



## AN INTELLIGENT FLOOD CONTROL DECISION SUPPORT SYSTEM FOR DIGITAL URBAN MANAGEMENT

Guanlin Chen<sup>1</sup>, Xinxin Sun<sup>2\*</sup>, Shengquan Li<sup>3</sup>, Jiang He<sup>3</sup> and Jiawei Zhang<sup>1</sup>

<sup>1</sup>School of Computer and Computing Science, Zhejiang University City College, Hangzhou, 310015, P.R. China, Email: chenguanlin@zucc.edu.cn

<sup>2</sup>Department of Computer Science and Information, Zhejiang Water Conservancy and Hydropower College, Hangzhou, 310018, P.R. China, Email: sunxx@zjwchc.com

<sup>3</sup>Digital Urban Management Information Center, City Management Committee, Hangzhou, 310003, P.R. China, Email: GPLLEE1975@163.com

\*Corresponding author: Xinxin Sun

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*Abstract- Digital Urban Management has become a trend in the development of contemporary cities. This paper presents the design and implementation of an intelligent flood control decision support system (IFCDSS) using statistical analysis to determine the relationship between the data, and integrate data mining technology for digital urban management based on Java EE. The system also provides location-based decision making in urban management by using the Baidu Maps API.*

**Index terms:** digital urban management, flood control, decision support system, Java EE.

## I. INTRODUCTION

Digital Urban Management [1] has become a trend in the development of contemporary cities, and is the only way to the urban modernization [2]. The implementation of digital urban management can bring the innovative model of city management, and create a new process of urban management. Digital urban management is also enabling the integration and sharing of the resource of e-government affairs, which can improve the city government management and public service ability [3].

With the advancement of urbanization, the damage caused by city floods becomes increasingly serious, and people have begun to pay more attention to city flood control decision and prediction [4]. Hence, the decision support system for flood control emerges as the times require [5]. To aid the decision-making in city flood control, the flood control decision support system uses many modern technologies like computer science [6], decision support system [7], management engineering [8], intelligent system [9], flood control [10], etc.

In this paper, we design and implement an Intelligent Flood Control Decision Support System (IFCDSS) for digital urban management. The system collects and collates the data of city watercourses and reservoirs to monitor the key areas effectively, and also uses the base flood data to provide decision-making support in city flood control.

IFCDSS is developed using the mainstream Java EE platform and MVC pattern [11], which employs SSH2 (Struts2 + Spring + Hibernate) framework and Oracle 10g database. The system integrates the display space technology [12], the statistical analysis method [13] and data mining technology [14], to provide comprehensive and intuitive statistical analysis for urban flood control, and thus provides better decision-making support for flood prevention work.

## II. OVERALL SYSTEM DESIGN AND ANALYSIS

### 2.1 System requirements

This system collects and collates the data of key areas like city watercourses and reservoirs to enforce supervisory control effectively, and to build and optimize the database for supporting flood prevention decision-making. At the same time, we present a new flood prevention model which consists of multilayer architecture. The system not only supports water regime statistics

and analysis, disaster analysis and forecast, but also is able to provide reliable flood prevention decision-making service.

The main functionalities of IFCDSS involve system management, flood information acquisition, real time hydrologic analysis, flood early warning, statistical inquiry, etc.

The basic framework of IFCDSS is shown in Figure 1.

