Envisioning a Tiled Elevation Extension for the OGC GeoPackage Encoding Standard

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i. Abstract
The GeoPackage Standards Working Group (SWG) presents a vision for storing tiled gridded elevation data in a GeoPackage.

ii. Keywords
The following are keywords to be used by search engines and document catalogues.
ogcdoc, OGC document, GeoPackage, elevation, tiles, TIFF

iii. Preface
The GeoPackage Standards Working Group (SWG) has identified a need for the ability to store tiled gridded elevation data in a GeoPackage. This document describes the vision and proposed approach, which is an extension to the OGC GeoPackage Encoding Standard. The SWG proposes to leverage the existing structure for raster tiles using TIFF files as the container for the elevation values themselves.

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iv. Submitting organizations
The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

Image Matters LLC

v. Submitters
All questions regarding this submission should be directed to the editor or the submitters:

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeff Yutzler</td>
<td>Image Matters LLC</td>
</tr>
</tbody>
</table>
1. **Scope**

The GeoPackage Standards Working Group (SWG) has identified a need for the ability to store tiled gridded elevation data in a GeoPackage. This capability will be used to support use cases such as the following:

- **Visualization**
  - 2D (hillshade, color relief, slope)
  - 3D (supporting changing view angles and level of detail)

- **Analysis**
  - Viewshed and line-of-sight
  - Cross-country mobility (off-road routing)
  - Site suitability and planning (slope analysis such as helicopter landing zones)
  - 3D geometry representations of features (ground-based, airspace)
  - Terrain association (associating images to mapped locations)
  - Augmented reality training

Ideally this capability will be relatively easy to implement and will be suitable for a wide variety of computing environments including the mobile/handheld computing environment.

This document describes the vision and proposed approach, which is an extension to the OGC GeoPackage Encoding Standard. The SWG proposes leveraging the existing structure for raster tiles using TIFF files as the container for the elevation values themselves.

We acknowledge that the proposed approach will not support certain applications that require a high degree of precision and/or accuracy (e.g., targeting).

2. **References**

2.1 **Normative References**

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

- OGC 12-128r10 OGC® GeoPackage Encoding Standard
  https://portal.opengeospatial.org/files/?artifact_id=56357

- TIFF

- The Unified Code for Units of Measure (UCUM)
  http://unitsofmeasure.org/ucum.html
2.2 Informative References
GeoTIFF Format Specification Revision 1.0
http://www.remotesensing.org/geotiff/spec/geotiffhome.html

3. Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

For the purposes of this document, the following additional terms and definitions apply.

viewshed\(^1\)
the geographical area that is visible from a location

4. Conventions

This sections provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

GPKG: GeoPackage. When followed by a number, this refers to a numbered requirement from the GeoPackage Encoding Standard.

5. Process

The SWG developed the tiled gridded approach through a series of private and public interactions between March and May 2015. The SWG email list and teleconferences were the primary means of discussion and decision making. All decisions were made by the SWG as per OGC policies and procedures. A number of votes were taken to ensure that there was consensus.

Note that the SWG members made a concerted effort to solicit and encourage public feedback. Individual decision points were opened up as issues on the GitHub repository\(^2\) and this led to feedback from a number of OGC and non-OGC members. Additional feedback was solicited through the 3D GeoPackage Working Group sponsored by U.S. 3D GeoPackage Working Group sponsored by U.S.

\(^1\) Wikipedia

\(^2\) See https://github.com/opengeospatial/geopackage/issues?q=is%3Aissue+milestone%3A%22Elevation+Extension%22
Army Geospatial Center. (This working group brought together representatives from a
number of U.S. Army programs with an interest in elevation data.) This public feedback
helped us identify good ideas and reach consensus.

6. Proposed Approach

The SWG proposes extending the existing GeoPackage Encoding Standard and to
leverage the existing structure for raster tiles. The existing tile set tables\(^3\) are used as
normal with the following changes:

- A new value of “2D-gridded-coverage” is allowed in the “data_type” column of
  the “gpkg_contents” table.
- Create a new table called “gpkg_2D_gridded_coverage_ancillary” as described in
  Table 1.
- Add new columns to tile set description tables as described in Table 2 (we foresee
  these columns being used in other extensions which also leverage the tiles
  approach). When used for elevation data the new columns have the following
  values:
  - content: “tiled-elevation”
  - ancillary_table: “gpkg_elevation_ancillary”
  - ancillary_key: (foreign key to row in gpkg_elevation_ancillary)
- Instead of JPEG or PNG files, elevation data is stored in TIFF files. These files
  are constrained as follows:
  - Either 16-bit signed integer or 32-bit floating point
  - One sample per pixel
  - LZW compression may be used
  - No subfiles or internal tiles
- Use ISO metadata (optional) to encode other details about the elevation data.

7. Next Steps

The SWG proposes the following next steps:

- Discuss this proposal in the broader community (outside the SWG itself) to reach
  a consensus on approach.
- Plan and perform interoperability experiments that allow implementers the
  opportunity to develop compliant software and demonstrate its interoperability
  (this could be as part of OWS 12 or in an independent interoperability experiment
  or plugfest)
- Document the extension as part of an updated version of the GeoPackage
  Encoding Standard or as a separate document

\(^3\) See sections 2.2.6, 2.2.7, and 2.2.8 of the GeoPackage Encoding Standard
8. Frequently Asked Questions

Q: What about GeoTIFF?

