RE-ENGINEERING OF BUILDINGS BASED ON GROUND PLANS AND VERTICAL SECTIONS

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ABSTRACT

In this contribution a concept to concatenate the information retrieved of different construction drawings is presented. This concatenation is performed in order to build up a three dimensional product model. This approach is based on previous work of the authors dealing with the semantic interpretation of a single ground plan. This semantic interpretation is related to the generation of a topological model, a construction element model and a system model. This approach of analyzing ground plans is transferred to the identification of construction elements in vertical section. Finally, the three models of a single drawing are enhanced to a system of several topological models and a construction element model for several construction drawings. The scope of this enhancement is to represent the building in a three dimensional construction element model which refers to the different ground plans and vertical sections. This approach is explained for a small example of a coign of two different storeys.

KEY WORDS

re-engineering of construction elements, analysis of construction drawings, stitching of drawings

INTRODUCTION

CAD-models are often unavailable for existing buildings. In the case of re-organization, re-use or modification of the static structure the relevant geometric information of these buildings is required. In order to perform these planning tasks with standard software tools, the relevant geometric information has to be available in an appropriate digital format. At the CIB-W78 conferences in Auckland and Dresden the authors presented a software tool to analyse ground plans and to build up a product model (Berkhahn & Esch, 2003) (Berkhahn & Komorowski, 2005). These contributions have the deficiency of dealing exclusively with a single ground plan. This means, the information gained by the analysis of ground plans of different storeys have to be stitched manually in order to receive a three dimensional product model of all storeys. In addition, the information included in vertical sections is neglected.

Two key enhancements are developed by the authors in order to overcome these shortcomings: First of all, the development of a three dimensional construction element

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model with relations to the topologic models of all ground plans and vertical sections is focused. Secondly, fitting algorithms are developed to stitch ground plans of different storeys and vertical sections.

GROUND PLANS AND VERTICAL SECTIONS

The explanations are related to two simple coigns represented in two ground plans shown in figure 1 and a vertical section shown in figure 2. Figure 1 illustrates two ground plans G1 and G2 of two coigns and a window. The location of the vertical section V1 is marked in both ground plans.

This example is reduced to a very limited number of construction elements and to just two storeys. In addition, the dimensions of wall thickness, length and height are modified in order to make the example more descriptive. Although this example is very simple and not very meaningful from the architectural point of view, several special features are covered such as non fitting coigns of different storeys or different wall thickness in different storeys.

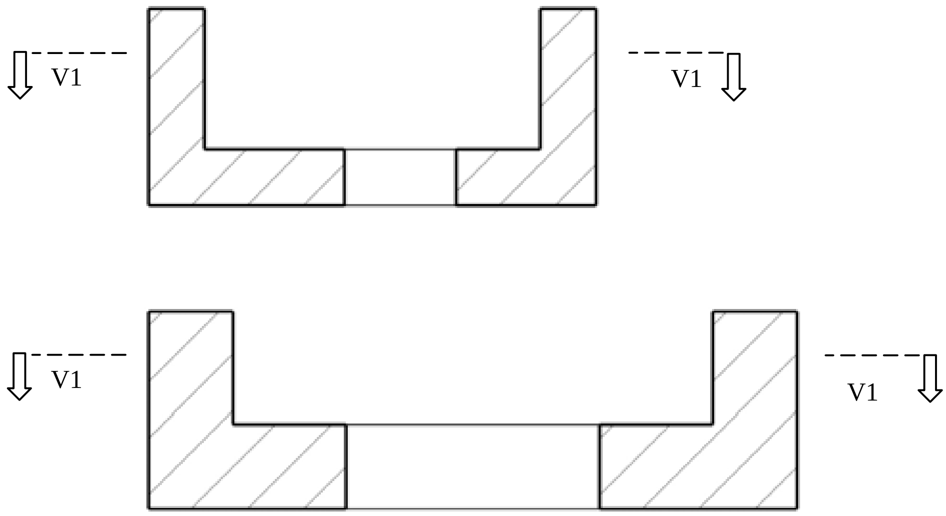

Figure 1: A coign of two different storeys represented in ground plans G1 and G2.

