Journal of Applied Science and Agriculture, 8(5) October 2013, Pages: 688-695

AENSI Journals

Journal of Applied Science and Agriculture

Journal home page: www.aensiweb.com/jasa/index.html

Euler deconvolution of 2D gravity data interpretation: New approach

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ARTICLE INFO

Article history:
Received 11October 2013
Received in revised form 19 November 2013
Accepted 23 November 2013
Available online 1 January 2014

Keywords:
Euler deconvolution,
2D gravity data interpretation,
Talwani's method

ABSTRACT

Euler deconvolution method is used for rapid interpretation of potential field (magnetic and gravity) data. It is particularly good at delineating contacts and rapid depth estimation. This technique is belong to automatic depth estimates methods and, is designed to provide computer-assisted analysis on large volumes of magnetic and gravity data.The depths to magnetic or gravity sources are a very useful product from any magnetic or gravity interpretation. In this paper two-dimensional models has been considered first and the gravity attraction of this models is extracted by using Talwani 's method(Matlab programming).So these values have been used as code input of two-dimensional Euler deconvolution. All values of possible depths has been extracted per all values of SI and W size by using written codes and its best values have the most frequency by drawing Z values histogram.

To Cite This Article: Reza Toushmalani, Meisam Hemati., Euler deconvolution of 2D gravity data interpretation: New approach. ***J. Appl. Sci. & Agric.***, *8(5): 688-695, 2013*

INTRODUCTION

In this paper two-dimensional model has been considered first and the gravity attraction of these models are extracted by using Talwani’s method (Mat lab programming).So these values have been used as code input of two-dimensional Euler deconvolution. All values of possible depths has been extracted per all values of SI and W size by using written codes and we use new approach for finding best values of depth.

1)2D gravity modeling (Talwani's method):

A Many geological structures are approximately linear, and the problems connected with them can be solved with two-dimensional forms of analysis. For gravity computations (Nettleton, 1940) has determined the criteria for making an adequate two-dimensional computation. Various methods exist for the computation of the gravitational attraction caused by irregularly shaped two-dimensional bodies. These methods can be divided into two categories. In the first category lie those that involve the use of graticules, dot charts, or other such graphical computing aids. (Manixtalwani *et al*, 1959) While in theory these methods can be made as precise as one pleases, merely by increasing the Scale to which the graticule is constructed, in actual practice this may be difficult, if not impossible. In the second category lie those methods that involve breaking up the irregularly shaped bodies into several smaller bodies of different sizes but of shapes that are regular and for which the gravitational attraction can be easily computed. (Manixtalwani *et al*, 1959)

A convenient form of regular body to use is the rectangular block, as proposed by (Meinesz *et al* 1934). Here again the method can be made as precise as one pleases by using a sufficiently large number of small blocks. (See for example, shurbet *et al*, 1956). However, the computations become increasingly more tedious as the number of blocks is increased. Further, the blocks may be so small that their individual contributions at distant points are neglected even though the total sum of their small contributions is appreciable. This may cause considerable error in computations. The periphery of any two-dimensional body can be approximated closely by a polygon, by making the number of sides of this polygon sufficiently large. Analytical expressions can be obtained for the vertical Component of the gravitational attraction due to this polygon at any given point. (Manixtalwani *et al*, 1959)

The gravity attraction of an n-sided polygon in an arbitrary point can be calculated by Talwani's method (Grant and West, 1965)

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$$g_{cal} = 2G\rho \sum_{k=1}^{nsides} \left\{\frac{b_k}{1+a_k^{\ 2}}\right\}\left\{\frac{1}{2}\ln\left(\frac{x_{k+1}^{\ 2}+z_{k+1}^{\ 2}}{x_k^{\ 2}+z_k^{\ 2}}\right)\right\} + a_k\left\{\tan^{-1}\left(\frac{x_{k+1}}{z_{k+1}}\right)-\tan^{-1}\left(\frac{x_k}{z_k}\right)\right\} \quad (1)$$

$$a_k = \frac{x_{k+1}-x_k}{z_{k+1}-z_k}$$

$$b_k = \frac{x_k z_{k+1} - x_{k+1} z_k}{z_{k+1}-z_k} \quad (2)$$

Where G is gravitational constant, ρ is contrast density between anomaly and host rocks, x and z are coordinates of the sides of the polygon.