A: The SWG was just looking for a simple container to hold the elevation values. The geo-referencing is handled by the tile structure so GeoTIFF would have been redundant. TIFF is self-describing (a plus for many SWG members) but is otherwise a fairly simple format with broad API support (libtiff, etc.). Requiring GeoTIFF would have significantly increased the cost and complexity of the approach. This approach is also consistent with other OGC standards such as Web Map Tile Service (WMTS).

Q: What about supporting other types of coverages?

A: The SWG foresees this approach being used for other types of coverages (for example, in the weather domain). However, since elevation is the top priority, the SWG chose to focus on that single use case for now. Once the approach is proven, it should be easy to support other types of coverages as well.
Annex A  Proposed Extension Clauses

A.1  MIME Type

Req1 (extends GPKG 35, GPKG 36): A GeoPackage that contains a tile pyramid user data table MAY store tile_data in MIME type image/tiff. The content of the data table SHALL NOT be raster tiles as per the core specification and SHALL be described by an extension such as this one.

A.2  TIFF Encoding

Req2 (constrains TIFF Section 2): A TIFF file storing tiled gridded elevation data SHALL have one sample per pixel.

Req3 (constrains TIFF Section 2): A TIFF file storing tiled gridded elevation data SHALL have one of the following two data types: 16-bit signed integer (SSHORT – 8) OR 32-bit floating (FLOAT – 11).

Req4: A TIFF file storing tiled gridded elevation data MAY use the LZW compression option as per TIFF Section 13. Client applications SHALL support this option.

Req5 (constrains TIFF Section 2): A TIFF file storing tiled gridded elevation data SHALL NOT contain multiple images per TIFF file.

Req6 (constrains TIFF Section 15): A TIFF file storing tiled gridded elevation data SHALL NOT contain internal tiles as per TIFF Section 15.

A.3  Table Definitions

Req7: A GeoPackage that contains tiled gridded elevation data SHALL contain a gpkg_2D_gridded_coverage_ancillary table or view as per Table 1.

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
<th>Null</th>
<th>Default</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>INTEGER</td>
<td>Autoincrement primary key</td>
<td>no</td>
<td></td>
<td>PK</td>
</tr>
<tr>
<td>datatype</td>
<td>TEXT</td>
<td>'float' or 'integer'</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uom</td>
<td>TEXT</td>
<td>unit of measure, as per UCUM</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>scale</td>
<td>REAL</td>
<td></td>
<td>yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>offset</td>
<td>REAL</td>
<td></td>
<td>yes</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>precision</td>
<td>REAL</td>
<td></td>
<td>yes</td>
<td>if datatype is</td>
<td></td>
</tr>
</tbody>
</table>
**Req8** (extends GPKG 37): A GeoPackage that contains tiled gridded elevation data SHALL contain a gpkg_tile_matrix_set table or view as per Table 2.

*Table 2 – Updated Tile Matrix Set Table Definition*

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Type</th>
<th>Description</th>
<th>Null</th>
<th>Default</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>table_name</td>
<td>TEXT</td>
<td>As Per Table 8 in OGC 12-128r10</td>
<td>no</td>
<td></td>
<td>PK, FK</td>
</tr>
<tr>
<td>srs_id</td>
<td>INTEGER</td>
<td>As Per Table 8 in OGC 12-128r10</td>
<td>no</td>
<td></td>
<td>FK</td>
</tr>
<tr>
<td>min_x</td>
<td>DOUBLE</td>
<td>As Per Table 8 in OGC 12-128r10</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>max_y</td>
<td>DOUBLE</td>
<td>As Per Table 8 in OGC 12-128r10</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>content</td>
<td>TEXT</td>
<td></td>
<td>yes</td>
<td>tiles</td>
<td></td>
</tr>
<tr>
<td>ancillary_table</td>
<td>TEXT</td>
<td></td>
<td>yes</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>ancillary_id</td>
<td>INTEGER</td>
<td></td>
<td>yes</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

**A.4 Table Values**

**Req9** (extends GPKG34): The gpkg_contents table SHALL contain a row with a “data_type” column value of “2D-gridded-coverage” for each tile pyramid containing tiled gridded elevation data.

**Req10** (extends GPKG39): Values of the gpkg_tile_matrix_set table_name column SHALL reference values in the gpkg_contents table_name column for rows with a data_type of “2D-gridded-coverage”.
**Req11** (extends GPKG40): For each tile pyramid user data table containing tiled gridded elevation data, rows in the `gpkg_tile_matrix_set` table SHALL contain values as denoted in Table 3.

*Table 3 – Required Column Values in gpkg_tile_matrix_set*

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>content</td>
<td>tiled-elevation</td>
</tr>
<tr>
<td>ancillary_table</td>
<td><code>gpkg_2D_gridded_coverage_ancillary</code></td>
</tr>
</tbody>
</table>

**Req12**: For each row in the `gpkg_tile_matrix_set` table that references tiled gridded elevation data, the value of the `ancillary_id` column SHALL reference a value in the `gpkg_2D_gridded_coverage_ancillary id` column.