PALGrav4.0 programs and examples

PALGrav4.0 is a window 64-bit assembly developed using QT C++ (Inteface), Intel Fortran (Professional algorithm functions) and mathGL C++ (Data visualization) code mixed programming technology in Visual studio 2017 x64 integrated environment.

PALGrav4.0 is composed of more than 40 win64 executable programs which include nearly 200 independent modules (more than 500 functions).

For each Win64 executable program, there are the computation example files saved in the directory C:\PALGrav4.0_win64en\examples which includes the operation process file "processinf.txt", some input/output data files, and screenshot images. The directory name of the example files is the same as the name of executable program.

It will take about 3 working days to complete all the example exercises.

No	Executable Program Title	Name of Program or Example directory	Computation Purpose
1	Compute anomalous gravity field elements at observation points	ProbsAnomousgrav	Compute normal gravity field elements at the observation points with the spherical harmonic series formula, and then obtain the gravity anomalies (mGal), gravity disturbances (mGal) or disturbing gravity gradients (E) from the measured gravities (mGal) or gravity gradients (E).
2	Compute the normal earth gravity field elements	PrNormalgravfdcalc	With the spherical harmonic series formula, compute the normal gravity potential (m²/s²), normal gravity (mGal), normal gravity gradient (E), normal gravity line direction (', expressed by its north declination relative to the center of the earth) or normal gravity gradient direction (', expressed by its north declination relative to the center of the earth).
3	Compute anomalous gravity field elements with a geopotential model	PrModelgravfdcalc	Compute the height anomalies (m), gravity anomalies (mGal), gravity disturbances (mGal), vertical deflection vector (", southward, westward), (Vertical) disturbing gravity gradient (E), horizontal gravity gradient vector (E, northward, eastward) and disturbing potential (m²/s²) at any point in the earth space with a geopotential coefficients model.
4	Boundary value corrections on a spherical or ellipsoidal surface	PrBoundaryvalueAdj	Compute boundary value corrections of the anomalous field elements on a spherical or ellipsoidal surface with a geopotential coefficients model, which can convert the Molodensky boundary value problem to the Stokes boundary value problem.
5	Compute Molodensky I outside the earth	PrMolodenskyFirst	On the non-equipotential boundary surface outside of the earth, using the height anomalies, ellipsoidal heights grid models of the boundary surface and the ellipsoidal heights grid model of an equipotential surface, compute the Molodensky I (mGal) for gravity anomalies or for gravity disturbances, which can converts the Molodensky boundary value problem to the Stokes boundary value problem.
6	Analytical continuation of	PrGradicontinuation	Using the ellipsoidal heights and anomalous field elements grid

	anomalous field elements with radial gradient method		models on the current heights surface, the radial gradients at the computed points are determined according to the strict radial gradient integral formula. And then the analytical continuation corrections from the current heights to the target heights are computed.
7	Horizontal gradient vectors estimation of geodetic grid	PrHorizontalgradent	Using the least square estimation method, the first or second order horizontal gradient vectors is estimated with an geodetic grid data, with the first order gradient unit is /m, the second order unit is /m². The horizontal gradient grid is represented in the form of a vectors grid.
8	Low-pass filtering for the geodetic grid model	PrGrdlowpassfilter	Low-pass filters such as moving average, Gaussian, exponential or Butterworth are employed to perform low-pass filtering on a geodetic digital grid model. Before and after filtering, the grid specifications (area range and spatial resolution) are the same.
9	Compute local terrain effects for anomalous field elements outside geoid	TerLocalterraininfl	With ground digital elevation model and ellipsoidal heights grid model, the rigorous numerical integral or FFT algorithm is employed to compute the local terrain effects for the height anomalies (m), gravity disturbances (mGal), gravity anomalies (mGal) or disturbing potential (m²/s²) outside the geoid.
10	Compute Bouguer or isostasy effects for land/sea surface gravity	TerSurfacegravinfl	With the land/sea topographic model and land/sea surface ellipsoidal heights grid model, compute the land/sea Bouguer plate effects, sea water simple Bouguer effects, land/sea topographic plate Bouguer or isostasy effects for the land/sea surface gravity.
11	Compute land-sea complete Bouguer/residual topographic effects for field elements outside geoid	TerCompleteBougure	With the land-sea topographic model and land-sea surface ellipsoidal heights grid model, the rigorous numerical integral or FFT algorithm is employed to compute the complete Bouguer effects for the height anomalies (m), gravity disturbances (mGal), gravity anomalies (mGal) or disturbing potential (m²/s²) outside the geoid.
12	Compute Helmert condensation effects for field elements outside geoid	TerHelmertcondensat	With ground digital elevation model and ellipsoidal heights grid model, the rigorous numerical integral or FFT algorithm is employed to compute the topographic Helmert condensation effects for the height anomalies (m), gravity disturbances (mGal), gravity anomalies (mGal) or disturbing potential (m²/s²) outside the geoid.
13	Spherical harmonic analysis for land-sea topographic masses areal density	TerGloharmanalysis	With a global land-sea topographic grid model in geocentric spherical coordinate system, compute the land-sea topographic masses areal density grid model, and then perform spherical harmonic analysis to create a spherical harmonic coefficients model (kg/m²).

