Implementation of a Cross-Platform 3D Virtual Construction Progress System (Postprint)

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Date: 2017-11-06T00:00:00+00:00

Abstract

Construction engineering necessitates intuitive and visual progress management tools. The integration of BIM technology and virtual reality technology facilitates the development of information-rich, visualized, multi-terminal construction progress demonstration systems. This research establishes standard-compliant building construction models via Revit, modifies material textures using 3DMAX prior to importing into Unity3D, and utilizes Unity3D to develop a cross-platform construction progress system. The transfer of Revit model information to Unity3D through the IFC format enables facile deployment across PC, Web, and mobile platforms, thereby offering enhanced services for construction management.

Full Text

Preamble

Volume 8, Issue 1, February 2016

Realization of a Cross-Platform 3D Virtual Construction Progress System

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Abstract: Engineering construction requires intuitive and visual progress management tools. Integrating BIM technology with virtual reality technology enables the development of an information-rich, visualized, multi-terminal construction progress demonstration system. This paper establishes a standard-compliant construction model through Revit, modifies material textures using 3DMAX, imports the model into Unity3D, and develops a cross-platform construction progress system. Revit model information is transmitted to Unity3D

data in IFC format, enabling easy deployment to PC, Web, and mobile terminals to provide better services for construction management.

Keywords: BIM; Virtual Reality; Cross-Platform; Construction Progress

CLC Number: TU17; P642
Document Code: A
Article ID: 1674-7461(2016)01-0080-03
DOI: 10.16670/j.cnki.cn11-5823/tu.2016.01.14

Research Approach

Time, cost, and quality constitute the three core elements of engineering project management. Whether a project can be completed within the total contract period directly affects payment processing and overall project profitability. Traditional construction progress management relies on flowcharts, Gantt charts, or planar diagrams. While these methods are simple and clear for short-term planning, they suffer from poor data preservation and lack accuracy and visualization for whole-project progress control. Li Yong [1] detailed BIM-based research methods for construction project scheduling using Revit and cost-related client software. Zhao Bin et al. [2] discussed the advantages of BIM and 4D virtual construction technology over traditional methods but did not elaborate on technical implementation. Ji Fanrong et al. [3] studied 3D visualized progress management based on BIM, but their solution lacked cross-platform and multi-terminal capabilities. With the growing adoption of BIM technology in domestic construction projects, 3D construction progress can be realized through client software such as Navisworks, though the visualization quality is suboptimal and sharing is limited to file copying. While architectural visualization is a current research hotspot, few systems achieve cross-platform, information-rich, and realistic 3D virtual construction progress. This paper leverages BIM and virtual reality technologies to develop a multi-terminal 3D construction progress platform.

Three years ago, while managing civil construction, the authors learned that construction management prioritizes component information over visual effects, focusing on whether models can directly guide construction—a need precisely fulfilled by Building Information Modeling (BIM) technology. The most commonly used BIM software in China—including Revit, Microstation, ArchiCAD, and Tekla—creates model components rich in information that can be directly queried during construction. Different disciplines require different component attributes. For example, a concrete frame beam' s top elevation, bottom elevation, and concrete volume can be directly extracted from the software, while manufacturer information, construction quality, and concrete strength grade must be extracted from component properties. Such information proves highly valuable for construction management.

BIM technology emphasizes convenient project management, whereas virtual reality technology focuses on visual presentation. Virtual reality immerses users in

computer-simulated environments that stimulate authentic sensory experiences, creating a sense of presence. This technology provides superior user interactivity [4]. Commonly used virtual reality software includes Autodesk' s 3DMAX and Maya, as well as Lumion. These tools can realistically represent the entire construction process, making progress immediately comprehensible. By combining BIM with virtual reality technology, we can deliver both practicality and enhanced user experience to construction managers.

Platform Selection

Revit Platform

Revit, developed by Autodesk, is a BIM software that automatically generates planar and detailed drawings from 3D information models. Changes to a component model update simultaneously across all views, significantly reducing modification time. Each component is assigned authentic physical properties, transforming walls, beams, and columns from mere geometric primitives into intelligent objects. This reduces logical design errors and improves efficiency. The data assigned during modeling can interoperate with other Autodesk products such as 3dsmax, AutoCAD, and Navisworks, with each software leveraging its specialized capabilities. Consequently, Revit holds a substantial market share in China. Many large-scale construction projects, particularly prefabricated building projects, now equip their BIM departments with appropriate hardware. The authors consulted with project managers in Shanghai, all of whom use Revit for information modeling. Beyond its powerful information modeling capabilities for architecture, structure, and MEP systems, Revit also supports secondary development, enabling functional extensions and accelerated modeling through C# programming on the .NET platform.

