4D DATA FUSION TECHNIQUE IN URBAN WATERLOG-DRAINING DECISION SUPPORT SYSTEM

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ABSTRACT

This paper studies urban waterlog-draining decision support system based on the 4D data fusion technique. 4D data includes DEM, DOQ, DLG and DRG. It supplies entire databases for waterlog forecast and analysis together with non-spatial fundamental database. Data composition and reasoning are two key steps of 4D data fusion. In describing it, this paper gives a real case: Ezhou Waterlog-Draining Decision Support System (EWDSS) with two application models: DEM application model, water generating and draining model.

1. GENERAL INTRODUCTION ON 4D DATA FUSION

4D technique's generated from modern Remote Sensing and GIS, it provides new models on digital surveying productions. 4D products include Digital Elevation Model (DEM), Digital Othophoto Quadrangles (DOQ), Digital Raster Graphics (DRG), and Digital Line Graphs (DLG). 4D technique can be employed in raster and vector data fusion, overlapping multi-layer information of different type and different structure. After correction and rectification of raster data, then matching with vector data, professionals can then analyze the overlay graph of raster-vector data comprehensively and extract information that are interested in.

Spatial data fusion combines information to estimate or predict the state of some aspect of the world and the information includes: images, maps, text, html and the like. 4D products and non-spatial fundamental database cover all the information that needed to merge. 4D products data has relatively lower cost and much higher efficiency than traditional vector data production. Putting them in full use and we will get overlays of images, raster graphs and vector graphs within the same spatial coordinate frame, find out changes of features through temporal images contrast, fast update of current raster and vector data etc. 4D technique has a prosperous future on hotspots research of social sustainable development such as resource surveying, disaster monitoring etc.

2. OBJECTIVES OF URBAN WATERLOG-DRAINING DECISION SUPPORT SYSTEM

In China, flood and waterlog are two major natural disasters each year. Some densely-populated areas are characterized by their complicated river networks with many lakes dotted in, which give the cities economic impetus but at the same time regular natural disasters. In flood seasons heavy rain falls down, which makes it inevitable to have flood in areas around the rivers and waterlog inside the urban areas. For cities containing an inside lake or something alike, the case may be serious, they would pay more waterlog losses than these caused by flood. Thus, urban waterlog-draining decision support system is necessary to be adopted to improve the work for forecasting and evaluating urban waterlog, to supply scientific proof for waterlog-draining decision and waterlog-preventing plan decision, to make scientific analysis to relieve waterlog losses in best way and achieve great economic and social efficiency.

Naming a real case: Ezhou Waterlog-draining Decision Support System (EWDSS). EWDSS is developed by informatics school of WTUSM and urban planning bureau of Ezhou city. The system application model is based on two basic models: DEM application model and water generating and draining application model, they supply instant waterlog analysis and waterlog-draining assistant decision, which cannot be treated as separate parts. This paper's going to focus on the 4D data processing in DEM application model that could instantly analyze waterlog and make assistant scientific decision on waterlog-draining together with water generating and draining application model.

4D data involved in the system covers whole urban areas of Ezhou city, all produced by all digital photogrammetry, these include:

DEM database, scale 1:5000; DOQ database, scale 1:5000; Frame DLG database, scale 1:5000; Thematic DLG database, scale 1:1000.

DEM files' closest grid interval is 5m; its elevation accuracy is 0.1m.

