

Perspective Distortion

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Perspective distortion is a bucket of snakes because the issues are complicated and, as photographers and investigators, we like to keep things simple. Simple things are easier to explain to supervisors, prosecutors, defense attorneys and jurors.

See <http://www.anwylaw.com/wp-content/uploads/2014/03/dri-in-transit-trucking-article-winter-2009.pdf> for legal arguments relating to the manner in which photographic perspective can influence juror perspective.

The issue is not perspective per se but some combination of the following factors:

- What did the scene and objects of interest within the scene really look like to the investigators processing the scene?
- What could the witnesses see from their respective vantage points?
- The intensity and direction of incident light falling on the scene.
- The distance from the camera to the subject?
- The distance from the subject to objects of interest in the foreground and the background?
- The relative size of various objects within the scene?
- The focal length of the lens controlling angle of view?
- The shooting aperture controlling depth of field?
- Was the camera more or less level with respect to the horizon?
- How will the photos be presented to the triers of fact (the jury)?

In linear perspective, parallel lines appear to converge towards the horizon and the height of objects of uniform height such as parking meters diminish at a rate consistent with the rate of parallel line convergence.

When linear perspective is more or less what we expect to see, we think that the photograph is an accurate two dimensional representation of a three dimensional scene. In other words, the photo looks right.

In extension distortion, commonly known as wide angle distortion, the photographer uses a wide angle lens to include more of the scene from a given vantage point.

In compression distortion, commonly known as telephoto distortion, the photographer uses a telephoto lens to capture detail that could not easily be recorded with a normal or wide angle lens.



We normally think of linear perspective with respect to horizontal lines. This set of horizontal lines is US 24 from a point just west of the intersection of US 24 and CO 9 near Hartsell, Colorado, disappearing towards an infinity point somewhere in the general area of the continental divide. Nikon FE with a 24 mm lens wide angle lens.



We can have linear perspective with oblique views. Here, the main drag (US 24) in beautiful downtown Woodland Park, Colorado. Nikon D7100 with 18 - 70 lens at 18 mm, 28 mm full frame equivalent. Parallel lines are converging on an infinity point somewhere well to the right of the picture area.

These photos do not give us good distance clues. However, we expect to see converging horizontal lines and we're not concerned as long as the convergence is not extreme. Converging verticals when we tilt the camera skyward are somewhat more noticeable.



This Leica IIIc , courtesy Ken Rockwell, is similar to the Leica IIIb that Charles C. Scott would have used in the mid-Thirties. Scott was a lawyer, photog-

rapher, educator, naval intelligence officer and questioned document examiner. In *Photography in Criminal Investigations* published in 1938, Scott wrote:

"By common usage a lens is said to be of normal focal length when its focal length is about equal to a line drawn diagonally through the two corners of the film size being used."

See <http://scholarlycommons.law.northwestern.edu/jclc> for an abstract of Scott's early writings.

The 1948 edition of Kodak's *Photography in Law Enforcement* states, "In addition to the regular all-purpose lens, the focal length of which should be equal to the diagonal of the negative, two lenses are recommended for special uses: (1) wide angle lens for photographing interiors and (2) a telephoto lens for photographing views when it is impossible or inadvisable to approach close to the subject."

In the fifth edition of *Police Photography*, Larry Miller writes, "In photography, a normal lens is one with a focal length equal to the diagonal measure of the image area... The image area of a 35 mm camera is 24 x 36 mm; thus, a normal lens for any 35 mm camera is 50 mm."

The 2007 edition of *Crime Scene Photography* by Edward Robinson has a chapter heading for "Normal Lenses" and states that, "Only the 50 mm lens will capture the image without this distance distortion."

I'm sure that a diligent paralegal could come up a long list of publications extoling the virtues of normal lenses generally and the 50 mm focal lenses in particular.

To set the record straight, the diagonal of a 24 x 36 mm frame of 35 mm film is 43 mm, not 50 mm as often claimed. Writers often depend on previously published works without doing enough independent research to verify that previously published writings will withstand rigorous scrutiny.

When Scott was publishing his early writings, slow B&W films were the only films that could be conveniently processed in a wet darkroom. These films, and even today's Tri-X and T-Max 400, aren't all that sharp when printed larger than 6.7 x 10 on 8.5 x 11 paper.

