GEOSPATIAL INFORMATICS TECHNIQUES
BASED REPRODUCTIVE HEALTH SURVEILLANCE SYSTEM

L.Q. Zhang [a,b]

a Institute of Remote Sensing Applications, Chinese Academy of Sciences, P.O.BOX 9718, Beijing, 100101, P.R China
- lqzhang@irsa.ac.cn
b Graduate University of Chinese Academy of Sciences, P.O.BOX 9718, Beijing, China, 100101, P.R China

KEY WORDS: Statistics, Geospatial Informatics Techniques, Analysis, Thematic mapping, Integration, Programming, Software

ABSTRACT:

Reproductive health has been paid more attention by international society since the concept was put forward in the International Conference on Population and Development (ICPD) in Cairo, Egypt in 1994. This paper analyzes firstly the application of geospatial information techniques, including Global Positioning System (GPS), Remote Sensing (RS) and Geographic Information System (GIS), in surveillance of reproductive health in China. Based on the present Electronic Reproductive Health Surveillance System (ERHSS), the solution scheme of Reproductive Health Surveillance Geographic Information System (RHS/GIS), including data architecture and organization, system logic structure and development, was discussed to integrate geospatial information techniques in the reproductive health surveillance in detail. And an applied paradigm was made to demonstrate its application effect.

1. INTRODUCTION

Reproductive health has been paid more attention by international society since the concept was put forward in the International Conference on Population and Development (ICPD) in Cairo, Egypt in 1994. The conference urged all national governments to make responsible efforts on reproductive health care to resolve the population issues. ICPD explained that the meaning of "Reproductive Health" is reproductive ability, health protection of pregnant women and infants, harmonious sex life between two spouses, preventing and controlling the sexually transmitted diseases(M.J. Alcala, 1994). To prevent birth defects and disabilities, the cooperation in the surveillance of reproductive health in China has been implemented by Sino-US for 10 years(Ye RongWei, 2005). The on-going system, called Electronic Reproductive Health Surveillance System (ERHSS) runs in National Center for Maternal and Infant Health（NCMIH. It consists of four main sub-systems as follows: Electronic Data Collection System，Electronic Data Transmission System, Electronic Information Reporting System, Back-up system. It c a n transfer the surveillance data to the server in Reproductive Health Information Management Centre from the selected counties by Local Area Network (LAN) or by dial-up Internet(Ye Rongwei, et al., 2001, IIU Yousheng, et al., 2002, Ye RongWei, 2005). The surveillance area coves only about 40 counties in Hebei, Jiangsu, Zhejiang and Shanxi Provinces.

A series of researches shows that there are certain relationships between reproductive health and the environment factors(Bai Tingjun, et al., 2007). It is necessary to apply the geospatial informatics techniques to carry out the surveillance, deal with the information, analyze and confirm the environment factors to impact on reproductive health defects and disabilities. But due to lack of the corresponding spatial analysing tools, some further analysis and processing of the data can only be done by statistical analysis tool software, such as SPSS and etc. Moreover, the data and some analysis results can only be displayed by statistic spreadsheet, statistic bar chart, statistic pie chart, or histogram. Geospatial Informatics techniques , especially for Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS), can be integrated by different applications in an applied system (Du Pei-jun, et al., 2000). They can meet the requirements of public health researches via providing above powerful tools, and will bring traditional public health researches great changes. Geospatial Informatics techniques are more and more popular in public health(Bai Tingjun, et al., 2007).

On basis of this consideration, Reproductive Health Surveillance Geographic Information System (RHS/GIS) was put forward. RHS/GIS can not only deal with the surveillance data but also implement some above special analysis and generate some thematic maps. It is suitable to complete the routine process of the data by surveillance and spot survey.

This paper aims to discuss the scheme of RHS/GIS which is taken into account the integration of Geospatial Informatics techniques and ERHESS. It analyzes firstly the application of Geospatial Informatics Techniques in reproductive health surveillance, which is the objective of the system. Then it discusses the technical scheme to implement the above objective. Then an application was made to demonstrate its applied affectivity. Finally, its advantages and disadvantages are summarized and analyzed.

