SERVING FEATURE-BASED TOPOGRAPHIC MAPS FOR FACILITATING CROSS-DOMAIN APPLICATIONS IN SDI

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Abstract

The development of domain applications often requires a tremendous volume and a wide variety of data from different resources. A well-developed Spatial Data Infrastructure (SDI) can successfully meet such sharing demands. To spatially enabling the use of domain data, we argue topographic maps can play an active role in the SDI and should be aggressively shared with all participants to reduce unnecessary and duplicated investments, and improve the quality and consistency of the cross-domain applications. This paper presents a feature-based service mechanism, such that users from other domains can take full advantages of the high-quality topographic map data in their applications. The distributed topographic features are designed following a standardized and self-describe principle, such that users can acquire fundamental information, as well as correctly interpret auxiliary information, e.g., semantics, technical specification and data quality, for further operation references. As topographic map data includes a large volume of continuously updated data depicting the phenomena in the real world, this mechanism offers a sustainable foundation for bridging the supply-and-demand communication between participating domains and in the meantime establish a solid and common spatial reference for the NSDI.

Keywords: topographic map, feature, SDI, cross-domain

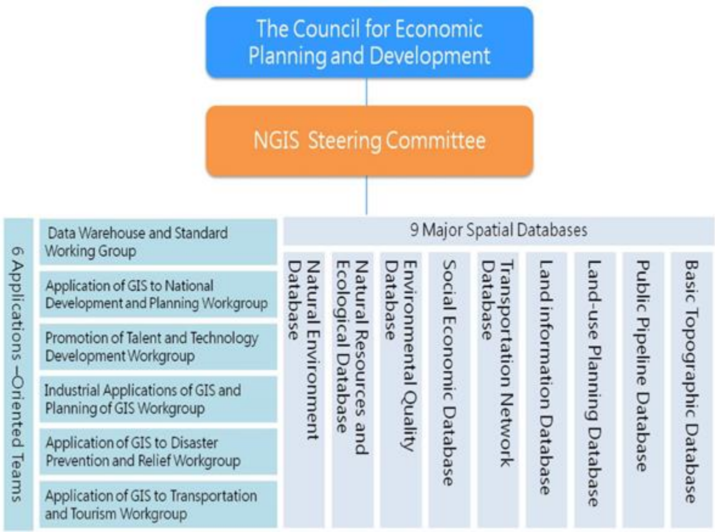
INTRODUCTION

In recent years, web-based service has become a major technology trend in the SDI to facilitate the sharing of data, geo-referenced or not, across the internet. The successful development of domain applications often requires a tremendous volume and a wide variety of data from different resources. Due to the complexity and heterogeneity nature of the shared data, the interoperability problem among sources from different domains is a key challenge for the SDI to conquer. Spatially enabled data adds a brand new viewpoint to the description of the phenomena in the real world. For example, the mapping ability offers the possibility of visualizing and analyzing the locational relationships of acquired data, which often cannot be well presented by text-based data. Unfortunately, domain users normally have limited or even no knowledge about how the acquired geospatial data is collected and produced. As a result, the data selected for specific applications may contain all kinds of uncertainty and inconsistency that may endanger the quality of the decisions. SDI offers an obvious advantage for making the sharing of georesources easier, but the correct integration of data from different resources certainly demands a more comprehensive approach to enable the cross-domain data exchange and the interactions on a common and reliable spatial reference basis.

Following rigorously designed technical specifications, topographic maps are well known as an effective medium for visually presenting spatial phenomena in the real world. The content of many famous web-based electronic map services nowadays are based on the nation-level topographic maps (TGOS, 2016; NLSC, 2010; OS, 2016). In addition to this visual reference map role, current digital topographic maps are composed of a selected set of well-defined feature classes designed according to individual types of objects in the real world (MOI, 2014). Maintained by professional survey agencies, government topographic maps are special products that provide superior characteristics of both nation-coverage and fixed level of data quality. This implies features extracted from topographic maps are excellent sources for sharing with other agencies to spatially enable their representation, as long as a bridging relationship can be correctly and successfully established. For doing so, we propose a self-describe feature framework in this paper, where the design of distributed topographic features consists of well-informed description about their unique identifier, location, theme code, time, data quality and links to the technical specifications. As every distributed feature can hence describe itself, agencies from other domains can easily add or link their domain-specific information to the distributed topographic features via common identifier and spatially enable their data in an interoperable fashion. Because the content of topographic maps are consistently geo-referenced to the nation coordinate systems, the above approach also makes the spatial integration of data from different domains much easier. Furthermore, because government topographic maps are updated with a fixed frequency, the temporality of features can be also well handled. After all domains can take full advantages of the continuously updated topographic features, the duplicated cost for surveying projects in other domains can be largely reduced.

