Design and Development of Air Traffic Management Safety Database Analysis System

Lixin Wang*
Civil Aviation Management Institute of China
Beijing, 100102, China
e-mail: wanglixincamic@163.net

Yi Liu
Civil Aviation Management Institute of China
Beijing, 100102, China
e-mail: liuyi61@ustc.edu

Mingjun Li
Civil Aviation Management Institute of China
Beijing, 100102, China
e-mail: limjun72@hotmail.com

***Abstract*—With the rapid development of civil aviation, air traffic management system plays a more important role in ensuring aviation safety, and hence there is an urgent need to use information technology to improve analysis level and efficiency of aviation safety information. In this paper, an air traffic management safety database analysis system is developed. It can not only store basic information of safety events by entering data directly or acquiring data from other sources, but also quantify and classify the incidents according to human factor analysis, defense failure analysis and organization factor analysis of SHELL model so as to achieve in-depth analysis of the safety information. In the development of the system, B/S mode, MySQL database, Java language and Struts 2 + Spring + Hibernate framework are adopted. Via flexible user role and permission mechanism it could ensure a safe and ordered access to safety data. Moreover, considering importance and complexity of data acquisition, this module is deployed on cloud computing platform as a service, which could improve data acquiring efficiency and also lay a foundation for follow-up data mining of ATC safety data. The system could provide a quantitative decision support for ATC safety information management.**

Keywords- air traffic management; database; cloud computing; civil aviation safety

I. INTRODUCTION

In recent years, with the rapid development of China's civil aviation industry, the number of aircraft taking off and landing guaranteed by air traffic management systems has increased dramatically, up to 250, 000 sorties used during 2012 Spring Festival transportation. Ensuring the safety and orderly operation of aircraft is the basic function of ATC (air traffic control) or ATM (air traffic management)[1]. In order to provide strong support for ATC safety management, information technology is usually used to improve information analysis level and efficiency of air traffic control safety.

Currently, there has developed a number of safety database systems in the international civil aviation industry, such as AIDS (Accident/Incident Data System) database in the ASIAS (Aviation Safety Information Analysis and Sharing) plan of FAA (Federal Aviation Administration) [2], in which data from multiple sources are used in FAA 8020-5 format [3]. The American next generation air transportation system declares, in the national airspace system, ASIAS participants (including FAA, airlines, airports, air traffic control organization) will work together to realize the data integration, analysis and dissemination. ASN (Aviation Safety Network) is another important database belonging to FSF (Flight Safety Foundation) which as an independent institution has recorded more than 10,700 worldwide aviation safety incidents of all kinds [4]. This database also offers detailed statistical analysis of period, flight phase, flight nature, geographical breakdown and the worst accidents particularly.

In China, the civil aviation safety databases mainly include "Civil Aviation Safety Net of China" which as working system of aviation safety office of Civil Aviation Administration of China(CAAC), holds all kinds of safety data recorded and reported by each regional authority of civil aviation; "Sino Confidential Aviation Safety reporting System"(SCASS)[5] whose role is to collect unsafe events and hidden danger reports of unsafe events in the running process of aircraft or existing and potential problem and shortcomings of current aviation safety system from the civil aviation employees of their own accord including pilots, controllers, flight attendants, maintenance personnel, security personnel and other related personnel, handle and analyze them, and send out warning information according to the degree of hidden danger; two other systems focused on ATC safety developed by the Second Research Institute of CAAC: "ATC safety information system" and "rapid detection system of unsafe ATC events" which provide a comprehensive record of all kinds of air traffic control safety incidents and realize early warning of hazard through real-time monitoring of radar data.

Taking into account diverse and systematic causes of unsafe ATC events, this research involves not only storage and analysis of time of the events, the occurrence region, the event level and other factors, but also in-depth analysis from human factors, defense factors, organizational factors and other aspects of the events by using SHELL model [6] (reflecting interrelation of people, hardware, software and environment), aiming at discovering key safety problem from safety information and achieving truly data-driven safety management. SHELL model is used to analyze

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safety events putting particular emphasis on following relations: life and hardware (device) L-H; life and software L-S; life and environment L-E(including soft organizational environment and actual working environment);life and life L-L.

