ASCIB3D Python Program

This program is referred to the manuscript

“Li, W., Schmitt, D.R., Tibbo, M., Zou, C.C., submitted. Stress state around an inclined borehole in anisotropic formation. Geophysics”.

The program is composed of a main function file ASCIB3D.py and 3 modules: ASCIB3Dlibrary.py, ASCIB3Drotation.py, and ASCIB3Dplot.py. ASCIB3Dlibrary.py is a collection of the mathematical functions used in the program, ASCIB3Drotation.py contains the subroutines used to perform the matrix rotations, and ASCIB3Dplot.py containts the two plotting functions. ASCIB3D.py constructs the various input and output parameters as shown in Table 1. The function of all the subroutines in the 3 modules are shown in Table 2. The inputs and outputs of all the subroutines are shown in Table 3 and 4, respectively. It should be noted that the output matrices are in cylindrical co-ordinate frame with the rows indicating the radius and columns indicating the azimuth, NaN in the middle represents the borehole. The program outputs seven figures. Fig. 1 shows the stress distributed on the contour of the borehole. Fig. 2 to 7 are the polar colormap images showing the distribution of stress components near the borehole.

Table 1. The inputs and outputs of the main program. ‘I/O’ means inputs or outputs.

|  |  |  |
| --- | --- | --- |
| I/O | Variables | Description |
| Inputs | rbh | The radius of the borehole rbh = *R* in meters. |
|  | boreholeAdeg  boreholeIdeg | Azimuth of the borehole in degrees from the y-axis.  Inclination of the borehole in degrees from the y-axis. |
|  | stress1 | stress1= . It is a symmetric 3 X 3 matrix containing the components of the stress tensor in MPa units. |
|  | orientS | orientS = [strikeS, dipS, rakeS] = (*ψs*, *δs*, *γs*): a 1 X 3 vector containing the strike, dip, and rake of the stress tensor in degrees. |
|  | pw | The borehole fluid pressure pw= *pw* in MPa units. |
|  | C1 | .  It is a symmetric 6 X 6 matrix according to Voigt’s organization containing from 2 to 21 independent elastic stiffnesses that depend on the material symmetry. |
|  | orientM | orientM = [strikeM, dipM, rakeM] = (*ψm*, *δm*, *γm*): a 1 X 3 vector containing the strike, dip, and rake of the stiffness matrix in degrees. |
|  | n1n2  rmedia | Number of points, aka size, of the matrix for the calculated stresses  rmedia is the maximum radial distance into the medium that the calculations are to extend. |
|  |  | Plot the Pcolor images in cylindrical co-ordinate. |
| Outputs | radial\_sigmarr | n1 X n2 matrix containing the calculated values for *σrr* in MPa. |
|  | hoop\_sigmass | n1 X n2 matrix containing the calculated values for *σθθ* in MPa. |
|  | axial\_sigmazz | n1 X n2 matrix containing the calculated values for *σzz* in MPa. |
|  | tausz\_sigmasz | n1 X n2 matrix containing the calculated values for *σθz* in MPa. |
|  | taurz\_sigmarz | n1 X n2 matrix containing the calculated values for *σrz* in MPa. |
|  | taurs\_sigmars | n1 X n2 matrix containing the calculated values for *σrθ* in MPa. |

Table 2. The purpose of the subroutines.

|  |  |
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| Subroutine | Purpose |
|  |  |
| BondY | The rotate matrix for the elastic stiffness tensor around y-axis. |
| BondZ | The rotate matrix for the elastic stiffness tensor around z-axis. |
| StiffnessRotationEuler | Z-Y-Z elastic stiffness rotation from NED to borehole frame. |
| StrRMatrixY | The rotate matrix for the far-field stress tensor around y-axis. |
| StrRMatrixZ | The rotate matrix for the far-field stress tensor around z-axis. |
| StressRotationEuler | Z-Y-Z far-field stress rotation from NED to borehole frame. |
|  |  |
| plottin  plottin2  nan\_borehole  beta  miu  lsoln  zeta  borehole\_wall360 | Plot the polar colormap images in cylindrical co-ordinate.  Plot the stresses at the borehole wall.  Sets all the coordinates in the n1n2 matrix that are (R<1) inside the borehole to NaN.  Calculates the matrix of reduced strain coefficents.  Calculates the roots of equation (C.2).  Solves the functions in (C.2) and considers the special cases.  Solves the equation (D.2) and selects the correct sign for the inverse function.  Selects the coordinates at the borehole wall, and unzips them into an array |

Table 3. The inputs of all the subroutines.

