ENVIRONMENTAL DATA MANAGEMENT SYSTEM - FROM DATA MONITORING, ACQUISITION, PRESENTATION TO ANALYSIS

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Abstract

Air pollutions have been a serious concern for citizens around the Las Vegas area, Nevada. Concentration of CO, ozone (O_3) and particulate matters (PM10, PM2.5) have been monitored for years. To compile Environmental Protection Agency's air quality monitoring regulation, Air Quality Department (DAQM) at Clark County, Nevada is required to create a system with the capability to collect the required air pollutant data and present to the public in a timely manner. The real-time and archived data will be applied to forecast model simulation whose results can provide more insight information to the agency administrator as well as the public.

This paper will demonstrate a web-based environmental data management system that provides both the responsible agency staffs and the pubic a simple and direct tool for data monitoring, presentation and analysis through its middle-tier data analysis/simulation modules and back-end database repositories. This system has efficient object-oriented design (OOD). Due to the complicity of data nature, the critical issues of dynamically adjusted data collection schedules through scattered monitoring stations and intensive model computation are discussed. By completing the system, the DAQM can provide the community around the Las Vegas Valley with more accurate and responding environmental data management system.

Keyword: data management, environmental system, database, data acquisition, air quality pollutant

Introduction

Air pollutions have been a serious concern for citizens around the Las Vegas area, Nevada. Concentration of CO, ozone and particulate matters (PM10, PM2.5) have been monitored for years. To compile Environmental Protection Agency's air quality monitoring regulation, Air quality department at Clark County, Nevada is required to create a system that collects the required air pollution data and reports to the public in a timely manner. Those data will be used for intensive model simulation.

Objectives

This paper will demonstrate a web-based environmental data management system that provides both the responsible county staffs and the pubic a simple and direct tool for data monitoring, presentation and analysis. The font-end of the site provides dynamically generated information pages from database. Meanwhile, the system will combine simulation model that provides the air pollution forecasting results for the Las Vegas Valley using real-time and historical database.

The critical issues of dynamically adjusted data collection schedules through scattered monitoring stations and intensive model computation are the flexible module design for data collection and efficient communication management between model forecasting output and real-time data feeding. More details will be discussed.

Methodology

A good object-oriented design (OOD) and object-oriented programming (OOP) are crucial to the success of the system. Hierarchical object model usually designs for extendibility with an object-oriented paradigm in mind. The application will also be scalable, flexible and easily maintainable.

To provide high flexible system, we have define the environmental system into four distinct tiers as shown in Figure 1:

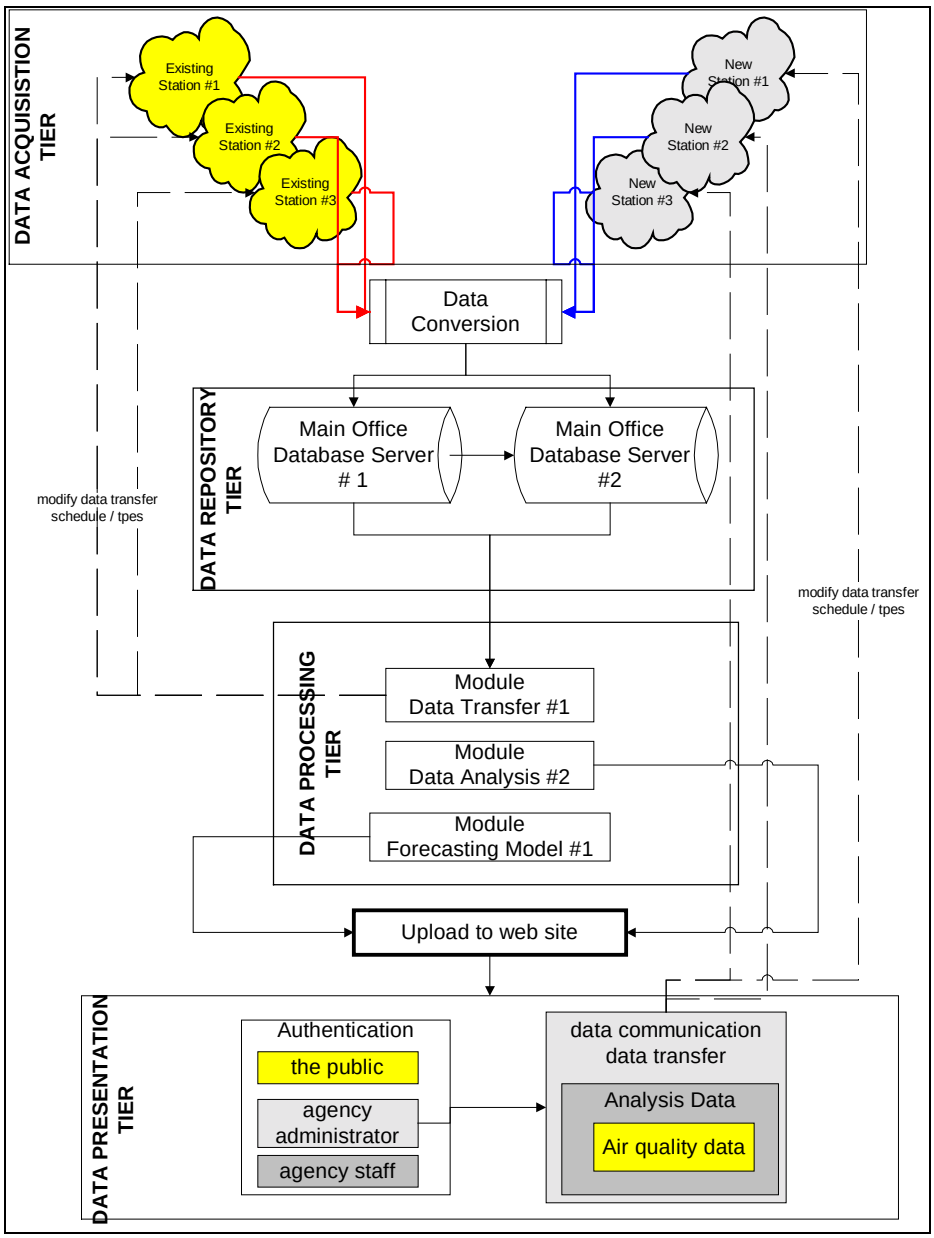

Figure 1. System design flow chart

1. Data acquisition tier – for monitoring station PCs that collect raw air quality data and transmit back to the main office,
2. Data repository tier – for real-time data repository and historical data retrieval,
3. Data processing tier – for data analysis and forecasting modules,
4. Presentation tier – external public access interface and internal role-defined administration interface.

Taken into the consideration of current agency monitoring operation and data collection flow, the system migration is expected. To some point, the agency will have both existing and new systems. Uninterrupted data provision through the system is crucial and required by the agency. During the transition, both new and existing data acquisition systems transfer data back into the main office. Since the data stream from two systems are not identical, the data acquisition system resides on the main office can identify the station source and convert to standard data format prior to the database storage. The business modules can be extended to include more processors as needed. The data module outputs can be sent to the data presentation tier for public accessing. Data management

module can be used to update and modify data transfer schedule and to analyze pollutant types.

The data presentation tier is a web-based application that provides all the available data to both the public and internal administration and analysis. As shown in Figure 1, the single portal entry with role-defined web authentication mechanism simplifies the web site design and strengthens the data utility rate for all level of users. The definition of user's role determines the hierarchical data presentation. By abstracting the data access into components that provide stateless, single-call data load, update, delete and insert operations, the underlying database can be changed or upgraded without significant impact on the application.

To optimize the data flow efficiency, data services layer maintain transitory state that is loaded when the component is activated and disposed when the component is disposed of or returned to the object pool. More details on each tier are discussed.

Data acquisition

The Nevada Center for Advanced Computational Methods (NCACM) at the University of Nevada Las Vegas uses LabVIEW (Laboratory Virtual Instrument Engineering Workbench) instrumentation and analysis software system for the Apple Macintosh computers, IBM PC compatible with Microsoft Windows, and Sun SPARC workstations. LabVIEW departs from the sequential nature of traditional programming languages such like BASIC and provides a graphical programming environment and all the tools needed for data acquisition, analysis, and presentation. The LabVIEW-based data acquisition and monitoring system for air quality related issues such as CO, NOx, PM10, PM2.5, ozone, wind speed and direction, and ambient temperature in Clark County.[1][2]

Virtual Instruments (VIs), programs used for LabVIEW, consists of a front panel (see Figure 2) and a block diagram (see Figure 3). The front panel (with knobs, switches, graphs, and so on) specifies the inputs and outputs and provides the user interface for interactive operation. Behind the front panel is the block diagram, which is the actual executable program. The components of a block diagram, icons, represent lower-level instruments and program control structures. The icons are "wired" together to indicate data flow in the block diagram.[1]

LabVIEW integrates data acquisition, analysis, and presentation in one system. For acquiring data and controlling instruments, LabVIEW supports IEEE-488 (GPIB) and RS-232/422, as well as plug-in A/D, D/A, and digital I/O boards. An instrument library with drivers for over 150 popular instruments simplifies instrument control applications.

