From Stereotomy to Subdivisions

Crafting a BIM tool for discrete elements design

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The meaning of stereotomy has evolved from its traditional association with stone masonry to its contemporary application in surface subdivisions and cladding design. This shift reflects modern architecture's focus on non-structural, aesthetic segmentation rather than load-bearing assembly. However, current BIM tools lack efficient methods for generating and managing these complex subdivisions, forcing architects to rely on manual processes that compromise design integrity. This research presents a computational framework that embeds parametric subdivision logic into a flexible macro-element, enabling dynamic control over patterns and joints while maintaining geometric coherence. The system automates fabrication data generation, bridging the gap between design intent and construction. Through case studies in veneer and structural applications, we demonstrate how this approach reconnects digital workflows with stereotomic principles—balancing precision with creative expression. By integrating subdivision-aware tools into BIM environments, our method enhances both efficiency and design possibilities, using non-destructive methods and keeping stereotomy thinking relevant in contemporary architecture.

Keywords: *BIM, subdivision, parametric, digital tool, automation.*

INTRODUCTION

In architectural design, certain elements cannot be defined solely by their continuity. While a brick wall or ceramic tile flooring might be successfully described by its main geometry and a definition of a repetitive tiling, other elements rely on carefully designed subdivisions. Examples include stone wall cladding or precisely divided marble flooring, as seen in the works of Gio Ponti and Álvaro Siza (figure 1). Architects with a careful approach to detail often design construction elements with precision, defining the exact morphology of each block—particularly when working with bespoke materials such as stone, metal cladding, or concrete falsework. Given its significance in architectural expression, it is only natural that this level of detailing is integrated into BIM workflows. However, as will be demonstrated, BIM lacks a standardized method for accurately managing such processes. The act of designing the subdivision of materials is sometimes referred to as "stereotomy" within architectural discourse, though this terminology is often applied inaccurately in this context.

THE MEANING OF STEREOTOMY

Stereotomy is the art and science of cutting stone to construct precise, geometrically complex structures, particularly for spanning spaces such as arches and vaults. This discipline, deeply rooted in architectural and engineering traditions, involves both theoretical knowledge and practical skill, requiring an understanding of geometry, material behavior, and structural integrity.

Origins of a construction technique. The origins of stereotomy can be traced back to ancient Greece, where early instances of carefully cut stone appear in monumental architecture such as theatres (Boyd, 1978). The Romans later advanced these techniques, employing precisely shaped masonry in their widespread use of arches and vaults in buildings and bridges. The mastery of stone cutting reached new heights during the Gothic period, as masons—often trained within exclusive guild traditions—developed highly sophisticated vaulting systems, such as ribbed vaults and trompes. These innovations allowed for daring architectural feats, enabling structures with complex and intricate designs that pushed the boundaries of both engineering and aesthetic expression. The knowledge required to cut stone at precise angles remained largely within the domain of masons, passed down through generations as a closely guarded craft.

The roots of stereotomy lie in this seminal masonry techniques, which were systematized during the Renaissance, where the practice was elevated from the exclusive domain of masons to a scholarly pursuit accessible to architects, following ideas of dissemination of knowledge. Philibert de l'Orme played a pivotal role in bringing stereotomy into the architectural discourse (Sakarovitch, 1998). His *Le premier Tome de l'Architecture* (1567) contains one of the earliest comprehensive treatises on *coupe des pierres*, establishing a systematic approach to stone cutting. By framing stereotomy as an intellectual pursuit, de l'Orme set the stage for subsequent generations of architects and theorists, who continued to refine and expand upon its principles.

The word "Stereotomy". Although the concept of stereotomy had been in use for many centuries, the term itself was first introduced in 1644 in Curabelle's *Examen des œuvres de Sr. Desargues*. Curabelle introduced the term without providing a specific terminological or graphic description, using it merely to refer to the sections of solids. The etymology of "stereotomy" is of particular interest, as it is believed to derive from the Greek *stereos* (solid) and *tomia* (cut). Fallacara and Barberio (2018) speculate that it shares a connection with the term *stereoma*, which traditionally referred to the celestial vault believed to house the fixed stars. In Christian cosmology, especially in the 6th-century writings of Cosmas Indicopleustes, the firmament was conceptualized as a perfect, immutable dome encircling the Earth, symbolizing divine order and stability. It is a plausible hypothesis that this metaphysical notion influenced the development of stereotomy, imbuing it with a celestial geometry that sought to mirror divine perfection in the construction of stone vaults and domes.

