Weeks Eight/Nine - Painting, The Dutch Golden Age

Thursday, 21 March 2024, 12:00 - 2:45 PM EST.
Thursday, 28 March 2024, 12:00 - 2:45 PM EST.
Science Center 102

The Dutch Golden Age witnessed the dual rise of optics and photorealistic painting, providing science and art with new ways to see and describe the world. Except for Galileo, the leading scientists who used glass lenses to discover new worlds – Leeuwenhoek with his microscope in Delft, Kepler with his telescope in Germany, and others – were in Northern Europe. New worlds being discovered had to be described. Before photography, visual description required art. Reliable visual representation was becoming a new way describe and know the world, apart from the written word.

Figure 152: *Portrait of Constantijn Huygens and his Clerk* by Thomas de Keyser. Huygens's table is the story of his duties, interests, and talents – a musical instrument, architectural plans, and terrestrial and celestial globes. Link to painting at the National Gallery in London

Northern Europe was receptive to devices like the camera obscura. Sir Constantijn Huygens, Lord of Zuilichem, (1596-1687) was a leading polymath of the Dutch Golden Age (Fig. 152). Constantijn corresponded with Descartes, championed Rembrandt, and inspired his son Christiaan. Christiaan Huygens (1629-1695) became an important mathematical physicist, discovering 'Huygens Principle' of wave propagation. Constantijn's writing about the camera obscura – bought by his friend Cornelis Drebbel, another leading scientist – reveals the Dutch attitude toward image-making devices as well as the increasing importance of visual over written communication.

> It is not possible to describe for you the beauty of [the camera obscura] in words: all painting is dead by comparison, for here is life itself, or something more noble, if only it did not lack words.

A poem by Constantijn is another insight into an attitude to seeing as unique means to knowledge and experience of God's creation:

> O you who give the eyes and the power,
> Give eyes through this power:
> Eyes once made watchful, Which see the totality of all there is to see.

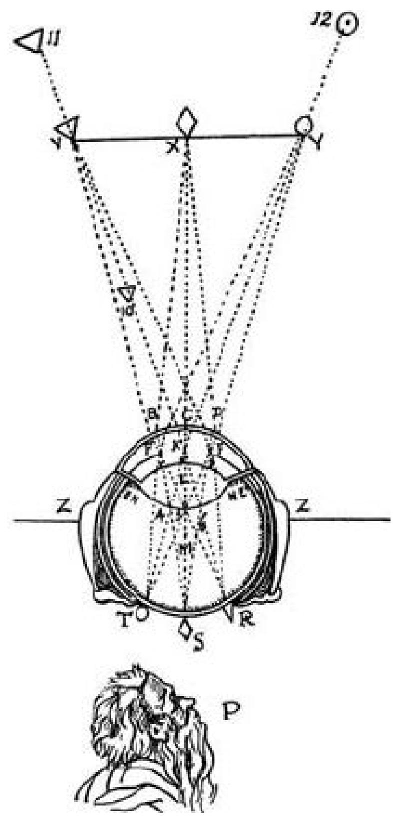

Figure 153: Illustration of the theory of the retinal image from *La Dioptrique* by Descartes.

There had been doubts about the truth of images seen (and typically distorted) by lens and mirror. The truth of visual representations with devices was validated in 1604, with Kepler's discovery that the human eye *works* like a camera obscura, literally equipped with lens and pinhole that project images onto the retina. Kepler wrote: "ut pictura, ita vision" or "sight is like a picture".

Updated: April 6, 2024

BEFORE THE CAMERA OBSCURA, the art of Northern Europe, exemplified by van Eyck, had been characterized for its optical detail, precision, and patient craftsmanship. When Constantijn Huygens looked into Drebbel's microscopes, he realized that new visual worlds were being discovered that demanded to be captured. As a young man, Constantijn had wanted to study drawing and painting with the Dutch realist painter Jacob de Gheyn II (1565-1629), whose renderings of flora and fauna would grace any biology textbook (Fig. 156). Constantijn wrote:

> For in fact, this concerns a new theater of nature, another world, and if our revered predecessor De Gheyn had been allotted a longer life span, I believe he would have advanced to the point to which I have begun to push people (not against their will); namely to portray the most minute objects and insects with a finer pencil, and then to compile these drawings into a book to be given the title of the *New World* .

Figure 154: Vermeer's *Astronomer* and *Geographer*

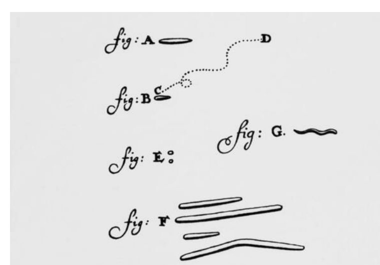

Figure 155: Animalcules from a letter by Leeuwenhoek from 1683

Figure 156: *Studies of a Fantastic Bird, Toad, Frog, and Dragonfly* by de Gheyn, 1596-1602. Link to Morgan Library and Museum.

CONSTANTIJN HUYGENS became a supporter of Leeuwenhoek (1632-1723), the contemporary and neighbor of Vermeer (1632-1675) in the small town of Delft. Leeuwenhoek might have posed for Vermeer's *The Astronomer* and *the Geographer*. Leeuwenhoek discovered the microorganism by inventing the (then) most powerful microscope in the world, and would make the first drawings of bacteria (what he called animalcules). [21]

[21] Nick Lane. The unseen world: reflections on leeuwenhoek (1677) 'concerning little animals'. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1666):20140344, 2015

Updated: April 6, 2024

FRANCIS BACON (1561-1626), student at Trinity College, Cambridge, philosopher, and statesman in the Court of Elizabeth I, has been called the inventor of the modern scientific method and empiricism, – knowledge by inductive reasoning from careful observation of nature. Constantijn Huygens was deeply influenced by Bacon, as were Robert Hooke (1635-1703) and Isaac Newton (1643-1727). Hooke, a Fellow of the Royal Society, corresponded with Leeuwenhoek in Delft and conducted his own microscope experiments. Huygens's call for a book titled the *New World* – a scientific program of accurate visual representation of the microscopic world – would be realized by Hooke's *Micrographia* published in 1665. [22] Working with the best available microscopes, Hooke made extraordinarily accurate and detailed discoveries of many objects including the exquisite architecture of insects (Fig. **??**).

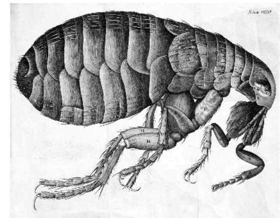

Figure 157: *Flea* from *Micrographia* by Robert Hooke, 1665

[22] Martin Kemp. Hooke's housefly. *Nature (London)*, 393(6687):745–745, 1998b. ISSN 0028-0836

MICROGRAPHIA communicates by word and image. But comparing Hooke's verbal description (quote below) with his drawing only emphasizes the poverty of language when communicating thoughtful observation of the visible world with rigor and reliability.

> The Eye of a Fly in one kind of light appears almost like a lattice, drill'd through with abundance of small holes... in the Sunshine they look like a surface cover'd with golden Nails' in another posture, like a surface cover'd with pyramids; in another with Cones; and in other postures of quite other shapes.

