

An Internet GIS System to Support the Water Resource Management

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Abstract— This paper addresses a computer system capable of integrating, storing, analyzing, and displaying geographic information. Currently, the Geographic Information System is not only limited to cartography but also related to various data management such as natural resource management, environmental impact assessment, and etc. The Internet system allows more geographic information sharing as many users can access at the same time. The Internet GIS system including Management Information is a research and application area that utilizes the Internet systems to facilitate the access, processing, and dissemination of geographic or non-geographic information.

In this study, the Internet GIS application has been developed for the water resource management as it gives users better understanding of the overall country watershed.

Internet GIS; Geographic Information System; Management Information System; water resource management;

I. INTRODUCTION

Geographic Information System (GIS) is a collection of computer hardware, software, and geographic data for managing, analyzing, and displaying all forms of geographic information. The vector and raster data formats are two basic data types to store geographic data. GIS can be linked to location data, such as dams to conserve, reservoirs to plant, rivers within a network, or telemeter stations to measure rainfall [2].

The water demand and supply information can give the users to find best solution for each area and manage water resource. Therefore, both geographic and management information related to these geographic information can give a better understanding when it all works together [3]. The Internet GIS system has been developed to fulfill various demands from mapping functions to advanced GIS-MIS applications with user interfaces and highly interactive function. The Internet GIS system is both research and application areas that utilizes the Internet system to facilitate the access, processing, and dissemination of geographic or non-geographic information and spatial analysis knowledge [15]. This system has become a technology to support spatial analysis and expand information representation in GIS and MIS. The display part of this system can represent the water demand for supporting in management, analysis, estimation,

and decision. In other words, Internet GIS can serve the water resource information to help manage water resource.

The widely used software is OpenLayers, which is a JavaScript library for displaying and building web-based geographic applications, similar to Google Maps and MSN Virtual Earth. OpenLayers is open source software that supports many different maps, including Google, Yahoo, and other data sources [8]. OpenLayers displays the geographical maps produced by GeoServer. These maps are interactive maps represented on web clients. Furthermore, OpenLayers can render the vector map layers in the various types of web browser (Internet Explorer, Mozilla Firefox, Google Chrome, etc.). The vector data are used to represent the information with their attributes on the map. This work is also focused on the vector layers overlay techniques based on the OpenLayers viewer. Moreover, the converter was developed to convert the spatial data in spatial database to graphic formats based on XML format for displaying the vector data on the Internet GIS applications [12].

The purpose of the implementation in this work is to describe and display the Internet GIS application architecture and the general features to provide the framework of water resource management.

The remaining of this paper is organized as follows: Section 2 presents the general background information about the research. Internet GIS application architecture. Section 3 proposes the whole research system architecture, the detail of conversion technique, and the spatial analysis tools of Internet GIS system are discussed in Section 3. In Section 4, the examples of Internet GIS Application for supporting water resource infrastructure are shown Finally, Section 5 is the conclusion.

II. BACKGROUND

This Internet GIS system development project is a research project of Hydro and Agro Informatics Institute or HAI. It uses GeoServer and OpenLayers which are the open source software for generating and rendering geographic information, respectively. This research focuses on various aspects of spatial data analysis, spatial data management, non-spatial data management and advanced web-based geographic visualization. Our purposes include the research into geo-

information science, spatial analysis tools and techniques for data management.

A. Geographic Information System

GIS dataset is the spatial representation of real-world features. These features are described with their attributes that are the non-spatial data. There are two types of data to represent the feature and attribute in GIS: as vector data types or as raster data types. Both data types are the basic data structures for storing GIS data [2].

A vector GIS data layer is stored as a set of coordinates. It represents the real-world features using basic GIS elements: points, lines and polygons. Point represents the locations such as telemeter stations, wells, dams, etc. Line represents the path passing through two or more different points such as rivers, roads, railways, etc. Polygon represents the close path or the boundary. One advantage of vector type is the ability to store multiple attribute data for each feature [2]. Three features mentioned above are illustrated in Fig. 1.

The raster GIS data layers represent real-world features by dividing data into equal-sized cells or pixels [2]. The raster data structure is illustrated in Fig. 2. One pixel of raster data can contain only one value.

Internet GIS is the application area that utilizes the Internet system to access, processing, and distribution of geographic or non-geographic information. Internet GIS allows more information sharing as many users can access GIS at the same time. In our system project, Internet GIS has become a technology to support spatial analysis and can expand information representation in GIS and MIS [9].