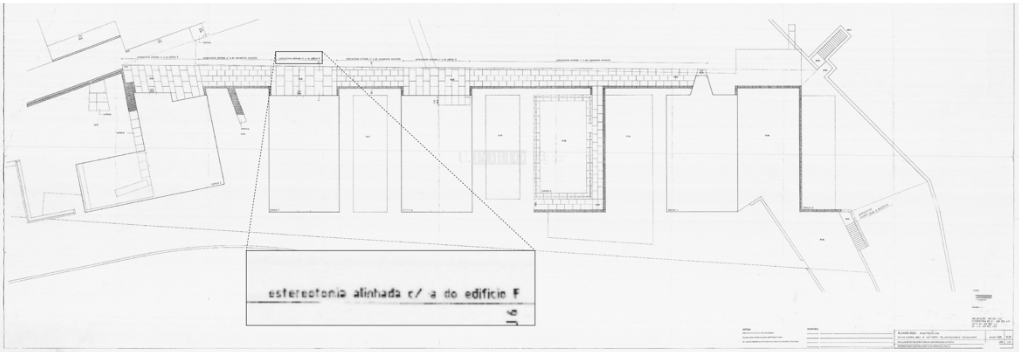

Figure 1
Plan by Álvaro Siza for FAUP, where the word "estereotomia" is used to refer to the planar design of raised stone flooring system. (Direcção de Serviços de Planeamento, 1995)

As stereotomy progressed, it developed alongside advances in geometry, optics, and statics. Its principles were foundational in the work of figures like Girard Desargues, whose early work contributed to projective geometry, and Philippe de La Hire, whose studies on engineering statics influenced the development of the field. The most significant breakthrough came with Gaspard Monge's creation of descriptive geometry during the late 18th century (Azambuja Varela, 2020). Monge's double orthogonal projection method, developed during the Industrial Revolution, provided a rigorous framework for representing complex three-dimensional forms, further transforming stereotomy and industrial design.

The decline of classical stereotomy. However, with the advent of the Industrial Revolution, the prominence of stereotomy began to diminish. As iron and steel became more affordable and widely used, architectural practices shifted toward structural solutions based on metallic frameworks, moving away from stone-cutting traditions.

The original principles of stereotomy, grounded in geometric precision and the division of materials—particularly stone—have evolved to influence the modern architectural practice of subdividing surfaces. In contemporary façade systems, digital tools allow architects to apply these traditional geometric principles to the subdivision of new, industrialized materials such as metal sheets and stone panels. While often offering enhanced flexural strength, these materials also come with higher embodied carbon. The process of subdividing surfaces, now made more efficient and precise through computational design, continues to echo the careful geometry of stereotomy, adapting to today's architecture's technological advancements and material realities.

Stereotomy vs Subdivision. This evolution has eventually led to the use of the term "stereotomy" to describe the design of surface subdivisions, albeit in a much more superficial context (Azambuja Varela & Sousa, 2016). Modern construction techniques, now reliant on repetitive materials like cement, brick, and frame structures made of wood or metal, increasingly focus on the subdivision of the visible, noble material—its cladding. Cladding, or even concrete falsework, as the most visible and aesthetic layer of a building, has become the central focus of stereotomy, representing the careful division and articulation of surfaces in contemporary architectural practice.

Although today stereotomy has been revitalized through digital fabrication and parametric modeling, which provide precise control over material optimization, structural behavior, and visual continuity, a parallel interpretation of the term has emerged. No longer confined to the traditional notion of stone-cutting, stereotomy now serves as a flexible word for describing the subdivision of architectural surfaces. Given that this approach now focuses on surfaces rather than volumes, perhaps the term "subdivision" would more accurately describe this modern application.

EXISTING SOLUTIONS FOR SUBDIVISIONS IN BIM

Current BIM workflows lack native tools to specify such subdivisions while preserving the integrity of the overall element. Two common strategies are used: retaining the macro-element and adding drafting markers for subdivisions or modeling each subdivided component independently. The first approach, while highly efficient in execution, functions primarily as a drafting method rather than a fully integrated solution. Since the building element itself remains unchanged, any newly generated view will fail to display the intended division lines. Furthermore, this approach does not align with BIM methodology, as it does not generate accurate quantity takeoffs or fabrication data for individual components. The second strategy, while offering detailed information on the smaller units, compromises the geometric integrity of the original building element by fragmenting it. This approach undermines the architectural intent of maintaining continuity, which should only be interrupted by intentional division gaps between flush elements.