14	Compute residual topographic effects by spherical harmonic synthesis	TerHarmrntinfluence	With an areal density spherical harmonic coefficients model (kg/m²), compute the residual topographic masses or complete Bouguer effects for the height anomalies (m), gravity anomalies (mGal), gravity disturbances (mGal), vertical deflection ("), disturbing gravity gradient (E), horizontal gravity gradient (E,) and disturbing potential (m²/s²) outside the earth.
15	Compute sea or lake water complete Bouguer effects for anomalous field elements	TerLakeseabouginflu	The rigorous numerical integral algorithm is employed to compute the sea or lake water complete Bouguer effects for the anomalous gravity field elements outside the geoid.
16	Compute height anomalies outside geoid by Stokes/Hotine Integral	IntgenStokesHotine	Inputting the ellipsoidal heights of an equipotential surface outside the geoid and gravity anomalies or gravity disturbances grid model, the rigorous numerical integral or FFT algorithm of the Stokes/Hotine formula is employed to compute the height anomalies outside the geoid.
17	Compute vertical deflections outside geoid by Vening-Meinesz Integral	IntgenVeningMeinesz	Inputting the ellipsoidal heights of an equipotential surface outside the geoid and gravity anomalies or gravity disturbances grid model, the rigorous numerical integral or FFT algorithm of the Vening-Meinesz formula is employed to compute the vertical deflection vectors outside the geoid.
18	Compute anomalous field elements by various inverse operation integral	Integralgrainverse	Inputting the ellipsoidal heights of an equipotential surface outside the geoid and height anomalies gird or vertical deflection vectors grid model, the rigorous Inverse operation integral formula is employed to compute the other elements of the anomalous gravity field.
19	Compute gradients of anomalous field elements outside geoid by numerical integral	Intgendistgradient	Inputting the ellipsoidal heights of an equipotential surface outside the geoid and anomalous field elements grid model, the rigorous integral formula is employed to compute the radial gradient (unit: /km) of the anomalous field elements. Inputting the ellipsoidal heights of an equipotential surface outside the geoid and disturbing gravity gradients(E) grid model, the rigorous integral formula is employed to compute the gravity disturbances (mGal). Inputting the ellipsoidal heights of an equipotential surface outside the geoid and gravity disturbances (mGal) grid model, the rigorous inverse integral formula is employed to compute the disturbing gravity gradients(E) on the equipotential surface.
20	Possion integral operation for anomalous field elements outside geoid	IntgenPossioncontn	Inputting the ellipsoidal heights of a boundary surface and its anomalous gravity field elements grid model, the rigorous Possion integral formula is employed to compute the anomalous gravity field elements outside the geoid.

21	Error analysis and accuracy evaluation of regional geoid model	AppGeoiderrorestim	Evaluation of geoid model accuracy using the GNSS leveling residuals is that according to the frequency domain error characteristics of the GNSS leveling height anomaly and gravimetric geoid model, the GNSS leveling residual height anomaly(m) is used to estimate and determine the gravimetric terrestrial height anomalies error, hybrid height anomalies internal error, hybrid height anomaly differences error-curve and GNSS leveling height anomaly differences error-curve (cm). Replacing the height anomaly with the geoid height, the program here becomes the evaluation of geoid model accuracy of the orthometric system.
22	Height correction of height anomaly and difference computation between height systems	AppHgtsysdifferent	①Firstly, determine the height anomaly model differences. ② Then compute the height anomaly residual differences using the regional gravity field data by the remove-restore scheme. ③ Finally further correct the differences by the measured gravity at the computed point. Take one of the following three results according to the gravity data available: ①, ①+②, or ①+②+③.
23	Compute geopotentials and ellipsoidal heights of equi-height surface passing a given point	AppEquihgtpotential	Using an earth geopotential model, compute the model geopotential (m^2/s^2), model ellipsoidal height (m) and model gravity (mGal) grids of the equi-height surface passing the given point (B, L). The heights of the surface can be orthometric or normal heights. Using the ellipsoidal heights and residual gravity disturbances grid models of an equipotential boundary surface, compute the geopotential corrections (m^2/s^2) and ellipsoidal height corrections (m) grids of the equi-height surface passing the given point.
24	Determination and refinement of the equipotential surface passing a given point	AppEquipotentialhgt	Using an earth geopotential model, compute the model gravity (mGal) and model ellipsoidal height (m) grids of the equipotential surface passing the given point (B, L, H). Using the ellipsoidal heights and residual gravity disturbances grid models of an equipotential boundary surface, refine the ellipsoidal heights grid of the equipotential surface passing the given point.
25	Geodetic observations gross error detection and weighted basis function gridding	AppGerrweighgridate	Select the low-pass grid as the reference surface, interpolate the reference value of the given attribute value at the discrete point, and then detect and separate the gross error records according to the statistical properties of the differences between the given attribute and reference value. Give the reference attribute in the geodetic records file, and estimate the weight of the attribute according to its statistical property using the weight function defined by PALGrav4.0. According to the given grid specifications (area range and

