"Seen one, you've seen them all"…

by Mark Fihn

As a long-time amateur photographer, I must admit that I've not yet reached the point at which I'm tired of seeing enough sunsets or waterfalls… I frequently go out of my and miss other time-sensitive commitments in order to get a great photo of water deferring to gravity or of the sun ending another day of the earth's rotation. I now have hundreds of photos of sunsets and waterfalls – leading a friend of mine to quip not long ago, "Seen one, you've seen them all"…

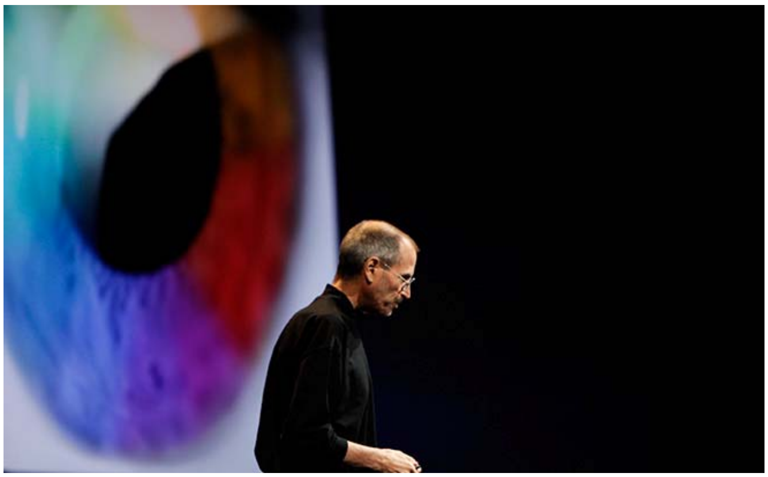
Well, it's not often you see a photo that captures the sunset within a waterfall. Unfortunately, I didn't capture the accompanying images of the "fire" waterfall of El Capitan in the Yosemite National Park. These spectacular views of the waterfall are created by the reflection of sunlight hitting the falling water at a specific angle. This rare sight can only be seen during a 2-week period towards the end of February. To photograph this rare event, photographers would often have to wait and endure years of patience in order to capture them. The reason is because its appearance depends on a few natural phenomena occurring at the same time and luck.

First is the formation of the waterfall – the water is formed by the melting of snow and ice at the top of the mountain. It melts between the month of December and January and by the end of February there might not be much snow left to melt.

Second is the specific angle of the sun's ray hitting the falling water – the sun's position must be exactly at a particular spot in the sky. This occurs only in the month of February and at the short hours of dusk. It coincides with the fact that the weather in Yosemite at that time of the year is often volatile and unpredictable. It compounds to the difficulty of getting these pictures.

Like sunsets and waterfalls, I am continuously surprised when I hear people refer to displays as “commodity” items. And I am particularly dismayed when so-called industry “experts” try to convince me that display resolution is necessarily limited by the human visual system. Sure, I suppose there is some practical point of diminishing returns with regard to display resolution, but I personally think we are so far away from achieving that point that it’s absurd to already be referring to such “commodity” implications when it comes to display technologies.

Apple’s announcement of the iPhone 4 with a 3.5-inch display at 960x640 pixels (326 pixels per inch) is likely to spark tremendous interest in high resolution displays – and not just in handheld devices. Despite critics, Apple is right on target with their hype about this display.

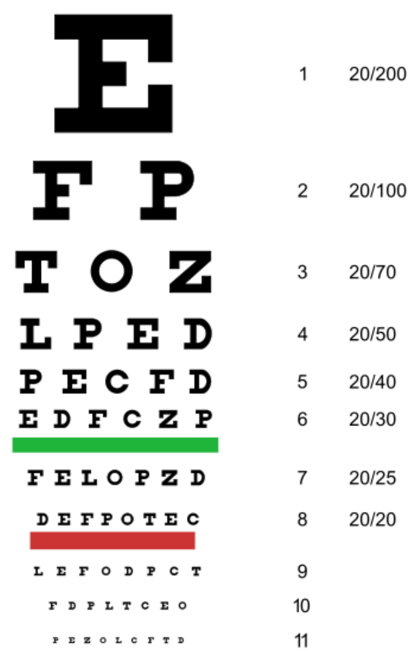


There’s already been considerable discussion as to whether Apple’s Retina Display really matches the resolution capabilities of the human visual system. I personally don’t believe it does, as discussed below, but Apple’s move is bold enough so that I will forgive them if they spin a bit of fiction about the human visual system.

