DEVELOPING AN AUTOMATIC CODE CHECKING SYSTEM FOR THE URBAN PLANNING BUREAU OF HUANGPU DISTRICT IN SHANGHAI

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Abstract. As Chinese cities entering a so-called 'organic renewal' era, building projects runs with much more constraints from high-density and high-rise surroundings. Such a situation makes the technical review in any urban planning bureau time-consuming and error-prone, which conflicts with the developer's profits and citizen's rights. This study introduces a preliminary system being developed for the planning bureau of Huangpu District, Shanghai. It has covered 21 code items among 44 computational ones of the local planning codes last year, which automatically generates technical reviews upon developer's submissions. Due to the feasible level of BIM application in domestic projects, a set of strategic approaches, such as the standardization of CAD drawings and the reconstruction of an internal building information model, are adopted rather than developing the system on any BIM platform directly. Two examples of technical reviews about distance-checking between buildings and length-checking of facades are demonstrated, in which officers reached confidential judgments in seconds rather than several days conventionally.

Keywords. Planning Constraints; Code Checking; 3D Reconstruction; Design Automation; Building Information Model.

1. Introduction

In a so-called 'organic renewal' era (Zhou 2019), to keep both the citizen's rights and the developer's profits in high-rise and high-density urban surroundings, every Chinese city authorizes its urban planning bureau to make technical reviews on all the building projects according to its local planning codes from the very beginning. On one hand, the technical officers have complex code items to check carefully, which is a time-consuming and error-prone duty. On the other hand, they have to reach the final judgment as soon as possible to keep the business efficiency of the whole city for the developers. Suffering from such a situation in the last decades, the planning bureau of Huangpu District, Shanghai, appointed our team to develop an automatic code checking system for them to raise efficiency and to avoid errors.

A preliminary system has been developed since the winter of 2019. Currently, twenty-one items of the forty-four computational items in the planning codes are covered. Although a BIM platform always comes to mind immediately to support

PROJECTIONS, Proceedings of the 26th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2021, Volume 1, 291-300.

such a system, the current system is still developed to accept CAD drawings with a set of strategic approaches, such as the standardization of CAD drawings and the reconstruction of an internal building information model. It keeps the system feasible in real domestic projects nowadays and makes the algorithms migratable to any BIM platform in the future.

2. Reviews On Automatic Code Checking

2.1. BIM-PLATFORM-BASED METHODS

The popular BIM platforms can provide inborn data for automatic code checking through object properties and geometric features of a building. Thus, most existing researchers follow this method.

FORNAX is the first automatic code checking platform based on IFC (Industry Foundation Class) model. The platform is a C++ object library. Programmers don't need to develop algorithms for retrieving the required information from the IFC model, but only need to use the FORNAX object and its member functions to 'interpret the rules written in natural language into a programming language' (Eastman et al. 2011). The disadvantage is the lack of openness, and that the user can only program to customize the rule according to specific needs and write system.

Solibri Model Checker (hereinafter referred to as SMC) has the largest user group, which is a desktop application based on JAVA language. It only supports IFC model, which can complete clash check and find out the violation of regulations in the model. These detections are all based on a 'detection rule set'. SMC provides some 'rule sets' in various fields and it has been developing and improving. Due to different local standards, users can modify these 'rule sets' to meet localization needs (Eastman et al. 2011). At the same time, SMC is the first to realize pre-checking to validate that the data needed for checking is available from the model to improve the checking efficiency (Ding et al. 2004).

SMARTcodes can realize semi-automatic interpretation from written language regulations to computer code through IECC dictionary, using a dictionary of domain-specific terms and semi-formal mapping methods (Martins and Monteiro 2013). However, the current system focuses on checking easily-obtained or easily-derived attributes, rather than simulating complex situations based on various model views (Ke 2016).

2.2. CAD-DRAWING-BASED METHODS

On the contrary to the BIM-platform-based methods, CAD-drawing-based methods can only describe the building in a 2.5D way with distributed data, from which the object properties and geometric features are hard to extract. However, due to its long history in the design industry, CAD drawings and data sheets are still adopted by some researchers for automatic code checking development in real projects.

