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

Color

Controlling Value

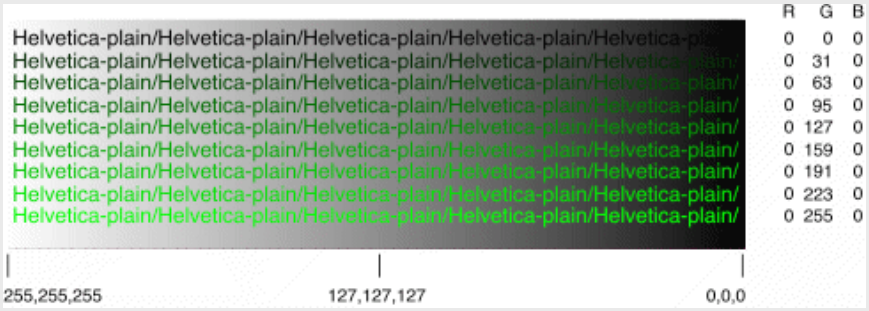
Get it right in black & white

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



colorusage.arc.nasa.gov

Legibility

Drop Shadows

Drop Shadow

Drop shadow adds edge

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

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

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

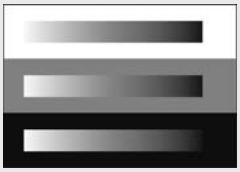
How do we specify contrast?
- Ratios of foreground to background luminance
- Different specifications for different patterns

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 ΔL*

- 1 is ideally visible
- 10 is easily visible
- 20 is legible for text

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

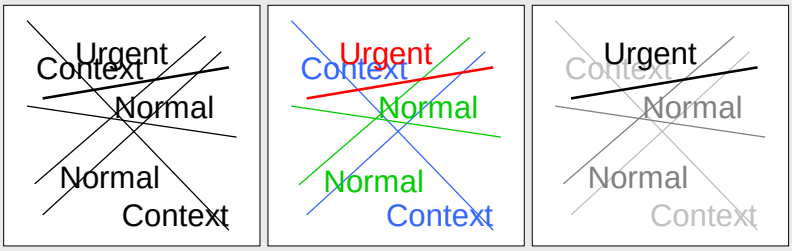
Reasons to use a light background

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

Dark background better for dark environments

Contrast and Layering

Value contrast creates layering



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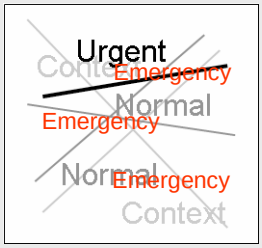
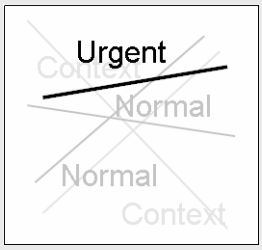
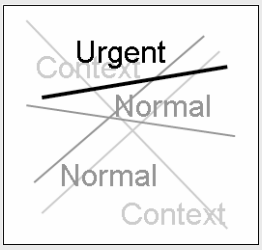
What Defines Layering?

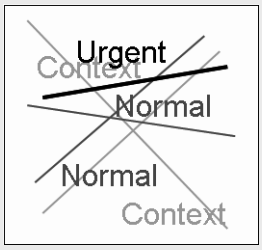
Perceptual features

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









Grid Example

Grid sits unobtrusively in the background

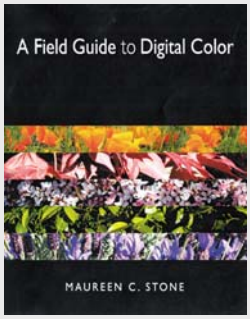
Grid sits in foreground, obscuring map

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
- Final copy of slides, references