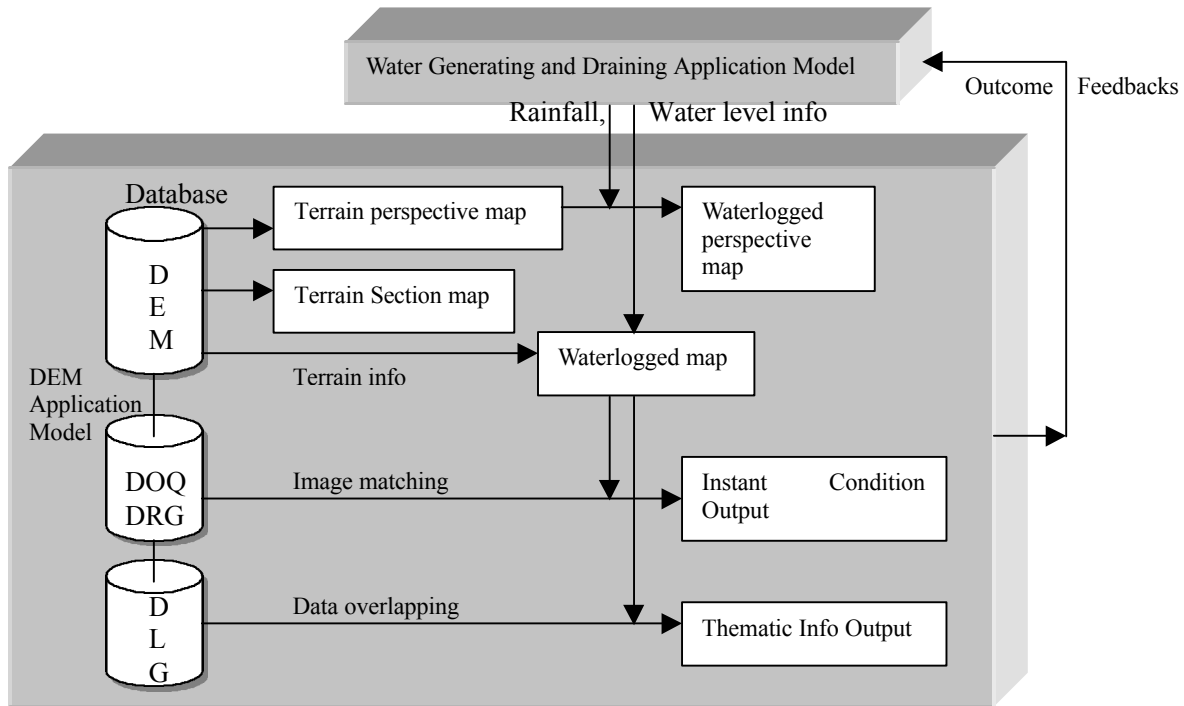Fig1 shows system data flow chart with two application models.

Fig1. Data Flow Chart

The objectives of the Urban Waterlog-Draining Decision Support System are:
¢   Comprehensive information query
¢   Disaster forecasting and real time disaster analyzing
¢   Waterlog-draining assistant decision

The first two objectives are mainly based on DEM Application model; hence the last one's based on both models.

3.   SPATIAL DATA FUSION

Performing spatial data fusion involves the following steps: data production, data organization, data composition and data reasoning. 4D data has been well sorted, classified, indexed and placed in relational context, so 4D data fusion tends to solve data composition and reasoning. Fig2 shows data fusion steps.

3.1 4D Data Composition

4D data include raster and vector data, the composition process builds coherent or aligned spatial relations of all data: DEM, DOQ, DRG and DLG. The uniform relation will provide the next step—data reasoning to go on information analysis and extraction, to go further, data mining works.

3.1.1   Raster Data Composition

In Ezhou Waterlog-draining Decision Support System, DOQ files are acquired from airborne sensors, after correction and rectification, the DOQ frame coordinate system should be determined by choosing at least 4 control points. Real scene perspective map can be obtained by adding DOQ to terrain perspective map based on DEM. The decision makers may receive more detail information on waterlog conditions suppose inputting instant water level data into DEM application model. The instant generated overlays will help to understand what the real condition is and how it would be in the future.
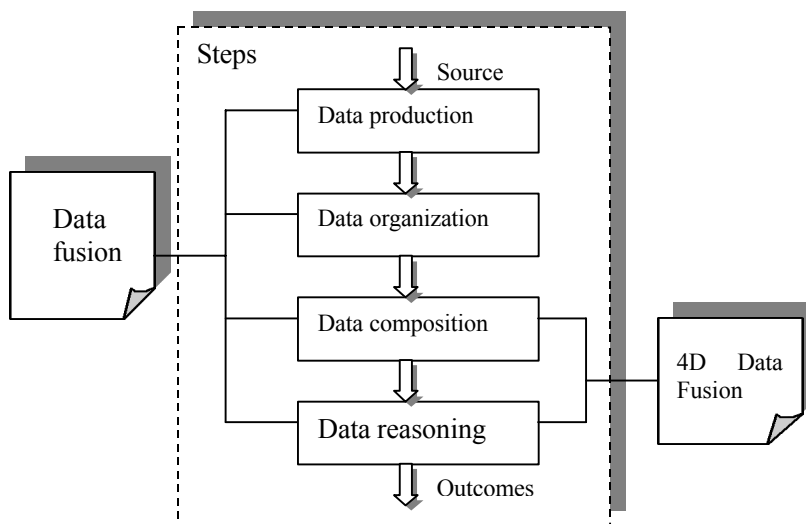
Fig2. Data fusion steps