The earliest effort named 'CORENET' was led by Singapore, who started considering code checking on CAD drawings in 1995. The initial method of code checking in this project was to use artificial intelligence and feature-based CAD technology to check the floor plans of buildings, thus developing the BP-Expert application. Due to the limited coverage of regulations, the inability of processing inconsistent or wrong data, and the instability of the overall performance, the program was not successful, but it provides some great learning experience for the follow-up code checking program e-PlanCheck based on IFC model (Khemlani 2005).

At the end of the 20th century, starting from Shanghai, Guangzhou, Shenzhen, and other cities with huge amount of urban planning management business, China also began research on online approval and automatic code checking systems, with a batch of commercial software emerging. For example, Urban Planning Results Management System developed by the Guangzhou Urban Information Research Institute; Urban Planning CDS developed by Luoyang Zhongzhi Software Company; Planning Management Information System developed by Hongye Technology; Santong Software developed by the Guangzhou Urban Planning Automation Center including 'Baojian Tong','Xiuxiang Tong', 'Yanshou Tong' (Tang 2013).

These systems require huge and redundant data input by designers and extra extraction algorithms to work. Almost all of them rely on a concept of 'block' popular in CAD platforms, with which geometric features and object properties are bound. Designers have to input a large number of additional block attributes manually and the programs require extra algorithms to extract data from these distributed files with high redundancy. It comes with unnecessary workflow and it makes coherence problem easily.

In summary, in the field of automatic code checking, there are two camps, namely "BIM-platform-based method" and "CAD-drawing-based method". Obviously, the former is much more popular. However, the domestic design industry in China has not yet fully entered the era of BIM-based design, which means submission with a set of BIM documents is infeasible. Instead, the methods based on "CAD drawings + data sheets" fit the current situation. The only problem is that the existing methods relying on the concept of 'block' in CAD still require many manual operations, and are not able to support complex geometric algorithms.

3. Methodology

3.1. A REVISED CAD-DRAWING-BASED METHOD

"CAD-drawing-based method" and "BIM-platform-based method" are essentially two ways to describe a building. The following are their pros and cons.

A CAD-drawing-based method: It uses 'CAD drawings + data sheets' to describe a design project comprehensively from the general plan, each floor plan, elevation, profile and other views, which is still the absolute mainstream at present in China. Such a method can efficiently describe those buildings with horizontal ground and orthogonal exterior walls and roofs (see Figure 1, the first row and the second row). It makes the scale of the submitted files smaller and makes files convenient to check and transfer. Meanwhile, the CAD drawing platforms have a much larger user group than BIM platforms have in China currently. It can also seamlessly connect to the existing descriptions of planning codes printed on paper. The disadvantage is that when describing non-vertical (such as folded surface, curved surface) wall (see Figure 1, the third row), or non-horizontal (such as folded surface, curved surface) roof, the method is inefficient and approximative through a large number of section drawings with huge redundancy to cause errors.

A BIM-platform-based method: It inherits all the advantages from the integration of building data, which means that the object properties and geometric features can be easily extracted by algorithms of automatic code checking (Sun and Ke, 2016, p.145). It can describe buildings of various shapes efficiently and accurately without redundancy. However, due to the design of current BIM platforms, the method runs through a much larger file set, which is difficult to transfer for the submission. Meanwhile, its user group is much smaller than the CAD camp in China, which means huge money for better computers and numerous training hours make such automatic code checking system too expensive to run. Furthermore, the current 2D version of planning codes has to be upgraded into a 3D version through a legal process. All these issues make the BIM-platform-based method infeasible currently in China.