In those days, the primary police and press camera was the 4 x 5 Speed Graphic. *These cameras were customarily purchased with non-interchangeable wide angle lenses such as the 127 mm Kodak Ektar or the 135 mm Graflex Optar. You can safely assume that virtually all evidence photos taken between a 4 x 5 from the early twenties through the late sixties camera were taken with a wide angle lens, theory to the contrary notwithstanding.*

I doubt that Scott and his contemporaries shooting 35 mm were working with anything large than full frame 6.3 x 9.5 prints on 8 x 10 paper, unless they used the 7.5 x 9.5 enlarging easels commonly used to make 8 x 10 prints with a quarter inch border, *losing an inch off of the image area at either end of the negative when printing 35 mm negatives.*

Scott himself said something to the effect that 8 x 10 prints were sufficient. He did not tell us whether he preferred to work with 6.3 x 9.5 full frame prints or cropped 7.5 x 9.5 prints when working with a 35 mm camera.

In a nutshell, respected writers have made statements to the effect that we must use a 50 mm lens on a full frame camera or a 35 mm lens on an APS-C camera (providing an equivalent angle of view) to avoid perspective distortion. Well, maybe. And then again, maybe not.

In the mid-70s, I spent some time with the late Axel Hansen, a photographer on the staff of the Southern Pacific legal department. Railroads have money and when there is money on the table, accidents no matter how minor, end up in court.

Civil suits involving substantial sums, more so than run of the mill robbery, rape and murder trials, often come down to a question of who could see what and when they could plausibly have seen it.

Axel shared with me a little pamphlet published by the Evidence Photographer's International Council which stated that photographic prints are free from perspective distortion when viewed at a distance equal to the magnification times the focal length.

This same formula was repeated in an recent Internet article written by Keith Cooper that you can read for yourself at:

www.northlight-images.co.uk/article_pages/print_viewing_distance.html

Photographic prints are best viewed at a distance equal to from 1.5 to twice the diagonal.

- The diagonal of a 6.7 x 10 print on 8.5 x 11 paper is twelve inches. 1.5 x 12 = 18 inches. 2 x 12 = 24 inches.
- The diagonal of a 12 x 18 print on 13 x 19 paper is twenty-one inches. 1.5 x 21 = 31.5 inches. 2 x 21 = 42 inches.
- The diagonal of a 20 x 30 print is thirty-six inches. 1.5 x 36 = 54 inches. 2 x 36 = 72 inches.

The problem becomes really complicated when you consider that many courts now depend on audio-video systems to display photographic evidence. The diagonal of a 50" screen is approximately 50" but the aspect ratio 16:9, or 1.78:1. The aspect of a digital image taken with a DSLR camera is 3:2, or 1.5:1.

Thus, it becomes difficult to give each juror an opportunity to view a set of prints at the correct viewing distance regardless of the focal length.

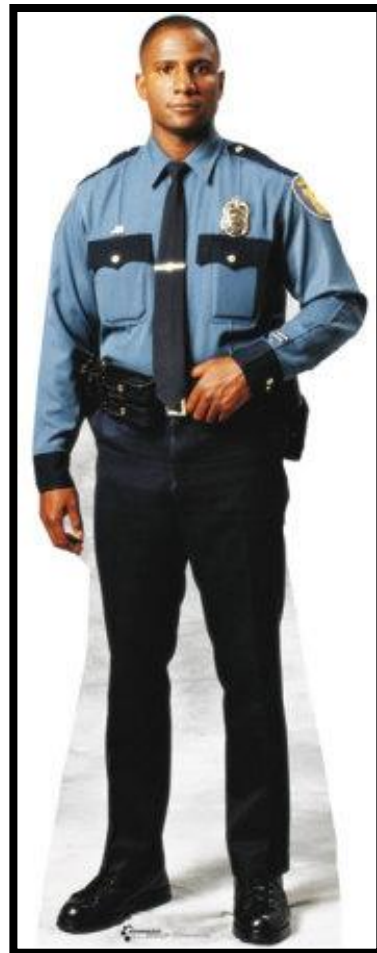
It would be interesting if an affluent student in a Master of Forensic Science program would undertake to write a thesis on presenting distortion-free photographic evidence to a jury.

