AKADÉMIAI KIADÓ

Use of algorithms in building construction preparation

Patrik Márk Máder*, Olivér Rák, Nándor Bakai, József Etlinger and Márk Zagorácz

Research Group 'BIM SKILL LAB', Faculty of Engineering and Information Technology, University of Pécs, Boszorkány u. 2, 7624 Pécs, Hungary

Pollack Periodica • An International Journal for Engineering and Information Sciences

17 (2022) 2, 26–30

DOI: 10.1556/606.2021.00501

ORIGINAL RESEARCH PAPER

Received: October 16, 2021 • Revised manuscript received: November 20, 2021 • Accepted: November 21, 2021
Published online: May 4, 2022

ABSTRACT

Nowadays, it is increasingly important to develop economical construction processes and determine predictable costs. The current level of technology offers countless, even undeveloped opportunities to support architectural, engineering, and construction processes. Building information models created as results of design processes and databases associated with them can provide an appropriate base to fulfill the requirements. However, this information is mainly available only for the largest projects; the possibilities offered by traditional editable vector files (e.g., *.DWG) should also be examined. This study analyzes the efficiency increasing possibilities that can be achieved using low-detail 3D models generated by algorithms and applying 2D-based digital quantity estimation workflows.

KEYWORDS

visual programming, building information modeling, algorithm, quantity estimation, DWG, database management

1. INTRODUCTION

In the case of smaller-scale projects, typical design methods are traditional 2D-based digital workflows or the creation of technical drawings separated from a low detailed 3 Dimensional (3D) model, even in a modular system [1]. Occasionally Building Information Models (BIM) are built to support design documentation. Model-based quantity calculation is not always provided when models are available, however, design sheets are usually generated in *.PDF and *.DWG formats.

Because the graphical information content of *.PDF files can be described as a limited and incomplete base for algorithms, and how drawing elements are converted is specific (for example, a previously dashed line is interpreted as small solid lines in algorithmic processing). In contrast, *.DWG files and their objects have better information content (but it is still negligible compared to BIM models) [2]. Several studies have already been established on the use of 2 Dimensional (2D) files, which provide a comprehensive view of the results achieved in recent years. Some of these examine the translation possibilities of 2D drawings related to mechanical elements [3, 4] and 2D (vector or image) architectural floor plans into 3D components [5]. The methodologies discussed in the articles either attempt to solve geometry formation using custom image and document analysis software or, as it can be found in other studies [6], they do not exit from the AutoCAD environment. In addition, there are complex algorithm-based solutions to support, for example, the design optimization of reinforced concrete beams [7].

In this study, the possibilities of BIM and authoring tools [8] have been introduced considering the quantity take-off methods for construction support [9–12]. The focus is on the graphical element properties in the case of *.DWG file format especially line type, line color, layer name, block properties, file name. By using these parameters, conditional rules and filters can be established (without any image or document analyzer software), which

*Corresponding author.
E-mail: mader.patrik@mik.pte.hu

AKJournals

allows algorithm-based processing. Therefore, the goal is to develop algorithms applying these rules.

2. THE MAIN PHASES OF THE WORKFLOW

Considering the goals, algorithm development has been started that is not performing geometric transformation and optimization [13]. However, it processes the information content of detached house scaled *.DWG technical sheets according to predefined rules (that can be used as a template for further projects). This algorithm can calculate the base quantities (e.g., volume, length, area) in the context of 3D model and data content.

In this research, the Graphisoft ArchiCAD 22 and the Grasshopper parametric add-on (which operates in Rhinoceros 6 (hereinafter referred to as Rhino) environment) were used. Additionally, the fills in the *.DWG files were edited in AutoCAD 2020.

2.1. Required processes by the designer platforms

The preparation begins in the design software, producing the technical plans according to the appropriate rules and exporting the files with *.DWG extension (Fig. 1).

The main purpose is to develop a solution fitting into the traditional workflows and by applying it only basic functions and tools must be used. Just a general use of layers, basic line types and colors, common text objects (e.g., IDentification code (ID), zone stamp), and fills that are differentiated by materials is necessary to create a correct base file. Usually, these settings must be also defined for a traditional project before the modeling process.

2.2. Additional workflows related to other engineering platforms

In the second phase of the preparation, the *.DWG files must be optimized in Autodesk AutoCAD software. During this inspection, grouping and layer correction of 2D objects should be carried out (Fig. 2).

