2-D? 3-D? THE TECHNOLOGY AND AESTHETICS OF DIMENSION IN EARLY CINEMA AND TURN-OF-THE-CENTURY STAGE PERFORMANCE

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The links of motion pictures to the science of optics and perception are well known. For many decades any book on the history of film was essentially incomplete without a carefully charted ancestry from the camera obscura to the *cinématographe*. Concerns with dimension – how we view space – were, perhaps, secondary to photographing and projecting movement, but depth perception was no less an object of scientific and popular curiosity; consider, for example, the ubiquity of stereopticons in middle-class Victorian households. In a lecture to the Royal Photographic Society of London, reprinted in *The Moving Picture World* in 1907, Robert Thorn Haines articulated an aim for motion pictures that expresses the aesthetic basis of realism:

> *Manifestly the highest perfection that could possibly be attained would consist in the reproduction of the moving objects, in such a manner that they would appear upon the screen exactly the same in every respect as they in reality naturally do – that is to say, that in their reproduction upon the screen they should be presented to the eyes precisely as they are in nature.*[1]

The degree to which an artistic medium achieved a recognizable representation of human perception was a yardstick by which to measure, almost scientifically, its realism. Dimensionality was a primary factor in this perceptual aesthetic.

In the Western world, space has been viewed in terms of linear perspective since the early decades of the fifteenth century; in fact, the field of physics can trace important aspects of its heritage to perspective's mathematical spatial concepts. However, the scientific understanding of space does not automatically transfer to spatial perception. For instance, the *seeing* of three-dimensional space via perspective representation in a two-dimensional drawing, painting, or photograph is *taught*; perspective representation is a convention that is not necessarily natural or transcultural, and it is merely one of many cues we use to see objects in depth. Six are illustrated as follows (figure 1):

- *Size perspective* – the observer measures depth by comparing the apparent size of objects which are known to be similar in height;
- *Interposition* or occlusion – one object hides part of another from view, providing the observer with information about the objects' order in depth;

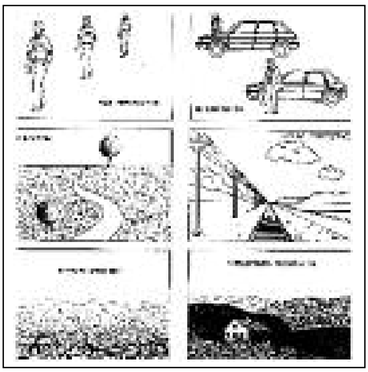


Figure 1: "Some monocular cues for the visual perception of depth"

- *Elevation* or height in the visual field – depth is determined by the observer from the comparative relationship between the bases or tops of objects;
- *Linear perspective* – information is received about the angle of convergence between the optical axes of the observer's eyes: the farther the distance, the greater the convergence;
- *Texture gradient* or regular density – the degree of texture, or similarities in a cluster of objects transmit to the observer how far or near they are to each other;
- *Atmospheric perspective* – the relative density of particles in the air (moisture, pollutants) between the observer and the scene creates sharper foreground and hazier background images.[2]

All of these cues are present in two-dimensional perspective painting, in traditional illusionistic theatre (which used scenery painted in perspective), and in photographs and motion pictures. Two additional cues are of particular importance to the aesthetics of film and stage realism:

Stereopsis – solid space is perceived due to binocular disparity;

Motion perspective – This involves motion *parallax*, the apparent displacement of a still object, due to the motion of the observer; *edge rate*, in which countable objects or edges pass a reference point, such as trees seen passing at the side of the road from the seat of an automobile; and *global flow*, which involves motion flowing all around the observer, moving most rapidly underneath the person and decreasing with distance towards the visual horizon.[3]

Although stereopsis was a technical concern of pre-cinema technology throughout the nineteenth century, it does not appear as a visual cue in two-dimensional motion pictures. In 1839, Charles Wheatstone invented the stereoscope. Methods of stereoscopic projection were in commercial use by the 1860s; audiences peered through two-color "tinters" placed in a fan or worn as spectacles – early 3-D glasses.[4] The Lumières had some success projecting moving pictures in low-stereoscopic relief in 1903, as did Famous Players Film Company in 1915,[5] but the conceptualization of the principles for stereoscopic projection outran developments in its technology. Polarized light systems were patented in the 1890s, but were not "perfected" until nearly half a century later.[6]

Haines, in *The Moving Picture World* article mentioned earlier, ranked stereoscopy as the second essential element required for cinematography to reach an ideal realism of effect. Steady projection (no flickering) was first on his list, and color was his third requirement.[7] Picture projection became smoother over the years, but like stereoscopic motion, effective (realistic) color was dependent on technical practices that took decades to develop. In the meantime, however, inventors continued to experiment, employing other cues of depth perception to increase the sense of dimension in motion pictures.