3DMAX Software

With a long history and the largest global user base, 3DMAX excels in online gaming, interior design, and film advertising. It offers robust modeling capabilities, supporting polygon modeling, NURBS modeling, subdivision surface technology, and image-based rendering to create realistic architectural animations. 3DMAX also supports scripting for development and can render near-photorealistic scenes. Since Revit models lack convenient architectural animation information, we combine 3DMAX to create construction process animations for progress demonstration while improving model visual quality.

Unity3D Platform

Unity3D is a comprehensive game development tool for multi-platform interactive content, including 3D video games, architectural visualization, and real-time 3D animation. As a fully integrated professional game engine, it enables developers to deploy products across iOS, Windows, Android, and other platforms with a single development effort. Unity3D features a complete physics

engine capable of simulating various physical phenomena, making it widely used for virtual world creation. For implementing 3D virtual construction progress, Unity3D primarily provides cross-platform capabilities and convenient programming features.

Implementation Method

Development Process

Man Qingpeng et al. [5] analyzed information requirements for construction processes and, based on IFC standard definitions of building information, established model standards consistent with IFC data entities. According to these standards, we can create BIM models for construction scheduling that include data such as concrete grade, volume, planned construction date, and actual construction date when modeling beams. After model creation, the Revit model is exported to an IFC intermediate data file. Numerous plugins and software can read IFC files, or custom development can be implemented for reading. Simultaneously, the Revit model is exported to 3DMAX via the FBX intermediate format for texture and appearance animation setup. The model is then imported into Unity3D through the FBX format, where animation playback control integrates with IFC information before deployment to various platforms. The development workflow is illustrated in Figure 1 [Figure 1: see original paper].

Revit Data Export

Revit can export models to IFC as an intermediate format or to databases through secondary development. Data exchange between Revit and other software primarily occurs through two methods: First, using third-party software such as Excel or SQL Server as information carriers, where C# secondary development exports component information from Revit to Excel. In this process, ElementID can serve as a unique identifier [6] for matching component information with Unity3D models. Second, adopting the IFC data standard format—Revit natively provides IFC export functionality for elements and their parameters, or custom data export can be implemented through software development.

3DMAX Animation Settings

Although 3DMAX offers powerful modeling and animation capabilities, testing revealed that Unity3D has limited support for modifier-based animations. It supports overall movement, scaling, and rotation animations, as well as skeletal animations. 3DMAX model processing involves two main aspects:

(1) Texture Modification
Texture mapping is the primary method for conveying building component appearance. Testing showed that the commonly used UVW Map modifier in interior design displays incorrectly in Unity3D when Gizmo is adjusted. This issue was completely resolved by using the UVW Unwrap modifier instead.

(2) Simulating Component Appearance in Construction Progress Demonstration

The most fundamental method for simulating building component appearance is frame animation. Understanding how to create importable animations for Unity3D saves considerable time and avoids pitfalls. FBX models exported from Revit and imported into 3DMAX consist of independent individual components. Appearance animations must be created according to the construction plan or actual progress. A scaling animation effectively simulates the "from nothing to something" process: the Gizmo center point is moved to the component' s bottom, two keyframes are set at a specific time interval—one with 0% scale and another with 100% scale—creating a realistic emergence animation. For construction projects, models imported from Revit to 3DMAX often contain numerous components. While this operation is labor-intensive, it is relatively simple and can be automated using 3DMAX scripting. The result should produce animation effects consistent with the required construction progress when the play button is clicked in 3DMAX.

Unity3D Platform Development

After 3DMAX processing, models are imported into Unity3D via FBX format files. Unity3D' s visual development approach and detailed property editor facilitate operations and reduce bug-fixing workload. Unity3D' s physics engine enables simulation of various physical phenomena. By developing custom controls, we implemented a slider to control FBX model frame animation playback for construction progress management. The window panel is shown in Figure 2 [Figure 2: see original paper].

Conclusions and Limitations

This paper developed a cross-platform 3D virtual construction progress system, achieving the following breakthroughs: (1) Integrating building model information from BIM technology into the management system for on-demand retrieval during construction to facilitate management; (2) Introducing virtual reality technology into 3D construction progress management systems, significantly improving visual effects; (3) Selecting Unity3D as the model publishing platform to enable easy cross-platform deployment, allowing construction managers to view project progress through multiple terminals.

The progress management system requires improvement in the following aspects: (1) Due to the large number of building model components, large-scale construction projects require high-performance hardware platforms to support Revit and 3DMAX operations; (2) Future development could support multi-user input of construction plans or progress by different project management personnel for different zones.

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Note: Figure translations are in progress. See original paper for figures.