

# 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:

# Popup Automatic Paper Architectures From 3d Models

**Frederick W.B. Li, Ralf Klamma, Mart  
Laanpere, Jun Zhang, Baltasar  
Fernandez Manjon, Rynson W.H. Lau**

## **Popup Automatic Paper Architectures From 3d Models:**

*Pop-Up Geometry* Joseph O'Rourke, 2022-03-24 Anyone browsing at the stationery store will see an incredible array of pop up cards available for any occasion The workings of pop up cards and pop up books can be remarkably intricate Behind such designs lies beautiful geometry involving the intersection of circles cones and spheres the movements of linkages and other constructions The geometry can be modelled by algebraic equations whose solutions explain the dynamics For example several pop up motions rely on the intersection of three spheres a computation made every second for GPS location Connecting the motions of the card structures with the algebra and geometry reveals abstract mathematics performing tangible calculations Beginning with the nephroid in the 19th century the mathematics of pop up design is now at the frontiers of rigid origami and algorithmic computational complexity All topics are accessible to those familiar with high school mathematics no calculus required Explanations are supplemented by 140 figures and 20 animations [Issues in Computer Engineering: 2011 Edition](#), 2012-01-09 *Issues in Computer Engineering 2011 Edition* is a ScholarlyEditions eBook that delivers timely authoritative and comprehensive information about Computer Engineering The editors have built *Issues in Computer Engineering 2011 Edition* on the vast information databases of ScholarlyNews You can expect the information about Computer Engineering in this eBook to be deeper than what you can access anywhere else as well as consistently reliable authoritative informed and relevant The content of *Issues in Computer Engineering 2011 Edition* has been produced by the world's leading scientists engineers analysts research institutions and companies All of the content is from peer reviewed sources and all of it is written assembled and edited by the editors at ScholarlyEditions and available exclusively from us You now have a source you can cite with authority confidence and credibility More information is available at <http://www.ScholarlyEditions.com> **Smart Graphics** Lutz Dickmann, Gerald Volkmann, Rainer Malaka, Susanne Boll, Antonio Krüger, Patrick Olivier, 2011-07-06 This book constitutes the refereed proceedings of the 11th International Symposium on Smart Graphics SG 2011 held in Bremen Germany in July 2011 The 10 revised full papers presented together with 12 short papers and 4 systems demonstrations were carefully reviewed and selected from numerous submissions covering a wide range of topics including view and camera control three dimensional modeling visual information encoding video projection information visualization interaction techniques visual communication and graphics and audio **Design, Representations, and Processing for Additive Manufacturing** Marco Attene, Marco Livesu, Sylvain Lefebvre, Stefano Ellero, Szymon Rusinkiewicz, Thomas Funkhouser, 2022-06-01 The wide diffusion of 3D printing technologies continuously calls for effective solutions for designing and fabricating objects of increasing complexity The so called computational fabrication pipeline comprises all the steps necessary to turn a design idea into a physical object and this book describes the most recent advancements in the two fundamental phases along this pipeline design and process planning We examine recent systems in the computer graphics community that allow us to take a design idea from conception to a digital model

and classify algorithms that are necessary to turn such a digital model into an appropriate sequence of machining instructions

**Perspectives in Shape Analysis** Michael Breuß, Alfred Bruckstein, Petros Maragos, Stefanie Wuhrer, 2016-09-30 This book presents recent advances in the field of shape analysis Written by experts in the fields of continuous scale shape analysis discrete shape analysis and sparsity and numerical computing who hail from different communities it provides a unique view of the topic from a broad range of perspectives Over the last decade it has become increasingly affordable to digitize shape information at high resolution Yet analyzing and processing this data remains challenging because of the large amount of data involved and because modern applications such as human computer interaction require real time processing Meeting these challenges requires interdisciplinary approaches that combine concepts from a variety of research areas including numerical computing differential geometry deformable shape modeling sparse data representation and machine learning On the algorithmic side many shape analysis tasks are modeled using partial differential equations which can be solved using tools from the field of numerical computing The fields of differential geometry and deformable shape modeling have recently begun to influence shape analysis methods Furthermore tools from the field of sparse representations which aim to describe input data using a compressible representation with respect to a set of carefully selected basic elements have the potential to significantly reduce the amount of data that needs to be processed in shape analysis tasks The related field of machine learning offers similar potential The goal of the Dagstuhl Seminar on New Perspectives in Shape Analysis held in February 2014 was to address these challenges with the help of the latest tools related to geometric algorithmic and numerical concepts and to bring together researchers at the forefront of shape analysis who can work together to identify open problems and novel solutions The book resulting from this seminar will appeal to researchers in the field of shape analysis image and vision from those who want to become more familiar with the field to experts interested in learning about the latest advances