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



Using Space Effectively: 3D

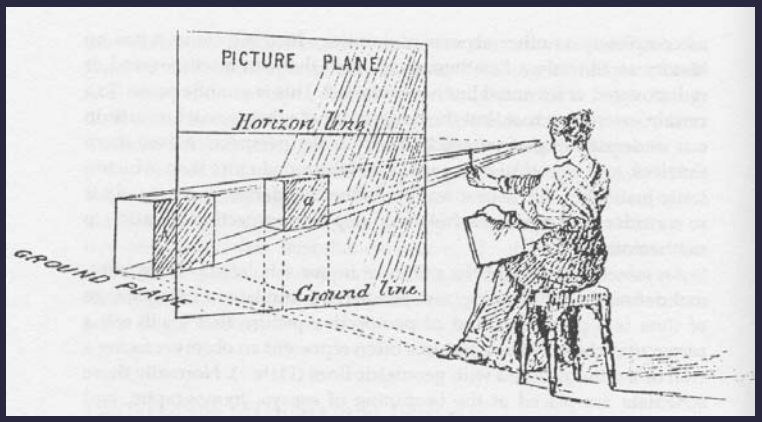
Topics

- 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

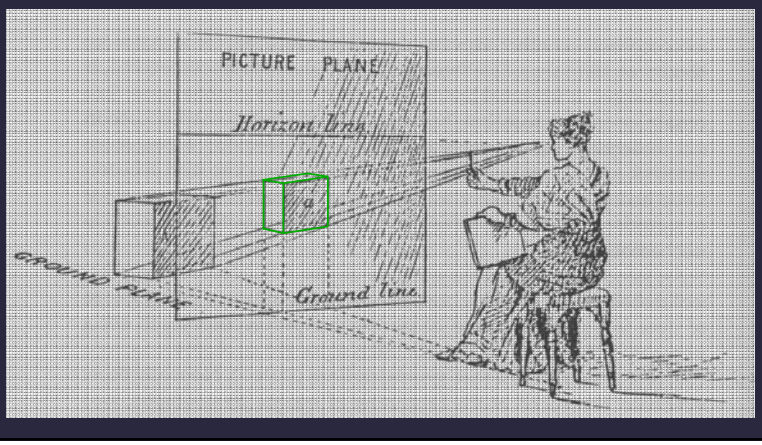


Secondary geometry

Description in 2D image-space

e.g. true shape of front face, side faces recede to vanishing point, …

Often better corresponds to drawing approach

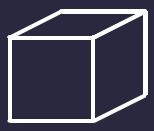


Linear Projections

Linear projections

Straight lines and alignments are preserved

Parallel



Perspective

British standard classification

Primary geometry

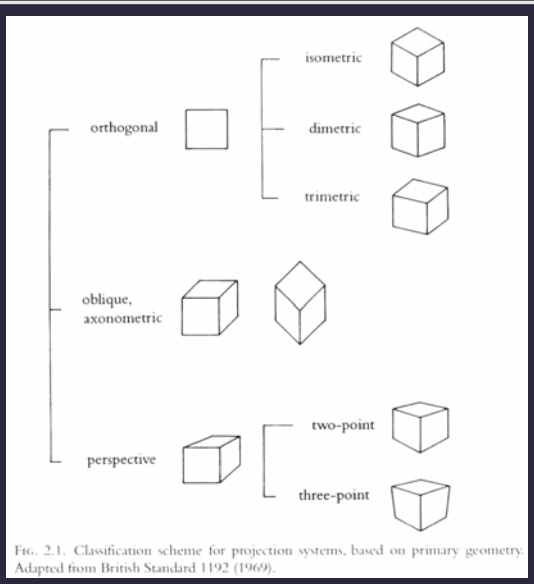


FIG. 2.1. Classification scheme for projection systems, based on primary geometry. Adapted from British Standard 1192 (1969).

Willats' classification

Secondary geometry

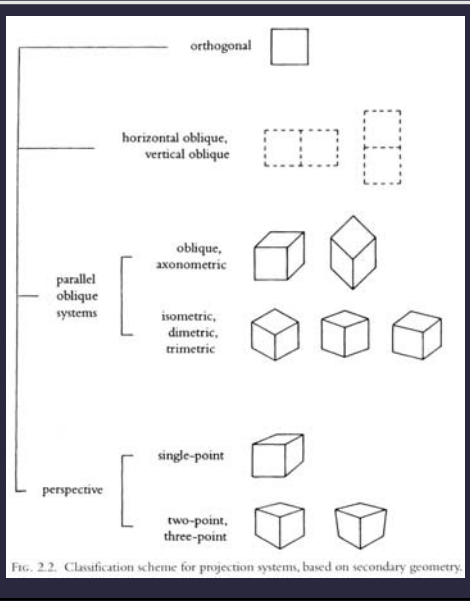


FIG. 2.2. Classification scheme for projection systems, based on secondary geometry.

Parallel projections

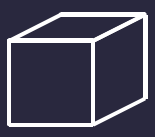
No vanishing points or foreshortening

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

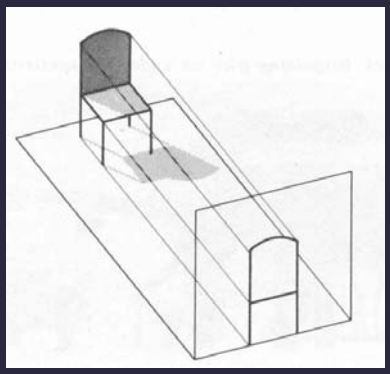
- Others

Orthogonal

Direction

- Perpendicular to image plane
- Along one principal direction

True shape for faces parallel to image plane



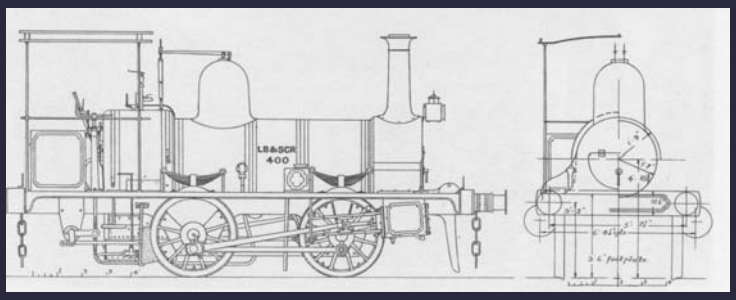
Orthogonal

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

Orthogonal

Child drawing

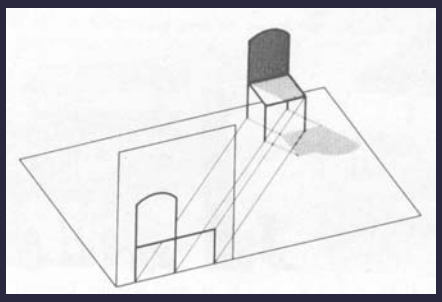
Fold-out oblique

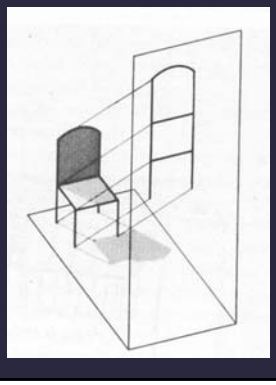
Horizontal oblique 

Vertical oblique 

Direction

- 45º, parallel to one principal face (top or side)