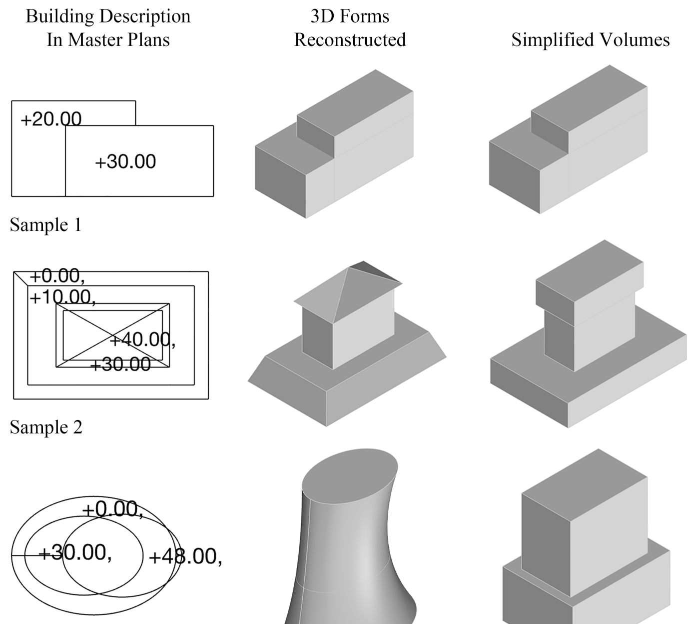

Figure 1. Three Samples of Building Description.

Obviously, neither of the above methods is suitable for the current requirements from the Planning Bureau of Huangpu District. Thus, a revised CAD-drawing-based method is proposed for the real projects running in Shanghai, China.

First, it uses a combined building description comprised of layers with specific names, 2D outlines on specific layers, and text objects on specific layers (Figure 1, the first column), to define a 3D face belong to any building object, such as a piece of wall or roof. In the CAD drawings, a 'nearest principle' and a 'leading line rule' are designed to automatically establish the relationship between 2D outlines and text objects. And the layer name of any graphic object defines its properties. The binding mechanism is based on relationships between objects and the layers they located rather than 'blocks', which is closer to designers' daily operations.

Next, any 3D building object is defined by a set of 3D faces, which enables the revised method to reconstruct any complex 3D building form (Figure 1, the second column) even with non-vertical walls or non-horizontal roofs. A set of 'automatic face complementation rules' is designed to make designers' CAD drawing as simple as possible, with which algorithms generate all the faces according to a few 2D outlines in master plans (Figure 1, the first column) rather than all the edges of the object.

Last, the 3D forms reconstructed from the lines in master plans will be simplified as volumes with vertical facades furtherly (Figure 1, the last column), which matches the building concept currently described in the planning codes.

3.2. A COMPATIBLE STRATEGY WITH BIM-PLATFORM-BASED METHODS

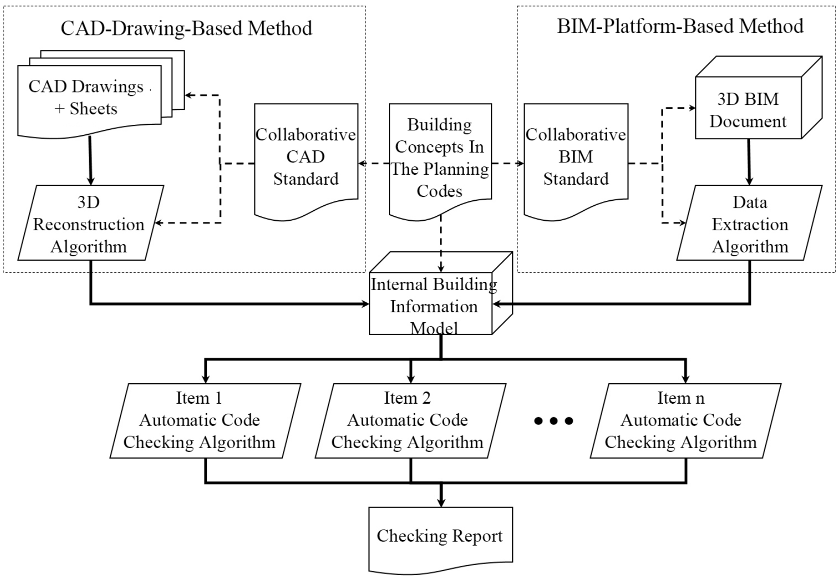

Figure 2. A Compatible Strategy.

