# Experience in Building GML-based Interoperable Geo-spatial Systems

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Abstract:
We report our experience in using GML for integrating heterogeneous geo-spatial datasets in building an experimental geographic information system (GIS). A GML application schema is developed to serve as an application profile that includes 1:1000 scale topographic maps, urban land-use zoning maps, and digital terrain models (DTM). In addition to using and modifying open source data conversion tools to transfer dgn-, shp-, and grd-formatted datasets to GML-coded documents, we have also developed our own query tools to retrieve collections of geo-spatial features from large GML documents. The retrieved collection of GML-coded geo-spatial features is rendered to SVG at the server-side and sent to the client-side for visual presentation and navigation.

Keywords:
Geo-spatial Data Processing, GML, SVG, Web-based GIS.

# 1. Introduction

Geographic Information Systems (GIS) are widely used in government and municipality institutions, resulting in massive increase in the amount of geo-spatial information that is available to the citizens (Stoimenov et al., 2005). This paper describes our experience in using GML as a basis for the integration and presentation of heterogeneous geo-spatial data sources in a municipal setting. This is part of a pilot project conducted with the help and sponsorship of the Taipei City Government. This pilot project aims to assess the feasibility, and to understand the related issues, of introducing Open GIS principles and techniques to an existing municipal GIS environment.

Currently there are many geo-spatial data sources and applications that have been created by various agencies and departments in the Taipei City Government, as shown in Figure 1. However, data sharing and exchange continue to be a challenge. In order to provide citizens with more geo-spatial services, the Taipei City Government has developed several Web-based geo-spatial information servers that integrate various geo-spatial data sources and systems, see Figure 2. However, setting up these geo-spatial information servers, as argued by Devogele et al. (1998), demands a lot of programming and management efforts in the acquisition, integration, and presentation of various geo-spatial datasets. Often the effort is spent in splitting the services into pieces, so that each piece is tailored to access a single dataset and to pass the retrieved data in an appropriate format to the main application which then performs global data processing and synthesis. Alternatively, the data of interest can be extracted from their sources, converted through ad-hoc routines, and is moved into a new database. The new database is then made available to the main applications, such as the Taipei

Storm Sewer GIS shown as Figure 3. As geo-spatial data sharing and exchange within a municipal environment has been recognized as a labor-intensive and problematic issue, new approaches based on GML and SVG are bieng explored by others and us to address this challenge.

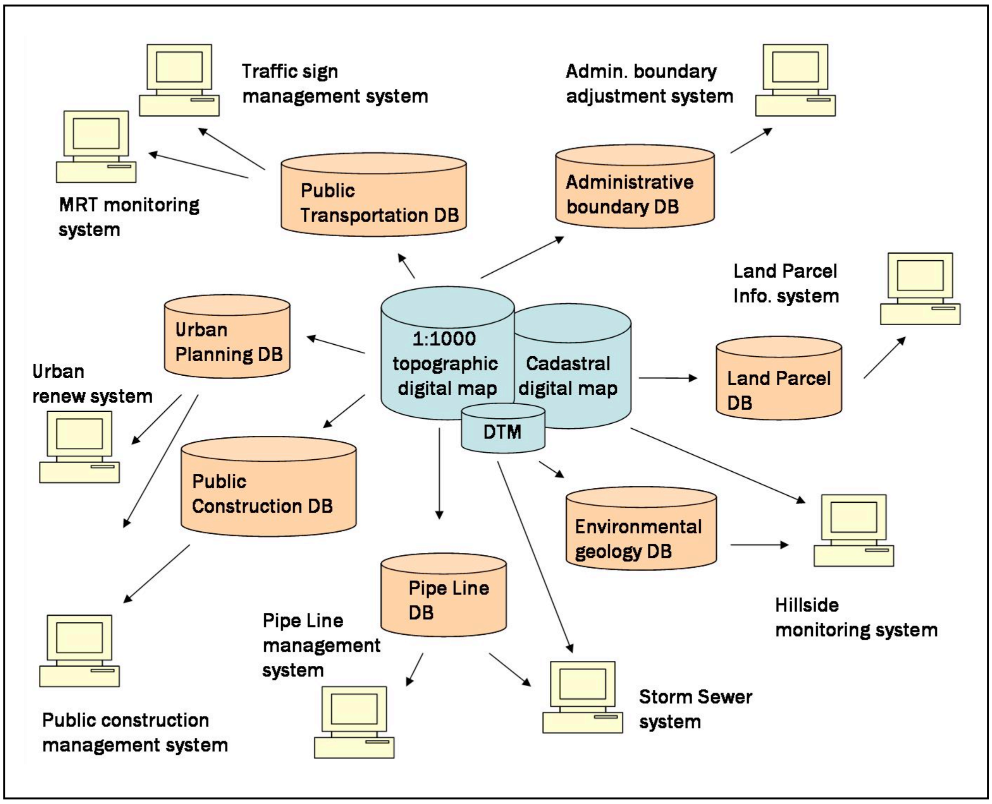


Figure 1. Exemplar geo-spatial datasets and services currently deployed within the Taipei City Government.