One tactic was to create physical distance between the viewers and the movie screen. According to Dennis Sharp, in *The Picture Palace and Other Buildings for the Movies*, the downstage area in front of the screen was "indispensable [...] for giving a shadow box effect around the screen and to add depth to the picture itself;" often the stages of neighborhood "Pictureplay Theatres" had permanent settings consisting of architectural features, plants, fountains, or scenes "depicted on angled flats which were meant to emphasize the three-dimensional make-believe of the picture on the screen."[8] One such arrange-

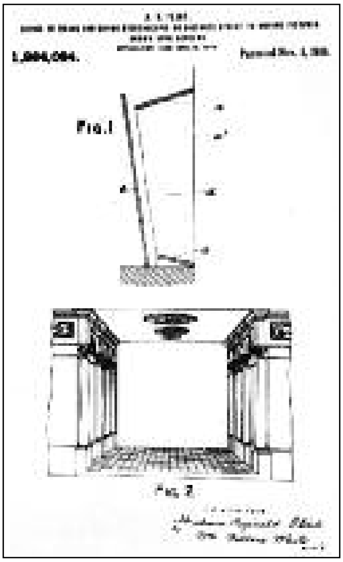


Figure 2: Flint's stereoscopic device

ment, patented by A.R. Flint in 1918, recycled an old theatre trick – forced perspective. Flint described his "Device or Means for Giving Stereoscopic or Distance Effect to Moving Pictures Shown upon Screens:" "I arrange a proscenium [...] of box or cone shape at an interval in front of the screen [...], the picture is thus exhibited as though shown at a distance through an elongated aperture" (figure 2).

Capitalizing on the visual cues of size perspective, interposition, and linear perspective, his device employed "various decorative treatments of the proscenium." The area in front of the movie screen could be designed to "harmonize with the subjects being thrown upon the screen," showing in its treatment the

rapidly vanishing sides of an apartment or a continuation of the sides of the theater, or of a street or parts of an open-air scene; the top of the proscenium may represent the ceiling of an apartment or the sky; and the bottom thereof the floor of an apartment, ground surface, sea or the like.

An illusion of depth was created, he explained, since

the eye receives a distance illusion from the surroundings and unconsciously carries this idea of gradually increasing distance into the flat picture itself, the movement of the objects shown upon the screen increasing the illusion that they actually stand in front of their background.

Binocular disparity also was intended to play a part in the dimensional enhancement:

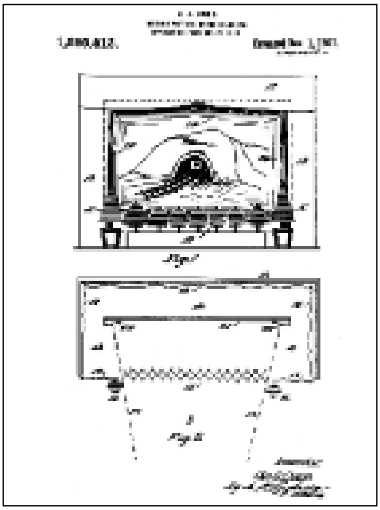


Figure 3: Owen's "Motion-Picture Stage Illusion"

The surrounding device forming an aperture in front of the picture; when the eye is fixed upon the latter the structure of the device impinges on the line of vision of each eye at a slightly different angle, the two eyes therefore do not take identical vision as they would from a flat surface, and the receipt by each eye of a different picture produces the effect of stereoscopy.[9]

Another inventor, Ole Andrew Owen, in a 1921 patent, added a specially-crafted screen to his treatment of the stage area in an attempt to "remove the suggestion of a flat surface by removing the sharp edges of the picture itself and to give it an effect such as if the picture were suspended and viewed through a tube."[10] A row of shrubbery provided an interposition cue, and the deflected edges of the ground-glass screen were designed to blend the motion picture gradually outwards, so that it faded into the shadow box of dark velvet drapes that enclosed the stage (figure 3).

Solid glass mirror-screens, as described by Robert Grau in *The Stage in the Twentieth Century* (1912), gave motion pictures a “roundness, stereoscopicness and depth, that can be produced in no other way;” transparent glass was used for rear projection.[11] Stage effects with glass screens had been in use as early as 1847, and were popularized by

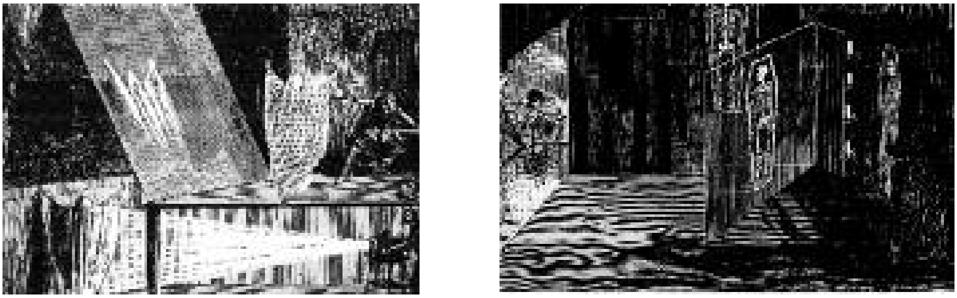


Figure 4: Engravings of two “Pepper’s Ghost” effects

Professor John Henry Pepper and Henry Dircks in the 1860s and 1870s as “Pepper’s Ghost” and the “Dircksian Phantasmagoria,” in which the movements of an offstage performer were reflected onstage onto a sheet of glass placed diagonally across the stage (figure 4).[12]

