SmartGIS: A SVG-based Tool for Visualizing and Monitoring of SARS Movement

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Abstract **Location-based data visualization employing geographical information system and information visualization provides an advanced means to assist with visual data exploration, hypothesis formation and decision making. An effective location-based data visualization system can significantly enhance the communication among decision-makers and facilitate the agreement on the most appropriate alternatives. This study presents SmartGIS, a tool integrating SVG, Web GIS, and data visualization techniques to augment the analytical capabilities of GIS-based spatial and temporal decision-making process. It provides an intuitive, interactive manipulation of SVG-based SARS map, dynamically generated from GIS database. SmartGIS provides hierarchical operations to allow a user to view SARS data at multiple levels of details on the Web. This facilitates the continuously visualizing and monitoring of SARS outbreak status. The implementation issues of SmartGIS are described and its applications to other areas are discussed.**

Keywords: GIS, SVG, Information Visualization, SARS

I. INTRODUCTION

Recent outbreak of SARS (Severe Acute Respiratory Syndrome) has gained great attention world wide. During the spring of 2003, people lived in Taiwan have only little or no knowledge about the newly deadly virus. How was the virus spread? What kind of actions people should take against the SARS virus? Do we need N95 masks when we went to hospitals? Unfortunately, our warriors in hospitals and the government failed to defend the deadly virus in the first round. As a result, it caused great panic and economic depression in our society. From management's perspective, their sense of risk management obviously was not good enough for them to deal with the newly crisis. During the SARS crisis, we had top officials from health department to talk and explain the virus outbreak status to the public on the TV program each day. However, the visualization tools and information systems they used were far from effective to communicate with people well about the SARS crisis. Lacking strong support in logistics management, tracking, and information systems was one of the key reasons that why we could not control the spreading of virus effectively. Apparently, we need a better information system and visualization system to help monitoring, and tracking potential virus-affected persons so that potential life-lost can be reduced and people can live safely and travel freely.

Visualization, graphical communication of information, meant constructing a visual image in the mind (Shorter Oxford English Dictionary) [1]. But now it has been recognized as a powerful paradigm that exploiting human visual processing to explore, understand and explain the insight of data. Scientific visualizations gained its popularity in last decade. While information visualization, which aims at supporting discovery and analysis of non-spatial business data, has just gradually emerged as a distinct research filed. Information visualization techniques such as scatter matrix, parallel coordinates, hierarchical tree-map or distortion techniques such as hyperbolic tree-map are some of the most popular techniques to help people exploring and understanding large quantity of data at a glance [2]. Location-based data visualization employing geographical information system and information visualization provides another paradigm that can provide effective communicative paradigm to help exploring, forming and confirming hypothesis, and explaining location-associated data. An effective location-based data visualization system can significantly enhance the communication among decision-makers and facilitate the agreement on the most appropriate alternatives, and spatial data can be systematically organized, understood, and used to make strategic decisions.

On-line delivery of GIS maps using Web as an interface is getting popular recently. Maps on-demands, overview, zooming, and level of details are often required for real-time interaction with GIS applications. Image-based maps are not suitable for such interactions. Vector-based map representations provide substantially improving delivery on the Web than those of image-based maps. In addition, it offers adaptable images for high quality display. SVG (Scalable Vector Graphics) [3], the two dimensional web graphics standard, has recently gained its popularity among the Web GIS research community. SVG is a XML-based 2D Graphics format that provides resolution independent scalable graphics and SMIL (Synchronous Multimedia Integration Language) [4] animation. It inherits all the advantages of XML (Extensive Markup Language), including (1) dynamic interactivity, (2) search ability, (3) time and space efficiency, (4) extensibility, (5) accessibility, (6) interoperability, (7) internationalization, (8) distributed authoring, (9) progressive rendering and (10) readability [5].

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These benefits make it a good choice as a Web visual interface for on-line map delivery, manipulation and interactions on any computing devices, ranging from desktop PC to portable PDA.

The SmartGIS project was evolved during the SARS outbreak period. Our goal is aimed to develop a visual metaphors using advanced visualization, SVG, XML, and GIS techniques to help the public monitoring and understanding the virus outbreak situations. This paper presents SmartGIS, a tool integrating SVG, Web GIS, and data visualization techniques to augment the analytical capabilities of GIS-based spatial and temporal decision-making process. It provides an intuitive, interactive manipulation of SVG-based SARS map, dynamically generated from GIS database. SmartGIS provides hierarchical operations to allow a user to view SARS data at multiple levels of details on the Web. This facilitates the continuously visualizing and monitoring of SARS outbreak status. The implementation issues of SmartGIS are described and its applications to other areas are discussed. The rest of this paper is organized as follows. Section 2 discusses background and related works in detail. Section 3 presents the SmartGIS-A SARS VISULIZATION TOOL, including design and philosophy, architecture and implementation, and showing some empirical results of visualization. Section 4 concludes the research results and discusses potential applications and future research.