*Frontiers of Science and Technology* Gabriela Celani, Olfa Kanoun, 2017-10-10 Sponsored by the Alexander von Humboldt Stiftung the Bragfost Confernce brings together about 60 outstanding German and Brazilian Scientists to discuss most topical issues in the field of electrical engineering energy supply as well as sociological impact of technology This book presents the most relevant contributions in extended and revised form

**Advances in Web-Based Learning -- ICWL 2015** Frederick W.B. Li, Ralf Klamma, Mart Laanpere, Jun Zhang, Baltasar Fernandez Manjon, Rynson W.H. Lau, 2015-10-12 This book constitutes the refereed proceedings of the 14th International Conference on Web Based Learning ICWL 2015 held in Guangzhou China in November 2015 The 18 revised full papers presented together with 2 invited papers and 7 short papers were carefully reviewed and selected from about 79 submissions The papers are organized in topical sections on collaborative and peer learning e learning platform and tools design model and framework of e learning systems intelligent tutoring and tools pedagogical issues personalized and adaptive learning and Web 2.0 and social learning environments

*Entertainment Computing - ICEC 2017* Nagisa Munekata, Itsuki Kunita, Junichi

Hoshino,2017-08-23 This book constitutes the refereed proceedings of the 16th International Conference on Entertainment Computing ICEC 2017 held in Tsukuba City Japan in September 2017 The 16 full papers 13 short papers and 2 posters presented were carefully reviewed and selected from 46 submissions **Architectural Graphics** Manuel A.

Ródenas-López,José Calvo-López,Macarena Salcedo-Galera,2022-04-27 This book reports on several advances in architectural graphics with a special emphasis on education training and research It gathers a selection of contributions to the 19th International Conference on Graphic Design in Architecture EGA 2022 held on June 2 4 2022 in Cartagena Spain with the motto Beyond drawings The use of architectural graphics **Architectural Draughtsman (Theory) - I** Mr. Rohit Manglik,2024-05-18 EduGorilla Publication is a trusted name in the education sector committed to empowering learners with high quality study materials and resources Specializing in competitive exams and academic support EduGorilla provides comprehensive and well structured content tailored to meet the needs of students across various streams and levels

Advances in Automation, Mechanical and Design Engineering Med Amine Laribi,Giuseppe Carbone,Zhiyu Jiang,2022-09-02 This book presents the proceedings of the 2021 International Symposium on Automation Mechanical and Design Engineering SAMDE held in Beijing China on 3 5 December 2021 and organized by the Hong Kong Society of Robotics and Automation HKSRA It gathers contributions by researchers from several countries on the following topics digitalized development and use of sustainable products and manufacturing systems artificial intelligence automated reasoning human robot collaborative interaction sensors and autonomous sensor systems cyber physical control systems generative design including topology optimization advanced simulation and modelling intelligent automation smart materials materials processing and factories and circular economy etc The book offers a source of information and inspiration for researchers seeking to improve their work and gather new ideas for future developments **Computer Vision Systems** Antonios Gasteratos,Markus Vincze,John K. Tsotsos,2008-05-09 In the past few years with the advances in microelectronics and digital technology cameras became a widespread media This along with the enduring increase in computing power boosted the development of computer vision systems The International Conference on Computer Vision Systems ICVS covers the advances in this area This is to say that ICVS is not and should not be yet another computer vision conference The field of computer vision is fully covered by many well established and famous conferences and ICVS differs from these by covering the systems point of view ICVS 2008 was the 6th International Conference dedicated to advanced research on computer vision systems The conference continuing a series of successful events in Las Palmas Vancouver Graz New York and Bielefeld in 2008 was held on Santorini In all 128 papers entered the review process and each was reviewed by three independent reviewers using the double blind review method Of these 53 papers were accepted 23 as oral and 30 as poster presentation There were also two invited talks by P Anandan and by Heinrich H Bultho The presented papers cover all aspects of computer vision systems namely cognitive vision monitor and surveillance computer vision architectures calibration and reg

