Using Space Effectively: 3D

Maneesh Agrawala
CS 294-10: Visualization
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Last Time: Design Principles

Approach
Identification of design principles
- Production
- Preference
- Comprehension

Instantiation of design principles

Validation of design principles

Announcements
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: 3/14
- Project presentation: 4/4
- Final paper and presentation: 5/3

Grading
- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

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 their eye

Secondary geometry
Description in 2D image-space
- e.g. face 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

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

Orthogonal

**Amphora, 6th century BC**

Orthogonal

**Telephoto**

*As the hijack bargaining goes on under the scorching sun...*

Orthogonal

**Child drawing**

Fold-out oblique

**Horizontal oblique**
- 45°, parallel to one principal face (top or side)

**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

Vertical oblique
Soriguerola, 13th

Vertical oblique
Soriguerola, 13th

Vertical oblique
Juan Gris, *Breakfast*, 1914
**Vertical oblique**

Andre Kertesz, *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

- 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

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
Isometric
Brooks-Greaves
St Paul’s Cathedral 1928

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

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 vs. wide angle

Curved perspective

Curved perspective

Perspective Projection

Fish-eye

Panorama

Preserve verticals

[from Kopf 07]
Cylindrical Projection

Spherical Projection

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>

HD View

http://research.microsoft.com/ivm/HDView/HDGigapixel.htm

Optimizing the Projection
**Goal**

*Given a wide-angle image, produce a projection that preserves straight lines in the scene and the shapes of objects.*

**Our Approach**

1. Mesh the viewing sphere
2. Define mapping constraints
3. Optimize energy function
   - Conformality
   - Straight lines
   - Smoothness
Limitations

Multiple Projections

Multiple center-of-projection images

Unfolding an elephant
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

Paolo Uccelo’s Sir John Hawkwood

Wide-angle distortion

Image Plane

Viewpoint

Correction via multiple projections

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

Multiviewpoint Panoramas

How to Depict All Buildings on Street?

How to Depict All Buildings on Street?

How to Depict All Buildings on Street?
A Better Approach

Michael Koller  www.seamlesscity.com

Why is this better?

Perhaps because local sense of perspective is preserved

Input – 107 Hand Held Photographs

Approach

1. Estimate camera pos. & depths of feature pts (SFM)

2. Project images onto user chosen picture plane

3. Use graph cut to “seamlessly” merge images

Approach

Building 1  Building 2  Picture surface

Building 1  Building 2  Picture surface
Apply Graph Cut

\[ C(L) = \sum \text{image objective} + \sum \text{seam objective} \]

Result

A Longer Street

Grocery store aisle

Grocery store aisle