2) Euler deconvolution:

2-1) Introduction:

Euler deconvolution method is used for rapid interpretation of potential field (magnetic and gravity) data. It is particularly good at delineating contacts and rapid depth estimation. This technique is belong to automatic depth estimates methods and, is designed to provide computer-assisted analysis on large volumes of magnetic and gravity data(Dawi, *et al*, 2004; Kirkham and Hildenbrand, 2002). Euler's equation has been used by a number of authors for analyzing both magnetic anomalies (Thompson, 1982; Barongo,1984; Reid *et al*, 1990) and gravity anomalies (Marson,Klingele, 1999). Euler's homogeneity relationship offers a quasi-automated method to derive the plan location and depth estimation of buried Ferro-metallic objects from magnetic data. Euler's homogeneity equation relates the magnetic field and its gradient components to the location of the source with the degree of homogeneity expressed as a structural index, (Thompson, 1982). Thompson Developed the technique and applied it to profile data. developed the technique more widely used version for grid-based data. Also recent improvements on the technique had occurred which included the estimation of the structural index (Barbosa, Joao and Medeiros, 1999, Hansen, and Suciu, 2002). Developed a multiple-source generalization of Euler deconvolution, which is capable of handling complex systems that the single-source algorithm can only deal with approximately. (Dawi, *et al*, 2004; Kirkham and Hildenbrand,2002).

The advantages of this technique over more conventional depth interpretation methods (i, e. characteristic curves, inverse curve matching, etc...), are that no particular geological model is assumed, and that the deconvolution can be directly applied and interpreted even when particular model, such as prism or dyke can not properly represent the geology.

2-2. Theory of Euler Equation:

However, for applying the Euler's expression to profile or line-oriented data (2-D sources). In this case, the x-coordinate is a measure of the distance along the profile, and the y-coordinate can be set to zero along the entire profile(10):

$$(x-x_0)\frac{\partial \Delta T}{\partial x} - z_0\frac{\partial \Delta T}{\partial z} = -n\Delta T(x) \quad (1)$$

Rearrangement of the above expression

$$x_0\frac{\partial \Delta T}{\partial x} + z_0\frac{\partial \Delta T}{\partial z} = x\frac{\partial \Delta T}{\partial x} + n\Delta T(x) \quad (2)$$

Where (x_0, z_0) is the position of a 2-D magnetic source whose total field T is detected at (x, z). The total field has a regional value of B, and n is a measure of the falloff rate of the magnetic field. n is directly related to the source shape and is referred to as the structural index (Thompson, 1982). By evaluating the total field T and

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its derivatives (calculated or measured, The gradient can be calculated using standard potential theory in the space or wave number domain or the vertical gradient may be calculated and can be used directly in the above equation) at all points on a magnetic dataset, a system of simultaneous linear equations is obtained with the unknowns being the x0, z0 represent the location and depth of the magnetic source, n, the structural index of the source and B the regional magnetic field. Using the derivatives of potential–field anomalies enhance the field associated with shallow features and de-emphasize the field from deeper sources. Used appropriately, the method is suitable for characterizing sources from all potential-field data and/or their derivatives, as long as the data can be regarded mathematically as continuous(Kirkham and Hildenbrand, 2002).

The application of equation (2) directly to the observed data makes the exact solution unreliable and erratic.

The problem of removing the bias from the observed data is solved in the following way by (Thompson, 1982). Assume the anomalous field is perturbed by a constant amount B in the window in which equation (2) is being evaluated. The observed quantity is:

$$T(x) = \Delta T(x) + B \qquad (3)$$

Where B is a constant in the coordinate x over the portion of the profile where the analysis is being made.
Solving equation (3) for ΔT , substituting into equation (2) and arranging terms yield:

$$x_0 \frac{\partial T}{\partial x} + z_0 \frac{\partial T}{\partial z} + NB = x\frac{\partial T}{\partial x} + nT \qquad (4)$$

Equation (4) with three unknowns x0, z0, and B can be solved by using a least squares procedure.