tration object recognition and tracking learning human machine interaction and cross modal systems      *Intelligent Computing Theories and Application* De-Shuang Huang,Kang-Hyun Jo,Junfeng Jing,Prashan Premaratne,Vitoantonio Bevilacqua,Abir Hussain,2022-08-14 This two volume set of LNCS 13393 and LNCS 13394 constitutes in conjunction with the volume LNAI 13395 the refereed proceedings of the 18th International Conference on Intelligent Computing ICIC 2022 held in Xi an China in August 2022 The 209 full papers of the three proceedings volumes were carefully reviewed and selected from 449 submissions This year the conference concentrated mainly on the theories and methodologies as well as the emerging applications of intelligent computing Its aim was to unify the picture of contemporary intelligent computing techniques as an integral concept that highlights the trends in advanced computational intelligence and bridges theoretical research with applications Therefore the theme for this conference was Advanced Intelligent Computing Technology and Applications Papers focused on this theme were solicited addressing theories methodologies and applications in science and technology      *Urban and Regional Data Management* Sisi Zlatanova,Hugo Ledoux,Elfriede M. Fendel,Massimo Rumor,2011-09-05 Human activities as well as various natural phenomena change the environment and impact on the quality of life Analysis of those dynamics is required for a better understanding of urban modifications and to facilitate urban growth and development Research related to the management of urban data has a long tradition Through the years a variety of challenging research questions has been investigated related to the collection storage use and visualisation of the data representing the urban phenomena in a computer based environment The role of the citizens and their wellbeing has become a critical aspect in all research and development activities Since 1971 the Urban Data Management Society UDMS has organized international symposia across Europe to promote the development of information systems at a local government level Initially the focus of these symposia was mostly on urban applications but both regional and rural issues have grown in importance over the years Nowadays an important aim of UDMS is to provide a forum for people to discuss new approaches to consider new technologies and to share practical experiences in the field of urban data management This book contains a selection of the best 19 out of 42 full papers that were submitted for UDMS 2011 The topics covered represent current trends in urban and regional data management Urban and Regional Data Management 2011 is divided in four parts 1 3D modeling and applications 2 Data management for local government 3 Environmental monitoring and assessment 4 Remote sensing for urban applications and will proof to be a useful source of information for urban regional and rural data related professionals such as scholars GIS engineers geomatic professionals photogrammetrists land surveyors mapping specialists urban planners and researchers as well as for postgraduate students and lecturers      Proceedings ,2005      **Up and Running with AutoCAD 2011** Elliot J. Gindis,2010-09-22 Up and Running with AutoCAD 2011 2D and 3D Drawing and Modeling provides an introduction to the fundamental concepts of AutoCAD These concepts have been distilled down to basic easy to understand explanations for the benefit of beginner students Each chapter explains the new concept or command and

why it is important Readers are given the chance to apply just learned knowledge to a real life exercise drawing or model They can also test their knowledge with end of chapter quizzes and drawing exercises The book is organized into three parts Level 1 Level 2 and Level 3 Level 1 offers a wide breadth of knowledge on many topics Its chapters comprise the complete essential knowledge set of an intermediate user Students can then work on if not necessarily set up and manage moderate to complex drawings Level 2 is meant for advanced users who are CAD managers full time AutoCAD draftspersons architects or self employed and must do everything themselves The goal here is depth and several features not deemed critically important in Level 1 are revisited to explore additional advanced options Also introduced are advanced topics necessary to set up and manage complex drawings Level 3 is all about 3D Solid knowledge of the previous two levels is highly recommended before starting these chapters The 3D material covers all aspects of AutoCAD solid modeling including lights and rendering Strips away complexities both real and perceived and reduces AutoCAD to easy to understand basic concepts Teaches only what is essential to operating AutoCAD first thereby immediately building student confidence All basic commands are documented step by step meaning that what the student needs to type in and how AutoCAD responds is all spelled out in discrete and clear steps with screen shots added as needed Using the author s extensive multi industry knowledge of what is important and widely used in practice versus what is not the material is presented by immediately immersing the student in practical critically essential knowledge with no padding of text or filler material All concepts are explained first in theory and only then is AutoCAD introduced and the actual button pushing discussed This is one of the key concepts in having students understand exactly what it is they are doing and why before they do it     **Architecture** ,1997     *The Software Encyclopedia* ,1988     **Data Sources** ,2000     **Wood & Wood Products** ,1988