OpenLayers is an object-oriented JavaScript library for displaying map data in web browsers. OpenLayers implements a JavaScript API for building web-based geographic applications, similar to the Google Maps and MSN Virtual Earth APIs. It is free open source software [8].

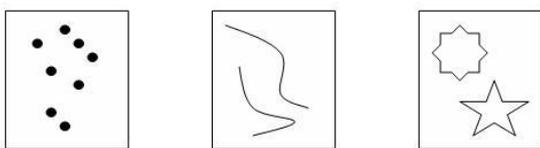


Figure 1. Three vector data representations of real world features.

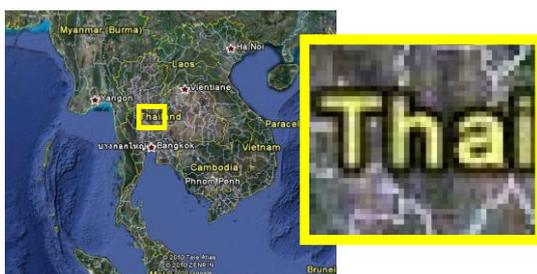


Figure 2. The raster data is divided and collected into pixels.

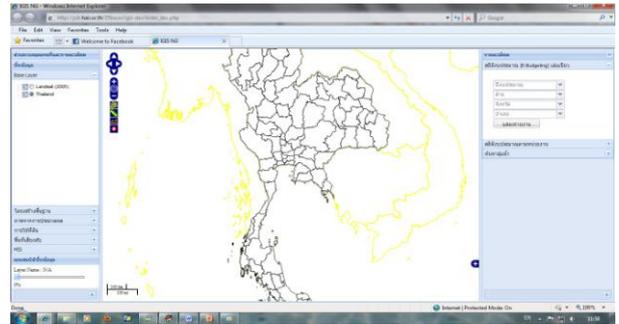


Figure 3. A web interface of Internet GIS application using OpenLayers and GeoServer.

GeoServer is an open source software server written in Java programming language that allows users to share and generate geospatial data [4]. Our Internet GIS system has applied OpenLayers for viewing and managing geographic data on the web clients. GeoServer is also used for generating the geospatial data from the data collections. Internet GIS system can generate its applications as user interface shown in Fig. 3.

B. XMLParser Converter

The objective of XMLParser software development is to create a software tool for converting spatial data in shape file format to *svg* or *vml* form based on the open source software. XMLParser can run under UNIX environment. The whole detail of this technique was described in [8]. However, it was applied in this system.

The workflow of XMLParser software using in the system is shown in Fig. 4. The non-spatial and spatial data in the shape files are imported to database and spatial database, respectively. XMLParser accesses and queries these data in order to produce an input text file which has the specific format. It reads and then converts the input text file to SVG files. These SVG output files are the representation format on the web applications.

Definition 1: Let I be an input space that represents an input file of XMLParser and contains a lot of stream lines. In this case, one stream line indicates only one corresponding data record.

$$I = \{s_j \mid s_j \text{ is the input stream and } j \text{ is a number of input streams}\}$$

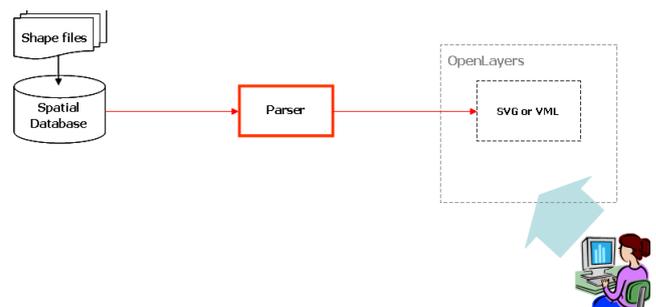


Figure 4. XMLParser workflow.

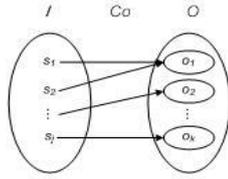


Figure 5. Mapping function diagram.

Definition 2: Let O be an output space which contains the set of XMLParser output files.

$$O = \{o_k \mid o_k \text{ is the output file and } k \text{ is less than or equal a number of } geocode\}$$

where *geocode* is a geographical code to identify a point or area at the surface of the earth [13].

