Visual Perception of Pictures

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Picture Perception

- How do we perceive 3D spatial structure from cues in a photograph or painting?
- The eye is NOT a camera
- There is NO homunculus
- Vision is NOT veridical
  - What we see is NOT really there; the HVS transforms the raw data

Is it real?

Photo by Patrick Jennings (patrick@synaptic.bc.ca). Copyright 1995, 96, 97 Whistler B. C. Canada
No, of course it’s not real

- It was “real” light
- Then a photograph
- Then bits
- Then projected light
- Then reflected light
- Then imaged by your eyes
- And interpreted by you

Pictures have a history (how they came to be). For the observer of the picture the history is virtual, not real.

A pictorial object is a purely mental entity. Although often related to some “fiducial” physical scene that existed at the time of exposure (say), this is by no means necessary.

A picture is a planar object covered with pigments in some simultaneous order.

What looks like a "photograph" may turn out to be fungus growth on a sheet of dried wood pulp.

Even if a fiducial scene existed, this is of no consequence to the visual process.

In most settings the notion of "veridical" is void!
Pictorial Space Structure Cues

- Size, texture, shading, occlusion, etc.
- But NOT stereo, motion parallax, accommodation, etc.

Layout of objects in scene is specified by their relative locations on ground surface
- Ground texture provides intrinsic scale of relative distance and size
- Horizon ratios specify relative depth and size
- Information is preserved in image from any viewpoint

Shading
Shading is an important shape cue, but it only yields quantitative results under strong prior assumptions:
- uniform albedo, Lambertian scattering
- uniform, unidirectional beam
- globally convex objects
Origins of Picture Making: Shadows

- **Corinthian Maid**
  - Traced an outline of her lover’s shadow to create a permanent reminder of him before he left the country.
  - Favored explanation for the origin of painting and drawing in 18th and early 19th centuries.

- **Depicting Our World: The Beginning**
  - Prehistoric Painting, Lascaux Cave, France, ~ 13,000 -- 15,000 B.C.

- **Depicting Our World: Middle Ages**
  - Cimabue, *Madonna in Majesty* (c. 1280)
The Empress Theodora with her court.
Ravenna, St. Vitale (6th c.)

Filippo Brunelleschi’s Discovery of Linear Perspective, c. 1413

Why Did It Work?
- Burnished silver
  - reflects sky
  - moving clouds
  - virtual image at infinite distance
- Mirror
  - blurs painting
  - surface texture
  - little mirror
  - surface texture
  - virtual image behind mirror
- Unified perspective & cues
- Reduction screen:
  - monocular view
  - no stereopsis
  - no convergence
  - no motion parallax
  - increases depth of field, reduces accommodation
  - occludes frame/edges
  - eye at station point

Alberti’s Window
- Leon Battista Alberti, *De Pictura*, 1435
- Look through a stretched gauze sheet (“window”) held at a fixed distance to see the distant scene. Note the location on the cloth corresponding to key points in the scene. Transfer to grid on painting canvas.
- Can be done with a frosted glass window
- Same basis as in Dürer’s perspective methods
Alberti’s Reticolato (“grid”) (c. 1450)

- On table for stability
- Post to ensure stable viewing (eye position)
- Wires on wooden frame form grid
- Place frame perpendicular to line of sight, at a distance to frame scene
- Draw on separate page
- Proper viewing position: where the top of the post was

Dürer, “Draughtsman Drawing a Recumbent Woman” (1527)

- Same basic principle as Alberti’s veil
- Leonardo used a related technique in 1510
- Geometrical (rather than orthoscopic) perspective
- Proper viewing position: tip of rod

Depicting Our World: Renaissance

Masaccio, *Trinity*, c. 1427, Santa Maria Novella, Florence

Carlo Crivelli (1486) *The Annunciation, with St. Emidius*
Perspective analysis of Crivelli’s Annunciation

Illusionism

“The light ought to come from the Picture to the spectator’s Eye in the very same manner as it would from the objects themselves.”

-- Brook Taylor, 1715

Painting as a cross-section of Euclid’s and Alberti’s visual cone

Trompe L’Oeil

“Deceiving the Eye”

A depiction of an object, person, or scene, which is so lifelike that it appears to be real

A style of painting which gives the appearance of three-dimensional, or photographic realism. It flourished from the Renaissance onward. The discovery of linear perspective in 15th-century Italy and advancements in the science of optics in the 17th-century Netherlands enabled artists to render object and spaces with eye-fooling exactitude.

Trompe L’œil

“Deceive the eye”

“A completed painting is as a mirror of nature, where things that do not appear seem to appear, and which deceives in an allowably entertaining and praiseworthy manner.”

Samuel van Hoogstraten (1662)
Perspective illusion
Andrea Mantegna (1461-74) Ceiling fresco, Camera degli Sposi, Palazzo Ducale, Mantua

Richard Haas Mural, 1987, Madison, Wisconsin

Fra Andrea Pozzo (1691-1762) The glorification of St. Ignatius. Church of St. Ignazio, Rome. Viewed from marble disk at CP

Pozzo’s Drawing Technique

1. Made a detailed drawing of the false architecture, and transferred it onto a square grid.
2. Suspended a matching network of strings from the top of the nave, just below the curved vault.
3. Strings attached at chosen viewpoint on the floor.
4. Visually project string onto cylindrical ceiling.
Linear Perspective is only Correct when Viewed from the Center of Projection

Perspective Distortion
- Back-project from incorrect viewpoint (assuming parallel edges)
- Shear: line to VP = center of corridor
- Expansion: smaller angle = farther distance

The Robustness of our Perception of Perspective
- Yet it’s been observed that we don’t often notice perspective distortions caused by the observer not being at CP!
- Station Point Paradox:
  - Perspective is geometrically correct only when viewed from the center of projection (CP), yet pictures don’t look distorted from many other viewpoints. How?
Rousseau’s Village of Becquigny, viewed from about 45˚ to the left.

