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Development of Hydrologic and Geographic Database for Yodo River Basin

Nirupama*, Yasuto TACHIKAWA**, Akira FUJITA***
Michiharu SHIIBA****, and Takuma TAKASAO*****

Data acquisition, preprocessing, management, manipulation & analysis and product generation are essential parts of any research application. To save researchers and engineers from the enormous efforts, time and money, we should have an open structured hydrologic database containing various types of hydrologic and geographic data, which is independent of any specific project application and could be easily accessed by multiple users. In this paper we are presenting the use of the Relational Data Base Management System (RDBMS) to arrange the hydrologic and meteorologic time series data and the Geographic Information System (GIS) to integrate many different kinds of information for a particular objective about the spatial objects in an area. Our objective is to store and manage large amount of data involved in the rainfall-runoff processes. As a case study we have processed the data for the Yodo River basin and as one of applications we have illustrated a system to estimate hourly evapotranspiration for river basins by using RDBMS and GIS techniques.
Keywords : Database, RDBMS, GIS.

1. Introduction

An important aspect of hydrologic studies is the manipulation and management of large volumes of data. Usually, such data are acquired by engineers from various sources and processed according to the requirements of a specific project. After accomplishing the project no one looks back on the data and it becomes almost impossible to reuse the data for another project. This situation causes wastage of time and money.

A successful database system performs two basic processes - (i) data storage and (ii) data retrieval. We have adopted Relational Data Base Management System (RDBMS), to store and manage hydrological and meteorological time series data, in which the data is seen as a set of rectangular tables. The user does not need to know about physical order of the data to use this system.

Keeping hydrological application in mind database should consist of tabular information about observation stations, measurements taken at these stations, and in addition about the geographical data such as elevation, longitude and latitude of the study area, along with knowledge on stream network, basin delimitation data and remote sensing data etc. Then comes the role of the Geographic Information System (GIS) which is to integrate many different kinds of information we may need for our project including the spatial objects in an area. When combined with RDBMS, GIS can idealy serve in the development of distributed hydrological models, as a means to assemble diverse spatial data. In this study, we store and manage large amount of data for Yodo River basin using RDBMS and GIS, and as one of applications we present a system to estimate hourly evapotranspiration time series.

* Student member, M.E.,Doctor Course student, Department of Civil Engineering, Kyoto University (Sakyo-ku, Kyoto 606)
** Member, M.E., Research Associate, Department of Civil Engineering, Kyoto University (Sakyo-ku, Kyoto 606)
*** Member, M.E., Engineer, NEWJEC Co.,LTD (Chuo-ku, Osaka 542)
**** Member, Dr.Eng., Professor, Disaster Prev. Res. Inst., Kyoto University (Uji, Kyoto 611)
***** Member, Dr.Eng., Professor, Department of Civil Engineering, Kyoto University (Sakyo-ku, Kyoto 606)

2. Hydrologic and Meteorologic Time Series Data and Database

Information about hydrologic observations in the Yodo River basin (8,249 km^2) is compiled by the Ministry of Construction [1]. They have 45 rain-gauge stations and 70 discharge measurement stations. Similarly, as can be observed in **Fig. 1**, the Japan Meteorological Agency manages observation stations that record meteorologic phenomena, which are 82 rain recording stations (shown by circled dot), 40 observatories to measure temperature, wind velocity and sunshine hours (shown by underlined circled dot) and 5 sites (shown by station name in box and position with circled dot) at which vapor pressure is being recorded.

We have made use of ORACLE [2] for handling RDBMS and thus stored the data in two sets of time series of measured hydrologic and meteorologic observations. The first set of measurements has been put together from observation stations under the jurisdiction of the Ministry of Construction and affine agencies. This set contains hourly measurements of precipitation, discharge and water stage values for a 16 year period starting in 1976 and lasting until 1991. The second set of measurements is from observation stations under the jurisdiction of the Meteorological Agency (AMeDAS). This set contains hourly measurement data of precipitation, temperature, wind velocity, vapor pressure and sunshine duration from 1982 until 1993. To store and manage these data we have prepared 9 tables as shown in **Table 1**, to cover all required database for Yodo River basin.