In order to keep the automatic code checking algorithms of the revised method compatible with BIM platforms in the future, an internal building information model is designed. Firstly, CAD drawings and data sheets are compiled according to a specific CAD standard. They are converted into an internal building information model by a 3D reconstruction algorithm. The model supports any data extraction as a conventional BIM platform does (see Figure 2). Actually, all the code checking algorithms are developed item by item based on this model. When BIM platforms are adopted everywhere in China, the current automatic code checking algorithms can be immigrated to any of them seamlessly. That is the compatible strategy.

3.3. WORKFLOW OF AUTOMATIC CODE CHECKING

The workflow of automatic code checking is divided into two major parts, conducted by ‘A Project Developer’ (Figure 3, the left part) and ‘A Planning Bureau Officer’ (Figure 3, the right part).

- A Project Developer

Step 1: Prepare documents in accordance with format requirements. For a long time, because the CAD drawings only require ‘looks correct’, but it is very difficult for machine identification, so it is necessary to put forward certain format requirements for the submissions (see ‘Result A’ in Figure 3). The Developer shall follow this requirement for document preparation.

Step 2: Check the format of the submissions automatically by computer. This ‘Self-Check Tool’ (see ‘Result B’ in Figure 3) is an automatic verification program to check whether the submissions meet the preparation requirements. The Developer can use this tool to check the format of the submission to reduce the possibility of submission being returned.

Step 3: Submit documents online or offline. And the management preventing version tampered should be provided.

- A Planning Bureau Officer

Step 1: Check the format of the submissions again. Use ‘Self-Check Tool’ again (see ‘Result B’ in Figure 3) to conduct a second check on the documents submitted to ensure that they meet the requirements before proceeding to the next step of checking.

Step 2: Check Visually in way of human-computer interaction (optional). The ‘Visual-Check Tool’ (see ‘Result C’ in Figure 3) can display as classified regions in the CAD submissions, which is convenient for the management department to conduct a semi-automatic visual check to avoid malicious traps. In this way, in the initial stage of implementation, it’s also helpful to find loopholes in self-check logic to continuously improve the algorithm.

Step 3: Check various regulations automatically (see ‘Result D’ in Figure 3). The computer automatically calculates the content of the submissions according to the designation of the officer, and the results are displayed both in the two-dimensional and three-dimensional windows, and detailed reports are used to facilitate on-site confirmation and subsequent review. If there is any problem, it will be returned to the Developer.

Step 4: Follow up other approval tasks. After obtaining the reports of automatic code checking, officers can not only carry out other regulation checking that has not yet been automatic, but also make various 'judgments' based on the detailed reports immediately, and finally complete the checking process.

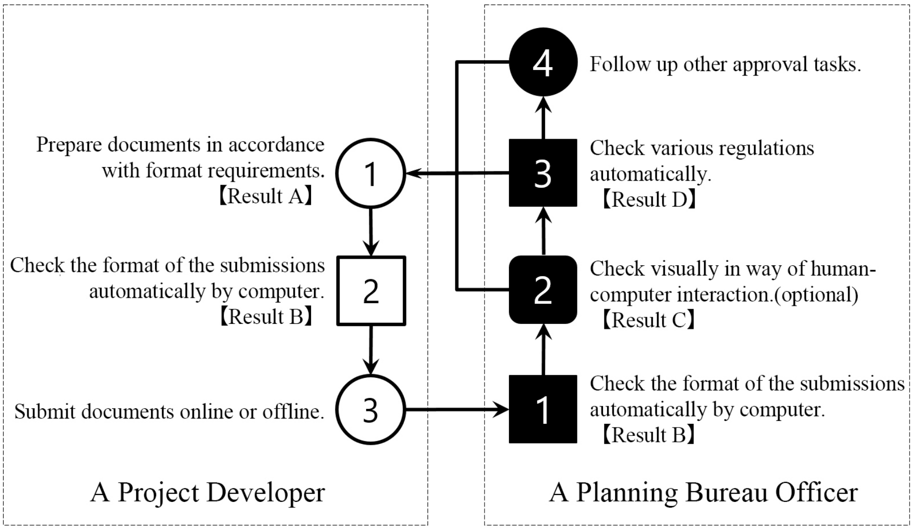

Figure 3. Workflow of Automatic Code Checking.