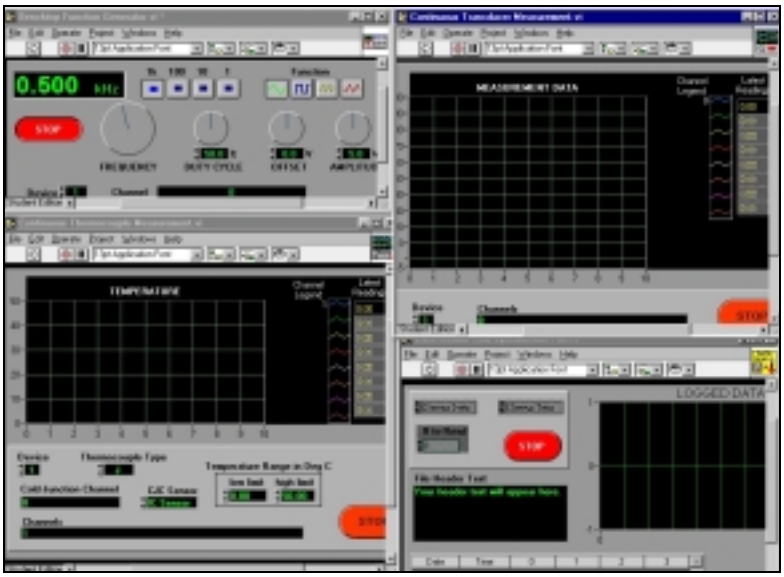

Figure 2. The virtual instrument front panel.

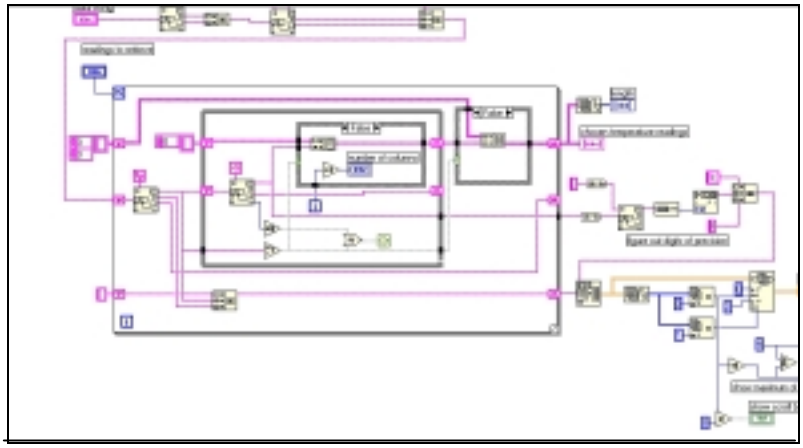

Figure 3. The virtual instrument block diagram.

The database access resource is expensive, the integrated analysis libraries installed in each PC of the engineering station can transform the raw data the signal, remove noise perturbations, correct for data corrupted by faulty equipment, or compensate for environmental effects, such as temperature and humidity prior to transfer the data into the main office.

Data Repository

A relational database management system (RDBMS) is selected for data repository. After qualifying those data from the stations, the data is saved to the designated database.

Data Processing/Model Simulation

The collected data from the station transmits into the main office. The Nevada Center for Advanced Computational Methods (NCACM) provides the data analysis module that calculates the raw concentrations into the more understandable Air Quality Index (AQI) required by Environmental Protection Agency (EPA). Any required data analysis module can be added into the system and report to the web-based system. Meanwhile, an intensive computation air quality forecast model is under development. By incorporating such module into the existing system, the agency can provide a complete air quality monitoring system to the public in the region of Las Vegas region.

Data Presentation Tier

According to the request from Department of Air Quality Management (DAQM) at the Clark County, Nevada, the NCACM designed an integrated air quality data management system that monitors air quality concerned pollutants such as CO, NOx, PM10, PM2.5, ozone, wind speed and direction, and ambient temperature in Clark County.