Definition 3: Let Co be the mapping function from I : the input file to O : the set of output files. In this paper, Co is the XMLParser processes.

$$Co: I \rightarrow O \text{ or } O = Co(I)$$

Fig. 5 shows the relation of the input streams with the set of output files. In this system, the function Co is many-to-one function. Since the Internet GIS system supports one output file for one *geocode* of GIS. So many input streams containing the similar *geocode* but different positions are mapped to one output file.

The XMLParser Co is verified by an assertion about program correctness. The XMLParser is correct with respect to the input assertion s_j and the output assertion o_k . Suppose that s_j is true, so that the s_j contains the data in database and has the satisfying pattern. Then XMLParser converts s_j to o_j . Hence, o_k is true. The output is the svg file that is used for displaying the map on the Internet GIS application. Thus, Co is correct with respect to the input assertion s_j and the output assertion o_k [5].

However, when a number of the input streams in input file I are added and these input streams associate with the original, a closure occurs. Hence, the new input files I^* have both the original and the added input streams. Thus, $I \subseteq I^*$. In case of the output files O , the closure of the output relation is also constructed in the similar condition. Thus, $O \subseteq O^*$ where O^* is a new set of output files which contains both the original and the added output files.

Then, the assertion $s_j \in I^*$ if $s_j \in I$ and $I \subseteq I^*$. Also, the assertion $o_k \in O^*$ if $o_k \in O$ and $O \subseteq O^*$. Therefore, Co implies correct with respect to the input assertion s_j and the output assertion o_k . As the correctness assertion of input space, output space, and closures of their relations, XMLParser can be inferred that it is the robust program.

Definition 4: A *finite automaton* is a 5-tuple $(Q, \Sigma, \delta, q_0, F)$ [6], where

Q is a finite set called the *states*,

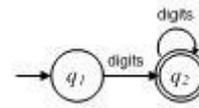


Figure 6. The state diagram of two-state finite automaton

Σ is a finite set called the *alphabet*,

$\delta: Q \times \Sigma \rightarrow Q$ is the *transition function*,

$q_0 \in Q$ is the *start state*, and

$F \subseteq Q$ is the *set of accept states*.

For example, Fig. 6 shows the state diagram of finite automaton (M). This machine accepts all strings that have at least one digit. Thus

$$L(M) = \{w \mid w \text{ contains at least one digit}\}$$

Definition 5: A *context-free grammar* is a 4-tuple (V, Σ, R, S) [6], where

V is a finite set called the *variables*,

Σ is a finite set, disjoint from V , called the *terminals*,

R is a finite set of *rules*, with each rule being a variable and a string of variables and terminals,

$S \in V$ is the *start variable*.

For example, a grammar for coordinate **point(0,0)** is

$$S \rightarrow T(C)$$

$$T \rightarrow \mathbf{point}$$

$$C \rightarrow D, D$$

$$D \rightarrow \mathbf{digits}$$

where V is $\{S, T, C, D\}$ and Σ is $\{\mathbf{point}, \mathbf{digits}, (,), ,\}$

III. TECHNIQUE IMPLEMENTATIONS

In this section, our Internet GIS system architecture is discussed in more detail. The vector layer overlay techniques is also discussed. The spatial analysis tools of how each using are briefly displayed as well.

A. Internet GIS Architecture

The architecture of Internet GIS system is given in Fig. 7. The architecture can be classified into three main modules as follows: Data Collections as Database, Pre-processing, and Display module included Operations and User Interface [12].

Database module includes the general database and the spatial database management system, data collections, import and query data processing. The application has been specifically developed not only to handles both geographic and

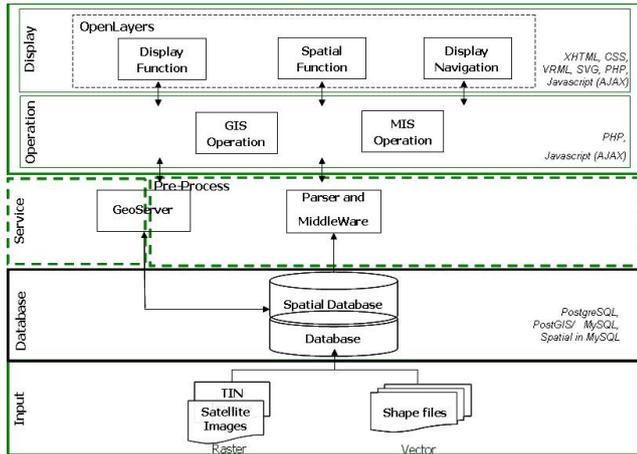


Figure 7. The Internet GIS system architecture.

