Advances in Computer, Signals and Systems (2022)
Clausius Scientific Press, Canada
DOI: 10.23977/acss.2022.060510
ISSN 2371-8838 Vol. 6 Num. 5

BIM-Based 3D Digital Design System for Airports

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Keywords: BIM Model, Airport 3D, Digital Design, GIS Model

Abstract: BIM serves as a data base for the entire airport project by establishing a three-dimensional digital information model. It also provides accurate and reliable information for each phase of the airport project life cycle and builds a platform for information exchange and sharing. In order to solve the shortcomings of the existing airport 3D digital design system research, this paper discusses the basic features of BIM, 3D digital design system performance requirements and airport 3D spatial platform, and briefly discusses the development environment and project overview of the design system proposed in this paper. And the design of the design system is discussed, and finally BIM is experimentally analyzed for the progress of the airport 3D digital construction image. The experimental data shows that the average accuracy of BIM in the measurement of four areas of the airport reaches 97.9%, while the average accuracy of 3D grid and 3D point cloud measurement is less than 90%. Therefore, it is verified that the BIM-based airport 3D digital design system has a good performance.

1. Introduction

The purpose of the airport 3D digital design system platform is to enable airport staff to store and edit airport information and visualize operations in maintenance and repair through an interactive user interface that can be used in remote network devices and connected to the Internet through a web browser.

Nowadays, more and more scholars have conducted a lot of research through various technologies and system tools in regional economic medium and long-term forecasting, and have achieved certain research results through practical research. koteswara R S believes that with the rapid development of 3D digital design technology in the field of airport construction, the data base and technical means of 3D digital airport construction are becoming more and more perfect. 3D digital airport design has gradually developed into an important part of airport construction and management. In view of the complex environment around the airport and the difficulties of airport construction and management, Koteswara R S takes the airport project in Southwest China as the basis, aiming to build a 3D digital airport in Southwest China to provide effective support for airport construction and operation management.By combing the 3D digital airport key technology, Koteswara R S discusses the data architecture of 3D digital airport construction, technical architecture and system design and implementation process [1].Mcconnell P studied the rapid measurement method of airport runway ground reference based on 3D laser lidar scanning technology, and used laser lidar to obtain high precision and high density 3D point cloud data of airport runway environment for constructing high precision airport environment digitization for surface model (DTM), plane virtual measurement and profile generation . And the experimental analysis shows that the 3D LIDAR scanning technology can efficiently and accurately obtain the ground reference spatial 3D geographic information data and provide comprehensive spatial data measurement reference for airport runway space design management [2].Hackett R BIM technology has the advantages of visualization and informatization. However, BIM technology is mainly applied in the field of construction, and BIM technology is less applied in airport road engineering.Hackett R studied the application of BIM technology in the 3D design of airport roads. Based on Revit platform and using secondary development technology, a parametric model library of airport roads was established using Revit, and 3D curve fitting algorithm was applied to design airport road paths, and finally a 3D digital model of airport roads was established [3]. Although there are abundant existing studies on regional economic medium- and long-term forecasting, there are certain shortcomings in regional economic medium- and long-term forecasting based on least squares support vector machines.

This paper focuses on the design and application of a BIM-based 3D digital design system for airports, which is one of the most important components of the paper. Firstly, the analysis of the performance requirements of the 3D digital design system is analyzed. Secondly, the framework of system composition is introduced and the software interface design is given; then the standardized integration and unified management of data in airport 3D digital design by BIM in the data layer of the system is introduced in detail, and the analysis of 3D digital functions such as quantity calculation, drawing design, collaborative design and collision check in the 3D digital design of airport in the application layer is introduced, and finally the construction image progress of an airport by BIM is analyzed. The experimental analysis is carried out to verify the high accuracy of BIM technology measurement results.

2. BIM-Based Three-Dimensional Digital Design of the Airport

2.1 BIM Basic Characteristics

BIM is building information model, BIM has the following characteristics.

(1) Informationization of model: BIM uses informationization to simulate various real properties of structural units, for example, in track engineering, structural components such as track plates, bearing blocks, fasteners and rails are used as the basic expression objects, and no longer use geometric elements such as points, lines and surfaces as the basic expression objects like CAD [4].

(2) Parameterization of the model: BIM-based 3D parametric design is to create and drive the model by inputting and modifying design parameters, and at the same time, the parametric model can be used to analyze various building performance of the structure [5].

(3) Uniformity of information: the successful application of BIM concept in an engineering project needs to rely on the support of several software with different functions, and the BIM software in the market nowadays all interact with information through a unified standard (IFC) [6].

(4) Synergy of information: as a common platform for information communication among different parties involved in the project (design unit, construction unit, operation unit), BIM makes data interaction and communication and coordination among multiple participants more rapid and efficient, which guarantees timely and accurate transmission of engineering information [7].