Various software solutions employ distinct strategies to address these limitations. In Archicad, one modeling approach involves drafting division lines as simple 2D elements, which are then utilized with the Magic Wand tool to generate Walls, ensuring the desired gap width. These Walls are subsequently converted into Fills, which are incorporated into a new Complex Profile. This profile is then applied to a new Wall or Beam to extrude the gap shape, functioning as an operator in a Subtract Solid Element Operation (Graphisoft, 2019). This method allows the original wall to maintain its integrity while enabling independent modifications to the division design.

Revit, in turn, provides a built-in tool for creating linear voids in walls, known as Reveal, which effectively generates voids but is limited to horizontal and vertical orientations (Autodesk, n.d.). For Floor slabs, the Slab Edge tool can replicate the functionality of Reveal (Autodesk, 2024), albeit in a more complex manner. To achieve greater flexibility, the community often recommends using the Cut Geometry tool (MLApps, 2021), which aligns with the strategy employed in Archicad.

Although other BIM software solutions were not examined in this study, it is notable that the leading market alternatives do not offer robust tools that directly address the architectural need for seamlessly designing separations between constructive flush elements.

METHODOLOGY

This research investigates architects' workflows for designing subdivisions and identifies

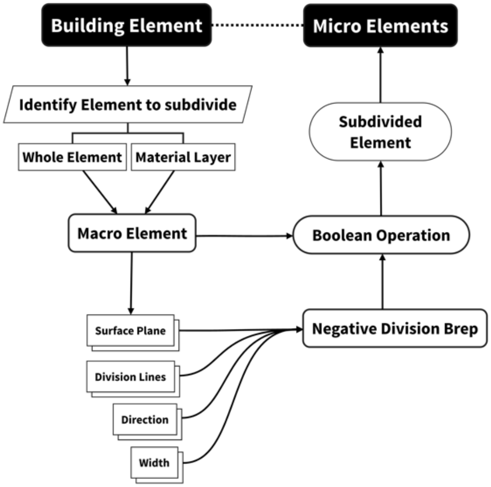

Figure 2
Relationships of elements and flow of operations in the proposed BIM subdivision tool

scenarios where this methodology is essential. Beyond veneers, structural elements like walls built from large blocks or vaults constructed with voussoirs also greatly benefit from this approach. To address these challenges, the idea of a digital tool is proposed as a proof of concept – Figure 2. This tool integrates two key elements, manually designed by the architect: the subdividable Macro Element and the Division Lines. The macro-element, understood as the Building Element in IFC terminology, is the architectonic surface intended for subdivision, such as a large stone wall, or floor slab. The Division Lines is the design of the subdivision itself. In the realm of 2D CAD this might have sufficed, but the holistic accuracy and possibilities of BIM workflows benefit from the precise modelling of the resulting discrete elements.

Division lines are not dimensionless in construction. The separation of construction

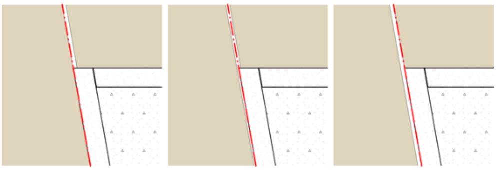

Figure 3
Section of a stair nose and stone stair panneling in the elevation: three different scenarios for the location of gap according to construction line.

Figure 4
Photograph of the stair subject in FAUP. Notice the stone cladding in the flooring and walls, composed of carefully cut stone.

elements always has a measurable width. However, the architect design thinking is more tightly related to the concept of a border that separates two materials, than to the actual void thickness itself. As such, this tool should use the border geometric information, which is widthless, to guide the overall morphological solution; much as a typical wall creation BIM workflow uses a line and the remainder geometry is generated parametrically. It should be noted that a construction line and a width do not specify the location of the gap (Figure 3). As such, there should be an option to specify a location different from center, which might be necessary in specific case scenarios where the gap is large.

In a similar fashion to the design of walls in BIM, Parametric controls allow architects to define geometry, dimensions, and metadata for each operation. By streamlining the design process, this tool aims to ensure the continuity of the macro-element while generating bespoke data for fabrication, ultimately improving workflow efficiency and design accuracy.