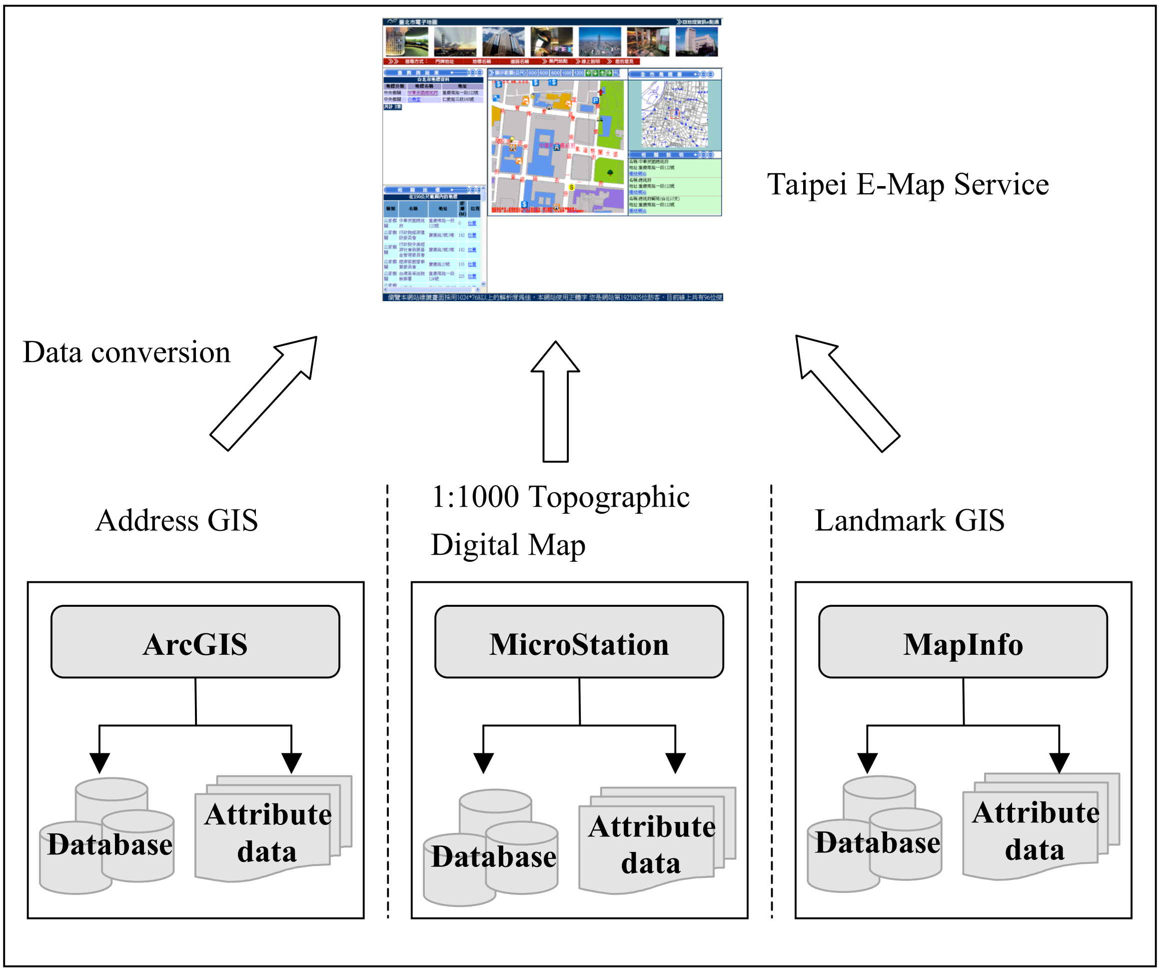


Figure 2. The Taipei E-Map service uses disparate data sources and

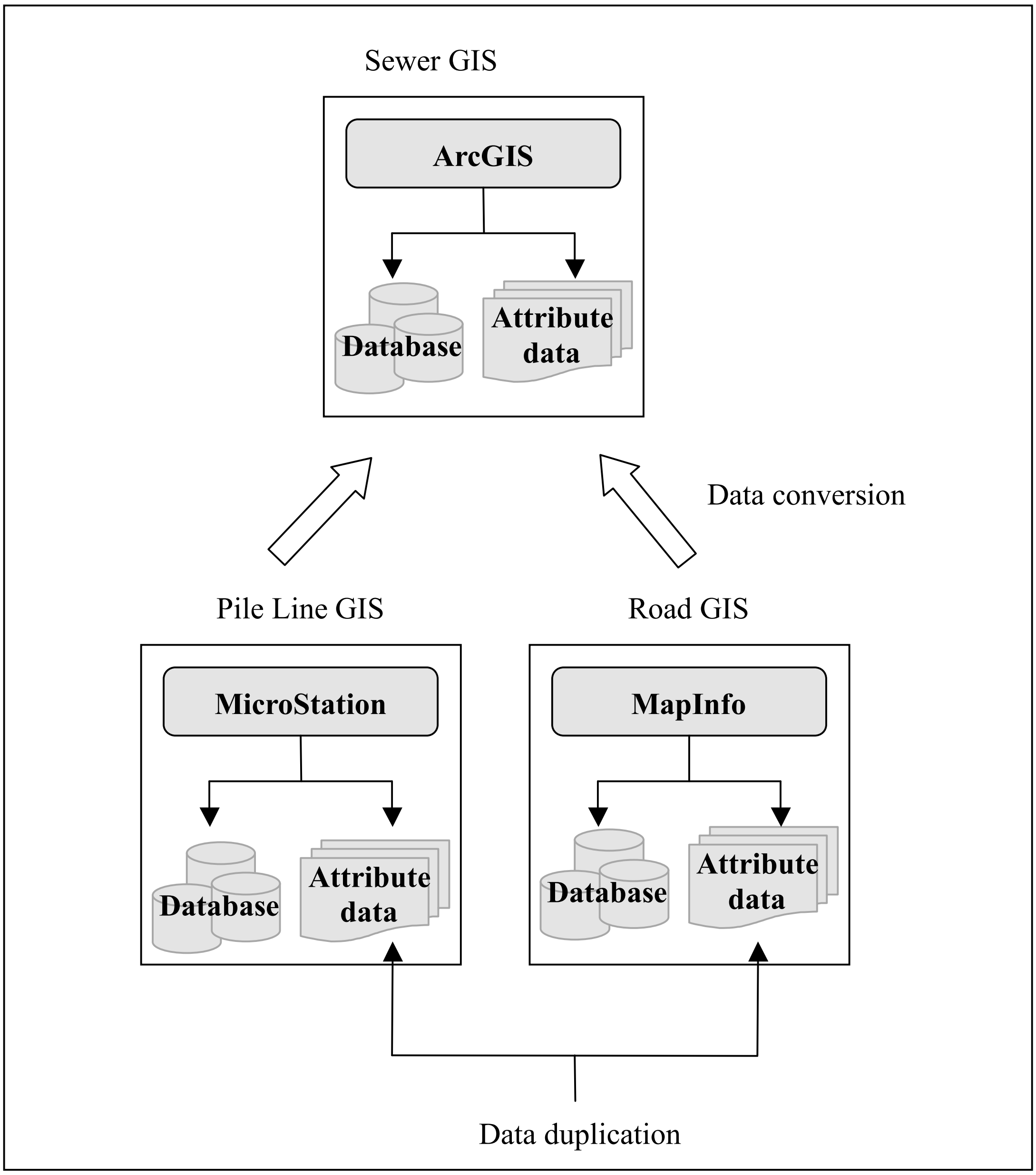

Figure 3. The Taipei Sewer GIS extracts geo-data from their sources through ad-hoc routines.

## 2. Data Model and Interoperability

Interoperability is the ability of two or more systems or components to exchange information, and to use the information that has been exchanged (IEEE, 1990). Problems related to distributed and heterogeneous data sources have been recognized as a key issue in achieving an interoperable GIS (Genesereth et al., 1997; Bishr et al., 1998; Devogele et al., 1998; Stoimenov et al., 2005). Information systems heterogeneity may be considered as structural (schematic heterogeneity), semantic (data heterogeneity), and syntactic heterogeneity (database heterogeneity) (Bishr, 1998; Stoimenov et al., 2005). A good way to avoid causing serious problems from semantic heterogeneous interoperability is through standardization that can be used in the transparent communication between data consumers and data suppliers. Devogele et al. (1998) suggested that the data model definition shall provide a reference point which facilitates data exchange among heterogeneous systems. Indeed, a data model provides a set of primitive data types organized to enable geo-spatial processing applications, communicate with one another though a shared interface that uses this data model.

