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# From Conceptual Model to Detailed Geometry

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**Abstract**

In this work we present a method for the automatic advancement of the LOG of a BIM model from LOG100 to LOG300 or LOG400 by means of SIMULTAN[1], Rhinoceros® and Grasshopper. We start with a conceptual model comprised of volumes representing functional or energy-based zoning. Each face, edge, and vertex along the volume's boundary can be assigned a predefined detailed surface or joint construction. These stem from a standardized Rhinoceros® library of details. Once all assignments are performed, the volume's boundary is generated with full detail, taking column and beam spacing and surface openings into account and adapting the standardized models to the specific geometry of the volume. This makes quick adaptations and comparison of the applicability of different details quite quick and straightforward.

## Introduction

One of the major challenges when applying Building Information Modelling (BIM) across multiple project phases is model continuity. Having a BIM model that retains its geometry from the conceptual phase all through to the construction phase, in addition to more detailed geometry, is generally infeasible due to the vast number of changes and adaptations to the model in the intervening planing iterations, which typically involve multiple domain experts from the Architecture, Engineering and Construction (AEC) industry. In this work, we present a method for generating and re-generating the geometry with higher level of detail out of the conceptual model of the building, as necessary, with minimal involvement of the user.

## Approach

We regard the conceptual model as the *reference geometry* for all subsequent phases. The relationship between this model and the one generated from it is shown in Figure 1. Here, we see the corner of a building where two exterior walls and a slab intersect. What the user has to do by hand is assign the wall and slab construction to the appropriate face of the *reference geometry* (see Figure 1(a)). The joint details between walls, between the walls and the slab, and the corner detail can be picked by the user, or chosen automatically by the system, since they can be derived from the neighbouring faces. The application of these details is demonstrated in Figure 2(a) for the corner, and in Figure 2(b) for the edge joints, so that we can arrive at the completed model in LOG300 or LOG400 in Figure 2(c).

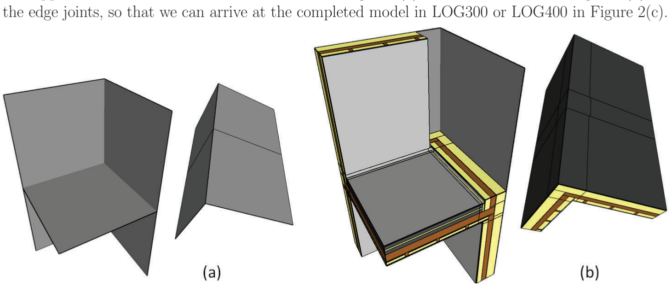


**Figure 1:** From concept geometry, LOG100 (a) to detailed geometry, LOG300 or LOG400 (b) on the example of a laminated timber board structure.

Along with the increased level of geometry, we generate or query additional domain-specific properties for building physics (e.g., thermal transmittance), fire protection (e.g., fire rating), and acoustics (frequency-dependent behaviour) via Grasshopper. These properties are attached to the affected elements for the purpose of subsequent simulations [2].

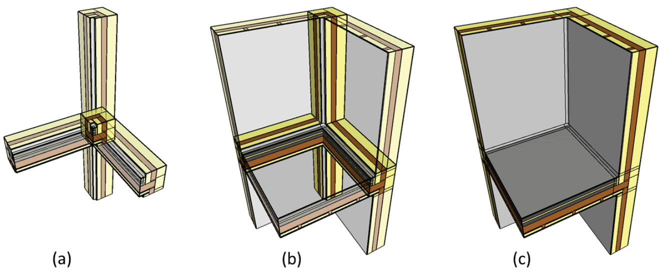


**Figure 2:** Applying the detailed geometry (a) to the corner, (b) to the edges, and (c) the complete detailed model.

## Results

The backbone of our BIM model is a metamodel, SIMULTAN, developed in C# specifically for the needs of the AEC industry [1]. It allows the creation of domain-specific models by the domain experts themselves without the involvement of software engineers, which contributes to the flexibility of the BIM environment. Our approach takes this flexible BIM model and a library of standardized details in Rhinoceros® as input and deliver a fully detailed BIM model as output. This workflow is shown in Figure 3 as a UML[2] activity diagram.