Fold-out oblique

Horizontal oblique 

Vertical oblique 

Direction

- 45º, parallel to one principal face (top or side)

True shape for 2 faces with 45º 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

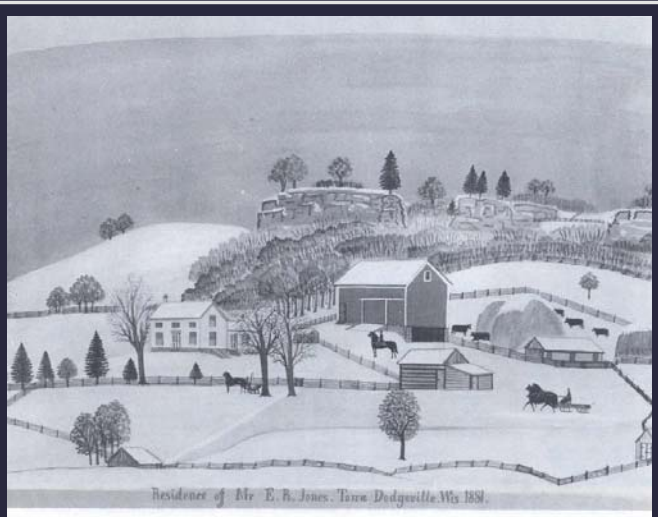


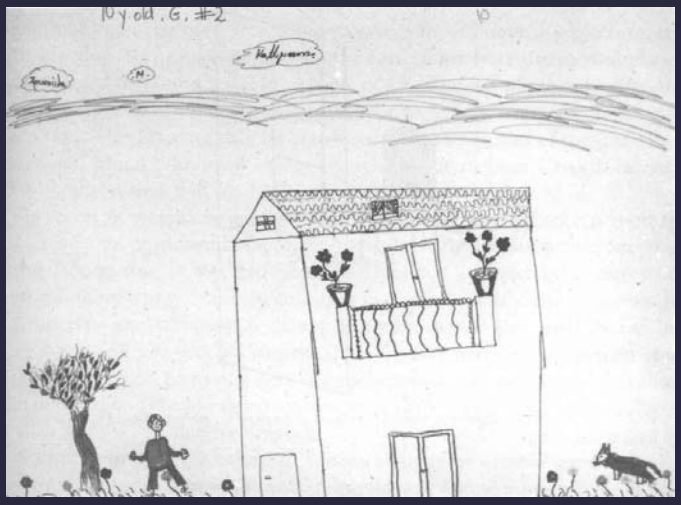
FIG. 2.8. Paul A. Seifert, *Residence of Mr. E. R. Jones,* 1881. Watercolor, 54.6 × 69.9 cm. New York State Historical Association, Cooperstown, New York.