Once a model is completed and made available, e.g. a GML application, it plays two important roles (OGC, 2005): One is for those representing their own native data models, the other is for those organizations looking to make their data sharable with neighbors, states, and commercial entities in a broader Spatial Data Infrastructure (SDI). In this study, we develope a common data model that acts as a basis to integrate three kinds of geo-spatial data: 1:1000 scale topographic maps, urban land-use zoning maps, and DTM, respectively. This common data model, which is a GML profile, is the starting point for other data model creators. Based on this common data model, more specific data models can be created.

The Geography Markup Language (GML) published by Open Geo-spatial Consortium (OGC) is a specification for modeling geo-spatial data. The GML is an XML (eXtensible Markup Language) encoding for the modeling, transport and storage of geographic information including both the spatial and non-spatial properties of geographic features (OGC, 2003). GML provides a lot of components that are used in the creation of application schemas such as geometry, topology, reference systems, coverage, observations, units of measure, and map styles. It is helpful to group these GML core schemas into different object classes and to achieve interoperability at the feature level. Because of its completeness and strength, GML have been recognized to play an important role as a Web-based geo-spatial data exchange standard. In the following, we will focus on the definition of a suitable GML profile for the three geo-spatial data sources (topographic, zoning, and DTM) in the Taipei City pilot project.

## 3. GML Profile and Geo-spatial Data Integration

GML is a flexible and extensible data modeling language. However, the richness offered by GML could also create interoperability issues, as different GML application schemas may cause confusion about their semantics (Peng and Zhang, 2004; ESRI, 2003). A profile of GML can be defined to enhance interoperability and to curtail ambiguity by allowing only the use of a specific subset of GML in the definition of a GML application schema. GML application schemas conforming to a GML profile can then take advantage of any interoperability or performance benefits offered by the profile, as shown as Figure 4 (OGC, 2003). GML application schemas that adhere to a GML profile can still have different data models, while making interoperability between different vendors and applications possible (ERSI, 2005). A systematic diagram is shown in Figure 5 to illustrate the role of the GML profile in the Taipei City Government pilot project: The profile acts as a common exchange format for various geo-spatial datasets and systems in use in the municipality, while at the same time it remains as a basis for extending to more specialized GML application schemas.

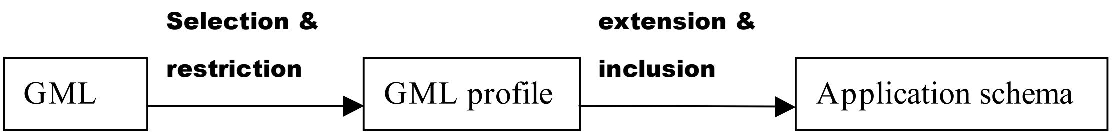


Figure 4. A GML profile acts a filter between GML and application schemas.

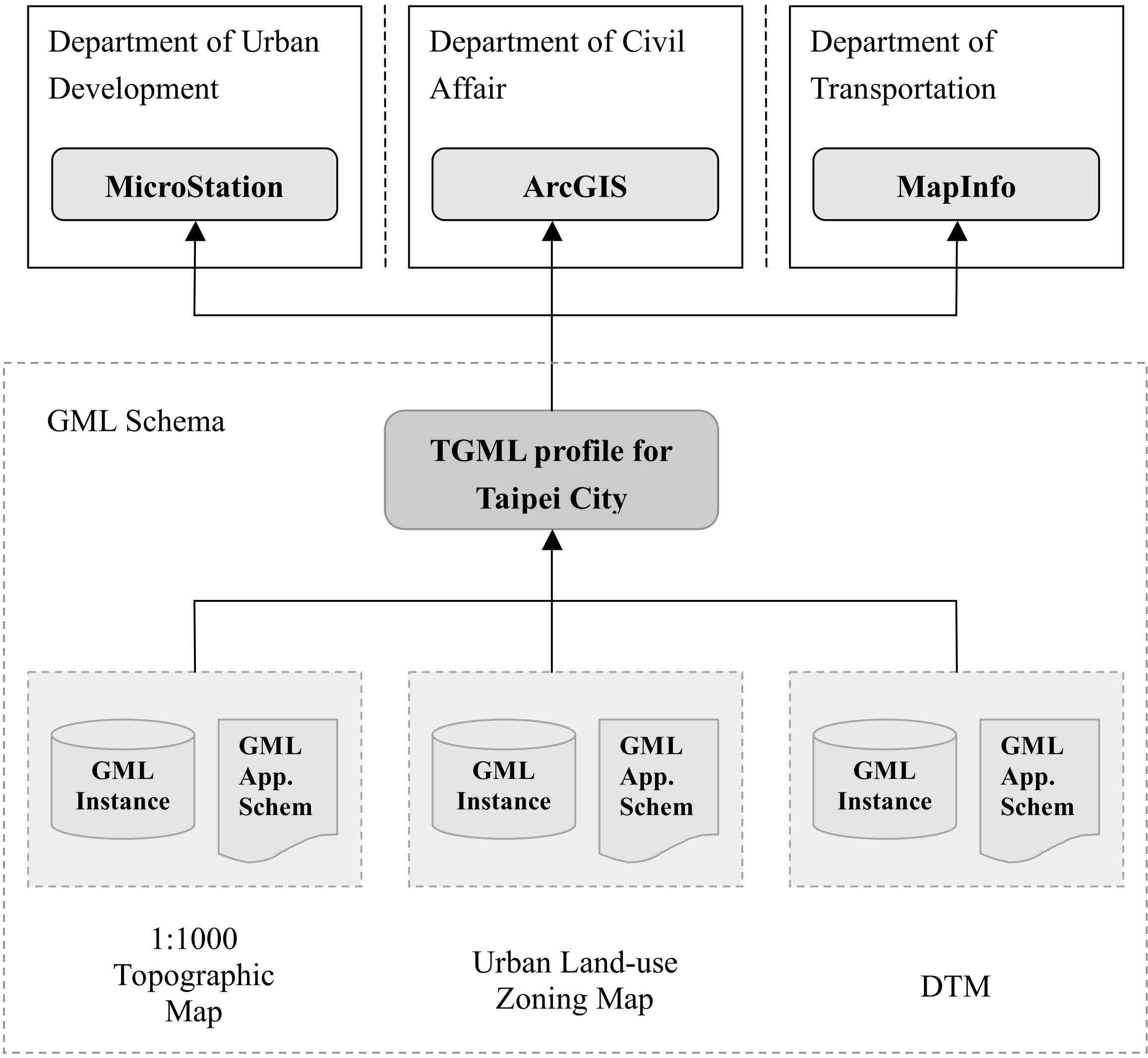


Figure 5.　Interoperability enables all departments to share data.