Figure 2 shows the vertical section V1 and the marker for the location of both ground plans. This example is reduced to the relevant construction parts in order to clarify the explanations in the following sections. Consequently the ceilings below the lower storey and above the upper storey are neglected.

The entire example of two coigns in two storeys and the ceiling in between are schematically illustrated in figure 3. In addition, the three considered construction drawings are integrated in this three dimensional view. This illustration facilitates the understanding of three dimensional construction element model and the relations to the topologic models of different construction drawings which areexplained in the following sections.

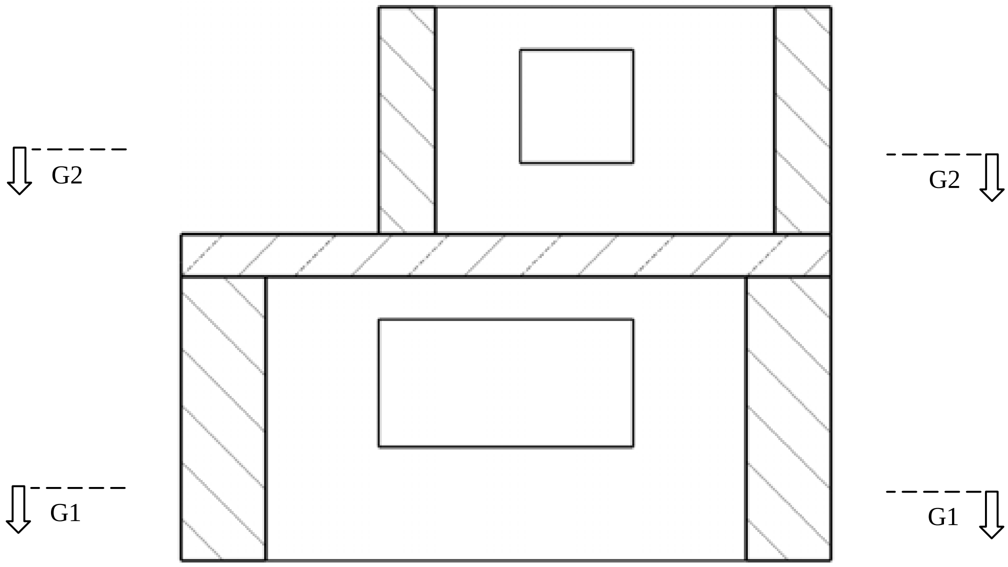

Figure 2: A coign represented in a vertical section plan (section V1).

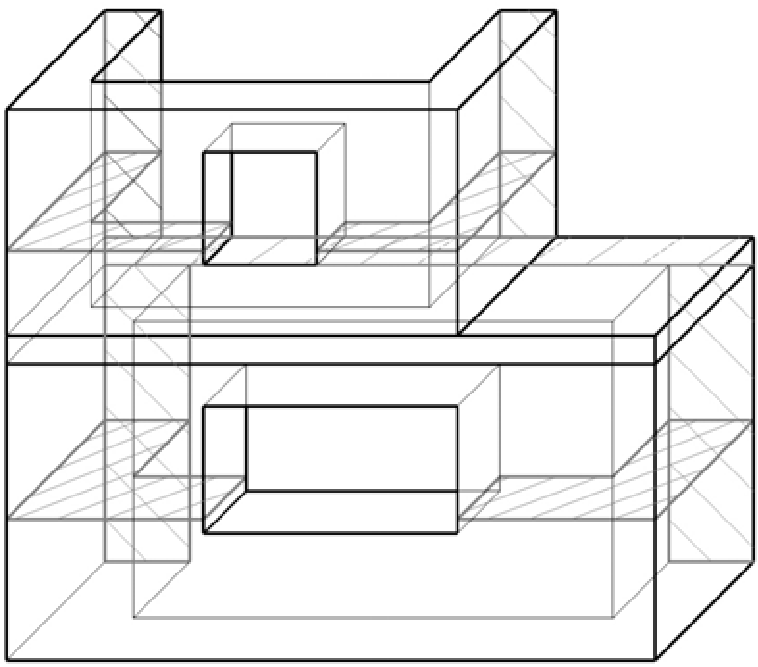

Figure 3: Ground plans and a vertical sections represented in an schematic 3D view.