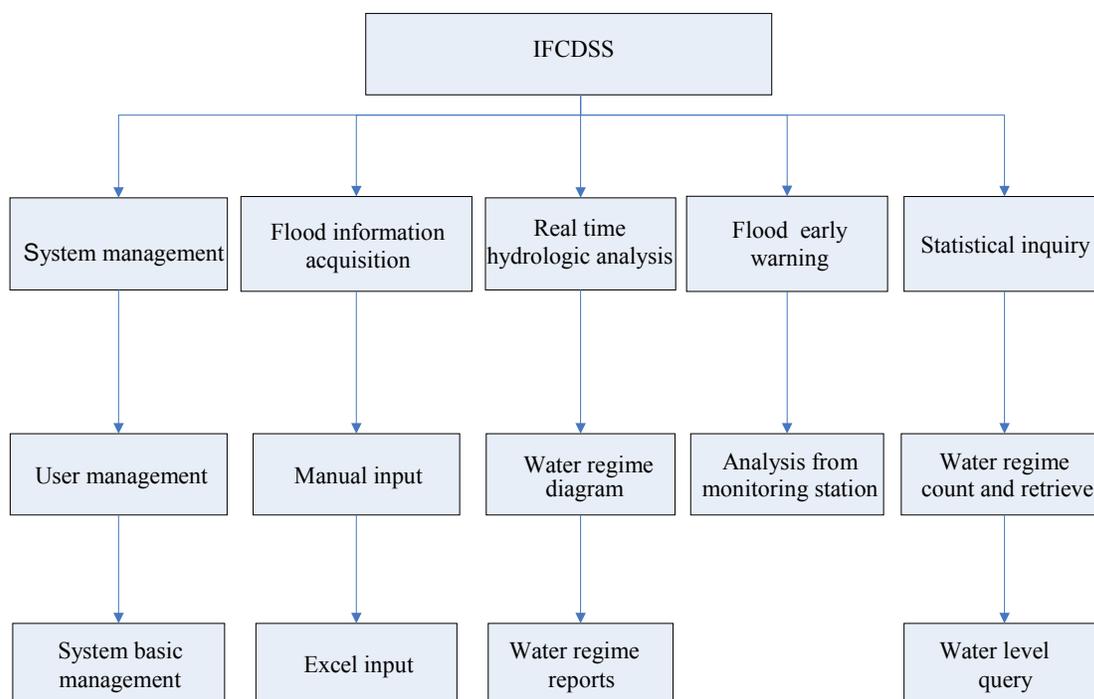


Figure 1. The basic framework of IFCDSS

(1) System management, which involves user management and system basic management. For one thing, user management involves a series of users' functions such as adding, deleting, modifying and resetting the password. For another, system basic management includes CRUD to the basic information of the regions and detection stations.

(2) Flood information acquisition, importing water level information from each detection station, which is the main source of data. Import methods include manual input and Excel input.

(3) Real time hydrologic analysis, which can show the latest data from each detection station to users with various forms. There are two main forms, diagram and report forms.

(4) Flood early warning, predicting water level data from the previous data using a certain algorithm to provide the support for flood control decision.

(5) Statistical inquiry, which count the water information in a period of time, using data from the system with various chart forms.

## 2.2 System business process

The business process of IFCDSS is shown in Figure 2.