Apple’s “Retina Display” on their recently released iPhone 4 is likely to change the limited focus most engineers have maintained over the past decade on display resolution. Although Steve Jobs is the center of this image, I like how the human visual system is shown to be of dominant importance…

For as long as I’ve been in the display industry, (almost 25 years now), display engineers have explained to me that 20/20 vision is accurately represented by a display that subtends about 1 arcmin. The typical “scientific” analysis is explained something along the lines of what was recently written in a popular article by Phil Plait from the blog “Bad Astronomy”: http://blogs.discovermagazine.com/badastronomy/2010/06/10/resolving-the-iphone-resolution/. It’s an interesting article, but the conclusion that 326ppi is representative of what the human visual system can resolve is somewhat flawed, as we are actually able to see much better than 1 arcmin.

Consider the Snellen test which is used frequently to determine visual acuity. If you can read the properly sized and formed letters above the red line from 20 feet, given certain ambient light conditions, then you are said to have 20/20 vision. But, keep in mind that if you can read those letters, you can also see that there are additional lines below them on the chart. While you might not be able to read them, you can almost certainly recognize that there are differences in the letters.

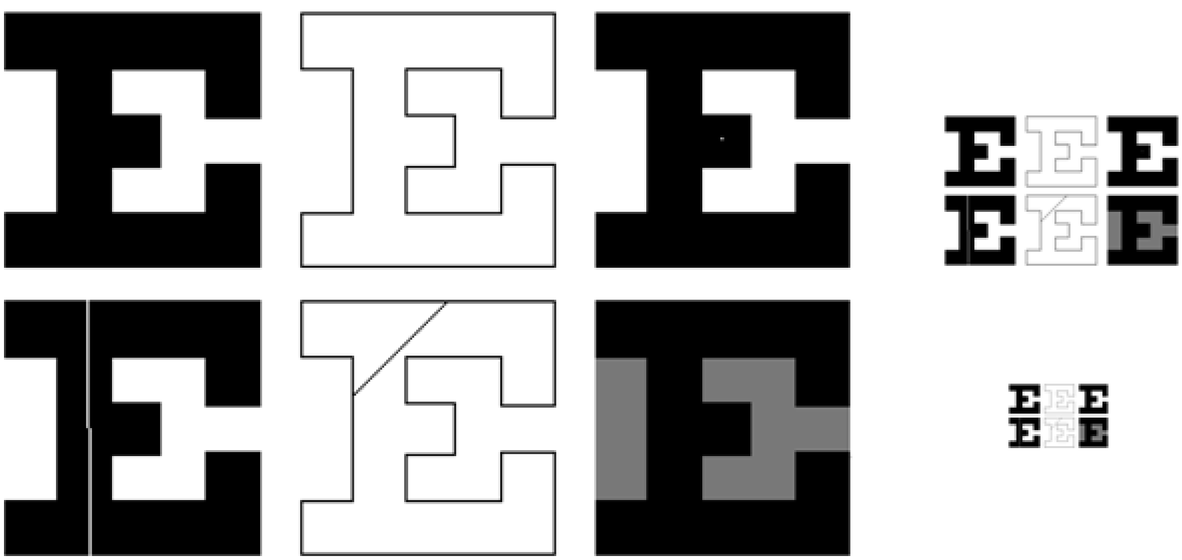


Among other things, the Snellen exam fails to recognize the importance of light intensity. When we look at the stars in the sky, for example, we are able to more easily see very bright stars as opposed to very large stars. Likewise, if we consider a “bright dot” pixel defect on a display, the size of the pixel defect is actually less important than the brightness of display. Even on the iPhone 4, a bright dot pixel defect will not be obvious if the display brightness is low, but it will become obnoxiously obvious as brightness is increased. I have a bright green pixel defect on my 133ppi notebook PC display. When set to maximum brightness, I can see the defect from up to 7 feet away from the screen – but the display “experts” still try to convince me that from a “normal viewing distance” of 24 inches, that I shouldn’t be able to see it.