2.3. Rhinoceros and grasshopper workflows

In the third phase the developed algorithms can be used, which are responsible for the analysis, information examination, and the generation of a 3D model with related quantities of *.DWG files imported to Rhino (Figs 3 and 4).

3. STRUCTURE AND OPERATION OF THE ALGORITHM

Figure 5 presents the main operations of the workflow due to the logical rules.

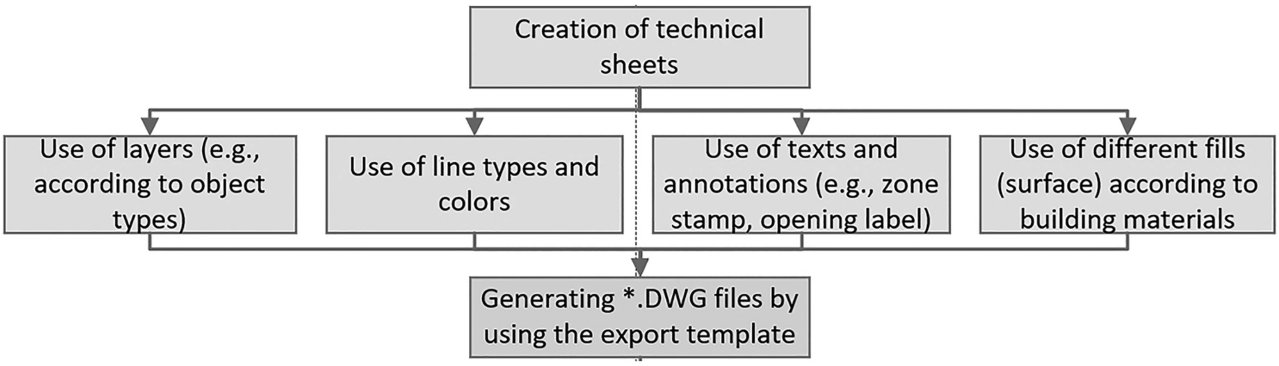

Fig. 1. The main design platform-based workflows

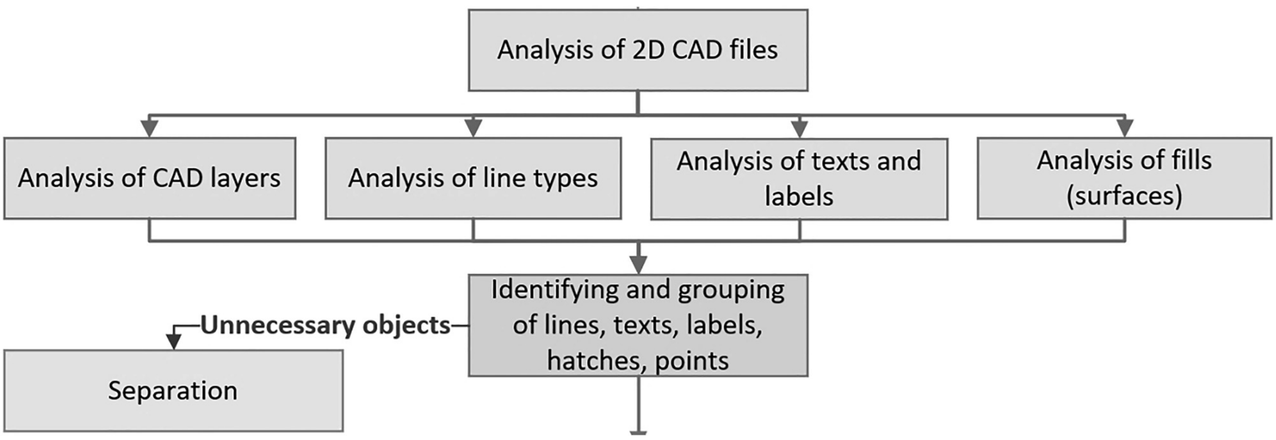

Fig. 2. The main engineering platform-based workflows

During the preparation process, the path of the variable parameter values (e.g., ceiling height, slab thickness, tile height, building materials for special structures, roof slope, and thickness) and the export spreadsheets have to be defined. After the definition of the parameters, the examination of the *.DWG files must be carried out. Its first step is to connect the imported elements to the algorithm. After this operation, the platform allows to filter, search, or group the imported objects according to the parameter values. The classification was made by the type and layers in this phase. Because the methodology is based on handling hatch patterns, it is essential to separate "Hatch" elements from other objects.

