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Simple Python-Based Application for Transforming Apparent Resistivity Data from Schlumberger Configuration to Wenner Configuration Using the Linear Filter Method

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ABSTRACT

Research has been conducted regarding the design of a simple Python-based application to transform apparent resistivity values from the Schlumberger configuration into apparent resistivity values from the Wenner configuration using the linear filter method. The application developed was then validated using field data measurements from two different locations, namely Nendali Village in the East Sentani district and Buper Waena in the Heram Jayapura district. At each measurement point, two Vertical Electrical Sounding (VES) measurements were performed using Schlumberger and Wenner configurations. The apparent resistivity values from the Schlumberger configuration were transformed using the application created, and the results were compared with observational data from the Wenner configuration. Field data were taken for as many as six samples per logarithmic cycle, with the Schlumberger AB/2 configuration electrode spacing equal to the Wenner configuration electrode spacing. The maximum stretch lengths in Nendali and Buper villages were 26 m and 40 m, respectively. The research results show a match between the apparent resistivity values of the Wenner configuration obtained from field observations and the transformation results. This suitability was demonstrated qualitatively through the similarity of the apparent resistivity curve trend between the transformed and field observation data. Quantitatively, this suitability is shown by the slope value of the comparison curve of field observation data and transformed data, which in Nendali and Buper Villages is 0.75 and 0.98, respectively. The conclusion of this study is that a simple application that has been designed and created can be used to transform apparent resistivity values from the Schlumberger configuration to the Wenner configuration. A comparison between the transformed data and field observation data shows that suitability is highly dependent on the quality of the field data.

Keywords: Vertical Electrical Sounding (VES); Wenner; Schlumberger; Python

1. Introduction

The resistivity geoelectric method is a popular active geophysical method that is often applied in the fields of civil engineering, mining, geology, hydrology, and the environment [1][2]. This method involves measuring the electrical resistivity of subsurface materials by using electric currents and electrodes. By utilizing variations in the resistivity of subsurface geological materials, resistivity data can be analyzed to determine the depth, thickness, and distribution of various geological structures, such as rock, soil, and groundwater [3]. Vertical Electrical Sounding (VES) is the most frequently used operating mode, in which the distance between the electrodes varies with respect to a fixed reference point called the sounding point.

The Schlumberger configuration is the most widely used configuration for the VES resistivity method. Its advantages include ease of field data collection and deeper investigation, which is approximately 10% deeper than the Wenner configuration [4]. This is especially important considering the topography of Papua, which is hilly and mountainous, with tropical rainforest vegetation. This configuration allows only the current electrode pair to be moved at each measurement, whereas the potential electrode pair is only changed when there is a drastic decrease in the potential difference value.

Although not as popular as Schlumberger's, the Wenner configuration has its own advantages. One of them is its higher sensitivity to vertical changes in subsurface material, making it very effective for detecting horizontal structures [2][5]. Recent research about highlighted the improved accuracy of detecting horizontal structural variations using the Wenner configuration in noisy environments [6]. In addition, the Wenner configuration has the strongest signal among all configurations, making it ideal for use in areas with high background noise [5]

The theoretical basis for the relationship between the Schlumberger and Wenner configuration VES methods was developed by [7], who introduced the use of filter coefficients for data interpretation. Further research by [8] proposed an equation for converting the apparent resistivity data from the Schlumberger configuration to a dipole configuration using linear filter theory. Recent research by [9] demonstrated the development of new algorithms to improve the efficiency of resistivity data transformation between these configurations. Mathematical equation for converting apparent resistivity data from the Schlumberger to the Wenner configuration using 19 filter coefficients [10].

However, the gap in this research lies in implementing this theory in a practical application that can be used by end users. Therefore, this research aims to fill this gap by designing and creating a simple Python-based application and validating the application using field observation data. This study aims to fill this gap by designing and creating a simple Python-based application and validating the application using field observation data.

