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ORIGINAL RESEARCH PAPER

Use of algorithms in BIM-based audit processes

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ABSTRACT

Building information modeling is a complex and structure-based methodology. It applies predefined steps and frameworks; however, an audit procedure can be complicated and time-consuming. The steps of the evaluations are based on logical connections that also form algorithms in a manual workflow. Algorithms can be interpreted by computers with the help of software languages. A higher level of automation, more efficient workflows, and more economical and accurate results can be developed by using algorithms.

KEYWORDS

visual programming, building information modeling, algorithm, quality analysis, audit, database management

1. INTRODUCTION

The first phase of the development of Building Information Modeling (BIM) is usually called "Classic BIM", which means a methodology of creating models after completing construction design. This method has been induced by using 3D models for audit purposes to highlight mistakes of plans before starting construction [1].

As a result of technology development, an increasing number of BIM uses have been revealed that require the creation of more accurate information models and a higher level of precision [2]. For instance, these are facility management and documentation-based BIM methods [3]. Fulfilling requirements, the audit process has been more profound, and stricter criteria have been applied. Some rules have been developed based on predefined steps (forming simple algorithms) to comply with the final goals of audit processes that have been the creation of perfect models. In the past, these have been mainly manual audit workflows involving some clash detection software. However, these methods can be further developed and automated [4]. This research also supports its feasibility and usage possibilities through test situations according to real project experiences.

2. ALGORITHM-BASED AUDIT WORKFLOWS

The definition of BIM is more than modeling it also includes the meaning of management processes that are connected to this technology. Due to this technology development audit processes have also been improved to a higher level. BIM contractual documents [5] have appeared that regulates processes specified to projects according to BIM standards [6]. Missing these requirements may also lead to the refusal of contractual compliance. It results in higher responsibilities on the quality control processes. The Auditors, as in addition to the

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previous audit workflows (e.g., examination of element types, dimensions, duplicates, collisions) it is also necessary to check the compliance with the information content was defined in design programs and other BIM documents.

The software may help during audit processes but it should be noted, that these are not ready solutions. The software platforms can provide a framework for examining various parameters and parameter values, also allowing the incorporation of algorithm-based workflows.

2.1. Examination of BIM model, element content, content plan and budgeting

The emergence of simultaneous design and construction workflows (Design & Build method [7]) allowed constructors, investors, and customers to define new requirements. Due to the modeling and designing processes are parallel, models can be used for the calculation of quantities or budget for the moment in time. Its bases are the placed model elements and their attributes, which means the inaccuracy of the calculations is disparate in different project phases. Generally, in the case of a conceptual design, only a few elements are placed in the model therefore, the calculation is rather estimation while in the construction phase thousands or millions of elements are placed which may result in a more accurate Quantity Take-Off (QTO).

Because of the numerous elements, the classification of elements must have a precise structure and needs to be updated. It can be documented in a form of Content Plan (CP) however the enormous number of elements makes budgeting and audit more complicated. In the case of model-based budget creation, it is suggested to develop an element-based item list aligned to CP. Thereby the accuracy and content may be followed and controlled by time-consuming manual methods or by more efficient automated algorithms. The element-based item list needs to be considered. Currently, in Hungary, there is no uniformly developed and accepted budget system of norms that may provide a framework for BIM content. It is not common to use but it can support the work of budgeting professionals.

2.1.1. Developing the connection between model, CP, and budgeting documents. The first step is to create a connection between spreadsheet documents and the classification of budget items (Table 1). Inconsistent BIM workflows result in more complex algorithms. In a consistent situation matching of items can be made by using classification or some element-specific parameter. During this research, Autodesk Revit and Dynamo add-on was used for creating algorithms.

2.1.2. Developing of algorithms. The first components of the script have been used to define the parameter values for comparison purposes (Fig. 1). It is necessary to compare the values of the model and CP and besides converting the identifiers of model elements to be able to compare with budget items. After the parameter assignment process, a test was done, which resulted in differences between the budget list, BIM model, and CP. Results have been presented in a spreadsheet format in a specific column of the budget list and in a new empty table.

2.1.3. Results of the examination. The result of the test is an algorithm that can be used for auditing documents and BIM models with the same data structure (Table 2). It is applicable for future project audit processes but the specification of the algorithm is always necessary.

