Using Space Effectively: 3D

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CS 294-10: Visualization
Fall 2007

Final project

Design new visualization method
- Pose problem, Implement creative solution

Deliverables
- Implementation of solution
- 8-12 page paper in format of conference paper submission
- 2 design discussion presentations

Schedule
- Project proposal: 10/24
- Initial problem presentation: 10/24, 10/29 or 10/31
- Midpoint design discussion: 11/19, 11/21 or 11/26
- Final paper and presentation: To be determined

Grading
- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member
Get it right in black & white

Value
• Perceived lightness/darkness
• Controlling value primary rule for design

Value defines shape
• No edge without lightness difference
• No shading without lightness variation

Value difference (contrast)
• Defines legibility
• Controls attention
• Creates layering

Controls Legibility

<table>
<thead>
<tr>
<th>Helvetica plain</th>
<th>Helvetica plain</th>
<th>Helvetica plain</th>
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<th>Helvetica plain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.310</td>
<td>0.950</td>
<td>0.127</td>
<td>0.191</td>
</tr>
<tr>
<td>0.223</td>
<td>0.255</td>
<td>0.255</td>
<td>0.127</td>
<td>0.950</td>
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</tbody>
</table>

colorusage.arc.nasa.gov
Legibility

Drop Shadows
Drop Shadow
Drop shadow adds edge

Primary colors on black
Primary colors on black
Primary colors on black
Primary colors on black
Primary colors on black
Primary colors on black
Primary colors on white
Primary colors on white
Primary colors on white
Primary colors on white
Primary colors on white
Primary colors on white

Readability

If you can’t use color wisely, it is best to avoid it entirely
Above all, do no harm

If you can’t use color wisely, it is best to avoid it entirely
Above all, do no harm.
Why does the logo work?

Value Control
Legibility and Contrast

Legibility
- Function of contrast and spatial frequency
- “Psychophysics of Reading” Legge, et. al.

Legibility standards
- 5:1 contrast for legibility (ISO standard)
- 3:1 minimum legibility
- 10:1 recommended for small text

How do we specify contrast?
- Ratios of foreground to background luminance
- Different specifications for different patterns

Contrast

General formulation
- Luminance difference ($L_f$, $L_b$)
- Depends on adaptation and size

Small symbols, solid background (Weber)
- $C = (L_f - L_b)/L_b$
- Adapted to background

Textures, high frequency patterns (Michelson)
- $C = (L_f - L_b)/(L_f + L_b)$
- Adapted to average

Luminance is intensity modulated by wavelength sensitivity
Contrast (continued)

Contrast using $\Delta L^*$
- 1 is ideally visible
- 10 is easily visible
- 20 is legible for text

Reasons to use a light background
- More like a reflective surface
- Contrast metrics are more accurate
- Easier to look at in mixed environment

Dark background better for dark environments

L* is the same as Munsell Value, computed as a function of L

Contrast and Layering

Value contrast creates layering
What Defines Layering?

Perceptual features
- Contrast (especially lightness)
- Color, shape and texture

Grid Example

Grid sits unobtrusively in the background  Grid sits in foreground, obscuring map

Great Grids: How and Why? (APGV06 and SIGGRAPH poster)
Maureen Stone, Lyn Bartram and Diane Gromala
Additional Resources

My website
- [http://www.stonesc.com/Vis06](http://www.stonesc.com/Vis06)
- Final copy of slides, references

*A Field Guide to Digital Color*
- A.K. Peters

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Using Space Effectively: 3D
Topics

Linear projections
Non-linear projections
Cartographic projections

Primary geometry

Description in 3D object-space

*e.g. trace rays from object through image plane into they eye*
Secondary geometry

Description in 2D image-space
  e.g. true shape of front face, side faces recede to vanishing point, …

Often better corresponds to drawing approach

Linear Projections
Linear projections

Straight lines and alignments are preserved

Parallel

Perspective

British standard classification

Primary geometry

Fig. 2.1. Classification scheme for projection systems, based on primary geometry. Adapted from British Standard 1192 (1969).
Willats’ classification

Secondary geometry

Parallel projections

No vanishing points or foreshortening
Can represent some aspects of true shape
Can shrink or stretch lengths

Projection direction
- Orthogonal to image plane or not
- Along principal axes of object or not
## Parallel projections

### Orthogonal

- Fold-out oblique
  - Horizontal oblique
  - Vertical oblique

### Non orthogonal

- Oblique
- Axonometric

### Orthographic

- Isometric
- Others

### Orthogonal

**Direction**

- Perpendicular to image plane
- Along one principal direction

**True shape for faces parallel to image plane**
Orthogonal

Direction
- Perpendicular to image plane
- Along one principal direction

True shape for objects parallel to image plane
Typically engineering

Amphora, 6th century BC
Orthogonal

Telephoto

As the hijack bargaining goes on under the sweltering sun...

