, it begins by arranging the geophone configuration to be placed in a straight line with the wave source. The data obtained from the survey is the wave travel time from the source to each geophone indicated in the wave traces. This research concludes that a geophone sensor that can read the speed of waves in passing through stone, split stone and sand. Each medium produces a different speed—the denser the density of the medium, the faster the velocity of the wave propagation through it. In this final project the fastest is split stone with 1.62ms, brick is slightly slower with 4.02ms, and sand is the slowest with 15.86ms.

1. Introduction
An object is composed of different particles, so it has a different density with the others. The difference in density can be used as a reference to distinguish each material, because density is a characteristic of every object. the higher the density of an object it allows a wave to propagate through it faster than objects that have a more tenuous density. by utilizing these properties, the author uses seismic waves and aims to make a tool to detect differences in soil structure [1-3].

Three materials will be used and seismic waves will be made by using a punch to the material with a hammer and using a geophone sensor to receive the seismic waves produced by the hammer. Some testing has been done using a seismograph, so I want to make a simpler tool with Arduino Uno. Two geophones are used as triggers and receivers. Then the velocity of the wave propagation between the two geophones will be used as a reference in this experiment.

2. Background

2.1. Seismic waves
Body waves are waves that propagate on elastic media and their direction of propagation spreads within the earth. Based on the motion of particles in the media and the direction of propagation of the waves can be divided into P and S waves.
P waves are called compression waves / longitudinal waves. This wave has the greatest propagation speed compared to other seismic waves, it can propagate through solid, liquid, and gas media. S waves are also called shear waves / transverse waves. This wave has a slower velocity than the P wave and can only propagate on a dense medium. S wave is perpendicular to the direction of propagation. In this study the P wave is used as the observed wave, because the P wave has the fastest propagation speed and the difference in the medium can be known by the difference in the P wave speed. And the speed of P wave is illustrated in Table.1.

Table 1. Speed of P-Wave in different medium.

| Material         | P wave velocity (m/s) |
|------------------|-----------------------|
| Air              | 331.5                 |
| Water            | 1400-1600             |
| Topsoil          | 100-700               |
| Peat             | 200-800               |
| Clay             | 500-2800              |
| Loam             | 200-1900              |
| Loess            | 600-1200              |
| Sand             | 500-2800              |
| Gravel           | 100-2000              |
| Sandstone        | 800-4500              |
| Marlstone        | 1300-4500             |
| Dolomite         | 2000-6200             |
| Limestone        | 2000-6200             |
| Magmatic Rock    | 2400-5200             |
| Metamorphic rock | 3100-5800             |
| Talus Deposits   | 600-2500              |
| Till             | 1500-2700             |
| Permafrost       | 2400-4300             |
| Glacial ice      | 3100-4500             |

2.2. Geophone
A geophone is a sensor that functions to convert vibrations into electrical signals that can be recorded at a recording station. Geophone is a sensor that is widely used to be applied in mining, because geophone has a relatively cheaper price, has a fairly large bandwidth and also good durability. Geophone consists of two main components, namely permanent magnets that will be placed on the surface of the earth to follow vibrations from the surface of the earth, and next is the coil of wire that will move when a seismic wave occurs.

The workings of a geophone are the presence of seismic waves and vibrations that cause springs in the oscillating geophone. Oscillation of the spring causes the flux to occur due to a change in position of the magnet or vice versa. And because of the flux there is an induced Electric Motion Force, which can be visualized in the form of sinusoidal signals.

The voltage produced by a Geophone is proportional to [4]:

- Strong magnetic fields produced by permanent magnets
• The number of turns of the wire
• Coil diameter
• The speed of movement of the coil to the magnet

Can be known through Faraday's induction legal formula, namely:

\[ \varepsilon = -N \frac{\Delta \Phi}{\Delta t} \]

\( \varepsilon = \) Induction Electric Force Motion (volts)
\( N = \) Number of coil winding
\( \Delta \Phi = \) Change in magnetic flux (weber)
\( \Delta t = \) interval (s)

And also the magnetic flux formula:

\[ \Phi_m = B.A \]

\( \Phi_m = \) Magnetic Flux (Weber or Wb)
\( B = \) Magnetic Induction (Wb/m²)
\( A = \) cross-sectional area (m²)

3. Method

General description of the system that will be applied in this thesis, namely detecting the soil structure using geophone sensors, will be shown in the block diagram in Fig.2. The input in the form of seismic vibrations will be detected by the geophone and released again in the form of a voltage. Then the output of the geophone will be processed by the ADC to convert the analog signal from the geophone into a digital signal on a digital oscilloscope. To run a digital oscilloscope requires an application installed on the laptop as a processor used on the system [5].