II. Background and Related Works

Using maps as a spatial analysis tool to study the source of disease is not new. In 1854, a major cholera outbreak in London took nearly six hundred lives. Dr. John Snow stopped the major cholera epidemic by using a hand-drawn map to demonstrate that the source of the disease was a contaminated water pump. The map is the most famous and classical visualization example in the field of medical cartography [6]. The key was the relationship of case locations to other features (water supply) on the map. Today, GIS success in epidemiology and disease outbreak surveillance is well known [7]. GIS is defined as an information system designed to work with data referenced by spatial or geographic co-ordinates [8]. GIS systems rely on two interrelated types of databases: the spatial database containing spatial features such as points (i.e. hospitals), lines (i.e., roads), or polygons (i.e., administrative districts) and the attribute database containing descriptive information of the spatial features: land use, type of soil, or distance from the regional centre. Maps in Geographic Information Systems are represented thematically. A standard topographic map will show roads, rivers, contour elevations, vegetation, human settlement patterns and other features on a single map sheet [9].

With the advancement of computer and network technologies, the Web-based GIS spatial analysis tool, WebGIS, is booming in both industry and research field. WebGIS is the solution for distributing electronic-map (e-map), GIS data and services on the Web. It plays a vital role in public health surveillance, safety, tour guide, crime analysis, environment monitoring, and urban ambulance planning and scheduling applications. Unfortunately, efficient delivering spatial information and related attributes on the Web is not a trivial task. Traditionally, maps are usually represented with image formats and are not well suited for map navigation and Internet transmission. Vector graphics such as Flash has shown wide popularity for Web multimedia. However, Flash's format is proprietary and it is not designed to interact with backend information server.

Developed by W3C, SVG, on the other hand, is designed to take advantages of XML's open standard while offers the same multimedia capabilities of Flash. SVG brings rich, compelling, interactive, high-resolution graphics to the Web. The SVG graphics can be progressively rendered to fit any size of display screen without suffering resolution loss. The suitability of SVG for deploying wireless application has been detailed discussed in [10]. The adaptive visualization of geoinformation using SVG on mobile devices can be found in [11]. In summary, SVG can be an idea visual interace for GIS applications, even on a small screen PDA or cellular phones. In addition, accessibility features of SVG can help the user search for information by adding metadata to a document [12].

There are different formats to encode GIS information. To support interoperable solutions between different systems and data formats, the Open GIS Consortium (OGC) develop GML (Geography Markup Language) [13] for presenting spatial information as well as related attributes in XML. The benefits of using GML has been discussed in [14].Using GML, XSLT (Extensible Stylesheet Transformation) and SVG, users can view the resulting maps on any computing devices such as PCs, PDAs and even cell phones without purchasing proprietary client-side GIS software. This approach is much more versatile and powerful than the conventional image-based method.

The discussion of visualization methods with GIS data such as assignment, joint analysis by linking and multiple views, brushing, focusing, viewpoint manipulation, fish-eye view, and color-map manipulation method can be found in [2,15].

III. SmartGIS - A SARS Visualization Tool

An effective location-based data visualization system can significantly enhance the communication among decision-makers and facilitate the agreement on the most appropriate alternatives. Hypotheses forming, exploring, and confirming can also be conducted through it. The integration of SVG, Web GIS, and data visualization is expected to greatly augment the analytical capabilities, such as monitoring and tracking, of GIS-based spatial decision-making process.

SmartGIS, a SVG-based tool for visualizing and monitoring of SARS movement developed in this study, provides an user friendly information visualization interface for data analysis and decision-making. Through SmartGIS, the decision-maker in SARS control center is expected to be able to develop and plan options for SARS prevention, make clear the implications of SARS outbreak, report the virus outbreak status to general public to let their mind at ease, and demonstrate the benefits of actions or procedures taken. The net effect is to provide strong support in logistics management for decision-makers, to improve the decision-making process and communication among the epidemic prevention planner, workers, and the various groups comprising the general public, and to encourage citizen participation through graphical presentations and data visualization that are familiar and easy to understand.