2.2. Parameter audit according to the architectural design program

BIM includes management processes that require a higher level of audit processes. Examination of model elements

Table 1. Assignment of model-based CP and budget items

IFC BIM model element content					
Uniformat II. code	Family Name / Type Name parameter	Name	Size	System	Budget category
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	200 mm x 100 mm	Low current	Parking below ground level
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	200 mm x 100 mm	Low current	Apartments
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	400 mm x 100 mm	Low current	Parking below ground level
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	100 mm x 60 mm	Power	Apartments
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	200 mm x 100 mm	Power	Parking below ground level
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	400 mm x 100 mm	Power	Parking below ground level
Construction budget data content					
Uniformat II. code	Family Name / Type Name parameter	Name	Size	System	Budget category
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	200 mm x 100 mm	Low current	Parking below ground level
D5020.30	Cable Tray with Fittings: Channel Cable Tray	Cable Tray	400 mm x 100 mm	Low current	Parking below ground level

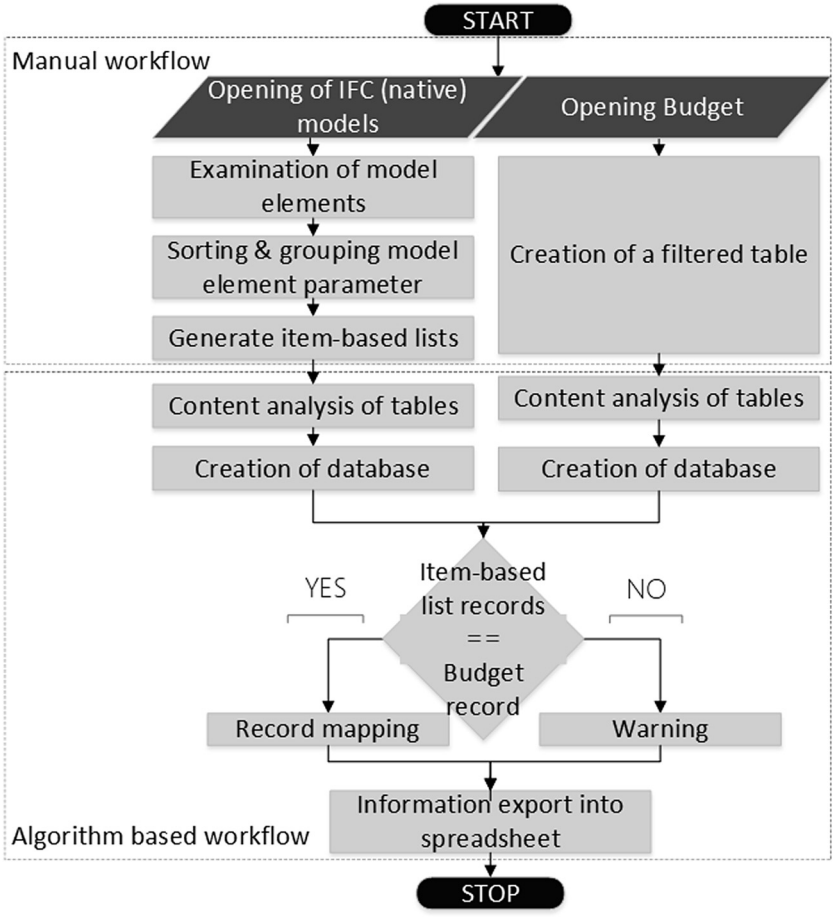

Fig. 1. Operating principles of the developed algorithm

Table 2. The result of the test

BIM content plan				
Name				
Uniformat II. code	Model element name	Item number	Model based quantity	Results
A4020.20	Elevator plate, monolithic reinforced concrete	1.0.11.44.11.22	*14.05*	CP
B1010.20	Slab contraction joints, monolithic reinforced concrete	1.0.11.44.11.00	*756.27*	CP
B1010.20	Slab contraction joints, monolithic reinforced concrete	1.0.11.44.00.88	*2801.01*	CP
B1010.20	Slab contraction joints, monolithic reinforced concrete	1.0.11.44.11.66	*1143.77*	C
B1010.20	Slab contraction joints, monolithic reinforced concrete	1.0.11.44.00.88	*7420.38*	CP
B3040.10	Balcony - green roof	1.0.44.00.11.00	*3261.93*	CP+C
B3040.10	Terraces	1.0.44.00.88.00	*889.83*	CP+C

C is the item in cost table only; CP+C can be found in both the BIM content plan and the cost table; CP is the item found in BIM content plan only.

according to contractual documents is mandatory. One of the most important parts of an audit is to check the architectural design program because in most cases the assets or parts of the assets are sold before the planning or construction phase and it is essential to ensure the client what they have paid for. According to this statement, the permit and construction design documentation have to be aligned with the design program. In the case of BIM projects, the creation of plans should be connected to model elements.