3.1. Creating slabs, beams, and roofs

Once the data has been loaded and organized, the information can be used purposefully, and virtual 3D building structure objects can be created. In the first step, the generation of floor and beam structures and roofs can be realized (Fig. 6).

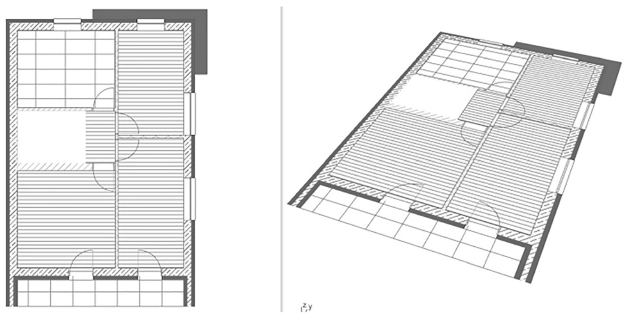

Fig. 3. Imported and prepared 2D *.DWG files in Rhino platform

3.2. Creating walls

In the second step, the walls can be generated by grouping and classifying the 2D fills and layers of the imported *.DWG file. According to the previously defined data structure, 3D object generation follows. As a result, quantities can be derived from the 3D model elements, which have different skins and surfaces as it is shown in Fig. 7.

3.3. Creating openings and final operations

After the creation of structural elements, the algorithm generates additional object and surface values that are relevant in the case of the quantity take-off. This method includes the creation of openings with connected geometries and rooms with their 3D geometry.

In the case of the openings, the first operations of the algorithm are finding the objects, which are positioned in the 2D wall and defining their edges with connecting lines. This method provides the 3D position of openings in walls (Fig. 8). As a result, overlapping rectangles are formed, after which it is necessary to connect the opening dimensions to them. This information is derived by the algorithm from the symbols of the openings and their textual parameters in the *.DWG file. Using the data, openings with the appropriate sill height, threshold, and head sizes can be produced (Fig. 8).

The structural details can also be derived from the drawings after the bounding size and position definitions. The algorithm uses the 2D graphical information of the wall layers around the openings (Fig. 9).

The 3D geometry has been finally created. As it is shown in Fig. 10 the partition walls, coverings, slab structures, openings, beams, and roof structures have been generated as