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the most important rhetorical devices written in the novel is in the form of a metaphor: "He and Dick were 'running a race ... In Cold Blood - LitDevices.com Jul 1, 2019 — The author uses vivid imagery to create a sense of place and atmosphere, such as when he describes the Clutter home as "a home with absolutely ... Language Devices In Truman Capote's In Cold Blood Truman Capote uses variety of language devices to vividly develop Perry Smith in his novel In Cold Blood. These language devices include, diction, similes ... Andean Lives: Gregorio Condori Mamani and Asunta ... This is the true story of Gregorio Condori Mamani and his wife, Asunta, monolingual Quechua speakers who migrated from their home communities to the city of ... Andean Lives: Gregorio Condori Mamani and Asunta ... Gregorio Condori Mamani and Asunta Quispe Huamán were runakuna, a Quechua word that means "people" and refers to the millions of indigenous inhabitants ... Andean Lives - University of Texas Press Gregorio Condori Mamani and Asunta Quispe Huamán were runakuna, a Quechua word that means "people" and refers to the millions of indigenous inhabitants ... Andean Lives: Gregorio Condori Mamani and Asunta ... Gregorio Condori Mamani and Asunta Quispe Huamán were runakuna, a Quechua word that means "people" and refers to the millions of indigenous inhabitants ... Andean Lives: Gregorio Condori Mamani and Asunta ... These two testimonial narratives illustrate a wide range of the rural and urban experiences lived by indigenous people in the Andean highlands of Peru, Andean Lives: Gregorio Condori Mamani and ... - AnthroSource by J Rappaport · 1997 — Andean Lives: Gregorio Condori Mamani and Asunta Quispe Huamán. Ricardo Valderrama Fernández and Carmen Escalante Gutiérrez, original eds.; Paul H. Gelles ... Andean Lives: Gregorio Condori Mamani and Asunta Rappaport reviews "Andean Lives: Gregorio Condori Mamani and Asunta Quispe Huaman" edited by Ricardo Valderrama Fernandez and Carmen Escalante Gutierrez and ... Andean Lives: Gregorio Condori Mamani and Asunta ... PDF | Andean Lives: Gregorio Condori Mamani and Asunta Quispe Huamán. Ricardo Valderrama Fernandez and Carmen Escalante Gutierrez. eds. Paul H. Gelles. Why read Andean Lives? - Shepherd Gregorio Condori Mamani and Asunta Quispe Huaman were runakuna, a Quechua word that means "people" and refers to the millions of indigenous inhabitants ... Andean Lives by R Valderrama Fernández · 1996 · Cited by 55 — Gregorio Condori Mamani and Asunta Quispe Huamán were runakuna, a Quechua word that means "people" and refers to the millions of indigenous ... How to remove engine on 2002 ls V6 Apr 22, 2013 — The factory procedure is to elevate the car and remove the engine from underneath. Others have done it from above, but you're not going to find ... I have a 05 Lincoln ls 3.9V8. I need info on pulling motor May 31, 2020 — If you read the instructions, it says to remove the engine without the transmission. Lincoln LS: Now, I have to take out the Engine of the 2001 Jul 1, 2014 — The engine has to come out from the bottom , you will need to lower the sub frame with the engine and trans attached . See steps 64 though steps ... how many labor hours to replace engine 3.0 2004 lincoln ls Jul 6, 2011 — The billable labor hours for this engine removal and transfer all needed parts is 20 hrs - 23.8hrs.This is from motor labor guide. SOLVED: I am removing a 3.9 engine on a lincoln ls 2000 Nov 8, 2009 — Remove the throttle body. Remove the 2 bolts, the nut and the upper intake manifold support bracket.

Disconnect the RH CMP electrical connector. Can you remove an engine without the transmission? Jan 2, 2019 — In this case, it is easy to remove the engine alone and remounting the engine is also easy. Another method is Transmission and Engine forming ... removing transmission - Lincoln LS Questions Jul 10, 2011 — removing transmission 1 Answer. Transmission seal on FWD is leaking.... · Transmission 3 Answers. What would cause a transmission to freeze up? Lincoln LS The Lincoln LS is a four-door, five-passenger luxury sedan manufactured and marketed by Ford's Lincoln division over a single generation from 1999–2006.