A. *Design Philosophy and Methodology*

Most current GIS systems are designed for the analysis and presentation of spatial data, lacking the support for the dynamic change of temporal data. Thus, the display for the same spatial data in different time series is mostly static. In order to display spatial data in different time series, it must be resorted to labor intensive human recognition. To solve this problem, SmartGIS augments spatial data with temporal information and is able to provide a dynamic view of spatial data in a given timeframe.

Data visualization techniques for exploring the GIS knowledge include assignment, joint analysis by linking multiple views, brushing, focusing, view point manipulation, fish-eye views, color map manipulation, and sequencing. SmartGIS incorporates several of them when displaying SARS movement in order to give real-time, precise, and easy to understand views to decision-makers to help them explain scenarios or predict future SARS movement.

Web GIS utilizes Web as a user interface for displaying or manipulating GIS information. While it allows easy access and offers a uniform interface, the use of BITMAP graphics format for presentation limits its applicability to diverse devices and its ability to show continuous changes of temporal data. SmartGIS takes advantages of SVG's capabilities such as XML-based standard, searchable embedded text, vector graphics, interactivity, and animation to provide an environment capable of showing the continuous changes of temporal and spatial data in addition to the manipulative animated SVG objects.

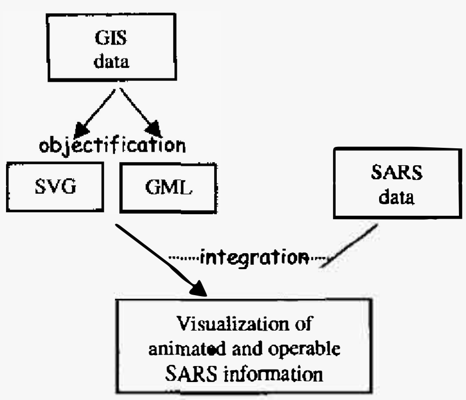

Figure 1 Integration process of GIS and SARS data

Figure 1 shows the conceptual data manipulation process of SmartGIS. SARS data are gathered from the official website of Department of Health in Taiwan and stored in MySQL database. GIS spatial data are obtained from ArcView and converted into GML and SVG formats respectively. The expressive power of GML is suitable for describing the structure and content of spatial data and for exchanging information with other GML systems. Through XLink and XPointer, an integrated distributed GIS system with indexing and querying can be built upon various GML data sources and destinations. SVG data are obtained first by transforming ArcView spatial data into SHP format which is then converted into SVG format through the use of ArcView-toWTK tool from Nedjo Rogers and Amri Rosyada [16]. Figure 2 shows the transforming and converting process from ArcView to SHP and SVG files.

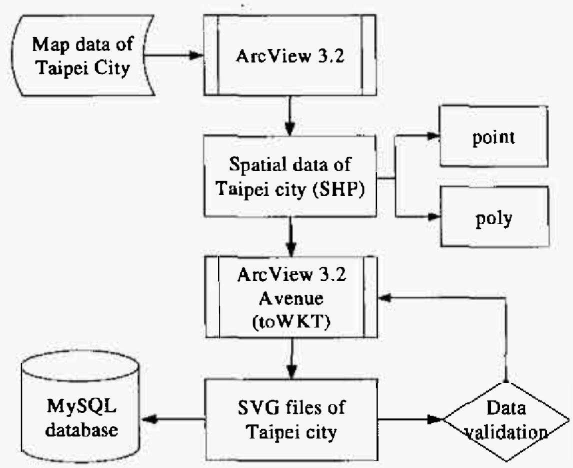

Figure 2 SHP and SVG representation of Taipei city

Figure 3 shows a GML example of the BeiTou county, Taipei. Figure 4 shows its corresponding SVG representation. After setting up the proper GML and SVG files for the targeted places, interactive visualizing of a specific area of the targeted places can be manipulated through the programming of SVG JavaScript DOM model via Web browsers (i.e. Internet Explorer with SVG plug-in).

```
<?xml version="1.0" encoding="UTF-8"?>
<_View1>
<StyledLayerDescriptor>
 <NamedLayer name="Tpe25_cl">
   .....
   .....
<featureCollection>
  <boundedBy>
    <Box>279867,2.7907e+006 326100,2.7599e+006</Box>
  </boundedBy>
  <featureMember>
    <Tpe25_cl>
      .....
      .....
        <LinearRing>
          <coordinates>305548.09,2789389.50 .....
          </coordinates>
        </LinearRing>
     .....
     .....
     <Tpe25_cl.Shape>Polygon</Tpe25_cl.Shape>
     <Tpe25_cl.Town_name>BeiTou</Tpe25_cl.Town_name>
     <Tpe25_cl.County_nam>Taipei</Tpe25_cl.County_nam>
   </Tpe25_cl>
   ....
</_View1>
```