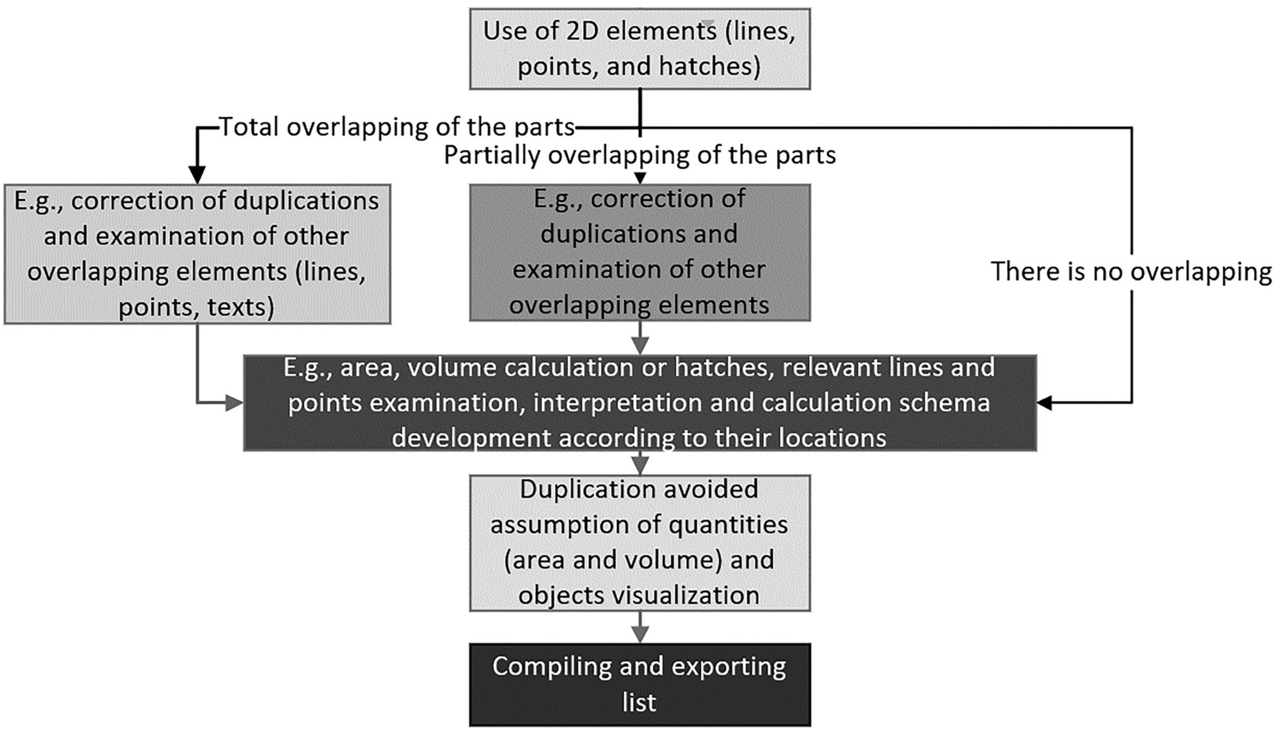

Fig. 4. The main Rhino and Grasshopper-based workflows

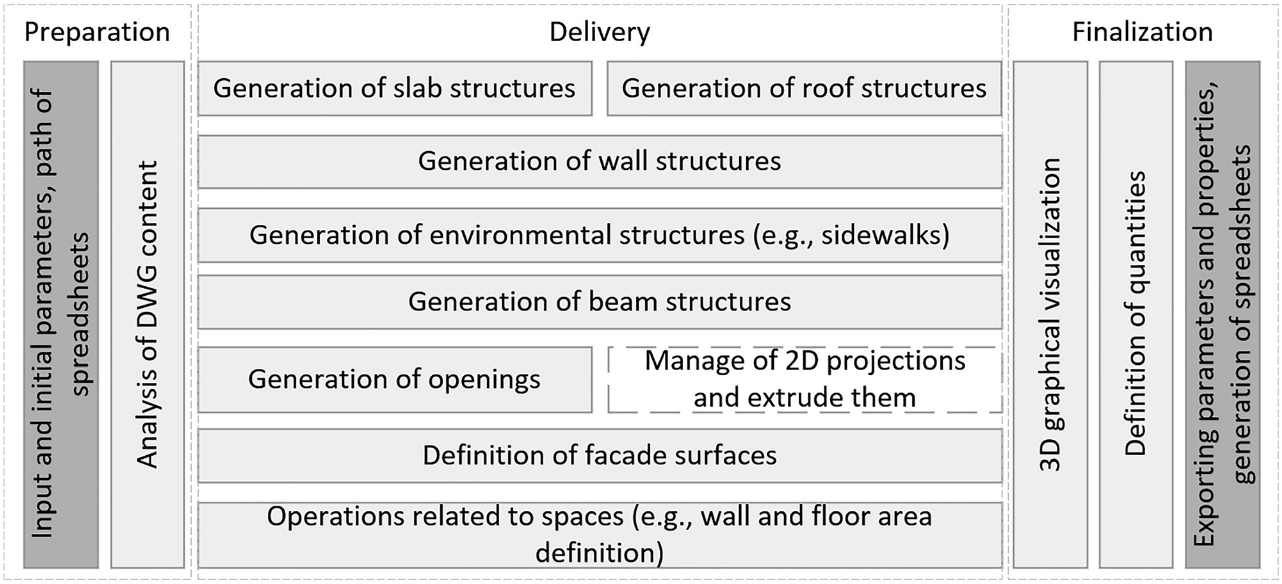

Fig. 5. The main operational groups of algorithm

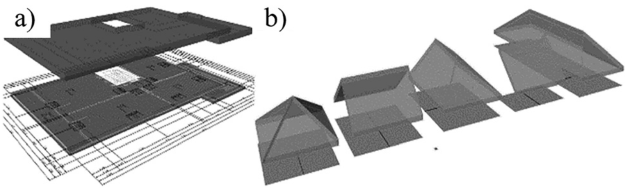

Fig. 6. a) 3D slab and b) roof objects generated by the algorithm

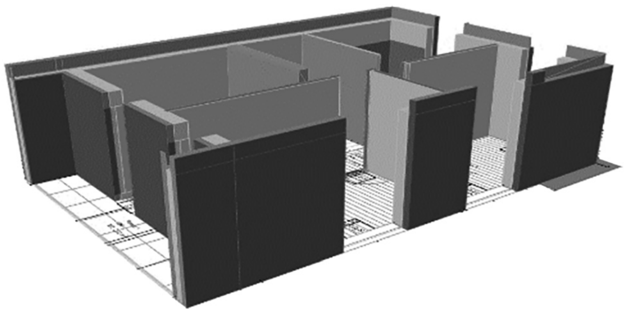

Fig. 7. Wall structure generated by the algorithm

3D objects. The geometries of the roof were also created by using the 2D floor plan information. The contour of the roof planes and the symbols representing the slope directions were examined during this operation.

3.4. Creating spaces

In addition to structures, the algorithm can create 3D objects related to rooms. The interior wall and façade surfaces can also be calculated. In the case of surfaces, the algorithm generates the boundary contour of the building according to the structural 2D hatch patterns, and then it is extruded with the story height value. Obviously, the surface of the openings is subtracted from the total. The method is quite similar in