Moritz Lewin, in a 1915 patent, applied the “Pepper’s Ghost” glass-screen arrangement to a theatrical appliance, “by means of which cinematographic figures may be projected upon the stage in a plastic manner, so as to assume a very realistic appearance and to be well set off from the background.”[13] For moving pictures, Lewin’s arrangement used two projectors, one with a film of the performers (which was rear-projected onto a screen [figures 5 & 6, #11] located in the “wings” at the side of the stage), and another with a film of the scenic background (projected onto a screen upstage, from the rear [#24]). The images from the two screens were reflected together, from two directions, onto a plate-glass screen (#20). Separate projection of performer and background images had been a

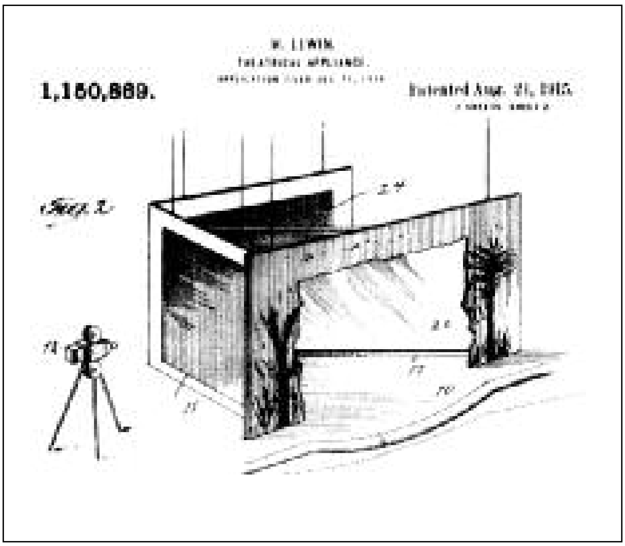


Figure 5: Lewin’s “Theatrical Appliance”

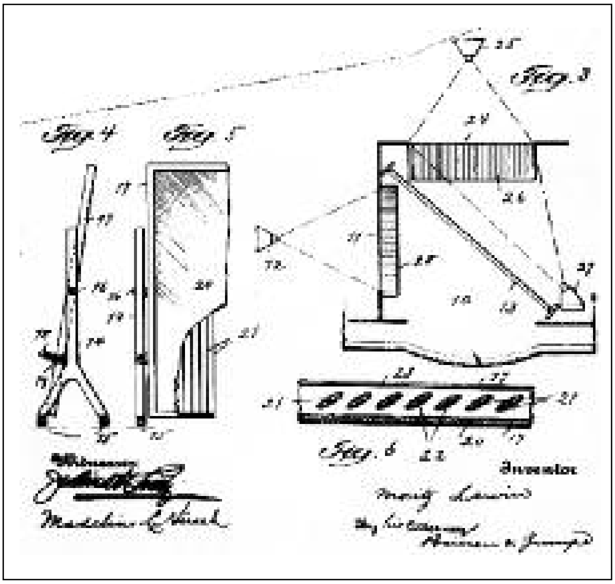


Figure 6: Side and front elevations of screen; top views of screen and stage set-up

mode of exhibition since around 1898.[14] Lewin claimed to increase the appearance of depth further with his screen's double-reflecting construction: a row of oblong glass bars, arranged behind the glass screen and backed by scrim fabric, which is opaque when lighted from the front, and transparent when lighted from the back (figure 6: front view, patent's "Fig. 5," and top view, patent's "Fig. 6").

Reflecting the motion-picture images through two thicknesses of glass, Lewin believed, caused them "to assume a plastic shape, thus resembling living and other solid bodies in space."[15]

A supplementary alternative he suggested for his patent was for a multi-media effect with motion pictures and live actors. In this case, the living actors performed atop a platform (figure 6, #26) in front of the second, upstage screen (#24) and appeared to take part in the filmed scene by positioning themselves and reacting properly as their images on the glass screen intermingled with those of the film. The 2-D and 3-D elements, in a sense, were equalized as visually consistent in the reflected picture.

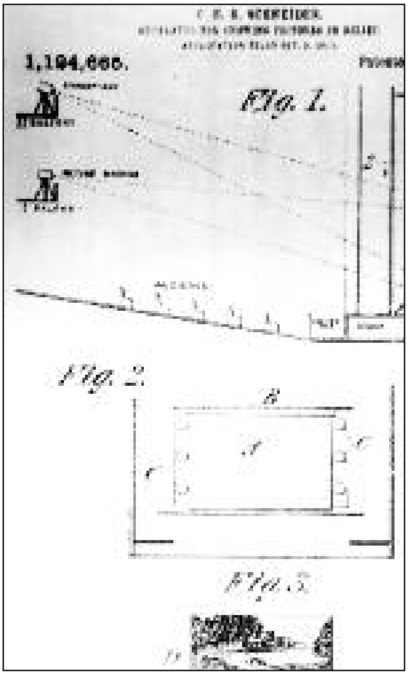


Figure 7: Schneider's "Apparatus for Showing Picture in Relief"

