Designing and Developing an AIDS Transmission Management and Spatial Decision Support System Based on GIS

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***Abstract*—BACKGROUND: AIDS is a significant threat to global human health and raises many concerns with regards to social development. The prevention and control of the spread of this incurable disease is of utmost urgency with long-term efforts required to make it a reality. Our country is now at a pivotal time point in the fight against AIDS. Due to the increasing urgency in AIDS prevention, control, and treatment, we need to reexamine our approaches to tackling this disease from a scientific perspective. MOTIVATION: Designing and developing a powerful and user-friendly GIS which is data-rich and has a reasonable structure. This GIS should allow easy sharing of data while maintaining high data security in addition to being a highly scalable system that has the capability of monitoring and preventing AIDS transmission. RESULTS: The system is able to show the spread of AIDS and other aspects of the overall process by charts, virtual environments, and output files. Furthermore, the integration of ABM and GIS allows the system to predict future trends of the AIDS epidemic. Thus disease control departments can set different predictive and decision-making measures to control the impact of the AIDS epidemic spread more effectively.**

***Index Terms*—AIDS transmission; GIS; management and spatial decision support system**

I. INTRODUCTION

AIDS is an infectious disease that poses a significant threat to human health and survival due to its rapid transmission rate worldwide [1]. While AIDS is present in almost every country worldwide, the distribution of infected patients per country is uneven but ever-increasing. This has had great social and economical impacts on the lives of the human population [2]. Given the high incidence rate of this fatal and incurable disease, the governments of countries worldwide as well as the World Health Organization have diverted significant manpower and resources to analyze and study the pathogenesis of AIDS in order to find an effective way to control the AIDS epidemic [1].

AIDS has a lot of typical spatial characteristics such as incidence, prevalence, distribution, etiology, local characteristics, the distribution of medical and health institutions [3]. An important aspect of AIDS research is to understand and grasp its distribution, spatial characteristics, and to identify high risk groups in order to provide accurate data to support decision-making strategies for disease prevention and control. It is often difficult to find the appropriate tools to help solve such complex problems with manual methods and simplistic softwares being unsuitable especially when large amounts of data are to be analyzed. Geographical Information System (GIS) provides a powerful spatial analysis tool that can be utilized in epidemiological studies. GIS is a computer system that collects, stores, manages, spatially analyzes, and displays the outputs of the geospatial data analyzed [4]. It can be used to analyze and visualize the spatial distribution of AIDS transmission thus effectively managing the spatial data of the AIDS epidemic. Integration of GIS and intelligent simulation techniques can be used to analyze the distribution and variation in different regions inhabited by AIDS patients, explore the leading causes of AIDS in a given region and a variety of other factors. This in turn allows science-based decision making for early warning and forecasting of AIDS control programs [5].

The AIDS transmission management and spatial decision support system which integrates basic geographical data and thematic business data on the one hand can provide information query statistics, spatial visualization, decision support and other related business epidemic management functions [6], while on the other hand can predict the AIDS epidemic trends by integrating an agent-based model (ABM) and GIS [7]. It is a good tool for preventing and controlling the transmission of AIDS by relevant parties involved in AIDS prevention and control. The ABM is based on the theory of complex systems and artificial intelligence, is a development to the cellular automata (CA) and computer simulation theory [8][9]. Each agent in ABM will put an open environment to learn, adapt and survive, largely meet the characteristics of human activity, is a best bonding point of individual, space and time. By integrating ABM and GIS, and using an AIDS patient as an agent while using attribute data from the real world, this system allows the simulation of AIDS activities in a given geographical space to mirror the real world. Given that this system has a wealth of information query statistics, spatial analysis, spatial search and other functions, this system can also be applied to manage and control other epidemics other than

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AIDS prevention. In addition it can provide a public health management information platform [10].

II. The Overall Design of the System

A. The Objective of Overall Design on the System

The key task of overall design is to determine the overall system architecture, functional modules, the relationship in modules, the configuration of hardware and software, system data structures, the technical specifications and standards [11]. The overall design guides the whole process of system development. The aim is to make short-term goal of system development and long-term goals to achieve, and to make the system designed to optimize.

