Concord2
Coordinate conversion program

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14 March 2005

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Introduction

Concord2 is a program to convert coordinates between the various coordinate systems. It is designed primarily to convert coordinates in data files, but can also be used to convert manually entered coordinates. The program supports conversions which involve projections (Transverse and equatorial Mercator, Polar stereographic, Lambert Conformal Conic, New Zealand Map Grid), and changes of geodetic reference frame (e.g. WGS84 to NZGD49). It also can convert between ellipsoidal and orthometric heights (the accuracy of this is limited by the geoid model used - errors of up to 1 metre are typical).

Coordinate systems used by concord2 are defined in a file called coordsys.def. For each coordinate system this specifies the reference frame, ellipsoid, and projection that is used. This is a simple text file and can be readily edited to include additional coordinate systems.

Conversions between ellipsoidal and orthometric height are done using a geoid model derived from the geopotential model EGM96 from NASA and NIMA (http://cddis.gsfc.gov/926/egm96/egm96.html). This is a spherical harmonic model of degree and order 360. Geoid heights have been derived from this model on a 0.25 by 0.25 degree grid. The geoid height at other points is interpolated from this grid (which is stored in the file geoid.bin).

Command syntax

The syntax for running concord2 is:

concord2 [*switches*] [*input_file_name*] [*output_file_name*]

The two parameters that can be specified are:

input_file_name — Specifies the name of the input file of coordinates. This parameter may only be supplied if the -K switch (see below) is not present. If it is not specified input is taken from the standard input channel. A file name of "-" is equivalent to the standard input channel. The required format of an input file is defined below.

output_file_name — Defines where output is to be directed. If no output file is specified, or if the file name is "-" then output is directed to the standard output stream. If a file is specified, then a summary of the processing is sent to the standard output stream.

The command line switches that can be specified are:

-A — Ask for all parameters interactively rather than using only the information in the command line. All the options described below are available interactively using the -A switch. If no switches other than the C and G switches are specified then this becomes the default.

-I*xxxx* — Defines the input coordinate system to be *xxxx*. The format for the code is described below.

-K — Keyboard entry of coordinates - prompts for coordinates to be converted at the keyboard rather than reading from a file. Converted coordinates are always displayed on the standard output with this option. The coordinates may also be directed to a file by specifying an output file name in the command line.

-L — Lists the valid coordinate system codes to the standard output stream. No coordinate conversion is done.

-O*xxxx* — Defines the output coordinate system. The code *xxxx* is described below.

-Nc — If the -N switch is present then the input coordinates are assumed to be preceded by a point identifier. The switch can specify the maximum number of characters in the identifier as c.

-Pn	Defines the number of decimal places in the output coordinates.
-Sc	Defines a field separator to be used for the input and output files. The default separator is whitespace (blank or tab characters).
-V	Verbose output - columns of coordinates are headed and input coordinates are echoed in the output.
-C*filename*	Specifies the name of the coordinate system definition file (default is coordsys.def). The format of the file is described below.
-G*filename*	Specifies the name of the geoid model file (default is geoid.bin). The format of this file is defined below.
-H	Print a help page listing these switches.
-Z	List the program version and copyright information. No coordinate conversion is done.

The input and output coordinate systems are specified by a code which consists of up to three items separated by commas.

The first item is the code for the coordinate system. This must match an entry in the coordinate system definition file (the format of this file is described below).

The second item defines the order of the coordinates in the input or output file. This is a two or three character string in which each character defines one of the coordinates in the file. The first two must be characters must be EN (easting/longitude followed by northing/latitude) or NE (northing/latitude followed by easting/longitude). The third character specifies the height and can be H for ellipsoidal height or O for orthometric height. If the third character is omitted then input file is assumed to contain no height data. (i.e. heights are 0).

For latitude/longitude coordinates the definition can include a third character which specifies how the angles are entered. Use H for hexaguesimal format (degrees, minutes, seconds followed by a hemisphere). or D for decimal degrees.

For example the input coordinate system could be defined by a switch -iNZGD49,ENO,H.This specifies that the input is in the NZGD49 coordinate system (New Zealand Geodetic Datum 1949). This is a latitude and longitude coordinate system. The coordinates are ordered as longitude, latitude, ellipsoidal height. An example of the input in this case could be

172 43 58,22 E 42 25 02.179 S 298.53

Input data file format

Files of input coordinates should contain one pair of coordinates per line. Blank lines and lines starting with an exclamation mark are ignored, and pass unchanged into the output file. Each data line should contain the following fields separated by space or tab characters (or a delimiter character specified with the -S switch).

id coordinate1 coordinate2 coordinate3 additional_data

The id must be present if the -N switch is specified, and must be omitted otherwise. The -N switch defines the maximum number of characters that are read from the id. It can be longer than this specified length, but any extra characters will be discarded and will not be copied to the output file. Following the id are the two or three coordinates and then optional additional data (which is copied to the output file without modification). The order and format of the coordinates is defined by the -I switch as described above.