Another 1915 patent used similar reflecting principles. The image of moving performers (filmed or from a stereopticon device) was front-projected onto a white screen placed upstage, at the rear of the stage (figure 7, B). The film was viewed through a plate of glass (A) that was slanted back and upwards, angled from the proscenium-line of the stage floor. A painted background (D), was hung above – parallel to – the stage floor, and its image was reflected onto the glass screen and viewed in combination with the image of the filmed actors. Charles E.R. Schneider, the inventor, explained the resulting effect of stereoscopic relief: "This is accounted for by reason of the distance between the inclined glass showing the landscape and the back screen on which the image is actually reflected, and which being viewed through the glass,

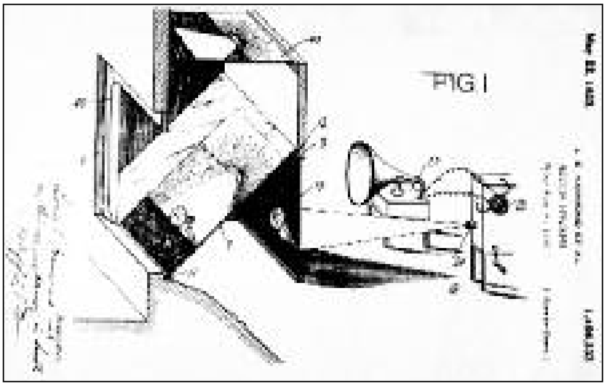


Figure 8: Hammond and Smith's "Illusion Appliance"

acquires the aspect of bulk, relief and distance"[16] – essentially the visual cue of interposition.

This sort of arrangement was critiqued and evidently improved upon by Louis E. Hammond and Herman A. Smith in 1923. The wording of their patent's text suggests that an ongoing problem-solving "discussion" regarding stereoscopy had been taking place over many years in the entertainment community, at least in terms of inventors' reactions to and improvements upon each other's designs. Regular motion pictures, said Hammond and Smith, lost their "desired realistic effect" because of the

> *constant [...] flickering movement of the entire scene or setting. Furthermore, with the present methods of projection the pictures are what is commonly known as "flat," it being impossible to obtain the proper degree of perspective to overcome this in the slightest degree. [...] [V]arious means have heretofore been suggested [for combining filmed figures with a still background,] but none has presented a satisfactory solution of the problem.* [17]

The difficulty with earlier arrangements (see, for example, Schneider's 1915 invention), Hammond and Smith explained, was that light which was meant to illuminate the still, painted background tended to fall onto the glass screen, causing reflective distortions. Also a front projection of filmed performers, shown on a glass screen, produced a "ghost," or double image "visible to spectators in certain portions of the auditorium." Hammond and Smith's invention used back projection for the film of the performers, and still-scenery front-projected from a stereopticon; a synchronized phonograph gave voice to the pictures (figure 8). They claimed that:

> *In some instances where our appliance has been employed, and the focal planes of the co-operating apparatus have been so adjusted to produce increase of life-like size [life-sized projections], there has been considerable confusion in the minds of the auditors or spectators of the exhibittion as to whether the performance was by human beings or mechanical devices.*

Theatre productions at the turn of the last century can be divided into two general categories concerning the depiction of realistic stage pictures. Most familiar is the "slice of life" style associated with the movements of Naturalism and Realism, in which the stage set became a three-dimensional environment, with few or no painted *trompe-l'œil* or perspective effects. David Belasco's 1909 production of *The Easiest Way* (in which the entire interior of a boarding-house room was bought, down to the wallpaper, and reassembled on the stage), is an extreme example of realistic scenic authenticity. The second category involves a style of realistic illusionism that derived much of its inventive vitality from scenic practices developed for, or popularized by, melodrama.[18] Many of these practices recreated the perceptual effects of motion perspective, and were meant to set dramatic scenes spatially free (in the imagination of the audience) from the static confines of the stage. Frequently the fantastic, action-packed plots of the plays in this category were hardly veritable depictions of actual life, but, as we also see today in suspense, fantasy, and science-fiction movies, the more improbable the plot, the more important it was (and is) to ground its presentation in a familiar, realistic scenic style, so as to infuse the story with believability.

During the second half of the nineteenth century, effects involving motion were enormously popular. The scenic depiction of depth in motion was epitomized in effects that employed stage panoramas and treadmills for races between horses, automobiles, and/or locomotives. It is evident in engravings illustrating the workings of stage machinery, often published in popular science journals like *Scientific American*, that the cues for spatial motion perception were well understood. In, for instance, productions of *The County Fair* (1889) and *Paris port de mer* (1891), passing fence-posts gave edge rate information in the