Orthogonal

Child drawing
Fold-out oblique

Horizontal oblique  
Vertical oblique  
Direction
  ■ 45°, parallel to one principal face (top or side)

Fold-out oblique

Horizontal oblique  
Vertical oblique  
Direction
  ■ 45°, parallel to one principal face (top or side)

True shape for 2 faces with 45° projection rays
  ■ Horizontal: Shrink/stretch top face at other angles
  ■ Vertical: Shrink/stretch side face at other angles

Mainly interesting for secondary geometry
Horizontal oblique

Folk art

Horizontal oblique

Icons
Horizontal oblique

Child drawing

![Child drawing image]

Vertical oblique

Soriguerola, 13th

![Vertical oblique image]
Vertical oblique

Soriguerola, 13th

Juan Gris, *Breakfast*, 1914
Vertical oblique

Andre Kertész,
Tulipe Melancolique
Non orthogonal

Direction
- non orthogonal to picture plane

Oblique
- Picture plane parallel to front
- True shape for front face

Axonometric
- True shape for top face
- True length for up direction
- Direction 45° of the picture plane

Oblique

Picture plane parallel to front
True shape for front face
Can use true length for 3rd direction
Oblique

Henry Lapp, 19th century

Oblique

Chinese paintings 12th century
Axonometric

Axonometric
- Like vertical oblique, but object turned 45° to picture plane
- True shape for top face
- True length for up direction

Le Corbusier was a big fan
Axonometric

James Stirling, 1953

Orthographic

Direction
- Orthogonal to picture plane
- Along no principal axes

Isometric
- Direction along the average of the principal axes
- True lengths along 3 axes

Others
- Generic orthographic
- Nothing preserved, rarely used
Isometric vs. axonometric

Isometric
- No true shape
- True lengths in 3 directions
- Less distortion

Axonometric
- True shape for top face
- True length for up direction
Isometric

Brooks-Greaves
*St Paul’s Cathedral*
1928

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Linear perspective

Foreshortening
The spectator is “immersed”

One point
Two points
Three points
Primary geometry

Trace rays from object, through image plane, into eye

1-point perspective

Central focus
Preserves horizontals and verticals
1-point perspective

Jean Vredeman de Vries, 1604

1-point perspective

Unknown artist Ideal city, 15th
1-point perspective

*Interior of St Bavo's church at Haarlem, Pieter Jansz Saenredam, 1648*

Optical center is not always the center of the image

Requires view camera to adjust angle of film plane

2-point perspective

Objects stand out of the picture
Preserves verticals
3-point perspective

Dramatic 3D effect

The generic case, nothing preserved

Historically, seldom used in art or technical drawing

Perspective Distortion
Marginal distortions in perspective projection, Olmer [from Kubovy 03]

**Perspective distortion**

Wide angle projection  
Does not preserve subjective size
Perspective distortion
Wide angle projection
Does not preserve subjective size

Perspective distortion
Wide angle projection
Distorts shape
Perspective distortion

Portrait: distortion with wide angle and telephoto

Wide angle  Standard  Telephoto

Perspective distortion

The sphere is projected as an ellipse
Symmetry is not preserved
Perspective distortion

The sphere is projected as an ellipse
Symmetry is not preserved

Perspective distortion

The sphere should be projected as an ellipse
But a circle is used
Non-Linear Projections

Fish-eye
Fish-eye vs. wide angle

Curved perspective

Panorama
- Preserve verticals
Curved perspective

Rotating lens panoramic camera

Perspective Projection

[from Kopf 07]
Cylindrical Projection

Spherical Projection

[from Kopf 07]
### Perspective vs. Cylindrical/Spherical

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Cylindrical / Spherical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Close to human perception</td>
<td>• Straight lines → curved</td>
</tr>
<tr>
<td>• Straight lines → straight</td>
<td>• Feels flat</td>
</tr>
<tr>
<td>• Wide angle distorted</td>
<td>• Whole FOV possible</td>
</tr>
<tr>
<td>= Best for narrow angles</td>
<td>= Best for wide angles</td>
</tr>
</tbody>
</table>

[from Kopf 07]

### HD View

[http://research.microsoft.com/ivm/HDView/HDGigapixel.htm](http://research.microsoft.com/ivm/HDView/HDGigapixel.htm)
Multiple center-of-projection images

[Rademacher 98]

Unfolding an elephant

[Rademacher 98]
Combining multiple views

Viewing Anomalies
- Cezanne’s *Still Life with Fruit Basket*

Schematic from Loran (1943)
Combining two perspectives

Best Views
- Large display: billboard, mural
- Oblique viewing angle
- Wide range of viewpoints

Application: wall-sized displays

Wide-angle distortion
Correction via multiple projections

Artificial perspective

Multiple parallel (oblique) projections
- Orient receding parallel towards vanishing point
- Some area comparisons possible

53rd Street Map [Guarnaccia 93]
CG example of artificial perspective

Multiple oblique projections

Standard perspective projection [Agrawala et al. 00]

Combining orthographic/perspective

Camera path

Pushbroom panorama [Román 04]
A Better Approach

Why is this better?

Perhaps because local sense of perspective is preserved
Multiviewpoint Panoramas  [Agarwala 06]