2. THE APPLICATION OF GEOSPATIAL INFORMATICS TECHNIQUES

According to the authors' investigation and analysis, Geospatial Informatics techniques can provide a strong support to the reproductive surveillance in the following aspects.

2.1 The Application of GIS

GIS is a computer system relevant to administration and analysis of spatial data together with multi-source of data, including remote sensing image raster or vector map and displaying them by visualization. GIS can complete some

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* Corresponding Author: lqzhang@irsa.ac.cn

applications as follows: spatial display, thematic map, analysis with multi-sources and time series analysis(Alain F. Zuur, et al., 2007). GIS is able to do rapid mapping on cases distribution and display the prevalence visually and precisely in detail. It can also detect or extrapolate where the problems are in the surveillance area(Jin Kyung Park, et al., 2007, Bai Tingjun, et al., 2007). The characteristics of its spatial distribution and its evolution may be explored through spatial display. GIS is convenient to draw thematic maps for the results of reproductive surveillance. And its spatial analysis function is also very helpful to find the correlation with other environment factors. In a word, GIS can improve the analysis ability of making full use of the reproductive health routine surveillance data.

2.2 The Application of GPS

The spatial location of research objects and associated factors is the foundation on spatial analysis. The statistics data, collected for the administrative unit, may be located according to its administrative code. But the administrative boundaries are only the artificial boundaries, while the disease development is not confined by them. It is always the foundation of any research of disease and generating maps for its specific location and range of occurrence. Besides, some relevant factors, such as hospitals, chemical plants and so on, need be mapped to analyze their correlation. In a word, the spatial location with high precision will make great improvement in the research of reproductive health.

GPS is a form of satellite communication that allows users to get their three dimensional position with a possible accuracy of less than 15 meters in any weather conditions, anywhere in the world, 24 hours a day (MIS Bureau, 2001). It is convenient to investigation for the interesting observation spots.

2.3 The Application of RS

The geometric and geographical information for a large range can be acquired frequently by RS sensors with low price; this can help the researchers know the study area roughly in a macro scale. Some ecological indicators, such as rainfall, humidity, fractional vegetation coverage, surface temperature and so on, may be extracted quickly and economically using remote sensing techniques. So it can provide vast resource for exploring all the associated factors to the research object. Some famous experts, such as Curran, Rogers, Tucker, Mayer, Dister, Pinson and so on, have already done some associated pioneering researches(NIU Hong-feng and GUO Jia-gang., 2006). In a word, it has been well known that RS will have an abroad applied prospect in reproductive health surveillance researches.

In short, Geospatial Informatics techniques can not only supplement the measures for the present surveillance effectively, but also make great improvement in data analyzing and processing. It may finally enhance the analysis ability of exploring the reproductive health surveillance data.

3. THE TECHNICAL SCHEME

RHS/GIS was developed to implement the application of Geospatial Informatics techniques in reproductive health surveillance based on ERHSS. Besides, the three basic requirements were made to RHS/GIS as follows. Firstly, there are four levels of administrative units from bottom to top, township, county, city and province, the basic surveillance unit is the administrative township. Secondly, it will be also required

to ensure the application throughout mainland China, and ERHSS was only implemented in 45 counties Mainland China. Finally, it is not an independent but an auxiliary system, and is nearly equal to the extensive function module for ERHSS.

This section will discuss the technical scheme of ERHSS. It includes four components as follows: workflow, data analysis and organization, logic structure and its development and implementation.

3.1 Workflow

RHS/GIS aims mainly to integrate the routine statistic analysis and spatial analysis based on the locations of reproductive health surveillance information, and improve the analysis ability of exploring reproductive health surveillance. Its workflow shows in figure 1.
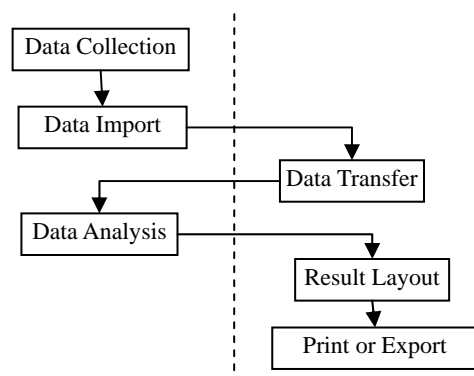