MODELS OF GROUND PLANS

The different models of ground plans are built up in order to represent the geometric, topologic and semantic information of walls, windows and doors. The pixel based drawing is transformed into a geometric model which consists of geometric point and geometric line. Detailed information about the methods and algorithms of this approach of line identification is given by Berkhahn et al. (2004).

Based on this geometric model the models for the topology, for construction elements and for the construction systems are generated. These different models are explained in detail in the following sections.

TOPOLOGIC MODEL

The topologic model consist of topologic points TP and topologic sections TS. Topologic points imply the geometric information e.g. the coordinates. A topologic section refers exactly to two topologic points. On the other hand one topologic point refers to one up to n topologic sections. This system of two elements sets and the corresponding relations between these two sets build up the bipartite graph *T* for the topologic model:

$$T = (TP, TS; TPTS, TSTP) \text{ with } TPTS \subseteq TP \times TS; TSTP \subseteq TS \times TP \quad (1)$$

A visualisation on the bipartite graph of the topologic model is shown in figure 4. The relation between topological points and topological sections is represented by a double-headed arrow. The cardinalities of these relations are indicated the numbers beside the arrow.

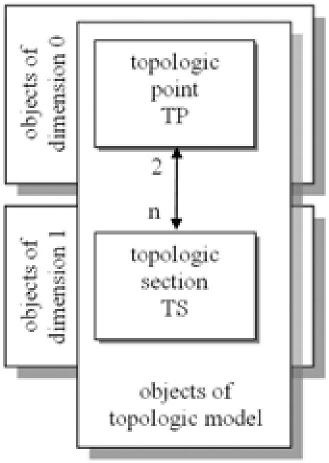

Figure 4: Bipartite graph of the topologic model of a construction drawing.

Figure 5 illustrates the topologic model of the ground plan G1 of the lower storey. Topological sections are displayed by a line connecting two circles, which represent two topologic points. The topologic sections and topologic points of the hatching lines displayed in figure 1 are eliminated by topological and geometrical criteria described in the flowing section.

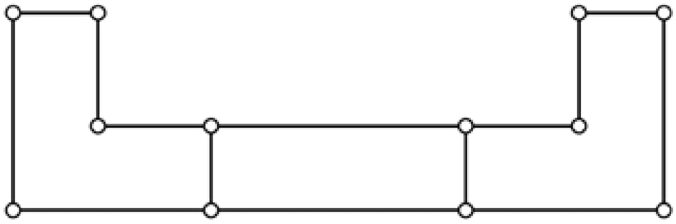

Figure 5: Topologic model of a coign identified in a ground plan (G1).

CONSTRUCTION ELEMENT MODEL AND SYSTEM MODEL

In ground plans and vertical section each construction part builds a closed loop of topologic sections. This means, every topologic point of a closed loop refers at least to two topologic sections. Topologic points referring to exactly one topologic section are called topological end-points. Consequently, all topological sections referring to topological end-points are not taken into account for the process of construction element identification.

In the next step hatching lines are identified by their parallelism and missing of 180 degree connections. In order to simplify the topologic model topologic sections representing hatching lines are deleted. In addition, the topologic points of hatching lines are also deleted and the corresponding topologic sections are stitched.

Based on graph methods closed loops of topologic sections are identified construction parts such as walls, columns, windows or doors. In order to generate the system line (i.e. centerline) of a construction element very effectively, all identified construction parts are split into parts referring exactly to four topologic points. Construction parts such as windows and door are identified by specific topologic and geometric criteria and are neglected in the following considerations. The remaining construction parts of walls are stitched together as shown in figure 6.

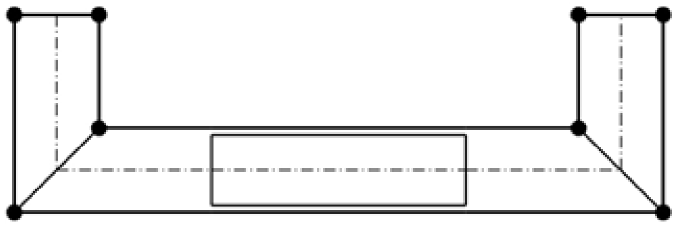

Figure 6: Construction model and system model of a coign
identified in a ground plan (G1).