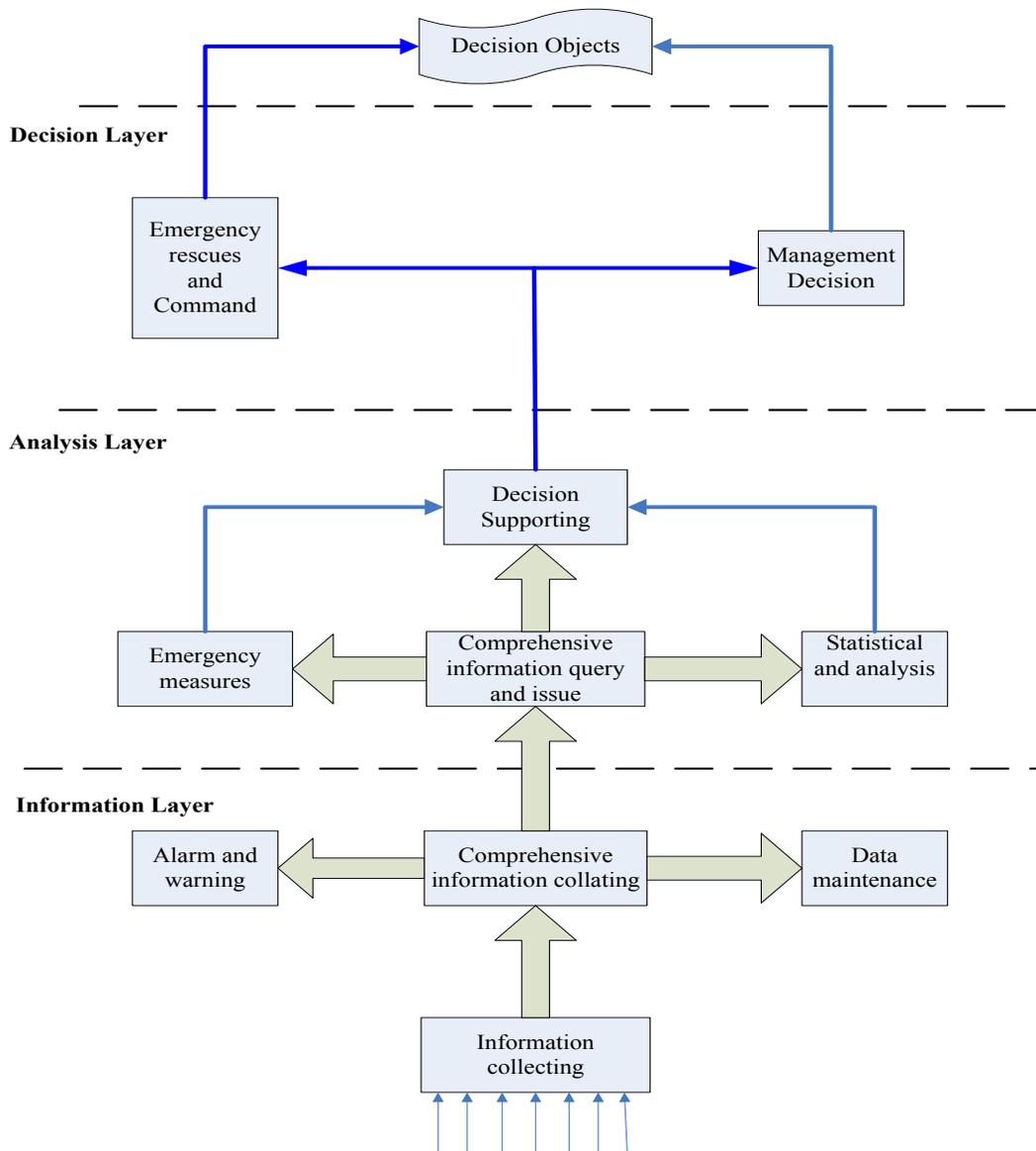


Figure 2. The business process of IFCDSS

The overall business process of IFCDSS consists of three levels.

(1) Information Layer, which includes information collection and summary. The information source comprises two parts: one is the flood-related environmental data such as water level, weather conditions, flood control materials, rainfall information, etc.; the other part is the information linkage of feedback after issuing a command and decision-making, such as the scheduling process, departmental interaction, the impact on the environment, etc.

(2) Analysis Layer, which mainly provides information query, statistics, analysis of statistical functions to achieve some of the past, relying solely on the manual difficult to achieve further deepen the comprehensive information and find the inherent relationships.

(3) Decision Layer, which provides the command of rescue and daily management decision. Creating various predictive models including trend forecasting, spatial and temporal prediction and other pre-stored logical models, which are combined with expert knowledge to be able to provide direct help for the flood control decision.

### 2.3 Database design

The system primarily designed five chief tables: water body, area, detection station, water level information and user.

(1) Water body table is mainly used for storing all the water bodies (watercourses and reservoirs) data including some information such as name, type, etc.

(2) Area table takes charge of storing regional information, including the name of the region, range of latitude and longitude information.

(3) Detection station table is used to store station information, including the location of a water body, the position, the coordinates and other information.

(4) Water level information table mainly stores the station measured by the level information, including the information of the recording time, the water level, etc.

(5) User table is used to store user information, including attributes such as login name, password and other personal information.

Among these five tables, the area table, detection station table and water level information table are most important, which are related to the next processes of space display, analysis and forecasting functions.

Table 1 shows the detail of the area table.

Table 1. The table of area

<b>Field</b>	<b>Type</b>	<b>Meaning</b>
ID	int	Area ID, primary key
ParentID	int	Parent area ID
RegionName	varchar(50)	Area name
SwLng	double	Southwest corner of longitude
SwLat	double	Southwest corner of latitude
NeLng	double	Northeast corner of longitude
NeLat	double	Northeast corner of latitude
Remark	varchar(200)	Remark of the area

Table 2 shows the detail of the detection station table.