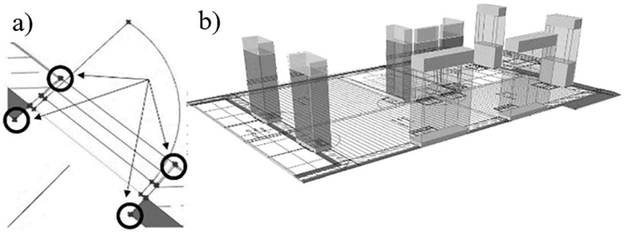

Fig. 8. a) Door edges and b) homogeneous opening geometries generated by the algorithm

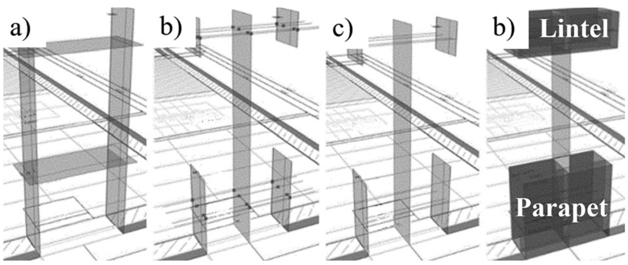

Fig. 9. Opening structure generating workflow

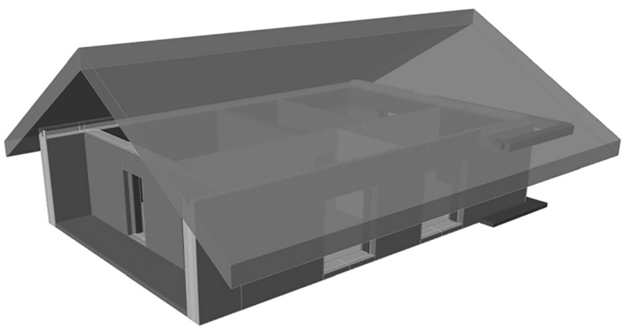

Fig. 10. Building geometry generated by the algorithm

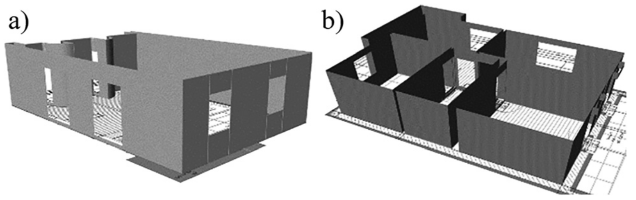

Fig. 11. a) Exterior and b) interior wall surfaces generated by the algorithm

the case of interior walls, but there the space boundaries are extruded, and the contact surfaces are filtered to avoid duplications (Fig. 11).

3.5. Quantity take-off

The last operation of the algorithm is to define the calculation and export methods related to the generated 3D geometries. It results in spreadsheets, which saves the information below:

– building material quantity according to layers and types;
– assumed facade surface;
– quantities related to spaces (e.g., wall surface, floor border);
– number of openings according to the sizes and textual information;
– surface of the roof.