4. Two Examples of Technical Reviews

According to the above method, a preliminary system has been developed since the winter of 2019. Currently, twenty-one items of the forty-four computational items in the planning codes are covered. Among them, the length-checking of facades and the distance-checking between buildings are the most popular items for daily review, which are demonstrated in the following.

4.1. LENGTH-CHECKING OF FACADES

First, the officer selects the building outlines in a master view in Rhino and clicks 'Start' toggle to run the program in Grasshopper. The system analyses the building outlines and text objects on the specific layers. An internal building information model depicting the simplified building volumes are reconstructed. All these buildings are divided into multi or low-rise groups, or high-rise groups, according to the adjacency between any two volumes.

Secondly, taking each group as a unit, bounding boxes are calculated along all the axis directions hinted at by segments of the outlines in the group. The box with the minimum volume is recognized as the presenting box of the group. Its height and length are extracted as the key parameters for the group. Group by group, the algorithm checks these parameters according to the height-length formula in the item of planning codes to make the judgment.

Finally, as a kind of visualized report, a rectangle at the top of each building group indicates the checking result through a Rhino view. The height and size of a group hint at its bounding box. Its color hints at the result: pass in green and fail in red. (Figure 4, the bottom part). Meanwhile, detailed reports in text are also provided through the interface in Grasshopper (Figure 4, the top part). The officer can read the text in detail after a quick visual confirmation in the 3D view.

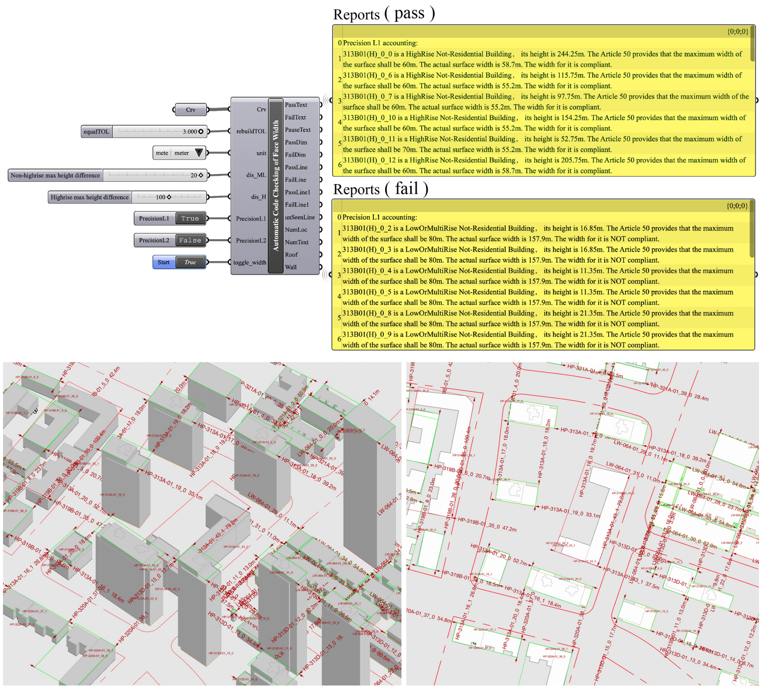

Figure 4. Length-checking of facades (top: system interface embedded in Grasshopper; bottom: graphic interface embedded in Rhino).

4.2. DISTANCE-CHECKING BETWEEN BUILDINGS

First, the officer selects the building outlines in a master view in Rhino and clicks ‘Run It’ toggle to run the program in Grasshopper. The system reads the required data including building outlines and text objects according to their layers. The 3D form of any 3D building volume is reconstructed from an outline and figures in text objects bound to it indicating its elevation and height.