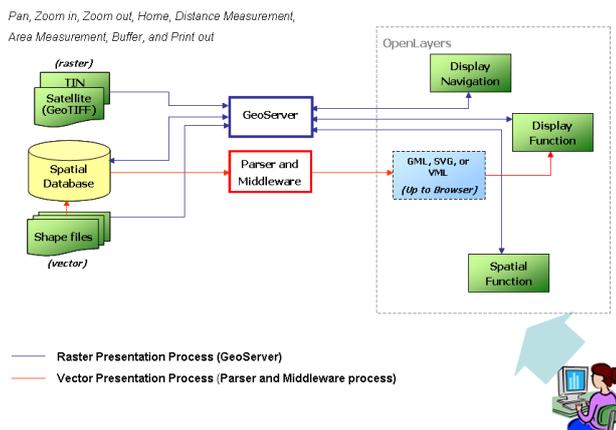


Figure 8. The Internet GIS system workflow.

non-geographic information, but also to handles both vector and raster data formats. In Pre-processing module, the vector and raster data inputs are prepared and processed before they are arranged in the forms of HAI Internet GIS representation in the display interface [11]. The workflow of the internet GIS system is shown in Fig. 8.

The vector data is the geographic data representation in coordinate form which includes points, lines and polygons. In the Internet GIS application, the original vector input files (shape files) are imported to the open source spatial database. These data must be converted to SVG or VML data format (depend on types of web browser) by Parser processing before they can be represented in the map images on the client.

The raster data is the geo-referenced image, for example, aerial or satellite photograph. These images are generated by applying GeoServer that queries data from spatial database. Both types of data representation are managed by and overlaid on OpenLayers which also generates the base map of the system.

GIS can arrange the location data such as rivers, reservoirs, and telemeter stations that are line, polygon, and point types,

respectively, into GIS layers or thematic layers. Each layer should be designed to contain only one type and one category of spatial data [11].

Our Internet GIS system have been developed and run on a Linux operating system server using Javascript for interface programming. In addition, we use the open source database and spatial database such as PostgreSQL and PostGIS, respectively, to collect the spatial and non-spatial data. These data are converted to the map form and can be accessed from anywhere clients.

B. Vector Data Overlay Technique

The main aim of this section to present the concept and algorithm associated with vector overlay technique to render vector data on OpenLayers. The detail of mentioned technique is addressed in [12].

The technique in Fig. 4 or the *model interaction environment* style [7] is the process of vector data file converted to the SVG data file by the XMLParser before overlaid on OpenLayers base map. The data can be generated and manipulated at the server, and the client is only a passive viewer as illustrated in Fig. 9. However, this method has to have executed program within the server for providing a dynamic map interaction.

XMLParser generates the lookup table to retrieve the values or the corresponding operations. The lookup table is a data structure, usually array or associative array [14]. The structure of lookup table applied in XMLParser is illustrated in Tab. I.

C. Spatial Analysis Tools

Recently, the GIS technology has been developed and applied for spatial data management and utilize that data for problem analysis and solving such as monitoring natural disasters, solving water insufficiency in agricultural areas, and etc. Consequently, there are many effective software tools for GIS analysis on web applications.

Additional technologies are needed to handle elevation and calculate the distance display on the websites and to be able to calculate the surface areas with the elevation values. Therefore, this section proposes and applies the procedure of an area with elevation value calculator tool on the Internet GIS System as the data limited in the vector type [10].

The previous mentioned spatial analysis tools have been developed in the Internet GIS system. It consists of four tools as follows:

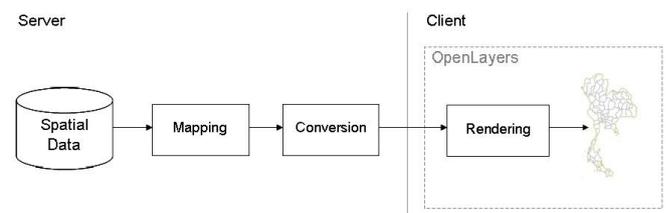


Figure 9. Model interaction environment architecture.