Table 3. A general example of room's requirements in the design program

Requirements of height	• free ceiling height of underground garage levels: min. 2.10 m; • ground floor garage level free ceiling height: min 2.4 m; • free ceiling height of the lobby shops: 4.25 m; • general level ceiling height in the elevator lobby: min. 2.65 m; • general level ceiling height in the corridor: min. 2.50 m; • free ceiling height of floor levels: 2.95 m;
Minimal requirements of apartment design	• minimum size of rooms: 12 m^2; • minimum size of living room: 17 m^2;
General requirements of apartment design	• in the case of living room +2 rooms, additional bathroom with shower is required per apartment (double comfort); • in the case of living room +1 room, a separate toilet from the bathroom is required; • pantry room required for larger apartments (>55 m^2); • in the case of large flats (>62 m^2) there must be a utility room; • as many rooms as possible have windows.

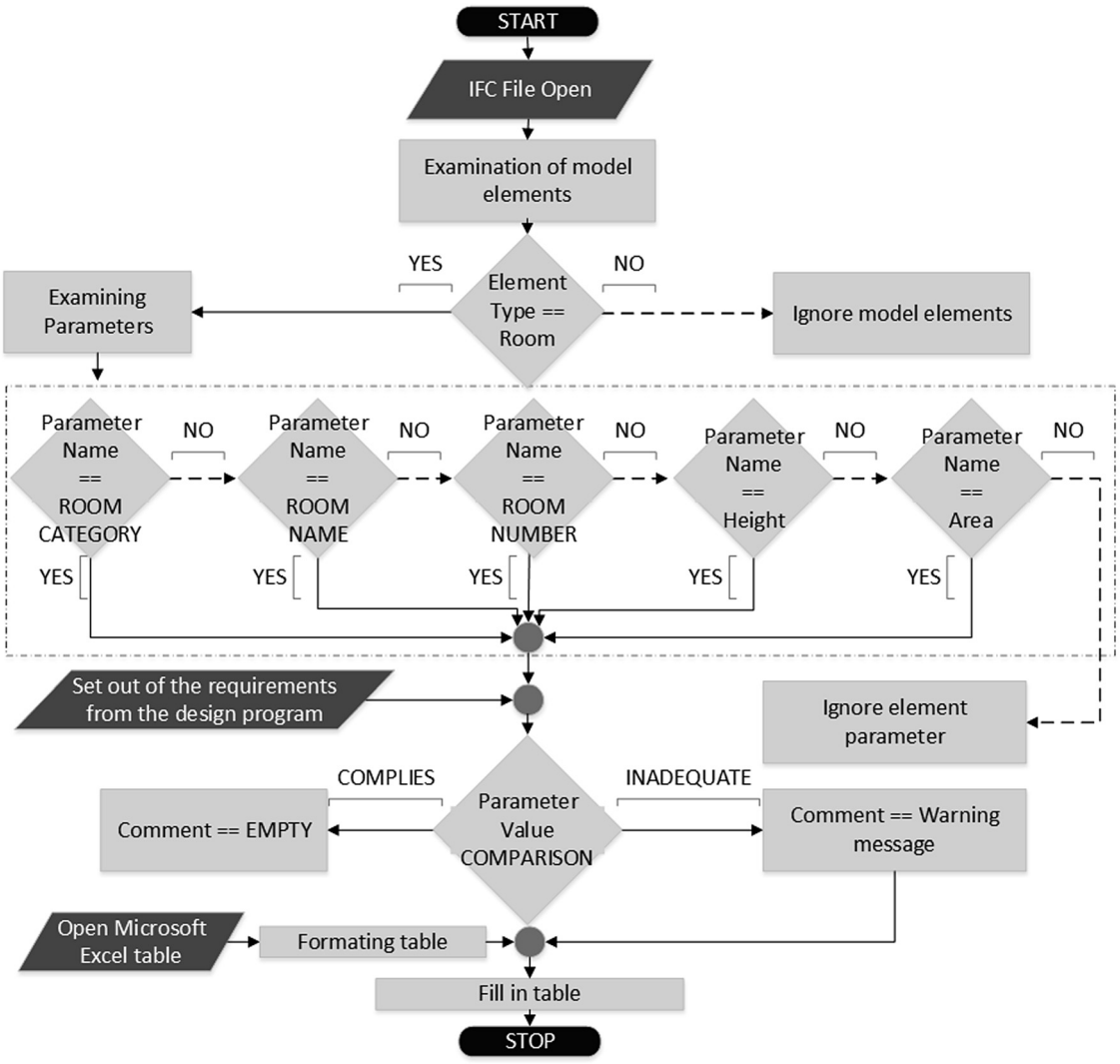

Fig. 2. Flowchart showing the principle of operation of an algorithm

Table 4. The result of the test ("Comments" column)

Room category (Archicad Properties)	Room name (AC_Pset_room_ stamp _3_20)	Room number (AC_Pset_ room_stamp _3_20)	Room area (Archicad Quantities)	Room height (Archicad Quantities)	Comments
Common Service Areas	Staff	000-00-06	6.78	3,000	
Commerce	Commerce	000-03	43.46	3,000	The height does not meet the design specifications.
Corridor Areas	Corridor	000-00-03	3.43	3,000	
Corridor Areas	Smoke-free lobby	000-00-02	17.3	3,000	
Corridor Areas	Lobby	000-00-05	41.5	3,000	The height does not meet the design specifications.
Commerce	Commerce	000-02	38.1	3,000	The height does not meet the design specifications.
Fitness	Fitness/5	000-05	8.8	3,000	
Fitness	Air mechanical room	000-11	41.2	4,070	
Commerce	Commerce	000-01	73.53	3,000	The height does not meet the design specifications.
Apartment area	Living room	001-01-04	21.88	2,900	
Apartment area	Room	001-01-07	11.71	2,900	The area does not meet the design specifications.
Apartment Area	Room	001-01-08	10.39	2,900	The area does not meet the design specifications.

Design programs (Table 3) are also written or spreadsheet documents in which data must be examined with the content of the BIM model. It can be managed with manual methods or using algorithms that may be an automate solution.

