A Web services solution for Work Management Operations

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Abstract

The GeoResources Institute at Mississippi State University is leveraging Spatial Technologies and Web-based services for addressing rural septic system problems. Current methods are inadequate for mapping and managing wastewater resources and execution work management operations. This paper presents an Open GIS web services architecture providing streamlined workflow for wastewater work and utility management operations. Mobile GIS solution is developed with Arcpad supporting work order query, download and update services. Microsoft .NET framework is utilized to provide services to mobile application. Desktop application implemented with Map Objects (Java) supports services such as parcel finding, query utility maintenance history, map view, work order creation and redline features operations for field inspection. The work management operations and feature characteristics of wastewater utilities are modeled with GML schemas standardizing the structure and content of geographic information for validation and use. This enabled spatial data interoperability with both desktop and mobile GIS applications.

Introduction

Geographic data is critical to applications that need to view, query, edit and update information from different locations to achieve business objectives. Traditionally, GIS applications were limited to the desktops, running GIS software for displaying and querying geographic data that is often stored in a spatial database. With the introduction of mobile devices, a desktop GIS system could be extended to any remote location by providing easy, accurate and efficient methods for remote data access. The data was still stored and transported in proprietary formats. As a result only certain GIS software packages and databases could read and store the geographic datasets respectively. Organizations developed different data models and structures to support their business cause, resulting in diverse data formats and software packages to interpret. Some data formats are proprietary and can only be read by certain software packages. To be usable with diverse GIS software products, data conversion tools are required at additional cost and time. This not only limits the GIS data interoperability but also places the constraint on software packages and spatial databases to be used for developing the user application itself. The ability to use a dataset across multiple user applications is interoperability. Often desktop and mobile applications that need data may not be able to utilize a dataset because of the proprietary structure. An approach to provide data conversion from a proprietary to format usable by applications is the first step towards providing data interoperability.

ESRI has been a key player in promoting and implementing geographic data interoperability standards [1] resulting in data conversion tools, simple feature specification for SQL and OLE/COM and direct data access API's such as Java and C ArcSDE API's. ESRI products such as ArcWeb services and Interoperability extension implement web services technologies to provide data interoperability support. Interoperating mobile and desktop applications provide significant step towards field data availability. Different levels of data interoperability exist depending on the level of knowledge about the dataset provided to user applications. The levels of interoperability are structural, schematic and semantic. At structural level, basic meta information about the dataset is available. E.g. ESRI ArcIMS image service that provide information on spatial extents, width and height of an image but does not provide details on how to query an image for extracting some features. At schematic level, explicit knowledge about the structure of the data is provided in the form of schema. E.g. Describe Feature Type operation in OGC Web Feature Service provides the schema information as XML to user applications. The schema describes the geometry and feature attributes associated with a dataset. E.g. XMML [2], ESML [3] and LandXML [4] are being used to represent geology and mining and earth science dataset respectively. At semantic level, agreement on common vocabulary to represent geographic entities is required. Ontologies are required for this purpose.

This paper presents web services framework providing interoperable spatial data services. An interoperating spatial data service provides services such as data access, query, editing and conversion (spatial services or geo-services) to remote desktop and mobile user applications. The user applications using such a service are not constrained to use specific software product or platform.

Geographic Markup Language

GML [5] is an XML encoded format for representing and storing the structure and content of geographic features. GML is an OGC (Open GIS Consortium) standard, primarily targeted at addressing geographic data interoperability among GIS applications. Since GML uses XML encoding, it inherits all the features such as extensibility, interoperability and human readability. GML is an open source data exchange standard and hence freely available to everyone. GML encoded information is portable and can be transported over the Internet to diverse applications on desktop and mobile platforms. Users of GML data do not require investment in complex and expensive software. ESRI provides extensions for accessing geographic data from GML data sources in ESRI ArcIMS and ArcExplorer products. GML can be used to store and transport geographic features over the Internet to remote GIS applications including mobile devices. It can be used to represent spatial and non-spatial aspects of geographic features. Feature characteristics such as topology, routing, units and measurements can be captured. GML also provides schemas documents for modeling feature attributes and geometries. For example, waste water features such as manholes, sewer lines and pumps can be modeled in GML. Likewise Application objects or entities such as intersection, drill hole and work order can be modeled from GML schemas. The application schema represents the structure or placeholder for data that will be populated during the data exchange operation. The application schema is used by organization or applications interested in sharing geographic information. Further communities interested in sharing geographic information in GML can custom develop GML schemas based on data requirements. E.g. ESML and XMML. Use of OGC standard such as GML to model the geographic information structure will provide increased interoperability across multiple GIS systems.