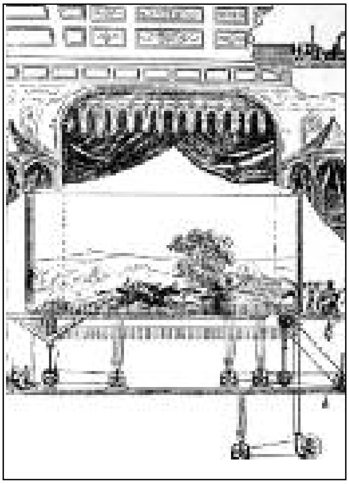


Figure 9: Illustration of stage machinery for *The Country Fair*

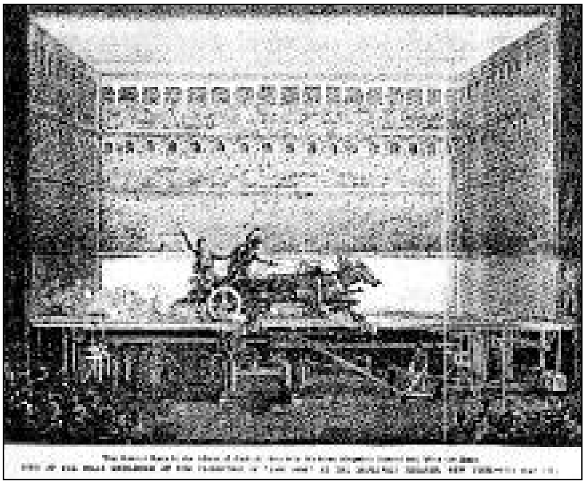


Figure 10: Engraving for article, "Some Stage Effects in *Ben Hur*"

foreground of the stage picture (figure 9). For some plays the stage floor, painted as a dirt track, appeared to move with receding speed as it approached the "horizon" at the back of the stage. Rows of belts, painted in earth tones, "were set parallel to the curtain line; they were motor-controlled and the speed was gradually reduced on each succeeding upstage belt to give the effect of motion perspective,"[19] creating a sense of parallax, and even of global flow, since the ground effects were combined with a more slowly moving stage panorama which unrolled a background of painted scenery across the rear of the stage. This set-up was particularly effective when, as in *Ben Hur* (1899), three (or more) panoramas were arranged in a semicircle behind the action (figure 10). Sometimes the panoramic scene at the back of the stage was "stepped" into receding rows of mini-panoramas, each band of scenery moving at a slightly different speed, such as in *Bedford's Hope*, a 1906 melodrama written and designed by an "effects man," Lincoln J. Carter. "Audiences are captivated by the marvelously realistic reproduction of natural phenomena in form and motion," stated Robert Grau in 1912, "The theatre-going public senses the greatest pleasurable emotions when it sees action delineated in a realistic atmosphere; its attention follows easily [...] the unfolding of the play when the imagination is not distracted by grotesquely inadequate scenic accompaniment. Reality is the thing."[20]

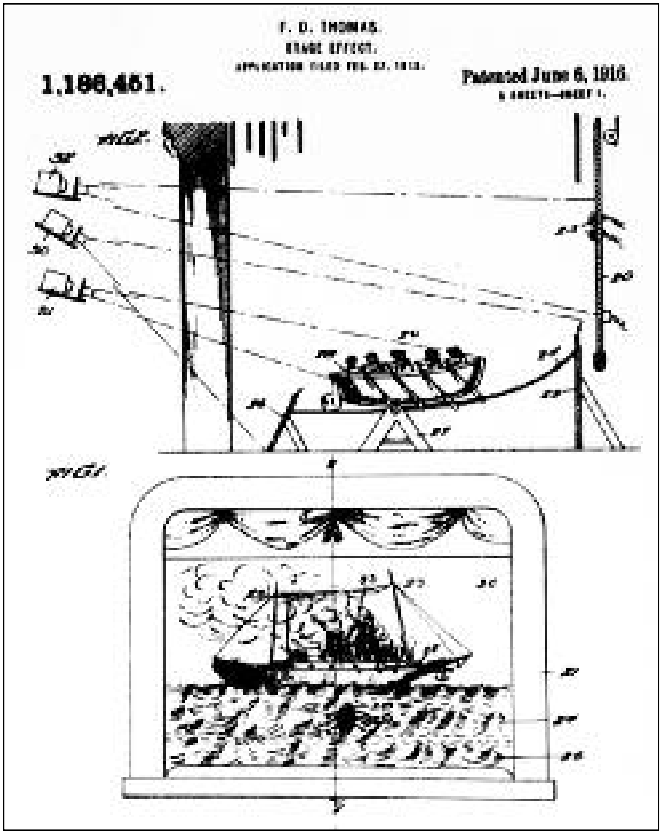


Figure 11: Thomas' "Stage Effect"

After theatres began installing electric stage lighting in the 1880s to replace gas lighting (which had cast an uneven, yet atmospheric glow that softened the appearance of the stage picture), painted settings – whether still or moving – were, with growing frequency, viewed as "grotesquely inadequate" because of their stark two-dimensional contrast to three-dimensional actors. Beginning around 1898, moving pictures were incorporated in a number of productions as replacements for painted stage panoramas.[21] Frank D. Thomas, certainly the most prolifically patented American inventor of multi-media effects, supplied motion-picture scenery for Broadway producers (including Florenz Ziegfeld, Lew Fields, Eddie Foy, and the Shubert Brothers) from 1907 into the 1920s. "I realized that we had at last hit the bull's eye with something totally different from anything that had preceded us in this sort of stage-craft," he said in a 1911 article for *Green Book*.[22] For a time, at least, motion pictures provided a photographic realism, with accurate dimensional cues, that audiences reportedly accepted as more convincing than painted scenery.