3.1.1   Raster To Vector Data Exchange

Raster-vector data exchange is frequently employed in data fusion, though sometimes it's a time-consuming process, its outcomes supply image matching, information extraction, quantitative analysis etc. In EWDSS, DEM application model generates vector graph: waterlogged map. It derives from extra rainfall and water level information as well as DEM. Based on DEM of urban area, small range of water surface could be considered as water plane. With the plane model and DEM, system completes urban terrain section and slope analysis, computes waterlogged area on given water level condition or real time condition, and judges the grade of the waterlogged area. The process can be described by fig3.
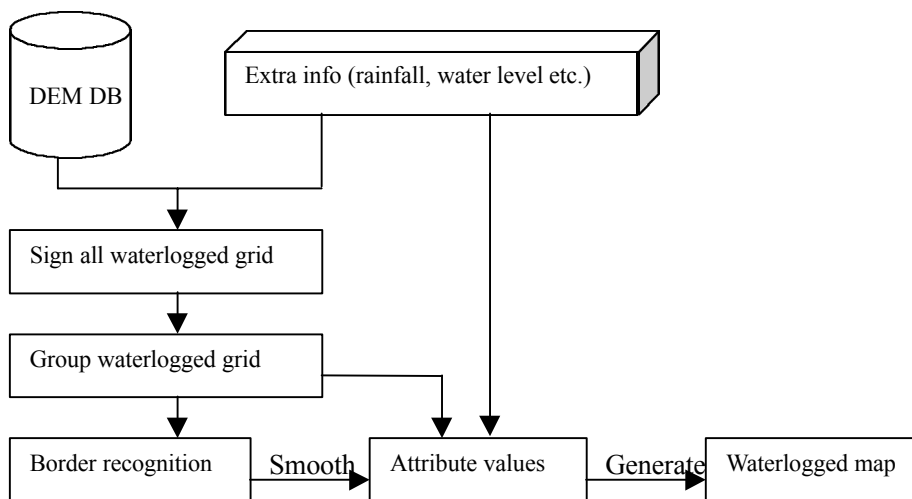

Fig3 generation process of waterlogged map

3.1.2   Raster-Vector Composition

Vector data's traditional applicable data format, EWDSS databases contain frame DLG and thematic DLG database. The frame features are fundamental geographic information such as district boundary, river system, traffic lines etc. The thematic DLG contains detail multi-layer thematic information, such as buildings, roads, electronic lines, punctate ground features etc. In a uniform coordinate system, through analyzing overlays between DLG and DOQ of different scales, overlays between frame DLG and DEM, overlays between DOQ and instant generated waterlogged map, EWDSS outputs qualitative information on waterlogged areas. Since it's easy work to

change the legend of the vector data such as DLG and waterlogged map, EWDSS clearly displays the actual and future waterlog conditions by setting different colors to frame and thematic DLG, or setting waterlogged map to be half transparent to overlap with DOQ.

3.1.3 Vector Data Composition

Vector data composition is a popular way to acquire valuable spatial and non-spatial information. All vector data in EWDSS belongs to the same coordinate system, including frame DLG database, thematic DLG database and all waterlogged maps. According to their topology, spatial relationships between features such as intersection, embedding, overlay are fixed. As the operator set covers all the spatial relationships, it would be convenient to describe 2 or 3 dimensional state and transformation of features. After determination of the unique spatial relation, quantitative analysis and query could be easily performed.

With more accurate outcomes being reached, waterlog forecasting and real time analyzing in EWDSS will be more effective and efficient, which together with knowledge database and water generating and draining application model, will lead to fast and reliable waterlog-draining assistant decision.

3.2 4D Data Reasoning

4D data reasoning performs understanding, discovery, extraction, description of the scene context; it provides a resolving model toward interesting areas. In EWDSS, the 4D data reasoning model is mainly the DEM application model. In fact, water generating and draining application model is another reasoning model on assistant decision.

DEM application model collects all necessary waterlog information with data flow from water generating and draining application model, say rainfall and water level etc, then DEM application model outputs numerical statistic on a theme, such as urban retaining water capacity, waterlog losses evaluation, all influenced industrial centers, effects on regions about to be submerged, regions having been submerged etc. In this process, image understanding and appropriate visualization are critical work to effective waterlog analysis and assistant decision. Besides graphs, tables, word descriptions and vivid figures (histogram, pie chart) are other means to tell professionals what they need.