Besides the analysis system, the safety data acquisition is another necessary part which involves more operations. Considering its characteristic of big data volume and high computing requirement, cloud computing mode is applicable to this part. Cloud is a large, configurable and scalable virtual pool of resources suitable for dynamic programming and easy to access, covering hardware, development platform and services provided [7]. The pool of resources carries out allocation on demand, and provides security and safety protection. The main characteristics of cloud include resource virtualization, resource diversity, resource scalability, easy to optimize resources, Internet-centered design and distribution according to needs. According to provided services, cloud mode can be divided into IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service). The infrastructure of cloud computing mainly provides end users with hardware and software resources as the content of service by using SOA (Service Oriented Architecture) framework. Service developers can obtain corresponding hardware and software resources to work through the public interface provided by cloud computing platform, and end users will custom or utilize services according to their own needs. Cloud computing system architecture is shown in Figure 1[8].

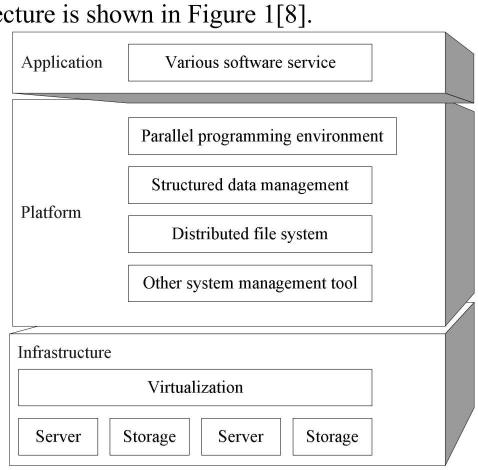

Figure 1. Cloud Computing System Architecture

The architecture is divided into three layers. A) Infrastructure layer. It mainly includes computing resources and storage resources. The whole infrastructure can be provided to the user as a service (IaaS), which provides users with not only virtualized computing resources and storage, and also network bandwidth for reliable access. B) Platform layer. Designed above the infrastructure layer, the platform layer can be considered as the core layer of the whole cloud computing systems, including parallel program design and development environment, distributed storage management system of massive structured data, distributed file system and other system management tools to implement cloud computing, such as resources deployment of cloud computing in the system, distribution, monitoring and management, security management, concurrency control etc.. The platform layer is mainly designed for application developers, and it provides all platform resources needed in application program running and maintenance which shouldn't be within developers' consideration when using these resources. C) Application layer. The application layer provides users with simple application services and user interactive interfaces.

In this study we developed ATC safety database system based on B/S (Browser/Server) mode using MySQL database technology, Java programming language and the Eclipse integrated development environment. The data acquisition module as the part involving more computing resources, individually adopts advanced cloud computing mode in order to improve efficiency and also provide a platform for the follow-up data mining of ATC safety data.

II. System Architecture and Function

A. System Architecture

As an aviation safety information system, ATC safety database analysis system must meet the following requirements: (1) the ATC system shall record the basic information of safety events, such as the event occurrence time, place, air space environment, meteorological grade, flight phase, event class etc.; (2) the system should have survey data for SHELL model, and function of in-depth analysis based on these data, which is an important part of this system; (3) the system should provide statistical functions for managers and decision makers; (4) the system should provide different services for different users and maintain sufficient stability and security.

Taking into account these requirements, we chose B/S (Browser/Server) mode as system development mode, eliminating the need of client development, which is convenient for the users and helpful to system security because of central management and maintenance of the servers. As to database management tools, MySQL is selected due to its open source, reliability and scalability [9]. The overall structure of the system is shown in Figure 2. The system is generally composed of safety incident database module and data query and analysis module. The safety incident module covers functions of data acquisition, data entry, data edition and data delete, in which data acquisition part individually adopts cloud computing mode further detailed below. The data query and analysis module implements information query, information statistics, analysis of SHELL model and causing factor analysis.

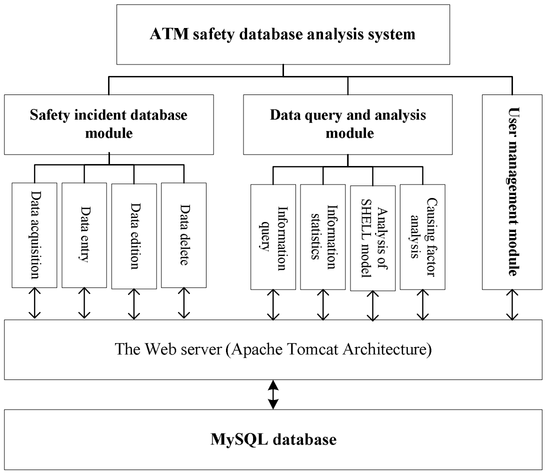

Figure 2. Atm Safety Database Analysis System Architecture

In this system, the most important database table is safety events data as shown in Table 1. This table holds the basic information of safety events and analysis results of them, among which SHELL model data is divided into five aspects: people, software, hardware, environment, organization. Based on these factors, events can be analyzed according to aspects of behavior, condition, defense and organization.