2.2 3D Digital Design System Performance Requirements Analysis

The BIM airport digital system analyzes and processes the three-dimensional data of the airport road surface, so that the airport manager can grasp the current situation of the airport in a timely and accurate manner, which largely determines the plan and decision of the manager for airport maintenance and reconstruction [8]. Therefore, the system needs to meet the following performance requirements:

(1) Accuracy of calculation results: accurate test results are crucial for managers, and only through accurate alignment results can effective airport index analysis be performed to ensure the accuracy and reliability of subsequent analysis results [9].

(2) System practicality: When the digital system is built, on the one hand, the format of its input data should support the common 3D point cloud format, and on the other hand, its final output data should correspond to the common indicators in airport road surface management, so that the system has strong practicality.

(3) System scalability: When the system is in actual use, users often put forward new functional requirements, so the system needs to have a modular structure to facilitate the addition of new functional modules, so that the software has good scalability [10].

(4) System stability: Due to the large amount of data on the airport road surface, the system runs with complex calculations, which puts higher requirements on the stability and fault tolerance of the system. The system must be able to have a certain degree of recovery capability in the event of an accident to ensure stable operation.

2.3 Airport 3D Spatial Platform

The fitted plane is obtained from the discrete points in space, which is actually an optimization process, i.e., the problem of finding the minimum sum of distances from these points to a certain plane [11].

The algorithm can be described as follows:

For all the input points that need to be fitted to the airport 3D digital plane, the number of points is x. If x is less than 2, it is not enough to fit the plane. If x is greater than or equal to 2, set the point cloud set as $\{G_1, G_2, \ldots G_x\}$, the coordinates of G_y is $(u_y, v_y, i_y)^M$, calculate the point cloud center of gravity $\hat{G}$.

$$\hat{G} = \begin{bmatrix} \hat{u} \\ \hat{v} \\ \hat{i} \end{bmatrix} = \begin{bmatrix} (u_1 + u_2 + \ldots + u_x)/x \\ (v_1 + v_2 + \ldots + v_x)/x \\ (i_1 + i_2 + \ldots + i_x)/x \end{bmatrix} \tag{1}$$

(2) each point minus the center of gravity $\hat{G}$,to get $G_y^{'} = (\Delta u_y, \Delta v_y, \Delta i_y)$

$$G_y^{'} = \begin{bmatrix} \Delta u_y \\ \Delta v_y \\ \Delta i_y \end{bmatrix} = \begin{bmatrix} u_y - \hat{u} \\ v_y - \hat{v} \\ i_y - \hat{i} \end{bmatrix} \tag{2}$$

(3) Calculate the covariance matrix Q:

$$Q=\begin{bmatrix} \sum_{y=1}^{x}\Delta u_y^2/x & \sum_{y=1}^{x}(\Delta u_y\cdot\Delta v_y)/x & \sum_{y=1}^{x}(\Delta u_y\cdot\Delta i_y)/x \\ \sum_{y=1}^{x}(\Delta u_y\cdot\Delta v_y)/x & \sum_{y=1}^{x}\Delta v_y^2/x & \sum_{y=1}^{x}(\Delta v_y\cdot\Delta i_y)/x \\ \sum_{y=1}^{x}(\Delta u_y\cdot\Delta i_y)/x & \sum_{y=1}^{x}(\Delta v_y\cdot\Delta i_y)/x & \sum_{y=1}^{x}\Delta i_y^2/x \end{bmatrix} \tag{3}$$

(4) Calculate the eigenvalues and eigenvectors of Q. The smallest eigenvector corresponds to the airport plane normal to X, and the final fitted airport plane is considered to be over the center of gravity, so that a unique spatial plane can be fitted.

3. BIM-Based Airport 3D Digital Design System Investigation and Research

3.1 System Development Environment Construction

(1) Development tools

The development tool of RevitAPI is VSTA which comes with Revit. VSTA supports C# and VB.NET syntax, and the principle of development through VSTA is to generate a script macro, and the process of developing the function expansion of Revit software mainly includes the following steps:

(1) Start ViuslStudio2022, create a new class library project.

2) Reference the interface assembly library files: RevitAPI.dll and RevitAPIUI.dll, and set their CopyLocal property to False, which means you don't need to copy the assembly files to the current folder.

3) Add namespace references in the program.

4) Add the command class property.

5）Create an external command, which requires a new class.

6）After the program code is written, compile the class file.

(7) After the program is loaded, click the loaded external command or external application button to run the program.

(2) Plug-in loading

Add-InManager plug-in loading To realize the secondary development of Revit, after installing Revit product development tools in the computer, you also need to install Add-InManager to realize the loading and management of custom programs.