Table 2. The table of detection station

<b>Field</b>	<b>Type</b>	<b>Meaning</b>
ID	int	Detection station ID, primary key
WaterBodyID	int	Water body ID
StationName	varchar(50)	Station name
Location	varchar(200)	Location of the detection station
WaterLevel	double	Water level
Longitude	double	Longitude of the detection station
Latitude	double	Latitude of the detection station
LevelLimit1	double	Limit 1 of the water level
LevelLimit2	double	Limit 2 of the water level
Remark	varchar(200)	Remark of the detection station

Table 3 shows the detail of the water level information table.

Table 3. The table of water level information

<b>Field</b>	<b>Type</b>	<b>Meaning</b>
ID	bigint	Water level information ID, primary key
StationID	int	Detection station ID
MonitoreeID	varchar(50)	Surveyor ID
RecordTime	varchar(200)	Record time
WaterLevel	double	Water level
Remark	varchar(200)	Remark of the water level

### III. KEY TECHNOLOGIES AND IMPLEMENTATION

IFCDSS is implemented in Java EE platform, which is the mainstream development technology nowadays. What's more, the system employs Oracle 10g as its database system, Hibernate as persistence layer management, Spring as dependency injection, and Struts2 as the controller layer, fully reflecting the application of the MVC design pattern. At the same time, IFCDSS uses the Baidu Maps API to display urban space, uses the sensor data to import flood information, and uses the statistical analysis method to determine the relationship between the data, as well as integrate data mining technology to provide flood control and decision functions.

The following are details of these key technologies and implementation.

#### 3.1 Space display integrating the Baidu Maps API

IFCDSS uses the Baidu Maps API to display a map of urban space, which is a set of application program interfaces. Using the API, we can create feature-rich, personalized, efficient and functional maps containing multiple interfaces to build the basic functionality of the map, such as the location search, the surrounding queries, travelling route planning service.

The system mainly uses the map display function of the Baidu Maps API to represent the location information in the form of covering, which is superimposed or covered with the contents of the map.

Following is the JS code of loading the map and initialization.

```
var map;
$(document).ready(function() {
    // Create a map instance
    map = new BMap.Map("container");

    // Disable double-click to enlarge
    map.disableDoubleClickZoom();

    // Add navigation controls
    map.addControl(new BMap.NavigationControl({
        type : BMAP_NAVIGATION_CONTROL_LARGE
    }));

    // Add map type controls
    map.addControl(new BMap.MapTypeControl());

    // Add cutline controls
    map.addControl(new CutLineControl());

    // Add region controls
    map.addControl(new RegionControl());

    // Initialize the map and set the coordinates of the center and map level
    map.centerAndZoom("HANGZHOU");

    // Save a list of created situation
```

```

var stationMarkers = new Array();

});

```

Figure 3 shows the real-time hydrological situation using the Baidu Maps API.