- First, we create an experimental tool to simulate the behavior of a BIM subdivision

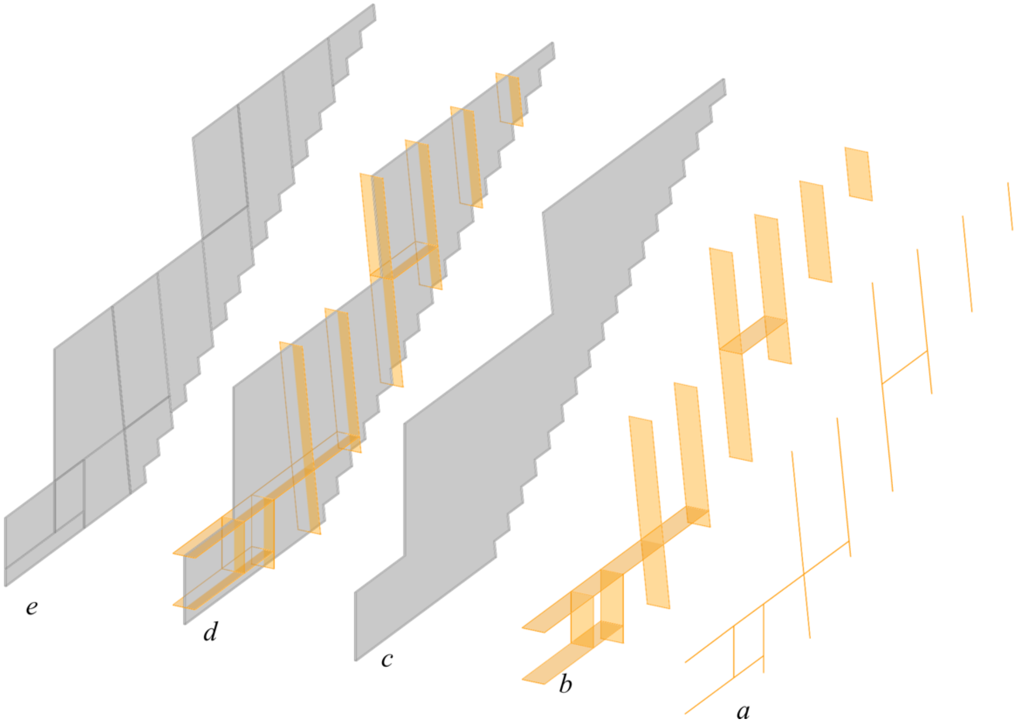

Figure 5
Flow of operations from (c) Building Element and (a) Division Lines to (e) Micro Elements.

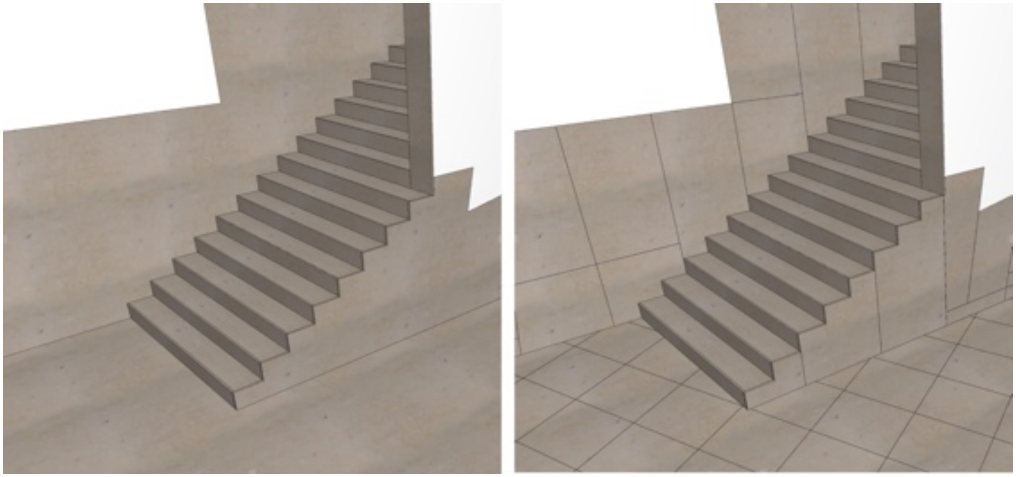

Figure 6
Archicad environment with Building Elements before and after being subdivided.

tool (BST) using Grasshopper as a prototyping tool.