A traditional jury box is sixteen feet wide by twelve feet deep seating two rows of six seats each. Evidence is presented in the form of:

- Photographic prints ranging in size from 4 x 6 to 6.7 x 10 inches passed from juror to juror.
- Photographic prints ranging in size from 12 x 18 to 24 x 36 inches displayed on an easel in front of the jury box.
- Photographic prints ranging in size from 4 x 6 inches to 6.7 x 10 inches displayed on a monitor or projector using a document camera (aka Elmo, after one of the early manufacturers).
- Displayed via a laptop on one or more TV-style monitors ranging in size from 40 to 80 inches diagonally.

- Displayed via a laptop on one or more electronic projection screens ranging in size from 84 to 120 inches diagonally.
- The position of monitors and projection screens can vary from courtroom to courtroom, even within the same courthouse.

I say affluent because an objective experiment would require a modern APS-C camera such as a Nikon D500 with a 16 - 80 mm lens or a Canon 7D Mark II with 15 - 85 mm lens. These lenses cover the 24 - 120 mm range on a full frame digital at half the cost of a full frame camera, but you're still looking at \$2,000 plus another \$1,000 for a tripod and a flash. It would cost around \$6,500 to replace my Nikon D7000 kit which includes a 35 mm f/2 AF-D lens, a wide angle on my Nikon F4 during the film era but "normal" on an APS-C camera.



Setting up a plausible scenarios should be easy using free-standing life-size cutouts from outfits like <http://www.allposters.com>, about \$35 each.

The first trick is to use layouts based on real-life felony crime and major accident scenes when:

- Accurately dimensioned sketches and drawings are available.
- What witnesses could see or thought they could see is an issue.
- The scene is more or less a worst case scenario in terms of width and depth, requiring either a wide angle lens or a series of shots stitched together to form a panorama.
- You have the equipment and skills required to photograph a worst case scene at the professional level.

Angles of view are generally specified in terms of the diagonal, which is misleading. According to Canon's handy-dandy angle of view calculator, the horizontal angle of view for common 35 mm full frame focal lengths are:

- 50 mm - 39°
- 35 mm - 54°
- 28 mm - 65°
- 24 mm - 74°

You're going to have to stand well back to cover a large scene with a 50 mm lens or the APS-C equivalent. Move in close to shoot with a 24 mm lens and you will see wide angle distortion obvious to the naked eye. Back in the film era when fixed focal length primes were the norm, I found that a 35 mm worked well outdoors and that a 28 mm worked well indoors.

Of course, our hypothetical student looking for a suitable subject for his or her master's thesis might come up with an altogether different idea based on the type of scene scenarios he or she decides to use.

The second trick is set up a simulated jury box seating twelve volunteers and present your test photos to your volunteer jury using photographic prints or electronic projection just as they would be presented in a felony courtroom.

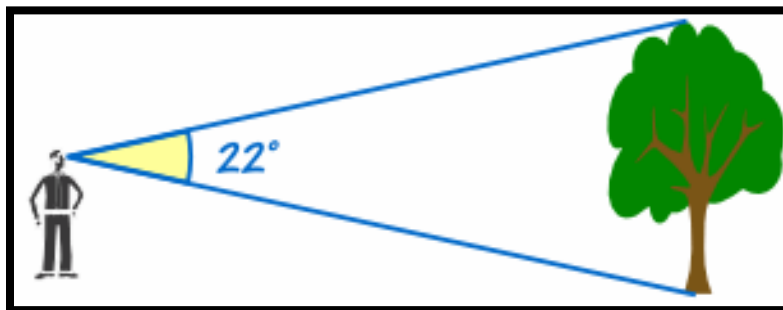
Shoot JPEGs. Keep the camera-original JPEGs with embedded EXIF files. Work on copies saved under a new file name. Use a copy with a unique file name for each variation of the camera original. You might have one variation for 6.7 x

10 prints, another for 12 x 18 prints, another for 20 x 30 prints and yet another down-sampled to 2 MP for electronic projection. As far as I know, nobody has ever done it and published the result.