Horizontal oblique

Icons

Horizontal oblique

Child drawing

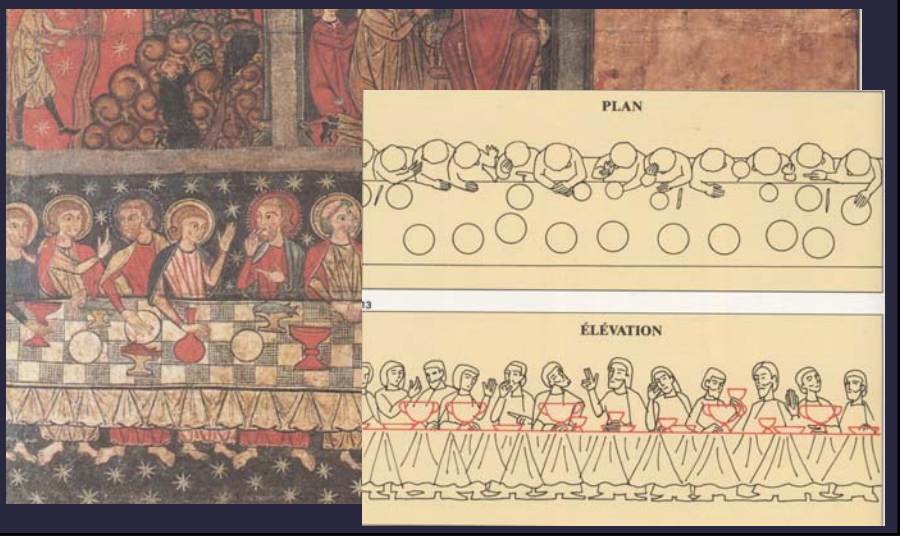


Vertical oblique

Soriguerola, 13th

Vertical oblique

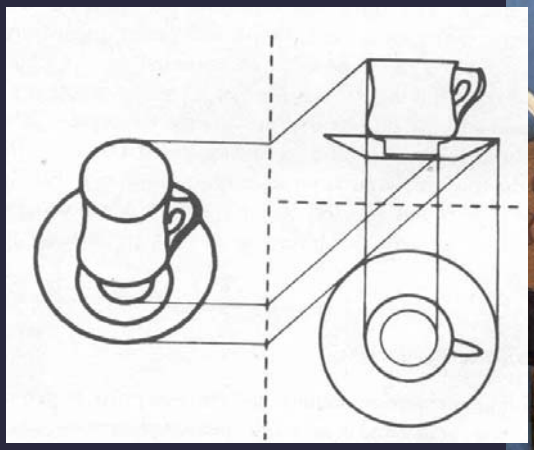
Soriguerola, 13th



Vertical oblique

Juan Gris, *Breakfast*, 1914

Vertical oblique



Vertical oblique

Andre Kertesz,
Tulipe Melancolique

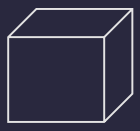
Non orthogonal

Direction

- non orthogonal to picture plane

Oblique

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



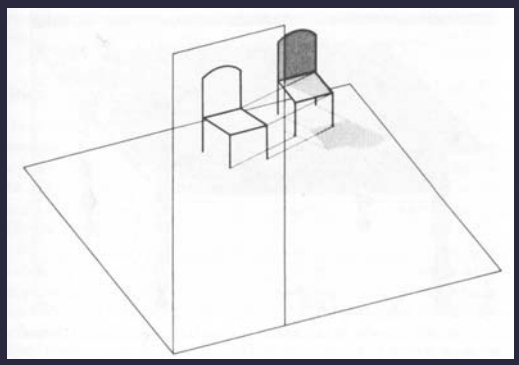
Axonometric

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

Oblique

Picture plane parallel to front
True shape for front face

Can use true length for 3rd direction

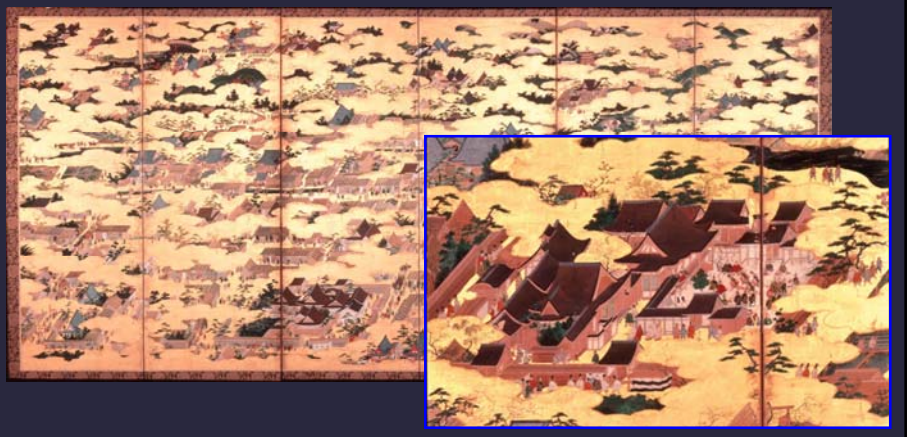


Oblique

Henry Lapp, 19th century

Oblique

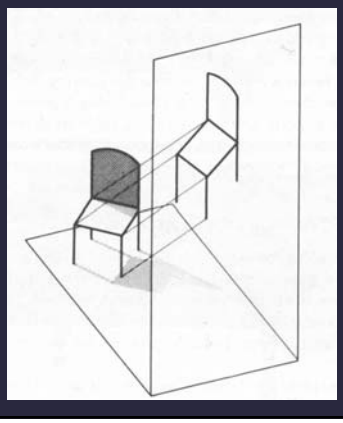