The proposed method involves setting an appropriate value for the structural index of the suspected source bodies and then solving the system by least-squares inversion for an optimum x0, z0 and B. The inversion process also yields an uncertainty (standard deviation) for each of the fitted parameters. These uncertainties may be used as criteria for acceptance or rejection of solutions.

To solve for the source location x0, z0 the process normally solving the following least square normal equation associated with equation (4):

$$G^T G m = G^T d$$
(5)
$$m = G^T d \left(G G^T\right)^{-1} \qquad (6)$$

Where m is the vector of unknown parameters:

$$m = \begin{bmatrix} X_0 \\ Z_0 \end{bmatrix} \qquad (7)$$

$$G^T G = \begin{bmatrix} \left\langle \frac{\partial T}{\partial x}, \frac{\partial T}{\partial x} \right\rangle \left\langle \frac{\partial T}{\partial x}, \frac{\partial T}{\partial z} \right\rangle \\ \left\langle \frac{\partial T}{\partial x}, \frac{\partial T}{\partial z} \right\rangle \left\langle \frac{\partial T}{\partial z}, \frac{\partial T}{\partial z} \right\rangle \end{bmatrix} \qquad (8)$$

And

$$G^T d = \begin{bmatrix} \left\langle \frac{\partial T}{\partial x}, x\frac{\partial T}{\partial x} \right\rangle + \left\langle \frac{\partial T}{\partial x}, z\frac{\partial T}{\partial z} \right\rangle + n\left\langle \frac{\partial T}{\partial x}, T \right\rangle \\ \left\langle \frac{\partial T}{\partial z}, x\frac{\partial T}{\partial x} \right\rangle + \left\langle \frac{\partial T}{\partial z}, z\frac{\partial T}{\partial z} \right\rangle + n\left\langle \frac{\partial T}{\partial z}, T \right\rangle \end{bmatrix} \qquad (9)$$

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3) New approach:

In Euler deconvolution method that is used to estimate the depth and the form of anomaly, gravity and magnetic resources, the value of two factors of Structural Index (SI) and the width of Moving window size (Wsize) is not clear to the commentator and he may use primary information of geology, rule thumb or his experience for determining these values in some cases (toushmalan, 2010).In this paper in spite of previous works that were mentioned in the introduction, two loops are included in codes written in Matlab language. In the first loop all values of Structural Index (SI) of sets of o -3 values with the increase rate of ./5 is included and in the second loop all values of Moving window size (Wsize) – odd values of 3-19 with the increase rate of 2 is included. All the possible depths is extracted. By drawing the histogram of all Z values we will see that accepted values will have the most frequency regarding the depth of model. The result holds true for both models and we can even say that it estimates the depth with an inaccuracy of less than 10 %. We suppose that acquired data from Talwani's pattern-making is away from noises or errors. (figures.1,2,3,4)

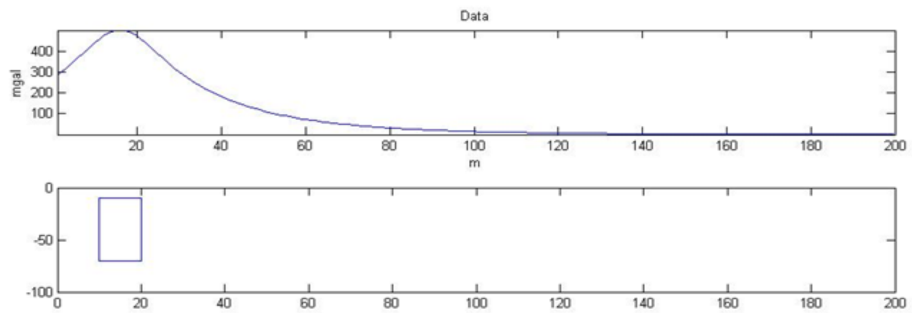

Fig. 2: Gravity effect and shape of Model 2.

