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GeoPackage as Future Ubiquitous GIS Data Format: A Review

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Graphical abstract

Abstract

The emerging geospatial technologies in earth and space science informatics have led to the advancement in developing international standards for geospatial interoperability. In the last few years, two main trends are making disruptions in geospatial applications; mobile and context sharing. Geospatial data format used in mobile GIS to support advance mobile application is challenged. This is due to the lack of interoperability, open-standard, cross platform and standard APIs for access and management. For instance, most mobile GIS developments are application-dependent, contains redundant geospatial data, consume large storage capacity, and require custom applications for data translation. Based on these issues, new OGC file format named GeoPackage will enable greater geospatial data sharing on mobile and web platform. This data format is an open standard, non-proprietary, platform-independent, container for distribution, and direct use of all kinds of geospatial data will increase cross-platform interoperability, geospatial applications and web services. This presents a comprehensive review of mobile GIS hence, the concept of GeoPackage as a modern geospatial tool was discussed, while its relevance in contemporary geospatial technology are highlighted.

Keywords: GeoPackage, ubiquitous; interoperability; mobile GIS; geospatial data

Abstrak

Kemunculan perkongsian teknologi geospatial bumi dan ruang informatik sains telah membawa kepada kemajuan dalam pembangunan piawaian antarabangsa, bagi data geospatial saling-beroperasi. Pada beberapa tahun yang lepas, dua trend utama yang menjadi perhatian dalam aplikasi geospatial ialah mobile dan perkongsian konteks. Format data spatial yang digunakan dalam mobile GIS sekarang menghadapi cabaran yang perlu diambil perhatian pelbagai pihak. Ianya disebabkan kekurangan dari segi antara-operasi, standard terbuka dan kebolehan untuk mengakses dan menguruskan data sptial secara langsung. Sebagai contoh kebanyakan mobile GIS bergantung kepada sistem operasi, mengandungi data spatial berlebihan dan memerlukan kepada pertukaran format untuk perkongsian data di antara aplikasi yang berbeza. Berdasarkan masalah ini, format baru OGC yang dipanggil GeoPackage akan membolehkan perkongsian data geospatial pada skala yang lebih besar. Dalam kajian ini, komprehensif menyeluruh tentang konsep GeoPackage sebagai format data geospatial yang moden dibincangkan, sementara kebergunaanya dalam teknologi geospatial diketengahkan.

Kata kunci: GeoPackage; antara-operasi; mobile GIS; data geospatial

■1.0 INTRODUCTION

Ubiquitous GIS is based on mobile computing technology environment, offers mobile and distributed geographic information services. It integrates geographic information system (GIS), global positioning system (GPS) and wireless communication. Mobile GIS is a comprehensive system that is not only limited to application of mobile computing but also an integration of space information applications that is based on various techniques involving geographic information systems, mobile positioning technology, embedded systems and wireless communication.[1] Due to this, mobile GIS have become a new hot spot following desktop GIS and web GIS.[2]

Because of increasing popularity of gadgets like smart phones and tablet PCs, mobile GIS has gone into an era of rapid development.[1] Applications of GIS in multi fields such as exploration, analysis of spatial data, car navigation and daily travel has led to rapid mobile GIS development.[3] A study reported that spatial query and spatial analysis is no longer necessarily limited to a fixed environment, it can now be accessed any time and any place.[4] Compared to desktop GIS, a mobile GIS can provide geographic information services as a portable platform to assist field-based data collection and management.[5] Recent study has highlighted the current rising trend in the need for mobile GIS which has grown into an enterprise-wide solution; starting with the old bulky computer to the present day handheld devices and interoperable data format.[6]

Currently mobile GIS are appearing at an increasingly rapid pace, such as in enhancements to unified critical communication suite,[7] leakage management systems,[8] real-time field survey using Android based,[9] communication network for disaster-damaged areas, [10] smart eco-path finder for mobile users,[11] and a time cost optimization for mobile GIS queries.[12] These patterns have introduced a paradigm shift in geographic information services towards the needs for ubiquitous GIS. Ubiquitous GIS provides information and geolocation data that can be disseminated and accessed anytime and anywhere. As a result, sharing geographic contents among users and public have become frequent and common. In order to facilitate these trends, interoperability of geospatial data is needed and has become a main concern.