Specifically, behavior analysis include six factors: critical information acquisition, information interpretation, goal setting, strategies and methods, action plans, implementation of plans; condition analysis include five factors: workplace conditions, organizational climate, human capacity constraints, attitude and personality, psychological and emotional factors; defense analysis include six factors: knowledge, means of restraint, warning systems, control and timely restoration, protection and inclusion, escape and rescue; organization analysis include twelve factors: training, human resource management, safety responsibilities, communication(include communication, navigation and surveillance), organizational culture, goal conflict, policies and procedures, maintenance management, equipments and infrastructure, risk management, change management, the external environment. The data is composed of two parts, one is the basic information of events (including event area, unit, class, level, etc.), the other part is professional ATC safety analysis personnel according to the former, gets SHELL model factors and further analysis including behavior, condition, defense and organization analysis.

B. Data Acquisition Module

In addition to manually input data, the system also offers data acquisition function from other data sources,. Data acquisition module is an important and relatively independent one in the database analysis system, because data will be derived in future from different sources such as branch offices. The main characteristic of the module is computing-intensiveness and modularity, which is applicable to cloud computing platform.

The data acquisition process is shown in Figure 3. Data acquisition flow is composed of metadata extraction, data property mapping, data cleaning and data loading. The former two steps of the flow are taken as data preparation procedure, and these steps and relevant configuration are designed to process data types which are mainly designated by metadata. The third step belongs to data pre-processing procedure which covers data cleaning and dirty data processing etc.. The last step is data loading in which actual original data are compared and identified before information are extracted.

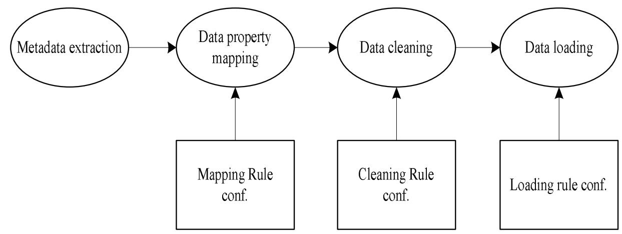

Figure 3. Data Acquisition Process

According to the requirements of service project on cloud computing platform, the data acquisition process of the system is decomposed into several service modules, completing the task of data acquisition through the combination of these modules. As shown in Figure 4, this part is divided into four layers, including the data persistence layer, component layer, service composition layer and presentation layer. Data persistence layer represents a variety of data sources, such as database systems, file systems or other systems (data interface transformation service can be customized between different systems). Component layer includes modules of data interface transformation, property mapping, metadata extraction, cleaning rule configuration, data loading and other services. Service composition layer combines these service modules according to certain logic relationship to complete the acquisition process. Services composed in service composition layer are provided to users in webpage form.