2. Method

Schlumberger's forward configuration model

The apparent resistivity value in subsurface layers using the Schlumberger ρ_{aS} configuration can be calculated using the following equation [11].

$$\rho_{aS} = r^2 \int_0^\infty T(\lambda) J_1(\lambda r) \lambda d\lambda \qquad (1)$$

where r,λ, J_1, and T(λ) are the electrode spacing $\frac{AB}{2}$,, the integration factor, the first-order Bessel function, and the resistivity transformation function, respectively. The resistivity transformation function T(λ) can be calculated using the Pekeris recursion equation [12] as follows

$$T_i = \frac{T_{i+1} + \rho_i tanh(\lambda h_i)}{1 + \frac{T_{i+1} tanh(\lambda h_i)}{\rho_i}} \qquad (2)$$

wherw ρ_i and h_i are the resistivity and the thickness of the ith layer, respectively.

Forward modeling calculations are carried out using the linear filter method [7] as follows

$$\rho_{aS} = \sum_j f_j T_j(\lambda) \qquad (3)$$

where j and f_j are the number of filters and filter coefficients, respectively. This study used the filter coefficient proposed by [7].

Schlumberger–Wenner transformation of apparent resistivity values

The mathematical relationship between the apparent resistivity of the Schlumberger and Wenner configurations can be expressed in Linear Filter theory as follows [10].

$$\rho_{aW} = \sum_{j=1}^{n} C_j \rho_{aS}(y_i) \qquad (4)$$

where ρ_{aW} is the output in the form of apparent resistivity data of the Wenner configuration, ρ_{aS} is the input in the form of apparent resistivity data of the Schlumberger configuration, and C_j is the filter coefficient proposed [10].

The procedure carried out in this research is to create a pseudocode that converts the apparent resistivity values from the Schlumberger configuration into a Wenner configuration using equation (4), create a puthon script based on the pseudocode that has been created previously, validate the Python script that has been created using field data, and finally create a display interface (graphical user interface) and convert the script into an executable file.

Field data validation

Python script validation was carried out using two field measurement datasets, each carried out in Nendali Village, East Sentani District, and in Buper Waena, Heram Jayapura District **(Figure 1).**

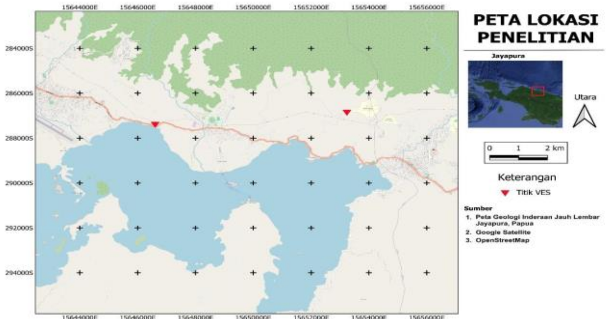


Figure 1. Map of VES measurement locations

Based on the geological map of Jayapura, the villages of Nendali and Buper are located on ultra-mafic rocks (Mzum). In Nendali Village, ultramafic rocks are in contact with alluvial deposits (Qa) to the north.

The procedure for measuring field data is as follows: at each sounding point, two measurements are made, namely VES in the Schlumberger configuration and VES in the Wenner configuration. Six data points were used per logarithmic cycle [10]. The electrode spacing for the Schlumberger AB/2 and Wenner a configurations is made the same (AB/2=a) to make it easier to graph the comparison of transformation results.

Python script validation was carried out using two field measurement datasets taken in Nendali Village, East Sentani District, and in Buper Waena, Heram Jayapura District. At each sounding point, two measurements were carried out: VES in the Schlumberger configuration and VES in the Wenner configuration. Six data points per logarithmic cycle were used [9][10]. The electrode spacing for both configurations was made the same to facilitate a comparison of the transformation results.

3. Result and Discussion

The ReSc2W interface consists of three main parts, as shown in **Figure 2**: load data, data transformation, and Graphs of Schlumberger input data on the left and Wenner output data on the right. The load button was used to load the field data stored in the form of a CSV file. When the input data (Schlumberger configuration) were selected, the apparent resistivity curve of the input data is displayed on the left. The transform data button is used to transform the input data. The transformation output islayed on the right and saved in the form of a CSV file in the same folder that contains the executable file and the ithe nput data.