This paper presents an overview of mobile GIS data format as a critical tool for geospatial solution therefore, the concept of GeoPackage as a future ubiquitous GIS data format is discussed while its benefits in contemporary geospatial technology are highlighted.

2.0 THE NEED FOR SEAMLESS GEOSPATIAL DATA FORMAT

At the moment, geospatial data format used in mobile GIS to support multifaceted mobile application is still a challenging task that need to be addressed.[13] This includes limitation of geospatial data sharing due to lack of interoperability, open-standard, cross platform and standard APIs for access and management. For instance, most mobile GIS development are application-specific, contains redundant geospatial data which consume large storage capacity, and require custom applications for data translation, replication, and synchronization.[13] Unavailability of mobile-friendly data format has caused mobile GIS developments[9-11] to tend to web based GIS architecture approach which is difficult to operates in limited network environment. Therefore a seamless and interoperable data format is needed to support the process of geographic information sharing, and to enable cross-platform geospatial desktop, web and mobile applications.[14]

The greatest limitations in the distribution of geographic information over Internet and wireless environments is the difficulty in handling large amounts of geospatial data.[4] While Min *et al.*,[15] had studied on the design of a complete, high efficient database based on embedded GIS in order to improve the data management ability in mobile platform., lack of robust spatial database in current mobile GIS would subject its edited spatial data to the dilemma of not being reliable because they may contain several topological errors.[16]

Consequently, many mobile GIS developments[17-26] are biased towards visualizing spatial contents based on map using available mapping APIs. A current research[27] has developed a mobile GIS application which extends to support spatial features editing in mobile platform. The research aims to develop a high flexible mobile GIS-based system for collecting arable land quality data. The developed system used Shapefile and XML as data exchange, which is known as a binary file format and platform-dependent, thus limited the ability to cross-platform and interoperable.

The other challenges in the development of cross-platform mobile GIS applications is the limitations in mobile hardware performance.[28] This is due to limitations in battery powers, display size, device's memory, storage capacity, and computing power.[3&29] Therefore, it is difficult to directly port a geospatial database into an embedded mobile devices,[30] and most of mobile GIS development are designed relatively straightforward server sides approach to avoid performance issues.[9] For this reason, in embedded systems, a new lightweight geospatial data structure or format is needed.[15]

Due to the gaps that have been addressed, OGC®[14] has introduced a new GIS data format called GeoPackage (*.gpkg) which was carefully designed to facilitate widespread adoption and use of a single simple file format by both commercial and open-source software applications-on enterprise production platforms as well as mobile hand-held devices. This data format is non-platform-specific like other current formats, thus increases the interoperability and geospatial data sharing. It is also lightweight and suitable for mobile-based application since mobile devices are limited in storage and processing speed. Therefore using suitable data format for ubiquitous GIS applications would improve the existing GIS services and applications.

3.0 MOBILE GIS – A DISTRIBUTED GIS

Mobile GIS as a fresh inter-cross research field integrating modern mobile computing techniques with geographic information science, has attracted more and more researchers in exploring and developing new practices in mobile GIS. It is built on the mobile terminal environments of limited capacity, providing moving, distributed and flexible mobile geographic information services. Specifically, mobile GIS is based on embedded GIS integration and comes with advanced GPS technology, mobile communication technology, wireless Internet technology in order to expand GIS application and improve the ability of spatial information collection, management and analysis.[31]

Further development of technology in related fields has led mobile GIS to expand its application areas in various disciplines. Leaders in GIS industry are actively involved in research of mobile GIS and have launched related products on data collection and public services. The world's leading GIS vendors such as ESRI, MapInfo, Autodesk, Intergraph and other companies have launched their own Mobile GIS platform.[32] Table 1 shows current needs in mobile GIS developments.