- Following this, a typical BIM interface is used as a test bed for developing a draft for the UX of the BST.
- Finally, a draft for the IFC specification is discussed to support the wide adoption of this kind of modeling strategy.

EXPERIMENTAL TOOL

We create an experimental tool to simulate the behavior of a BIM subdivision tool (BST) using Grasshopper as a prototyping tool. For this to be accomplished, we used Archicad as a BIM software setup with the Grasshopper – Archicad Live Connection, allowing for geometry to be referenced from Archicad into Grasshopper and returned in the inverse direction. This is only used for prototypical reasons, as the proposed tool should be embedded in the BIM software as a native tool.

A base BIM model was created in Archicad, following a survey of a stair and landing within Álvaro Siza's Faculty of Architecture building seen in Figure 4. Stone veneers were modelled as continuous surfaces, and division lines were drafted with 2D line objects.

For the BST prototyping the following flow of events (Figure 5) was executed. We imported the geometry of the Building Element and the Division Lines, both designed in the BIM environment. The Archicad Building Element is imported as a Brep, which includes triangulated faces in the case of 5+ sided polygons, as well as juxtaposed Breps, or even faces with no area because of collinear edges. The first issue is easily resolved with a "Merge Faces" command. However, the other two required a more involved process: after culling faces with near zero area, these were grouped by normal – by evaluating each normal and using a "Point Groups" command to distribute them into branches according to result – and then joined and merged, resulting in effective coplanar united faces. This action is important in order to have a good base Brep, which is later going to be subdivided and brought back to Archicad.

Once the geometry is prepared, the subdivision process begins. The division lines are thickened based on their location (Figure 2), forming distinct regions that are projected onto the plane of the Building Element. These regions are then extruded and serve as Boolean Difference operators, effectively subdividing the Building Element. Finally, a clean mesh is generated for each Micro Element and synchronized back to Archicad as a Morph, leveraging its geometric flexibility (Figure 6).

BIM INTERFACE

The workflow within the BIM interface pertains to two primary objects: the Building Element (subject to subdivision) and the Division Lines (which guide the subdivision process). The former is not the primary focus of this paper, as each software package possesses its own methods for creating building elements. It is noteworthy, however, that this Building Element is expected to have its principal surface parallel to a specific plane, whether horizontal, vertical, or otherwise.

The example below uses stair paneling as a Building Element. As such, the Division Lines are to be drafted in the elevation view of the paneling (Figure 7). A proposed user interface creates a contextual menu option for the Building Element to "Create Subdivision...", which brings a user interface similar to the Edit Mode already existing for the Stair and Curtain Wall objects in Archicad.

This mode would allow for the creation of line, arc, polyline or spline objects within its specific "Division Lines" component. Each of these 2D division lines includes adjustable parameters for thickness and alignment (left, center, or right). Another option available in the Display Palette is a selector for the Building Material to be subdivided, which is useful for Composite or Complex Profile objects. The projection of the division lines is executed along the normal relative to the view in which the "Create Subdivision..." command was invoked. As this operation is constrained to a 2D plane, subdivisions cannot be generated from multiple projections simultaneously. Consequently, the command is unavailable in contexts where its execution would conflict with an existing projection.

This strategy ensures that the Building Element remains intact and retains its parametric adaptability, allowing modifications in thickness, location, and material while preserving the subdivision. In cases where the element's orientation changes—such as the rotation of a wall—the division lines rotate accordingly, maintaining a consistent parallel relationship with the element's primary surface.

Another significant advantage of preserving the ability to manipulate discretized elements is the efficient calculation of material quantities and optimization procedures. This includes nesting strategies that arrange components within predefined rectangular boundaries corresponding to standard stock dimensions used in manufacturing, such as those supplied by stone providers. Figure 8 illustrates an abstract representation of the stacked panels, and below their positioning within the stock material limits, prepared for CNC cutting.

