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Challenges and Ideas in Procedural Modeling of Interiors

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Abstract

While the creation of convincing cityscapes from the outside is already possible, there is a lack of robust and efficient techniques for modeling the interior of buildings. In particular, we focus on challenges for the subdivision of the interior space into rooms and for placement of furniture in those rooms.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling—Geometric algorithms, languages, and systems

Introduction

Procedural modeling is a powerful tool for the creation and reconstruction of urban models. It takes advantage of a priori knowledge about the structure and properties of certain object classes and exploits repetitions and similarities that can be expressed by mathematical formulas or sets of rules.

We aim our research at methods for the semi-automated creation of interiors with possibilities of rapid interactive editing. After changing an object manually, the rest of the geometry should automatically adapt to the most similar, valid form or layout. In the following sections, we analyze three interior design stages (see Figure 1). We address open problems and outline suggestions for further research.

1. Floor Planing

Depending on the type of architectural project, there are two scenarios to distinguish. For newly designed houses, the layout of rooms might be a strong influencing factor for the resulting footprint and facade appearance. Thus, there is no given contour to be followed. Reconstructions of existing buildings do not allow such freedom to the interior architects and impose the floor footprints, some columns and walls as fixed geometric constraints. We consider the latter scenario as the most challenging and the least explored one.

Open problems: The optimal arrangement of rooms according to some constraints is an NP-hard problem. Architects are well skilled in efficient manual layout design mainly for small problem instances. Procedural methods should assist with large scenarios.

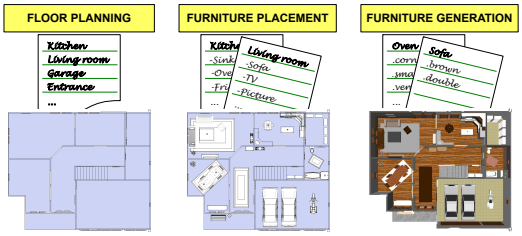

Figure 1: *The topics of procedurally generated interiors.*

Merell et al. [MSK10] provide a good floor planning method, applicable only to residential houses with free footprints. Lopes et al. [LTS*10] use a related base concept for fixed footprints. Both of these state-of-the-art approaches are limited to orthogonal shapes and use a high number of parameters to be optimized. The reason is that they manipulate rooms separately, while overlooking the shared geometric elements (walls, corners). Leblanc et al. [LHP11] propose a component-based approach. It tries to solve some of these issues, but lacks efficient automation.

Our proposal: We favour algorithms based on planar graphs where moving a corner or a wall always influences all adjacent rooms. This implicitly avoids emergence of leaks and minimalizes the number of optimization parameters.

2. Furniture Placement

A simple placement of furniture with local topology is not sufficient for creation of plausible, realistic interiors. Global functional relations must guide the placement. Objects need

to be connected by semantic links reflecting possible usage scenarios [YYT*11]. To generate layout suggestions, Merrell et al. [MSL*11] use predefined design templates and functional criteria for relative placement. An important step forward is example-based layout synthesis [FRS*12].

Open problems: Editing furniture layouts so that they follow desired placement semantics involves a lot of manual work when using the state-of-the-art approaches. A major difficulty is hard constrained placement and stylization of layouts. To overcome these issues, direct manipulation and indirect interfaces to placement must work in symbiosis.

It is also important to include layout rules which deal with safety aspects for effective evacuation in case of emergencies and with optimal accessibility for impaired people.

Our proposal: Application of different visual styles to a model while preserving its structure characteristics is a common practice [Fin08]. We suggest to apply this philosophy not only to single items, but to furnished rooms containing plenty of objects. Styled layouts can enable efficient reorganization of items, letting the rooms look inhabited or abandoned, used or new, tidy or messy etc. The selected style should affect selection, placement and appearance of furniture.

3. Furniture Creation

Procedural generation of furniture seems to be rather unexplored yet. Most interior design methods just use a database of parametric models [ZCOM13]. The amount of diversity and originality of resulting interiors is low.

Similar to buildings, many furniture classes show a stable structure with repetitions and similarities, which can be exploited by application of procedural rules. The most important differences are predomination of smooth shapes and distinct structure of interior parts like items in bookcases.

Open problems: Furniture has more curved, complicated forms than buildings. Efficient procedural modeling of arbitrary geometric shapes is a difficult task of highest importance. It should be researched in more detail. Krecklau et al. [KK12] presented the most advanced approach yet. It supports basic free-form deformations.

Many furniture items are not static models and by manipulation, their shape and the space they occupy changes [KMYG12]. They have to be generated so that they fit inside the assigned space in any possible configuration, similarly as by spatially constrained growth [TLL*11]. Organizing elements of a furniture piece to a limited space is a challenging task. Envisaging the possible kinematics early enough has a high potential to increase the scene realism. The basis is given by encoding postures into the derivation grammars [IFPW10].

Our proposal: Our vision is to extend the modeling grammars. Adding support for animation, subdivision surfaces, advanced mesh manipulation and volumetric texturing will lead to realistic furniture appearance and to a larger variety of details. Semantic context of a room and available space should influence the automatic selection of the best furniture posture or animation sequence.

Conclusions

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