Creases and Folds: Applying Geometry to a Pop-Up Fashion Pavilion

by

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Submitted to the Department of Architecture
in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Art and Design
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ABSTRACT

This thesis explores the architectural opportunities embedded in geometric folding by studying the limitations and possibilities of a variety of patterns. In particular, the thesis focuses on the Yoshimura or diamond folding pattern. By manipulating specific rules guiding the diamond fold, the surface can be adapted to enclose a variety of volumes for different programs. The adaptations of the diamond fold rules are tested in a design for a pop-up fashion pavilion. The result is a geometric form that acts as a canopy, enclosure and inhabitable surface to hold program elements such as a marketplace, small fitting rooms, and a runway.

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To my parents for their support and advice
To archfamily for keeping a smile on my face
To Robert and Bill for being the best cheerleaders
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INTRODUCTION

The first half of my thesis semester was spent researching geometric folding, their rules and patterns, and also how they can be applied architecturally and spatially. The initial explorations simply involved folding mathematical patterns with bristol paper and observing their behavior at different states of folding and unfolding. However, it soon became apparent that these studies did not suggest any architectural qualities and remained only paper objects and surfaces. My research then turned to how the surfaces and patterns could be manipulated, mutated, activated to create sectional and volumetric variety, facades, or adaptable walls.

The cataloging of pure mathematical folding forms allowed me to discover the advantages and disadvantages of each system, while the research of the folding manipulations provided the basis of the design proposal.
RESEARCH

Folding Catalog
  Accordion Patterns
  Protruded Patterns
  Hybrid Patterns

Pattern Manipulations
  Scale
  Hard/Soft
  Cinching
  Pop In/Pop Out
unfolded  surface area: 100%

partially folded  surface area: 50%

folded  surface area: material thickness x number of ribs
unfolded surface area: 100%

partially folded surface area: 50%

folded surface area: material thickness x number of ribs
unfolded  surface area: 100%

partially folded  surface area: 50%

folded  surface area: 22%
unfolded  surface area: 100%

partially folded  surface area: 50%

folded  surface area: 3%
unfolded  surface area: 100%

partially folded  surface area: 50%

folded  surface area: 30%
unfolded surface area: 100%

partially folded surface area: 50%

folded surface area: 18%
unfolded  surface area: 100%

partially folded  surface area: 50%

folded  surface area: 45%
HYBRID FOLD
unfolded surface area: 100%

partially folded surface area: 60%

folded surface area: 50%

fig. 1

fig. 2
PATTERN MANIPULATIONS

SCALE MANIPULATION
This series explores the effects of different scales of a hybrid pattern applied to surfaces of the same dimensions. As the scale of the pattern increases, it begins to act as a volume rather than a surface pattern when folded.
HARD / SOFT
A hard plexi surface is applied to the ‘outer’ surface of a protruded pattern (left) and a hybrid pattern (right) such that only the plexi is exposed when the pattern is fully folded. The hard panel surface suggests a sheltered canopy, protective facade or inhabitable surface, while the soft inner surface suggests something porous. In the hybrid pattern test, on the right, the soft surface is removed entirely and can become an operable aperture for daylight or ventilation.
CINCHING
This series explores how a surface can be folded and unfolded via a cinching mechanism. The hybrid pattern is applied to a cylindrical surface. The surface can be folded by pulling strings at two ends which forces the surface to bunch. Due the creases, the bunching takes on the geometric pattern. A detail of this particular cinching method not illustrated here is the change of the inner space from one large volume when uncinched and two smaller volumes when cinched.
POP IN / POP OUT
This exploration looks at the adjustments to the sectional properties of the diamond fold. By changing a valley fold to a mountain fold, or by applying a horizontal fold instead of a valley fold, the volume has an entirely different spatial quality.
ANALYSIS

PATTERN VARIATION | GROWTH | SURFACE
---|---|---
PROTRUDED PATTERNS | heavily dependant on symmetry | only multidirectional growth | uniform outer surface when fully folded (no valleys and peaks)

ACCORDION PATTERNS | not symmetry dependant | potential for variation both linear and multidirectional | only ribs are revealed when folded, no 'outer surface'

HYBRID PATTERNS | somewhat dependant on symmetry | multidirectional expansion | outer surface with peaks and valleys when folded

MUIRA ORI PATTERN and DIAMOND PATTERN
Both patterns are based on folded parallelograms. The nature of the diamond fold is more 'architectural' because the folded surface forms a curvature that can be read as a vault space or a c shaped enclosure. The thesis explores the possibilities and variations in manipulating and deploying forms created by the diamond pattern using the pop in/pop out method.
DIAMOND PATTERN BEHAVIORS

The diamond fold is characterized by straight valley fold (ribs) and diagonal mountain folds.

A characteristic of the diamond pattern is its ability to vary between a solid surface and a single strip surface. A strip occurs when a solid surface is cut along the rib. The separation allows the strip to fold independently from the surface. Independent folding allows gaps to appear between the strips. These gaps can become apertures for visual connections, daylight, ventilation and circulation.