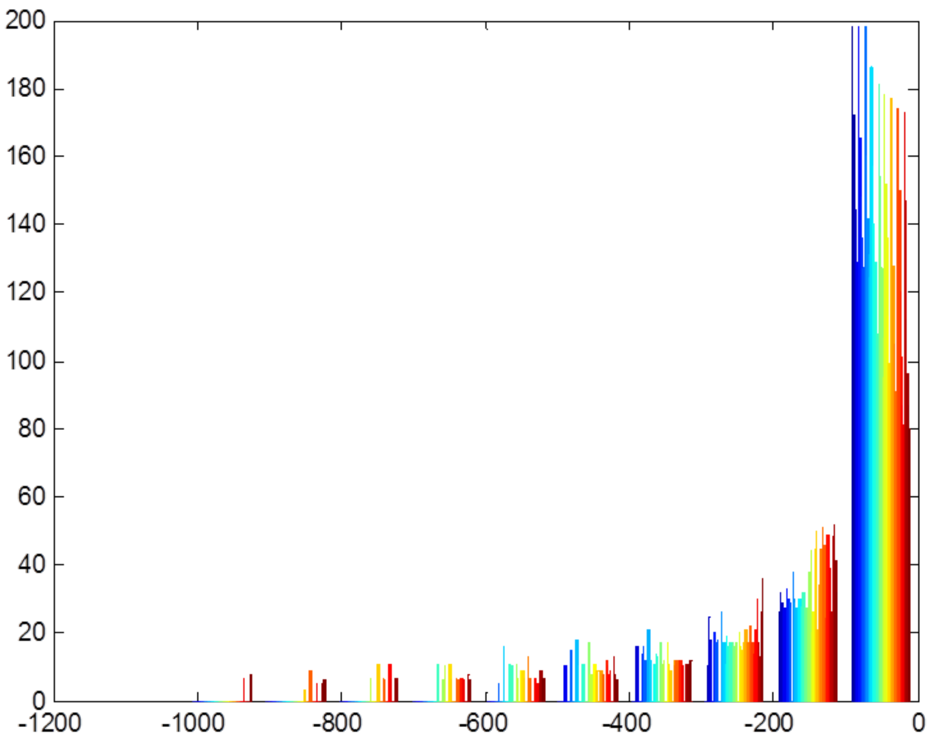

Fig. 2: Gravity effect and shape of Model 2.

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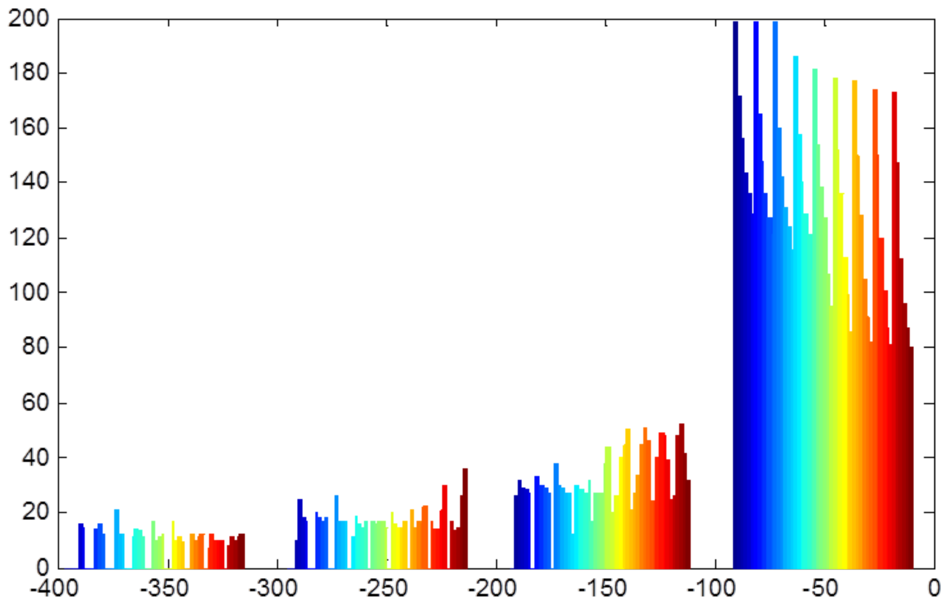

Fig. 3b: Histogram of z values for fist model (zoom in).

