

Popup: Automatic Paper Architectures from 3D Models

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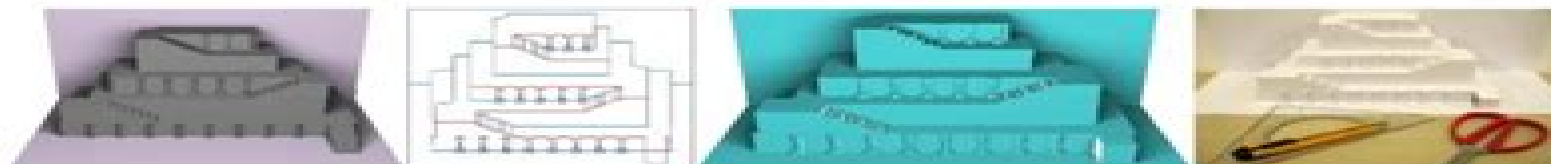


Figure 1: Given a 3D architectural model with user-specified backdrop and ground (left), our algorithm automatically creates a paper architecture approximating the model (mid-right, with the planar layout in mid-left), which can be physically engineered and popped-up (right).

Abstract

Paper architectures are 3D paper buildings created by folding and cutting. The creation process of paper architecture is often labor-intensive and highly skill-demanding, even with the aid of existing computer-aided design tools. We propose an automatic algorithm for generating paper architectures given a user-specified 3D model. The algorithm is grounded on geometric formulation of planar layout for paper architectures that can be popped-up in a rigid and stable manner, and sufficient conditions for a 3D surface to be popped-up from such a planar layout. Based on these conditions, our algorithm computes a class of paper architectures containing two sets of parallel patches that approximate the input geometry while guaranteed to be physically realizable. The method is demonstrated on a number of architectural examples, and physically engineered results are presented.

CR Categories: I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling—Geometric algorithms, languages, and systems;

Keywords: paper architecture, pop-up, computer art, planar layout

1 Introduction

Paper architectures, also called *origami architectures*, are paper buildings created by folding combined with paper cutting. Originated in Japan by Masahiro Chatani [1987] in the 1980's, the craft has been popularized by artists around the world, in particular Bianchini, Siliakus and Ayta [2009]. Paper architecture appears in many forms, such as greeting cards and desktop decorations, and

can be “stunning realistic” [Chatani et al. 1987]. Some examples created by artists are shown in Figure 2. Further exhibits could be found from the online galleries of Ingrid Siliakus and Gerry Stormer.

A paper architecture is made from cutting and folding from a single piece of paper, and is stored by folding the two halves of the paper close. As the paper is opened, the 3D building “stands-up” or “pops-up”. While similar to pop-up books, a paper architecture is made with no gluing or splicing, which puts additional constraints to the design of cut and fold patterns on the paper (called a *planar layout*). What is even more challenging is to create layouts that would pop-up into a desired 3D look. Numerous books exist on the mechanism of designing pop-up crafts [Birmingham 1997; Carter 1999; Cheong et al. 2009], and a number of computer-aided tools have been developed to provide virtual design environments [Lee et al. 1996; Glassner 2002; Hendrix and Eisenberg 2006; Mitani and Suzuki 2004a]. However, the user is ultimately responsible for deciding where and how the cuts and folds should be placed on the 2D paper, and it remains a labor-intensive and highly skill-demanding task to generate 2D layouts that pop-up into realistically looking 3D buildings.

In this paper, we develop a completely automatic algorithm that produces paper architectures approximating user-given 3D models, which enables novice users to create realistic and complex crafts in an effortless way (see the example on Figure 1 right). Our algorithm is grounded on novel geometric formulations of planar layouts that can physically pop-up to paper architectures. In particular, regions in the layout should maintain rigid and non-intersecting when popping-up, and the architecture should be able to stably erect with no additional help from the user other than holding the two halves of the paper. Based on the formulation, we present sufficient conditions for a class of 3D surfaces, consisting of planar patches oriented in two directions, to be physically realizable by popping-up a planar layout. Guided by the conditions, we design a grid-based algorithm that produces 3D realizable paper architectures automatically from any input model given by the user, while requiring only the users to specify the paper location with respect to the model. An example is shown in figure 1.

Contributions To the best of our knowledge, our algorithm is one of the first automated methods for creating paper architecture that mimics a given 3D input. To achieve this goal, we make the following contributions:

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