# 4. TGML: A GML Profile for Municipal Geo-spatial Data

## 4.1 The TGML Profile

The structure of a GML profile for Taipei City geo-spatial data would be constrained by the relationship among GML element types gml:FeatureCollection, gml:featureMembers and gml:Feature. The relationship between a feature collection and features is expressed by gml:featureMembers, rather than by gml:featureMember, as shown in Figure 6. On the other hand, a profile is a set of rules that constrain how GML can be used to ideally increase data sharing by lowering the bar of efforst required to read data (Murary, 2004). Beside the basic GML profile in Figure 6, another profile is derived from it for sharing Taipei municipal geo-data. This profile is named TGML and is shown as Figure 7. In TGML, the “Taipei GML application schema,” has its root element “TGML” that always belongs to the substitution group gml:FeatureCollection. The “themes” element, on the other hand, belongs to the substitution group gml:featureMembers; and the “Group” element belongs to gml:FeatureCollection. In GIS point-of-view, a “Group” can be considered as a layer of the map. The “geoObject” elements can be contained in a “Group” element through the “groupMembers” element that is a substitution group of gml:featureMembers. Child elements of a “Group” element all inherit from gml:AbstractFeature. The “geoObject” element inherits from gml:AbstractFeature and contains multiple geometries to descript 2D geographic objects. Even though we have simplified the relationship of feature collections and features in GML, the TGML schema remains a proper GML application schema and does not lose any expressiveness of GML. However, the TGML subset proves helpful in mapping GML-coded data to SVG documents, and the GML-to-SVG mapping is easy to program.

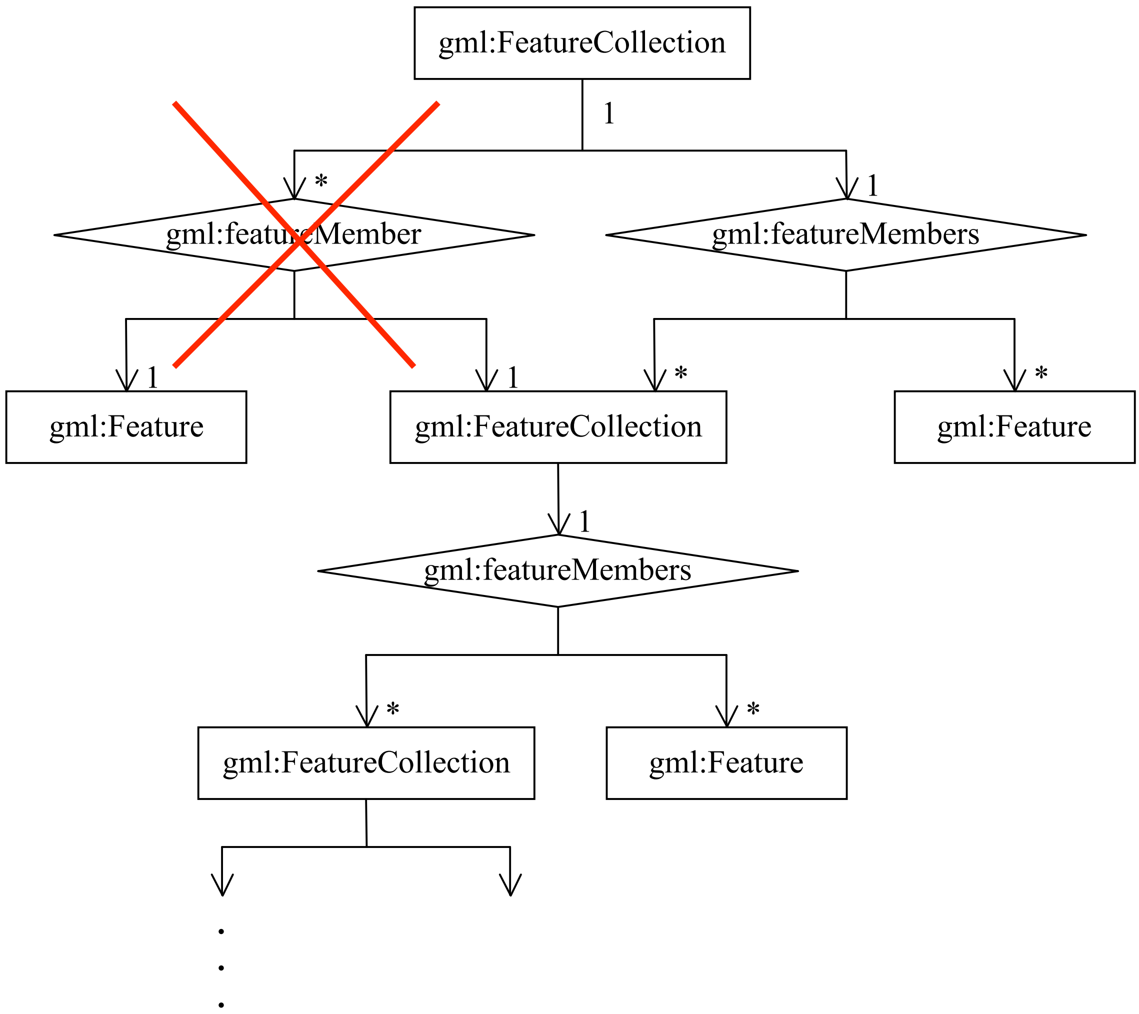


Figure 6. The ER-model diagram of a GML profile for sharing municipal geo-data.