Chinese paintings 12th century



Axonometric

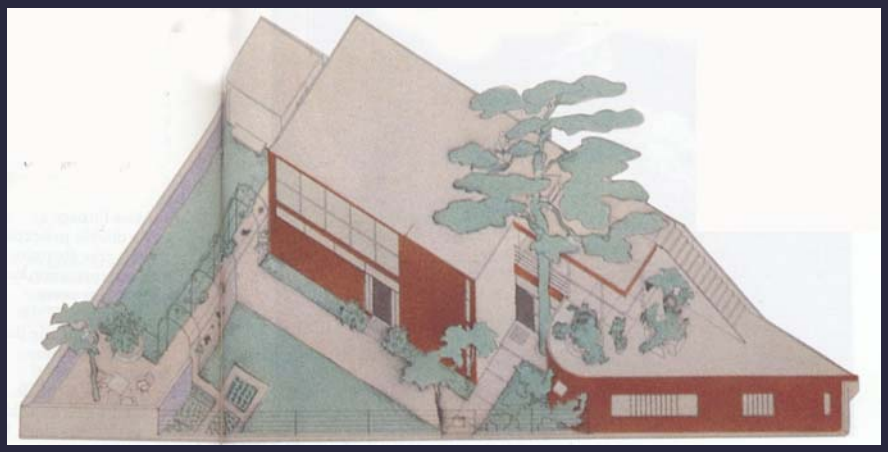
Axonometric

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



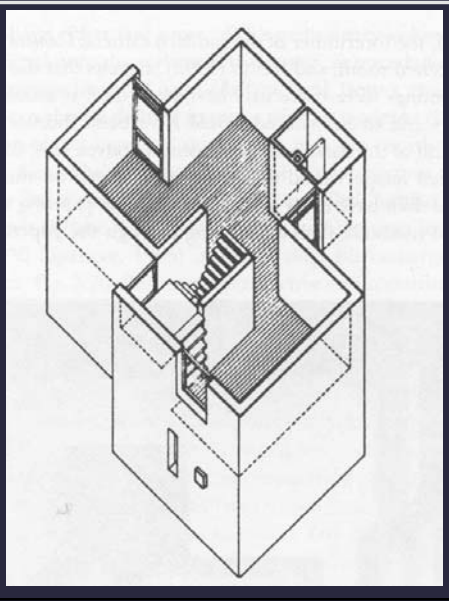
Axonometric

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

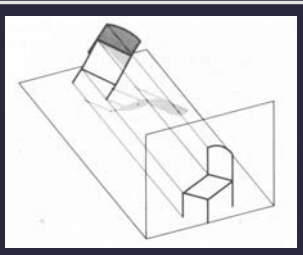
Others

- Generic orthographic
- Nothing preserved, rarely used

Isometric vs. axonometric

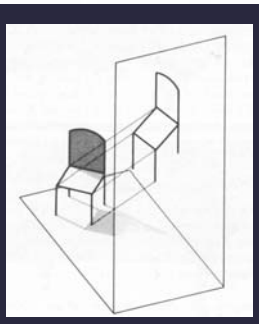
Isometric

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

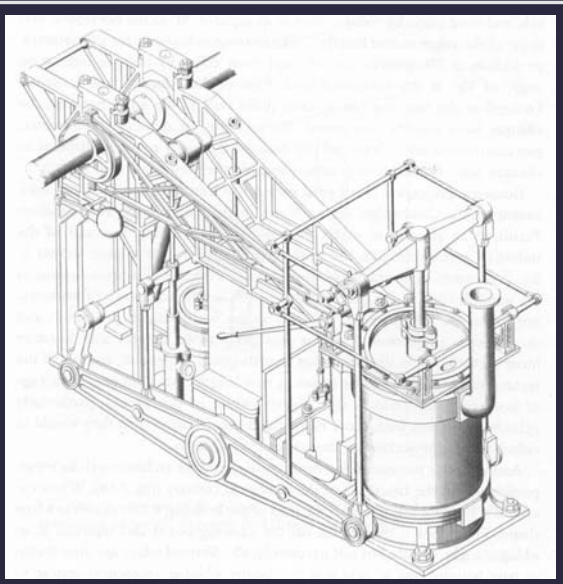


Axonometric

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



Isometric

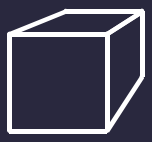


Isometric

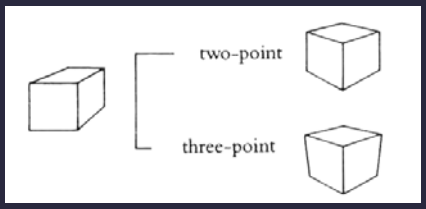
Brooks-Greaves
St Paul's Cathedral
1928

Linear perspective

Foreshortening
The spectator is “immersed”