Secondly, the system checks the distance between any two 3D volumes according to the planning codes. There are two precision levels during the checking. At a lower level, a volume is converted into a box first, which means any complex volume is treated as four pieces of facades. While at a higher level, every piece of façade is calculated. For each two volumes, the system actually checks the distances between their pieces of facades. The size, orientation, elevation, and building type are used in a formula of acceptable distances.

Finally, the building volumes with the distance dimensions annotated as visualized results are displayed in a Rhino view. The color of the volume hints at the result: pass in grey and fail in red (Figure 5, the bottom part). Meanwhile, the detailed reports including specific items of the planning codes are presented through the interface in Grasshopper (Figure 5, the top part). The officer can read the text in details and make the final decision after a quick visual confirmation in the 3D view.

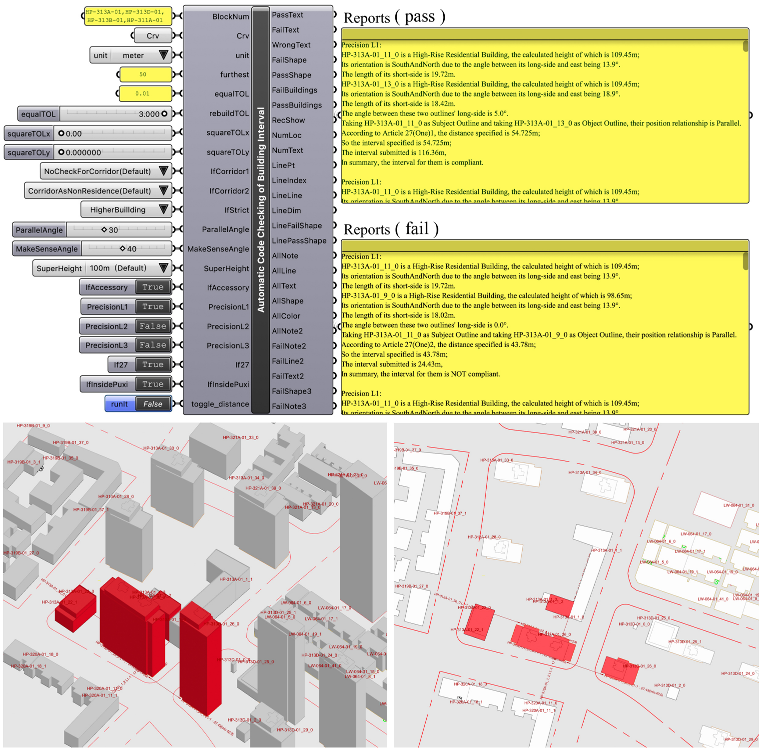

Figure 5. Distance-checking between buildings (top: system interface embedded in Grasshopper; bottom: graphic interface embedded in Rhino) .

5. Conclusions & Future Work

By the end of 2020, the above preliminary system has been tested in 14 building projects submitted to the Planning Bureau of Huangpu District, Shanghai. The conventional technical review period reduces from weeks to seconds, which keeps the citizen’s right in an efficient way and even makes negotiations between government and developers possible in an acceptable schedule.

The development does not stick to the popular BIM platform as many other existing systems did, due to a deep understanding of the real level of BIM application in China. Feasibility in the daily workflow is concerned in the first priority. A revised CAD-drawing-based method is proposed to realize the automatic code checking and keep the compatibility with BIM platforms in the future.

Although the length-checking of facade and the distance-checking between buildings are two main issues in the daily review, many other code items are still on the way in our development. With these explorations, some problems from the code itself have come to the surface. The object model of buildings is found out of fashion seriously. For example, free forms can't be interpreted by the current codes. The team believes that a systematic revision of the codes should be done in the near future.

Acknowledgements

The research was supported by a project of Natural Science Foundation of China titled 'An internet-plus-based approach of crowd simulation for public buildings' (no. 51778417), a project of Shanghai Science and Technology Committee titled 'Study and application of 3D modeling technologies in urban renewal regions' (no. 19DZ1202300).

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