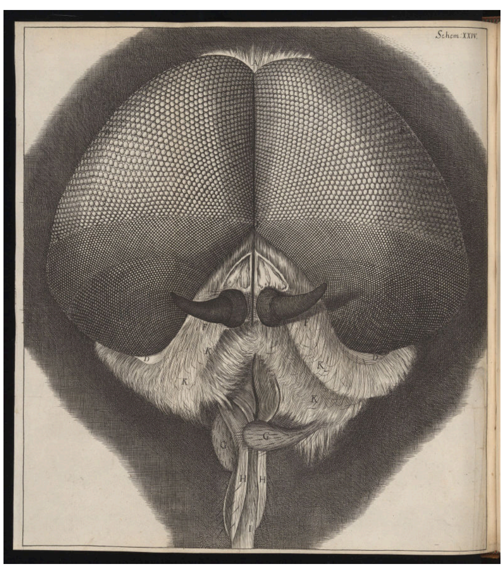

Figure 158: *Eyes and head of a grey drone fly* by Robert Hooke, 1665. Link to Wellcome Collection.

Robert Hooke's Micrographia followed Francis Bacon's project for empiricism, which, as he put it himself,

> Shewing, that there is not so much requir'd towards it, any strength of *Imagination* or exactness of *Method*, or depth of *Contemplation* (though the addition of these, where they can be had, must needs produce a much more perfect composure) as a *sincere Hand*, and a *faithful Eye*, to examine, and to record, the things themselves as they appear.

Constantijn Huygens bound Bacon's project to the art of the Dutch Golden Age, taken up by many including Samuel van Hoogstraten (1627-1678), student of Rembrandt and art theorist, who wrote:

> The Art of Painting is a science for representing all the ideas or notions which the whole of visible nature is able to produce and for deceiving the eye with drawing and color.

Hoogstraten followed his own advice with his *trompe l'œil* paintings, realistic optical illusions of three-dimensional spaces, such as a painted corridor (Fig. 159) or objects scattered on a two-dimensional surface (Fig. 160), attempts to delight the viewer with the trick of seeing spaces or objects that aren't there.

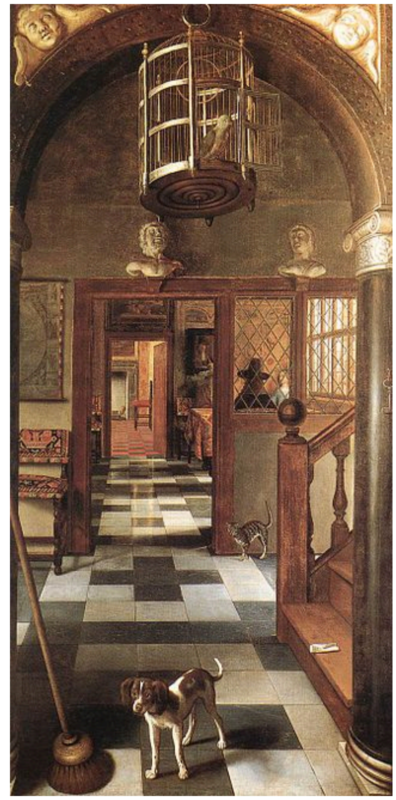

Figure 159: *View of a Corridor* by Samuel van Hoogstraten in 1662, hung in a doorway in Dyrham Park, a country house in England, as the artist intended.

Figure 160: *Trompe l'œil Still Life* by Samuel van Hoogstraten.

ONE SHOULD BE CAUTIOUS claiming causes and effects without direct evidence. But there are common themes in the art and science of representation in the Dutch Golden Age that seem to reveal its cultural attitudes and tastes. When de Gheyn, friend of Constantijn Huygens, painted a sick mouse, he captured the details of its swollen eyes and fur standing on end from multiple angles, rolling it over in his mind and art.

Figure 161: *Four studies of a diseased mouse* by Jacques de Gheyn. Link to Rijksmuseum.

THE STILL LIFE of the Dutch Golden Age also reveals a taste for microscopic dissection and multifaceted display for myriad objects. The still life genre was led by its pioneers including Pieter Claesz (1597-1661) and Willem Kalf (1619-1693). Cheese, fish, fruit, serving vessels are displayed in ways that reveal inside, outside, and underside. Foods are sliced open. Lemon rinds are unwound. Objects are dissected and exposed, arranged to be visually appealing, drawing the eye to every optical detail of objects that are faithfully formed with paint and brush.

Figure 162: *Still Life* by Pieter Claesz, 1627. Still life did not develop into its own distinct style until the 17th century. Pieter Claesz in Haarlem specialized in these still lifes, devising different arrangements to display all dimensions of common objects. Link to Timken Museum.

Willem Kalf includes a lemon in this still life, maximizing its view with a sliced and unwound peel (Fig. 163). The lemon is deliberately exposed for dissection to the curious eye, not sitting in a fruit bowl. The many other objects are rare collectibles to interest the wealthy, a common theme used by high-end artists like Kalf and Claesz (Fig. 165).

Figure 163: *Still Life with Ewer and Basin, Fruit, Nautilus Cup and other Objects* by Willem Kalf, ca. 1660 Link to Museo Nacional Thyssen-Bornemisza, Madrid.

DAVID HOCKNEY came to alternative optical conclusion when looking at a still life by Juan van der Hamen y León (Fig. 164). [23] The grapes, sliced melon, and sliced pomegranates are painted separately. None would have remained fresh by the time that another was painted. This work is a montage of separately painted objects, each captured in a snapshot moment of time much briefer than painting requires.

[23] David Hockney. *Secret Knowledge*. Viking Studio, New York, 2006. ISBN 978-0-14-200512-5

Figure 164: *Still Life with Fruit and Glassware* by Juan van der Hamen y León, 1626. The Museum of Fine Arts, Houston

Figure 165: *Still Life with Tazza* by Pieter Claesz, 1636. Various objects strewn on a table, including sliced lemon. The tazza is the lavishly decorated silver drinking vessel. Link to Mauritshuis

THE NORTHERN EUROPEAN view of paintings being mirrored reflections of reality might be observed in the trend during the Dutch Golden Age of picture frames coming to resembling mirror frames, as in a painting by Gabriël Metsu (1629-1667).

Figure 166: *Woman Reading a Letter by Metsu, 1665-1667*. Metsu was better known than Vermeer. A woman reads a letter, seated by a window. She is elegantly dressed, and has put aside her embroidery to read a letter. Beside her, a maid draws aside a curtain to reveal a painting of a naval scene. Link to Wikipedia.

The progression of Northern European art towards realism contrasts to its contemporary progression in Italy, where different tastes and attitudes prevailed. A famous complain is attributed to Michelangelo:

> In Flanders they paint with a view to external exactness or such things as may cheer you and of which you cannot speak ill, as for example saints and prophets. They paint stuffs and masonry, the green grass of the fields, the shadow of trees, and rivers and bridges, which they call landscapes, with many figures on this side and many figures on that. And all this, though it pleases some persons, is done without reason or art, without symmetry or proportion, without skilful choice or boldness and, finally, without substance or vigour.

The Italian mode tended toward the idealistic, towards images constructed in the mind and shaped by mathematical or aesthetic judgment, towards geometrically coherent spaces organized by linear perspective – epitomized by Raphael's *School of Athens* (Fig. 167) – or human figures with ideal proportions – epitomized by Michelangelo's work on the Sistine Chapel (Fig. 168).

Figure 167: *School of Athens* by Raphael, 1509-1511.