2.2.1. The connection between document content and model elements. It was essential to have rooms or spaces placed in the model with their data content, to be able to compare it with the architectural design program. Furthermore, it was fundamental to list the used values from the document and define the calculation method for the audit. Model and algorithm management were made by Autodesk Revit and Dynamo add-in. The source format of the template was not authoritative because the Industry Foundation Classes (IFC) format may also be applied.

The base of this audit process was the accurate BIM model that has been created according to BIM methods and rules because the algorithm has used the information content of the model elements. It was obliged to check the model accuracy and if necessary then correct it.

2.2.2. Creation of algorithm. After opening IFC files the first step of the algorithm creation (Fig. 2) was to examine the element types and finding the room elements. The next step was to manage the 2D metadata according to the design program. After that, the identification, scheduling, and comparison of the reference value-based parameters with the design program had to be done. The result of the process was to find the matches or differences and record them in a previously formed spreadsheet with specified comments.

2.2.3. Results of the process. The final result of the study was an algorithm that contained about 100 Node and 175 logical connections, which can be used to evaluate the reference values with model information. Its principles can be applied directly in a project with the same data structure. It is applicable for future audit projects but the specification of the algorithm is necessary. Table 4 shows the commented final results.

3. CONCLUSION

The spread and development of BIM technologies have been obliged to use and integrate algorithms in future projects. This implied the fact that the time spent on creating algorithms is much less than the time that can be saved during its use. Therefore, the use of algorithms is efficient and economically favorable. A disadvantage is that the development of algorithms needs special knowledge and in many cases, only experienced professionals can perform. However, the use of an algorithm is not complicated and it can support all project stakeholders in any project phase. Applying algorithms to any project size saves time and resources.

However, its benefit may vary depending on the scale of each task and the number of activities performed.

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