Web Services

Web services are reusable software components that can be published, discovered and invoked over the Internet [6]. Web services are built around set of industry based protocols such as XML, SOAP and WSDL. WS extend the client/server architecture by enabling broader accessibility to diverse applications and reusability of the web components delivering the functionality. Web Services are the latest approach used to deliver data and geo-processing services to diverse user applications. ESRI ArcWeb services are based on web services. Three major components of web services framework are service registry, service provider and service user. Service registry is a searchable online catalog and is utilized by a service provider to publish a service. Service provider is an entity or organization willing to provide data or geo-processing services. Service user is an organization or person with a need for data or processing services. Typically a user with a specific data or processing requirement can query a service registry for a service provider offering the desirable data. On locating a service provider, the user application can send request for the required datasets.

A service provider creates service description using web service description language document (WSDL) that contains list of spatial or non-spatial operations supported, data types exchanged and location of the service. Using WSDL document, the user applications can create requests to the service provider. Simple Object Access Protocol (SOAP) is utilized for data exchange between service provider and user. SOAP provides XML envelope structure and data encoding rules to transport data between applications. XML data transport makes SOAP message platform independent. Encoding rules provides mapping mechanism from application or data objects to equivalent XML data types. E.g. SOAP message requesting image with GetImage operation shown in the figure 1.

```
  <?xml version=‘1.0’ encoding=‘UTF-8’ ?>
  <s:Envelope>
    <s:Header>Routing, security & session control</s:Header>
     <s:Body>
     <e:GetImage xmlns=“http://erc.msstate.edu/imgservice”>
            <e:parameters width=“500” height=“350”
                  minx="-122.524464" miny="37.690002"
                  maxx="-122.349621" maxy="37.834193"
             </e:parameters>
    <e:GetImage>
  </s:Body>
</s:Envelope>
```