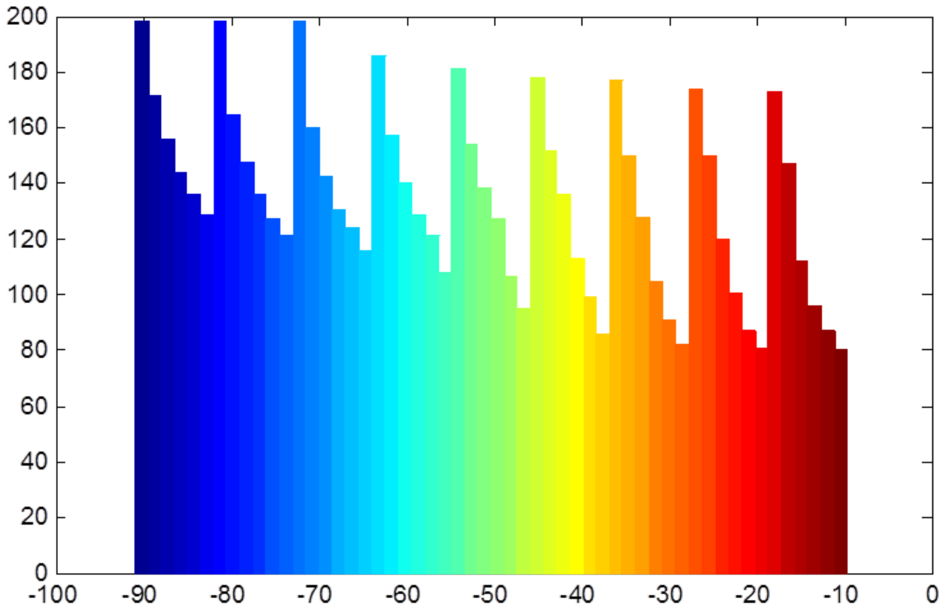

Fig. 3(c): Histogram of z values for fist model (zoom in).

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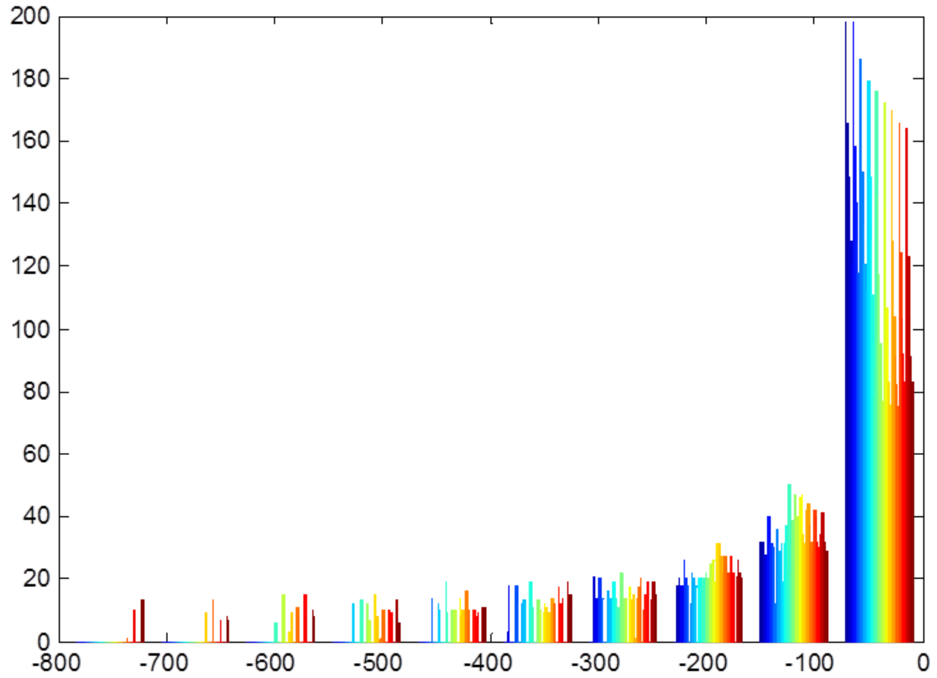

Fig. 4(a): Histogram of z values for second model.