Consider these facts about human visual acuity:

- "Optical infinity" is the least distance at which there is no significant accommodation by the crystalline lenses of a person's eyes, (to represent parallel lines of light). Traditionally, optical infinity has been accepted to be 20 feet, (hence the distance chosen for the Snellen test). However, at 20 feet there is an accommodative demand on the eye of about 1/6 D (one-sixth of a diopter), which can be significant. Many experts maintain that optical infinity, for purposes of examining the refractive error of the human eye, should be at least 8 meters or 26 feet. In any case, 20/20 vision is primarily valuable when measuring visual acuity at optical infinity – it is a less valuable measure for determining visual acuity of objects that are positioned inside the point of optical infinity.
- 20/20 visual acuity resolves 1 arcmin. However, 20/20 is defined for a room maintained at a very dim ambient illumination (e.g. 100 lx). In nature the range of illumination is many orders of magnitude higher (0.01-100,000 lx) and luminance contrast is often sufficient to resolve objects smaller than 50 arc seconds.
- Also, 20/20 is defined for black/white luminance contrast and ignores color, 3D, and motion as image resolving features of human vision.
- Human visual acuity is much finer than 20/20 implies. Stars subtend far less than 50 arc seconds, perhaps as small as 5 arc seconds in some cases, yet people see stars. Similarly, glint from a highly reflective surface is readily visible, but often subtends 20-25 arc seconds or less.
- Humans have a visual capability known as hyperacuity. The most famous example of hyperacuity is Vernier acuity, also known as positional acuity. An attribute of Vernier acuity is the ability to perceive colinearity between two line segments. Humans can resolve two line segments as being distinct if they differ by as little as 1 second of an arc.

In other words, when you hear some display "expert" (or even Steve Jobs) explain that a "retina display" enables 1 arcmin of visual acuity (20/20 vision); bear in mind that our visual systems actually can resolve details to a point that is 100 times finer that!



Here are three groupings of the letter "E" from the Snellen eye test. In the upper left is the "E" from the exam; the upper middle shows an outline of the letter; the upper right shows a single white dot in the letter; the lower left is an example of Vernier acuity, with a white line that is broken by a single line width; the lower middle shows a diagonal line within the outline; and the lower right is an example of contrast sensitivity, identifying the importance of contrast with regard to visual acuity.

Note that even though you are probably looking at the "E" image on the prior page with a display that with less than 100 pixels per inch, and even though the image itself has been mangled by both bitmap and Acrobat compression issues, you can probably see things that the "experts" say the human eye cannot see. For example, if you are looking at the smallest cluster of "E"s on a sub-100ppi monitor, you may not see the outline "E"s at all – the lines are less than a pixel wide and may not be reproduced at all. But on my 133ppi display, both the outline and the diagonal within the lower outline are clearly visible, even from a distance that is well beyond the "normal" viewing distance.

But that's the problem of trying to explain the benefits of a high resolution display – you actually have to see it to appreciate it. It's much like trying to explain what the color green looks like to a blind person…

While there are many who will tell you that display resolution is similar to sunsets and waterfalls – that if you've "seen one, you've seen them all" – I disagree vehemently. In fact, I believe that to ignore the natural beauty of sunsets and waterfalls is an indication of a small mind. Likewise, to ignore the improved visual experience enabled by high-resolution displays, is only an indication of the blindness of the "commodity-limited" thinking of so many "experts" in the industry.