The Design of National Standard on Global Position Grid Codes (GPGC) and its Applications

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Design of the national standard

- The principal of GPGC
- Design requirements
- Horizontal subdivision
- Height subdivision
- Grid encoding
The entire global space can be divided into continuous three-dimensional grids. Each grid can be assigned with a unique code. This code is called Geographic Position Grid Code (GPGC).

Besides the existing latitude/longitude system, GPGC gives another way to describe the global position with discrete gridding codes which can identify, represent and calculate the real earth space.

While latitude/longitude system is convenient for identifying, representing and calculating geospatial objects, GPGC is more effective in identification, representation and calculation of regions in space. Every object can be represented with grid attributes at a period of time.
Chinese government has been developing a national standard on GPGC which to be officially released in 2019. The following are the design requirements:

- The subdivision grids cover the complete Earth space without leaks or overlaps;
- Different level grids form a recursive hierarchical tiling structure;
- Each grid occupies a unique space;
- Each grid has a unique code;
- Grid code can be used to identify any three dimensional space;
- Grid codes shall be effective for indexing, calculating, and representing by computer;
- Grid codes can be directly converted to geodetic coordinates.
The Earth reference ellipsoid is based on the national standard CGCS2000;
In the three-dimensional space of the Earth, the spherical surface is divided according to the latitude and longitude coordinates defined by CGCS2000, and the elevation is divided in the direction of the geodetic height defined by CGCS2000.
Subdivision origin

The origin of global subdivision is set at the intersection of the earth reference ellipsoid, the first meridional plane and the equatorial plane (point O).
For the convenient of building hierarchical $2^{\text{nth}}$ coding structure, the initial space extension for subdivision is defined by extending latitude/longitude coordination.

The latitude coordinate is extended from $180^\circ$ to $512^\circ$, the longitude coordinate is extended from $360^\circ$ to $512^\circ$, and the height range is defined as between two virtual global surfaces at $-256^\circ$ and $256^\circ$. 
The horizontal subdivision is composed of 4 levels and 32 layers:

- The degree-level includes 10 layers (0\textsuperscript{th}-9\textsuperscript{th}) until 1°
- The minutes-level includes 6 layers (10\textsuperscript{th}-15\textsuperscript{th}) until 1'
  
  Each 1°×1° (60′×60′) grid space at the 9\textsuperscript{th} level is expanded into 64′×64′
- The second-level includes 6 layers (16\textsuperscript{th}-21\textsuperscript{st}) until 1"
  
  Each 1′×1′ (60″×60″) grid space at the 15\textsuperscript{th} level is expanded into a 64″×64″
- The subsecond-level includes 11 layers (22\textsuperscript{nd}-32\textsuperscript{nd})
Grid subdivision for Antarctic and Arctic areas

Since in polar areas the length of latitude lines shrink sharply. Grids for level > 8 in the 88°S-90°S Antarctic region and the 88°N-90°N Arctic areas are divided in a special way.

The 8th level grid in the Antarctic and Arctic areas

The 9th level grid in the Antarctic and Arctic areas
Direction of Height Dimension

There are multiple directions possible to expand the third dimension, such as: geodetic height, orthometric height, normal height, and geocentric connection. The direction perpendicular to the ellipsoid of the earth is selected in this standard as the direction of the height dimension.

The reason for choosing the direction of the geodetic height is because, in the design requirements, various users require that the geographical position grids (3D) can achieve consistent mapping relationship with the latitude/longitude grids on the ellipsoid of the earth by setting the height to zero. Other height systems are difficult to achieve this consistency, or need conversion.
Grid sizes at different heights

The granularity of grids in height domain should match the spherical domain direction, and should be consistent with the latitude of the equator on the corresponding level.

The granularity of the height domain of the nth grid in geographic position grids

\[ L_n = (1 + \theta_0)^n r_0 \theta_0 \]

\( \theta_0 \)—The geocentric angle of the grid, rad;
\( n \)—The nth 3D grid above (or below) the earth's surface. \( n \) is an integer; \( n \geq 0 \) indicates the grid is above the earth's surface, and \( n < 0 \) indicates the grid is below the earth's surface;
\( r_0 \)—The average radius of the earth is 6371008.77138 m, m;
\( L_n \)—The granularity (height) of the nth grid above (or below) the earth's surface, m.
extending into space based on the surface 1° grid

Corresponding to the 1° grid on the earth’s surface; there are 256 grids above and below the earth’s surface.
Grid encoding

三元组 $(C, T, A)$

编码 时刻 属性集 $A = \{A_1, A_2, A_3, \ldots\}$

mcode = 0 = 0^8 + 0
e = 1
V = 8
An example of the 10th level grids encoding in the Antarctic and Arctic areas
Grid position point and edge belonging
Application practices of GPGC

- Remote sensing
- Resource monitoring
- Digital earth
- Smart city
- Infrastructure management
- Route planning
Remote sensing
Remote sensing

区域 2016 年和2017 年 Planet 遥感影像图

网格遥感智能解译变化监测

网格遥感智能解译结果
Resource monitoring
Digital earth

- [Image of Digital Earth grid]

- [Detailed screenshot of Digital Earth interface]

- [Additional image of Digital Earth application]
地理位置网格编码规则

Digital earth
地理位置网格编码规则

Digital earth
Smart city
地理位置网格编码规则

数据列表

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东城区网格诊断与监控预警态势分析子系统

当前趋势

启动预测
地理位置网格编码规则

Infrastructure management

部件身份编码

井盖身份编码 电线杆身份编码 消防栓身份编码 建筑物身份编码
Infrastructure management
Infrastructure management
地理位置网格编码规则

Ruote planning
Route planning
Route planning
Route planning
Advantages of GPGC

- Compatible to earth surface mapping and remote sensing
- Hierarchical encoding as integer
- True three dimensional

Why not equal-area:
- Inclusion of quadrilateral subdivision models
- Matching maps and images
- Hierarchical structure for nested grids
- Extension to three dimensions (orthogonal in all directions)
Advantages of GPGC

与1:100万图幅严丝合缝
BNGC第1层网格

1:5万图幅可以用第4层BGC
表达内部网格

与气象图幅之间的关系

与海洋图幅之间的关系

与航空图幅之间
的关系
Thank you!