One merit of the SDI is the cross-domain collaboration that links all participants via partnerships (Nebert, 2004). In Taiwan, the government agencies are collaboratively working under the umbrella of the National Geographic Information System (NGIS). Figure 1 shows the collaborative framework for the NGIS in Taiwan, with 9 major spatial databases responsible of continuously providing particular themes of data and 6 applications-oriented teams dedicating to the development of applications for emerging issues. This matrix-like architecture implies a tremendous volume of data sharing may happen between different agencies, and a standard-based sharing mechanism is definitely necessary. Altogether 27 data standards following standards of the ISO/TC211 and OGC have been developed and published in the last 10 years to facilitate the development of an open and interoperable sharing environment (NGIS standardization homepage). Being as one of the 9 major spatial databases, the "Basic Topographic Database" is responsible of providing different types of topographic map products for other agencies' operation reference (MOI).

Figure 1: NSDI collaborative framework in Taiwan



We argue the data in SDI can be spatially enabled via existing topographic features and integrated with respect to a consistent spatial reference framework. This can improve the quality of the decision making, as well as reduce the cost of data production, both deemed as important and ultimate goals of the SDI. In the remaining of this paper, section 2 introduces the essential characteristics of topographic map data, followed by section 3 introduces the basic framework of the self-describe topographic feature. Section 4 uses examples to demonstrate the interoperable use of topographic features. Finally, section 4 concludes our major findings.

ROLES AND CHARACTERISTICS OF TOPOGRAPHIC MAPS

Topographic maps are considered as one of the core data in NSDI. In Taiwan, various scales of digital topographic map products were developed to address different needs. While 1/5000 topographic maps are widely used, major cities produce 1/1000 topographic maps for urban planning purpose. In recent years, the National Land Surveying and Mapping Center (NLSC) produced a simplified version of topographic maps, the Taiwan Electronic Map (Taiwan e-Map), to aid GIS needs. The basic characteristics of topographic maps are summarized below：

1. Nation spatial coverage: Except large-scale maps, all other scales of topographic maps provide national spatial coverage. This implies the national topographic map database can provide information for any region of interests.
2. Digital representation: All topographic maps are in digital format ready for direct use in GIS software. Data of both raster (images-based) and vector (feature-based) models are provided.
3. Theme classification framework: Every feature in the topographic maps has explicitly defined semantics. The Ministry of Interior published the "Topographic Data Classification framework (TDCF)" to provide a common reference to all the topographic map products. The selected themes are organized in a hierarchical architecture and given unique names and topographic codes. With the unambiguous text definition, users can correctly establish an understanding about any acquired topographic features. The comparison of semantics is also made possible with the common classification framework
4. Technical specification：All topographic maps are produced following professional surveying specifications. The specifications provide explicit surveying guidelines and procedure to ensure the quality of the map products. Users must carefully select appropriate map products according to their needs.
5. Data quality: Following the specifications, standardized data quality information of both datasets and features is recorded in the metadata for uses' operation reference. The TaiWan Spatial Metadata Profile (TWSMP) was designed for describing all the resources in the NGIS.
6. Update frequency: Topographic maps are maintained with the budgets available. The update frequency may be quite different.
7. Spatial reference：Topographic maps in Taiwan are geo-referenced to the nation coordinate reference system of TWD97/TM2. Additional map products geo-referenced to other CRSs are also available via coordinate transformation

8. Services: The Taiwan e-Map is accessible as a WMTS map tile service and an OPEN DATA (offline map tiles). Feature-based services are expected in the coming years.

FEATURE-BASED SHARING AND APPLICATION MECHANISM

In the past, topographic maps are mainly used as reference maps, where domain users overlay data onto the topographic maps to examine the neighboring phenomena of their features of interest. As this approach is purely for visualization purpose, users can only choose to believe the selected domain data matches well with what is illustrated in the topographic maps. Since the topographic features are precisely defined and surveyed following map specifications, using them as the basis of creating domain data can surely redude production cost and build a better consistency relationship with the topographic maps. We propose a feature-based approach for topographic maps, where all the fundamental and auxiliary information about a specific type of topographic feature is included in its schema design. When describing a particular object in the real world, domain users can therefore link their own attributes data to the corresponding topographic features to spatially enable the domain data, which can obviously perfectly match with the topographic maps. In addition, various domain data designed following this standardized procedure can also work together pretty well because they are referenced to the same source.