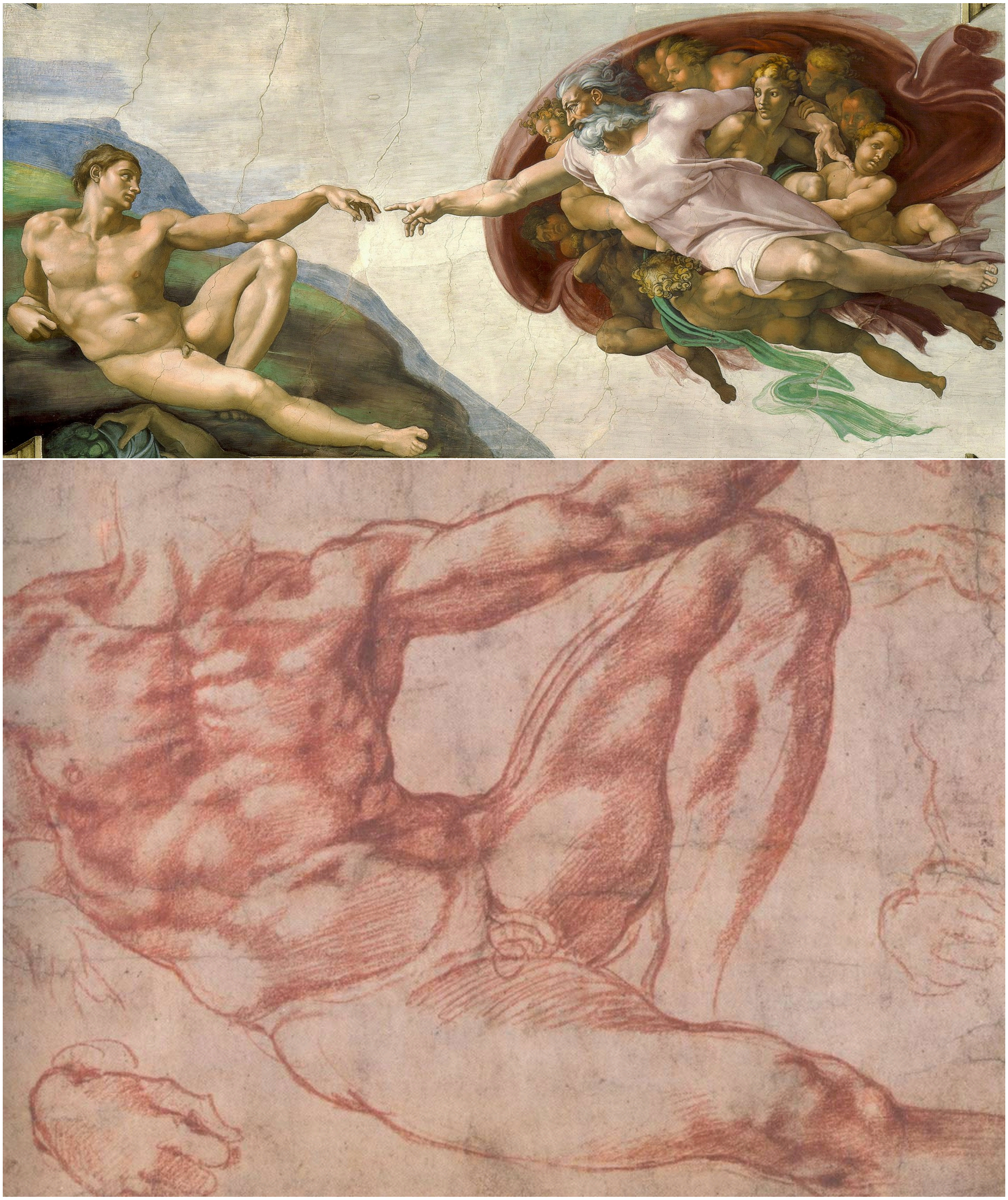

Figure 168: *Creation of Adam* by Michelangelo, 1512 and red chalk study showing his efforts towards achieving ideal human form.

Pieter Saenredam (1597-1665) was a student of linear perspective, best known for his architectural paintings of Dutch church interiors. Lines of convergence sweep upwards and downwards evoking linear perspective, at first glance evoking spaces constructed by Rafael's *The Temple of Athens* and della Francesca's *The Flagellation*. But, in fact, perspective was only a loose underpinning. Saenredaam did not construct the space using the precepts of perspective, he drew what he saw, as shown by preparatory sketches (Fig. 171), and then modified these drawings when making later paintings. Linear perspective, as discovered by Brunelleschi and described by Alberti, requires a fixed eye on a central viewpoint. Saenredaam drew what he saw with his moving eye, looking leftward for the sketch on the left, looking rightward for the sketch on the right, moving his eye all each architectural view as he sketched. The right sketch would be used for the painting now in the National Gallery in London (Fig. 170). The left sketch would be used for the painting now in the Kimbell Art Museum in Houston (Fig. 169).

Figure 170: *The Interior of the Buurkerk at Utrecht* by Pieter Saenredam, 1644. The Buurkerk was constructed between the thirteenth and fifteenth centuries but had been remodeled by the Dutch Golden Age in the unadorned Protestant style that Saenredam paints. Multicolored walls have been whitewashed. Catholic altarpieces have been removed. Link to National Gallery in London.

Figure 169: *The Interior of the Buurkerk at Utrecht* by Pieter Saenredam, 1644.Link to Kimbell Art Museum.