3.2 Project Overview

Anqiang airport is an airport under construction, the existing Anqiang airport is located in a straight line distance of about 11km west of the city center, about 4km southeast of a town on the river road. The proposed airport site is located in the hilly area in the northwest of the city, about 16.9km away from the city center, the road mileage is about 32km. the civil airport project flight area index 4C, mainly including a new 2750mx50m runway, 8 (3C3B) apron, 5400m2 terminal building and communications navigation, navigation lights, water supply, power supply, fire rescue and other Various supporting facilities. The project construction period is 2 years.

4. BIM-Based Airport 3D Digital Design System Application Research

4.1 The Overall Architecture of BIM-Based Airport 3D Digital Design Dystem

The platform architecture planning should fully consider the actual needs of airport informationization and visualization. In the architecture of the airport 3D digital platform, the internal and external airport environment and the characteristics of each stage of the whole project cycle should be fully considered, and the airport failure potential should be eliminated in the deployment architecture, and BIM 3D digital design, data backup and status monitoring mechanisms should be introduced in the application architecture to enhance the availability of the airport 3D digital platform as much as possible. The detailed system architecture is shown in Figure 1.

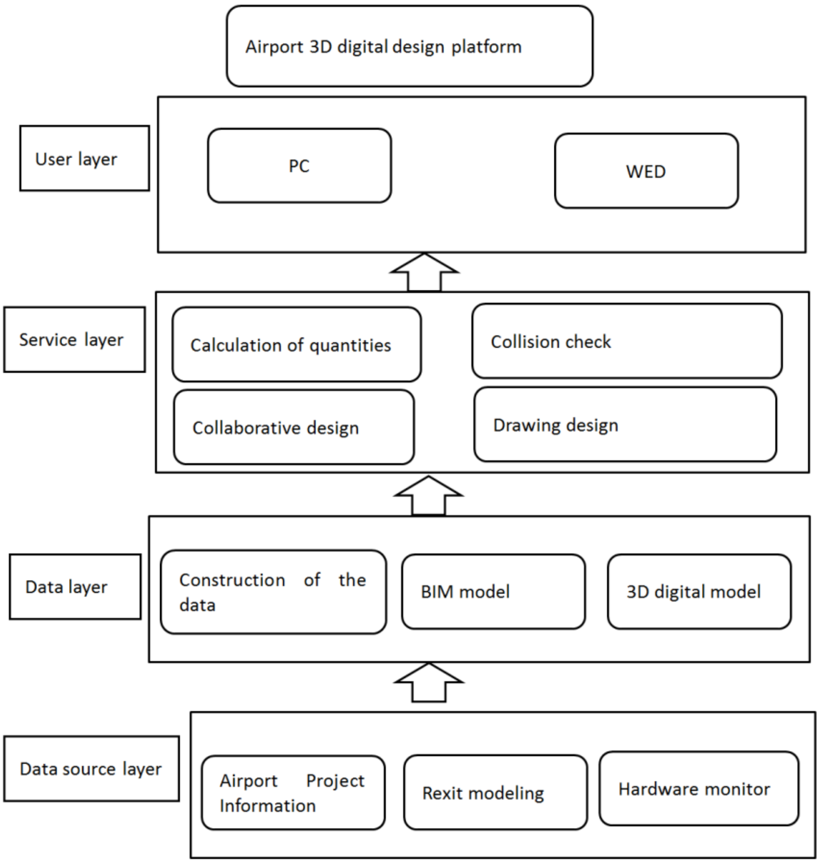

Figure 1: Airport 3D digital design system

For the overall architecture of BIM-based airport 3D digital design system, the specific functions are as follows.

(1) The system platform as a whole adopts the architecture of two ends and one cloud, the two ends are PC end and WEB end; one cloud is the service end (JAVA background).

(2) The system service layer is docked to the BIM model in the design stage, with BIM model for calculation of project quantity, drawing design, collaborative design, collision check and other 3D digital functions. The construction information is synchronously connected with the 3D model during the construction process and is managed on the 3D technology management module.

(3) Standardized integration and unified management of BIM model, GIS (Geographic Information System) model and construction data created in the design stage through the 3D data layer, output standardized BIM model based on IFC standard, unified data format and access rights

control. Real-time data on site can be shared remotely, and the BIM model of each project stage can be analyzed intuitively, as well as the information summary statistics of the single project under construction, to meet the demand of data exchange in different project stages and ensure the timely collaboration of project construction data.