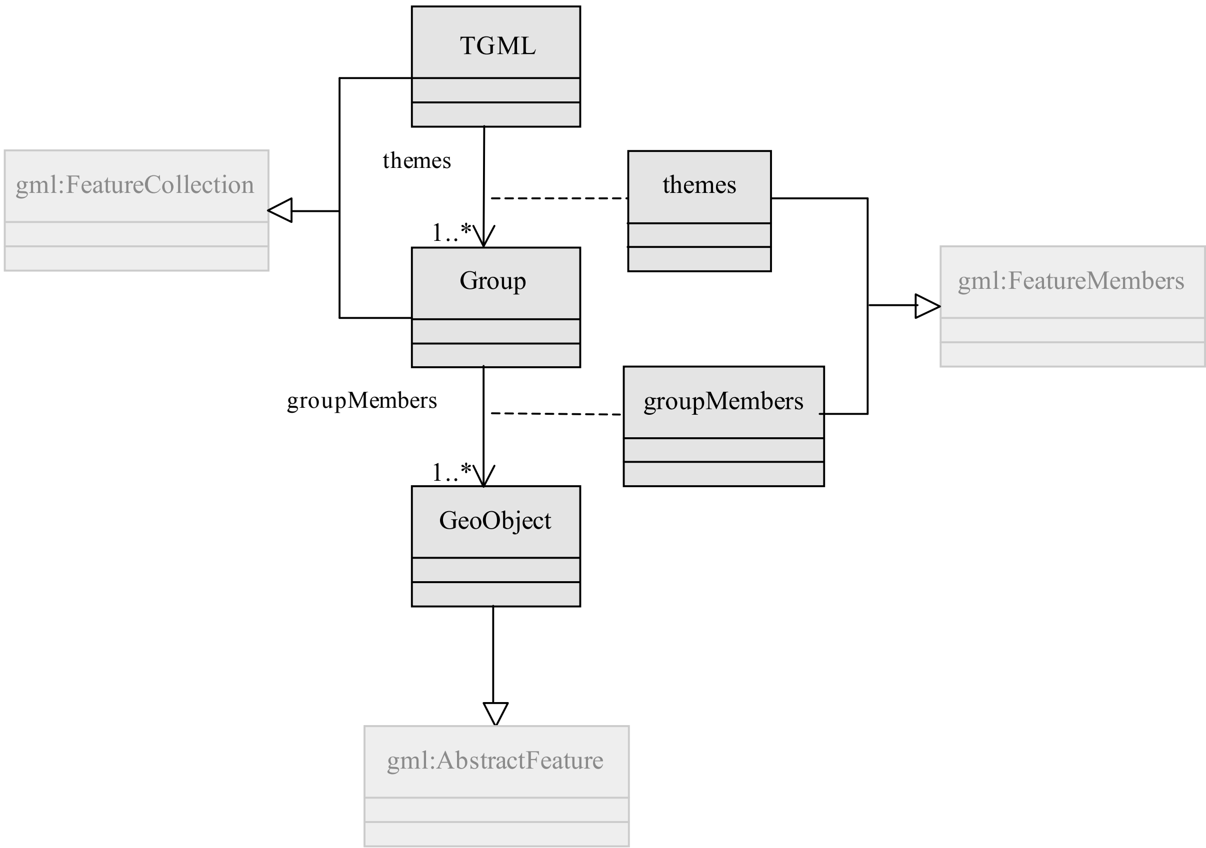


Figure 7. The UML diagram of the TGML profile.

## 4.2 TGML-derived Application Schemas

In the pilot project, we have created three application schemas. They are for 1:1000 scale topographic maps, for land use zoning, and for DTM, respectively. The application schema must follow the GML profile we just defined and is derived from TGML. An an illustration, in the 1:1000 scale topographic map, the root element is always the "TGML" element. There are many layers to be contained in a 1:1000 scale topographic map. Each "Group" element is considered a map layer. Consequently, a TGML element will contain many

"Group" elements such as TransportationGroup, ManholeGroup, BuildingGroup, PileGroup, WaterBodyGroup, EnergySupplyUtility, SewageUtilityGroup, AdministrativeBoundaryGroup, ElectricPowerUtitlyGroup, etc., as shown in Figure 8. Moreover, the relationship between TGML and Group is still connected via a "themes" element. Likewise, a "BuildinGroup" element will contain a set of "Buildings" elements through a "buildingMembers" element. The geometry property of a "Building" element is described by a "gml:multiPolygon" element, as shown in Figure 7-1.

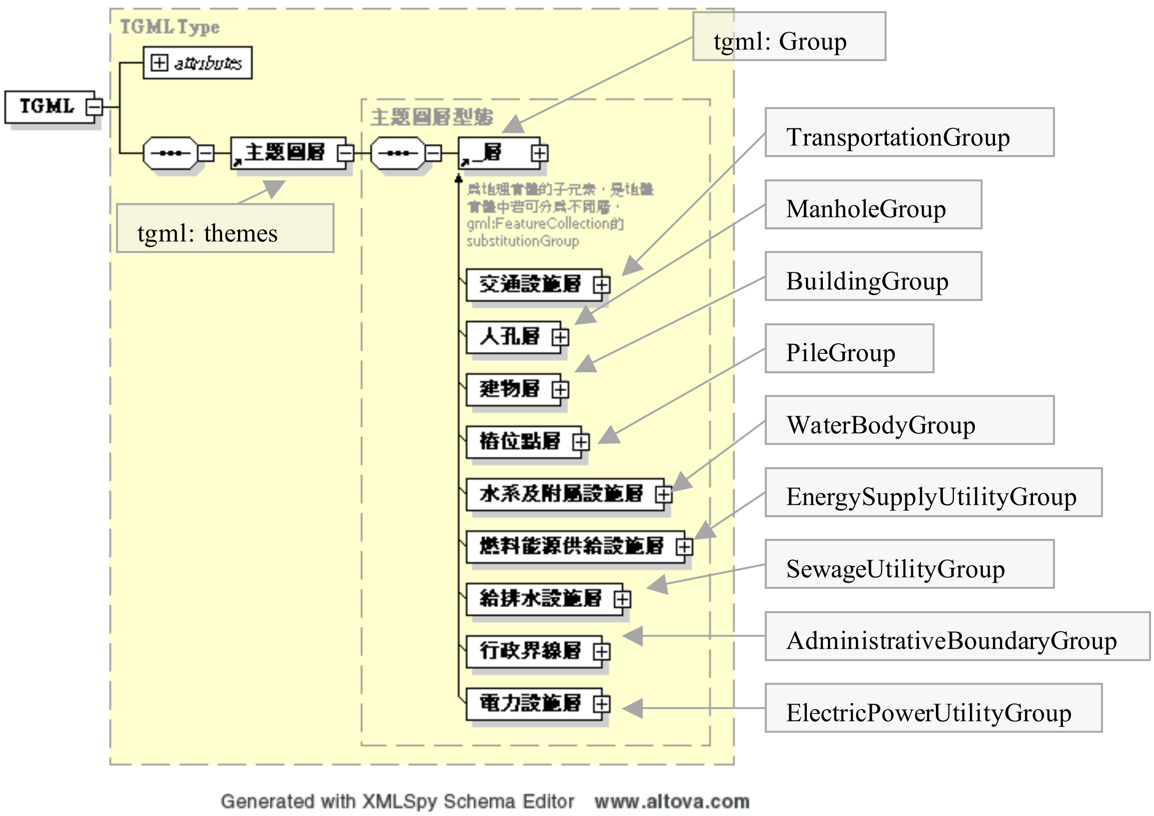


Figure 7. Part of the GML application schema for 1:1000 topographic maps.

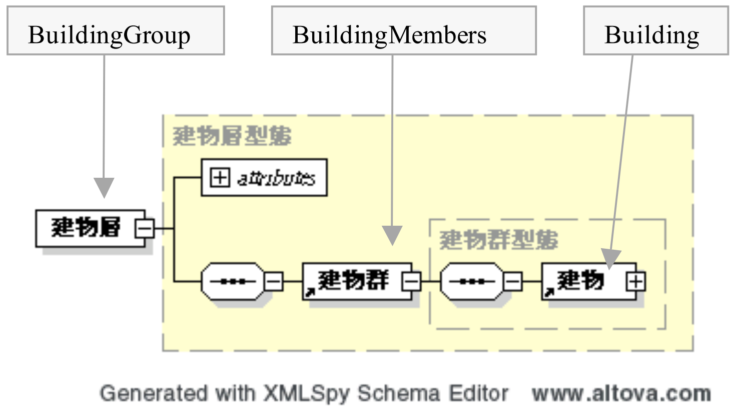


Figure 7-1. Part of the GML application schema for 1:1000 topographic maps.