Leonardo Da Vinci (1455-1519) The last supper. Refectory of the Church of Santa Maria della Grazie, Milan.

The Compensation Theory (Pirenne)

- We perceive the surface of the picture and use it to compensate for an incorrect viewing position, and thus for the geometric distortion.

  “When the shape and position of the picture surface can be seen, an unconscious psychological process of compensation takes place, which restores the correct view when the picture is viewed from the wrong position.” -- Pirenne (1970)

- We see an ellipse as a tilted circle

- Must see the surface to see through the surface
The Geometer Theory
(Kubovy)

- But how do you know where the correct viewpoint is?
- The visual system acts like a geometer to reconstruct CP
  - Inverse perspective analysis
  - Recover position and distance of CP
- Then compensate for current viewing position and correct distortions

Warren’s Non-Euclidean Theory

- Distortions are present, but we usually don’t notice them
  - Don’t attend to Euclidean shape and distance, but to relative (local) layout of scene
  - See distortions because projected shapes are wrong. Larger distortions are more noticeable.
  - Same image specifies receding road from any viewpoint. Rotation is more noticeable with deep perspective.
Ascending and Descending, 1960

Waterfall, 1961

Retinal Sampling

Density of receptors decreases exponentially from the center to the periphery of the retina

Visual Acuity

With one eye shut, at the right distance, all of these letters should appear equally legible

What Makes the Mona Lisa Smile?

The smile only becomes apparent if a viewer looks at her eyes or elsewhere on her face; the smile disappears when looking directly at her mouth.

Peripheral vision is low resolution and blurs, picking up shadows from the Mona Lisa’s cheekbones, which suggest the curvature of a smile.

"The elusive quality of the Mona Lisa’s smile can be explained by the fact that her smile is almost entirely in low spatial frequencies, and so is seen best by your peripheral retina."

-- Margaret Livingstone

The actress Geena Davis also shows the Mona Lisa effect, always seeming to be smiling, even when the text is, because her cheek bones are so prominent.
Field of View

- Human vision system uses narrow-field-of-view and wide-field-of-view naturally and intelligently
  - 2', high-acuity fovea window of the world
  - 3 saccades per second and gaze moves
  - Human vision can integrate information seamlessly

Saccadic Eye Movements

Work by Russian psychophysicist Yarbus who traced saccadic eye movements

When is Perspective NOT Robust?

- Trompe l’oeil
  - only 1 correct viewpoint
  - other viewpoints often yield visual distortions
- Pictures of pictures
- Anamorphic art

A photograph of a photograph

We can’t “see” the orientation of the photo relative to the viewer, so no automatic correction occurs and the photo looks distorted.

Time Magazine, 1968

Anamorphosis

- **ana-mor-pho-sis**: 1. a drawing presenting a distorted image which appears in natural form under certain conditions, as when viewed at a raking angle or reflected from a curved mirror. 2. the method of producing such a drawing. 3. Zoology, Entomology, the gradual change in form from one type to another during the evolution of a group of plants or animals. 4. (in certain arthropods) metamorphosis in which body parts or segments are added to those already present.

Leonardo da Vinci, *Codex Atlanticus*, c. 1486

Hans Holbein the Younger, *The Ambassadors*, 1533

William Scrots (1533)
*Portrait of Prince Edward VI of England*

**Anamorphic Projection**

2 Centers of Projection:
- Orthogonal PP
- Slanted PP
Painters have used Heuristics to aid in Robust Perception of Perspective

Example: Leonardo’s Moderate Distance Rule

To minimize noticeable distortion, use shallow perspective:

“Make your view at least 20 times as far off as the greatest width or height of the objects represented, and this will satisfy any spectator placed anywhere opposite to the picture.”

-- Leonardo

Example: Extreme Viewpoints

Mantegna, *Lamentation over the dead Christ*, 1480

Ogden’s photo recreation of *The dead Christ*. 
Out of Bounds Photography

focusing

Contour

Transverse crossing ("T-junction")

Ending contour

Genetic contour (fold)
OOB Predates Digital Photography!

*Escaping Criticism*, 1874, del Caso

**Why’s the Person in that Painting Staring at Me?**

It is well known that persons looking out from the picture or pointing out of the picture "follow you around the room". Such phenomena can easily be described in terms of the wider class of ambiguities.
In an oblique view the pictorial person keeps looking straight at the observer (no turns in pictorial space).

Foreshortening narrows the picture, otherwise all cues are identical. Thus pictorial space narrows in the horizontal direction.

The frame lives rather uneasily in two different spaces.

A mental eye movement suffices to let the frame live happily in two spaces without obvious discrepancies.

This corrects for the foreshortening too.

The main effect of walking about the room is a rotation of the pictorial person in pictorial space. It keeps looking straight at the observer at all times.

The frame of the picture stays put, it doesn’t "turn out of the wall".