The solid surface behaviors allow the surface to fold without any gaps between different ribs. However, this causes global curvatures along the surface which then need to be regularized in order to be placed on a flat site.
FOLDING ANATOMY

The diamond pattern is analyzed by observing the behaviors of single strip. All parts of the anatomy of a strip (including the dimension of the diamond) can change and are interrelated.

A few important characteristics to note:
- in order to go from flat to bent, the pattern must fold
- the greater the rotational angle, the smaller the pitch angle, the greater the depth of the strip.

The rules of a strip can be extrapolated to a solid surface. In the solid system, all the strips are aligned towards the global central spine rather than their individual spines.
In the system for my design, the surface always rises off the ground plane as a solids surface, but can then split into strips to provide spatial variety to accommodate different programs. The diagram illustrates how the system progresses and resets itself.
REGULARIZING
By applying horizontal creases to the system, the solid surface can fold while overcoming global curvatures as described previously. It also allows the strips to fit into a grid system which becomes important once it is applied onto the site.
DESIGN PROPOSAL

SITE
The site is located in Bronx, New York where there is a burgeoning street style fashion movement. Located off Fordham Road, the site is located along a stretch of ground floor commercial and retail stores. The pavilion can be used as a market during the weekends and weekday nights, but also serves as a semi-covered park during other times. The pavilion takes over a parking lot that connects two streets, Webster Avenue and Park Avenue.

Site: Bronx, New York
Current Use: Parking Lot
Square Footage: 20,000sf
GRAIN
The site is divided into 8' strips that align to the angles of the site. Some parts of the grain 'thicken' to become solid surface which provide coverage for a larger spaces.

The site plan on the right shows the parts of the design where the geometric form serves as canopy and as flat inhabitable 'runways'.

8' grain alignment to site

189th Street

plan through canopied spaces
CIRCULATION
The canopied zones serve as the space for the bulk of the program. The open zones provide space for a meandering flow. The zones are connected by the flat 'runways' which serve as circulation. The circulation paths can also be closed off in sections to serve as a formal runway with canopied audience seating areas along the sides.
GRAIN AND PROGRAM
The thickening of the grain can happen in multiples of 8 feet wide strips and can accommodate different programs which have varying capacity demands.

<table>
<thead>
<tr>
<th>retail</th>
<th>fitting rooms</th>
<th>clothing display</th>
<th>indoor event seating</th>
</tr>
</thead>
<tbody>
<tr>
<td>workshop</td>
<td>workshop space</td>
<td>workshop space</td>
<td>workshop space</td>
</tr>
<tr>
<td>runway</td>
<td>runway seating</td>
<td>runway seating</td>
<td>runway seating</td>
</tr>
<tr>
<td>park</td>
<td>park bench</td>
<td></td>
<td>outdoor movie seating</td>
</tr>
</tbody>
</table>

PANELING
The regularity in the dimensions of the strip allow the same size panel to be used throughout the entire design. All panels are 4'x 8', exactly half of the standard sheet material size.
FOLD ABNORMALITIES
By using the pop in / pop out manipulation, a mountain fold can change to a valley fold, creating a new spatial quality. In the design, the manipulation is applied to three specific programs that require differentiation from the standard diamond fold space.
bench
single strip flat to bent

fitting room
horizontal fold
RENDERINGS AND MODELS
MODEL AT 1/4 SCALE
APPENDIX
FOLDING / GEOMETRY PRECEDENTS

Liam O’Brien
Weathers Permitting (2010)
Materials: Wood
Employs geometric variations to create outdoor conditions

Office dA
Installation for MoMA (1998)
Materials: Folded sheet metal
Employs unique scoring technique for folding metal

Pier Luigi Nervi
Orvieto Aircraft Hangar
Materials: Concrete and brick
Diamond gridded structure allows for an extremely thin shell

Tom Wiscombe
Light - Wing (2003)
Materials: Metal, Fabric, Light
Uses a light fabric over a metal geometric framework

Obra
Beatfuse (2006)
Materials: Wood and fabric
Uses propelyene mesh pieces to cover structure

University of Cambridge
Cardboard Pavilion (2009)
Materials: Cardboard
Uses diamond pattern on cardboard to create pavilion structure.
FASHION PRECEDENTS

Work Architects
Target Pop Up Store (2003)
Free standing curtain dressing rooms throughout the store

OMA
Prada Epicenter New York (2001)
Integrates event space serves both as a circulation and retail display space

OMA
Prada Transformer Pavilion (2009)
A rotating fashion pavilion adapts to four programmatic needs. Textile cladding with street frame.

Zaha Hadid
Chanel 2.55 Traveling Pavilion (2008)
An art exhibition pavilion made out of fiberglass panel facade with a two year life span.

OMA
Prada Runway (2008)
Untraditional ramped runway winds through existing colonades to engage to the space.

Alexander McQueen Runway (2008)
Uses fabrics decoration as well as walking surface.

Yves Saint-Laurent Runway (2008)
Hyperbolic tensile textile surfaces used as enclosure for runway and seating within a larger hall.
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