Table 1 The current required elements for a distributed GIS application and services

any data	Interoperability between proprietary GIS data sources (Smallworld, ESRI, SpatialNET, Open Spatial, etc.).
any server	In-house or cloud hosting.
any client	iOS, Android, Windows 8 native apps.
anyone	From public to professional users.
anytime	On- or off-line availability often called 'sometimes connected' mode.

Several GIS vendors have developed some PPC (Pocket PC) based mobile GIS software which is viewed as one part of their GIS product. For example ESRI ArcPad mobile application is suitable to use for map navigation, basic attribute querying and basic field surveying, etc.[33] However, constrained by the hardware limitation and lacking of robust spatial database support in Mobile GIS, the vendors argue that the spatial data edited in their mobile GIS application must be checked in to their desktop GIS platform in order to correct the implied errors.[16]

On the other hand, Chen *et al.*,[32] developed a Geological Data Acquisition System Based on Mobile GIS and uses MapX Mobile (an OLE-based Embedded GIS component), which provides a simple and rapid method to embed map into applications of handheld applications. The system used MapInfo table (.tab) as mobile GIS data format which stores in the mobile device. The data format is not an interoperability data, thus it led to the application and platform dependent and limit the process of data sharing. Many acquisition environments are sparsely populated areas where there is poor and even no mobile communication network signal. Issue on how collected data can be sent to the data warehouse via the wireless network in real time is also a major concern.[34]

4.0 EXISTING MOBILE GIS ARCHITECTURE

Constrained by hardware limitation and considering the mobile computing environment characteristics, the architecture of mobile GIS is different from traditional GIS. There are several architecture approaches of mobile GIS due to varied application domains.[35-37]

Figure 1 presents the web GIS based integration approach of mobile GIS architecture which utilizes web GIS engine as its data source. It is noticeable that this approach is much more suitable for a navigation application.[16] However, this technique is not suitable for editing, inserting, or deleting spatial feature like operations because these would exhaust the web GIS server much more than common spatial query, because editing in mobile GIS would require tighter interaction with web GIS server and cost great communication. Besides, it would introduce great challenges of building robust web GIS engine to support concurrent multi mobile GIS users editing requirements.

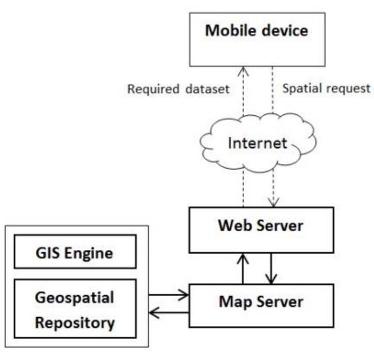

Figure 1 Web GIS based integration approach of mobile GIS

Another mobile GIS approach is desktop GIS integration, which mobile GIS is viewed as a sub-unit of desktop GIS. Figure 2 shows the interaction process between mobile GIS and desktop GIS. Mobile GIS application checkout its desired spatial dataset from the desktop GIS, desktop GIS will mark this dataset, and then mobile GIS user can modify the dataset in field work. When finished editing, the checked out dataset must be checked in into the desktop GIS so that the modified dataset can be post-processed to correct the implied errors and maintain the topological integrity of the all datasets. Though this method fulfills the editing requirements of mobile GIS by using the check in and checkout method, apparently, it introduces the spatio-temporal inconsistency issue. When mobile GIS users check in their datasets, the desktop GIS operator has no knowledge of the actual situations which these modified datasets confronted with, which inevitably would lead data processing improbability.[16]

