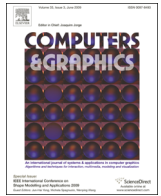




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## Modeling interactive furniture from a single image

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### ABSTRACT

We propose an interactive modeling framework to create 3D furniture models with interactive parts from a single image. Given a real furniture image, we first infer the potential structure of the furniture based on the labeled bounding box of each part. Then a novel interaction guided modeling algorithm is employed to make each part to be movable. With the interaction graph and user labeling, our algorithm automatically infers the assembly structure and the link relations of the model in part level. Moreover, the user can also utilize our interactive modeling tool to further design the inner structure of the furniture. We show furniture modeling results on numerous examples to demonstrate the effectiveness and efficiency of our approach.

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### 1. Introduction

Creating various and practical 3D models like man-made objects is a primary task in computer graphics. Furniture is one of the most common man-made objects in daily life. 3D models of furniture have received many demands such as indoor scene design, advertising and e-commerce. Creating furniture models from scratch quickly is a meaningful and interesting task, especially for novice users.

Recently, many approaches have been devoted to furniture modeling (or man-made object modeling). Example-based furniture modeling uses existing models to construct new shapes with parameter constraints [1] or part compatibility [2]. Other modeling methods depend on different principles such as physically valid shapes [3], interlocking planar pieces [4] and foldabilization of furniture [5]. Most of these methods directly process on 3D models, but might be not intuitive for novice users. Beyond merely changing the structure or adding connectors of furniture, we are interested in modeling 3D furniture from a single image. This is because images are easy to obtain and provide rich content of inspirations to model various objects. People often browse furniture images on the internet, and ask a question “what if I get this furniture in my room?” However, static images are not able to show the structure and function of the furniture, which cannot give customers a straightforward exhibition. If the furniture is illustrated in a 3D interactive mode, the structure and function of furniture can be demonstrated intuitively for customers.

High-quality 3D furniture reconstruction from a single image is a difficult problem, because furniture has various shapes, functions and different combination modes. However, we have the observation that people’s interactions on the furniture (pull, push, screw, etc.) have relations with the function of the furniture, and one can infer the functions or the moving mode of each part from the interaction. Furthermore, user interaction can bring design inspirations and fill the gap between the 2D image and 3D model. From this observation, we propose an interactive modeling approach to create 3D furniture models from a single image.

Given a kind of furniture, there are different movable parts in it. Each part has its own function, and different functions have their particular moving modes. People interact with different parts in different moving modes to achieve their functions. For example, a drawer can be pulled out by a user with a force action on it vertically outward. A door can be opened by a user with a force action on it around the axis. It is necessary to model these movable parts to achieve their functions. However, sometimes it is not easy to recover the moving mode of the part from images directly. For example, see the input image in Fig. 8(a), the moving mode of each part in the furniture is not clear. We have the observation that the *interaction* on the furniture is an important and direct experience for people. We propose an interaction guided modeling algorithm to model the moving mode of each parts to make them movable. Furthermore, inner structure of the furniture is also significant, but they are often not available in the image. Our framework can let the user design inner structure of the furniture simply and quickly.

Our main contribution is a furniture modeling framework which can quickly create 3D furniture models with interactive parts from a single image. An interaction guided modeling algorithm is proposed to model the interactive parts with reasonable

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moving mode and connection joint. We show furniture modeling results on numerous examples to demonstrate the effectiveness and efficiency of our approach (Fig. 1).

## 2. Related work

*Image-based 3D modeling.* Image-based 3D modeling is a technique that creates 3D virtual models from input images, which has been developed for a long time and is still a hot area of research. Some techniques create models from multiple images [6,7]. We focus on modeling from a single image. Oh et al. [8] proposed an image-based modeling and editing system that takes a single photo as input. They decompose the input image into several layers in different depths, reconstruct the scene in 3D space and enable editing on the input photo. Jiang et al. [9] presented an architecture 3D modeling method with textures recovered from a single image. They utilize shape symmetry prior in architecture to calibrate the camera and model each component of the architecture structure. User interaction is also needed during modeling process. Lau et al. [10] presented a framework that allows users to design their own 3D objects using a photo as a rough guide. They offer novice users a chance to create new objects within minutes. There are also approaches of image editing by creating 3D proxy such as interactive images [11] and 3-sweep [12]. Data-driven modeling methods [13,14] are also explored. A 3D model library is provided to fulfill the model retrieval and combination. Joint

modeling by analyzing image and shape collections [15] is also explored.