Figure 3 GML description for BeiTou, Taipei

```
<svg id="map" width="645px" height="437px" viewBox="0 0
   6450000 4370000">
  <g id="Tpe25_cl">
    <path id="Tpe25_cl" d="M 3184423 198636 L 3190374 199886
       L 3211073 209410 L 3217075 210157 L 3223866 210157 L
       3231322 214366 L 3233230 237279 L 3239232 259401 L
       3243720 273149 L 3253147 285761 L 3257295 296463 L
       3262908 320913 L 3265542 328958 L 3263638 341570 L
       3253876 364842 L 3250116 385456 L 3251238 390843 L
       3258420 410265 L 3262908 420651 L 3285848 445028 L
       3120418 230383 L 3125692 226965 L 3140729 223948 L
       3148636 222009 ......... L 3184423 198636 z" />
  </g>
</svg>
```

Figure 4 SVG description for BeiTou, Taipei

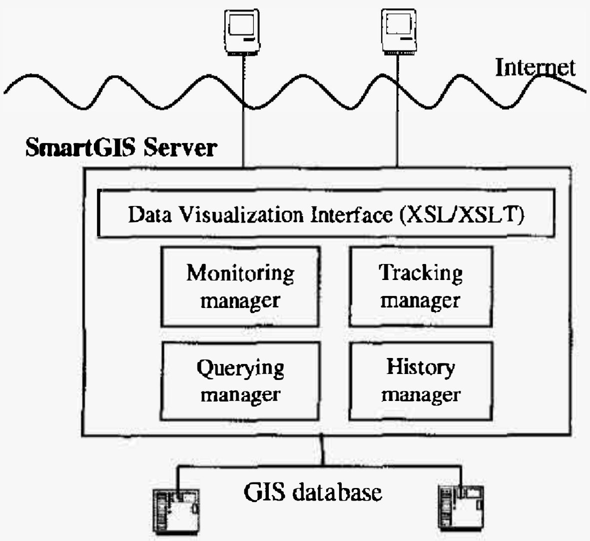

Figure 5 SmartGIS architecture

B. *Architecture and Implementation*

The SmartGIS architecture for Taipei city is shown in Figure 5. It is composed of five components: data visualization interface (DVI), monitoring manager (MM), tracking manager (TM), querying manager (QM), and history manager (HM). Taipei Web GIS database is built on top of MySQL database system. The architecture of SmartGIS is not assumed to be centralized. In fact, it is distributed in nature in that SARS data are gathered and integrated from different data sources. The communication between components is through SOAP (Simple Object Access Protocol) to ensure interoperability in case components are implemented in different programming languages. Currently, SmartGIS is built using JavaServlet, JavaScript, SVG, and GML. The functionality of each component is described briefly as follows.

- Data visualization interface (DVI)
  The component is responsible for accepting requests from SVG-enabled web browser and sending them to other components for processing. The presentation of responses is dynamically generated and formatted using XSLT into SVG for displaying on client's web browser.
- Monitoring manager (MM)
  Continuous monitoring the outbreaks of disease is a critical element in every epidemic control center. Monitoring manager intermittently scans and filters incoming SARS data and alters decision-makers whenever an abnormal situation has brought about, such as an unusual high number of infection instances have occurred in a specific hospital. This component uses the tracking capability of the tracking manger to track the consequences of a specific thing (person or place) of interest.
- Tracking manager (TM)
  The tracking manager is specifically designed for decision-makers to track a particular instance of interest. By utilizing the animation feature of SVG, a graphical animated tracking path in SmartGIS can be progressively displayed on client's browser as time goes by. The tracking intervals and altering methods can be specified in advance or can be dynamically set at any time.
- History manager (HM)
  Historical information provides an insight for the development of response plans, diagnostic methods or test procedures. Rapid access to historical information is a must for instantaneous emergency action and treatment. History manager records and maintains SARS outbreaks and progresses information.
- Querying manager (QM)
  Querying spatial data and disease data at the same time has been difficult in the past. In SmartGIS, the spatial data and SARS data are linked through XLink and XPointer and thus the querying of SARS in a particular place is made easy.

C. *SVG-based Web GIS Data Visualization*

The user interface of SmartGIS is shown in Figure 6, where the left panel in hierarchical tree structure shows the SARS outbreaks information. The right panel is for querying. Logical query operators include the disjunction OR, conjunction AND, and negation NOT. Relational operators such as >, <, >=, and != are also supported. Data visualization techniques such as brushing, focusing, or sequencing can be specified in order to display the desired presentation. Figure 6 shows SmartGIS's user interface where the system bar is enlarged and pointed by the red arrow. The system bar offers tools (from left to right) for zoom-in, restore zoom-out, single criteria query, multiple criteria query, data visualization techniques setting, time sequencing setting, book-mark setting, automatic label generation, manual label setting, system options, about SmartGIS, and system information.