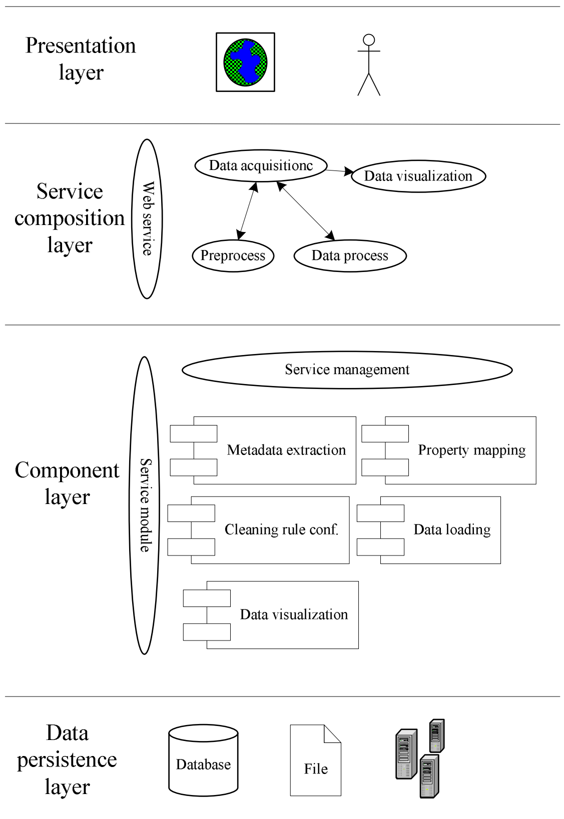

Figure 4. Service Framework Of Data Acquisition Module

C. System Functions

The system functions are mainly ATC safety information management, including queries and statistical analysis of unsafe events in aspects of time, region scope, event classification and grading etc., event causation analysis based on SHELL model, and statistical analysis of relevant human factors, defense failure factors and organization factors and so on. In terms of user management, the system owns a flexible hierarchical management method of custom user roles and permissions, such as system administrators, safety information analysts, and safety information recorders. Furthermore, data input ways include direct entering data and data acquisition from other data sources, and the latter is more efficient because it is based on a cloud computing platform.

III. KEY TECHNOLOGIES AND SYSTEM IMPLEMENTATION

A. Key Technologies

The system employs Java language for Web application development, key technologies of which are shown in Figure 5 [10]. Struts framework is an MVC framework (Model-View-Controller that divides application into 3 levels: model layer, view layer and control layer), which implements Servlet and JSP tags as part of their own functions. Struts 2 is an improved version of Struts, and has a more powerful scalability and functionality. Spring framework is a lightweight container frame with the core of IoC (Inversion of Control) and AOP (Aspect Oriented Programming), including the presentation layer of Spring MVC, persistence layer of Spring JDBC and business layer of transaction management, and many other enterprise application technologies. Hibernate is an ORM (Object-Relational Mapping) framework of lightweight JDBC package, by which developers can use it in an object-oriented way of thinking to operate the database.

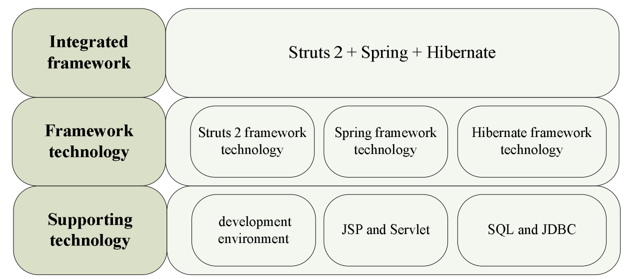

Figure 5. Web Application Development Technology Based on Java Language

The system uses Struts 2 + Spring + Hibernate technology framework for the development. Struts 2 is mainly responsible for display and request control, Spring is primarily responsible for transaction control of access to the database class and realization of Bean management and generation by using IoC, and Hibernate is mainly used to complete component functions of data access layer.

Data acquisition module is implemented on cloud computing platform shown in Figure 6. It can be seen that software tools involved include Eucalyptus, Hadoop, Java, Flex and so on.

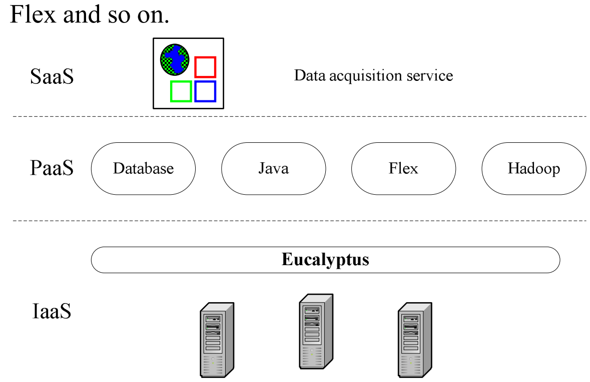

Figure 6. Basic Cloud Computing Platform Of Data Acquisition

Eucalyptus [11] means “Elastic Utility Computing Architecture for Linking Your Programs To Useful Systems” that was developed as an open source project by a group at the University of California, Santa Barbara. Eucalyptus mainly realizes hardware virtualization and unified management of hardware resources to meet elastic demand of cloud computing environment. It uses common Linux tools and basic Web-based services and is deployed on cluster or server group. The system uses secure SOAP internal communication, so it is scalable and easy to use. The software tools of this layer can be used to configure clusters to enable private cloud, and its interface is also compatible with the public cloud, which is helpful in building hybrid cloud to expand cloud computing environment. Hadoop [12] is an open source, distributed and parallel programming framework running on large-scale clusters. It can be used to easily write distributed parallel programs handling large amounts of data, running on large scale computer clusters comprised of the hundreds and thousands of nodes. Flex was originally developed to release as a J2EE application, or a JSP tag library. It can compile MXML (Flex markup language) and Action Script into FLASH application.