Hexaguesimal latitudes and longitudes each comprise four fields, these being the degrees, minutes, and seconds of the angle and the hemisphere indicator (N, S, E, or W). The hemisphere can precede or follow the angle, and if it follows the angle, need not be separated by a space from the angle. If a separator is specified by the -S switch it must be used between the components of angles as well as between the different coordinates.

Examples

To use concord2 to convert a few coordinates from the keyboard use the command

concord2

This will prompt for the input and output coordinate systems and prompt for input and output file names. If no files are specified then it will prompt for coordinates to enter and display the results.

To use concord as a filter converting NZMG eastings and northings to NZGD49 latitude and longitude use a command such as

concord2 -inzmg,en -onzgd49,ne,h file1 file2

Coordinate system definition

Coordinate systems in concord2

concord2 use a configuration file which defines the coordinate systems that may be used. Usually this file is called coordsys.def and is located in the same directory as concord2 and its related programs. If you need to use coordinate systems other than those supplied by default then you will need to modify this file or create your own coordinate system file. This section describes the definitions of coordinate systems in coordsys.def.

To use your own coordinate system definition file you must specify the file with the DOS environment variable COORDSYSDEF. That is, if you have created a file called CSLIST.DAT in directory C:\MYCRDSYS then you should use the command:

SET COORDSYSDEF=C:\MYCRDSYS\CSLIST.DAT

Alternatively you can use the -C switch on the concord2 command line. That is

concord2 -cC:\MYCRDSYS\CSLIST.DAT

What is a coordinate system

A coordinate system is a definition of how the coordinates of a point are determined from its physical position.

concord2 uses three types of coordinate systems. These are

- geocentric systems: the position is defined in a Cartesian system as X, Y, and Z coordinates. The origin is approximately the centre of the earth. The X axis extends from centre to the equator on the Greenwich meridian (0 degrees longitude). The Y axis extends from the centre to the equator at longitude 90 degrees East. The Z axis extends from the centre through the North Pole. Geocentric systems are not well supported by concord2 - in listing files they are always converted latitude and longitude.
- geodetic systems: the position is defined in terms of an ellipsoid by a latitude, longitude, and height above the ellipsoid. The ellipsoid is centred on the origin of the underlying geocentric coordinate system.
- projection systems: the position is defined by a projection northing and easting, and a height. The easting and northing are obtained by applying projection formulae to the latitude and longitude of the underlying geodetic system.

Each of these coordinate systems is based upon a reference system, that is a theoretically defined set of axes and (except for geocentric systems) a definition of an ellipsoid. The reference system is of little practical use for determining coordinates because it is expressed in terms of quantities we cannot directly observe (for example the centre of the earth).

To make the reference system useful we define a reference frame, which is a realization of a reference system. A reference frame adds the assigned coordinates of a set of measurable points to the reference system. We can make observations relative to these points to obtain the coordinates of other points in terms of the reference frame.

For example, the WGS84 (World Geodetic System 1984) reference frame is implemented in terms of the coordinates of a number of GPS tracking stations. These are used to calculate the orbits of the GPS satellites, which in turn are used to reduce GPS survey data of other points.

In New Zealand the NZGD49 (horizontal) reference frame is defined by the coordinates of the first order stations used in the 1949 adjustment. The vertical reference is defined by levelling from a number of tide gauges around the coast.

In both cases more stations are used to define the reference frame than are mathematically required. The coordinates are not perfectly consistent. That is, you could not construct a physical reference frame to exactly match the coordinates all the stations. Differences arise because of the errors in measuring the station coordinates and because the physical positions of the stations may have changed due to earth deformation since they were observed. This is particularly significant for the NZGD49 datum because: 1) the observations are relatively inaccurate (compared to GPS and modern EDM), 2) the analysis could not properly account for the gravity field, and 3) there has been significant deformation since the observations were made.

The coordinate system definition file

Structure of the file

The coordinate system definition file consists of three sections which define

- ellipsoids
- reference frames
- coordinate systems

Each section starts with the name of the section enclosed in square brackets, e.g. [reference_frames]. Within each section are a number of definitions, one per line. For coordinate systems the definitions can be quite long. They may be extended over more than one line by ending each incomplete line with an ampersand (&).