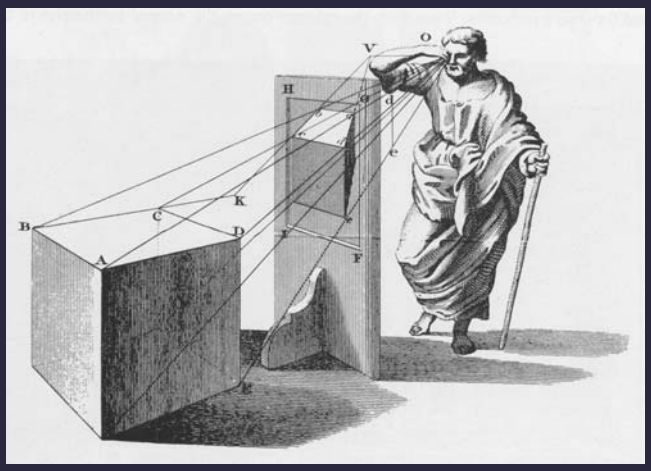


One point
Two points
Three points



Primary geometry

Trace rays from object, through image plane, into eye



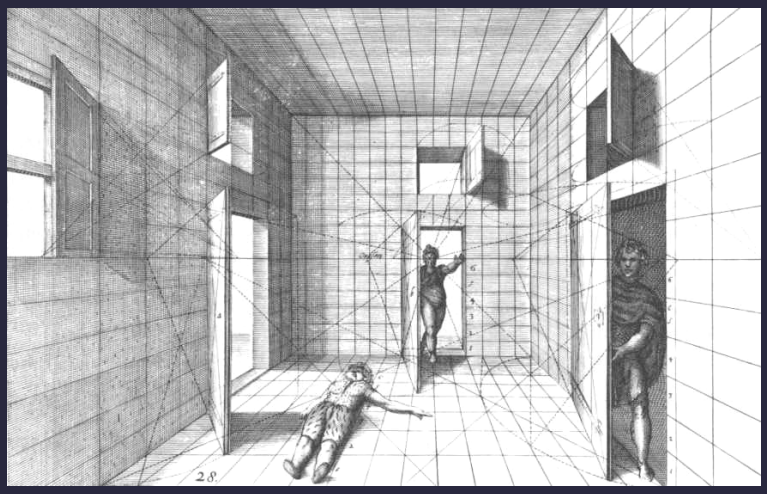
1-point perspective

Central focus

Preserves horizontals and verticals

1-point perspective

Jean Vredeman de Vries,1604

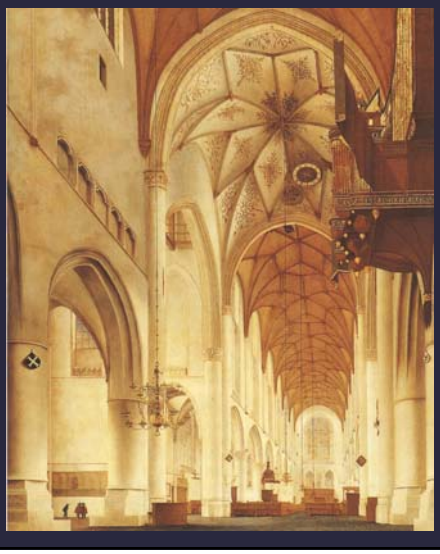


1-point perspective

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

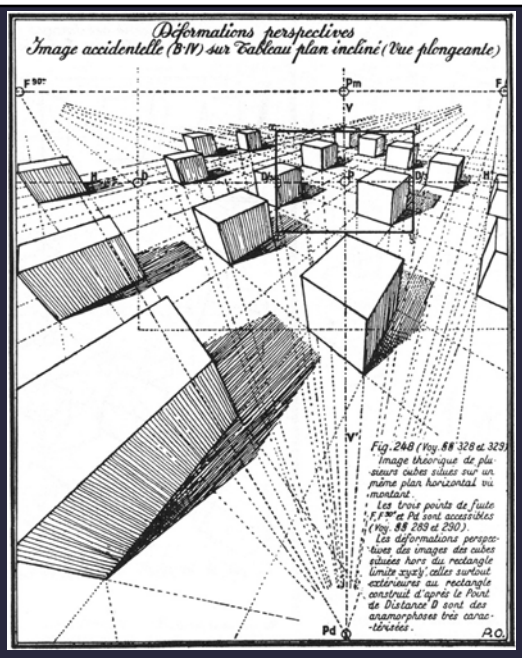
3-point perspective

Dramatic 3D effect

The generic case,
nothing preserved

Historically, seldom used
in art or technical
drawing

Perspective Distortion

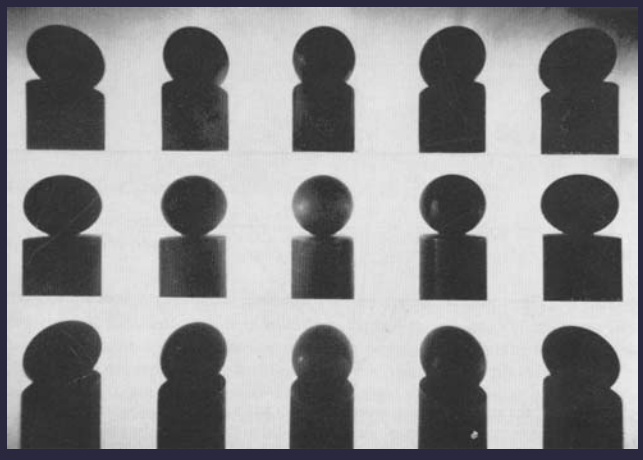


Marginal distortions in perspective projection, Olmer [from Kubovy 03]

Perspective distortion

Wide angle projection

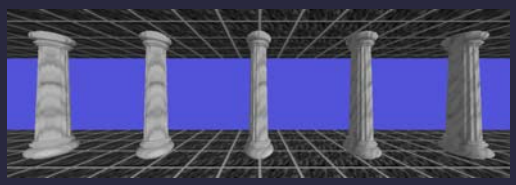
Does not preserve subjective size

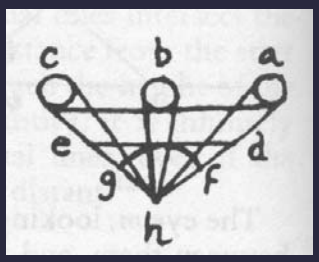


Perspective distortion

Wide angle projection

Does not preserve subjective size





Perspective distortion

Wide angle projection

Distorts shape

Perspective distortion

Portrait: distortion with wide angle and telephoto

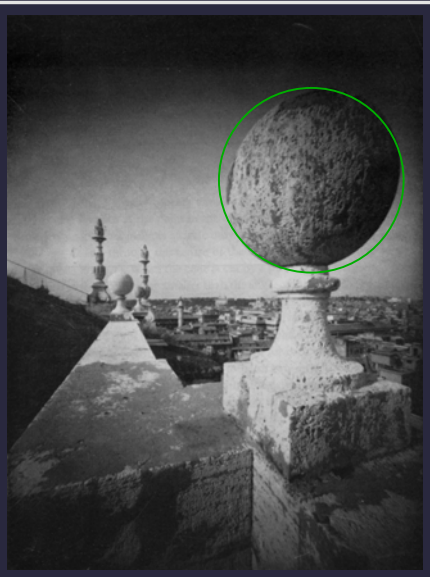
Wide angle | Standard | Telephoto

Perspective distortion

- **The sphere is projected as an ellipse**
- **Symmetry is not preserved**

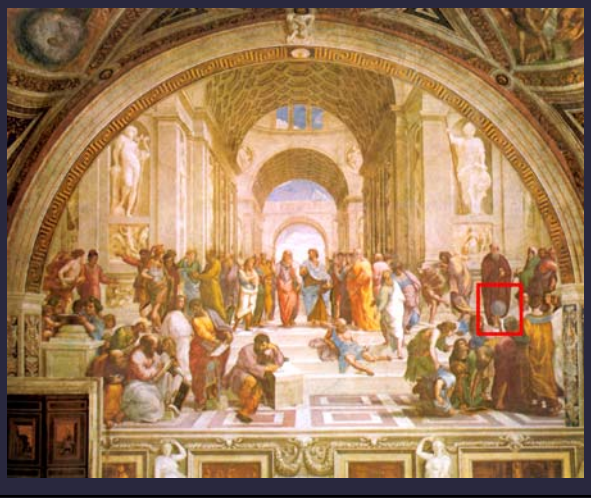
Perspective distortion

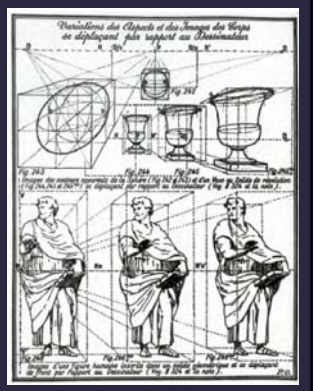
- The sphere is projected as an ellipse
- Symmetry is not preserved