4.2 BIM-Based Airport 3D Digital Design System Application

In order to compare the advantages and disadvantages of BIM model, 3D grid and 3D point cloud calculation, three methods were used to measure the image progress between the beginning and the completion of construction in different areas of the same site in the process of measuring the image progress of the four areas of the 3D digital model of the airport. Since the exact amount of fill during the period from the start of construction to the completion of construction can be determined, the accuracy of the two model forms in measuring the image progress of airport construction can be measured by comparing the calculated results with the actual results. By comparing the operation time, the measurement efficiency of the two methods can be analyzed. The specific experimental data are shown in Table 1.

Table 1: Measurement accuracy data

Model	BIM	Grid	Point cloud
Area1	98.2%	91.4%	86.3%
Area2	98.5%	89.6%	85.7%
Area3	97.8%	87.5%	86.8%
Area4	97.2%	88.4%	85.6%

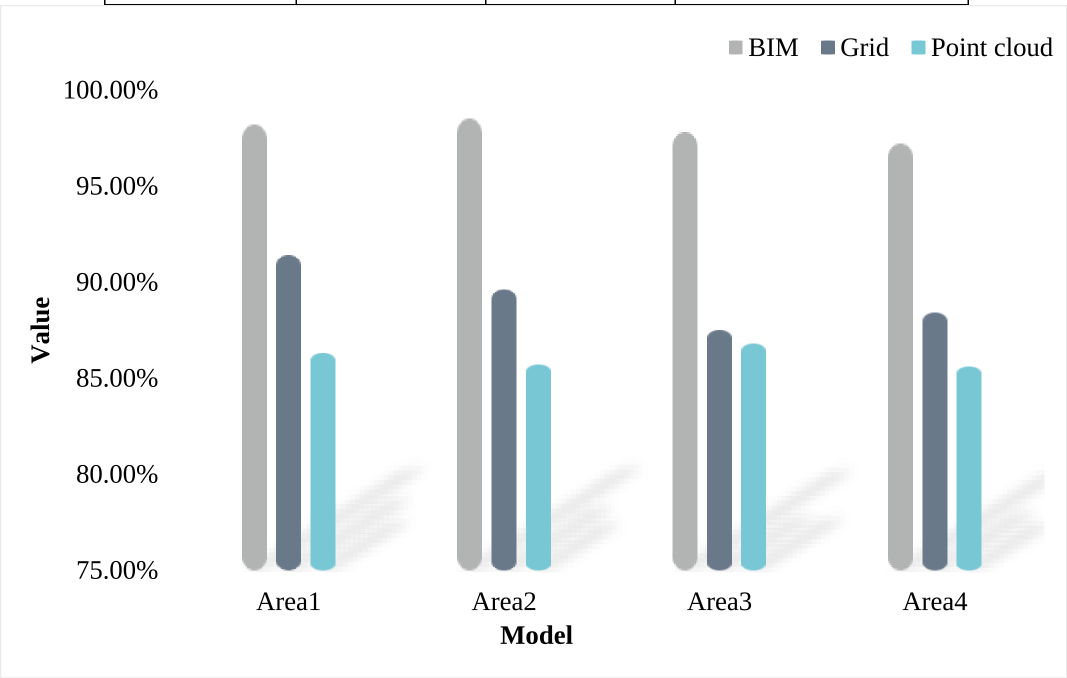

Figure 2: Comparison of measurement accuracy data

According to Figure 2, the accuracy of BIM's measurement of the image progress of area 1 in the 3D digital construction of the airport reached 98.2%, while the accuracy of the other two types of 3D grid and 3D point cloud calculation reached 91.4% and 86.3%, respectively. 98.5%. The accuracy of 3D grid and 3D point cloud calculation reached 87.65% on average. And the accuracy of area 3 image progress measurement reached 97.8%. The highest accuracy of 3D grid and 3D point cloud calculation is only 87.5%. And the accuracy of BIM in measuring the image progress of area 4 reached 97.2%, while the accuracy of 3D grid and 3D point cloud calculation reached 88.4% and 85.6% respectively. According to the above analysis, it is obvious that the accuracy of BIM measurement is better than the other two methods.

5. Conclusions

In this paper, the BIM-based airport 3D digital design system is selected as the research object, and the scalability, practicality, stability and accuracy of calculation results of the airport 3D digital design system are analyzed and discussed. We also analyze BIM informatization, parameterization, completeness, uniformity, and collaboration, as well as the analysis of airport 3D spatial platform fitting. Through the application of BIM in the airport 3D digital design system project, theoretical research, comprehensive evaluation and platform solution construction are carried out. On the basis of the construction mode and digital level of typical provincial and municipal airport 3D design projects, the difficulties and key points of the application of BIM technology in the whole cycle of airport 3D digital design in planning, design, construction and operation are discovered. The integration and standardized output of BIM data in the whole cycle of the project is proposed, and finally the BIM-based airport 3D digital design system is constructed and the superiority of BIM technology in its application is verified through specific experimental analysis.

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