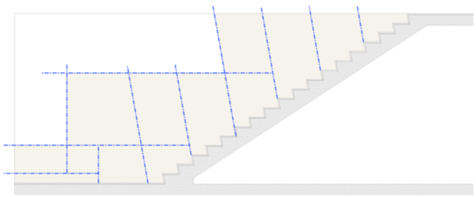

Figure 7
BIM interface showing the design of the Division Lines overlapping the Building Element

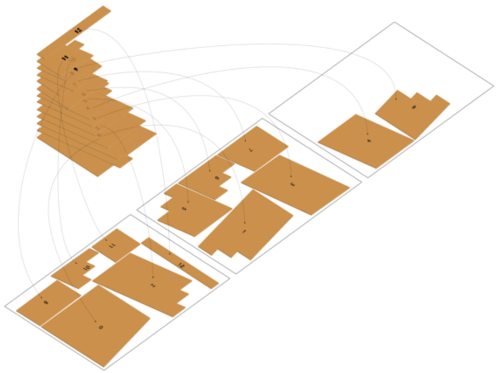

Figure 8
Once the subdivided elements are discretized, they can be quantified or nested into cutting jobs for material optimization.

IFC SPECIFICATION

Beyond the internal mechanics of programming such a tool and its user experience within a BIM environment, an effective BIM implementation relies on a robust, flexible, and practical IFC specification seen in Figure 9.

The relationship between the two primary element types, BuildingElement (which is actualy a IfcWall, IfcSlab, or other similar element) and Division Lines, is established through the IfcRelAggregates entity (buildingSMART, 2024), ensuring that each element remains independent within the file definition. A third entity, IfcMicroElement, analogous to IfcBuildingElementPart, contains the geometries of the subdivided MicroElements. The visibility of BuildingElement and MicroElements is alternated based on IfcGeometricRepresentationSubContext, which defines their representation according to a specific TargetScale.

The IfcDivisionLines entity encapsulates the majority of the division's properties, except for the actual drafted lines themselves. The Pset_DivisionLinesThickness property defines the offset value, determining the separation between MicroElements. The Pset_DivisionLinesLocation property specifies the void's position, enabling its alignment with other construction elements.

An additional optional property, Pset_DivisionLinesJoint, controls the presence and depth of a joint. If absent, the division results in an empty space corresponding to its thickness. If present, its numerical value defines the joint depth, such as in the case of mortar. The IfcRelAssociatesClassification entity enables the specification of the joint material, while IfcRelAssociatesMaterial facilitates the definition of joint morphology based on standardized construction typologies.

FUTURE AVENUES OF RESEARCH

The examples discussed presupposed that the Building Element is planar, such as a slab or a standard wall. Nonetheless, it should also be feasible to subdivide curved or composite surface geometries. This opens an avenue for examining the geometric space where division lines ought to be delineated to ensure a direct correspondence

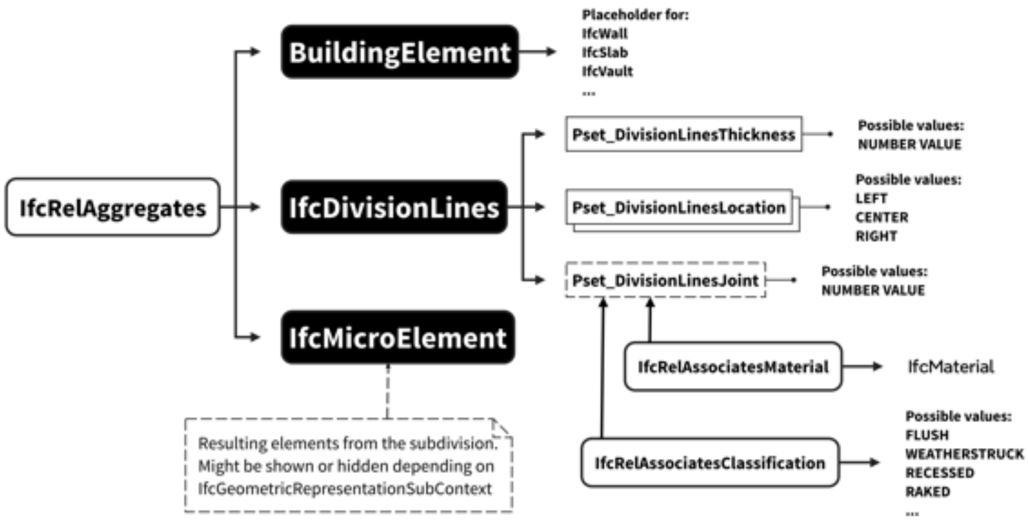

Figure 9
Proposed IFC structure for subdivided building elements

between these lines and the Building Element itself. The subsequent projection and boolean difference operations should adhere to the same principles.