Figure 1. Workflow of RHS/GIS

(1) Data Collection
The data from the routine reproductive health surveillance is directly collected into computers by the staff members in local of Maternal and Infant Health Center. The data include women's antemarital examination, prenatal examination, childbirth and postpartum visits, and the new-born children's medical care examination in hospitals. All these data will be stored in the server of surveillance center, and be managed uniformly using HRESS. According to the specific requirements, some surveys will be done for some specified regions using GPS by the professionals at random. And the background information is acquired by remote sensing.

(2) Data Import
The routine reproductive health surveillance data was firstly input into the database of EHRSS directly. RHS/GIS is only use the *.dbf file created by EHRSS to implement the location of surveillance data. And then the remote sensing data for the environmental background was firstly processed using other software, such as ERDAS, ENVI and so on. Its processing results were imported into the database. Next, the GPS data was imported into the vector layer files as well according to the coordinates collected by GPS in spot. The administrative boundary data, which was store in *.shp, was converted into the vector layer files before they are imported into the database. Finally, they are stored in the surveillance data server and can be downloaded in each client for specific applications. All spatial corresponding work is done in the local computer.

(3) Data Transfer

From the top to the bottom of the surveillance network, we designed the three-level nodes: national level, county level and hospital level, which are separately maintained and managed by National Center for Maternal and Infant Health of Peking University Medical Science Center, Miami Children's Hospital for counties or cities and local hospitals. The reproductive health surveillance data is firstly transferred to the certain county center from hospitals under its administrative area, then to the National Center (Ye Rongwei, et al., 2001). GPS data will be transferred to the National Center. The map data was made and imported in the client, then was uploaded to the sever to the further applications.

(4)Data Analysis

RHS/GIS can do the routine statistics analysis, spatial analysis and spatial display in data analysis workflow. By symbology, it can assemble the different attributes into specified classes in order that the corresponding analysis can be done to make sure of the status of reproductive health and to forecast some trends of reproductive health diseases or phenomenon. Sometime spatial display is necessary to the dynamic changes of surveillance information visually and based on their locations information. Besides, multi-layers display synchronously using the geo-coordinate can show the correlation among corresponding factors visually.

(5)Layout and Export

Besides these routine electronic forms, the thematic maps can also be the analysis results. Typically, thematic map includes some elements, such as title, legend, scale, annotation text, directional indicator, source and credits and a border. And these map pieces must be systematically arranged around and upon the map with standard format. Besides the thematic map can be exported into other picture files, such as *.tiff, *jpeg and so on.

In short, compare with RHESS, RHS/GIS implements the visual presentation of surveillance data, expands the surveillance means, extends the surveillance contents and enhances the analysis ability of reproductive health surveillance.

3.2 Data Organization

According to the above workflow, there are some types of data of RHS/GIS as follows: surveillance data of reproductive health, remote sensing image data and thematic map data, administrative boundary data and data collected by GPS.

(1) Surveillance data

The surveillance data for reproductive health were collected for township or community at an interval of a week. They were transferred into the database located in the server of Surveillance Center. In ERHSS, these surveillance data were managed using Sybase database. And the Sybase database was used to organize the surveillance data in RHS/GIS as well.

(2) Remote Sensing Image data and Thematic Map Data

There are only two types of map files, vector and raster in RHS/GIS. Thematic maps are vector data, and remote sensing image data are the raster data. So the two kinds of map files are developed to be stored respectively. And the vector data are stored as *.dig, which derive from the vector data format of an open-sources software named GRASS. Besides, the specified *.dbf files are added into the vector data file to store the attribute information of the different features (refer to the factors which are relevant to the reproductive health). And some necessary modification to the map files' format in order to process the complicated polygons composed by

multi-components. And the raster data are stored with *.ras format designed by authors' research group. The two types of data are useful for specific application projects and the important archives. So they are stored in the server, and may be used after be downloaded to the local computer.