B. Development Mode

Development mode: C/S, COM
Development tools: Visual Basic6.0, Eclipse
Development platform: ArcObjects9.3
Database platform: SQL2005, ArcSDE9.3

C. The Overall Structure

The overall structure should meet the system's stability, smooth operation in a specific hardware and software environment. The figure of the overall structure is as follows:

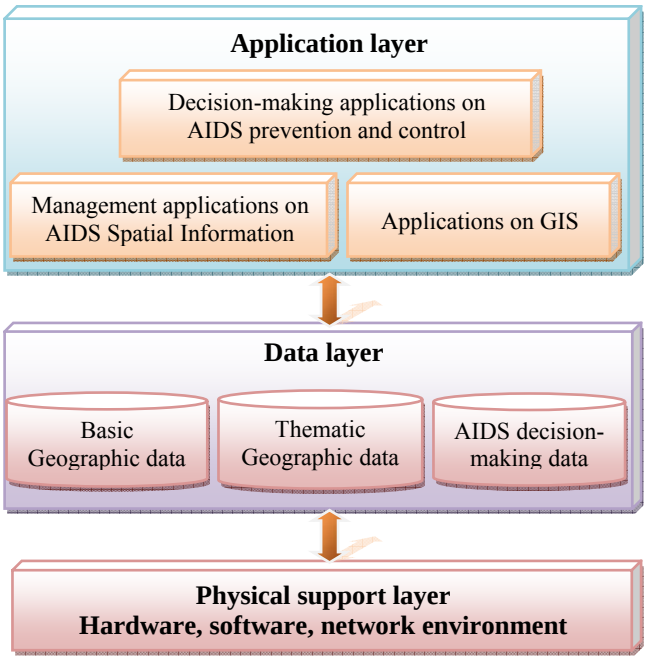

Figure 1. The overall structure

As can be seen in Figure 1, the data layer is large, content-rich, and forms the foundation and key of the system. It involves a variety of thematic data which is made up of the multi-scale and multi-level business information which include non-spatial or spatial component. This requires a system with high data management capabilities which includes the ability to meet the spatial and non-spatial data integration management, storage and editing capabilities, provides services such as transaction processing and long data history archiving of version management features. The Application layer provides three types of applications which are decision-making applications on AIDS prevention and control, management applications on AIDS Spatial Information and applications on GIS.

III. Database Design

Taking Kunming as an example, basic geographical data and AIDS thematic geographic data were used to simulate geographic data of AIDS model. There are three basic forms of geographic data, namely point, line and polygon data. Point data includes schools, government agencies, hospitals, hotels, testing and counseling agencies; linear data includes bridges, railways, highways centerline; polygon data includes water, parks, airports, buildings, roads, police districts, and government jurisdiction. AIDS-related topics and decision-making data include human, female sex workers, male sex consumers, police districts, and female sex workers in the workplace [12]. Each data element exists in association of behavior in the design of the system database. Geodatabase geographic data model can abstract the real world, which is supported by a series of map display, query, edit and analysis of the data objects, and can describe various geographic features. So, Geodatabase is a good choice for managing these data.

A. Overall Structure of the Database

According to the actual needs of the system and the design idea of database, building the required geographic layer and attribute information to facilitate query operation, thematic query statistics, predictive modeling, decision support and other functional modules.

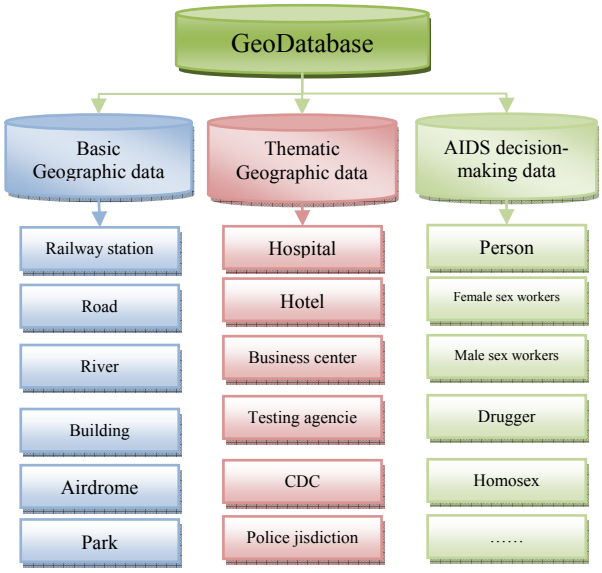

Figure 2. Overall structure of the database

B. Design of Basic Geographic Data

Basic geographical information data provide the most basic graphic background and geographic coordinate reference. It is made up of point, line and polygon shape. Point data includes business centers, railway stations, bus

stations, and so on. Line data consists of railways, roads, streets, rivers, etc. Polygon data consists of buildings, airdromes, parks, lakes, and so on.