Fig4 shows EWDSS main page, fig5 shows terrain perspective map on waterlogged areas, fig6 and fig7 are detail information of the same place obtained from 4D data reasoning.

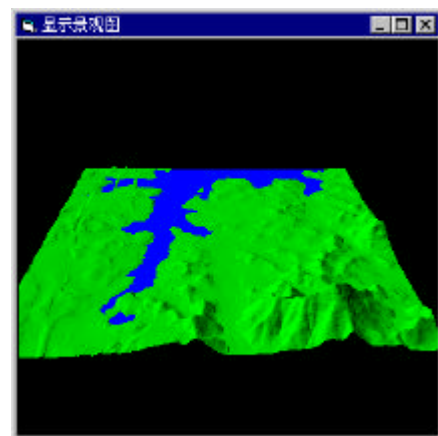Fig4 EWDSS: DOQ overlay with waterlogged map
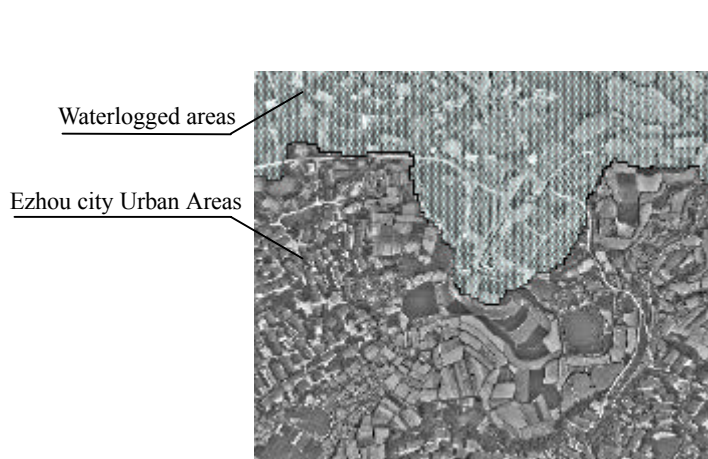

Fig5 Waterlogged perspective map

Waterlogged areas

Waterlogged areas

Ezhou city Urban Areas

Residential areas

塘

水桥村碎瓦场

吕家咀

塘

胡家书屋

Fig6 detailed information on DOQ overlapped with waterlogged map
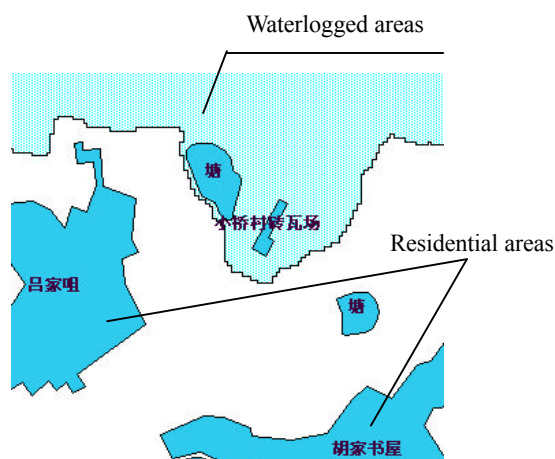
Fig7 Thematic DLG over waterlogged map with annotation

4. CONCLUSIONS

4D technique requires high accurate and well organized source data, these data are not acquired from traditional ways, but from much faster and more efficient means such as half or all digital photogrammetry. Comprehensive data composition and reasoning extracts information and knowledge from multi-layer, multi-source and multi-temporal data, through successive short-term updating resource data, it provides low cost, high efficiency production. 4D data fusion is a professional–oriented process that follows other information extraction process, which include information extraction, knowledge extraction, understanding extraction, wisdom extraction and so on. More work need to be done on those processes in data fusion and data mining field.

4D technique plays an important role in China's environment and resource management, many researches focus on disaster forecasting and relieving due to the frequent occurrences of flood and waterlog in the main land. Ezhou Waterlog-Draining Decision Support System is in the process of improvement and development. It's running now in urban planning bureau of Ezhou city and is praised for its practicability and high efficiency in the application. From the researches on EWDSS and other related fields, 4D data fusion proves considerable meaningful potential in applications on flood and waterlog control.

ACKNOWLEDGMENTS

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