Comments can be inserted anywhere in the file on lines starting with an exclamation mark (!). Blank lines and comments are ignored.

Ellipsoid definitions

Ellipsoid definitions have the following format

code “description” semi_major_axis reciprocal_flattening

where

code	is an identifier for the ellipsoid. This may contain letters, numbers, and the underscore character. It cannot contain blanks.
description	is a quoted text description of the ellipsoid
semi_major_axis	is the length of the semi-major axis in metres
reciprocal_flattening	is the reciprocal of the flattening

Here is an example of the ellipsoid definition section

```
[ellipsoids]
INTERNATIONAL "International ellipsoid" 6378388.0 297.0
WGS84 "WGS84 ellipsoid" 6378137 298.257223563
```

Reference frame definitions

Reference frames defines the ellipsoid for a reference frame, and the location, orientation, and scale of coordinates relative to a reference system. The reference system is arbitrary. Conversions can only be done between coordinates which have the same reference system.

Reference frame definitions have the following format:

code “description” ELLIPSOID ellipsoid_code refcode Tx Ty Tz Rx Ry Rz scale [transformation]

where

code	is an identifier for the reference frame. This may contain letters, numbers, and the underscore character. It cannot contain blanks.
description	is a quoted text description of the reference frame
ellipsoid_code	is the code for the ellipsoid associated with the reference frame. This code must have been defined in an earlier [ellipsoids] section of the file.
refcode	is a code identifying the reference system in terms of which translations, rotations, and scale are defined. This need not be the same a reference frame in the coordinate system file, but it must be the same for all reference frames between which coordinate conversions are required.
Tx Ty Tz	is XYZ position of the origin of the reference frame in the reference system (i.e. the translation that must be applied to coordinates to convert them back to the reference system). The coordinates are in metres.
Rx Ry Rz	are the rotations about the X, Y, and Z axes required to convert coordinates from the reference frame back to the reference system. The rotations are in arc seconds.
scale	is the scale difference between the reference frame and the reference system. It is applied to coordinates to convert them back to the reference system. The scale is defined in parts per million.
transformation	is an optional string definition of a transformation between the datum and the reference. The only supported option at present is “GRID SNAP2D *grid_file_name [description]*”. This uses a grid based transformation in which the 7 parameter transformation is modified by a latitude and longitude offset defined by bilinear interpolation on a grid.

Here is an example of the reference frames section..

```
[reference_frames]

WGS84  "World Geodetic System 1984" &
          ELLIPSOID WGS84 &
          WGS84 0.0 0.0 0.0 0.0 0.0 0.0 0.0

NZGD49 "New Zealand Geodetic Datum 1949 (Mackie 7 parameter)" &
          ELLIPSOID INTERNATIONAL &
          WGS84 59.47 -5.04 187.44 -0.47 0.10 -1.024 -4.5993 &
          GRID SNAP2D def492kt.grd &
          "LINZ NZGD49-NZGD2000 conversion grid"
```

Coordinate system definitions

The coordinate system definition is formatted as

code "description" REF_FRAME ref_frame_code type [proj_definition] [RANGE extents]

In this definition the square brackets denote optional components. The components of the definition are:

code	is an identifier for the coordinate system. This may contain letters, numbers, and the underscore character. It cannot contain blanks. It is used in concord2 coordinate files to specify which coordinate system to use.
description	is a quoted text description of the reference frame
ref_frame_code	is the code for the reference associated with the reference frame. This code must have been defined in an earlier [reference frames] section of the file.
type	is the type of coordinate system. This can be one of "GEOCENTRIC", "GEODETIC", or "PROJECTION"
proj_definition	is the projection definition. It is only defined for projection coordinate systems. The contents of this definition depends upon the type of the definition. It is detailed for the supported projections in the following sections.
extents	optionally defines the range of coordinates over which the projection is valid. This is detailed below.

