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Semantic volume texture for virtual city building model visualisation

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ABSTRACT

With the rapid urbanisation and development of three-dimensional (3D) space use, space objects in residential houses are of increasing concern. Illustrating these spatial entities within a clustered and multi-layered environment is confronted with the long-standing cognitive challenges of visual occlusion, visual clutter and visual navigation. Direct illustration as cross sections and cutaways provide valuable instruction for removing occlusion while preserving global contexts to give positioning cues. However, cross-sectioning or cutting away of the popular boundary-described models suffers from computational robustness and efficiency problems, while separated boundary geometry with surface properties prevents the efficient image-based direct illustrations from implementing a visually complete, semantically consistent practice easily. This article proposes a semantic volume texture (SVT) model for direct illustration. This true-3D raster model integrates spatial pattern embedding as well, thus avoiding the costly amendments to keep semantic consistent and visually complete during illustrative cutting and reconstructing operations. The proposed model is extended to the practical base of CityGML schema, the preparation of SVT is presented and applications imitating cross sections and cutaways are demonstrated. Experiments show that SVT-based direct illustrations are effective and efficient, making the proposed model suitable for explorative visualisations in the layered micro-scale environments.

1. Introduction

Ever since industrialisation era, houses have been crowded together into the narrow streets with the urbanisation process. At the same time, the space within a house has been divided into component parts according to functional, structural and legal requirements. It gradually makes the semantic meaningful while geometric complicated layered virtual building environment. These micro-scale environments concern most people with important aspects from everyday indoor activities to proprietary entitlement. The necessity for visual styling and exhibiting the special-interest objects from hidden positions with clear shape, distinguishable appearance and essential spatial relationship to surrounding objects has also emerged and been increased ever since. Among the plethora of illustrative approaches are the cross sections (Fig. 1), cutaways (Fig. 2) and notable industrial artworks of Frank Soltesz.

Nowadays, space usage stretches vertically above and below the land surface. The increased demand for residential space promotes a more flexible illustrative visualisation for inspecting, managing and planning purposes on the refined virtual building models. As a result, there are more demands on interactive illustration or visual exploration of the indoor environments (Hong et al., 2015; Isikdag, Zlatanova, & Underwood, 2013; Goetz, 2012) and three-dimensional (3D) cadastre (van Oosterom, 2013) models, rather than static manual illustration artworks (Zhou, Dao, Thill, & Delmelle, 2015; Shojaei, Kalantari, Bishop, Rajabifard, & Aien, 2013; Wang, Pouliot, & Hubert, 2012; Mao, Harrie, & Ban, 2012; Zhu et al., 2011). However, direct illustrative exploration as cross sections or cutaways of the layered building environment is confronted with some fundamental challenges.

For most 3D building models using boundary description, the first challenge might come from the visual style mapping conflicts. Taking CityGML for example, thematic surface textures and materials are attached to the boundary geometry. When mapping these surficial properties on the topologically shared facets, there will be conflicts. CityGML primarily adopts the *generic coverage scheme* (ISO-19123) to avoid this conflict in the *appearance model* (Fig. 3), which presumes the presence of sufficient observable surfaces. It can be seen that the coverage scheme mainly focuses on landscape scenarios (Open Geospatial Consortium (OGC), 2012), and does not guarantee a complete and consistent visual description of the target feature. This kind of inherent deficiency of describing objects that are hidden by outer layers implies that the appearance scheme may need to be extended for exploration tasks where focus targets are switched dynamically.

Vector boundary modelling with separated surface properties brings severe computational challenges to cross-section and cutaway illustrations. Xie, Zhu, Du, Xu, and Zhang (2013) recently surveyed the

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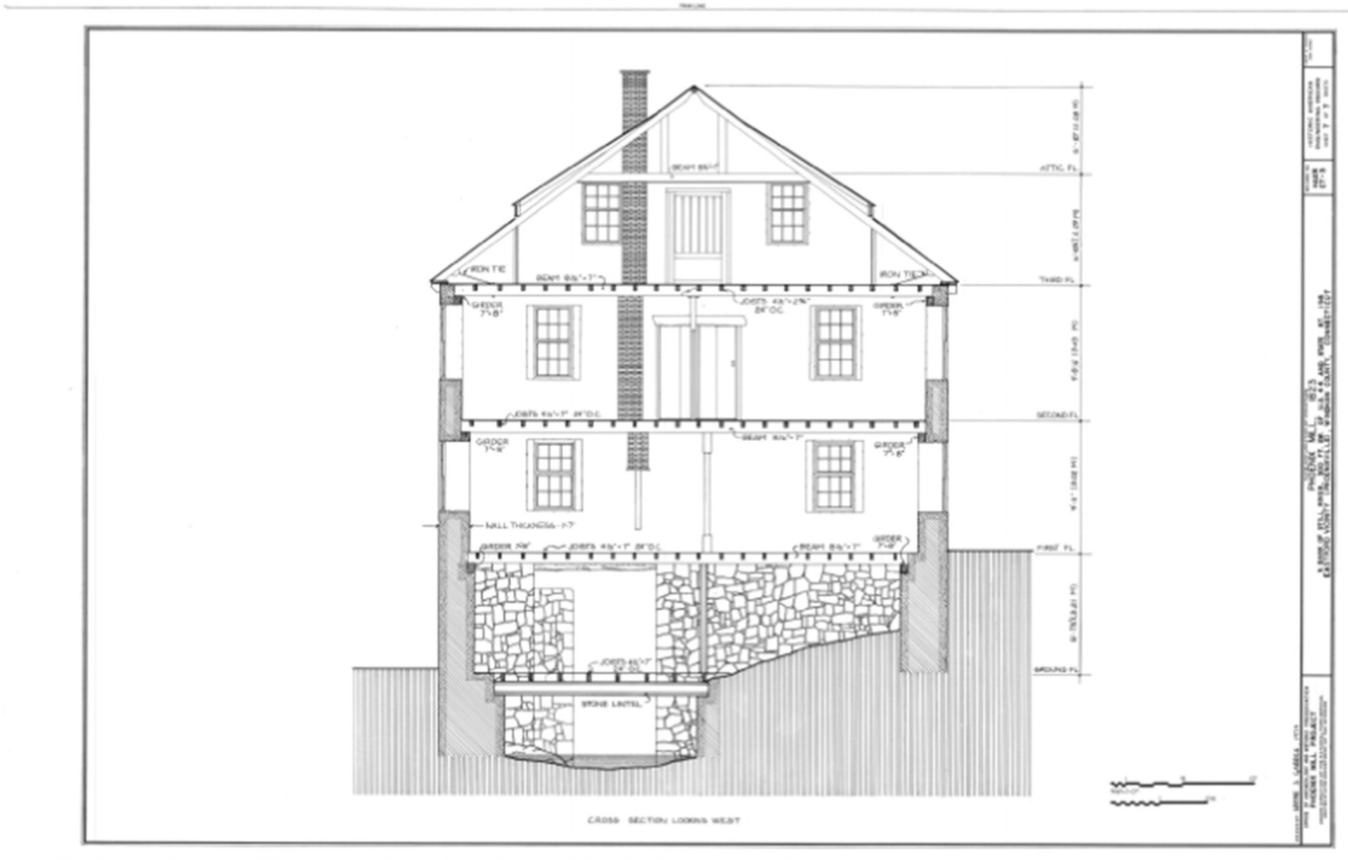

