Popup: Automatic Paper Architectures from 3D Models

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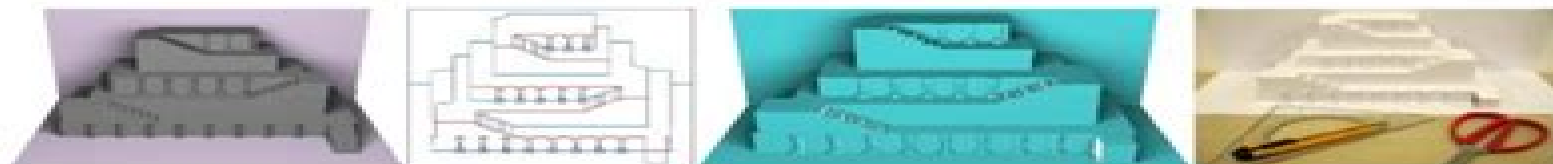[2]Department of Computer Science and Engineering, Washington University in St. Louis

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 *origamic 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 Ayuta [2009]. Paper architecture appears in many forms, such as greeting cards and desktop decorations, and can be "startling 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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Nagisa Munekata,Itsuki Kunita,Junichi Hoshino

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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 Humbold 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 Noavember 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 lerning platform and tolls 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 te nology cameras became a widespread media This along with the enduring increase in computing power boosted the development of computer vision s tems 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 eld of computer vision is fully covered by many well established and famous conferences and ICVS di ers 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 pers 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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