Computer-Generated Papercutting

Jie Xu¹ Craig S. Kaplan¹ Xiaofeng Mi²

¹Computer Graphics Lab David R. Cheriton School of Computer Science University of Waterloo, Canada

> ²Department of Computer Science Rutgers University, USA

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Outline

Background of Papercutting

- Traditional Papercutting
- Related Work

2 Approach

- Our Contributions
- Image-based Paper-cut Designs
- Pattern Synthesis
- Composition of Paper-cuts



Traditional Papercutting

- Papercutting is a folk art in many cultures.
- Back to around a thousand years ago.



Use tools such as scissors or knives to cut out parts from paper.



Modern Papercutting



Susan Throckmorton



Zhou family

Traditional Papercutting Techniques

- A paper-cut design is a shape with connected interior.
- Papercutting types: positive and negative paper-cuts.



Computer-aided Papercraft Design





Mitani and Suzuki, SIGGRAPH 2004

CGI 2004



Glassner, IEEE CG&A 2002

Papercutting in Computer Graphics





Li et al., CASA 2007

Liu et al., SIGGRAPH 2005 sketches

- Define the concept of valid paper-cut design: All shapes can be cut from a piece of paper.
- Provide a set of tools for constructing simple designs.
- Give a set of binary operations to compose complex designs.

- Convert a source image into a black-and-white image.
- Ensure that all black pixels are connected.
- Extract vector paths.



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Multilayer Thresholding

- Extract foreground.
- Decompose into layers.
- Threshold each layer with a different cutoff value.
- Merge the threshold layers.



Image Connectivity

- Identify connected components.
- Run Dijkstra's algorithm to find the shortest paths to connect components.
- Paths are weighted as the intensity value of source image.



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- Compute the oriented bounding box of path.
- Threshold the bounding box using the lightest intensity pixel on the path.
- Merge all pixels connecting to path.



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• Edge detection can be used to complete outlines.



Negative Paper-cut





Patterns in Paper-cut Designs



Geometric Pattern

Stylized Pattern



Kaplan and Salesin, TOG 2004



- Geometric patterns are useful paper-cut components, especially for backgrounds.
- Periodic tilings and other procedurally-generated geometric patterns are supported.



Stylized Patterns

- Stylized patterns highlight or abstract the features of objects.
- Stroke pattern synthesis is applied to place and deform patterns.



Patterns Synthesis Example



- Multiple designs can be combined to create complicated scenes.
- Enforce connectivity during composition.

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	А	Ai	Ao
В	AB	AiB	A₀B
Bi	ABi	$A_i B_i$	$A_{\circ}B_{i}$
Bo	AB₀	$A_i B_o$	A _o B _o

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	А	Ai	Ao
В	AB	$A_i B$	A₀B
Bi	ABi	AiBi	AoBi
Bo	AB _o	A.B.	A _o B _o

AB	AB_i	AB_o	A_iB	A_oB	
Τ	T	Т	F	F	A
Т	F	F	\top	\top	В
Т	Т	\top	\top	\top	A UNION B
Т	Т	F	\top	F	A AND B
Т	Т	\top	F	\top	A OVER B
Т	F	\top	\top	\top	A under B
Т	Т	F	\top	\top	A within B
Т	Т	Т	Т	F	A without B

AB	AB_i	AB_o	$A_i B$	A _o B	
Τ	T	Т	F	F	A
Τ	F	F	\top	Т	В
\top	Т	Т	Т	Т	A UNION B
\top	\top	F	\top	F	A AND B
Т	Т	Т	F	Т	A OVER B
\top	F	Т	Т	Т	A UNDER B
\top	\top	F	\top	\top	A within B
Т	Т	Т	Т	F	A without B

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Τ	Т	Т	F	\top	A OVER B
Τ	F	Т	\top	\top	A UNDER B
\top	Т	F	\top	\top	A within B
\top	\top	\top	Τ	F	A without B

AB	AB_i	AB _o	A_iB	A _o B	
\top	\top	Т	F	F	A
Т	F	F	Т	Т	В
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\top	T	Т	F	F	A	
Т	F	F	\top	\top	В	
Т	Т	Т	Т	Т	A UNION B	
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\top	Т	Т	Τ	F	A without B	

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Т	Т	Т	Т	F	A without B

XOR Operation

• XOR operation is a useful binary operation to represent overlapping objects.



XOR Operation

- But a naïve XOR isn't connected.
- Validity is ensured by thickening intersecting edges.



Composition Examples



Composition Examples



(Tiling WITHIN Window) XOR Teapot

Composition Examples



((*Teapot* OVER (*Tiling* WITHIN *Window*)) XOR *Cup*) XOR *SteamCup*

Results







Susan Throckmorton

- Explore the symmetries in traditional paper-cuts.
- Extract the layout information of scene.
- Construct rules to approximate image features using patterns.