However, modeling from image is a challenging problem. It is hard to develop a universal method which satisfies every kind of objects. One of the main reasons is that every kind of objects has their own structure and characteristic, and one varies from another significantly. Therefore, the key points of recent research on image-based modeling focus on modeling one particular kind of object. Many image-based modeling methods focusing on one specific object achieve good results, such as image-based plant modeling [16], image-based tree modeling [17], image-based facade modeling [18], image-based city modeling [19], garment modeling from a single image [20], and image-based hair modeling [21–24]. In this paper, we also focus on one kind of object, modeling home furniture from one single image, which is seldom involved in previous works.

*Furniture 3D modeling.* Pan and Wang [1] proposed an example-based furniture modeling approach by reusing existing models with parameter constraints. Zheng et al. [2] introduced a geometric approach based on symmetric functional arrangements to match, replace, and position parts to create functionally plausible models. Data-driven modeling methods are also studied recently such as designing 3D models by example [25], and assembly-based modeling by probabilistic reasoning [26]. These methods need a model database to be reused for creating new models.

Furniture design or assembly is another research hotspot recently. Lau et al. [27] generated parts and connectors from input 3D furniture models for building physical objects. They used lexical analysis to identify the primitive parts and structural analysis to generate connectors. Umetani et al. [3] proposed an interactive design framework for efficient and intuitive exploration of geometrically and physically valid shapes. The system can offer the valid range of each editing and give suggestions. Schwartzburg and Pauly [4] presented a design approach to generate 3D models composed of interlocking planar pieces. The model can be assembled by sliding the pieces into each other along straight slits, without glue, screws, or other means of support. This kind of method is extended by [28] to globally interlocking furniture assembly. Most of these methods directly process on 3D models. Rong et al. [29] proposed an interactive approach to recover the functional prototype from a single RGBD image. They only infer the plausible functions of the parts, while do not create practical 3D models. In this paper, we are interested in modeling 3D furniture with interactive parts from a single image.

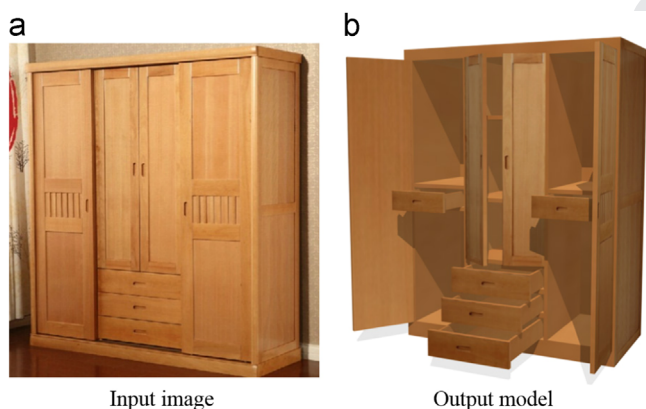


Fig. 1. Single image based furniture modeling with interactive parts. Given a single furniture image (a), with a few of user interactions, our framework creates 3D furniture model with interactive parts (b).

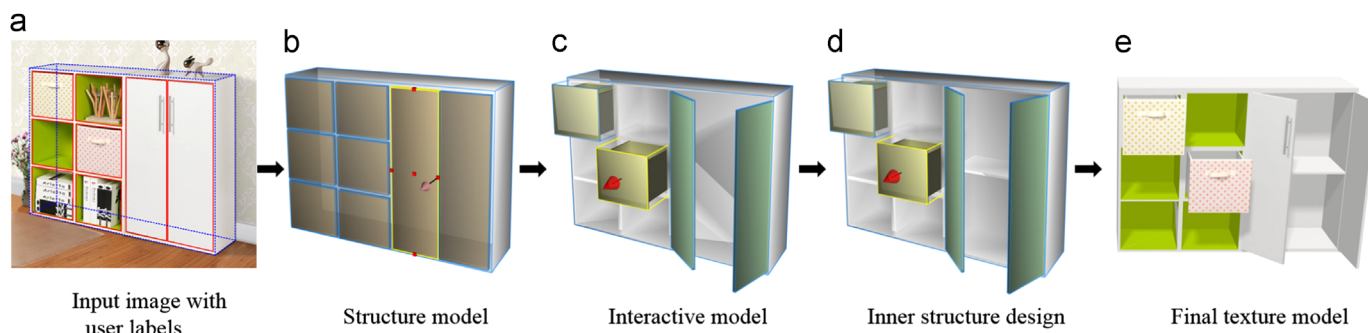


Fig. 2. The overview of our framework. Given a furniture image with user labels (a), the structure model is first initialed with potential parts (b). In (a), the blue dotted box is the initial 3D shape of the furniture, and the red bounding boxes are parts labeled by the user. Then user interacts with the control points (red points in (b)) to model interactive parts (c). After that, users are able to design their own inner structure of the furniture quickly with easy interaction (d). After mapping textures from the input image, we get the final texture model with interactive parts (e). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

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