BIM-Based Automatic Generation of Substation Bills of Quantities and Engineering Quantities (Postprint)

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Date: 2018-07-18T00:00:00+00:00

Abstract

This study establishes a BIM model for substations. Through Revit secondary development technology, the system achieves physical rebar modeling, BIM model information retrieval, and automatic quantity extraction for rebar, concrete, doors, windows, and walls. Additionally, it supports item application based on families and family types, thereby enabling direct generation of bills of quantities for substation projects from the BIM model.

Full Text

Research on Automatic Generation of Engineering Quantity Lists for Substations Based on BIM

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Abstract

This paper establishes a BIM model for substations. Based on Revit secondary development technology, it achieves physical rebar modeling and information extraction from BIM models, enabling automatic extraction of engineering quantities for rebar, concrete, doors, windows, and walls. The system can also apply quota items based on families and family types, thereby realizing the function of directly generating bills of quantities from substation BIM models.

Keywords: Building Information Model; Substation; Engineering Quantity

Introduction

The core of BIM technology is informatization—the digital information provided by BIM models. In engineering cost estimation, quantity calculation and quota application represent the most complex and tedious components. How to efficiently and accurately generate budget quantities and apply them to lists is an urgent challenge for the entire budgeting industry. BIM technology indeed provides effective technical means for achieving this goal, as using BIM models to extract digital information technically enables automatic generation of bills of quantities.

Ma Zhiliang et al. (2007) analyzed the possibility of applying IFC standards to engineering cost budgeting and identified problems and solutions in IFC standard application [2]. Pei Yan et al. (2016) analyzed the advantages and disadvantages of various BIM quantity calculation software both domestically and internationally, and proposed development methods for Revit secondary development technology in pipeline engineering quantity statistics [3]. Wu Jiali et al. (2017) discussed the basic process and methodology of using BIM technology for quantity calculation [4]. Lin Hanhan et al. (2015) proposed establishing a mapping between component properties and plugin data based on Revit' s ODBC database, demonstrating the feasibility of BIM software outputting list quantities [5]. Xie Sicong et al. (2017) verified the advantages of BIM technology in prefabricated building quantity calculation [6]. Wang Ru et al. (2017) used Revit secondary development to propose guidance methods for component deduction rules, focusing on domestic engineering quantity deduction rules [7].

However, due to the complexity of domestic budgeting rules, generating engineering quantity lists that comply with domestic quota standards represents the greatest challenge in deriving quantities from BIM models. Qi Cong et al. (2008) proposed a method of exporting ODBC data tables using Revit platform software [1], but current research both domestically and abroad rarely addresses rebar quantity statistics. In substation projects, rebar, concrete, walls, and doors/windows constitute important components of civil engineering costs. Therefore, statistics on their usage are of significant importance for cost control by owners and material management by contractors.

With the widespread application of BIM technology, establishing substation civil engineering models in BIM according to actual engineering conditions and integrating physical rebar BIM models can not only quickly calculate the usage of rebar, concrete, doors/windows, and walls, but also enable phase-by-phase statistics and quantity difference analysis before and after design modifications. This capability has practical cost control significance for both owners and contractors.

Therefore, to meet engineering needs, this paper utilizes Revit' s secondary development capabilities to implement classified rapid statistics functions for rebar, concrete, doors/windows, and walls usage, along with quota application and list generation functions.

1 Research Methods

This paper employs the Revit API and Visual C# language to implement physical rebar modeling and information extraction from Revit models. The Revit API is a secondary development package provided by Autodesk for Revit products, offering the class libraries required for Revit development that can be embedded in Revit to run. Through this powerful Revit API, plugins developed by users can be added to extend and enhance Revit' s functionality and applications.

Based on the Revit API, this paper developed a plugin for physical rebar modeling and engineering quantity statistics of BIM civil models, utilizing the IExternalCommand interface to add applications and achieve the purpose of extending Revit' s functions. This program can not only calculate engineering quantities for rebar, concrete, doors/windows, and walls, but also apply quota items for these categories, generate bills of quantities, and save them in Excel tables.

