Revit-Based Parametric Modeling of Space Frames: Postprint

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Abstract

Currently, Revit exhibits significant limitations in the modeling of grid structures. Conventional manual modeling approaches are nearly impracticable, while mass modeling yields identical types for all grid spheres and members, which fails to conform to engineering reality. To address this challenge, this study investigates modeling solutions for grid structures utilizing both Revit Extensions and Dynamo software, with particular emphasis on the application of the visual programming tool Dynamo for automated modeling within Revit. For design professionals, the Dynamo parametric programming tool is relatively accessible to master. The Dynamo program developed in this paper automatically generates accurate grid models by reading grid data, ensuring that the dimensions and positioning of grid spheres and members align with actual conditions, thereby enhancing both modeling efficiency and model quality.

Full Text

Parameterized Modeling of Grid Structures Based on Revit

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Abstract

Currently, Revit faces significant challenges in modeling grid structures. Conventional manual modeling approaches are nearly impossible to complete, while conceptual mass modeling produces identical grid balls and members that do not reflect actual engineering conditions. To address this problem, this paper investigates two modeling solutions for grid structures using Revit Extensions and Dynamo software, with emphasis on the application of the visual programming tool Dynamo for automatic modeling in Revit. For design professionals, Dynamo' s parametric programming tools are relatively easy to master. The Dynamo program developed in this paper can automatically generate accurate grid structure models by reading grid data, ensuring that the dimensions and positioning of grid balls and members match actual conditions, thereby improving both modeling efficiency and model quality.

Keywords: Revit; Dynamo; Parameterization; Grid structure

The creation of BIM models is a parametric design process where components are transformed into design models through parameter adjustments. Parametric design represents a core concept in BIM modeling software, making parametric capability one of the most important criteria for evaluating the practicality of a BIM software. Among current mainstream BIM software domestically and internationally, Autodesk' s Revit possesses exceptionally powerful parametric design capabilities, enabling the generation of various components through families.

However, at present, Revit lacks a dedicated module for creating spatial grid structure models. Grid structures consist of grid balls and members, typically involving a massive number of components—even a small-scale grid project contains hundreds or thousands of grid balls and members. Moreover, in actual projects, the sizes of grid balls and types of members follow no regular pattern, making conventional manual modeling nearly impossible to complete. If Revit' s conceptual mass is used to create grid structures, both the grid ball sizes and member specifications become identical, which does not align with actual engineering conditions and fails to ensure the precision and quality of grid models. In structural analysis software for grids, models are automatically generated; similarly, secondary development could be employed on Revit to write plugins for automatic grid creation. However, for design personnel lacking programming experience, secondary development presents considerable difficulty, making it urgent to explore alternative methods that are relatively easy to master.

In this context, this paper investigates and explores two solutions to address Revit spatial grid modeling challenges. It introduces the method of using the Revit Extensions plugin to generate models based on Excel, with emphasis on the solution for automatic grid modeling using Dynamo programs, hoping that the BIM project practices introduced herein can provide references for peers.

1. Preparations for Revit Grid Structure Modeling

Revit modeling relies on family components, making it necessary to first establish Revit grid families for grid structures. Grid structures consist of grid balls, top chords, bottom chords, and web members. Grid members employ either bolted connections or welding. For convenience, leveraging Revit' s powerful family capabilities, members are created as a universal family component. Through conceptual design of Revit families, this paper establishes two families

–grid balls and grid members–that can satisfy the diversity of grid components.

1.1 Grid Balls

The grid ball family uses the structural column category in Revit, utilizing the structural column family template. The ball center is locked to the bottom elevation, with the primary control parameter being ball diameter. [Figure 1: see original paper] shows the grid ball family model.

1.2 Grid Members

The grid member family uses the structural framing category in Revit, utilizing the structural framing family template. Three connection scenarios–cone heads, end closures, and welding–are integrated into a universal family that can be parametrically transformed into corresponding grid member families. The main control parameters for the grid member family include member diameter, member wall thickness, grid ball diameter, and end connection type. [Figure 2: see original paper] shows the grid member family and detailed construction of member ends, which matches actual conditions.

2. Solution Based on Revit Extensions

Revit Extensions provides a tool for generating models from Excel, which can automatically create grid models by reading Excel data of the grid structure. Note that this tool is not available in all Revit versions; the 2013 and 2016 versions include this module.

As shown in [Figure 3: see original paper], the "Model Generation Based on Excel" tool opens to the data input interface shown in [Figure 5: see original paper]. This tool can only generate five types of Revit elements: levels, structural columns, beams, walls, and foundations. Therefore, following Revit categories, this paper defines grid balls as the structural column category and grid members as the structural framing category (beams).

The primary challenge in using this tool for grid creation lies in processing the coordinate data of grid ball nodes and members. The specific solution approach is:

1. Export DAT text files of grid data from grid analysis software. As shown in [Figure 4: see original paper], this data format is used by MST (Zhejiang University Space Structure Analysis Software) and AMDE (China Automotive Engineering Corporation Grid Structure Analysis Software), both of which can directly save grid data in DAT format. This data format records grid ball node coordinates, ball diameters, grid member end ball node numbers, member specifications, etc.
2. Process the DAT text to obtain coordinates, dimensions, and types of nodes and members. According to the Excel data format required by

the Revit Extensions model generator, the necessary data includes grid ball and member specifications and coordinate points, which are batch-extracted from the DAT text (details omitted here).