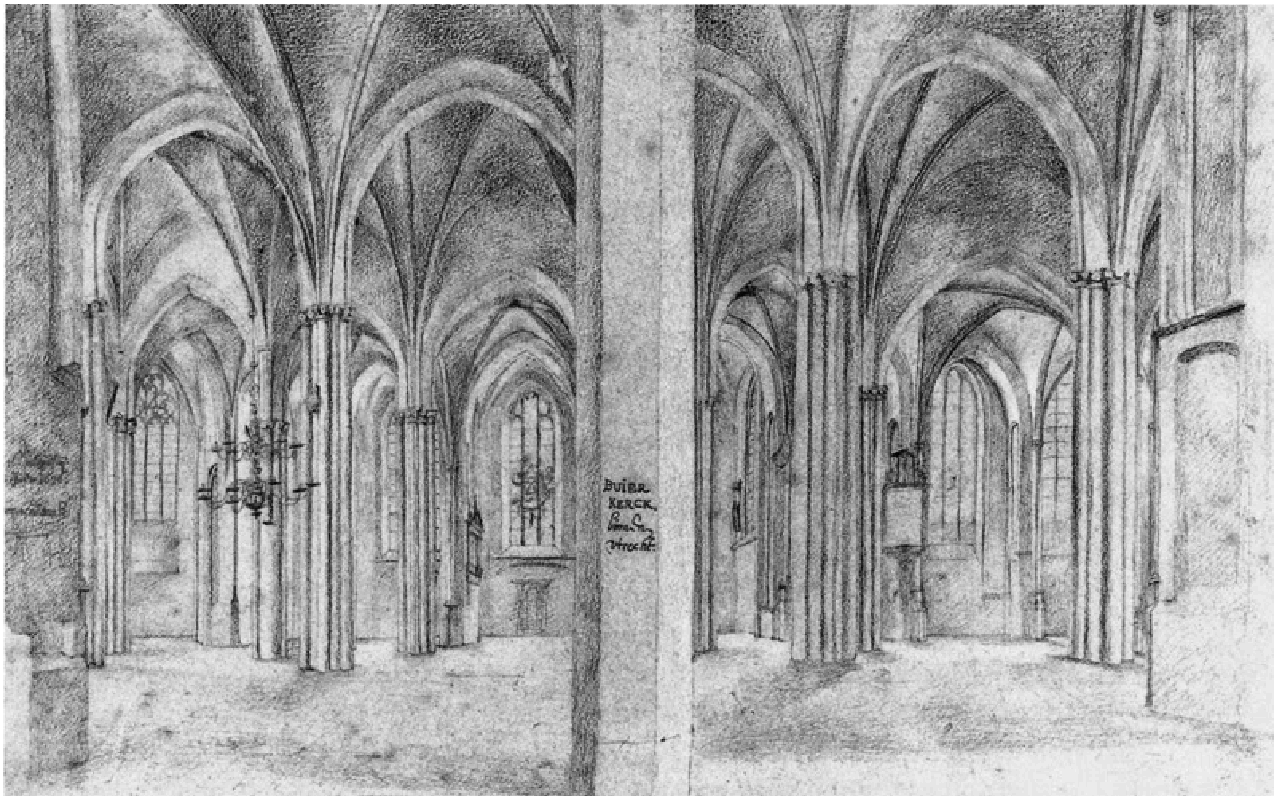

Figure 171: *The Interior of the Buurkerk at Utrecht* by Pieter Saenredam, preparatory drawings in pen and chalk on paper.

SAENREDAAM'S PAINTING of the St. Bavo Church in Haarlem in the Museum of Fine Arts in Boston depicts a pronounced departure from reality (Fig. 172). Saenredam painted this church over twenty times. Here, he purposely tilted converging perspective lines to heighten the nave.

Figure 172: *St. Bavo Church* by Pieter Saenredam, 1660. Link to MFA

SVETLANA ALPERS in her study of the unique character of the Dutch Golden Age, *The Art of Describing*, see Saenredaam's paintings of churches as one instance of the 'mapping impulse' of Dutch Art. Making accurate and beautiful maps is another explicit synthesis of art and science. The more detailed and reliable a depiction of the visible world, the more useful a map will be. During the 17th century, Dutch first began to use maps as decorative wall hangings. The deep interest in owing maps stems from the expeditions of the Dutch navy and merchant fleet, the source of wealth that underpinned Dutch achievements in art and science, wealth lavishly displayed in the newly genre of the still life.

Figure 173: *Young Woman with a Water Pitcher* by Vermeer, ca. 1662. Link to Google Arts and Culture.

VERMEER had an abiding interest in maps, used as props in many works. The only two lone male figures in his paintings – *The Astronomer* and *The Geographer* – are both map-makers in their professions. *The Art of Painting*, made near the end of Vermeer's career, also includes its largest and most extravagant map (Fig. 176). Vermeer paints its map of the Netherlands with exquisite detail, far more carefully than another contemporary painting that used the same map as a prop (Fig. 177, there is one surviving copy of the same 17th-century map in Paris). Vermeer uniquely signs *The Art of Painting* by signing the map itself, asserting himself as both artist and maker of maps.

Figure 174: *Woman Reading a Letter* by Vermeer, c. 1663. Link to Google Arts and Culture.

Figure 175: *Young Woman with a Lute* by Vermeer, ca. 1662–63, Link to Google Arts and Culture

Figure 176: *The Art of Painting* by Vermeer, ca. 1666/68, Link to Google Arts and Culture

Figure 177: *The Music Lesson* by Jacob Ochtervelt (1634-1682), 1671. Link to Art Institute of Chicago

Painting

- Nard Kwast, Dutch reality TV star known for his recreation of Rembrandt's *Nightwatch* in the Rijksmuseum will lead a workshop to paint a Dutch Still Life. Link to slides

Reading

- Introduction of *The Art of Describing* Download entire book
- Review of *The Art of Describing* Download paper

Bibliography

- Svetlana Alpers. *The Art of Describing*. University of Chicago Press, 1983. ISBN 978-0-226-01513-2
- Nick Lane. The unseen world: reflections on leeuwenhoek (1677) 'concerning little animals'. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1666):20140344, 2015
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- E H Gombrich. "the art of describing: Dutch art in the seventeenth century" by svetlana alpers (book review). *The New York Review of Books*, 30(17):13, 1983. ISSN 0028-7504

Updated: April 6, 2024

Week Ten - Camera perspectives

Thursday, 4 April 2024, 12:45 - 2:45 PM EST.
Northwest Building Room 243

David Hockney quipped that "Photography is all right if you don't mind looking at the world from the point of view of a paralyzed Cyclops." Here, the paralyzed Cyclops is the viewer locked into seeing linear perspective as discovered by Brunelleschi and described by Alberti. Hockney recognizes that we don't typically look at the world from a single, static viewpoint.

> When a human being is looking at a scene the questions are: What do I see first? What do I see second? What do I see third? A photograph sees it all at once – in one click of the lens from a single point of view – but we don't. And its the fact that it takes us time to see it that makes the space.

Across history, creating two-dimensional artistic representations has been in tension with the reality of our human perception of our three-dimensional world. Just pointing and clicking with a digital camera is an expedient solution, but a solution that is fixed to the prevailing viewpoint of 15 th century Florence.

Stereoscopic vision, simply using two eyes, is inconsistent with the premise of the illusion created by Brunelleschi's linear perspective, built from the fixed viewpoint of one eye. Our visual systems not only integrate information from two eyes, but also integrate information over time, dynamically building an internal representation of external scenes as our eyes wander over space. Beyond seeing three-dimensions with geometry, we use additional evidence from shade and luminosity. *Chiaroscuro* is the artistic use of light and dark to model three-dimensional volumes. Because many integrated processes in the human brain create our perceptions of our three-dimensional worlds, it was hard for Brunelleschi to 'discover' linear perspective. Brunelleschi had to limit himself to seeing like Hockney's paralyzed Cyclops. Artists have to battle their own brains to mimic the workings of the simply point-and-click camera that automatically projects three-dimensional spaces onto two-dimensional images.

Figure 178: Rembrandt self-portraits. Top: c. 1637, red chalk, Link to National Gallery. Middle: 1630, etching on laid paper, Link to National Gallery. Bottom: 1638, etching on laid paper, Link to National Gallery. .

One trick that helps in drawing a three-dimensional scene is to handicap oneself by eliminating stereoscopic vision. To do this, just close one eye. With one eye, we are stereoblind. When the field of view is flattened without stereoscopic vision, it becomes much easier to copy three-dimensional scenes onto a flat surface when drawing or painting. About 5-10% of people are naturally stereoblind due to 'lazy' or 'crossed' eyes.

When looking at self-portraits by Rembrandt, Marge Livingstone and Bevil Conway noticed an ever-present divergence in the point of his left and right eyes throughout drawings, paintings, and etchings. Rembrandt might have seen the world as flat, an inborn advantage when converting three-dimensions scenes onto flat surfaces. [24]

[24] Margaret Livingstone. *Vision and Art: The Biology of Seeing*. Harry N. Abrams, Inc., Publishers, New York, 2002. ISBN 0-8109-0406-3

Figure 179: *Self-Portrait*, Rembrandt, 1659

WHEN A THREE-DIMENSIONAL SCENE is drawn with the strict rules of linear perspective, the artist effectively chooses a vantage point that is viewed with one eye, without stereoscopic vision. The scene will only make the same geometrical sense to the beholder who maintains exactly the same viewpoint. From any other angle, the scene will be appear different. For the beholder to seem the same three-dimensional illusion intended by the artist, the beholder must be fixed to the same perspective. Artists of the Dutch Golden Age – notably two students of Rembrandt, Carel Fabritius (1622-1654) and Samuel van Hoogstraten (1627-1678) – did this with "peepshows". The peepshow is a confined three-dimensional space that is meant to be viewed with a carefully controlled perspective from one fixed point.