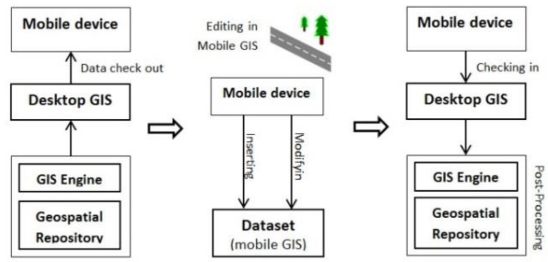

Figure 2 Desktop GIS integration approach of mobile GIS

Figure 3 describes the lightweight SDE integration approach of mobile GIS architecture which grants mobile GIS applications desktop GIS like ability.[16] Fetching their desired datasets from desktop GIS, editing these datasets in the field, importing these edited datasets into desktop GIS repository, it is no necessary for desktop GIS to handle burdened post-process tasks because the lightweight SDE can assure the quality of the modified datasets.

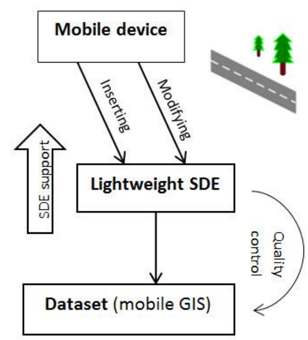

Figure 3 Lightweight SDE integration approach of mobile GIS

5.0 DRAWBACK OF EXISTING MOBILE GIS

Some mobile GIS are only support for viewing and overlaying of geospatial contents, some of them are able to perform basic functions of GIS such as simple analysis, query, editing and updating. Many of these developed applications are limited to the problems in mobile terminal data storage and hardware performance. Currently there are several types of mobile GIS architecture being use to deploy field-capability GIS systems which are web GIS, desktop GIS and lightweight SDE integrations as discussed in previous sub-Section. For Web-like integration, the drawback in this technique is that it is not suitable for editing, inserting, or deleting spatial feature like operations because these would exhaust the web GIS server.

While for desktop-like integration, user need to fetch the desire dataset from server/desktop to mobile device, then all editing and inserting new record will be in the dataset. This dataset will then be appended to the real database at office. For lightweight SDE integration, this technique is almost the same as Desktop-like but much better because it removes the burdened post-process tasks at office because the lightweight SDE can assure the quality of the modified datasets.

In view of this, the desktop-like/lightweight SDE integration for mobile GIS is better than the web-like integration (for complex application) because all processes are done on the client-side and not the server-side. This will allow the application to operates in offline mode (limited network) because all operations are done in the mobile device. When doing editing, inserting, querying, updating or deleting spatial feature-like operations in mobile GIS application, a suitable data format for mobile applications is required. These call for the introduction of new geospatial data format named GeoPackage by OGC.

■6.0 GEOPACKAGE, THE FORMAT OF THE FUTURE

GeoPackage is an open, standards-based, application and platform independent, and self-describing file format on SQLite.[38] It uses a SQLite database schema to maintain data model integrity. This format was designed this way to facilitate widespread adoption and use of a single file format by both commercial and open-source software applications. In addition, many existing geospatial data format are platform- specific, which means that users with different platforms must translate the data in order to share it. Nevertheless GeoPackage is built upon SQLite, and can therefore be used easily by a broad spectrum of software in a consistent way on every major mobile and desktop platform in the market. Adding GeoPackage support to an app can be done by any SQL-savvy programmer. Figure 4 shows the concept of multi-platform data format which can be used by cross-platform mobile GIS applications.

Figure 4 Concept of multi-platform data format[13]

There are some advantages of using this geospatial data format. For instance, the ubiquitous mobile mapping application can be operated in disconnected and/or limited network connectivity environment if this data is implemented as internal database. Furthermore, this format is lightweight and suitable for mobile-based application. Therefore, the use of GeoPackage for mobile GIS application will enable users to share their data across-platform, without need to copy the same dataset for different format, thus wasting storage available; or require custom application for data translation. This will increase cross-platform interoperability of geospatial applications. Moreover, using GeoPackage in mobile application will allows users to consistently query and update results, since the format has standard APIs for access and management.