Thomas' stage was, essentially, a white screen: "nothing but white drops and wings," floor cloths and groundrows, onto which filmed scenery – "colored true to nature" – was projected (figure 11: patent's "Fig. 1," #23, 24, & 26).[23] Actors performed in spotlighted areas amid, or from slits or areas cut into the screens (figure 11: patent's "Fig. 1," #30-32); the spotlights highlighted their performance, and probably muted the degree of relief in which the actors were seen, uniting their dimensional appearance with that of the scenery. A multi-media effect, Thomas observed, created a "sense of compelling realism" and "made audiences lose sight of the fact that while it was good, it was palpa-

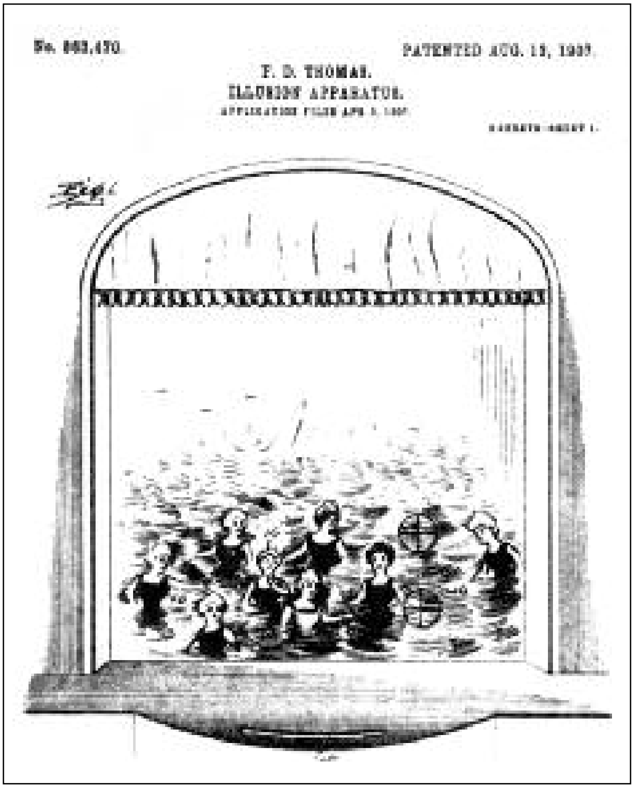
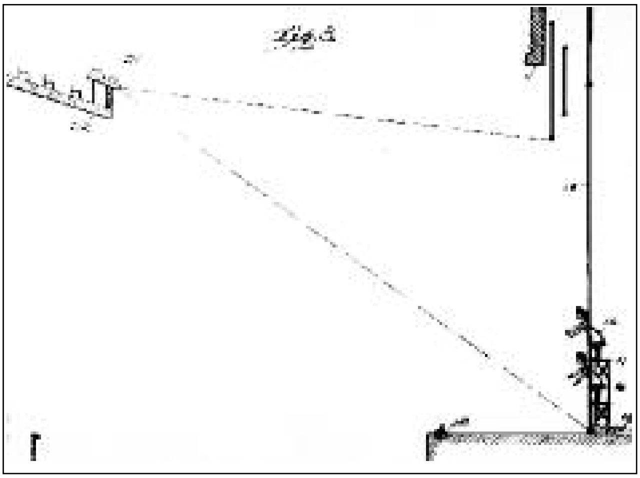


Figure 12: Design illustration of Thomas' "Illusion Apparatus"; front view (above) and side elevation (below)



bly artificial." He described a "Bathing Girls" effect he had created for Ziegfeld's first edition of the *Follies* in 1907 (figure 12):

> *When the effect was first tried out in public, it resulted in a most amusing incident. Just as the waves rolled down toward them, there was a wild, mad scramble on the part of the front row auditors to escape the deluge they unconsciously thought was coming their way. We could, of course, have had no better tribute to the realism of the impression.*[24]

The "punch" effect, commented on world-wide with regard to early film viewing, provided a sense of forward movement – possibly a depth-perception cue we could add to our list.

In closing, let me indulge in a conceptual *jeu d'esprit* that may serve as a referencing structure for the dimensional experiments discussed above. While turn-of-the-century inventors were puzzling over how best to achieve an "accurate" film- or stage-representation of visual dimensional perception, mathematicians were altering the substance of geometric space by investigating non-Euclidean theories, creating the framework in which modern math and physics subsequently flourished. Felix Hausdorff in 1919 laid the foundation for fractal geometry (which was developed more fully by Benoit Mandelbrot in 1975). Although nineteenth-century science was based in the observation of nature, the math did not "add up:" real-world objects do not occupy the regularized space assumed by traditional geometries which interpret nature through a "geometric fiction" that cannot describe in detail the irregular shapes of leaves, clouds, coastlines, mountains, etc.[25] Fractal geometry can.