			spatial resolution) and selected interpolation weight function and other parameters, the weighted basis function interpolation method is adopted to grid the discrete points data.
26	GNSS leveling fusion and regional height datum improving	AppGNSSlvlhgtdatum	With the GNSS leveling measured geoid heights (height anomalies, m), residual geoid heights (height anomalies, m), estimate the zero-height surface geopotential W_r of the regional height datum. Then with the geopotential W_o of the Gauss geoid, get the zero-height surface geopotential difference W_r -W_o of the regional height datum. With the GNSS leveling residuals and area range grid files, and the Possion integral constraint, the gravimetric geoid height (terrestrial height anomaly) corrections are estimated to realize the analytical fusion of GNSS leveling and gravimetric geoid. With the remaining GNSS leveling residuals and leveling routes in the GNSS leveling network, all the GNSS bench marks are used to form a quasi-stable datum, and then the least square adjustment method is employed to estimate the orthometric (normal) height corrections of the bench marks and geoid height (height anomaly) corrections. The program is suitable for the geoid results of the orthometric height system and terrestrial height anomaly results of the normal height system.
27	GNSS replaces leveling to determine the orthometric or normal height	AppGNSSrepleveling	Using the results of the regional geoid, determine the orthometric (normal) height of the GNSS positioning point.
28	Calculate basic geometry and physics constants of the earth ellipsoid	TlEllipsoidconstant	Input the four basic constants of the earth ellipsoid, and calculate the main geometric derived constants and physical derived constants of the ellipsoid.
29	Convert general ASCII records into PALGrav4.0 format	EdPntrecordstandard	Convert general ASCII data records file from different sources and non-standard formats into PALGrav4.0 own format geodetic records file.
30	Geodetic data interpolation, picking and separation of land and sea	Edatafsimpleprocess	Increase or decrease the grid spatial resolution according to the given grid resolution and interpolation method. From a grid file, the attributes of the geodetic points are interpolated according to the specified interpolation scheme. Pick the geodetic records in a point records file according to the maximum and minimum range of the given attribute Replace the land or ocean area grid values of an original grid file or vector grid with the given constant to separate the land and ocean data in the grid file.
31	Simple and direct calculation of geodetic data	EdFlgeodatacalculate	Perform weighted plus, minus, or multiply operations on two given attributes in the point records file.

	files		Perform weighted plus, minus, or multiply operations on grid elements in two (vectors) grid files with the same specification. Perform outer product or inner product operations on vectors grid elements in two vectors grid files with the same specification. Perform weighted operations on two normalized spherical harmonic coefficients model files.
32	Regional geodetic grid data file generating and constructing	Edareageodeticdata	From a geodetic point records file, according to the given interpolation scheme, grid range and resolution, generate a given attributes grid file. The direct averaging scheme is employed to grid the high-resolution discrete observations. According to the given latitude and longitude range and spatial resolution, generate the constant values, random numbers, 2D array index values, or Gaussian surface grid file. According to the given latitude and longitude range, pick the data in the point records file, grid file or vectors grid file.
33	Geodetic vectors grid file constructing and transforming	EdVectorgridtransf	Combine two grids with identical specifications as the two components of the vector into a vectors grid. Decompose a vectors grid file into two components grid files. The transform of the grid values of the vectors grid between plane coordinates (in-phase/cross-phase amplitude) and polar coordinates (amplitude/phase). Convert the (vectors) grid file into the discrete point records file.
34	Statistical analysis for geodetic data file	Tlstatisticanalysis	Extract the latitude and longitude range, mean, standard deviation, minimum, maximum and other statistical information from the given attributes of the geodetic records file, grid file or vectors grid file.
35	Global parameter settings for PALGrav4.0	Systemparameterset	Set the four basic constants of the earth ellipsoid and the user working directory.
36	3D visualization for given attributes in point records file	Viewpntdata	
37	3D visualization for grid values in geodetic grid file	Viewgridata	
38	Visualization for vectors grid	Viewvectgrd	