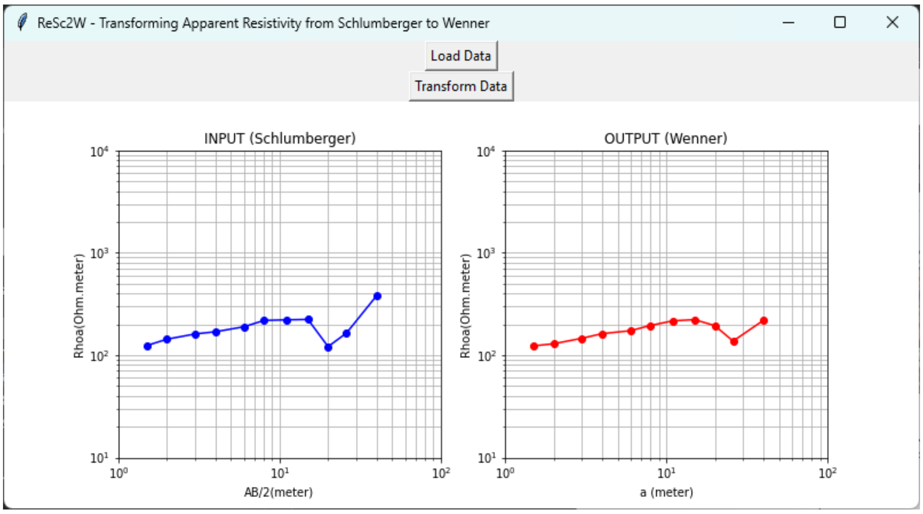
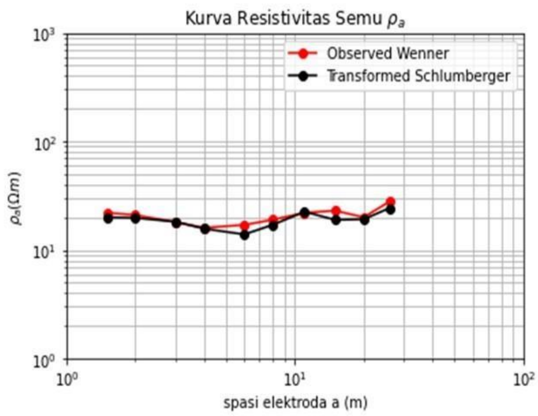
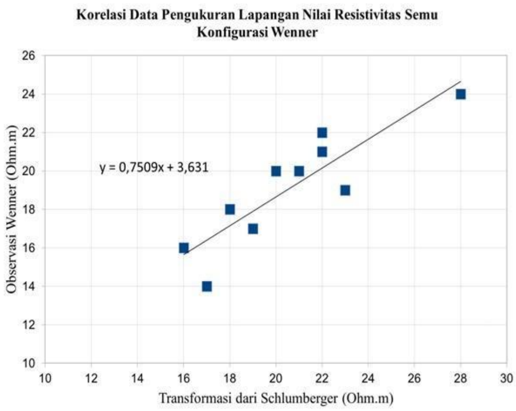


Figure 2. ReSc2W interface display.

A comparison of the VES apparent resistivity curve of the Wenner configuration from field observations and the transformation results in Nendali village in **Figure 3(a)** shows a similar trend, in that the subsurface consists of four layers. However, the apparent resistivity values for these two datasets are not exactly the same, but there is a difference of up to 18%. This is caused by differences in the contact resistance. The heterogeneous and anisotropic nature of the shallow material means that any difference in the electrode attachment points in the two measurements will result in voltage and potential measurement figures that are not the same. A quantitative comparison of the two data through correlation analysis and a plot of the two data shows that the Pearson correlation coefficient and slope of the curve are 0.88 and 0.75 respectively as shown in **Figure 3(b).**



