Preliminary Results of Subsurface Physical Properties using Resistivity Logger Prototype

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Abstract.
All geophysical techniques are depends on the existance of a contrasts in physical properties of materials. Since the complexity of the subsurface physical properties can vary, the knowledge of basic theories about it should be validated with practical skills. One effective way to improve the practical skills is by designing a small-scale instrument of well logging to identify the resistivity of the subsurface layers. In this research, a simple tunnel model is implemented in order to represent a complex geological model. Based on well-logging principles, this prototype is made to identify variations in resistivity value using a logger equipped with Wenner Array of four electrodes. An Arduino UNO microcontroller is utilized to arrange the work of the logger and programmed to process the potential values. It is obtained from the electrodes and displayed by the interface. In order to test the prototype, the air-filled tunnel models are performed. At the location near the air-filled tunnel, the resistivity log data give highest values compare any other location due to the air material. The results show that the resistivity well logging data are able to represent the air-filled tunnel model. The 3D model of well log data can identify the type of the physical properties of material in the air-filled tunnel model. Furthermore, the simple concept of this prototype can be developed for large-scale utilization.

1. Introduction
Borehole resistivity logging is essential to collect specific information about the geological formations using multi-electrode system. This equipment can be used to determine physical properties of material, such as water saturation and general formation geology. The application of resistivity logging devices has extensively been used for investigation of water-resources investigations (Key and MacCary, 1971), oil exploration (Bassiouni, 1994) and geological mapping for fault structures (Widodo, et.al, 2016). In this paper the application of borehole resistivity logger prototype develops based on subsidence cases. Subsidence is an event in which a ground layer subsides due to gravitational pull and the weight burden of the material above that layer. This fall of underground tunnel can be caused by either natural factors or human interventions. Subsidence is a disaster which has been occurred quite often and generally causing massive amount of damage (Izzati et. al, 2017). To mitigate the impact of land subsidence, methods to observe and gain information concerning the condition of a specific region's underground tunnel are needed. Resistivity method can be used to identify tunnel by mapping the resistivity's variation of each soil and rock formation (Mahartha et. al, 2017). One effective way to improve the chance to mitigate is by designing an instrument that can be identify the resistivity of the
subsurface layer. Therefore, instruments that are developed must have a small-size, good portability, easy to use, and give a result that is easy to understand.

2. Methodology

The constructions of borehole resistivity logger prototype based on the simple geoelectrical method principle. Resistivity of the layers is measured vertically from the bottom to the top of the models while in the simple geoelectrical methods, resistivity value is measured horizontally above the layer. The logger has four electrodes as well as the basic of geoelectrical methods. One pair of voltage electrodes and one pair of current electrodes, which the space between each electrode is 1.5 cm. The work principle of resistivity logger prototype here as follows in Figure 1.

For injecting the voltage, we use DC power from the 9 Volt battery. The value of injection current can be measured by constructing a simple ammeter with Arduino UNO (Banzi, 2011). Similar to the injection current, the voltage value between the voltage electrodes can be measured by making a simple voltmeter which able to convert analogue response to digital signals using Arduino UNO as shown in Figure 2. The logger is pulled up to the top while the current is injected to the layers using motor stepper. The resistivity log is obtained by multiplying the electrodes configuration with the resistance measured from the ADC. This mathematical computation is programmed on Arduino IDE software. The resistivity log is a measurement of a subsurface layer’s resistivity, that is its resistance to the passage of an electric current (Rider, 1999).

![FIGURE 1. The work principle of resistivity logger prototype](image-url)
3. Results

The Figure 3 shows the resistivity measurement in 5 shot points. A low apparent resistivity value (6 $\Omega$m - 7 $\Omega$m) is shown when the shot point is slightly away from the tunnel. On the other hand, when the shot point is close to the tunnel, we can see a very large apparent resistivity contrast, when at a depth of less than 25 cm the apparent resistivity value is about 7 $\Omega$m, already in accordance with the wet soil resistivity range, and at a depth of more than 25 cm where there is a tunnel (contains air), we get a large apparent resistivity value, approximately 100 $\Omega$m. We also made certain movements on the model so that the wet soil above the tunnel went down.
4. Discussion

The anomaly found tells us that the prototype has successfully identified the presence of an underground tunnel. Then, we create a 3D subsurface model from the log resistivity data (Figure 4). From the Figure 4 above we can see that the wet soil above the tunnel went down and it would indicate the occurrence of subsidence.

5. Conclusions

The borehole resistivity log data is able to represent the resistivity contrast anomaly of subsurface model. At the location near the air-filled tunnel, the resistivity log data shows very large resistivity contrast due to the air has a great value of resistivity.

To optimize data recording results, adding an ADC kit is needed to enlarge the bits from the tool. The prototype is still in developing stage, this need to be further validated in variety of geological environments for its wide ranging-application.
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