SAMUEL VAN HOOGSTRATEN was both artist and scholar, who wrote a well-known treatise on painting, *Introduction to the Academy of Painting, or the Visible World*. Hoogstraten's book provides the rare description of the state-of-the-art in Dutch artistic technique in the 17th century. Most of what we know has to be inferred from the paintings themselves. Hoogstraten's finest experiment with the peepshow is the *Dutch Box* in the National Gallery of London (Fig. 180).

THE DUTCH BOX has two high lateral eye holes in its end walls that control views into the interior. The interior walls and ceiling are painted with an awareness of anamorphosis, and compromises made for the two separate views. Conspicuous shifts in anamorphosis occur at the junctions between the orthogonal panels because of the abrupt changes in viewing angle. *Pentimenti* suggest that Hoogstraten worked out many of the perspectival problems by trial and error, looking through the peephole and making adjustments as needed.[25]

Figure 180: *The Dutch Box* by van Hoogstraten, 1655-1660

[25] Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

Carel Fabritius has been called the most brilliant of Rembrandt's students. Little remains of his work. He was killed by the Delft gunpowder explosion on 12 October 1654, destroying his studio and many of his paintings. About a dozen paintings survive, including *The Goldfinch* and his *View of Delft*. Fabritius's *View of Delft* reveals a fascination with a wide-angle perspective, reminiscent of the panoramic photographs now taken with modern smartphones captured by an angular sweep across a field of view. One theory is that Fabritius's painting was originally mounted on a curved surface in a rounded perspective box. [26] The painting is currently displayed in the National Gallery in London on a flat panel.

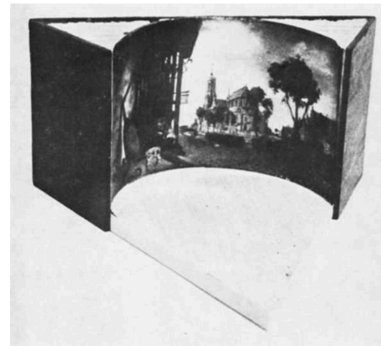

Figure 181: Interior view of a reconstruction of a perspective box that might have contained Fabritius's *View of Delft*.

[26] Walter Liedtke. The 'View of Delft' by Carel Fabritius. *The Burlington Magazine*, 118:61 – 73, 1976

Figure 182: *The View of Delft* by Fabritius, 1652. This very small painting (15x30 cm) is a view of the Nieuwe Kerk in Delft. Perspective is emphasized by two musical instruments, typical virtuoso subjects for foreshortening. The violin recedes into picture space, as if very close to the viewer. The church loom forward, and the street bends as if curved by a lens. Link to National Gallery.

DELFT IS DIFFERENT across its many different views, from the perspective painting by Fabritius in 1652 to the quietude of its painting by Vermeer in 1661. In the intervening years, Delft was shattered by a gunpowder explosion, equivalent to 22 tons of TNT, that destroyed a quarter of the city and hundreds or thousands of inhabitants, including Fabritius. The explosion and its aftermath were painted by Egbert van der Poel. Vermeer's Delft willfully omits grim realities of life in a city afflicted by regular cycles of war and plague.

Figure 183: *A View of Delft after the Explosion of 1654* by Egbert van der Poel, 1654, Link to National Gallery.

Figure 184: *A View of Delft During the Explosion of 1654* by Egbert van der Poel, 1654, Link to Rijksmuseum.

WE NEVER LOOK AT PAINTINGS WITH STILL EYES. The experimental psychologist Alfred Yarbus (1914-1986) pioneered the study of eye movement in perception, tracking the eye of a viewer while something was being viewed. When we look at a painting, our eyes are in constant motion, rapidly scanning, concentrating our foveal (high acuity) vision on alternating areas of interest.

Figure 185: *They did not expect him.* by Ilya Repin, 1888, and Yarbus's tracking experiment that followed a viewer's eyes as it viewed the same painting.

MARGARET LIVINGSTONE discovered that the moving eye might explain the enigma of Mona Lisa's smile. Viewers had long noted that Mona Lisa's smile flickers in and out. When looking at Mona Lisa's eyes with high acuity foveal vision, you see her mouth with low acuity peripheral vision. The low spatial frequencies of the shadows around her mouth increase its apparent curvature... she smiles. When you look directly at Mona Lisa's mouth, you see its lines that are drawn less curved... she does not smile.

Figure 186: Mona Lisa's elusive smile is due to her smile being painted with low spatial frequency shadowing, seen best by peripheral vision. Three images show her face filtered to show lowest (left) low (middle) and high (right) spatial frequencies.

Updated: April 6, 2024

DIMENSIONALITY IS A FUNDAMENTAL DILEMMA that confronts any artist trying to create 2-dimensional images of higher dimensional realities. In *Corpus Hypercubus*, Salvador Dali depicts Christ crucified on a tesseract, a four-dimensional cube (or hypercube) projected onto 2-dimensional space.

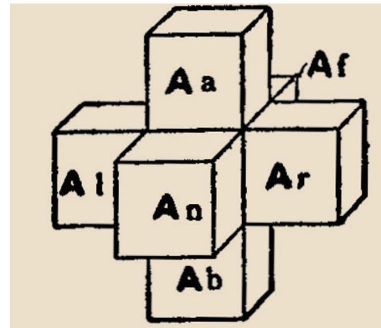

Figure 187: *Hypercube* by Charles Hinton, 1912.

Figure 188: *Crucifixion (Corpus Hypercubus)* by Salvador Dalí, 1954.Link to Metropolitan Museum of Art.

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Figure 189: *Enthroned Madonna and Child*. Byzantine, 13th century. Link to painting at Google Arts and Culture

BEFORE BRUNELLESCHI "DISCOVERED" LINEAR PERSPECTIVE, artists may have appreciated its limitations and invented their own workarounds. Byzantium thrived for centuries after the fall of Rome and before the Renaissance. Byzantine artists apparently thought hard about rendering three-dimensional space onto two-dimensional surfaces.

BYZANTINE PERSPECTIVE or 'reverse perspective' was a means of depiction that tried to capture *more* than is possible with linear perspective. The lines of perspective in the *Enthroned Madonna and Child* on the throne and footstool converge towards the viewer, not towards a central vanishing point as in linear perspective (Fig. 189). The result is an intentional and simultaneous view of all planes of the object. The perspective is called 'reversed' because the depicted objects are between the projective point and the viewing plane, not behind the viewing plane as in linear perspective (Fig. 191). In an Icon of St. John the Baptist painted in Constantinople in 1300, the multiple planes of the face, nose, neck appear to be turned forward. Here, many viewing surfaces are combined in one painterly view (Fig. 190).