### 4.3 Geo-spatial Data Conversions

In the pilot project, the procedure of geo-spatial data conversion is shown in Figure 8. Based on existing tools and methods, we first transfer the shp-formatted urban land-use zoning datasets and the dgn-formatted 1:1000 scale topographic maps to TGML. The 1:1000 scale topographic maps were first transferred from the DGN file format to the SEF (Standard Exchange Format) used in Taiwan. We then perform a SEF-to-TGML data conversion (c.f., Chang et al. 2003). Likewise, shp-formatted land use zoning datasets are first transferred to GML 2.1.2 by using the OGC Interoperability Add-on for ArcGIS. After that, we converted the GML 2.1.2 data to TGML data.

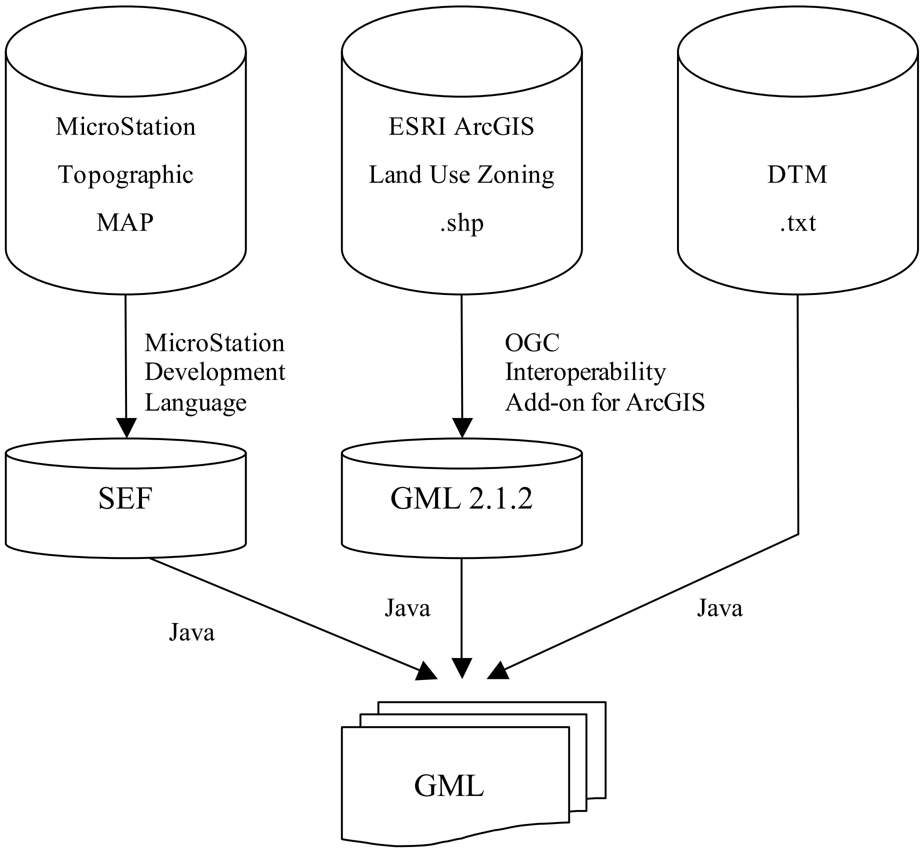


Figure 8. Geo-spatial Data Conversion.

# 5. A Prototype Web-Map Service: From GML to SVG

While GML provides a means to encode and transport geo-spatial features into XML, SVG (Scale Vector Graphic) provides a means to display these GML-coded geo-spatial features into vector maps on the Web (Chang et al. 2003; Peng and Zhang, 2004). Detailed issues in a GML-to-SVG mapping have been discussed in the Chang et al. (2003). There exist many examples of Web Map services that are based on a combination of SVG, HTML and Java, and with user friendly, interactive interfaces. The basic functions of interactive map publishing such as pan, zoom in, zoom out, identify and visibility control (switching on and off of map layers), are generally not serious problems. We have based our design on the GUI framework and navigation toolkits provided by carto.net (Williams and Neumann, 2005). In addition to the basic functions, we have built a simple interface that allows users to perform online spatial queries, and to receive GML datasets and SVG documents as results (see, Figure 9). Scenarios in using this prototype of the interactive map are shown in Figures 10, 11, 12 13 and 14.

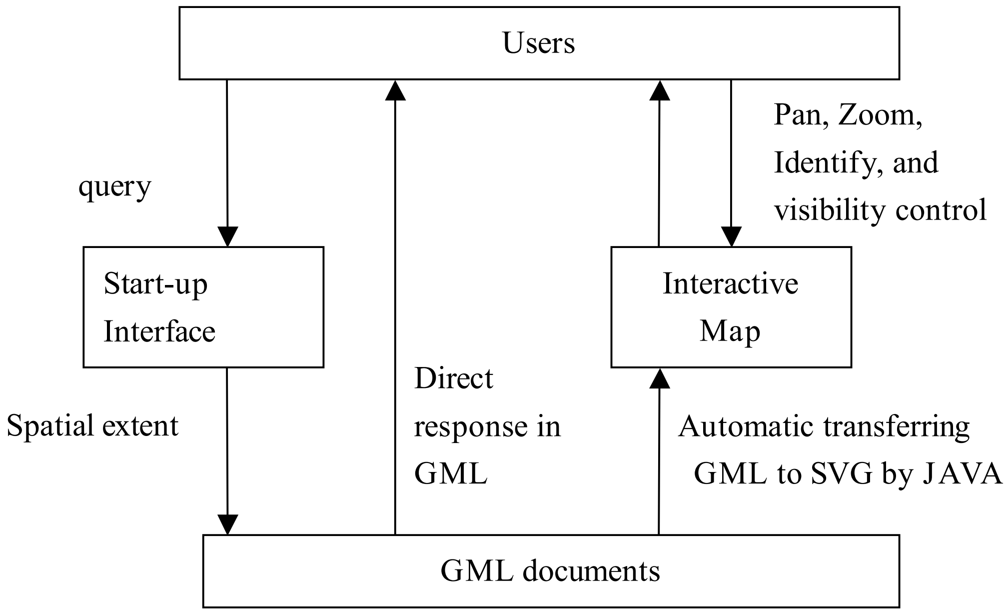


Figure 9. The architecture of a prototype interactive Web map.