A simple explanation of fractal geometry is provided by O.B. Hardison, Jr., in *Disappearing Through the Skylight: Culture and Technology in the Twentieth Century*. In Euclidean geometry, a point is said to have zero dimension, a line has one, and a plane has two dimensions. Now in fractal geometry, the line, which in traditional geometric terms has the one dimension of length, can be imagined to continue its path as a doodle that spreads across a page of paper. As the surface of the page is covered, the line starts to resemble a plane. In fractal geometry, the degree to which this one-dimensional line takes on two-dimensional planarity could be measured, assigning the doodle a dimensional measurement of, say, 1.6.[26] Similarly, a planar to cubic shift from two dimensions to three, could be imagined along the gradated, dimensional continuum of fractal geometry. Traditional "regular geometries" are clearly limited. At what precise point does one dimension become two? When do two dimensions become three?

A *trompe-l'œil* perspective painting, a stage scene with perspective scenery, a motion picture, or a multi-media scenic experiment – if "regular geometry" defines the spatial model for any of these, there are only two choices available with which to describe our *experience* of depth: two dimensions or three. Historically, in all of these examples, most viewers have chosen to see three. Inventors (and critics), however, seem to have operated in an aesthetic mode that was more fractal, as the comparative nature of the inventing process suggests: one person's stereoscopic effect could be improved upon by another. It almost seems as if these inventors were attempting to "stretch" the perception of 2-D media towards 3-D.

It would be absurd to employ fractals as an instrument with which to measure dimensional perception – attempting to determine quantifiably the fractal degrees to which we see two or three dimensions. However, a fractal *analogy* can be used to discuss perceptual experience and related technology. A fractal analogy removes the criteria from an "either/or," 2-D *or* 3-D, reference structure and places discussion in a broader, more comparative context. Analyses resulting from this context, therefore, can involve the many factors (such as visual cues and viewing conventions) that, as patents and production histories attest, were points of focus for experimentation in exhibition techniques, audience perception, and presentation context.

1 Robert Thorn Haines, "Animated Photography: The Principles and Advantages of Duplex Projection," Part I, *The Moving Picture World*, Vol. 1, no. 3 (March 23, 1907), p. 39.

2 James Cutting, Peter M. Vishton, "Perceiving Layout and Knowing Distances: The Integration, Relative Potency, and Contextual Use of Different Information about Depth," in William Epstein, Sheena Rogers (eds.), *Perception of Space and Motion* (San Diego: Academic Press, 1995), pp. 79, 83, 86, 88, and 91.

3 J. Cutting, P.M. Vishton, *op. cit.*, pp. 89-90.

4 The fan "tinter" is mentioned by Charles Francis Jenkins, Oscar B. Depue, *Handbook for Motion Picture and Stereopticon Operators,* cited in Joseph H. North, *The Early Development of the Motion Picture (1887-1909)*, Ph.D. dissertation, Cornell University, 1949 (New York: Arno Press, 1973), p. 248.

5 R.M. Hayes, *3-D Movies: A History and Filmography of Stereoscopic Cinema* (Jefferson: McFarland & Co., 1989), pp. 2-3.

6 Lenny Lipton, *Foundations of the Stereoscopic Cinema. A Study in Depth* (New York: Van Nostrand Reinhold Co., 1982), p. 33.

7 R.T. Haines, *op. cit.*, p. 39. In Part II of his lecture, Haines describes his own method of stereoscopic projection. See *The Moving Picture World*, Vol. 1, no 4 (March 30, 1907), pp. 54-56.

8 Dennis Sharp, *The Picture Palace and Other Buildings for the Movies* (London: Hugh Evelyn, 1969), pp. 54 and 70.

9 Abraham Reginald Flint, "Device of Means for Giving Stereoscopic or Distance Effect to Moving Pictures Shown Upon Screens," U.S. Patent no. 1,284,084 (November 5, 1918).

10 Ole Andrew Owen, "Motion-Picture Stage Illusion," U.S. Patent no. 1,395,513 (November 1, 1921).

11 Mirror-screens were overly expensive investments for most exhibitors. Robert Grau, *The Stage in the Twentieth Century* (New York: Benjamin Blom, 1969 [1912]), pp. 112-113.

12 By 1847 M. Henri Robin was exhibiting "Living Phantasmagoria" in Europe; in 1851 he presented the effect in London. Robin's illusion might have been copied by John Henry Pepper and Henry Dircks, who constructed their version of the effect in 1858. Robin later challenged Pepper's claim as its originator. See David Price, *MAGIC: A Pictorial History of Conjurers in the Theater* (New York: Cornwall Books, 1985), pp. 113 and 119.

13 Moritz Lewin (assignor to Henry Waterson), "Theatrical Appliance," U.S. Patent no. 1,150,869 (August 24, 1915).

14 Charles Francis Jenkins, *Animated Pictures* (New York: Arno Press & New York Times, 1970 [1898]), p. 79.

15 M. Lewin, *op. cit.*

16 Charles E.R. Schneider, "Apparatus for Showing Pictures in Relief," U.S. Patent no. 1,124,665 (January 12, 1915).

17 Louis E. Hammond, Herman A. Smith (said Hammond assignor to Edgar J. Marston), "Illusion Appliance," U.S. Patent no. 1,456,233 (May 22, 1923).