Table 1 Database tables prepared using RDBMS

	Table Name	Contents
1	General	attribute of observation stations
2	Precipitation_Yodo	hourly rainfall from ministry of construction
3	Discharge_Yodo	observed discharge from ministry of construction
4	Water Level_Yodo	water level from ministry of construction
5	Precipitation_AMeDAS	hourly rainfall series from AMeDAS
6	Wind_AMeDAS	wind velocity time series from AMeDAS
7	Temperature_AMeDAS	temperature data from AMeDAS
8	Sunshine_AMeDAS	sunshine hours data from AMeDAS
9	Vapor_AMeDAS	vapor pressure data from AMeDAS

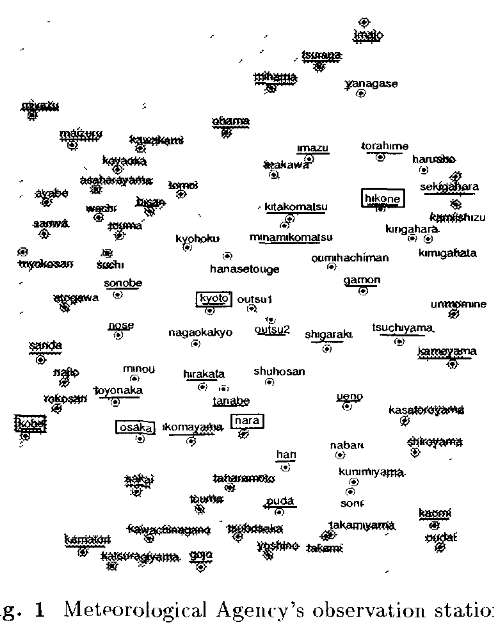

Fig. 1 Meteorological Agency's observation stations

Table 2 Example of GENERAL Table

River name	Station	St.No.	Data type	Table name	Station at which data is sought
Yodogawa	Hirakata	60532	discharge	DISCHARGE_YODO	Hirakata
Yodogawa	Takahama	60531	discharge	DISCHARGE_YODO	Takahama
Kizugawa	Ao	60451	precipitation	PRECIPITATION_YODO	Ao
Kizugawa	Shimagahara	60454	discharge	DISCHARGE_YODO	shimagahara
Kizugawa	Shimagahara	60456	precipitation	PRECIPITATION_YODO	shimagahara
⋮			⋮	⋮	⋮

Table 3 Example of PRECIPITATION_AMeDAS Table

YEAR	MONTH	DAY	HOUR	AO	SHIMAGAHARA	..
1989	6	16	0	0	0	...
1989	6	16	1	0	0	...
1989	6	16	2	0	0	...
1989	6	16	3	0	0	...
1989	6	16	4	0	0	...
1989	6	16	5	0	0	...
1989	6	16	6	0	1	...
1989	6	16	7	0	1	...
1989	6	16	8	0	0	...
1989	6	16	9	0	0	...
1989	6	16	10	1	1	...
1989	6	16	11	0	0	...
1989	6	16	12	1	1	...
.	.	⋮	⋮	⋮	⋮	⋮

We have created GENERAL base table which stores attributes of the observation stations, i.e. location, type of data, river basin name, station code number etc. as shown in **Table 2**. Along with the GENERAL base table other sets of base tables to store the time series data of various measurements have been arranged. For instance, the table PRECIPITATION_AMeDAS (**Table 3**) contains precipitation measurement data from stations under the jurisdiction of the Meteorological Agency, PRECIPITATION_YODO and WATER_LEVEL_YODO contain precipitation and water level time series data under the jurisdiction of Ministry of Construction. The DISCHARGE_YODO table holds the measurement data of discharge values from observation stations. The primary key for these tables consists of the four columns that uniquely identify each measurement instance in time, namely YEAR, MONTH, DAY, and HOUR. Similarly the AMeDAS meteorological data like air temperature, wind velocity, daylight hours and vapor pressure have been stored in 4 separate tables called respectively - TEMPERATURE_AMeDAS, WIND_AMeDAS, SUNSHINE_AMeDAS and VAPOR_AMeDAS. Some derived tables/views have also been established. The tool to reproduce precisely what we want, from these tables, is Structured Query Language (SQL) which tells RDBMS what information to SELECT, DELETE or UPDATE in certain columns in a table and show us the information row by row.

3. Geographic & Remotely Sensed Data and GIS

The geographic or topographic and meteorologic information for the Yodo River basin should be available to the users in the form of databases. GIS serves the purpose of turning geographic data into information. Each GIS must be designed to meet the needs of a particular objective. The data could be stored in three basic forms, (i) raster data (ii) vector data and (iii) point data. The point, line and area elements provide information about topology and location. We acquired these data sets from National Land Agency, Japan.

We also acquired some remotely sensed data. With the help of ERDAS 7.5 [3] these data were geometrically corrected and rectified to conform to UTM coordinate system so that they can be overlayed onto each other. We have arranged geographic data in three data structures as follows:

Raster Data : This data structure stores a value for the value of interest over space in an array. The original data is from a topographic map etc. The regularity in the array provides an implicit addressing system, allowing fast random access to specified locations in the database. Remotly sensed data, allows referencing of values through their position in the array. The analysis of data in raster format is usually easier than vector format data. Here grid values represent either the average value for the corresponding element area or the value for some point within the element. Usually land use and land cover data (see **Fig. 2**), elevation data (see **Fig. 3**) and latitude data (**Fig. 4**) are kept in raster data form.