Figure 190: Icon with St. John the Baptist, c.1300, Constantinople. Link to British Museum

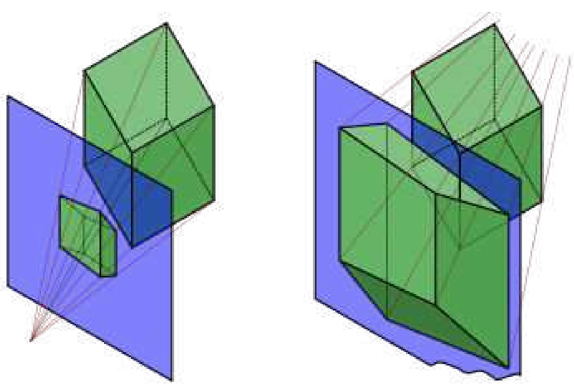

Figure 191: Linear perspective of a cube (left) and reverse perspective (right). The viewing plane is shown in blue, with the projection point where the red lines meet. Link to Wikipedia

LINEAR PERSPECTIVE is a choice, not an inexorable step in the evolution of art. While 15th century Florentines were discovering and painting their own illusions of three-dimensional space, sophisticated artists that were deeply grounded in their own traditions of science, technology, and mathematics were advancing on their own in different directions (Fig. 192). *The Story of Haftvad and the Worm*, painted in Iran in 1540, tells a story of Haftvad eating an apple in the shade of a tree, and who spares the life of the maggot in the fruit. The story of the entire town is told in the different areas of the painting, a sophisticated rendering of three-dimensional space without attention to the laws of linear perspective. Persian mathematics and geometry were extremely sophisticated when Dust Muhammad painted this scene. This artist did not limit himself to the rules of linear perspective.

Figure 192: *Story of Haftvad and the Worm*, c.1540, by Dust Muhammad in Safavid Iran. Link to Painting

DAVID HOCKNEY learned about Byzantine perspective from Martin Kemp, and found ways to incorporate its effects into modern painting. *The Avenue at Middelharnis* by Meindert Hobbema uses trees along an avenue to define strongly converging lines of linear perspective. This landscape is painted within a three-dimensional grid that controls the entire scene. David Hockney made his own version in 2017, *Tall Dutch Trees After Hobbema (Useful Knowledge).* Hockney dissected the scenes onto different panels, turning some panels inside-out by painting them in reverse perspective (Fig. 194)!

Figure 193: *The Avenue at Middelharnis* by Meindert Hobbema, 1689, Link to National Gallery.

Figure 194: *Tall Dutch Trees After Hobbema (Useful Knowledge)* by David Hockney, 2017.

David Hockney did many experiments on multi-point perspective using photography. David Hockney's photocollage of a chair combines views from many different perspectives into one image, but retains the recognizable shape of the chair and its sense of depth (Figure 195). We can try similar experiments with a camera and Adobe Photoshop.

Figure 195: *Chair Jardin de Luxembourg* (1985) by David Hockney

ABE MORELL found his own way to explode the dimensionality of the one-point perspective of the photographic camera. With long exposures and ultra-high resolution, he takes photographs *inside* camera obscuras made from darkened rooms with single controlled pinholes and his own traveling tent.

Figure 196: *View of Lower Manhattan, Sunrise* by Abe Morell, 2022.

Looking

- Abe Morell's Slide Show. Link to slides

Reading

- *The Camera Lucida* by Roland Barthes Download entire book

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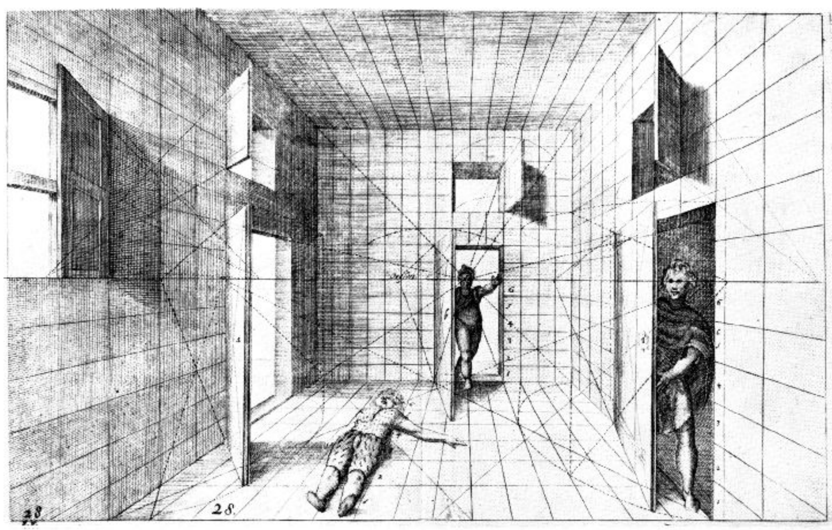
Figure 197: *Water Lilies in Monet's Garden* by Abe Morell, 2023, taken with tent camera obscura.

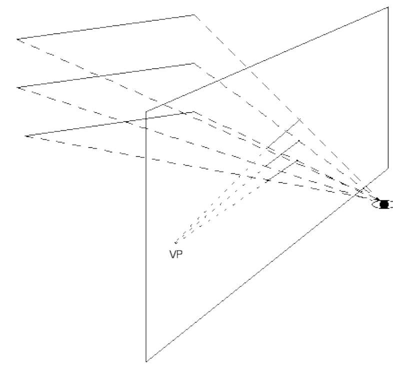
Appendix I - The Rules of Perspective by Chris W. Taylor

Linear perspective has a history going back at least to Aristarchus, a scene painter for Aeschylus in the 4th century BC who astonished his audience, including Plato, with his realistic depiction of depth by size reduction in the spatial layout of buildings. This Greek expertise was transmitted to the Roman Empire in the accurate central vanishing points in evidence in the wall-paintings of Pompeii, for example. The development of Renaissance one-point perspective may be traced over the 14th and 15th centuries. The elaboration of two-point perspective took another two centuries. Three-point perspective did not come into widespread use until well after the invention of photography, when the flexible availability of tilted camera angles revealed its visual effectiveness.



Jan Vredeman de Vries, *Perspective* (Leiden, 1604–5), plate 28. Courtesy, the Bancroft Library, Berkeley, California.

The following is an attempt to distill the rules of perspective into an elementary form that may be easily applied in practice. They are first stated in brief form, then elaborated to convey the rationale and significance of each of the rules.



The Rules of Perspective are first stated in their most direct form, then elaborated.

1. There is only one geometry of perspective projection onto a fixed picture plane.
2. All straight lines in space project to straight lines (or points, if end on) in the picture plane.
3. The projections of all lines that are parallel in space either remain parallel in the picture plane or intersect at a single vanishing point.
4. All sets of parallel lines lying within a specified plane in space have vanishing points that fall along the horizon line defined by the orientation of that plane.
5. For two sets of parallel lines at some angle in the scene, the two vanishing points form that same angle at the viewer's eye, regardless of the orientation of the angle in space. In particular, the vanishing points for any 90° angle in space form a 90° angle at the viewer's eye.
6. Any planar figure in space is foreshortened in the direction of its slant from the observer (up to a 45° viewing angle).
7. Circles in the scene, if foreshortened, project to ellipses in the picture plane.
8. For correct projection of its perspective, a picture should be viewed from its center of projection in space.
9. When the eye is at the center of projection, the perspective geometry in the picture plane is independent of where in the plane the eye is looking.