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| Subroutine | Iutput | Description |
| BondY | alpha | Rotational angles. |
| BondZ | alpha | Rotational angles. |
| StiffnessRotationEuler | C1 | The elastic stiffness matrix in the media symmetric frame. |
|  | alphazm1 | The rotation angle of the medium symmetry frame around D-axis. |
|  | alphaym | The rotation angle of the medium symmetry frame around y'-axis. |
|  | alphazm2 | The rotation angle of the medium symmetry frame around zm-axis. |
|  | boreholeA | Azimuth of a borehole. |
|  | boreholeI | Inclination of a borehole. |
| StrRMatrixY | alpha | Rotational angles. |
| StrRMatrixZ | alpha | Rotational angles. |
| StressRotation3D | stress1 | Stress tensor in the principle stress frame. |
|  | alphazs1 | Rotation angle of the far-field stress frame around D-axis. |
|  | alphays | Rotation angle of the far-field stress frame around y'-axis. |
|  | alphazs2 | Rotation angle of the far-field stress frame around zs-axis. |
|  | boreholeA | Azimuth of a borehole. |
|  | boreholeI | Inclination of a borehole. |
|  |  |  |
| plottin | geophy | Stress parameter. |
|  | theta | Angle around borehole in radians |
|  | R | Radial distance. |
|  | rmedia | Distance into media. |
|  | title | Title of plot. |
|  | fgnm | Figure number |
|  |  |  |
| plottin2 | radial | Radial stress matrix. |
|  | hoop | Hoop stress matrix. |
|  | axial | Axial stress matrix. |
|  | tautz | Tautz stress matrix. |
|  | taurz | Taurz stress matrix. |
|  | taurt | Taurt stress matrix. |
| nan\_borehole  beta  miu  lsoln  zeta  borehole\_wall360 | Rmedia  Title  x  y  n1n2  A  Beta  Beta  mius  z  miu  laplace  theta2  geophys  R | Distance into media.  Title of plot  x-coordinates  y-coordinates  Size of matrix.  The compliance matrix after rotation.  Matrix of reduced strain coefficients  Matrix of reduced strain coefficients  Roots of equation (C.2)  Complex variable mapping function  The root of equation (C.2)  Variable from equation (20)  Angle around borehole in degrees  The stress parameter being plotted  Radial distance away from borehole |
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|  |  |  |

Table 4. The outputs of all the subroutines.

|  |  |  |
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| Subroutine | Output | Description |
| BondY | M | The matrix used to rotate elastic stiffness matrix around y-axis. |
| BondZ | M | The matrix used to rotate elastic stiffness matrix around z-axis. |
| StiffnessRotationEuler | C | The elastic stiffness matrix in the borehole coordinate frame. |
| StrRMatrixY | M | The matrix used to rotate the stress tensor around y-axis. |
| StrRMatrixZ | M | The matrix used to rotate the stress tensor around z-axis. |
| StressRotationEuler | istress | The stress tensor in the borehole coordinate frame. |
| plottin2 | Fig1 | Plot of stress at borehole wall. |
| plottin | Fig2-7 | Plot of stress parameter in polar colormap plot |
| Nan\_borehole | newx | x-coordinates with the borehole=nan |
|  | newy | y-coordinate with the borehole=nan |
| beta | beta | Matrix of reduced strain coefficients |
| mius | mius | All of the roots to the six order equation (C.2) |
| lsoln | mius | Mius recalculated for special cases |
|  | l2,l3,l4 | Functions of (C.2) |
| zeta | zeta | Inverse function with correct sign |
| Borehole\_wall360 | wall2 | 360 degree array of theta2 coordinates at borehole wall |
|  | geophys2 | Values of stress parameter at 260 degrees around borehole wall |