TABLE I. THE STRUCTURE OF LOOKUP TABLE

Data Type	Regular Expression	Description
Geocode	[0-9][0-9][0-9]+	Geocode contains at least two digits i.e. 10, 4010, 500503.
Class	[a-z]*	Class indicates the feature and color of areas i.e. fill color, stroke color, and stroke width.
Geotype	POINT LINESTRING POLYGON	Geotype means geographical features i.e. points, lines, and polygons.
Coordinate	“(“[0-9]* [0-9]* ”)”	Coordinate i.e. (0 0), ((9 9), (30 40))

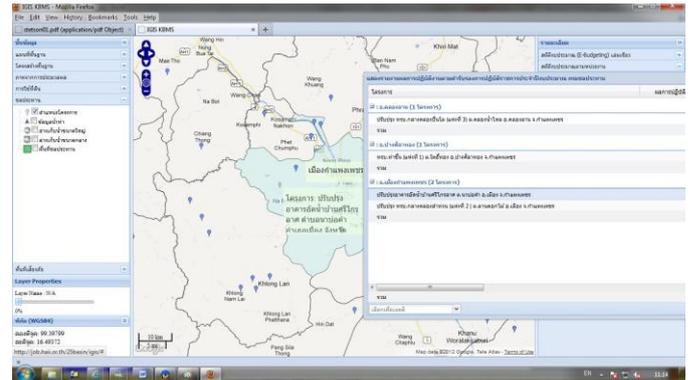


Figure 11. The MIS operation: selected positions.

- a)  *Surface calculator*: Calculate the surface areas.
- b)  *Distance measurement*: Calculate the surface distance.
- c)  *Elevation profile*: Display the elevation values of the surface.
- d)  *Buffer areas*: Display the buffer areas in required radius.

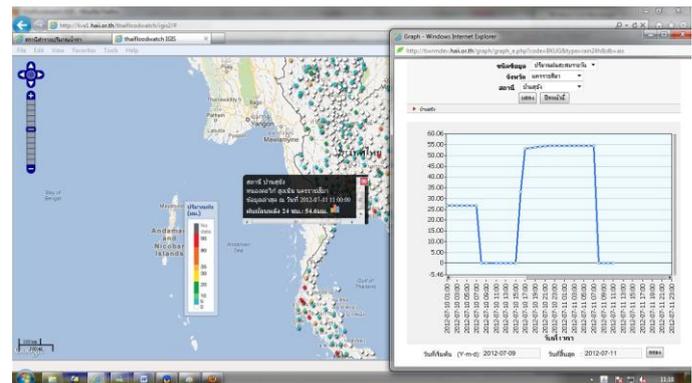


Figure 12. The position of telemeter stations and the record graph.

IV. EXAMPLES OF INTERNET GIS APPLICATIONS FOR THAILAND WATER MANAGEMENT

In this section, the interface example of Internet GIS system being GIS-MIS for Integrated Water Resources Management of Thailand project is illustrated. It is developed by Hydro and Agro Informatics Institute. Fig. 3 demonstrates a web application of GIS-MIS for Integrated Water Resources Management of Thailand. The left side of the screen is the GIS layer menu for overlaying on the map. The MIS operations are the representation of non-geographical information processing which all MIS operations appear on the other side of screen. Fig. 10 shows the applied MIS in Internet GIS application. All information is displayed in table form on the MIS area and the selected information is displayed on the map. These data are queried from databases and then are processed to represent the statistical data as the reports or charts. Moreover, the quantitative data can be indicated by filling colors on the map. In addition, the points or positions being spatial data associated with the selected information can be simultaneously overlaid on the map as an interface in Fig. 11.

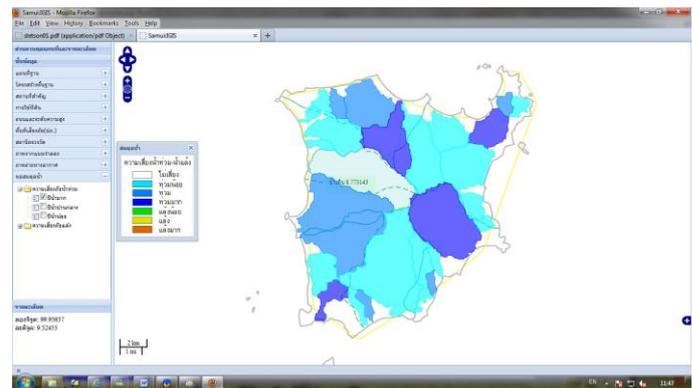


Figure 13. The water balance result.