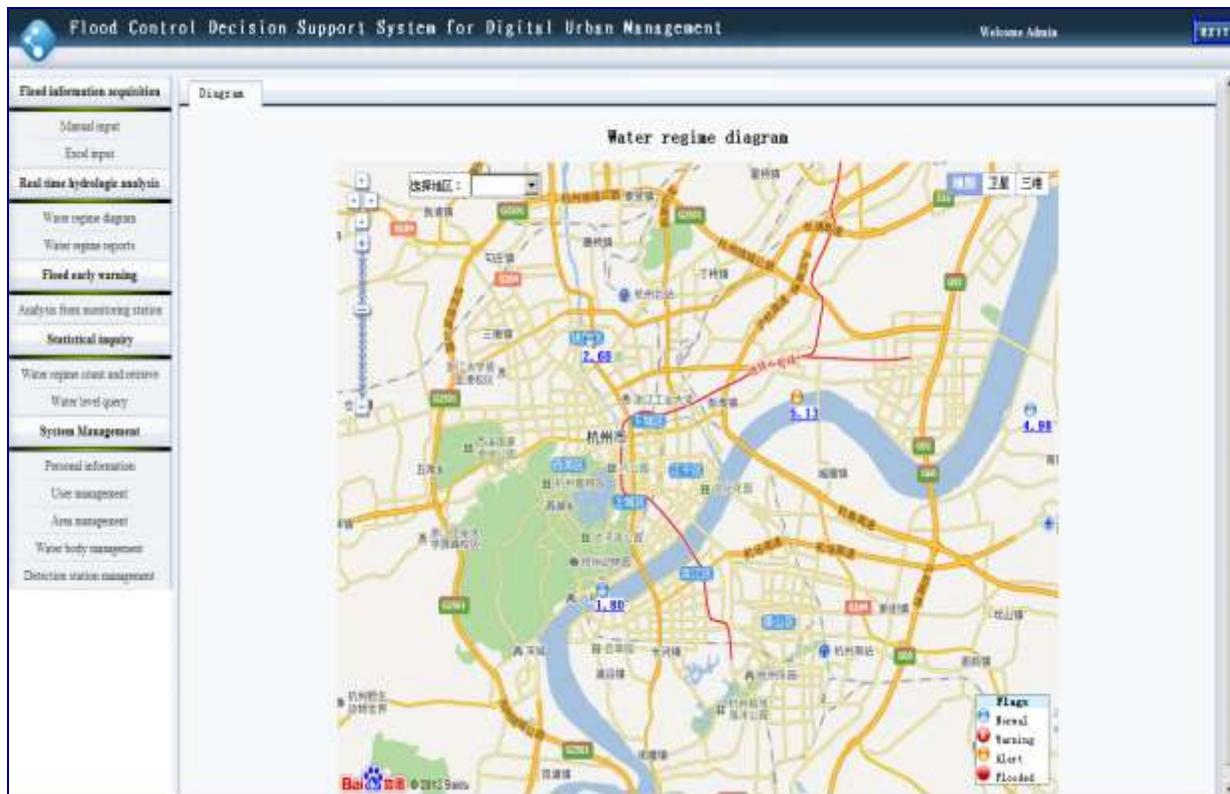


Figure 3. The real-time hydrological situation using the Baidu Maps API

Real time hydrologic analysis is implemented with the Baidu Maps API in IFCDSS, which takes advantage of the results in the table and figure showing a real-time hydrological analysis. It is convenient for users to grasp the real-time hydrological condition. The display types of real-time data include diagrams and reports. Diagrams indicate the location and status information of each detection station standing on a map, allowing users to have an intuitive understanding of the current water regime. Reports show that the real-time information of reservoirs and river channels is presented to users through the form of tables, which also include detailed hydrological statistics.

### 3.2 Flood information acquisition using sensor data

Flood information acquisition provides two operations: manual input and Excel input. The operator can import only one record each time by manual input, when the sensor data are large, he also can first save the data into an Excel table and then import all the records at once.

Currently IFCDSS uses about a hundred float type level sensors to obtain water level information of the key watercourses and reservoirs in Hangzhou. Before importing the sensor data, the formatted Excel file is needed to provide.

Figure 4 shows the example of a normative Excel document for Excel input.

	A	B	C
1	<b>Detection station ID</b>	<b>Record time</b>	<b>Water lever</b>
2	1	2012-1-1 9:00	5.486520105
3	1	2012-1-2 9:00	4.543935682
4	1	2012-1-3 9:00	4.828352512
5	1	2012-1-4 9:00	5.397019515
6	1	2012-1-5 9:00	4.718311713
7	1	2012-1-6 9:00	5.472952733
8	1	2012-1-7 9:00	5.119645027
9	1	2012-1-8 9:00	5.202975253
10	1	2012-1-9 9:00	5.048927014
11	1	2012-1-10 9:00	4.935890579
12	1	2012-1-11 9:00	5.41947074
13	1	2012-1-12 9:00	5.023891672
14	1	2012-1-13 9:00	4.663424695
15	1	2012-1-14 9:00	5.056688852
16	1	2012-1-15 9:00	4.952080386
17	1	2012-1-16 9:00	5.053396172
18	1	2012-1-17 9:00	5.357508063
19	1	2012-1-18 9:00	5.483553357
20	1	2012-1-19 9:00	4.793665307
21	1	2012-1-20 9:00	4.662786038

Figure 4. The example of a normative Excel document for Excel input

In IFCDSS, the specific implementation of the Excel reader function uses Java Excel API (JXL), which is an open source Java API enabling developers to read, write and modify Excel spreadsheets dynamically.

For example, when we select the correct Excel file including 20 records of water level information by clicking the Select button, and after the file is uploaded and imported, all the records have been input to the system.