C. Design of Thematic Geographic Data

Thematic geographic data is key data which consists mainly of AIDS-related medical institutions, hotels and other data. Hotels are places of high incidence and the source of HIV infection. Testing and counseling agency are responsible for epidemic monitoring, consulting and reporting. You can always look at each detail from testing and counseling agencies. Police jurisdictions are the smallest statistical unit to study in this system, which was used to count infection, the number of hospitals and hotels and its details.

D. AIDS Decision-making Data

The decision-making is based mainly on the simulation results of future development of the AIDS epidemic [14]. Therefore, the main data of AIDS decision-making is to build an agent model of AIDS, which include human, female sex workers, male sex workers, drug users and other groups in this system.

IV. Development and Implementation System Function

A. System Function Design

The aims of this system is to design and develop a geographic information platform which integrates a set of spatial and attribute data, simulates the temporal dynamics characteristics of AIDS transmission, queries and count AIDS-related information, timely and accurately reflect the spread of the epidemic of AIDS, provide decision support services for the AIDS prevention and control [15]. The platform is mainly composed of two parts, one part is basic GIS functions, and the other part is thematic business and decision support functions. GIS functions realize management and analysis to the properties and spatial data. Thematic business and decision support functions are be responsible for query, count, analysis of the trend forecasting of AIDS, early warning analysis of the AIDS epidemic, AIDS prevention and control plan production, spread of the epidemic of AIDS [16]. Main function modules were shown in Figure 3.

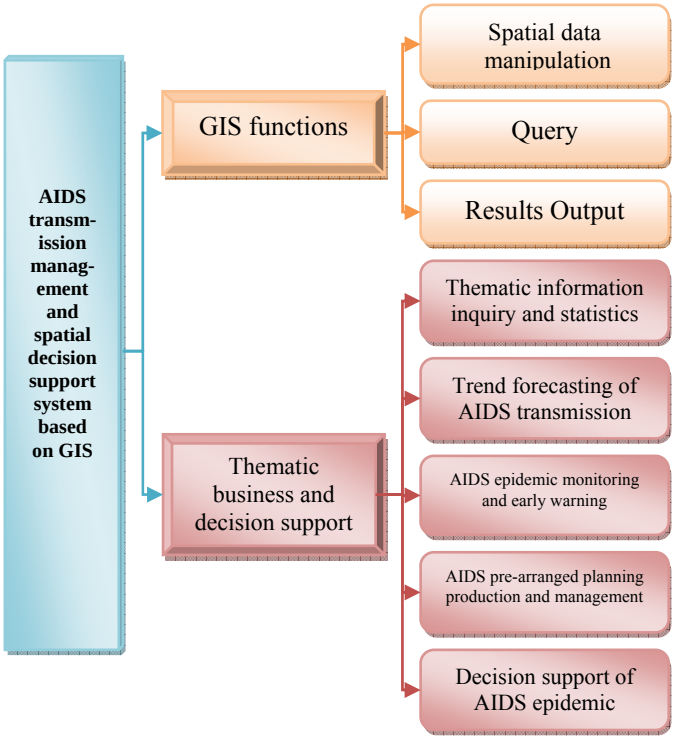

Figure 3. System function module

B. System Functional Description

1) Spatial data manipulation function

Spatial data manipulation function includes data loading, zoom, roaming, distance measurement, area measurement, layer removed and Hawkeye control, legend control and Forms control. Figure 4 shows the function of Hawkeye.