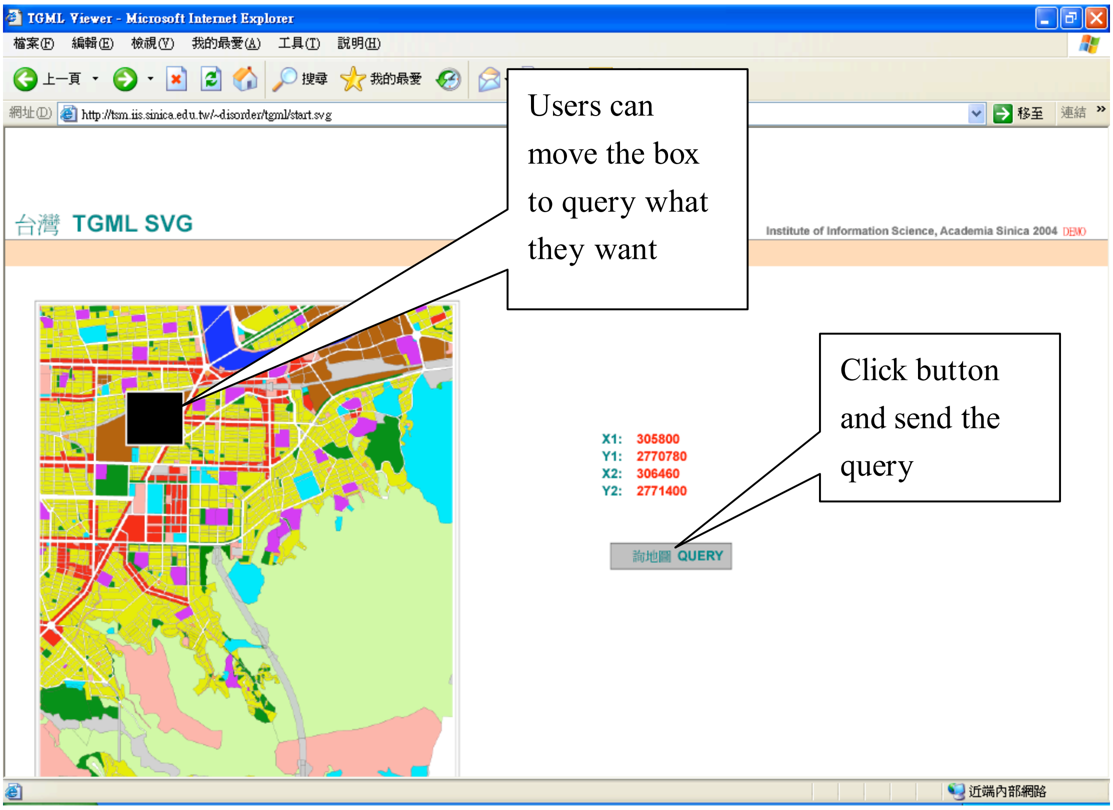


Figure 10. The start-up page where user query the datasets.

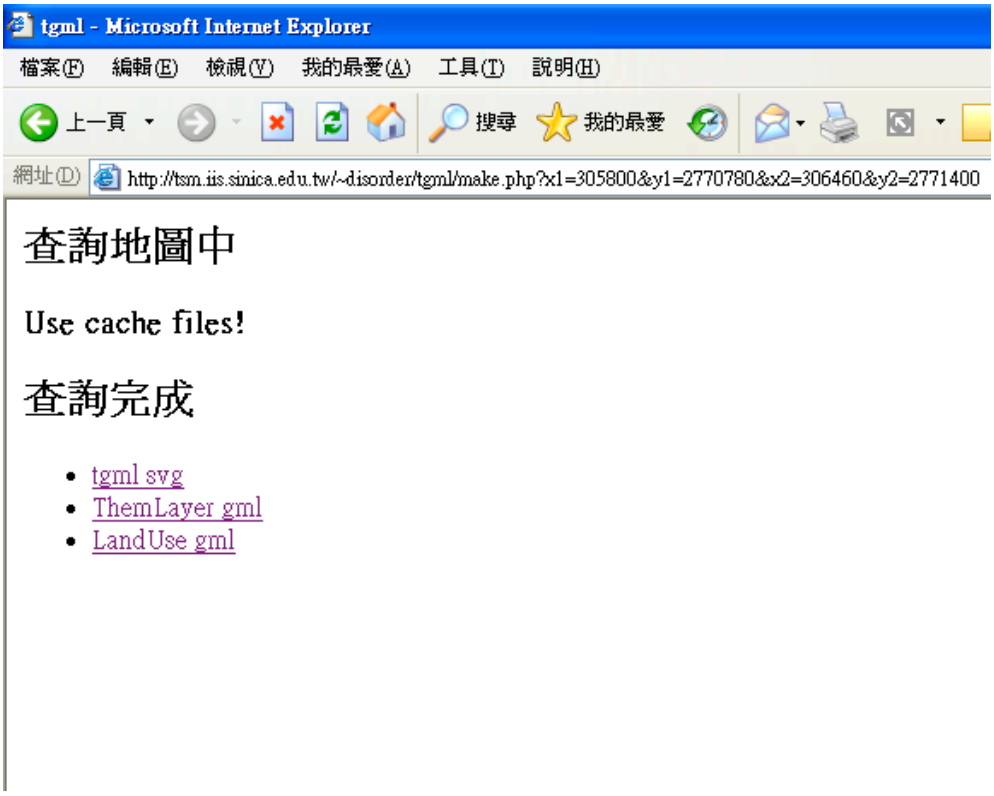


Figure 11. After the query, GML datasets and SVG documents are returned.

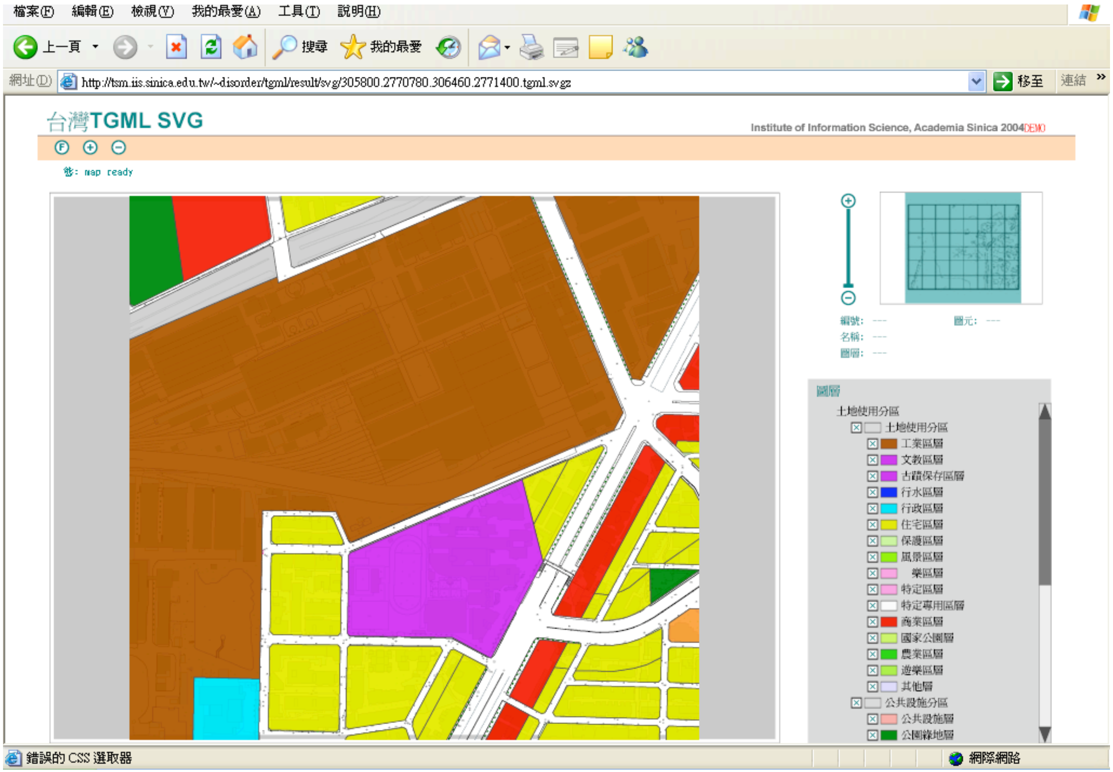


Figure 12. Web-based SVG presentation and navigation of the retrieved map.