Implications of the Rules of Perspective

1. There is only one geometry of perspective projection onto a fixed picture plane. Perspective is the geometry of projection from a scene through a plane to a point (or center of projection) corresponding to the pupil of the viewing eye. The plane is the picture plane on which the painter wishes to depict the scene. If the perspective is correct, the depiction on the plane will generate the same projective structure at the eye as did the scene behind it. The different forms of perspective construction concern the rules that apply to specific structures, allowing simplified forms of the projective geometry to be codified. But all are subcases of the same optical transform.
2. All straight lines in space project to straight lines (or points, if end on) in the picture plane. This fact is a simple consequence of the geometry of projection through a point in space (corresponding to the pupil of one eye). If a line is parallel to the picture plane, it must project to a straight line on that plane by virtue of similar triangles. Obviously, tilting the line within the plane of projection will not introduce any curvature, just a change in its extent within the line of projection. In the limit, the projected line may contract to a point in the picture plane when the line is viewed head on. Lines of any orientation can be described by this construction. Thus, all such point projections are to straight lines or points.
   (a) Introducing lens optics, as in the human eye, introduces the potential for curvature in the projection. Such curvature may consequently be a property of human perception at the extrema of the field, but the laws of perspective will be considered to be those of the point projection of pinhole optics, which permit no curvature.
   (b) Humans actually view scenes with two eyes, but the straight-line projections in each eye are both straight lines. The average, or binocularly-fused, projections is therefore also a straight line. No curvature is introduced by the geometry of binocular combination.
3. The projections of all lines that are parallel in space either remain parallel in the picture plane or intersect at a single vanishing point. This common intersection is valid for each entire set of parallels regardless of where in the visual field the lines arise. Each set of parallel lines intersects at a different vanishing point, of course. Thus, the first job in perspective projection is to identify all the lines in the scene that are parallel to a given line, then make sure that they are drawn so as to project to a common vanishing point.
   (a) Parallel lines in space that are also parallel to the picture plane remain parallel to each other in the projection. This leads to the particular case of central perspective, in which all the lines on the scene are either parallel with the line of sight or at right angles to it, parallel with the picture plane. The first set will be horizontal and receding from a viewer looking straight ahead. The vanishing point for this first set is directly in front of the viewer, making a central point of convergence for these horizontal receding lines. The second set consists of any lines at right angles to the first set, thus at any angle within the picture plane. These lines, such as the verticals of the sides of buildings, will all remain parallel within the picture plane if they were parallel in space. Note that what makes central perspective central is simply the choice of lines present in the scene. Perspective itself is universal, an optical projection of the light rays.
   (b) The corollary of the central perspective construction is that it is implicitly incorrect to set the "central" vanishing point is away from the viewing center of the picture. This modification was employed in the mid Renaissance, where the "central" vanishing point may have been moved even to a point beyond the edge of the picture. The "frontal" sides of all the squares nevertheless remained parallel

in such constructions (usually horizontal and vertical), so that the perspective is incorrect unless the picture is expected to be viewed from the unlikely position of directly front of the shifted vanishing point.

4. All sets of parallel lines lying within a specified plane in space have vanishing points that fall along the horizon line defined by the orientation of that plane. The particular case is the ground plane. All sets of parallel lines in the ground plane have vanishing points in the horizon line. (The fact that the earth is not flat means that it does not strictly conform to a ground plane, defined geometrically. The deviation is generally too small to be of consequence in art.)
   (a) Rules 3 and 4 may be combined to consider the vanishing points not just for lines within a single plane but within a sheaf or stack of parallel planes. All lines on all parallel planes still have vanishing points falling along the same line. For example, all lines on or parallel with the ceiling or floor have vanishing points in the line of the horizon, as do all horizontal edges of doors and casement windows. But all the lines at angles on the sides of a Ferris wheel, for example, would have vanishing points in a vertical line.
5. For two sets of parallel lines at some angle in the scene, the two vanishing points form that same angle at the viewer's eye, regardless of the orientation of the angle in space. In particular, the vanishing points for any 90° angle in space form a 90° angle at the viewer's eye. In particular, the vanishing points for any right angle in space form a 90° angle at the observer's eye. This result may be seen by considering the member of their respective parallel bundles, coming directly toward the viewer's eye. These lines form the same angle as any other pair from the two bundles. Their angle at the eye, and hence the viewing angle between the vanishing points, therefore match the angle of the lines in space.
   (a) A classic case of this rule is the diagonals of any square, which are always at 90° to each other. The vanishing points (or "distance points", Leonardo, 1492) for these diagonals should therefore form a 90° angle at the center of projection, regardless of their orientation in space. Twist the angle in any direction whatever in three-dimensional space (even to the point of complete foreshortening) and the vanishing points will nonetheless hold to a strict 90° angle at the viewer's eye. In terms of pictorial distance, this angle between the vanishing points corresponds to the same distance in the picture plane except for the tan transform for projection of the equal angles at the eye onto the plane.
   (b) The corollary of this principle is that, if the vanishing point in central perspective is displaced from the center of view, the simplicity of the central perspective construction has been violated and a second vanishing point arises at 90° from this displaced vanishing point (for lines in the same plane). In fact, an entire crescent of vanishing points is required to accommodate lines of all orientations, aligned diametrically opposite the direction of the displacement.
6. Any planar figure in space is foreshortened in the direction of its slant from the observer (up to a 45° viewing angle). In particular, any square in space must be foreshortened in the direction of its slant, even for the projection outside the frame up to the range defined by the vanishing points. Beyond that, the foreshortening becomes lengthening, but this will occur outside the range of almost any picture (unless its edges extend beyond a 45° angle from the line of sight).
   (a) The degree of foreshortening of a square of central perspective is defined by its diagonals, which should project to vanishing points at a 90° angle to the viewer. Thus, the vanishing point for the corners of horizontal squares in central perspective should be at 45° to (and at the same height as) the central vanishing point. The intersection of the diagonals with the cardinal grid defines the degree

of progressive foreshortening of the receding squares. This geometry of a second vanishing point to set the spacing of the horizontals corresponds to one version of the costruzione legittima, or distance point method, of Leonardo (1492).

(b) In general, foreshortening follows the construction of the multiple implicit vanishing points even in central perspective, which is conceptualized as having only a single vanishing point. As long as there are intersecting lines in the scene, as there will be in any piazza grid, the vanishing points for the construction lines through the intersections must obey rules 2, 3 and 5, lying in the same line at the horizon of the plane and at same angle to the viewer as the intersections of the lines themselves in space.

(c) The progressive foreshortening as equal divisions recede in space gives a sense of curvature to the perspective transform of a regular array. All the lines are straight, but the array elements change shape as they recede, violating one's expectation of self-similarity. On top of this gradient of shape, the line thickness in virtually all perspective diagrams does not vary as it should in true perspective. Thus, the lines form an increasing proportion of the element area and perhaps induce a sense of distortion in an otherwise correct transform.

7. Circles in the scene, if foreshortened, project to ellipses in the picture plane. Although perspective distorts rectangles to asymmetric trapezoids in general, the properties of circles are such that they always project to an ellipse of some orientation. If the circle is parallel to the picture plane, it projects to a circle, which is the limiting case of an ellipse with no bias.