A construction element consists of element sections and element points which refer to the corresponding objects of the topologic model. The connectivity of construction elements is represented by the relations between element points and construction elements and between element sections and construction elements. The construction model is built up by three bipartite graphs in analogy to the topologic model. Consequently, standard graph methods can be used for the analysis of the construction model. In figure 6 element points CP are displayed as black circles and construction sections CS as black lines. System lines are indicated by dashed centrelines. Figure 7 demonstrates the objects of the topologic model, of the construction model and of the system model. The relations inside every model as well as the relations between models are displayed.

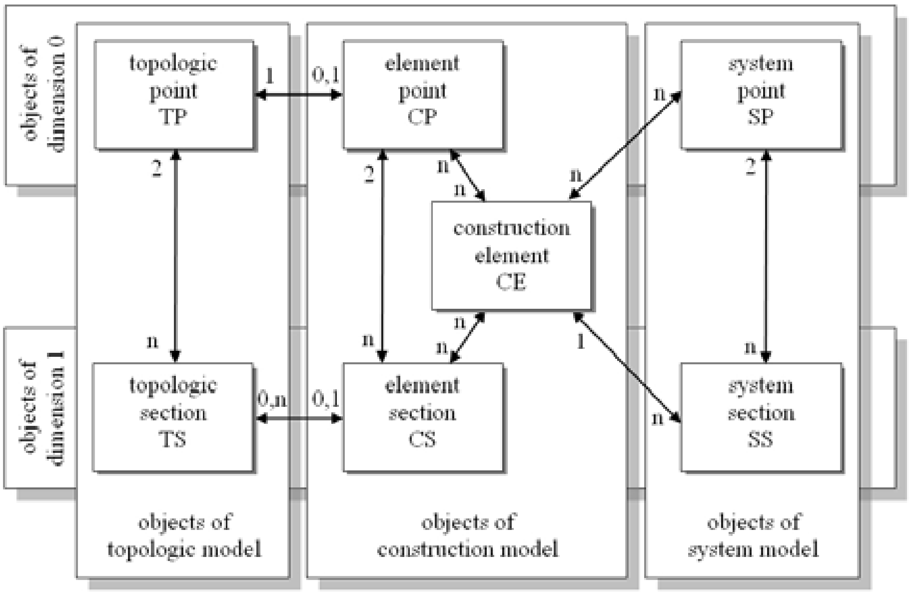

Figure 7: Classes and relations of different models of construction drawings of a building.

THREE DIMENSIONAL CONSTRUCTION MODEL

The construction model gained by a single construction drawing is still a two dimensional model. In order to represent the information of several construction drawings the construction model is enhanced to a three dimensional model. Obviously, the geometric information of an element point has to be extended by the third coordinate. Secondly, the construction face is introduced as a new entity of the construction model.

Finally, the relations between the construction model and the topologic model cross the dimensions. This means, a topologic point refers to a construction section and a topologic section refers to a construction face and vice versa. This is obvious, because a projection, such as a ground plan or a vertical section, of any three dimensional body reduces the dimension of the projected body. The relations with in the topologic model and the construction model as well as the relations between both models are displayed in figure 8. The wire frame view of the simple example of two coigns is displayed in figure 9. Black circles show a three dimensional construction point. Black lines show construction sections and construction faces are neglected in order not to overload the figure.