Vector Data : This data structure is useful when data need to be arranged as a quantity with a starting coordinate and an associated displacement and direction. Location information in vector structure is coded explicitly in the database. The stream network can be seen in the **Fig. 6** in which the darker color represents first order stream, the lighter shades are for second and third order streams. The big blank area with a dark line in between is Lake Biwa.

Point Data : This data structure is best to employ for identifying the location of observatories as shown in the (**Fig. 1**).

4. Computation of Evapotranspiration Using RDBMS and GIS

The variation of precipitation and potential evaporation throughout the year and from year to year results in variations in the soil moisture content and, consequently, evapotranspiration. This non-linear behavior of each river basin makes evapotranspiration an important factor which should be carefully and accurately estimated. To get the estimation of hourly evapotranspiration using routine meteorological data, we decided to adopted Energy Balance method, which requires and needs to process a large amount of spatially distributed parameters like - albedo estimated from land use data set, latitude, altitude and nearest observation station data set, additionally the meteorological time series data, i.e. wind velocity, air temperature, sunshine hours and humidity. To cope with this, we have developed a program which computes the hourly evapotranspiration using the Energy Balance method with the help of GIS database and RDBMS.

We have estimated hourly evapotranspiration for each $1km \times 1km$ grid. To achieve that we have prepared GIS database consisting of (i) sub-basin's polygon (boundary delineation) data set (ii) land use data set (iii) altitude data set (iv) latitude data set and (v) nearest observatory data set for the entire Yodo River Basin. The sub-basin boundary delineation data set is in vector structure while the other data sets are in raster data structure.

We acquired the land use (KS-202) and altitude (KS-110) data sets from Natinal Land Agency, Japan and then, for our study purpose, produced the land use data set and altitude data set for Kinki district from KS-202 and KS-110 respectively. The nearest observation station data set is in raster form, in which the number of existing observatories which is nearest to the grid, is stored in each grid. This number is then referred to extract the hydrological and meteorological time series data from RDBMS. These GIS data sets were rectified to conform to UTM coordinate system. To get the evapotranspiration for sub-basin, the sub-basin polygon data set is overlayed onto the the GIS data sets and thus the data sets for sub-basin are produced.