6.1 How GeoPackage Improves Mobile GIS

In the last few years two main trends are making disruptions in geospatial applications which are mobile and context sharing. People now have their own mobile devices to support their work and daily life. Mobile devices are intermittently connected to the internet and have smaller computing capacity than a desktop computer. Based on this trend a new OGC file format standard called GeoPackage will enable greater geospatial data sharing on mobile devices.[39]

Traditional mobile GIS application required uses of various data types (raster and vector), this is to keep the data in individual data format. This will cause limitation in storage capacity and device performance. Furthermore most traditional mobile GIS cannot operates in both environments (online and offline), GIS developers need to choose whether to go for online (web-like) or offline (desktop-like). Through GeoPackage implementation, online and offline are possible to be achieved. For example Adams *et al.*, [40] have studied on the integration of geospatial map-centric on mobile embedded system purposely for emergency supports to increased situational awareness. The system integrates with geospatial data to provide location awareness. They stated their support on the OGC GeoPackage standardization effort, because this data format will improve the existing system since the system is used to deploy and store critical data.

GeoPackage may also be implemented for web-like operation in mobile GIS in order to improve the functionality and capability of an application. As Masó *et al.*, [41] have studied about Geospatial Web Services and GIS applications and reported that by using GeoPackage, all geospatial data can be encapsulated into a single file format, thus can be used for multipurpose. GeoPackage can also make web GIS application to possibly operate in offline mode when access to Internet is limited. This data format has shown greats potential to improve in the way of the current mobile and web GIS deployment and implementation.

6.2 Current Status and Development

There is an initial charter of the Standards Working Group (SWG) for the GeoPackage with the purpose to produce a version 1.0.0 implementation standard (Figure 5). This SWG is focused on defining and documenting a new OGC GeoPackage candidate standard based on the specific contributions of existing work as a starting point.[14] GeoPackage data format is a RDBMS container, is desired to manage (create, update, delete as well as search and retrieve) both geospatial foundation data for multiple types of features, and newly collected feature observation data. Initial support for this data format is the basic simple feature geometry types – Geometry, Point, LineString, LinearRing, Polygon, GeometryCollection, MultiPoint, MultiLineString, and MultiPolygon. Subsequent GPKG specification versions may require support for Curves with non-linear interpolation, Surfaces, MultiCurves, MultiSurfaces, Polyhedral Surfaces, TINs, and Full 3D.[38]

Currently there are few software and libraries that support GeoPackage for viewing. One of them is Luciad, which has developed a viewer for Android that enables visualization of data following the OGC GeoPackage standard. The viewer is currently available free of charge. Luciad also develop a small C library that allows developers to easily read/write GeoPackage compliant SQLite files and making this library available to the entire community as an open-source library. The library only depends on SQLite. The Geospatial Data Abstraction Library (GDAL) also contributes to building support for GeoPackage by developing library to support GeoPackage implementation. Below are current GeoPackage standards for SQL functions and metadata tables:

a) GeoPackage standard functions
   i. Minimal available functions
      ST_SRID, ST_GeometryType, GPKG_IsAssignable, ST_Is3D, ST_IsMeasured, ST_MinX, ST_MaX, ST_MaxZ, ST_MaxM
   ii. Geometry access
      ST_GeomFromText, ST_AsText, ST_AsBinary, ST_AsGML
   iii. Queries and operations
      ST_Intersects, ST_Contains, ST_Touches, ST_Buffer, ST_Intersection, ST_Union,

ST_LocateAlong, ST_LocateBetween

b) Spatial SQL example

SELECT t2.Name, t2.Peoples,
ST_Distance(t1.geom, t2.geom) **AS** Distance
FROM Town **AS** t1, Towns **AS** t2
WHERE t1.Name = 'Hamid' **AND**
ST_Distance(t1.geom, t2.geom) < 10000;

c) Metadata

i. gpkg_contents: list of geospatial contents
ii. gpkg_data_columns: descriptive information about columns in user vector feature and tile matrix data tables
iii. gpkg_geometry_columns: vector data
iv. gpkg_tile_matrix_metadata: raster data
v. gpkg_spatial_ref_sys: coordinate reference system definitions
vi. gpkg_metadata: XML metadata
vii. gpkg_metadata_reference: row level metadata

d) Metadata (extensions)

i. gpkg_contents: list of geospatial contents
ii. gpkg_data_columns: descriptive information about columns in user vector feature and tile matrix data tables
iii. gpkg_geometry_columns: vector data
iv. gpkg_tile_matrix_metadata: raster data