2 BIM Model Standards

As this platform is an engineering quantity statistics platform based on BIM models, the standard and level of detail of BIM models are fundamental to ensuring the correctness of statistical results. In this study, to accurately reflect component usage, Revit models are created according to LOD 400 standards. Simultaneously, due to the complexity of rebar usage statistics, this paper studied the creation of physical rebar models in BIM, achieving consistency between BIM model rebar and actual engineering conditions. Additionally, to enable usage statistics for rebar, concrete, doors/windows, and wall components, the definitions of Revit families, family types, and other attributes in this model were formulated according to quota classification requirements, with corresponding naming rules established respectively.

3 Physical Rebar Modeling Issues

To ensure the accuracy of rebar statistics, structural components must be modeled with physical rebar according to actual engineering conditions.

(a) Rebar Modeling for Beams Since substation beam rebar typically includes torsion longitudinal rebar, multi-layer rebar, and other complex configurations, Revit' s extension plugins cannot model them adequately. Therefore, this paper employs Revit API secondary development and programming to implement modeling of stirrups, longitudinal rebar, web rebar, and torsion rebar in substation beams, thereby ensuring complete consistency between rebar in

Revit models and actual engineering conditions, as shown in Figure 1 [Figure 1: see original paper].

This paper uses the CreateFromCurves command in the Revit API for longitudinal rebar modeling, which draws rebar by specifying curves. The main parameters used in this command are RebarBarType, Curve, and host, where RebarBarType refers to the rebar shape that defines rebar grade, diameter, and other information; host represents the concrete component where the rebar is located; and Curve represents the rebar path. Curve is the most important parameter in the rebar creation command. To obtain the rebar path, the beam' s location information must first be obtained—its three-dimensional spatial coordinates. Based on these coordinates, plus the relative offset of the rebar' s start and end points from the beam, the three-dimensional spatial coordinates of the rebar' s start and end points can be calculated. From these two spatial coordinates, a straight line connecting the two points can be obtained, which provides the Curve parameter for the command. Moreover, the path parameter also supports curved paths, enabling the establishment of complex rebar paths. Additionally, since this parameter can also use the IList form—a collection of multi-segment paths—this command can also establish rebar with multi-segment paths, though it requires ensuring that each segment' s start and end points connect properly.

For stirrups and tie rebar, this paper uses the CreateFromRebarShape command in the Revit API to create them, which draws rebar by specifying rebar shapes. Since stirrups and tie rebar have complex shapes, using existing rebar shapes for creation in the Revit API is more convenient, eliminating the need to specify each segment' s path multiple times. The main parameters in this command are RebarBarType and RebarShape, i.e., rebar type and rebar shape. However, unlike CreateFromCurves, this command requires using ScaleToBox in conjunction to determine the rebar' s layout area.

(b) Rebar Modeling for Columns Columns in substations are primarily rectangular columns. Therefore, for simply reinforced rectangular columns, Revit' s built-in extension plugins can be used for layout, but for columns with complex reinforcement, the rebar creation commands from the Revit API used for beams are still employed for rebar modeling. The physical rebar model for columns is shown in Figure 2 [Figure 2: see original paper].

Simultaneously, to reduce modeling workload, columns with identical reinforcement all use Revit groups to achieve batch modification and creation.

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4 Engineering Quantity Statistics Issues

In rebar usage statistics, two methods were employed.

The first method: In BIM models, each reinforced concrete component has a

property. In the secondary development program, this property is read using the LookupParameter command to obtain the value of the parameter "Estimated Rebar Volume," which provides the component's rebar usage.

The second method: Statistics are conducted piece-by-piece for each rebar in each component, i.e., traversing each rebar in the BIM model with the categories "Structural Rebar" and "Structural Area Rebar," using the LookupParameter command to obtain the value of the parameter "Rebar Volume," which provides the rebar's volume. Through programming experiments, it was verified that the rebar volumes obtained by the two methods are identical. However, the second method takes a very long time—generally about 30 minutes for rebar statistics calculation of a standard substation project—which lacks practical value.