4. CONCLUSION

According to the generated quantities by the algorithm and the manually modeled simple and detailed model of a detached house, it can be stated that the values are almost equal, only ~0.5–2% average difference can be found. The differences are increasing if the complexity of the building escalates. It is because the algorithm at this level of development cannot manage or can manage with limitations the special situations (e.g., different levels in a story, complex shape of slabs, not rectangular opening geometries, or special roofs, etc.). These situations can be solved easily with design tools. In the case of complex test buildings, the average difference is between 7–10%, which can be 15–18% in the case of building material quantity. It is planned to develop the algorithm in the future.

As a summary, it is proven that an algorithm-supported workflow can be developed, which is controlled and integrated into traditional methods. This algorithm can support calculations and according to the special client requirements (e.g., short available working time) fasten the processes and it can also be used for accurate quantity take-off or cost estimation. It is important to mention that by using an algorithm in the scale of detached projects the processes can be more efficient and less time is needed compared to traditional BIM methods. Due to the use of algorithm circa 66%–80% of modeling time can be saved. These results justify the need for further development.

ACKNOWLEDGMENT

The research project is conducted at the University of Pécs, Hungary, within the framework of the Biomedical Engineering Project of the Thematic Excellence Programme 2020 (2020-4.1.1-TKP2020).

REFERENCES

[1] Á. Borsos, J. Balogh, B. Kokas, and B. Bachmann, "An eco-approach to modularity in urban living," *Int. J. Des. Nat. Ecodynamics*, vol. 14, no. 2, pp. 83–90, 2019.
[2] E. Charles, P. Teicholz, R. Sacks, and K. Liston, *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors*. Wiley, 2008.
[3] V. Nenorta, N. Puodziuniene, and R. Kersys, "Conversion of 2D drawings to 3D parts conversion of 2D drawings to 3D parts," *J. Biuletyn Polish Soc. Geometry Eng. Graphics*, vol. 14, pp. 48–51, 2004.
[4] A. Çıçek and M. Gülesın, "Reconstruction of 3D models from 2D orthographic views using solid extrusion and revolution," *J. Mater. Process. Technol.*, vol. 152, no. 3, pp. 291–298, 2004.
[5] L Gimenez, J. L. Hippolyte, S. Robert, F. Suard, and K. Zreik, "Review: reconstruction of 3D building information models from 2D scanned plans," *J. Build. Eng.*, vol. 2, pp. 24–35, 2015.
[6] X. Yin, P. Wonka, and A. Razda, "Generating 3D building models from architectural drawings: A survey," *IEEE Comput. Graphics Appl.*, vol. 29, no. 1, pp. 20–30, 2009.
[7] M. Shaqfa and Z Orbán, "Modified parameter-setting-free harmony search (PSFHS) algorithm for optimizing the design of reinforced concrete beams," *Struct. Multidiscip. Optim.*, vol. 60, no. 3, pp. 999–1019, 2019.
[8] J. Etlinger, O. Rák, M. B. Zagorácz, and P. M. Máder, "Revit add-on modification with simple graphical parameters," *Pollack Period.*, vol. 13, no. 3, pp. 73–81, 2018.
[9] A. Borhani, C. S. Dossick, C. Meek, D. Kleiner, and J. Haymaker, "Adopting parametric construction analysis in integrated design teams," in *Advances in Informatics and Computing in Civil and Construction Engineering*, I. Mutis and T. Hartmann, Eds, Springer International Publishing, 2019, pp. 351–358.
[10] B Kula, D. A. Ilter, and E Ergen, "Building information modeling for performing automated quantity take-off," in *5th International Project and Construction Management Conference*, North Cyprus, Nov. 16–18, 2018, pp. 645–653.
[11] C. Khosakitchalert, "Development of quantity takeoff methods for compound elements based on Building Information Modeling (BIM)," PhD Thesis, Graduate School of Engineering, Osaka University, 2020.
[12] F. H. Abanda, B. Kamsu-Foguem, and J. H. M. Tah, "BIM – New rules of measurement ontology for construction cost estimation," *Eng. Sci. Technol. Int. J.*, vol. 20, no. 2, pp. 443–459, 2017.
[13] R. Sárközi, P. Iványi, and A. B. Széll, "Formex algebra adaptation into parametric design tools and rotational grids," *Pollack Period.*, vol. 15, no. 2, pp. 152–165, 2020.