

Popup: Automatic Paper Architectures from 3D Models

Xian-Ying Li¹ Chao-Hui Shen¹ Shi-Sheng Huang¹ Tao Ju² Shi-Min Hu¹

¹TNList, Department of Computer Science and Technology, Tsinghua University, Beijing

²Department of Computer Science and Engineering, Washington University in St. Louis



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:

Popup Automatic Paper Architectures From 3d Models

Joseph O'Rourke



Popup Automatic Paper Architectures From 3d Models:

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Table of Contents Popup Automatic Paper Architectures From 3d Models

1. Understanding the eBook Popup Automatic Paper Architectures From 3d Models
 - The Rise of Digital Reading Popup Automatic Paper Architectures From 3d Models
 - Advantages of eBooks Over Traditional Books
2. Identifying Popup Automatic Paper Architectures From 3d Models
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Popup Automatic Paper Architectures From 3d Models
 - User-Friendly Interface
4. Exploring eBook Recommendations from Popup Automatic Paper Architectures From 3d Models

- Personalized Recommendations
 - Popup Automatic Paper Architectures From 3d Models User Reviews and Ratings
 - Popup Automatic Paper Architectures From 3d Models and Bestseller Lists
5. Accessing Popup Automatic Paper Architectures From 3d Models Free and Paid eBooks
 - Popup Automatic Paper Architectures From 3d Models Public Domain eBooks
 - Popup Automatic Paper Architectures From 3d Models eBook Subscription Services
 - Popup Automatic Paper Architectures From 3d Models Budget-Friendly Options
 6. Navigating Popup Automatic Paper Architectures From 3d Models eBook Formats
 - ePub, PDF, MOBI, and More
 - Popup Automatic Paper Architectures From 3d Models Compatibility with Devices
 - Popup Automatic Paper Architectures From 3d Models Enhanced eBook Features
 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Popup Automatic Paper Architectures From 3d Models
 - Highlighting and Note-Taking Popup Automatic Paper Architectures From 3d Models
 - Interactive Elements Popup Automatic Paper Architectures From 3d Models
 8. Staying Engaged with Popup Automatic Paper Architectures From 3d Models
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Popup Automatic Paper Architectures From 3d Models
 9. Balancing eBooks and Physical Books Popup Automatic Paper Architectures From 3d Models
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Popup Automatic Paper Architectures From 3d Models
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Popup Automatic Paper Architectures From 3d Models
 - Setting Reading Goals Popup Automatic Paper Architectures From 3d Models
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Popup Automatic Paper Architectures From 3d Models

- Fact-Checking eBook Content of Popup Automatic Paper Architectures From 3d Models
- Distinguishing Credible Sources

13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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