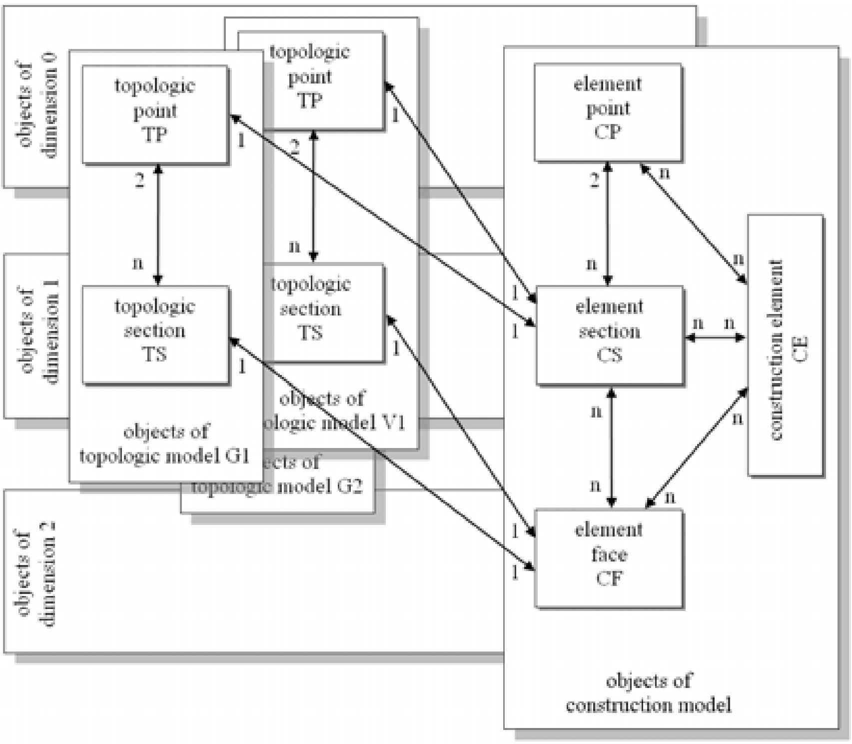

Figure 8: Classes and relations of the three dimensional construction model and topological models of different construction drawings.

STICHING OF GROUND PLANS AND VERTICAL SECTIONS

At first, all construction elements with the element point and element sections have to be identified in all ground plans and vertical sections. The identified construction elements of all ground plans are adjusted towards each other. This adjustment is performed by rotating and translating these construction elements with the objective to maximize the number of construction point with the same x-y-coordinates. This approach of adjustment works fine for standard buildings with similar storeys. In the case of strongly varying stores this approach would fail. The same approach of adjustment is applied for all vertical section.

Since all ground plans and all vertical section are adjusted in the corresponding plane, the stitching of two dimensional construction elements together is performed in order determine the three dimensional construction elements. This stitching process starts with any plan as a temporary three dimensional construction model. The process is continued by adding the information of a single plan to the temporary three dimensional construction model. This adding is performed by translating the plan orthogonal to its plane in order to minimize the number in inconsistencies in the three dimensional construction model.

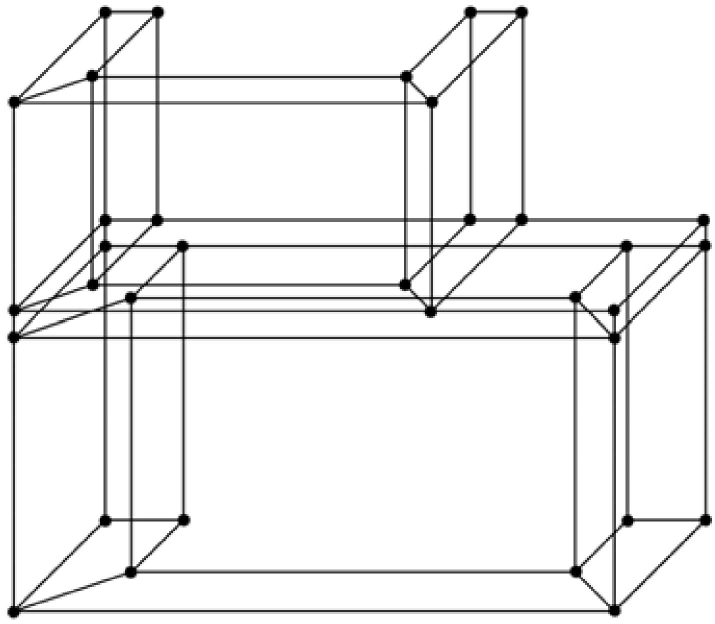

Figure 9: Wire frame view of the three dimensional construction model.

CONCLUSIONS

The authors presented an approach to build up a three dimensional construction model based on ground plans and vertical sections. Firstly, all two dimensional plans are analysed and topological models and construction models are generated. These two dimensional models are stitched together by minimizing the inconsistencies in the resulting three dimensional construction model.

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