Figure 1

Approach

The primary goal of the approach in this paper is to provide spatial or geographic data services to diverse user applications by leveraging industry standards such as web services and GML. For GIS applications to be able to share data a common data model is required. The common data model defines various geographic entities and their geometry and feature attribute characteristics. Common data model is developed using GML application schema that models geographic entities shared. Figure 2 shows application schema representing manhole feature.

```
<xs:complexType name="manholeFeatureType">
    <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureType">
        <xs:sequence>
          <xs:element ref="gml:location"/>
          <xs:element name="mh_code" type="xs:string"/>
          <xs:element name="fitt_type" type="xs:string"/>
          <xs:element name="elev" type="xs:float"/>
          <xs:element name="map_" type="xs:string"/>
        </xs:sequence>
      </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Figure 2

The application schema will provide user applications with explicit knowledge on the structure (geometry and feature attribute) of the dataset. After agreeing on the application schema utilized to share geographic information, a service provider can start defining the service interface using WSDL. The service interface provides operations supported (subset, query and buffer), input/output message to each operation and data types transported with each message. Additionally information about protocol (HTTP, SOAP, SMTP and JMS) for transport and location of the service (URL) are required.

Implementation

Application

Septic system failures are significant problem in fast growing rural areas. A majority of septic systems are greater than 30 years old, over 25 percent are in some sort of failure, and 10 percent overflow on an annual basis. Current methods are inadequate for mapping and managing resources as well as tracking problems and planning appropriate and effective solutions. New technologies must be identified and solutions implemented to provide information and work management solutions to address the existing problems.

Wastewater services are primarily maintenance, inspection and emergency response operations. Field inspectors use paper-based maps and work orders for locating housing facilities (parcels), sewer features (such as sewer lines, manholes, meters, pumping stations) and execute tasks in the field. Completed paper work orders are finally updated to spreadsheet or database through manual data entry. Current approaches are inefficient and not cost effective for achieving wastewater work management objectives. Paper-based data collection methods introduce data inconsistency and delays in work order execution due to manual data entry methods. Changes to spatial data in the field are difficult to incorporate into paper maps.

Requirements

The application framework should provide infrastructure and tools to execute wastewater work management operations efficiently at office and field.

- **User Requirements**

  1. Supervisor should be able to retrieve vector and raster data layers for a specified spatial extent from a remote spatial database.
  2. Supervisor should be able to view and query parcels and sewer features of the complaint area.
  3. Supervisor should be able to issue a work order by creating task description, date to complete, inspector's name and support vector data layers.
  4. Field inspector should be able to query and download work order and execute the tasks in the field remotely through the Internet or desktop synchronization.
  5. Field inspector should be able to execute tasks in the field and update the completed work order through the Internet or desktop synchronization

Work Flow

Workflow starts with incoming complaint call (e.g. Sewer backup). The supervisor will address the complaint call by creating a work order. Each work will contain task description, creation and completion dates, inspector's name and support vector and raster datasets. The field inspector will download the work order and execute the tasks in the field. Completed work order are updated and closed. Workflow starts with step 1, a supervisor at an office desktop receives a complaint. Based on complaint address, the complaint parcel is located. Step 2, image and vector data (manholes and sewer main) within the proximity of parcel are extracted by sending request to Image and Feature data services. The desktop application or manager extracts the data returned and display to the user. Step 3, suspected wastewater lines are redlined and tasks to execute are provided. Step 4, task information and redlined features along with the current extent of the map are saved to a work order in the database. Step 5, the field inspector user mobile application to retrieve work order assigned to him from the database. Step 6, view and edit the work order information in the field and finally update the completed work back to the database.