**Action 1** involves the creation or update of the conceptual model, which can happen at any time even after the conceptual phase of the project. We proceed on the assumption that this model is correct. **Action 2** creates the standardized detail library, which can be modified or expanded at any time, as needed. In **Action 3** the user actively assigns constructions from the library to each surface of the reference model. These constructions are parametrised, hence, in **Action 4**, some of their parameters can be set, e.g. the thickness of the thermal insulation (see the list of parameters attached to the BIM model in Figure 4(a)). In **Action 5a** the system derives the type of details that can be applied to the edge between two faces or to the corner between three or more faces from the user input in the previous steps. If the domain experts desire to make a modification, they can do so in **Action 5b**, otherwise the parametrised BIM model is again sent to Rhinoceros®, where the pre-defined Grasshopper scripts generate the geometry adapted both to the conceptual model geometry and the parameter input in **Action 5c**. All geometric transformations are matrix-based and implemented in C#. Additionally, in **Action 5d** some more geometry- and material-dependent properties are calculated, e.g., the thermal transmittance of various structures acc. to `ISO 6946`. Finally, the detailed sections of the geometry corresponding to faces, edges, and vertices, is returned to SIMULTAN, where a final fitting and merge takes place, which produces the detailed BIM model in **Action 6**. At this point the user can return back to **Action 3**, if a correction in the assignments of geometry or parameters is deemed necessary. Otherwise, the process terminates.

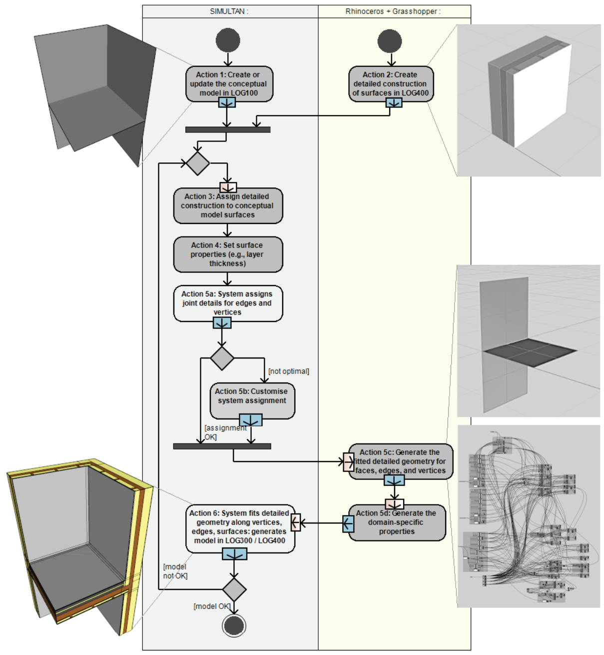


**Figure 3:** The workflow: generating a model in LOG300 or LOG400 out of a conceptual model with LOG100.

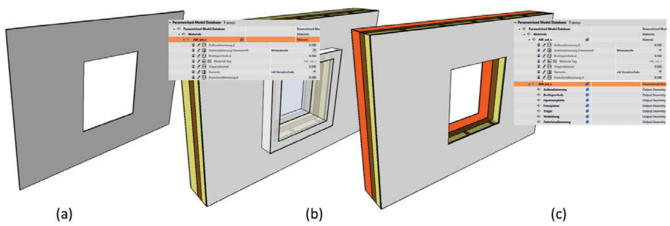


**Figure 4:** The user interface of SIMULTAN: the components attached to the BIM model at different granularity levels: (a) reference geometry, (b) and (c) detailed geometry.

In Figure 4(c) we can see that element **AW_wd_x** has been instantiated into a detailed geometry model in which each material layer is represented by its own geometry.

## Our Contribution

- We developed a method for preserving model continuity over multiple project phases while increasing the Level of Geometry of the digital BIM model from LOG100 to LOG300v or LOG400.
- We demonstrated that a flexible data model, which the domain experts can adapt on the fly, lends itself to integrating both geometric and domain-specific parameters on demand without the involvement of software engineers.
- Finally, this method can be extended even further, e.g., by generating an even more detailed (partial) BIM model of the load-bearing timber structure for simulating its behaviour under load.

## References

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[2] Bernhard Steiner, Andreas Sarkany, Zsombor Járosi, Galina Paskaleva, Thomas Bednar, and Christoph Bauer. Development of plugins for seamless integration of the simultan meta data model with ida-ice and rfem 6. 2654(1):012049, dec 2023.

## Acknowledgements

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[1]Actively developed by the Institute of Material Technology, Building Physics and Building Ecology at TU Wien.
[2]Unified Modelling Language