Fig. 1. Cross-section diagram of an old building in the United States. Cross section looking west – Phoenix Mill, North bank of Still River, Phoenixville, Windham County, CT, USA. HAER Register Number: HAER CONN,8-PHOE,1 (sheet 7 of 7).
From Library of Congress, Prints and Photographs Division, Washington, D.C. 20540 USA, http://hdl.loc.gov/loc.pnp/pp.print. HAER (Historic American Engineering Record) (1974).

difficulties of cutting polygonal meshes with and without borders (open surface objects and solid objects, respectively). Typical algorithms employ expensive numerical approaches, and they do not always warrant a topology correct cutting result (Rossignac, Megahed, & Schneider, 1992). After geometry cutting, there should always be a closure operation to make the cut objects 'solid', along with a high-cost joint-updating operation that makes geometry, topology and semantic consistent in order to ensure that the cut objects remain positively distinguishable (Burns & Finkelstein, 2008; Trapp & Döllner, 2013; Xie et al., 2013). Issues of robustness and high computational cost hinder the applicability of direct cross-sectioning illustrations on the boundary description model.

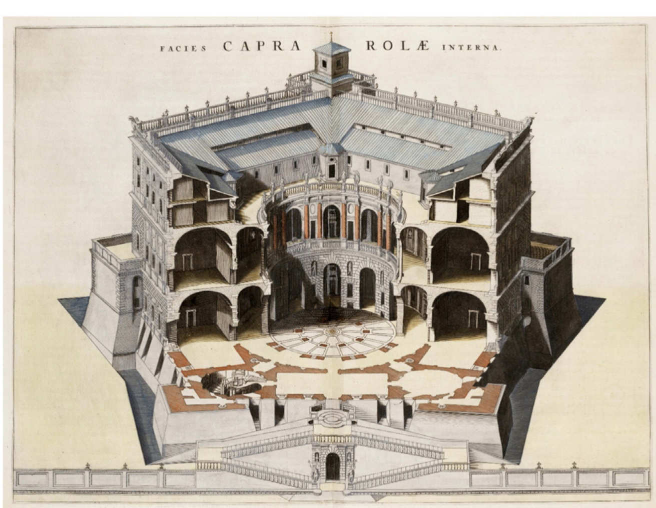

Fig. 2. Cutaway view of Villa Caprarola. Cutaway illustration differs from cross section in that it uses no single cut-plane and provides a '3D impression' rather than a planar diagram.
From "Theatricum Civitatum et Admirandorum Italiae Amsterdam", by Johannes Blaeu 1663. Image from Auctionata online©.

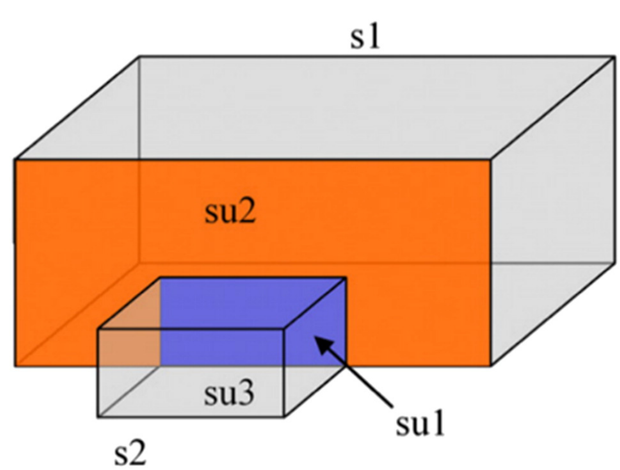

Fig. 3. Coverage scheme of CityGML. A building solid *s1* and a garage solid *s2* topologically touch at facet *su1*; the facet *su2* of solid *s1* is divided into two parts, the shared part *su1* will contribute no 'surface data' to *s1*'s appearance. In other words, when solid *s1* is singled out for illustration, it will have no complete surface description data.
Image from Gröger & Plümer (2012).