To make the topographic features self-describe, Figure 2 shows the design of UML-based standardized framework. Using the inheritance archiecture, the design of each topographic features consists of a set of well-informed descriptions about the the unique identifier, theme code, time, and URL links to the information of data quality, class definitions and survey procedures. Distributed on the basis of individual features, agencies from other domains can thus easily add or link their domain-specific information to the distributed topographic features on an individual feature basis (e.g., via the same feature identifier). As topographic maps are usually updated with a fixed time frequency, this approach further adds temporal aspects to the shared data and avoid wrong uses of data. Figure 3 shows the encoding archiecture, where all resources, data or specifications, are all web-based and easily accessible.

Figure 2: Conceptual Schema Design of Self-Describe Feature

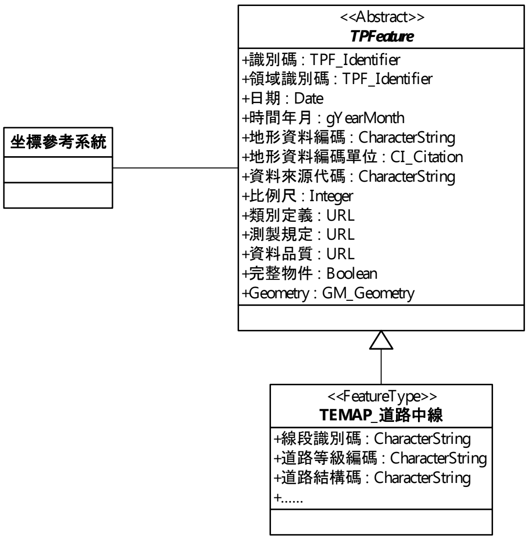
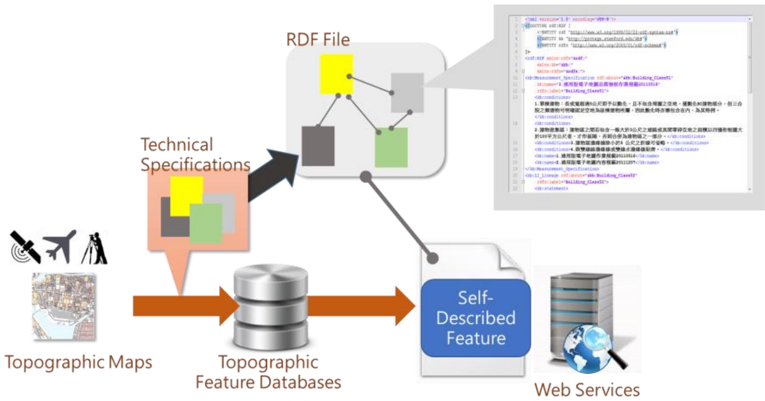


Figure 3: Self-describe Feature Encoding architecture

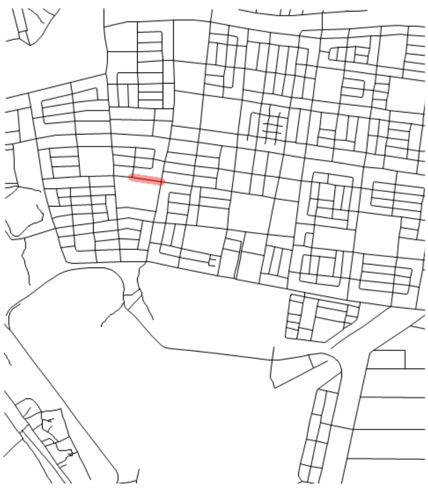


TEST ANALYSIS

Figure 4 shows the example of the self-described features of Road class from the Taiwan e-Map. The highlighted feature in the map has the identifier “NLSC-9420600-D0000000001”. The right side of figure 4 shows the attributes of this selected feature, including the unique identifier (NLSC-9420600-D0000000001), theme code (9420600), time (2015-05), spatial reference (EPSG:3826), TDCF link (http://140.116.47.115/schema/temap/category.xml), road level code (9420600), county name (臺南市), town name (安平區), road structure code (0), road name

(郡平路), road width (18), road segment node_from (D0007550), road segment node_to (D0007554) and URL links to the information of data quality (http://140.116.47.115/schema/temap/dataquality.xml), class definition (http://140.116.47.115/schema/temap/class.xml) and surveying procedures (http://140.116.47.115/schema/temap/surveyrule.xml) for this particular feature class. Users can thus easily build a complete understanding about the acquired topographic feature and determine how to use it in their applications (e.g., the positional accuracy or the meaning of the class). This feature can then be transferred to the GML format for distribution. The example of GML format was shown in figure 5.