The coordinate system definition may optionally be followed by a range defining valid values for coordinates. This does not apply for geocentric systems. For geodetic systems the range defines the minimum and maximum latitudes and longitudes of the coordinates in decimal degrees. The format is

RANGE min_long min_lat max_long max_lat

For projection coordinate systems the range defines the minimum and maximum values of the easting and northing, formatted as

RANGE min_easting min_northing max_easting max_northing

The following example shows a geocentric and a geodetic coordinate system definition. Projection coordinate systems are illustrated in the following sections.

```
[coordinate_systems]
WGS84_XYZ  "World Geodetic System 1984 - XYZ" REF_FRAME WGS84
GEOCENTRIC
NZGD49 "New Zealand Geodetic Datum 1949" REF_FRAME NZGD49 GEODETIC
```

New Zealand Map Grid

For the New Zealand Map Grid projection the projection definition consists of just the text "NZMG". Here is an example of an NZMG coordinate system definition

```
NZMG "New Zealand Map Grid" REF_FRAME NZGD49 PROJECTION NZMG
```

Transverse Mercator Projections

A Transverse Mercator projection is defined the word "TM" and the following items

- the central meridian longitude in decimal degrees
- the origin of latitude in decimal degrees
- the central meridian scale factor
- the false origin easting in projection units
- the false origin northing in projection units
- the unit to metres conversion factor

Here is an example of a Transverse Mercator projection coordinate system. Note the use of "&" to continue the definition over two lines

```
AMUR  "Amuri Circuit"   REF_FRAME NZGD49  PROJECTION &
    TM 173.01013339 -42.68911658 1.000000 &
         300000.00 700000.00 0.999998261
```

Equatorial Mercator Projections

The Equatorial Mercator projection is defined by the word "EM" and the following items

- central meridian longitude in decimal degrees
- standard parallel in decimal degrees

Here is an example of an Equatorial Mercator projection coordinate system.

```
TEST_EM "Test equatorial mercator" REF_FRAME NZGD49 PROJECTION &
             EM  170 -40
```

Lambert Conformal Conic Projections

The Lambert Conformal Conic Projection is defined by the word "LCC" and the following items

- first standard parallel in decimal degrees
- second standard parallel in decimal degrees
- origin of latitude in decimal degrees
- origin of longitude in decimal degrees
- false easting in metres
- false northing in metres

Here is an example of a Lambert Conformal Conic coordinate system.

```
TEST_LCC "Test Lambert Conformal conic" REF_FRAME NZGD49 &
     PROJECTION LCC -40 -70 -45 170 300000 700000
```

Polar Stereographic Projection

The Polar Stereographic projection is defined by the word "PS" and the following items

- the word "North" or "South", defining the pole for which the projection applies
- the central meridian in decimal degrees

- the scale factor
- the false easting in metres
- the false northing in metres

Here is an example of a Polar Stereographic projection coordinate system.

```
TEST_PS  "Test Polar Stereographic" REF_FRAME NZGD49 PROJECTION &
             PS South 170 1.05 300000 700000
```

Gnomic Projection

The Gnomic projection is defined by the word "GN" and the following items

the origin of latitude in decimal degrees

the central meridian in decimal degrees

the false easting in metres

the false northing in metres

Here is an example of a Gnomic projection coordinate system.

```
TEST_GN  "Test gnomic" REF_FRAME NZGD49 PROJECTION &
             GN -45 170 300000 700000
```

The geoid height file

For conversions between ellipsoidal and orthometric height a file of geoid heights is used. This is a binary file which defines the geoid heights at a grid of points. The heights at points of interest are calculated by interpolating from the grid points. Geoid heights represent the height of sea level above the ellipsoid defined by a reference frame, and so depend upon the reference frame being used. The geoid binary file defines the coordinate system for which the heights have been calculated. This system must be defined in the coordsys.def file in order for concord2 to convert the heights into the input and output reference frames.

The default name for the geoid file is geoid.bin. If a different file name is used the file can be specified either by setting an environment variable GEOIDBIN to the name of the file, or by specifying the name of the file on the command line with the -G switch. The format of the geoid file is defined in the following section.

Grid file format

The concord program uses gridded data in two places:

- defining the geoid model to convert between ellipsoidal and orthometric heights
- defining distortion in a reference frame definition

The grid file is also used to define gridded velocity models in SNAP.

For each of these functions the grid model is stored as a binary file. The grid model is aligned with its coordinate system – that is grid lines run along lines of constant longitude and latitude, or easting and northing. Model values at a point within the grid are calculated by bilinear interpolation of the values at the four corners of the grid cell within which the point lies.

A set of values are defined at each node in the grid. For the a geoid model there is just one value, which is the height of the geoid in metres at the node. For the distortion model there are two values, being the adjustment in degrees to apply to the longitude and latitude after the base 7 parameter model has been applied to convert from the distorted datum to the reference datum. For velocity grids there are two values each node, being the east and north velocities in metres per year.

For compactness the data values are stored in the binary file as two byte integer values. The grid model defines a scale factor to convert from the stored integer format to the actual data values.