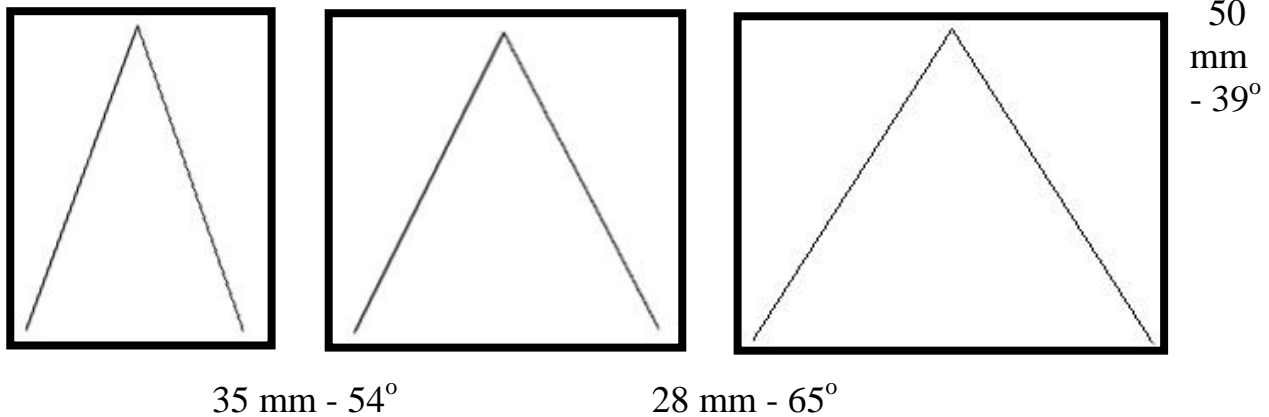
Until I see some peer-reviewed evidence that there really is inherent magic in a 50 mm lens on a full frame camera or a 35 mm lens on an APS-C camera, I'll continue to shoot with mid-range zooms using whatever focal length it takes to frame the scene to my satisfaction.

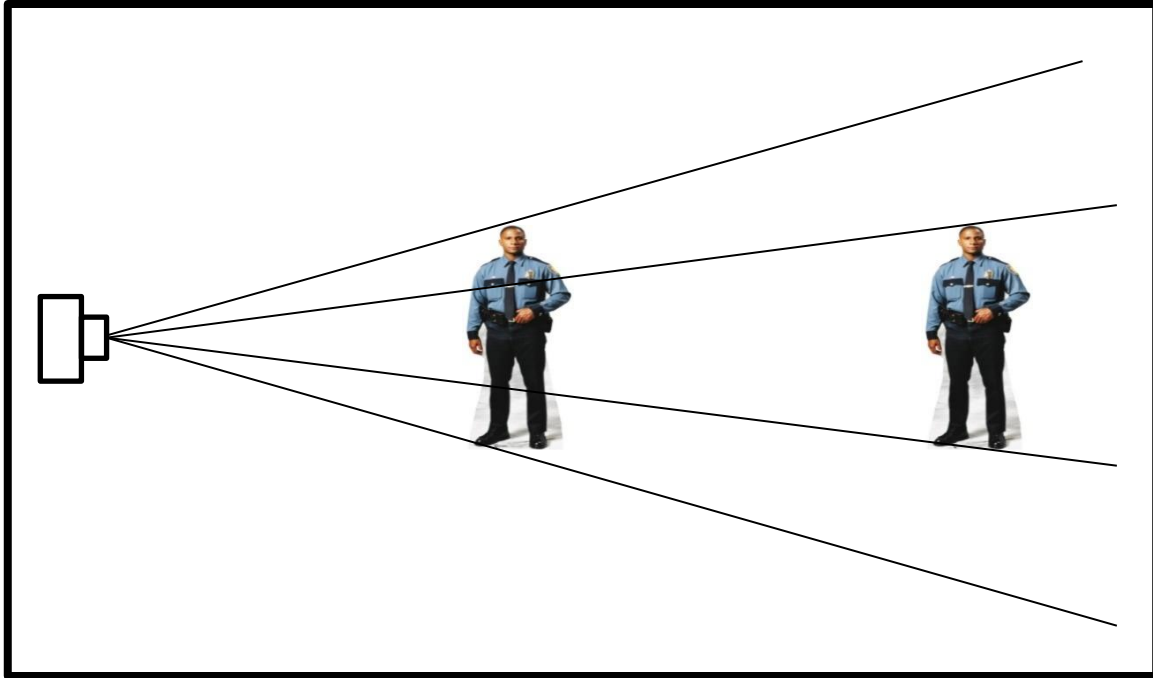
If I were looking for a faculty advisor to monitor a project of this nature, I'd look for someone in the art department. Artists have been studying perspective since the Renaissance with many textbooks, some based on Euclidean geometry, explaining the finer points to would-be Rembrandts.