Perspective distortion

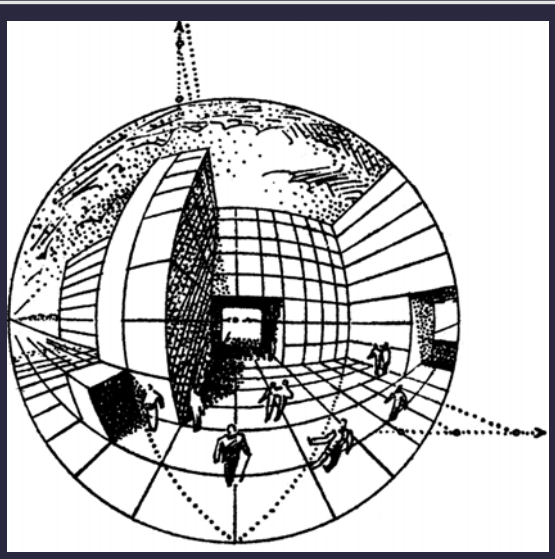
- The sphere should be projected as an ellipse
- But a circle is used





Non-Linear Projections

Fish-eye



Fish-eye vs. wide angle

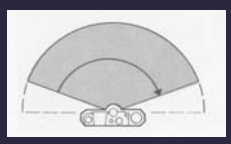
Curved perspective

Panorama

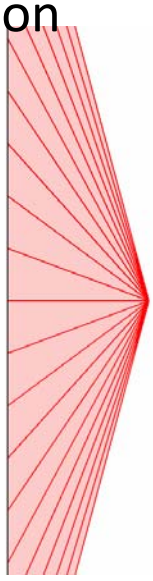
- **Preserve verticals**

Curved perspective

Rotating lens panoramic camera

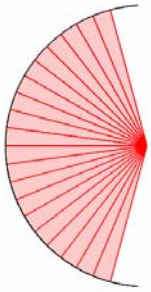


Perspective Projection



[from Kopf 07]

Cylindrical Projection



[from Kopf 07]

Spherical Projection

[from Kopf 07]

Perspective vs. Cylindrical/Spherical

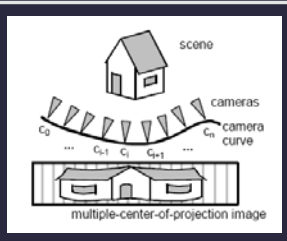
Perspective	Cylindrical / Spherical
• Close to human perception	• Straight lines → curved
• Straight lines → straight	• Feels flat
• Wide angle distorted	• Whole FOV possible
= Best for narrow angles	= Best for wide angles

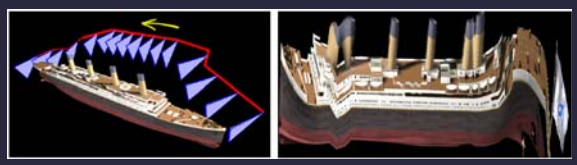
[from Kopf 07]

HD View

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

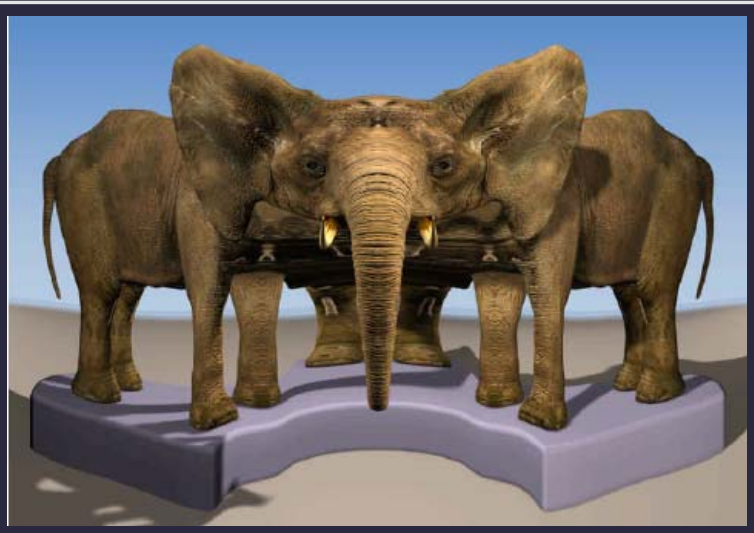
Multiple center-of-projection images





[Rademacher 98]

Unfolding an elephant



[Rademacher 98]

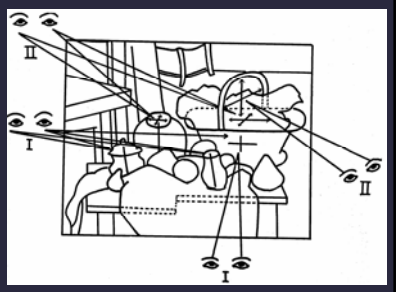
Combining multiple views

[Hockney]

Combining multiple views

Viewing Anomalies

- **Cezanne's *Still Life with Fruit Basket***



Schematic from Loran (1943)