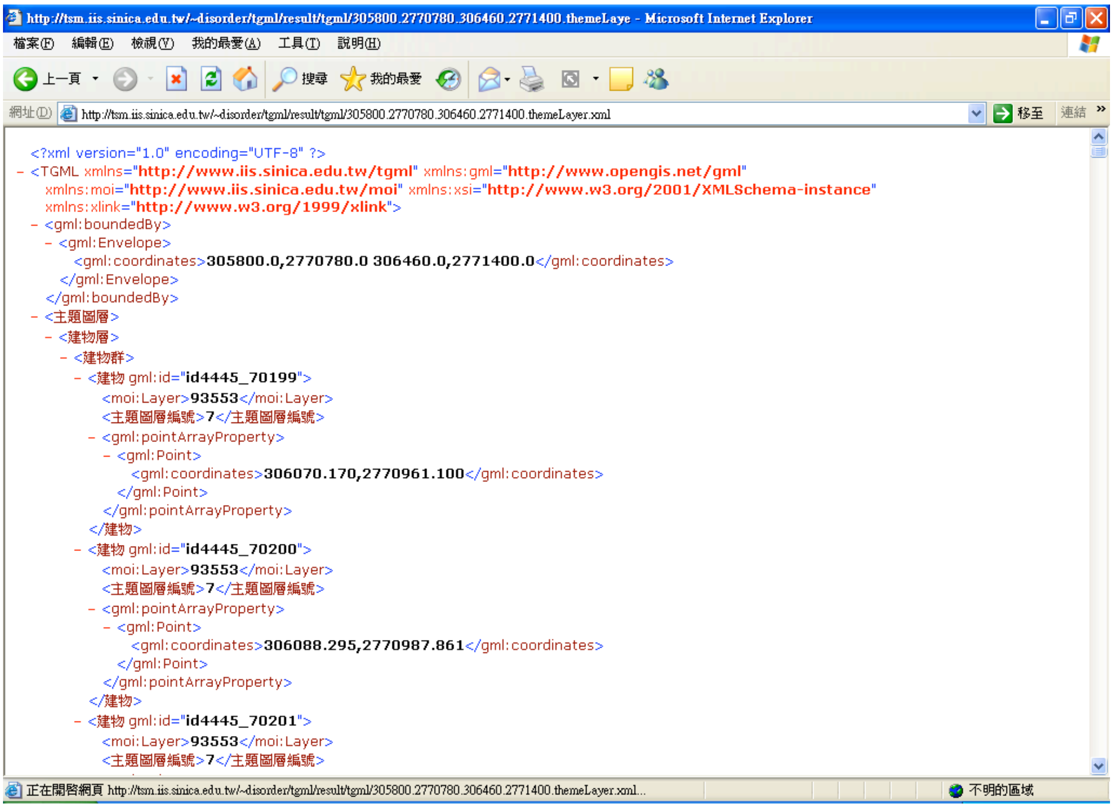


Figure 13. The GML document for part of a 1:1000 scale topographic map.

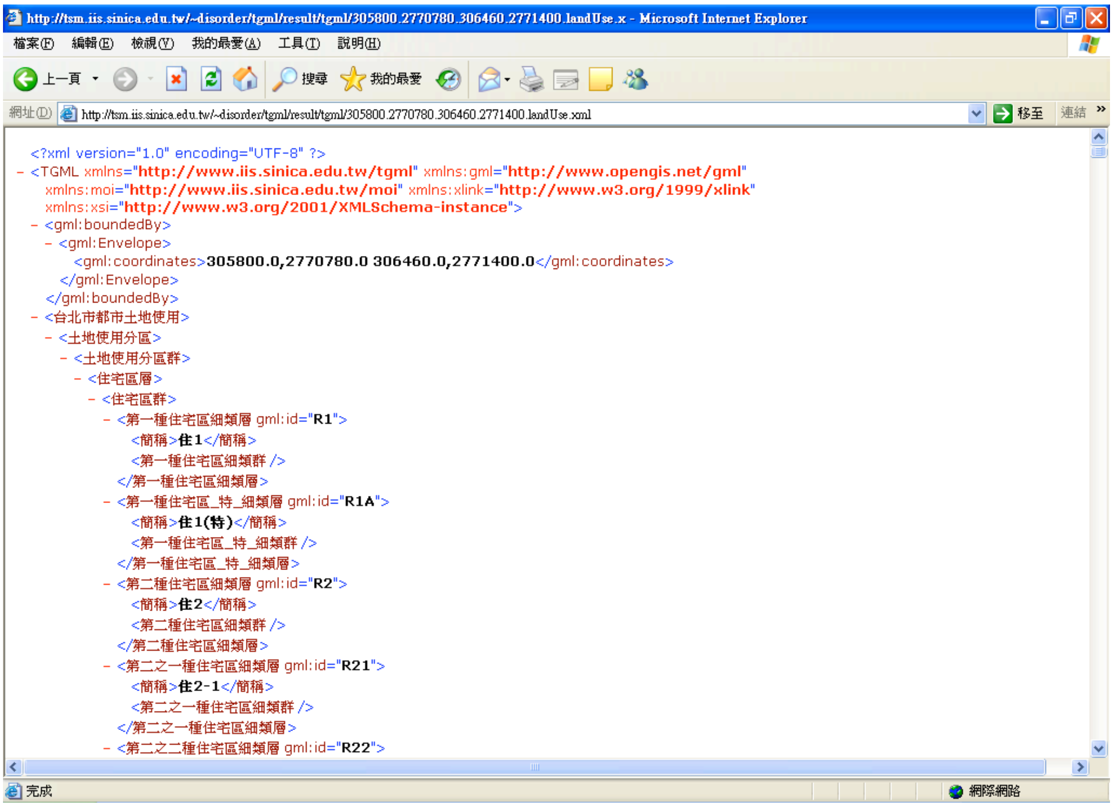


Figure 14. The GML document for part of a land use zoning map.

# 6. Conclusion

Our study has indicated that building a GML-based interoperable geo-spatial system for municipal applications is both feasible and can be very effective. What distinguished our study from others are that first we develop the TGML data model to correspond with OGC principles according to our local requirement. Second, we develop our own query tools to retrieve collections of geo-spatial features from large GML documents. Furthermore, we experiment with SVG technology for Web-based display of GML documents and we achieve promising results. Accordingly, the TGML model and approach enable an interoperable system environment, and assist the sharing and management of geo-spatial resources in an e-government context.

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