(3) Administrative Boundary Data

In china, there are four-level administrative units from top to bottom: province, city, county and town. For this study, we used the data according to the statistic in 2001. There are 2861 counties in the mainland of china and 40000 townships. Different administrative boundaries need to be presented visually with different scales. In order to save the processing time, the administrative boundaries map of town level was portioned into many data files according to the counties. Each of all the administrative boundaries data has its identified code, name, area and some corresponding attribute information. The corresponding attribute information were stored in *.DBF file. They were comprised into the setup file as a part of system files. And they will be set in the local computer during installing.

(4) Data collected by GPS

The data, collected by GPS, are the coordinates of a series of points in fact. And they are firstly stored with TXT format while they are produced in the field or the spot, and then they can be converted into the vector data in order to match with their background maps or environmental information. They can be converted in the local computer and then can be transferred to the server.
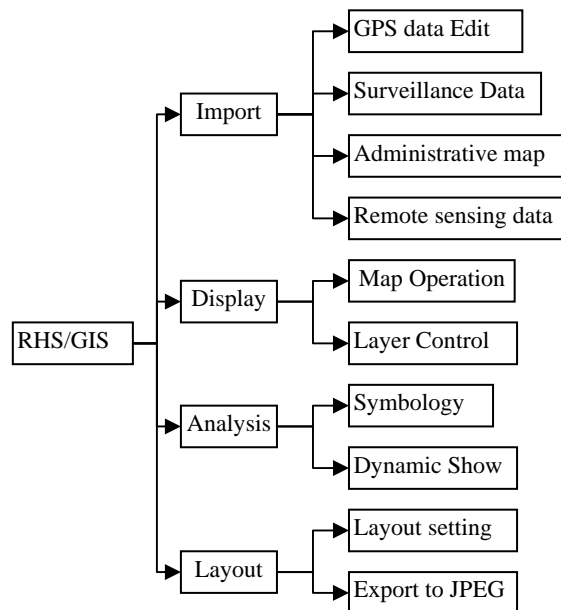

Figure. 2 The Function Structure of RHS/GIS for Client

3.3 System's Logic Structure

RHS/GIS was built based on the client/server structure, and it has two component sections, one is the sever and the other is the client. Its server manages all the collected surveillance data for reproductive health using Sybase database system in UINX Operational System. And it provides the different data accesses and operational service for the users under the different

authorizations. The client implements data importing, query, display, map browsing, analysis, generation of thematic maps and so on in Windows Operational System. It constitutes four modules as follows: Data Import, Data Display, Analysis and Layout. And its function architecture shows in Figure 2. The *.dbf file is used to connect EHRSS and RHS/GIS.

Import module implements mainly the creating of all map data files and their format transferring. Firstly, GPS Edit Module can import data of the spots from GPS receiver, and create a new thematic layer according to the recording coordinates of the spots. Then, Surveillance Data Module accomplishes the match to the locations of surveillance information by integrating the administrative boundary maps and the surveillance attribute data tables into a thematic layer according to their common codes. Next, Administrative Map Module can import the administrative map file with *.shp format into *.dig format. Finally, Remote Sensing Map Module converts the other common image data format, such as *.tiff, *.bmp and so on, to *.ras.

Display Module is used to implement the data display and some associated functions. There are two sub modules as follows: Map operation and Layer control. Map operation sub module mainly implements the correctly drawing of current documents. Besides, it also implements some common functions, such as zoom in, zoom out, pan, full-extent and etc. Layer Control Module controls the specified contents of the current document by inserting, removing and removing all map layers. In RHS/GIS, layer can only be processed as a logic unit for map data. And the two layer class, raster layer and vector layer, were separately designed for the two map data separately.

Analysis Module implements some special map drawing methods to visually expressing different thematic and is the extensive function module for Display Module in fact. Firstly, through setting some associated attributes, the layer can be drawn using different methods, such as unique values, graduated colors, pie and bar. Secondly, the order of the layers in current document is changed freely to draw firstly the interesting sections. Thirdly, the evolution progress of the disease may be shown for the specified region using Dynamic Show Module.