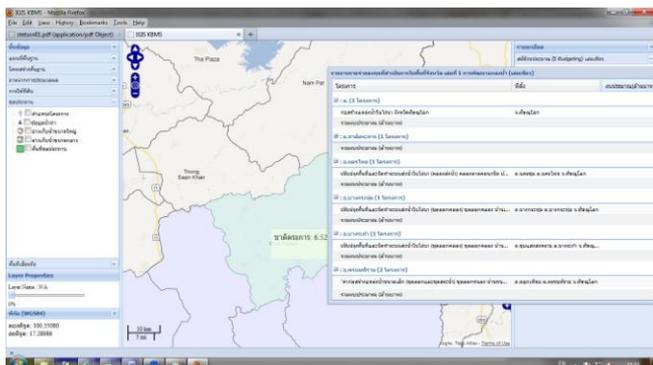


Figure 10. The MIS operation: filling color on the map.

Fig.12 shows the position of telemeter stations on the map which display the amount of rainfall that have accumulated within the last 24 hours. They are updated every 10 minutes. The graph result of each station can demonstrate and report the total precipitation values. The results of water balance which are the outcomes from water model can be displayed on the map as shown in Fig. 13 as well. Fig. 14 shows the image of one day rainfall forecast on the Internet GIS map. This image is generated from WRF climate model.

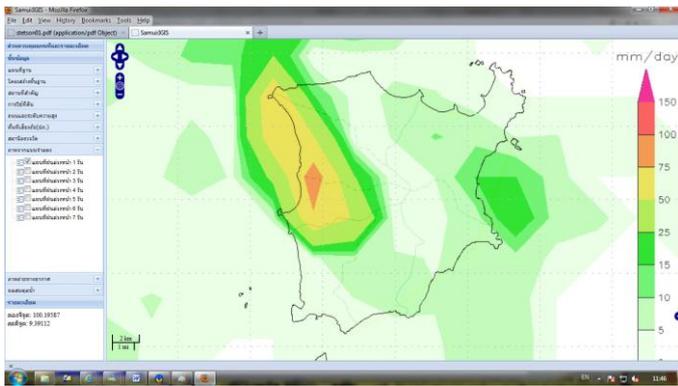


Figure 14. The output image from WRF climate model.

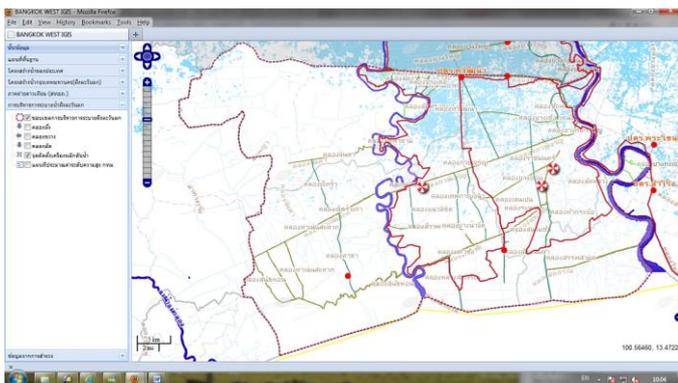


Figure 15. The western Bangkok area between Thailand flood event in 2011.

Fig. 15 shows the rivers, streams and flood areas of the Western Bangkok of Thailand in 2011 between flood event intervals. It was one part that helps support for decision on solving flood problems.

V. CONCLUSION

The Internet GIS system have been developed and applied to use for managing water resources, monitoring flood disasters, and sometime solving water insufficiency in agricultural areas. Its applications are the online decision support tools to help guide decision making and planning because it helps create understanding the water distribution networks operations in areas. In addition, the Internet GIS system is developed on combining GIS with MIS which can perform more perfectly and support government to make decisions better [7]. In other words, the implementations of

Internet GIS system can serve the water resource information to help us the water management plan in each area.

In this system, the vector data of GIS developed by XMLParser [7] are demonstrated high efficiency and robustly for complex geographic information. XMLParser is used to create and maintain spatial information and operation stored in PostGIS. Moreover, OpenLayers and GeoServer are implemented in the Internet GIS system to display and generate geographic information, respectively. All software programs using in the Internet GIS system are based on the open source software.

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