Dynamic and interactive spatial and temporal animation of SARS outbreaks provides detailed and important understanding of current situations and can be used to predict future trends. Figure 7 shows the SARS infection situations in four areas of Taipei city from April 12 to May 2 in 2003. Notice that significance of infection in those four areas is depicted using different color tones. For example, seriously infected area is shown using dark color while slightly infected area is shown using light color. In addition, pie graph or bar graph presentations are also supported.

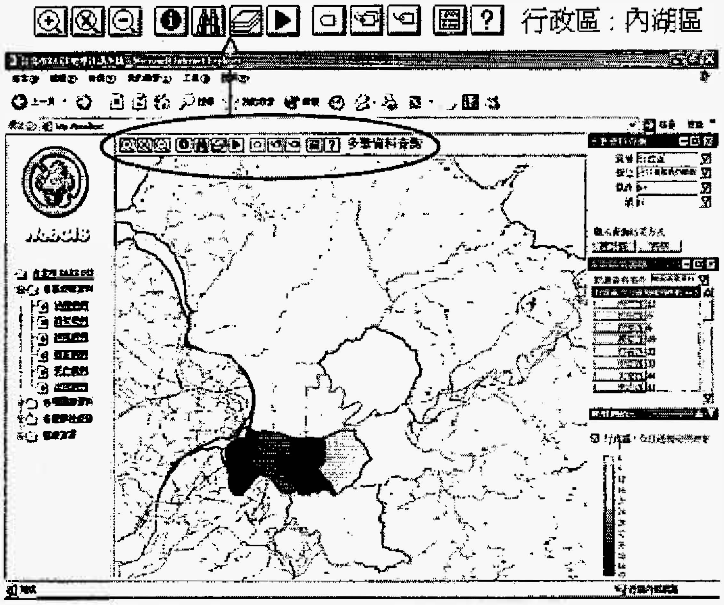

Figure 6 SmartGIS user interface

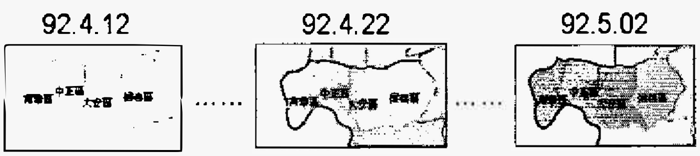

Figure 7 Temporal & spatial presentation of SARS outbreak

IV. CONCLUSION

Geographical information systems (GIS) have been widely used in research and practice projects. The advent of Internet and World Wide Web has pushed the development of Web GIS offering a uniform and user friendly interface for web browsers. However, most Web GIS systems fall short in using raster (BITMAP) graphics for presentation. Raster graphics is not scalable and extensible, and their file sizes are usually much bigger than vector-based graphics files.

This study builds a SVG-based data visualization tool SmartGIS, integrating SVG, GML, GIS, and Java technologies into a seamless environment. SmartGIS uses Scalable Vector Graphics to provide an interactive manipulation of SARS map. It augments spatial data with temporal information and provides a dynamic view of spatial data together with temporal data of SARS movement. Through SmartGIS, the decision-maker in SARS control center is expected to be able to develop and plan options for SARS prevention, make clear the implications of SARS outbreak, report the virus outbreak status to general public to let their mind at ease, and demonstrate the benefits of actions or procedures taken. The net effect is to provide strong support in logistics management for decision-makers, to improve the decision-making process and communication among the epidemic prevention planner, workers, and the various groups comprising the general public, and to encourage citizen participation through graphical presentations and data visualization that are familiar and easy to understand.

While this study shows the benefits of integrating SVG, GML, GIS, and data visualization techniques, there are still numerous challenges awaited to be overcome. Among them are:

- Mobile device support: mobile devices have been widely available and used in almost every area. The support for mobile device is an essential feature for epidemic disease control or disaster management. The small form-factor and limited computing power of mobile devices pose a great challenge for Web GIS researchers.
- 3D visualization support: the support of 3D visualization will open another door to look at the SARS outbreak movement in totally different view, which might not be achievable in 2D visualization.
- Data mining support: the powerful classification and association abilities of data mining will be useful in finding the hidden patterns of SARS outbreak. The relation between SARS and other epidemic disease might also be uncovered through the use of data mining techniques.

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