The data presentation tier is a web-based application that provides all the available data to both the public and internal administration and analysis. As shown in Figure 1, the single portal entry with role-defined web authentication mechanism simplifies the web site design and strengthens the data utility rate for all level of users. The definition of user's role determines the hierarchical data presentation. By abstracting the data access into components that provide stateless, single-call data load, update, delete and insert operations, the underlying database can be changed or upgraded without significant impact on the application

System Structure

The data acquisition and logging system designed by the NCACM uses National Instruments data acquisition (DAQ) hardware and Microsoft Visual Basic. The DAQ devices are controlled by Visual Basic through VI's Measurement Studio ActiveX controls. Each Measurement Studio control adds a specific function to program; we can use the control to set properties – such as the device, scan rate, and channel strings for DAQ devices – interactively through a set of property pages or programmatically in the Visual Basic code. [1][2][3][4]

As shown in Figure 4, the system includes a data logger, Station Manager, and a program that acquires analog signals with the Measurement

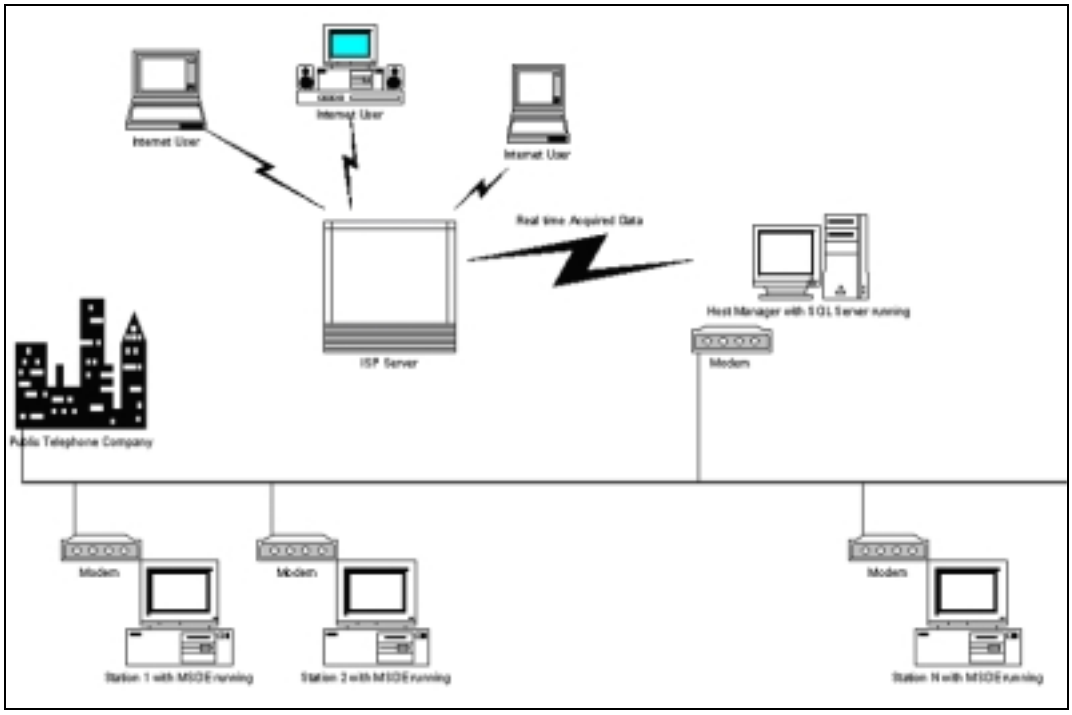

Figure 4. Air Quality Monitoring System Structure.

Studio Analog Input (CWAI) control. The data will be displayed on a graph and in tabular format and logged to both an ASCII file that can be viewed with any text editor and in MSDE database. Data loggers are useful for monitoring low frequency signals, such as temperature. Working with the data logger program, we can operate on scan rates, channel strings, named channels, and multiple channel objects and set these parameters programmatically. We can also visualize data in Visual Basic using the Measurement Studio Graph control and log data to a file and database using Visual Basic code.[5][6]

Results and Discussion

The air quality data acquisition and monitoring system developed by the NCACM provides high flexibility for data collection, data analysis and data presentation. The Integrated monitoring system allows the system to be operated as a stand-alone or fully integrated remote air quality data acquisition under the control of the main front panel of LabVIEW. It also includes a checklist to track standard maintenance and QA tasks in each monitoring station. By completing the system, the DAQM will better serve the community around the Las Vegas Valley with more accurate and responding environmental data management system

Acknowledgement

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