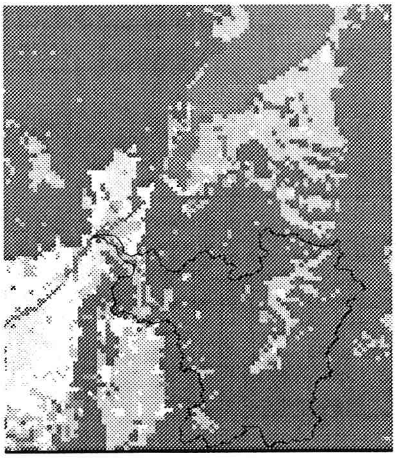

Fig. 2 Land Use Map of Yodo River Basin

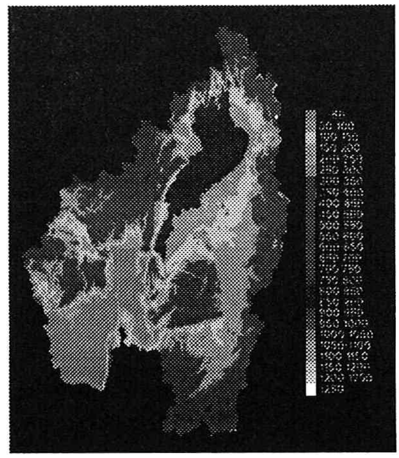

Fig. 3 Elevation Map of Yodo River Basin

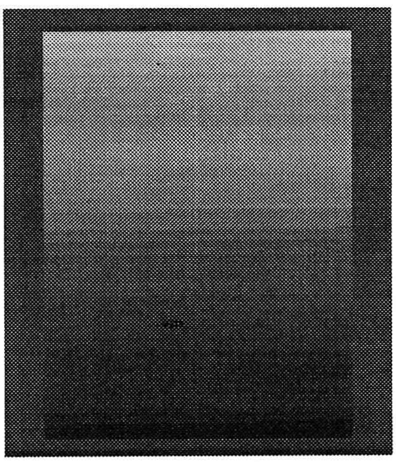

Fig. 4 Latitude Map of Yodo River Basin

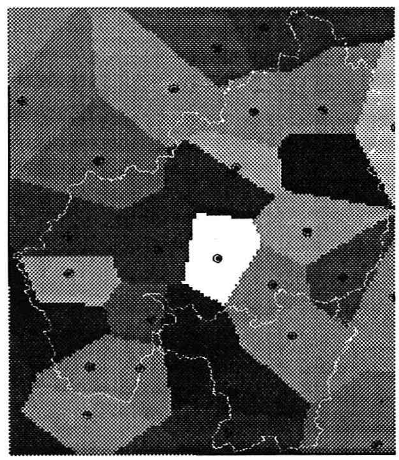

Fig. 5 Nearest Observatory Map

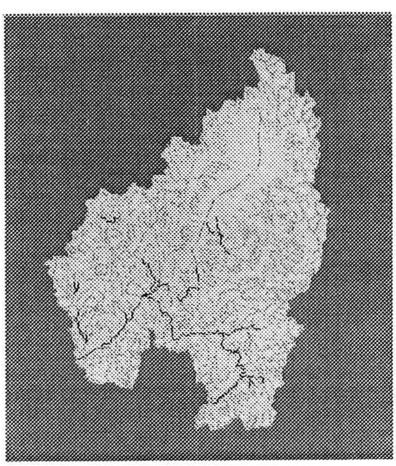

Fig. 6 Stream Network of Yodo River Basin

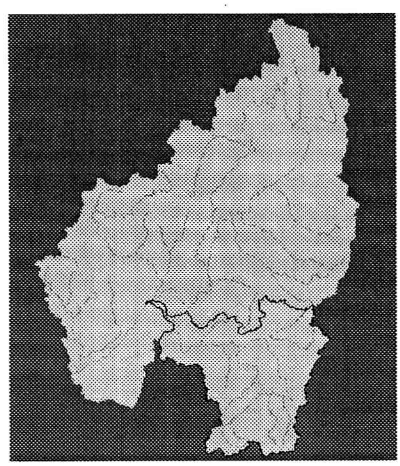

Fig. 7 Location of sub-basin Yahata.

The AMeDAS meteorologic data like sunshine hours, air temperature, wind velocity and vapor pressure for each grid within the sub-basin, needed to compute evapotranspiration, are extracted from RDBMS. An illustration of the overlay procedure is displayed in **Fig. 8** .

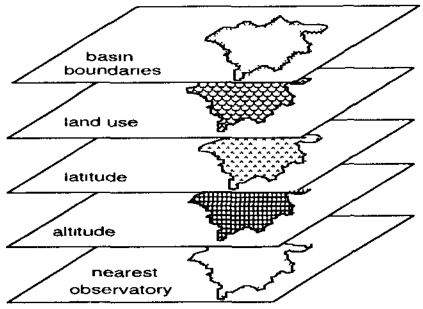

Fig. 8 Illustration of Overlay Technique

As explained above we overlay the study sub-basin (depicted by dark periphery line in **Fig. 7**) onto these databases and thus could create separate data sets consisting of land use/cover (**Fig. 2**), elevation (**Fig. 3**), latitude (**Fig. 4**) and nearest observation station selection (**Fig. 5**) for Yahata. In **Fig. 5** , the circled dots represent the location of observatories and each grid is depicted with different pattern/shade based on the distance from respective observatory. The program works in such a manner that outside the boundaries of the overlayed area the evapotranspiration is not calculated. **Fig. 9** is an illustration of the computed hourly evapotranspiration time series for the period of four years - 1988 to 1991 for Yahata sub-basin.

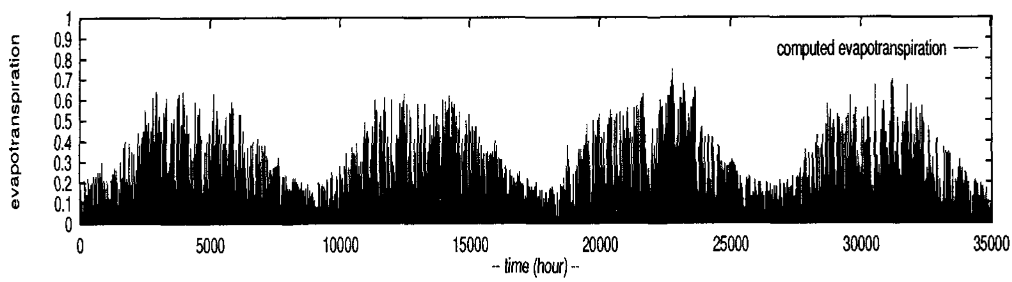

Fig. 9 Computed hourly evapotranspiration time series at Yahata

5. Summary

In few words - we have presented the use of the RDBMS to arrange the hydrologic and meteorologic time series data and the GIS to integrate different kinds of information for Yodo River basin with an objective of storing and managing large amount of data involved in the rainfall-runoff processes in mind. We can say that RDBMS and GIS are necessary to be used to achieve high level of accuracy, for, together they have the potential for efficient implementation of challenging research ideas & plans.

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References

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