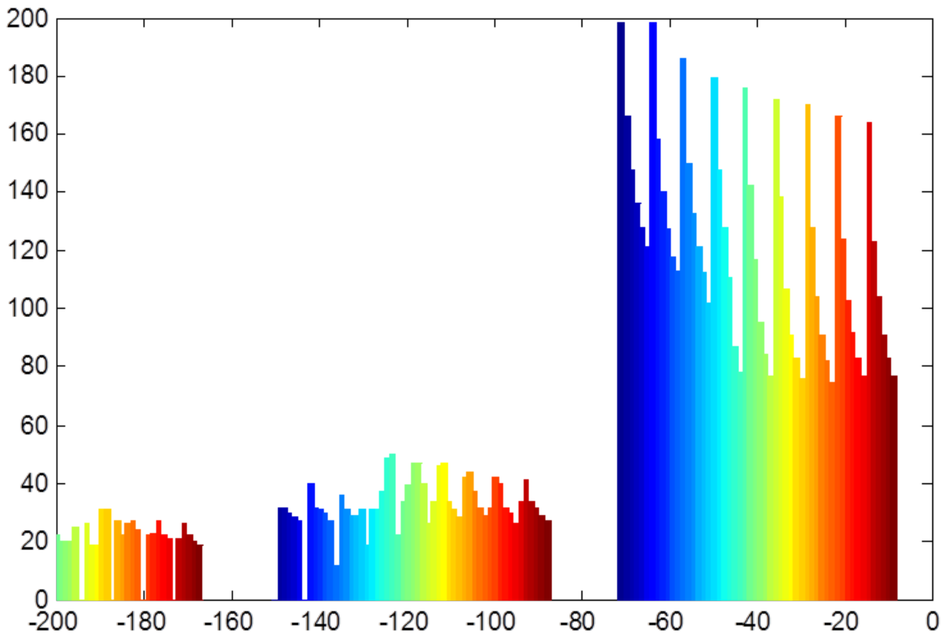

Fig. 4(b): Histogram of z values for second model (zoom in).

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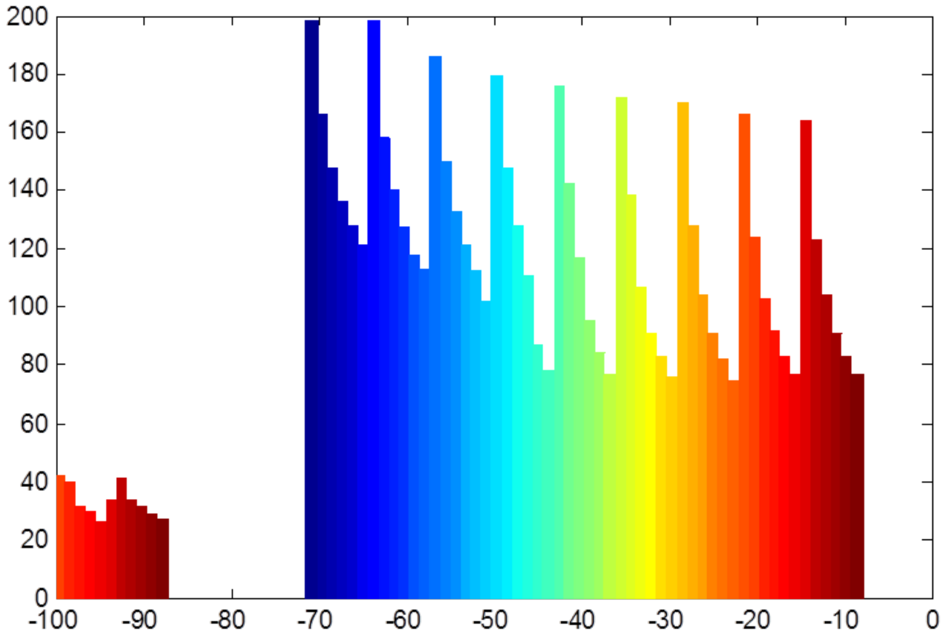

Fig. 4(c): Histogram of z values for second model (zoom in).

Conclusion:

Euler deconvolution method is used for rapid interpretation of potential field (magnetic and gravity) data. It is particularly good at delineating contacts and rapid depth estimation. This technique is belong to automatic depth estimates methods and, is designed to provide computer-assisted analysis on large volumes of magnetic and gravity data. All the possible depths of two-dimensional Euler deconvolution are extracted. By drawing the histogram of all Z values we will see that accepted values will have the most frequency regarding the depth of model. The result holds true for both models and we can even say that it estimates the depth with an inaccuracy of less than 10 %.

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