18 Motion effects were notably employed in the "legitimate" theatre as well. For example, a moving panorama combined with a boat were used in productions of *A Midsummer Night's Dream* in the second half of the nineteenth century by the American producer, Augustin Daly. After the royal hunting party discovered the quartet of young lovers (waking from their night of supernatural mismatchings), the group embarked for Athens on a "barge," and appeared to glide past splendidly changing scenes, which were rolled across the stage in the form of a background panorama and downstage groundrows. See Charles H. Shattuck, *Shakespeare on the American Stage: From Booth and Barrett to Sothern and Marlowe*, Vol. 2 (Washington, D.C.: Folger Books, 1987), p. 73. Four photographs of the panoramic setting are reproduced on pp. 74-75.

19 Richard L. Arnold, "Animated Scenery," *Educational Theatre Journal*, Vol. 16, no. 3 (October 1964), p. 251.

20 R. Grau, *op. cit.*, p. 344.

21 In the United States, this substitution (motion pictures for painted panoramas) was suggested only a few months after Edison exhibited his Vitascope (see George Parsons Lathrop, "Stage Scenery and the Vitascope," *The North American Review*, Vol. 163, no. 478 [September 1896], pp. 377-381). The earliest use of motion-picture scenery in the U.S.A. (of which I am aware) was in Lincoln J. Carter's *Chattanooga*, in 1898. During the first decade of the 1900s, films replaced panoramas in a number of horse-racing plays produced by stock, or touring, companies who could not afford elaborate stage machinery. See chapter two in my *Projection and Performance: Early Multi-Media in the American Theatre*, Ph.D. dissertation, Tufts University, 1991.

22 Frank D. Thomas, "The Realism of Modern Stage Effects," *Green Book*, no. 5 (May 1911), p. 1008.

23 F.D. Thomas, *op. cit.*, pp. 1010 and 1008.

24 F.D. Thomas, *op. cit.*, p. 1009; and Frank D. Thomas, "Illusion Apparatus," U.S. Patent no. 863,470 (August 13, 1907).

25 O.B. Hardison, Jr., *Disappearing Through the Skylight: Culture and Technology in the Twentieth Century* (New York: Penguin Books, 1989), p. 59. Felix Hausdorff (1868-1942) was interested in the continuity or closeness of spaces; he wrote about set theory and topology, and in his paper, "Dimension und äusseres Mass", *Mathemahische Annalen*, Vol. 79, no. 157, (1919), he introduced the concept of the fractal or "Hausdorff dimension." The difficulties of measuring irregular forms with classical geometry had captured the attention of mathematicians for nearly fifty years before Hausdorff's studies.

26 O.B. Hardison, Jr., *op. cit.*, p. 61.

List of figures

1. Illustration originally titled, "Some monocular cues for the visual perception of depth," in Theo C. Meyering, *Historical Roots of Cognitive Science: The Rise of a Cognitive Theory of Perception from Antiquity to the Nineteenth Century* (Dordrecht: Kluwer Academic Publishers, 1989), p. 160.

2. Design illustration of Abraham Reginald Flint's "Device or Means for Giving Stereoscopic or Distance Effect to Moving Pictures Shown upon Screens," U.S. Patent no. 1,284,084 (November 5, 1918); front view.

3. Design illustration of Ole Andrew Owen's "Motion-Picture Stage Illusion," U.S. Patent no. 1,395,513 (November 1, 1921); front and top views.

4. Engravings of two "Pepper's Ghost" effects: "Raising a ghost by magic lantern" from *The Magic Lantern: How to Buy and How to Use It, and How to Raise a Ghost* ("by A Mere Phantom"), 1880, rpt. in Erik Barnouw, *The Magician and the Cinema* (New York: Oxford University Press, 1981), p. 28; and "living skeleton" effect from Albert A. Hopkins, *Magic: Stage Illusions and Scientific Diversions* (New York: Arno Press, 1977 [1897]), p. 54.

5. Design illustration of Moritz Lewin's (assignor to Henry Waterson) "Theatrical Appliance," U.S. Patent no. 1,150,869 (August 24, 1915); isometric view of stage set-up.

6. *Ibid.*; side and front elevations of screen (patent's "Fig. 4" & "Fig. 5"), and top views of screen and stage set-up (patent's "Fig. 6" & "Fig. 3").

7. Design illustration of Charles E.R. Schneider's "Apparatus for Showing Pictures in Relief," U.S. Patent no. 1,124,665 (January 12, 1915); side elevation, top view, and example of painted background (D).

8. Design illustration of Louis E. Hammond and Herman A. Smith's (said Hammond assignor to Edgar J. Marston) "Illusion Appliance," U.S. Patent no. 1,456,233 (May 22, 1923); isometric view.

9. Illustration of stage machinery for *The County Fair* from Albert A. Hopkins (ed.), *Magic: Stage Illusions and Scientific Diversions* (New York: Arno Press, 1977 [1897]), p. 325.

10. Engraving for article, "Some Stage Effects in 'Ben Hur,'" *Scientific American*, Vol. 83, no. 8 (August 25, 1900), p. 119.

11. Design illustration of Frank D. Thomas' "Stage Effect," U.S. Patent no. 1,186,451 (June 6, 1916); side elevation and front view.

12. Design illustrations of Frank D. Thomas' "Illusion Apparatus," U.S. Patent no. 863,470 (August 13, 1907); front view and side elevation.