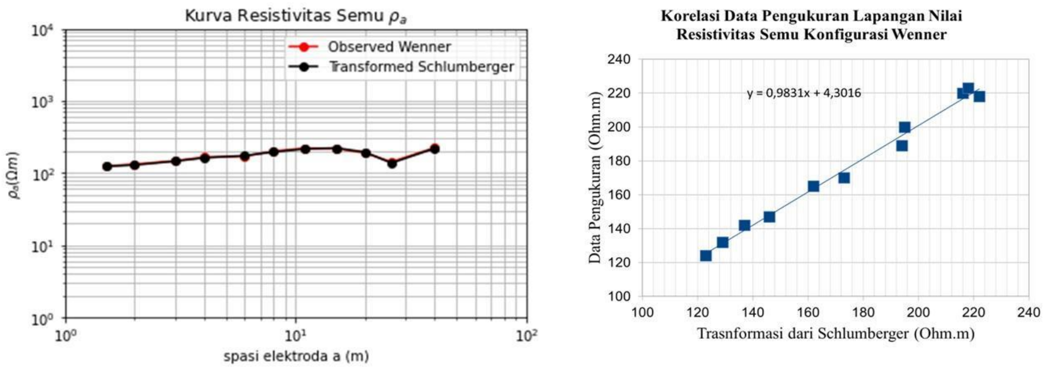
(a)



(b)

Fig 3. Apparent resistivity data for Nendali village. (a) Apparent resistivity curve ρ_aWenner configuration field measurements and transformation result curve. (b) Correlation between the apparent resistivity values of the Wenner configuration from field measurements and transformation results

.A comparison of the apparent resistivity curves at the Buper Waena measurement point, as shown in **Figure 4(a),** shows very good agreement, where the difference between the field observation data and the maximum transformed data was only 4%. The Pearson correlation coefficient and the slope of the comparison curve for the two data sets at the Buper Waena location are 0.99 and 0.98, respectively **(Figure 4(b)).** In addition, the transformed apparent resistivity data and observation results both show the same trend, that is, the subsurface at the measurement point has three layers.



(a) (b)

Figure 4. Apparent resistivity data at Buper Waena. (a) Apparent resistivity curve ρ_a Wenner configuration field measurements and transformation result curve. (b) Correlation between the apparent resistivity values of the Wenner configuration from field measurements and transformation results.

A comparison of the apparent resistivity values from field observations and transformation results shows the importance of field data quality. The quality of the input data (Schlumberger configuration) determines the output results (Wenner configuration). One step is to ensure good galvanic contact between the electrode and the ground.

The results of this research show differences in the apparent resistivity values between the Schlumberger and Wenner configurations. Although a high Pearson correlation coefficient value indicates a strong relationship between the two configurations, several other factors that can influence the measurement results also need to be considered.

Factors that Influence Measurement Results

1. Terrain Conditions: The environmental conditions of the measurement site, such as soil moisture, presence of groundwater, and vegetation, can affect the resistivity of the material. Wet or dry weather conditions can cause variations in the measured resistivity values [3]. [2] showed that changes in soil moisture can significantly influence resistivity measurement results, especially in areas with heterogeneous soil layers.
2. Equipment Used: The type of equipment and electrode configuration used can also contribute to variations in the results. The quality of the electrode and the installation technique used influence the accuracy of the measurement [5]. In addition, differences in the tool settings and calibration can cause differences in the data obtained.
3. Material Heterogeneity: Variations in the composition of subsurface materials, such as the presence of rocks or soil layers with different conductivities, can affect resistivity readings. [9] stated that the heterogeneity of subsurface materials must be considered in the resistivity analysis to obtain more accurate results.

Practical Applications and Advanced Research

The results of this study have significant practical implications, especially in the context of geophysical surveys for natural resource exploration and environmental management. The Wenner configuration, which is sensitive to vertical changes, can be used to more effectively determine the depth of the groundwater table. [6] showed that the use of this configuration in hydrological surveys can increase the accuracy of groundwater depth estimates. In the future, further research can be conducted to develop more sophisticated algorithms for resistivity data analysis. Additional research could also investigate the influence of different environmental factors on the measurement results and test methods of combining resistivity and other geophysical techniques to improve the accuracy and reliability of the obtained data. Considering the factors that influence the results and relating these findings to practical applications and research directions, it is hoped that this research will make a greater contribution to the development of geophysical science in the future.

4. Conclusion

Several conclusions were drawn from this study. First, this research fills the knowledge gap in the form of a simple Python-based program that transforms the apparent resistivity value of the Schlumberger configuration into that of the Wenner configuration.

Second, a comparison of the apparent resistivity values from observations and transformation results showed similar trends, even though the values at each measurement point were not the same.

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