Euclidean geometry? Perspective is all about magnification. An object of a certain size will subtend a certain angle or degree of arc at a given distance. The angle changes according to distance and the focal length.



This little graphic from mathisfun.com explains the concept. Now, apply the same concept to photos taken with 50, 35 and 28 mm lenses.





Regardless of focal length, if the distance from the camera to Subject A and the distance from Subject A to Subject B remains constant, the angles of view will remain constant. The only variables are how big you print or project the picture and the distance at which the picture is viewed.

However, if you change the distance from the camera to Subject A and the distance from Subject A to Subject B, the angles of view will change which in turn will cause a change in perspective, regardless of focal length. Thus, we've introduced additional variables in addition to print size and viewing distance.

In theory and in practice, viewing a print or a projected image at a distance equal to magnification times focal length should provide a perspective close that seen be the human eye. The problem with this theory is that photos taken with a wide angle lens will have to be viewed at distances measured in inches, perhaps twelve inches or less, impractical when viewing projected images from the jury box.

Why 50 mm Lenses?

In 1924, Leitz released the original Leica based on designs by Oskar Barnack and Max Berek. Barnack designed the camera to use inexpensive 35 mm motion picture film. Berek designed a 50 mm f/3.5 lens to provide sufficient resolution for high quality enlargements.

See http://en.wikipedia.org/wiki/leica_camera for the whole story. There is nothing in the published record to suggest that Barnack and Berek were concerned with perspective distortion. Landscape photographers are traditional users of wide angle lenses.

Be that as it may, the first successful 35 mm miniature camera as they were known in those days came with a 50 mm lens, as did the 35 mm cameras from Canon, Nikon, Exakta, Praktica, Zeiss-Ikon, Voigtlander and Contax that followed in the days prior to WW II.

Fifty millimeter lenses are among the most economical to manufacture. For any given focal length and aperture, the 50 mm focal length will be appreciably less expensive than comparable wide angles and telephotos with the same aperture. Here's proof from Nikon's web site:

- 24 mm f/1.4 AF-S G - \$2199.95
- 35 mm f/1.4 AF-S G - \$1,799.95
- **50 mm f/1.4 AF-S G - \$484.95**
- 85 mm f/1.4 AF-S G - \$1,699.65

Note that these are all AF-S G lenses. The older AF-D and AI-S lenses are slightly less expensive but we're comparing apples to apples.

Before zooms became popular, 35 mm cameras were typically sold with a 50 mm lens for the same reason that digital cameras are usually sold with a zoom. First time buyers can't take pictures without a lens so it makes sense to bundle the camera with an inexpensive lens. The notion that there is some inherent magic in the 50 mm focal length can be dismissed as a combination of happenstance, tradition and manufacturing economics.

Dr. Marc Green in [Photographs versus Reality](#) explains why we should not rely on photographs to prove what can and cannot be seen from a given vantage point or under a certain lighting condition. We look for simple answers such as "always use a normal lens" but the answers that we seek are not always simple.

That's why it is essential to prepare highly detailed, properly dimensioned drawings so we're not left to guess at spatial relationships based on what we can see on our laptops screens and in photographic prints.



The top photo taken with a 28 mm lens is clearly a wide angle shot. The bottom photo taken a few minutes later with a 50 mm lens is clearly a "normal" shot taken from thirty feet away, the distance at which most people would view something the size of a seventy foot locomotive. Wide angle distortion is a fact of life when you're obliged to shoot at oblique angles and conditions do not allow backing up far enough to shoot with a more or less normal focal length.