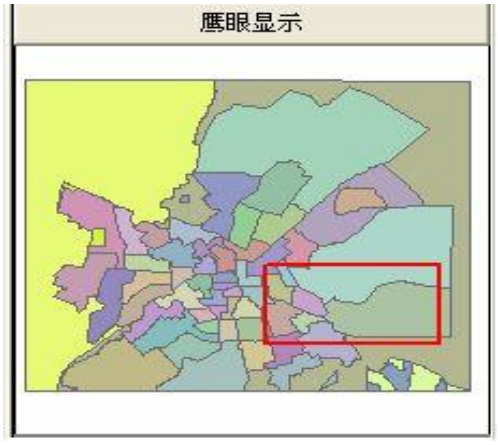

Figure 4. Hawkeye control

2) Information query

Information query function realizes to query spatial information by attribute information, and query attribute information based on the graphical overlay, buffer and other graphics operations. This function module has implemented query mutual between graphic and table. A detailed description of the module functions as follows:

TABLE I.
A DETAILED DESCRIPTION OF INFORMATION INQUIRY MODULE

Function module	Specific functions	Functional Description
Informa-tion query function	Identity	Getting attribute information by click map
	Query based on logical relational	Getting attributes and spatial information based on logic relationship. This function can be accurately positioned on the map through the attribute information.
	Find	This function traverses through the database with the input word or words that match the data
	Basic spatial query	This function supports the use of spatial relationships of geometric objects to query.
	Spatial overlay query	Query information by superposition of layers
	Buffer query	This function supports the use of the buffer of single or multiple geometric objects to query the spatial relationship, and also supports the use of a buffer layer of geometric objects to query.

Figure 5. Basic spatial query

Figure 6. Query based on logical relational

3) Thematic information inquiry and count

Thematic information inquiry and count is closely related to AIDS prevention and control of information queries, focusing on medical facilities, high-risk populations' settlements, sentinel surveillance, the hardest hit, etc [17]. A detailed description of the module functions as follows:

TABLE II.
A DETAILED DESCRIPTION OF THEMATIC INFORMATION INQUIRY AND STATISTICS

Function module	Specific function	Functional Description
Thematic information inquiry and statistics	Query and count to medical Facilities.	Query and statistical AIDS-related medical facilities, such as hospital, CDC, clinics, etc.
	Query and count to risk population agglomerations	This function is mainly queries and counts the spatial location and quantity of risk population agglomerations.
	Query and count to sentinel surveillance	Sentinel surveillance is critical information to get AIDS information. It is important to master this spatial location.
	Query and count to the harder-hit area	Query and count to the harder-hit area are based on prevalence which results can be divided into low areas moderate and highly epidemical areas.