Implementation

The primary components in the software architecture are namely, spatial services, spatial database, work manager and mobile application

1. Spatial Services

Spatial services are set of reusable components developed to execute work management operations. The services are implemented in both Java and .NET platforms. Java services interface with desktop application and .NET services interface with the mobile interface. Two primary services usable by any application are feature and image service. Feature service provides GML encoded dataset information for specific vector layer. Sub setting is possible by providing spatial extents. Image service provides image data to user applications.

2. Spatial Database

Spatial database is the central repository for geographic information. The database stores vector layers as tables. Postgresql [7] database is configured with PostGIS [8], spatial extension package, to store spatial data types such as ESRI Shape files and Arc Info files.

3. Work Manager

The work manager is a desktop based GIS applications developed to provide services to supervisors or managers to view, create and edit work orders on a daily basis. Work manager utilizes Java web services to access spatial datasets, create and track work orders. The work manager communicates with Java services using XML based SOAP protocol. For example, a user request for a vector layer or dataset will be executed against the database by a Java service and GML encoded vector dataset information is delivered. The work manager creates ESRI Shapefiles on the fly to visualize GML encoded vector datasets. Java web services also provide integration of image data into work manager along with vector datasets. Image datasets are published through ESRI ArcIMS image server. Figure 3 shows desktop manager interaction with feature and image data services.

Typically a work manager sends a SOAP request to a Java web service to retrieve vector and raster data with in a selected spatial extent. Java web service communicates with database for vector data and ESRI ArcIMS for image data. The Java web service returns vector data is GML and a raster image to the desktop application. The desktop application converts GML to ESRI Shape files and finally overlays the image extracted from ArcIMS image server. The work manager has been implemented in ESRI Map Objects Java product.

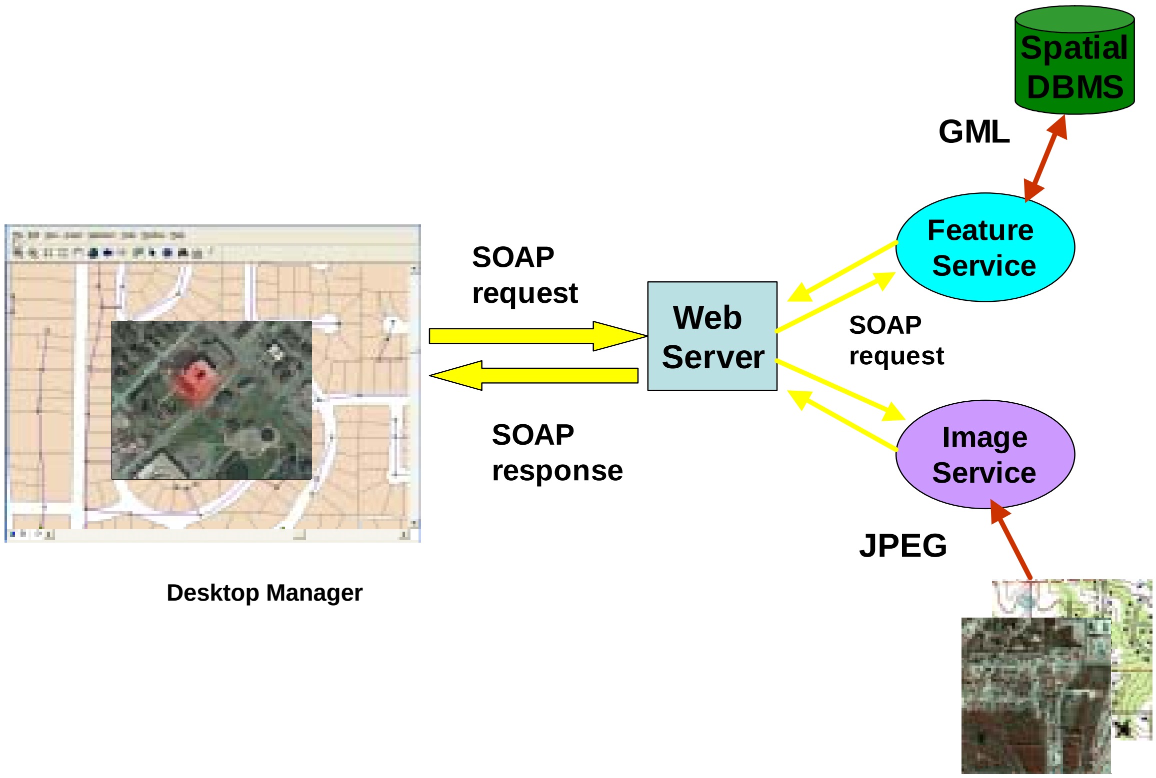

Figure 3

4. **Mobile GIS**

The mobile GIS application provides field users with map to view and query geographic information. Custom-built forms are developed to view and edit work order related information in the field. The mobile application utilizes .NET services to download and upload work order and support datasets (maps) to execute tasks in the field. Mobile application communicates with .NET services using XML based SOAP protocol. A SOAP request for work order information is processed by a .NET service and work order is delivered. Each work order will contain XML encoded information related to creation date, tasks to execute, priority and support datasets. The mobile application creates ESRI shapefiles from XML encoded information on the fly. The mobile application has been developed using ESRI Arcpad. The figure 4 below shows mobile application.

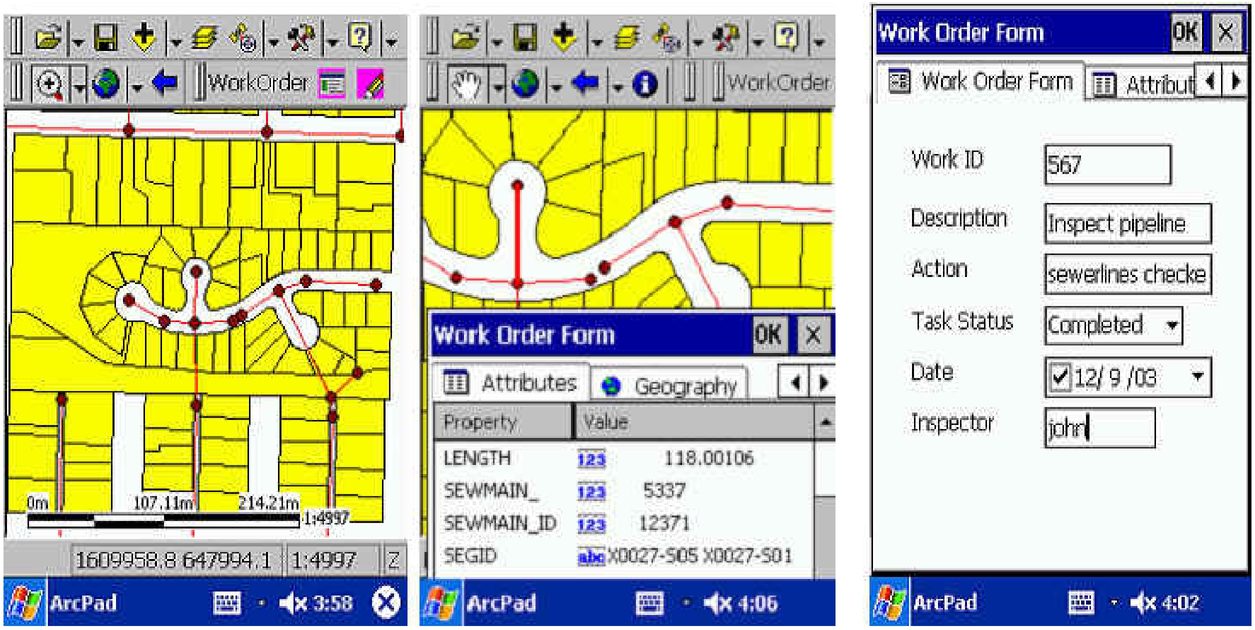

Figure 4

Conclusions

The results indicate that through web services framework, GIS applications can exchange geographic information transparently resulting in easy data integration. Since the data exchanged between applications is GML encoded, it is portable across multiple applications operating on different platforms. Data and business operations modeled through GML schema documents provide intelligence (semantics) to user applications for interpretation, validation of data exchanged and reusability. Limitations such as cost of data conversion from XML to others formats usable by applications still exists. With the increasing number of applications accessing spatial data services, interfaces to service providers and users need to agree on standard message structures and content of data exchange for interoperation. Utilizing an asynchronous messaging model for exchanging data between applications will provide improve scalability, throughput while reducing latency.

ACRONYMS

GIS	Geographic Information System
OGC	Open GIS Consortium
XML	Extensible Markup Language
GML	Geographic Markup Language
WSDL	Web Service Description Language
SOAP	Simple Object Access Protocol
JMS	Java Message Service
SMTP	Simple Mail Transport Protocol

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