Figure 4: Self-described Features of Road Data



Selected

TEMAP_道路中線_id	f206
TEMAP_道路中線_識別碼	NLSC-9420600-D0000000001
TEMAP_道路中線_坐標參考系統_坐標	EPSG:3826
資料分類架構_href	http://140.116.47.115/schema/temap/category.xml
TEMAP_道路中線_資料分類架構	
TEMAP_道路中線_線段識別碼	
TEMAP_道路中線_道路等級編碼	9420600
TEMAP_道路中線_縣市名稱	臺南市
TEMAP_道路中線_鄉鎮名稱	安平區
TEMAP_道路中線_道路結構碼	0
TEMAP_道路中線_道路名稱	郡平路
TEMAP_道路中線_路寬	18
TEMAP_道路中線_起節點識別碼	D0007550
TEMAP_道路中線_訖節點識別碼	D0007554
TEMAP_道路中線_時間	2015-05
TEMAP_道路中線_地形資料分類編碼	9420600
資料品質_href	http://140.116.47.115/schema/temap/dataquality.xml
TEMAP_道路中線_資料品質	
測製規定_href	http://140.116.47.115/schema/temap/surveyingrules.xm
TEMAP_道路中線_測製規定	
類別定義_href	http://140.116.47.115/schema/temap/class.xml
TEMAP_道路中線_類別定義	
TEMAP_道路中線_完整物件	1

Attributes Stats

Figure 5: GML Encoding Example of a Distributed Road Feature

```
<gml:featureMember>
  <TEMAP_道路中線 gml:id="f206">
  <tpfeature:識別碼>NLSC-9420600-D0000000001</tpfeature:識別碼>
  <tpfeature:時間>2015-05</tpfeature:時間>
  <tpfeature:地形資料分類編碼>9420600</tpfeature:地形資料分類編碼>
  <tpfeature:資料品質
xlink:href="http://140.116.47.115/schema/temap/dataquality.xml" />
  <tpfeature:測製規定
xlink:href="http://140.116.47.115/schema/temap/surveyingrules.xml"/>
```

```xml
   <tpfeature:類別定義
xlink:href="http://140.116.47.115/schema/temap/class.xml" />
   <tpfeature:完整物件>1</tpfeature:完整物件>
   <tpfeature:坐標參考系統>
      <tpfeature:坐標參考系統>
        <gmd:RS_Identifier>
          <gmd:code>
            <gco:CharacterString>EPSG:3826</gco:CharacterString>
          </gmd:code>
        </gmd:RS_Identifier>
      </tpfeature:坐標參考系統>
    </tpfeature:坐標參考系統>
    <tpfeature:資料分類架構
xlink:href="http://140.116.47.115/schema/temap/category.xml" />
     <Geometry>
       <gml:LineString>
         <gml:coordinates>164417.329999999,2543364.92
164585.620000001,2543338.42 </gml:coordinates>
       </gml:LineString>
     </Geometry>
     <線段識別碼></線段識別碼>
     <道路等級編碼>94213</道路等級編碼>
     <縣市名稱>臺南市</縣市名稱>
     <鄉鎮名稱>安平區</鄉鎮名稱>
     <道路結構碼>0</道路結構碼>
     <道路名稱>郡平路</道路名稱>
     <路寬>18</路寬>
     <起節點識別碼>D0007550</起節點識別碼>
     <訖節點識別碼>D0007554</訖節點識別碼>
   </TEMAP_道路中線>
  </gml:featureMember>
```


Assume an agency wants to establish a traffic flow data, all it needs to do is to associate the surveyed traffic flow data of this particular road segment with the above feature and immediately make the data mappable and GIS operable. Note the other themes of topographic features can be associated with other domains in a similar way, so this approach actually enables the integration of cross-domain data on a common spatial reference. The more self-described features the topographic maps can provide, the more potential it can offer to link different domains of data in the SDI.

CONCLUSION

Developing a solid and common foundation of geospatial reference to the data distributed and used in the SDI is very important. Due to the lack of consensus data design strategies and professional positioning technologies, data produced by different agencies may implicitly or explicitly includes heterogeneity and interoperability problems. Based on the nation-level topographic maps, this paper proposed a feature-based and self-describe framework to facilitate the spatial enablement of data and the development of add-value applications in the SDI. The standardized framework design allows users to establish a coherent and unambiguous understanding about the distributed topographic feature, even if it is only distributed on a single feature basis. As topographic map are continuously updated by professional survey agencies and served via web-based standardized framework, domain users can build their data based on the consistent and high-quality topographic feature for interoperable use. Topographic maps hence play a key role for serving a consistent geospatial reference to the applications. Following our analysis, the survey agencies must be fully aware of their new roles and responsibility in the future SDI and dedicate in developing new strategies to continuously improve their services.

6. REFERENCES

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