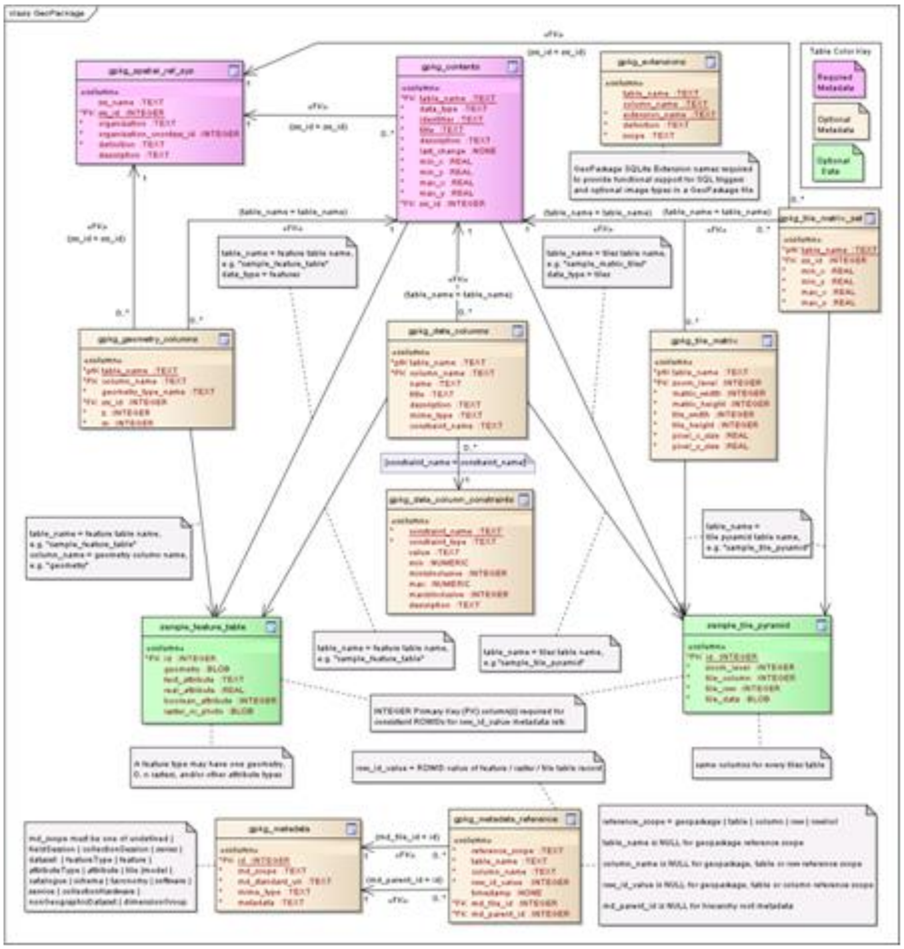

Figure 5 GeoPackage implementation standard (tables details)[38]

7.0 CONCLUSION

In conclusion, the new OGC file format named GeoPackage will enable greater geospatial data sharing due to its ability to fulfill the current needs in ubiquitous GIS development (mobile or web). A more modern lingua franca for geospatial data has now been fulfilled. GeoPackage fills these needs with support for vector data, image tile matrices, and raster data. And is built upon a database container - SQLite - that's self-contained, single-file, lightweight, cross-platform, serverless, transactional, and open source. Hardware limitation in mobile platform is no longer the main problem in mobile GIS development.

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