B. *System Implementation*

The user of the system can be divided into initial report user, analyst and administrator. User permissions are increased orderly, that achieve effective hierarchical management data and permissions. When the system works, data is read by the data acquisition module from other database automatically or inputted manually by report user, then by the analysis of professional staff to analysis and summary of SHELL model. The main interface of the system (log in as an administrator) is shown in Figure 7, where front items are provided in both lists and icons, including the event causation analysis, causation analysis database, class statistics, level statistics, human factors statistics, defense failure statistics, organization failure statistics, fault tree analysis, data download and password change.

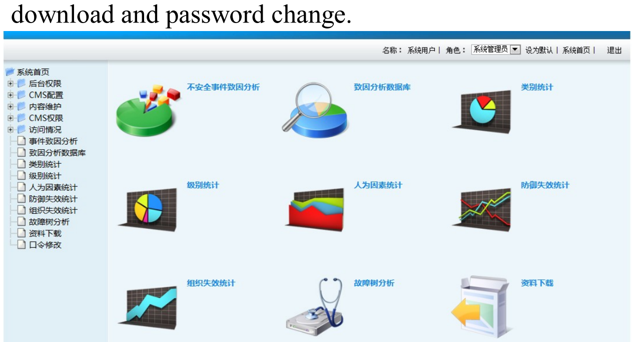

Figure 7. Main Interface of The Database System

Data can be entered by clicking "event causation analysis". Input data items include basic information, event class, event level, the survey data (SHELL model) and causation analysis items of behavior analysis, condition analysis, defense analysis, organization analysis, and the proposed measures shown in Figure 8.

Figure 8. Interface of Causes Analysis for Data Classification

In terms of statistical analysis of the data, the system supports statistics of the basic information (event area, event class, level, etc.), and also supports statistical analysis of the event causation, including human factor statistics, defense failure statistics, organization failure statistics, as shown in Figure 9.

Figure 9. Interface of Human Factors Statistics Analysis

As a relatively independent part of the whole system, data acquisition module is implemented under cloud computing architecture. In realization of data acquisition, Eucalyptus is similar to Amazon and mainly uses image files to create and manage Linux environment for users. These image files provide the size, type and mount point of the operation system. The concrete steps of creating cloud computing environment include:

1.user application: after cloud computing platform is created and provided, users can apply for platform certification and Secret Key etc..

2.hardware acquisition: install EC2 client and use client API to set environment variables, instantiate image and create platform environment etc..

3. platform tool deployment: use the obtained operation system to integrate required tools and develop applications. In this system, Java platform and Axis tool are employed to develop services, while hadoop is also deployed to implement distributed computing.

IV. CONCLUSIONS

The system has been designed using Struts 2 framework of MVC model to improve the efficiency of development. In the process of system development, we take into account access control requirements of the B/S system to ensure that different users be within their operating range of the corresponding data entry editing, query and statistical analysis of causation. Unlike previous ATC safety information systems, this system classifies and quantizes human factors, defense failures and organization factors based on SHEL model, achieving in-depth analysis of safety information. Furthermore, the system need improving its function and application in some aspects, such as data mining in safety index factors, data backup, which are our next work to consider.

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TABLE I. LIST OF SAFETY EVENTS DATA STRUCTURE

Keyword Meaning	Keyword name	Data Type	Note
Event sequence number	Evt_seq	Bigint	Primary key
Event identifier	Evt_id	Varchar	
Timestamp	Evt_time	Timestamp	Default: system time
Event occurrence region	evt_region	Varchar	
Event occurrence unit	evt_branch	Varchar	
Event occurrence area	Evt_area	Varchar	
SHELL model data	Evt_shel	Varchar	A total of 5 items
Event class	Evt_type	Varchar	
Event level	Evt_level	Varchar	
Behavior factors of event analysis	evt_behavior	Varchar	A total of 6 items
Condition factors of event analysis	evt_condition	Varchar	A total of 5 items
Defense factors of event analysis	evt_defence	Varchar	A total of 6 items
Organization factors of event analysis	evt_organization	Varchar	A total of 12 items
Event data	evt_attach	Varchar	A total of 3 items
Proposed measures	evt_result	Varchar	