Figure 5 shows the result of importing water level information successfully from the Excel file.

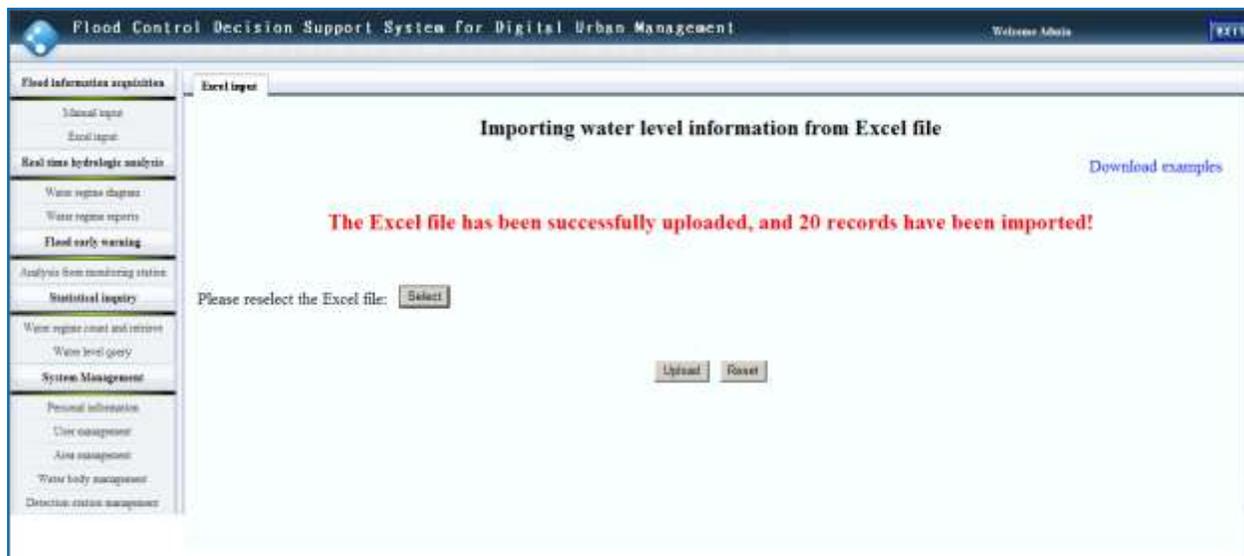


Figure 5. The result of importing water level information successfully from an Excel file

### 3.3 Statistical analysis determining the relationship between the data

The statistical analysis is the main function of IFCDSS, and we use common statistics (counting the maximum, minimum, sum, average value among the large amounts of data), regression analysis (using the regression equation to represent the quantitative relationship between the variables), correlation analysis (measuring the degree of correlation between the variables with a correlation coefficient) and other methods to analyze flood control and business data. With the statistical analysis methods, we can excavate the regularity and relevance of these data.

Using the input data of water level information, we can get some basic statistics for every detection station. For example, if you want to count the maximum and minimum water level value of the “2-Qibao” river station from March 2 2012 to March 20 2012, you can specify these conditions in the system. After you submit the request, you can immediately know that the maximum value is 5.34 on March 11 2012 and the minimum value is 4.70 on March 9 2012.

The detailed results are shown in figure 6, which describes the statistical table and corresponding hydrograph.

