FRAMESHIFT: SHIFT YOUR ATTENTION, SHIFT THE STORY

A Thesis

Submitted to the Faculty

in partial fulfillment of the requirements for the

degree of

Master of Science
in
Computer Science with a Concentration in Digital Arts

by

Tim Tregubov

in Conjunction with Rukmini Goswami

Department of Computer Science

DARTMOUTH COLLEGE

Hanover, New Hampshire

May 15, 2015

Examining Committee:

Chair ____________________
Lorie Loeb

Member ____________________
Michael Cohen

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Michael Casey

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F. Jon Kull, Ph.D.
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ABSTRACT

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Acknowledgements

To our

To our families

Contents

List of Tables

List of Figures

I. TODO

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II. TODO

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III. TODO

fdsf

IV. TODO

sfds

V. TODOsf

sfds

VI. TODO

fdsfsd

VII. Interface Data Structures

(a) Edges

An Edge represents a cut or fold. Edges are the basic building block of planes and

Driving Folds

A driving fold is not a special type of edge, but rather a . Any fold can be the driving fold for

(b) Planes

A plane is a list of Edges. **TODO: CITE MARISSA HERE**

(c) Fold Features

The central data structure of Foldlings is the FoldFeature: a representation of a shape drawn by the user that folds in 3d. Each fold feature is a single design element — and can be individually created, modified, and deleted. There are five types of FoldFeature: MasterCard, BoxFold, FreeForm, Polygon, and V-Fold, representing differences in drawing behavior, geometry, and (the differences are described in detail below). Each of these features is a subclass of the FoldFeature super class.

All FoldFeatures have functionality in common:

- Each feature contains a list of edges in the feature — both cuts and folds
- Each feature has a driving fold — in the case of unconnected features, such as the master card and holes, the driving fold is nil.
- Each feature can be deleted from the Sketch, "healing" the sketch by closing gaps left in any

- Features implement the encodeWithCoder and decodeWithCoder methods, allowing them to be serialized to a file on the device and restored from the saved file.
- Each feature can provide a list of current "tap options" — actions that can be performed on the feature given its state. **TODO:SEE tap options in interface design** [**?**]. **TODO:REMOVE – JUST TESTING**

In addition, each feature contains

MasterCard

Box Fold

FreeForm

Holes are a special case of FreeForm shapes. FreeForm shapes that do not cross a fold are considered holes — drawn in white in the 2d sketch and drawn as subtractions from planes in the 3d view.

Polygon

V-Fold

Validity

TODO: include preliminary user study 1

sfdaf

VIII. TODOfds

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IX. TODO23

fdjas

X. DAX User Study

On April 28, 2015, we tested our system with attendees of the Digital Arts Exhibition at Dartmouth. After a brief demonstration of how to create folds and preview their design, users designed cards using Foldlings. Users drew sketches and then sent an email containing an SVG file to the computer connected to the laser cutter. Finally, they placed a piece of paper in the laser cutter, and watched as the laser beam cut out their design. Over the course of two hours, users cut and folded 31 popup cards. <<TOOO: CITE DAX <<TODO:

The system we demonstrated at the exhibition was incomplete — it contained the basic box fold and freeform shape tools, but did not include some advanced features of the final software, such as dragging folds or shading based on plane orientation. The alpha software also contained several bugs that disrupted the experience. However, the system was usable enough for people to create cards, and observing user behavior was invaluable in designing our final product.

Because users were new to our system — and constrained by the pressure of other users waiting to design cards — designs were relatively simple. Sketches generally contained between 2 and 5 fold features in addition to the base card — the most complex design contained 10 fold features. Despite their simplicity, sketches showed a wide range of designs, ranging from abstract shapes to representational scenes — users sketched symbols, Chinese characters, and geometric forms. Most of the sketches utilized both freeform and box fold features, mixing the two element types to create a composition. One of the most popular design elements was the user's name: 5 of the cards contained names or initials. Roughly a third of the designs took advantage of nesting — constructing fold features inside each other.

Because users were able to quickly design and fabricate their design, people generally left satisfied. People typically spent around 20 minutes at our booth, leaving with a popup card they had created. However, the experience was not frictionless. Users were frustrated by crashes: touching the screen with more than one finger or drawing while calculating planes were the most common reasons for failure. Other common complaints were the lack of a delete/undo button and that the UI did not show which tool was currently selected.

Folding the fabricated design also presented difficulties. Although they were able to see a 3d preview of their design while creating it, users had often relinquished the iPad by the time they folded their design. They were often unsure how to fold their card, and struggled to discover the correct fold orientations. In some cases, it took longer for users to fold their creation than to design it.

We observed several unexpected behaviors. A few users rotated the screen to design a card in a landscape view, rather than the portrait orientation implied by the orientation of the buttons and 3d preview. They used this orientation to design cards that folded medially rather than laterally. Several users also constructed overlapping features by drawing on top of existing features. These features did not simulate correctly, as they intersected with existing edges. However, this behavior demonstrated a desire to construct more complex geometry. In the final software we implement unions for fold features — the most recently-drawn feature occludes features underneath it, modifying their edges.

Users also relied on the 3d preview to differing degrees. Some users viewed the preview after every operation, while others only switched to the preview occasionally. Many users relied on the 3d preview as a reference to how to fold their popup card. We were surprised by this, and conducted further user studies to determine the effectiveness of methods of displaying 3d information.

XI. TODO2

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XII. TODO

goal: test whether users understand the mapping of 2d fold patterns to 3d, and test the degree to which plane coloring, edge patterning, and a 3d preview help users understand how a popup card will fold.

Each subject received a set of five laser cut cards, and we recorded the time it takes them to successfully fold the card.

For each card, each subject was randomly given one of of the following five aids:

1) A two-dimensional design, showing planes shaded by whether they will be horizontal or vertical when folded.
2) A two-dimensional design, with edges patterned based on whether they are “hills” or “valleys” — whether they fold towards or away from the card.
3) A video showing a simulation of the card folding in three dimensions.
4) A still image of the card folded in dimension.
5) No visual aid.

The order of aids was shuffled randomly, and then balanced to ensure an equal distribution of orderings. I.e. each

Finally, we asked subjects to rank the visual aids

The effect each type of aid has on folding time will help determine which types of visualization to include in Foldlings