Additionally, during the process of using plugins for rebar usage statistics, because different components need to be distinguished, naming rules for components must be established during the modeling process to achieve classified statistics of rebar.

Figure 3 [Figure 3: see original paper] shows the rebar usage statistics interface. For doors and windows engineering quantities, this paper uses the Revit API to obtain the height and width parameters of door and window family types, thereby calculating the area of doors and windows. For walls, concrete, and other elements, the volume parameter of the element can be obtained directly to calculate its engineering quantity.

Figure 4 [Figure 4: see original paper] shows the Excel table generated from rebar usage statistics.

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5 Quota Application and List Generation

For quota application of BIM models, this paper distinguishes based on attributes such as families and family types in Revit. Therefore, it is first necessary to establish standards for Revit family and family type names in the model, with all components named according to these standards.

On this basis, the program traverses all families and family types in the BIM model and stores them in a table in the SQL Server database. Simultaneously, quota item names and codes are stored in another table in the database. Then, a relationship correspondence table between quotas and families/family types is established in the database. This table is first intelligently matched by the program based on similarity between quota names and family/family type names to generate a preliminary relationship correspondence table. However, due to the complexity of Chinese, the relationship correspondence table automatically generated by the program cannot be completely accurate. Therefore, this paper also provides a function for users to specify quota items themselves, i.e., users can re-specify quota items for incorrectly applied families and family types (see Figure 5 [Figure 5: see original paper]), thereby finally determining the quota

items corresponding to each family and family type. Although the program cannot completely and accurately complete quota item application, having the program generate a preliminary relationship correspondence table indeed saves time for users and reduces the workload for quota application.

After the program completes quota item application, it can call the previously obtained engineering quantities to generate the final bill of quantities. The automatic quota item application in this paper relies on the standardization of families and family types in the BIM model, as well as the standardization of standard formulation. As long as the standards are continuously expanded and improved, the research method of this paper can be applied to different engineering needs.

References

[1] Qi Cong, Su Honggen. Discussion on Several Issues of Engineering Quantity Calculation Software Based on Revit Platform[J]. Computer Engineering and Design, 2008, 29(14): 3760-3762.
[2] Ma Zhiliang, Lou Zhe. Discussion on Basic Issues of IFC Standard Application in Construction Cost Budgeting in China[J]. Journal of Information Technology in Civil Engineering and Architecture, 2009, 1(2): 7-14.
[3] Pei Yan, Wang Junfeng. Research on Fine Quantity Calculation Method Based on BIM Technology[J]. Engineering Economy, 2016, 26(4): 39-44.
[4] Wu Jiali, Jiang Fengxiang, Hu Nini. Research on Construction Drawing Budget Method Based on BIM Technology[J]. Shaanxi Architecture, 2017, 43(7): 232-234.
[5] Lin Hanhan, Zhou Hongbo, He Xi. Research on Engineering Quantity Calculation Implementation Method Based on BIM Design Software[J]. Construction Economy, 2015, 36(4): 59-62.
[6] Xie Sicong, Chen Xiaobo, Liang Yumei. New Type of Bill of Quantities Based on BIM and Prefabricated Buildings[J]. Journal of Engineering Management, 2017, 31(3): 130-135.
[7] Wang Ru, Fang Chao, Wang Liushu. Revit Model Quantity Extraction Based on China' s List Pricing Specification[J]. Journal of Graphics, 2017, 38(3): 447-452.

This paper achieves engineering quantity statistics for rebar, concrete, doors/windows, and walls in Revit models, along with quota item application and generation of bill of quantities Excel files, providing an effective technical approach for future full BIM implementation in the budgeting industry and enabling BIM-based engineering budget management.

The research demonstrates that statistically calculating engineering quantities by component category from BIM models and applying quota items is achiev-

able, offering a feasible method for comprehensive realization of bill of quantities generation functions based on BIM models. This work provides valuable guidance for engineering budgeting and management.

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