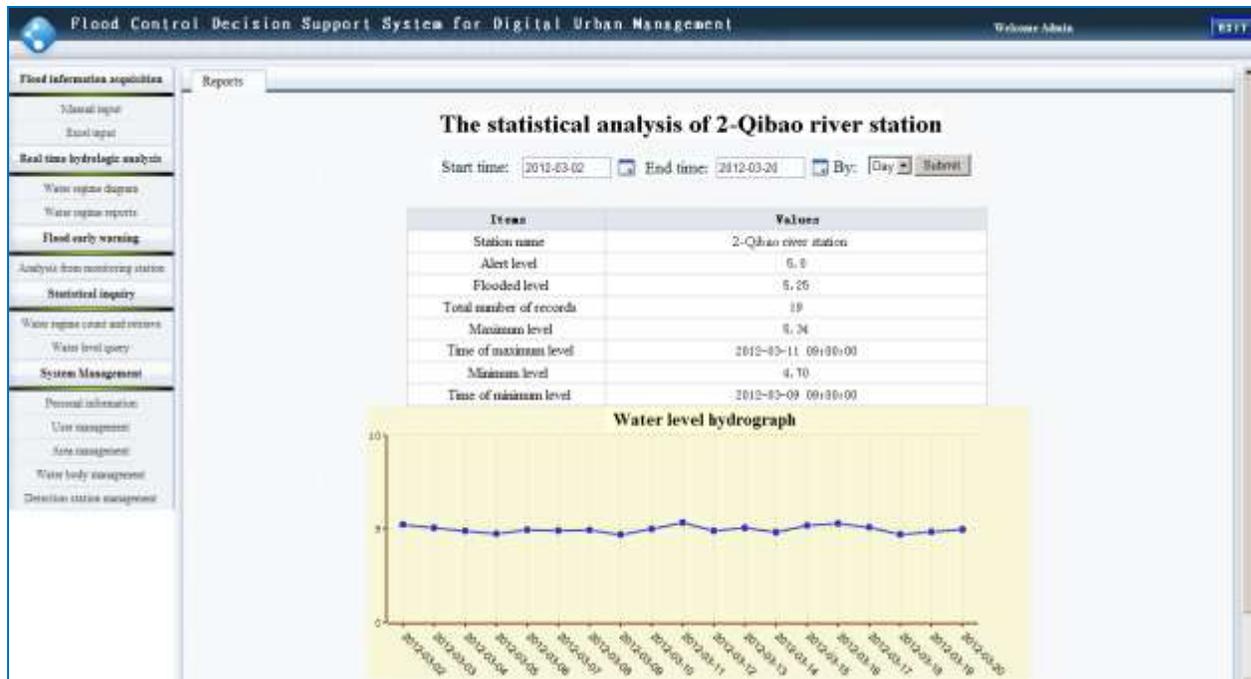


Figure 6. The statistical analysis results of a river station

Another important function to achieve statistical analysis is fully demonstrating the performance of the statistical data in the chart. According to the needs of a variety of charts, we mainly use Open Flash Chart plug-in, which is an open source chart generation tool based on Flash and JavaScript. Using Open Flash Chart, IFCDSS can create some great intuitive analysis charts. For example, IFCDSS can create real time hydrology pie charts with the plug-in. Following is the JavaScript code of implementing the function using Open Flash Chart.

```
$(document).ready(function(){
    swfobject.embedSWF(
        "../js/open-flash-chart.swf",
        "chart",
        "600",
        "300",
        "10.0.0",
        "expressInstall.swf",
        {"data-file": escape("getRealTimeChart.action")},
        {wmode:"transparent"}
    )
})
```

```
);
};
```

Figure 7 shows the real-time hydrological situation of reservoirs and rivers using Open Flash Chart.