Layout Module implements the presentation for layout, print and exporting the thematic map. Firstly, it provides several layout elements, such as north arrow, title, scale bar, text, legend, picture and border. It has also implemented some associated functions to deal with these items to layout a perfect thematic map. And the print function was realized to correspond to the expected paper maps. Finally, the layout result may be transferred into the image file with *.jpeg by Export to JPEG Module.

3.4 Development and Implement

RHS/GIS was developed by using object-orient method in the developing environment of visual C++ 6.0. Some open source programs were used in this system.

Raster data format and operations were accomplished by using OPENCV function library developed by Intel Inc. The OpenCV implements a wide variety of tools for image interpretation. It is compatible with Intel® Image Processing Library (IPL) that implements low-level operations on digital images. In spite of primitives such as binarization, filtering, image statistics, pyramids, OpenCV is mostly a high-level library implementing

algorithms for calibration techniques (Camera Calibration), feature detection (Feature) and tracking (Optical Flow), shape analysis (Geometry, Contour Processing), motion analysis (Motion Templates, Estimators), 3D reconstruction (View Morphing), object segmentation and recognition (Histogram, Embedded Hidden Markov Models, EigenObjects)(Intel Corporation, 2001).

And the format and some processing for vector data derived from the GRASS 5.0 open source program, which is a famous open source GIS for Unix Operational System. Some necessary modifications were also made to implement the data file format conversion.

And cj60lib, which is also an open source interface library for VC, was used in RHS/GIS system. The main interface shows in Figure 3.
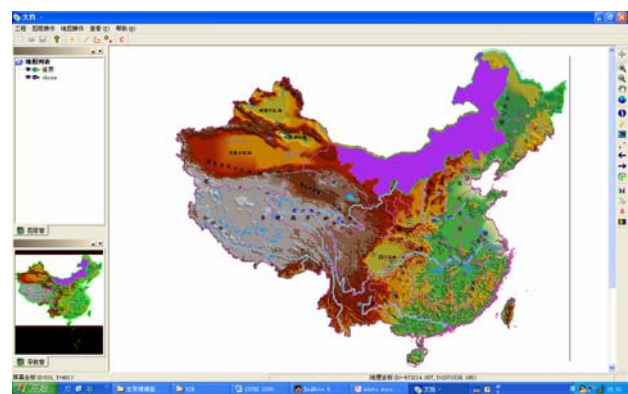

Figure 3. The Main Interface of RHS/GIS

4. APPLICATION PARADIGM

The maternal mortality and the under-five mortality were one of index for the reproductive health surveillance. Because the present surveillance covered only some counties of four provinces, there is not a suitable surveillance data for data test. Peking University Health Science Center (PUHSC) has collected annually associated surveillance data of counties throughout Mainland China with the help of a special monitoring network under the Chinese ministry of health from 1996. And the surveillance data comprised some reproductive health surveillance data, such as the number of live births, hospital delivery number, the mortality of children under five years and such corresponding indicators. The paradigm made use of these surveillance data collected from 2001 to 2005 by PUHSC. Five temp tables were created to store these annual surveillance data in our test database. And the paradigm demonstrates only the date importation, spatial analysis, results layout and print step without data collection and transferring which were already implemented in EPHSS.

4.1 The Thematic Map

Firstly, based on the above surveillance data, some calculation was conducted to get the statistics indicators, such as the maternal mortality and under-five mortality rate for all the counties using EHRSS. And a new table, which was stored in *.dbf, was created to store these indicators.

Secondly, the import surveillance data module imported the two tables to create a series of thematic map layer files, which include the surveillance information. The process implements the spatial location of surveillance data.

Thirdly, the two thematic map layer file was separately inserted into the current project document. Like other GIS tool software, some common map operations, such as zoom, pan and so on, were implemented in the graphic interface. The graduated-colors method was selected to describe the spatial distribution for the maternal mortality and under-five mortality rate visually.