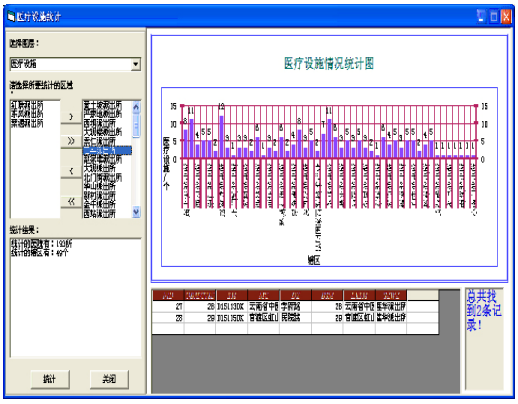

Figure 7. Query and count to medical Facilities

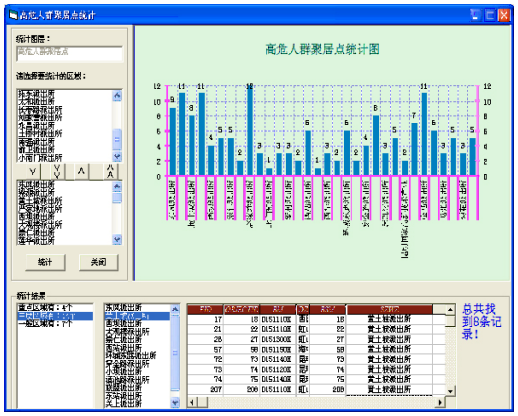

Figure 8. Query and count to risk population agglomerations

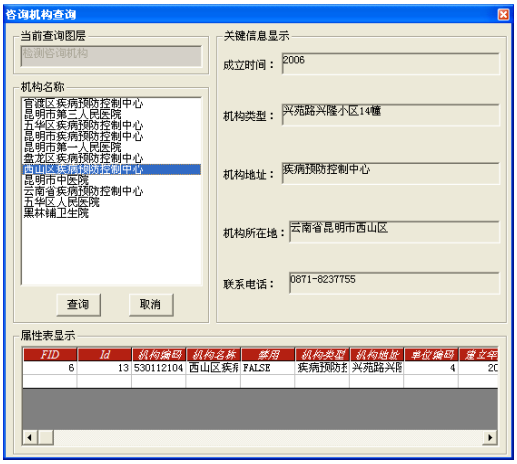

Figure 9. Query and count to sentinel surveillance

4) Trend forecasting of AIDS transmission

Trend forecasting of AIDS transmission is the key of this system which was involved in the integration of HIV transmission model and GIS. There are three major ways of AIDS transmission which are the swapping of bodily fluids through unprotected sexual intercourse, sharing of drug paraphernalia, and from mother to child. From the formal point of view, sexual and drug are the main modes of transmission [18]. Therefore, this system builds sex-agent models and drug-agent model. The spread of AIDS is a cross process of multi-mode transmission. Single-mode is difficult to simulate the phenomenon of cross-ways [18][19]. In order to more realistic simulation of the process of the spread of AIDS, a single mode of transmission will be integrated to form a comprehensive propagation model [20]. On this basis, the model will be integrated with GIS. GIS and AIDS agent models share the same spatial data, support each other in function. Agent-based model of AIDS get the spatial distribution, spatial patterns and other information by integrating GIS. GIS get epidemic spread, dynamic process and other information. This integration reproduces the epidemic spread trend of the real geographical space and spatial patterns of change, provides a secondary basis for decision making for the prevention and treatment of AIDS epidemic. A detailed description of the module functions as follows:

TABLE III.
A DETAILED DESCRIPTION OF TREND FORECASTING AIDS TRANSMISSION

Function module	Specific functions	Functional Description
Trend forecasting AIDS transmission	Simulating sexual transmission	Simulating spread trend of AIDS in graphic space based on sex-agent model and GIS.
	Simulating drug transmission	Simulating spread trend of AIDS in graphic space based on drug-agent model and GIS.
	Simulating integrated model	Simulating spread trend of AIDS in graphic space based on GIS and integrated agent model which is made of drug and sexual agent model.

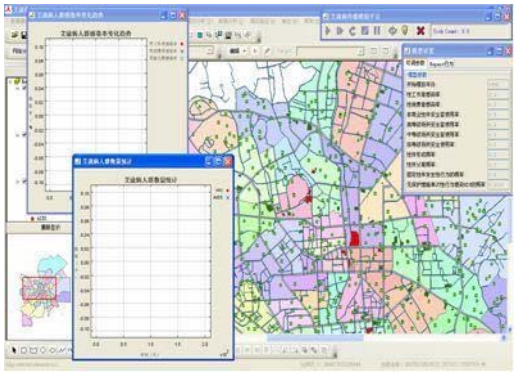

Figure 10. Simulating sexual transmission

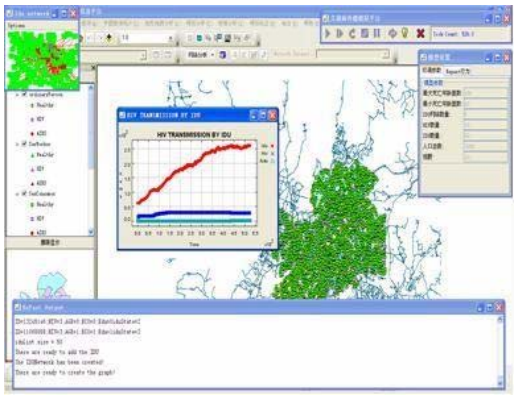

Figure 11. Simulating drug transmission

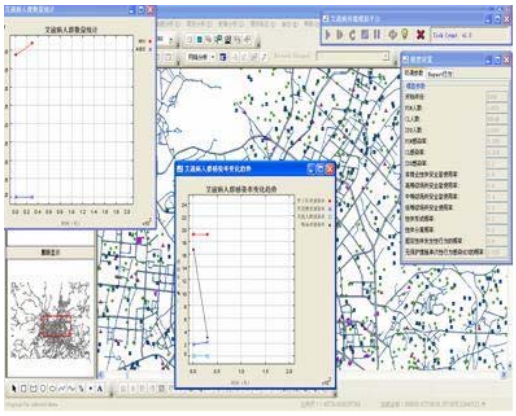

Figure 12. Simulating integrated model

5) AIDS epidemic monitoring and early warning

This function queries and counts the AIDS epidemic situations within a specific area based on the functions of Trend forecasting AIDS transmission and spatial query, while divided into low, medium and high-risk regions to send out warning information of the epidemic transmission.