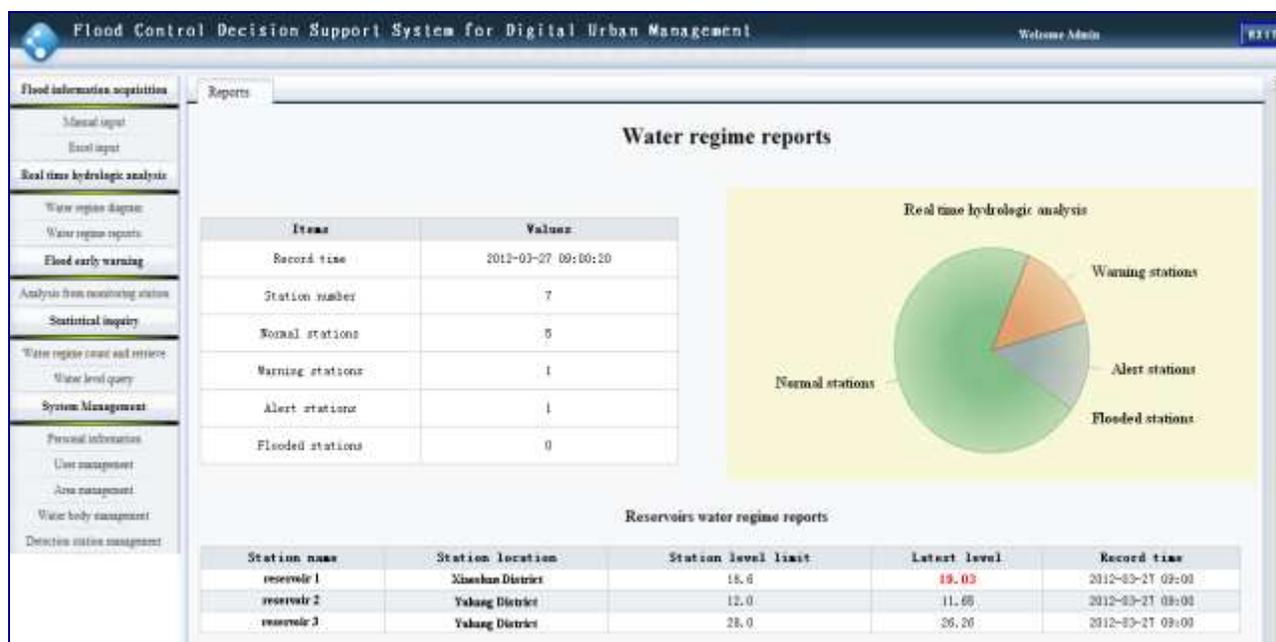


Figure 7. The real-time hydrological situation of reservoirs and rivers using Open Flash Chart

### 3.4 Data mining providing decision support

IFCDSS uses data mining techniques such as interpolation method to forecast and provide early warning. The working principle of the interpolation method is deriving a polynomial according to the water level values of some previous days with the polynomial interpolation algorithm, and then calculating the predicted value of the subsequent day. With the interpolation method, IFCDSS can provide data support for flood control decision-making.

Given the water level information on  $N$  ( $N \leq 7$ ) days before, we can forecast the water level of the subsequent day using the interpolation algorithm with the following code.

```
/**
```

```
 * interpolation algorithm
```

```
*
* @param x
* @return
*/
public Double interpolation(double[] x) {
    double p = 0;
    int n = x.length;
    double avg = average(x);
    if (n == 7) {
        p = x[6] - 7 * x[5] + 21 * x[4] - 35 * x[3] + 35 * x[2] - 21 * x[1] + 7 * x[0];
    } else if (n == 6) {
        p = -x[5] + 6 * x[4] - 15 * x[3] + 20 * x[2] - 15 * x[1] + 6 * x[0];
    } else if (n == 5) {
        p = 1 * x[4] - 5 * x[3] + 10 * x[2] - 10 * x[1] + 5 * x[0];
    } else if (n == 4) {
        p = -1 * x[3] + 4 * x[2] - 6 * x[1] + 4 * x[0];
    } else if (n == 3) {
        p = 1 * x[2] - 3 * x[1] + 3 * x[0];
    } else if (n == 2) {
        p = 1 * x[1] - 2 * x[0];
    } else if (n == 1) {
        p = x[0];
    }
    if (p < 0 || p > 2 * avg || p < avg / 2) {
        double xx[] = new double[n - 1];
        for (int i = 0; i < n - 1; i++) {
            xx[i] = x[i];
        }
        return interpolation(xx);
    }
    return p;
}
```

}

For example, if you want to predict the water level value of one river station on January 6 2012 based on the water level data of the previous three days, and these water level values are 5.05, 5.25 and 5.8, then using the interpolation method you can know that the water level value of the subsequent day will be 6.68. The system will give an alarm if the predicted value exceeds the alert value.

Figure 8 shows the result of predicting the water level using the interpolation method.



Figure 8. The result of predicting the water level using the interpolation method

## VI. CONCLUSIONS

Flood control decision support system for digital urban management is important to promote the construction of digital city [15], and can provide scientific decision-making support for urban flood control and management. This paper describes the overall system design and concrete realization of IFCDSS, which integrates Java EE-based technology platform, SSH2 framework and mainstream MVC architecture. The system uses display space technology, statistical analysis and data mining techniques to achieve the effective flood control, business data analysis and

forecasting, providing intuitive analysis results with graphical display forms for scientific decision-making of the flood control and management. In future work, we will continue to expand the functional modules of the system, and introduce more intelligent data mining algorithms to promote digital urban management and flood control.

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