Combining two perspectives

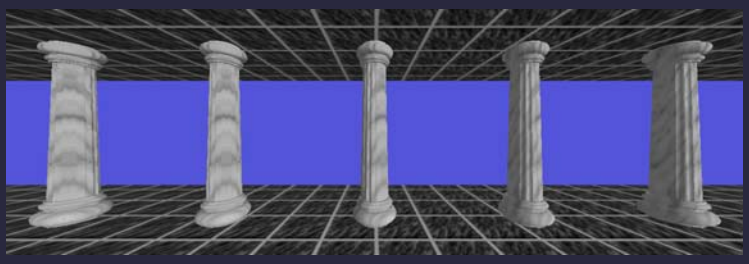
Best Views

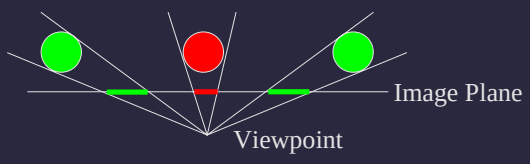
- Large display: billboard, mural
- Oblique viewing angle
- Wide range of viewpoints

Application: wall-sized displays

Paolo Uccelo's *Sir John Hawkwood*

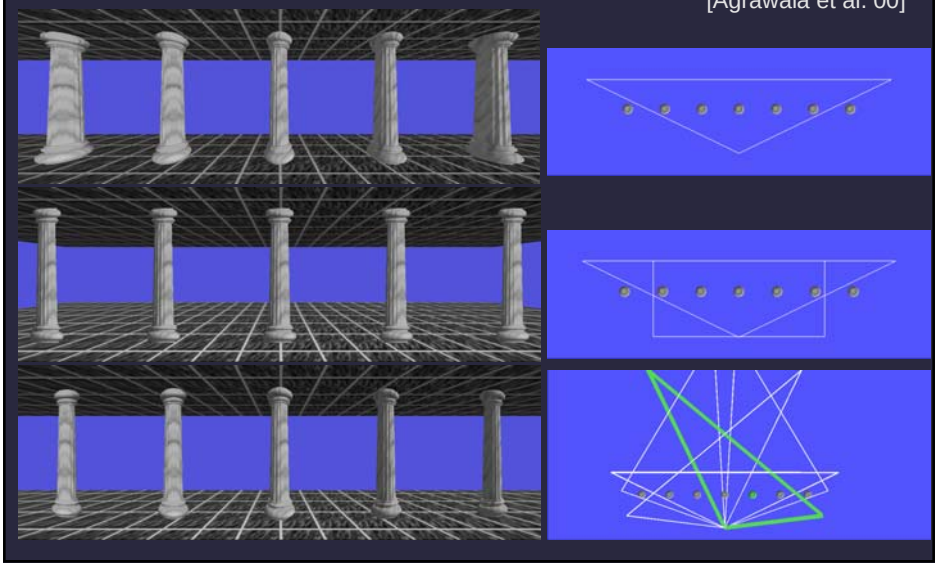
Wide-angle distortion





Correction via multiple projections

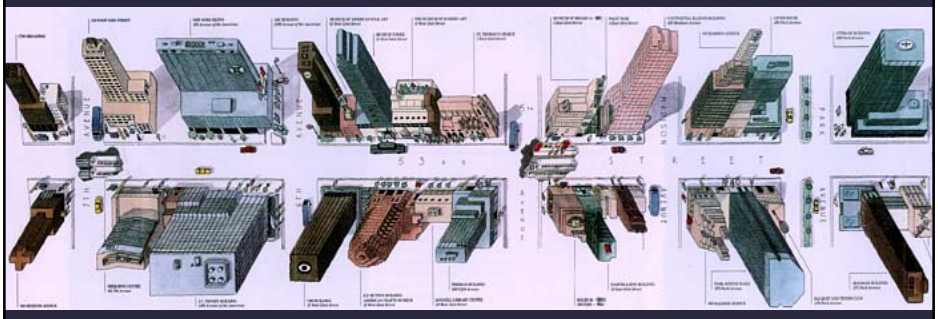
[Agrawala et al. 00]



Artificial perspective

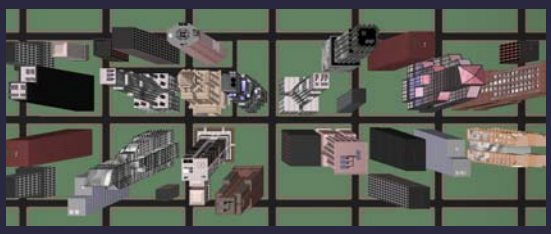
Multiple parallel (oblique) projections

- Orient receding parallel towards vanishing point
- Some area comparisons possible



53rd Street Map [Guarnaccia 93]

CG example of artificial perspective

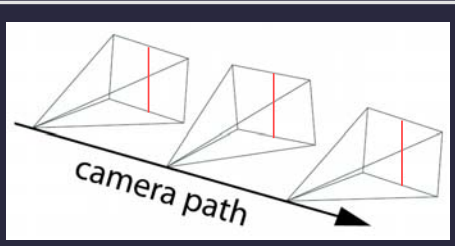


Multiple oblique projections

Standard perspective projection

[Agrawala et al. 00]

Combining orthographic/perspective



Pushbroom panorama [Román 04]

A Better Approach

Michael Koller www.seamlesscity.com

Why is this better?

Perhaps because local sense of perspective is preserved

Multiviewpoint Panoramas [Agarwala 06]