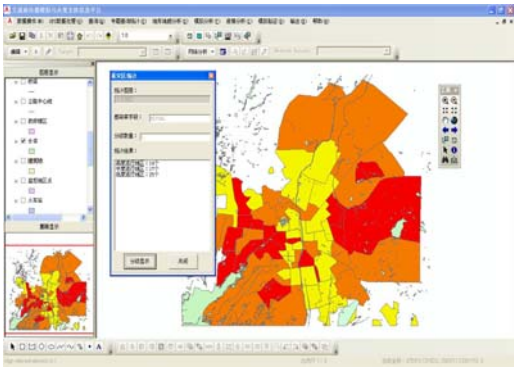

Figure 13. AIDS epidemic monitoring and early warning

6) AIDS pre-arranged planning production and management

This function uses the AIDS-related symbol to make pre-arranged planning that can allocate resources, direct and schedule ambulance persons, and make decisions. This function is based on the occurrence and development process of AIDS spatial spread.

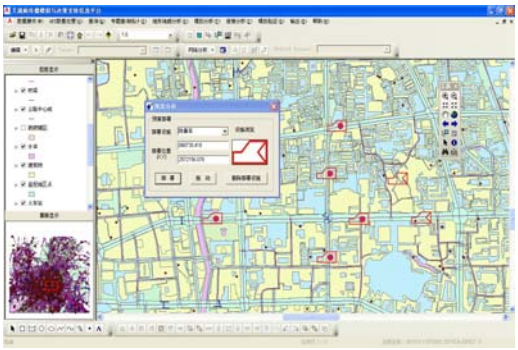

Figure 14. AIDS pre-arranged planning production and management

7) The decision support of AIDS epidemic transmission

The module includes the choice of sentinel surveillance sites and medical facilities sites, and shortest path analysis. The objective of these functions is looking reasonable point for monitoring and rescue management.

TABLE IV.
A DETAILED DESCRIPTION OF THE DECISION SUPPORT OF AIDS EPIDEMIC TRANSMISSION

Function module	Specific function	Functional Description
The decision support of AIDS epidemic transmission	Choosing sentinel surveillance sites	According to network analysis functions, analyzing the current sentinel surveillance site, found an empty server area in accordance with traffic, human settlements, etc. Finally, selecting the appropriate sentinel surveillance.
	Choosing medical facilities sites	Spatial analysis always easy to identify the areas of medical relatively weak.
	Shortest Path Analysis	Getting the shortest distance between two places based on based on the traffic situation.

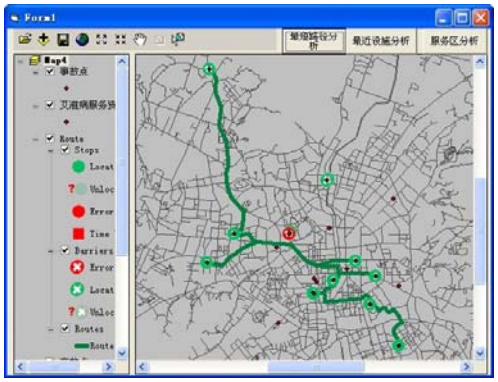

Figure 15. Choosing sentinel surveillance sites

V. RESULT

Developing an AIDS transmission management and spatial decision support system can provide new methods and strategies, scientific and rational basis to health and disease control departments in preventing and controlling the transmission and spread of AIDS epidemic. The infection and transmission of AIDS is a very complex temporal process as it has a closely linked to individual behavior. However, human behavior is both complex and difficult to predict. Thus much research must still be done to achieve accurate decision making functions on AIDS prevention and control

ACKNOWLEDGMENT

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