The binary file is created from a text formatted file using the makegrid.pl script supplied with concord2. This requires the perl script interpreter to run (perl for Windows and be obtained from www.activestate.com). The binary data can be converted back to text format using the dumpgrid.pl script.

The text format comprises a set of header records followed by records defining the values at each grid node. Each record comprises a code defining the contents of the record, followed by a colon and the value of the record.

The records are as follows:

Code	Type	Description
FORMAT	string	Defines the variant of the binary grid file format to generate. The possible values are GEOID Format specifically for SNAP binary geoid files – only allows one grid value at each node GRID1L Little endian binary format – format used for distortion grids and velocity grids
HEADER0	string	Descriptive information about the model (an arbitrary character string)
HEADER1	string	Descriptive information about the model
HEADER2	string	Descriptive information about the model
CRDSYS	string	Code for the coordinate system upon which the model is based (for example NZGD2000)
NGRDX	integer	The number of columns of values in the grid.
NGRDY	integer	The number of rows of values in the grid.
XMIN	real	The x value of the first (eastmost) column of the grid
XMAX	real	The x value of the last (westmost) column of the grid
YMIN	real	The y value of the first (southmost) row of the grid
YMAX	real	The y value of the last (northmost) row of the grid
VRES	real	The resolution of the data values in the grid. The values are stored as integers. Multiplying by VRES converts these to the actual data values
NDIM	integer	Defines the number of data values at each grid node
LATLON	integer	Either 0 or 1. If this is 1, then the grid coordinate system is treated assumed to be in terms of longitude (X) and latitude (Y). This means that calculating grid values can accommodate 360 degree offsets in the X coordinate (eg -170 is treated as equivalent to 190). Also if the grid spans 360 degrees then the code can treat the grid as cylindrical, so that the eastmost column of the grid can be used to interpolate beyond the westmost edge of the grid.
VALUES	string	Either REAL or INTEGER. If it is REAL, then the data values in the text file are expressed as their actual values. If it is INTEGER then the data values are expressed as the integer values in which they are stored in the binary file.

Vn,m	string	Stores the data values at the column n and row m of the grid. The data values are entered separated by white space. They will be either integer or real values, depending upon the contents of the VALUES header. The values should be ordered as $V_{1,1}$ $V_{2,1}$ $V_{3,1}$ … $V_{XMAX,1}$ $V_{1,2}$ $V_{2,2}$ … $V_{XMAX,YMAX}$

An example of a text format grid file follows:

FORMAT: GRID1L
HEADER0: Grid converting NZD49 lat/long to NZGD2000 lat/long - built 22/11/1999
HEADER1: Input coordinates are NZGD49 lat/lon
HEADER2: Output coordinates are NZGD2000 with 7 parameter transformation applied.
CRDSYS: NZGD49
NGRDX: 141
NGRDY: 141
XMIN: 166
XMAX: 180
YMIN: -48
YMAX: -34
VRES: 2e-008
NDIM: 2
LATLON: 1
V1,1: 7.502e-005 -3.27e-005
V2,1: 7.452e-005 -3.188e-005
V3,1: 7.404e-005 -3.104e-005
V4,1: 7.354e-005 -3.022e-005
V5,1: 7.304e-005 -2.938e-005
...
...
V137,141: -0.00011994 1.222e-005
V138,141: -0.00012204 1.3e-005
V139,141: -0.00012414 1.378e-005
V140,141: -0.00012624 1.456e-005
V141,141: -0.00012834 1.534e-005

Error messages

Errors can occur at two stages in the program - firstly processing the command line options, and secondly in converting the data.

If errors are encountered processing the command line a message is printed and the program stops immediately. Generally the error message is fairly self explanatory.

Errors occurring while converting coordinates do not stop the program. An error message is written to the output file, and the program continues reading data from the input file. All error messages in the output file start with the string "****". The error messages that may occur in the output are

Error reading data

The data format is invalid.

Input coordinate range error

The input coordinates are not valid values for the circuit and units specified. This is a likely error if the order of the coordinates is specified incorrectly so that eastings and northings are confused..

Output coordinate range error

The input coordinates are outside the valid range of the output coordinate system.

Cannot calculate geoid height

The geoid height cannot be calculated for the height. This may be because the point is outside the extents of the geoid model supplied.

Copyright

Copyright for concord2 is held by Land Information New Zealand. The program was written by Chris Crook. The name of the program was invented by Gary Williams of the Institute of Geological and Nuclear Sciences.