One particular application of this approach is in the design of vaults subdivided into discrete elements. When the vault is sufficiently thick to be considered volumetric and its material possesses high compressive strength, the process transitions from merely subdividing a surface into panels to segmenting a structural form into distinct components. This progression effectively bridges the gap—or even closes the circle—between contemporary panelized surface subdivisions and the structural principles of classic stereotomy.

CONCLUSIONS

This study demonstrates the value of re-examining historical concepts like classical stereotomy to advance contemporary BIM methodologies. As an evolving framework, BIM must continue to integrate insights from diverse disciplines - particularly at the intersection of traditional construction knowledge and emerging digital workflows. The tension between algorithmic design approaches and BIM automation proves particularly fertile ground for innovation. Once the algorithm was prepared and working, and the division lines were sketched, the 7 minutes it took for manually creating the panels, comparing to 10 seconds it took using the produced tool is very self-explanatory regarding the speed advantage of such as approach. Besides, the non-destructive procedure allows for easy fine tuning of the architectural solution.

We argue that architectural subdivision, rooted in stereotomic principles, provides the most conceptually sound basis for developing BIM tools that manage building element segmentation. Such an approach not only improves technical implementation but also bridges the gap between modern surface-oriented applications and classical stereotomy's volumetric, structural logic.

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REFERENCES

Autodesk. (2024). Help | Add a Floor Slab Edge | Autodesk. Retrieved March 31, 2025, from https://help.autodesk.com/view/RVTLT/2024/ENU/?guid=GUID-D54C7E2D-CCCE-4744-9507-0BFCEB6270B5

Autodesk. (n.d.). Help | Add a Wall Reveal | Autodesk. Retrieved January 15, 2025, from https://help.autodesk.com/view/RVT/2025/ENU/?guid=GUID-D843AE7A-457D-4860-9EAE-19FAF171723C

Azambuja Varela, P. (2020). *Reconstrução de uma Estereotomia—Para uma abordagem estereotómica multi-semântica* (PhD). Porto. Retrieved from https://hdl.handle.net/10216/129891

Azambuja Varela, P., & Sousa, J. P. (2016). Revising Stereotomy through Digital Technology. *Herneoja, Aulikki; Toni Österlund and Piia Markkanen (Eds.), Complexity & Simplicity - Proceedings of the 34th eCAADe Conference*, *2*, 427–434. Oulu. Retrieved from http://papers.cumincad.org/cgi-bin/works/paper/ecaade2016_182

Boyd, T. D. (1978). The Arch and the Vault in Greek Architecture. *American Journal of Archaeology*, *82*(1), 83. https://doi.org/10.2307/503797

buildingSMART. (2024). IfcRelAggregates. Retrieved April 1, 2025, from https://standards.buildingsmart.org/IFC/DEV/IFC4_2/FINAL/HTML/schema/ifckernel/lexical/ifcrelaggregates.htm

Direcção de Serviços de Planeamento, 1992-2001. (1995). Faculdade de Arquitetura da

Universidade do Porto: Proj. Execução: Estereotomia Cantaria Edifício E - Edifício H (Piso 2): 6. 02. *http://gisa.up.pt/pesquisa/documents/105458/*. Retrieved from https://repositorio-tematico.up.pt/handle/10405/6505

Fallacara, G., & Barberio, M. (2018). An Unfinished Manifesto for Stereotomy 2.0. *Nexus Network Journal*, *20*, 519–543. https://doi.org/10.1007/s00004-018-0390-z

Graphisoft. (2019, February 26). Wall Reveal. Retrieved January 15, 2025, from Graphisoft Community website: https://community.graphisoft.com/t5/Modeling/Wall-Reveal/td-p/288344

MLApps (Director). (2021). *Create void family to cut wall, floor, etc (using Generic Model face based)*. Retrieved from https://www.youtube.com/watch?v=jW19VGZpisc

Sakarovitch, J. (1998). *Epures d'architecture: De la coupe des pierres a la géométrie descriptive XVI-XIX siècles* (Vol. 21). Springer Science & Business Media. Retrieved from https://www.google.com/books?hl=en&lr=&id=uRJAm_neQF4C&oi=fnd&pg=PA1&dq=epures+architecture+sakarovitch&ots=_bLzC_Bv4l&sig=Q-FkHRPyENoWPVKNjMgnKmRZRu4