   (a) The projection for a circle may be derived by inscribing it in a square, for which the previous rules define the perspective distortion. The requisite ellipse is then obtained by inscribing it within the trapezoid obtained from the projection of this square. In practice, this ellipse may be selected from a set of ellipse templates as the one that just touches all four sides of the trapezoid without crossing them at any point. These constraints uniquely define the correct ellipse, since an ellipse is defined by four points in the plane (as a circle is defined by three points). The four 'touches' define four points and the avoidance of crossing anywhere provides the fifth constraint.

   (b) The center of the requisite ellipse does not correspond with the center of the circle being projected, but it displaced away from the vanishing point and toward the observer. The projected center of the circle may be determined by drawing the diagonals for the trapezoid, which intersect at the center of the projected circle. The degree of displacement may be determined by drawing the major an minor axes of the ellipse. The intersection of these axes defines its geometric center, which will be displaced from the projected center of the circle.

   (c) Spheres in space also project to ellipses in the picture plane, although generally with much less distortion than circles because the roundness of the spheres means that they are never foreshortened. Spheres always project to circles when at the center of projection. The elongation arises only because of marginal distortion, the stretching of the image as the picture plane itself recedes from the viewer at increasing angles of view. The requisite ellipse may be obtained by first projecting the sphere to a circle in a plane at right angles to the line of sight through its center, then projecting this circle to the picture plane. The major axis of the resulting ellipse is thus aligned with the axis of rotation of this projection and its ellipticity from the cosine of the (dihedral) angle between the intermediate and final projection planes.

8. For correct projection of its perspective, a picture should be viewed from its center of projection in space. In terms of distance, Rule 5 implies that the vanishing points for lines at right angles should

be viewed so as to be orthogonal, forming 90° angle at the viewing position. Any parallel pair of right angles in the picture thus defines its correct viewing distance, by defining two orthogonal vanishing points. In terms of angle, the plane of the picture should be viewed at the angle of slant for which the perspective was designed. Other viewing angles, away from the center of projection in any direction, will result in perspective distortion.

(a) For the particular case of central perspective based on a square grid aligned with the line of sight, the 45° angle between the diagonals and the line of sight means that the distance points should have a 45° to the main vanishing point at the viewer's eye. The geometry between the eye, the central vanishing point and a distance point is therefore a 45° triangle, which means that the picture is correctly viewed at the distance that matches the span to each distance point. The physical distance between the vanishing points depends on the intended viewing distance, but a good rule of thumb is that it should correspond to a distance of at least twice the width of the picture. Leonardo recommended at least 20 times the height of the largest objects depicted.

(b) Telephoto distortion and its limiting case, orthographic projection, conversely, represent a strong magnification of the image in true perspective. If a tiny piece of the scene is magnified, the distance of its vanishing points is correspondingly magnified. The effect may be so extreme that the rear of the object looks as though it curls up toward the front of that object. The perceived distortion is so strong that it has been termed "reverse perspective", as though the lines which should be converging were in fact diverging. The effect is particularly strong in orthographic projection, where parallel lines in spaces are drawn as parallel in the picture, as though it were viewed from an infinite distance. Nevertheless, the perceived "reversal" is an illusion obtained simply from abnormally distant projection. Despite the distorted appearance, telephoto distortion is a valid perspective projection if viewed at the correct distance (although the scene may in practice be invisible at that distance).

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(a) The center of view in the picture should not be confused with the line of sight of the viewer. The center of view is the point in the picture plane closest to the viewer. The line of sight is the direction in which the viewer's eye is pointing, which may be anywhere within (or outside) the picture. Where the viewer samples the optic array does not affect the correctness of the perspective. The perspective is correct when the viewer's eye is placed at the center of projection in space for which the perspective was generated (regardless of the direction of the line of sight).

(b) This point is contentious because most authors agree that the perspective projection changes with viewing angle. Presumably this misconception arises because lines that are parallel in central projection of a scene appear to converge as the viewer looks to the side. This observation, however, implicitly assumes that the relevant picture plane is rotated with the rotation of the line of sight. Rule 9 refers instead to an observer viewing a fixed picture, projecting an optic array to the viewer's eye. In this case, if the observer's eye looks away from the center of view, the picture plane itself will project to the eye with a perspective transform. It is the perspective distortion of this picture plane that provides the convergence of the parallel lines in oblique view, just as in the physical scene itself. Thus the correct geometry for perspective in the picture plane is indeed independent of the direction in which the viewer is looking at this plane (assuming the eye stays at the center of projection).

(c) As long as the viewer is directly in front of the central vanishing point (and the picture plane is frontoparallel), the verticals project to parallel lines in the picture plane (Rule 3A). Once the main vanishing point is moved up or down from the viewer's eye position, the verticals are required to converge so as to make an angle of 90° to the direction of this vanishing point (Rule 5).

Appendix II - Essay by ChatGPT 3.5

Harold Cohen and Generative Art: A Contemporary Dialogue with Piero della Francesca

Generative art, a form of artistic expression that leverages algorithms and computational processes to produce unique visual compositions, has emerged as a significant facet of contemporary art. Among the pioneers of generative art stands Harold Cohen, an artist and computer scientist whose work transcends traditional boundaries, engaging with the computational realm to create compelling and thought-provoking pieces. This essay explores the life and work of Harold Cohen in the context of generative art, drawing connections to the Renaissance master Piero della Francesca and his painting *The Flagellation.*

Harold Cohen's Journey. Born in London in 1928, Harold Cohen began his artistic journey as a painter and eventually transitioned to explore the intersection of art and technology. In the late 1960s, Cohen started developing AARON, a computer program designed to autonomously generate artworks. AARON evolved over the years, showcasing an extraordinary capacity for creativity and a unique blend of human intuition and algorithmic precision.

Generative Art and AARON. Cohen's generative art challenges conventional notions of authorship and creativity. AARON, equipped with a set of rules and parameters defined by Cohen, autonomously generates visual compositions, demonstrating a form of artificial creativity. Cohen's intent was not to replace human artists but to collaborate with the machine, pushing the boundaries of what is conceivable in artistic creation.

Piero della Francesca's The Flagellation. To contextualize Cohen's work, it is crucial to revisit the Renaissance era and explore the art of Piero della Francesca. *The Flagellation*, a masterpiece created in the 15th century, is a poignant representation of the biblical event where Christ is flogged before his crucifixion. Piero's meticulous composition, geometric precision, and use of color convey a sense of harmony and order that resonates with mathematical beauty.

Connections between Cohen and Piero. The parallels between Cohen's generative art and Piero's meticulous approach are evident. Both artists engage with underlying structures—whether algorithmic or geometric—to create visually compelling pieces. While Cohen's AARON relies on computational processes, Piero's artistic practice is grounded in mathematical principles and the pursuit of harmony.

Cohen's work is not an attempt to replicate Piero's style but rather an exploration of the timeless relationship between art and structure. Both artists, separated by centuries and technological advancements, demonstrate the enduring pursuit of order, balance, and beauty in their respective works.

Conclusion. Harold Cohen's journey into generative art, as exemplified by AARON, offers a contemporary perspective on artistic creation. By exploring the intersection of art and technology, Cohen engages in a dialogue with historical masters like Piero della Francesca. The connections between Cohen's generative art and Piero's meticulous compositions underscore the enduring quest for harmony and structure in artistic expression, bridging the gap between tradition and innovation. As generative art continues to evolve, it stands as a testament to the timeless human desire to explore new avenues of creativity and redefine the boundaries of artistic practice.

Updated: April 6, 2024