![Figure 2. System block diagram.](image-url)
Then monitoring is the stage of the appearance of waves generated by the geophone and the process of analyzing the wave velocity of the wave travel time. Seismic vibration input detected by the geophone sensor will be continued at the ADC for the process of converting analog signals to digital, then going to the microcontroller on Arduino, and the ADC amount will be generated at each geophone hit on the serial monitor of the Arduino application as a monitoring stage.

In the Fig.3 above is a system design flow chart with a digital oscilloscope in the form of a geophone sensor data modulation process in the form of seismic waves that can be seen its propagation speed.

4. Result and discussion

4.1. Testing of wave velocity spread with split rock
Tests carried out using the Arduino application and oscilloscope. Each time taken is seen from the peak to peak waves generated by the geophone, then the test results will be compared.

Based on the theory of waves can propagate through a split rock medium between 2000 - 6000 m/s. From the test results it was found that the average speed generated when propagating through a split rock medium using a digital oscilloscope is 891.57 m/s or takes travel time 1.62ms to propagate through a 1 meter split rock medium and when using Arduino Uno, the recorded speed is 114.34 m/s or 12.66ms travel time to propagate, a more complete data table is attached. With results that do not match the theory due to the arrangement of rocks that have a gap that causes imperfect wave propagation and oscilloscopes have test results that are closer to the theory because the ability to read oscilloscope data is digested faster than that of Arduino.
4.2. Testing of wave velocity spread with sand

Tests carried out using the Arduino application and oscilloscope. Each time taken is seen from the peak to peak waves generated by the geophone, then the test results will be compared in fig 4. From the following test results it can be concluded that the Vpp on the oscilloscope is higher than the Vpp obtained from Arduino Uno. For the Vrms oscilloscope results are slightly more stable than Arduino Uno, the Arduino results can reach more than 1000mv.

![Testing Chart with Sand](image)

**Figure 4. Sand experiment.**

Based on the theory of waves can propagate on the sand medium with a speed of 200 - 2000 m / s. And seen from the results of geophone testing with sand material, it is found that the average speed required by waves to propagate through the sand medium using a digital oscilloscope is 63.20 m / s or takes 15.86ms and when using Arduino Uno, the speed is 6.38 m / s or takes 176.28 ms to propagate through the sand medium as far as 1 meter, a more complete data table is attached. The test results obtained are not in accordance with the theory because it is difficult to arrange solid sand perfectly on PVC pipes so that if the sand can still move inside the pipe can affect the speed of the wave propagation produced.

4.3. Velocity and density comparison result

From the graph in the picture shows the connection of velocity with density, if the density is higher, the velocity will also be faster. First the density calculation is done by means of the entire medium inserted into the PVC pipe until it is full, then the medium is weighed in the pipe. Split rock has a mass of 17.1 kg, bricks have a mass of 16.1 kg, and sand has a mass of 13.3 kg. After that the volume is measured, the three mediums are in PVC pipes which have a diameter of 4.5 inches and a height of 1 meter, then the volume is 0.0095m³. to get the density with mass divided by volume, and the results are compared with the average velocity at the initial test.
5. Conclusion

From the results of the design, realization, implementation, and testing of the design results that have been obtained, then some conclusions can be drawn as follows. The geophone sensor can be used to distinguish the characteristics of the medium used. Medium with a higher level of density can be passed by waves faster than a denser level of density. Like a split rock with the highest density of 1800 kg / m³ on the medium used, the wave velocity is the fastest while the sand with a density of 1400 kg / m³, the wave velocity will be slower. Testing using a digital oscilloscope is closer to the reference results compared to using Arduino Uno. Material detection system for the composition of soil structure with Arduino Uno can recognize differences in material with initial test results with an accuracy rate above 90%.

References

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