3. Input the processed data into the Excel-based model generator, as shown in [Figure 5: see original paper].
4. Verify data—this is a function of the Revit Extensions model generator to check data format correctness and avoid errors during model generation.
5. Generate model.
6. Complete.

3.1 Dynamo Grid Structure Modeling Approach

Dynamo is a visual programming software that can run independently or on Revit. Through a node-based visual programming interface, Dynamo can significantly enhance Revit' s parametric design capabilities, enabling computational design models or other automated processes. Dynamo can automatically process calculations within the BIM environment (Revit platform) and interact with Revit in real time. Most importantly, for design personnel without programming backgrounds, Dynamo is relatively easy to learn and master, allowing designers to flexibly utilize Revit' s parametric design, enrich BIM models, and greatly improve model application efficiency.

Using Dynamo to create grid models requires solving three main technical challenges: (1) how to read standard DAT format grid data; (2) how to convert DAT data into coordinate points in Dynamo; and (3) how to generate grid balls and grid members in Dynamo based on coordinate points and 3D lines.

The Dynamo grid modeling workflow is shown in [Figure 6: see original paper].

3.3 Running the Dynamo Program

Running a Dynamo program involves connecting various Dynamo nodes together; the complete node graph formed thereby implements the corresponding functionality. Nodes 1 through 6 in the previous section are used to process coordinate data from the grid, as shown in [Figure 7: see original paper] and [Figure 8: see original paper]. Nodes 7 through 10 are used to generate straight-line paths and create grid balls and grid members. [Figure 9: see original paper] shows the node graph for creating grid members.

This project is an automotive industrial plant under an EPC general contract with high positioning and strict requirements from the owner. BIM technology was employed from the project conceptual design phase, leveraging BIM visualization to improve scheme review efficiency. During the design phase, a design BIM model was created, and the Revit grid structure model was generated through Dynamo, improving modeling efficiency. The grid dimensions and positioning matched actual conditions, enhancing collision detection accuracy while assisting in drawing production to improve drawing quality.

This project features a four-pyramid spatial grid structure with a planar dimension of 32m×51m and a rise of 2.5m, with a 3% roof slope. Spatial structure design software MST and AMDE were used for analysis. The grid contains 300 balls of 4 types and 1,092 members of 6 types. Conventional manual modeling would require substantial time and would be difficult to ensure modeling accuracy and precision.

Through the Dynamo program, automatic parametric modeling can be completed in less than 5 minutes, with grid balls and members consistent with actual conditions, ensuring model quality while saving significant modeling time. The completed grid model is shown in [Figure 10: see original paper].

3.2 Main Dynamo Nodes for Modeling

Each command block in Dynamo is called a node, with each node automatically performing functions such as data processing, calculation, data acquisition, and element creation. The Dynamo grid modeling program developed in this paper utilizes the following main nodes:

1. **File Path**: Allows users to select files on their computer to obtain filenames. This node enables users to open DAT grid data files on their machine; the program reads the file path and acquires the file.
2. **File.FromPath**: Creates a file object from a path. This node reads the file path from the File Path node and outputs a file object to the next node.
3. **Excel.ReadFromFile**: Reads data from Excel spreadsheets. This node reads the Excel file object from the File.FromPath node, requires input of the "worksheet name" from the file object, and outputs Excel file data to the next node.
4. **List.GetItemAtIndex**: Returns items from a given list. This node reads the Excel data list from the previous node, inputs the index of the data list item to extract, and outputs that item' s data.
5. **List.DropItems**: Deletes certain items from a list. This node is used to delete redundant items in data lists.
6. **Point.ByCoordinates**: Forms a point through three given Cartesian coordinates. This node inputs X, Y, and Z coordinate values and outputs coordinate points. Since the coordinate values are lists here, the output coordinate points are correspondingly lists as well.
7. **Line.ByStartPointEndPoint**: Creates a line between two input points. This node inputs start and end coordinate points and outputs a created line segment.

8. **FamilyType.ByFamilyNameAndTypeName**: Selects a family type based on family name and type name. This node inputs family name and type name and outputs the family type to the next node.
9. **StructuralFraming.ColumnByCurve**: Creates columns. This node inputs a line, level, and column family type, and outputs a created structural column model—here generating grid balls.
10. **StructuralFraming.BeamByCurve**: Creates beams. This node inputs a line, level, and structural framing family type, and outputs a created structural beam model—here generating grid members.

Detailed usage of the above is described in Section 3.3 on running the Dynamo program, which presents the grid member creation process.

Conclusions

This paper investigates the use of the Revit Extensions model generator and Dynamo visual programming to create Revit grid structure models, solving the challenge of Revit grid modeling. Through project practice in an automotive industrial plant, the feasibility of these two methods was verified, achieving good application results. The following conclusions are drawn:

1. The Revit Extensions model generator can create grid models with grid balls and members consistent with actual conditions. However, since the data format required by this plugin differs significantly from the original data format, extensive data processing is required. Additionally, the plugin' s operational stability needs improvement, as it crashes easily.
2. Using Dynamo visual programming tools enables automatic generation of grid models with dimensions matching actual conditions and high modeling efficiency, improving model precision and quality while reducing grid modeling time.
3. Compared with secondary development, Dynamo is relatively easy for design personnel without programming experience to master. It can solve parametric design of complex geometries and functions, with parametric geometric forms directly convertible to Revit elements.
4. This research provides solutions and specific operational methods for Revit grid modeling, which have been proven practically applicable through engineering project verification.

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