The results are thought as the important products for the reproductive health surveillance. Some map elements, including title, legend, scale and north arrow, were arranged with the help of layout module. And the layout results (Figure 4 and 5) were exported to the two image file with *.jpeg.
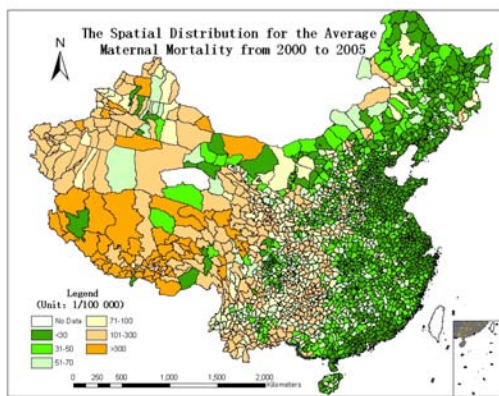

Figure 4. The spatial distribution map for the average maternal mortality from 2000 to 2005
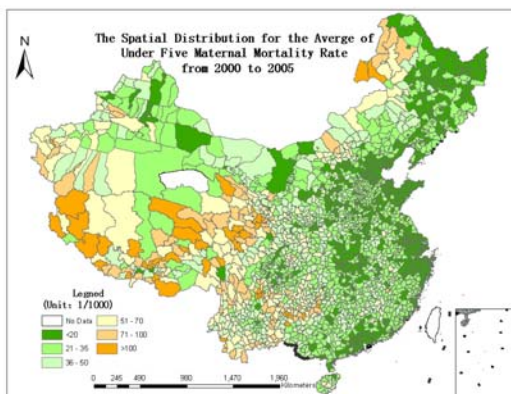

Figure 5. The spatial distribution map for the average under five mortality rate from 2000 to 2005

The two figures show clearly and visually that the two kinds of mortality are the similar in spatial distribution, which is lower in the east and higher in the west.

4.2 The Analysis of Multi-source Data

In the above third phase, the DEM (Digital Elevation Model is the representation of the terrain using point elevation information) data map layer file, which was store with *.ras, was also insert into the current project to analyze the relation between the maternal mortality and elevation. The elevation was draw with graduated colors and the maternal mortality was draw using graduated symbology in the paradigm. The final layout results show in figure 6. The high maternal mortality rate mostly appears in the region with high elevation (>1500 meter above sea level). And the low maternal mortality mostly appears in the low regions (<500 meter).
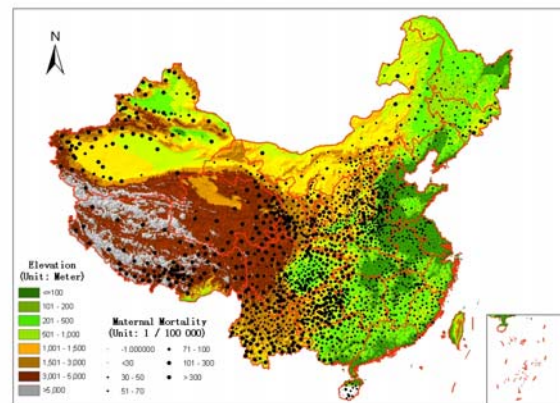

Figure 6. The spatial relation between the maternal mortality and elevation

4.3 Dynamic Show

In the above third phase, the maternal mortality rate, from 2001 to 2005, was separately shown one by one at the interval of 5 seconds using the thematic symbology, such as graduated color, graduated symbol, bar and so on, with the help of Dynamic Show module. The procedure reviews the progress story of the maternal mortality throughout mainland china. We discover that the west of Mainland China, especially in Tibet, was fluctuant greatly in maternal mortality rate, and the east was much stable in the maternal mortality during the five years.

5. CONCLUSION

RHS/GIS implements the functions of visualization of surveillance data for reproductive health, can depict the results in form of map, and does some spatial analysis as well. Furthermore, unlike traditional surveillance measures and analysis methods, it can not only enrich the contents of traditional surveillance, but also enhance the ability of data analysis and processing for reproductive health. Moreover, this system presents a friendly and easy operational interface. It can be used more widely and it is more operational, so it can expand the structure to the other candidate counties for reproductive health surveillance in mainland China. In conclusion, RHS/GIS is an effective application system which can support the reproductive health surveillance based on Geospatial Informatics techniques better.

Besides, the spatial analysis module need be ameliorated in the near future.

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