iPhone 4 Retina Display: Better than the human eye?

A Comparison of the Resolution of the iPhone 4 Retina Display and the Resolution of the Human Eye

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Introduction

According to a Wired article[1] published 9 June 2010, Raymond Soneira, president of DisplayMate, claims Steve Jobs, CEO of Apple Inc., has it wrong when claiming that the iPhone 4 Retina Display has a resolution that exceeds the limit of the human retina.

Jobs' Claim:

> *At 326 pixels per inch, the resolution of the iPhone 4 Retina Display exceeds that of the human eye when held at a distance of 10 to 12 inches.*

Soneira's Claim:

> *At a distance of 12 inches, a display would need to have a resolution of at least 477 pixels per inch to exceed the resolution of the human eye, which is 50 cycles per degree.*

This paper demonstrates that Steve Jobs' claims are in fact valid, and that Raymond Soneira's calculations are inaccurate.

[1] Article titled *iPhone 4's 'Retina' Display Claims Are False Marketing*, published at http://www.wired.com/gadgetlab/2010/06/iphone-4-retina/

Assumptions

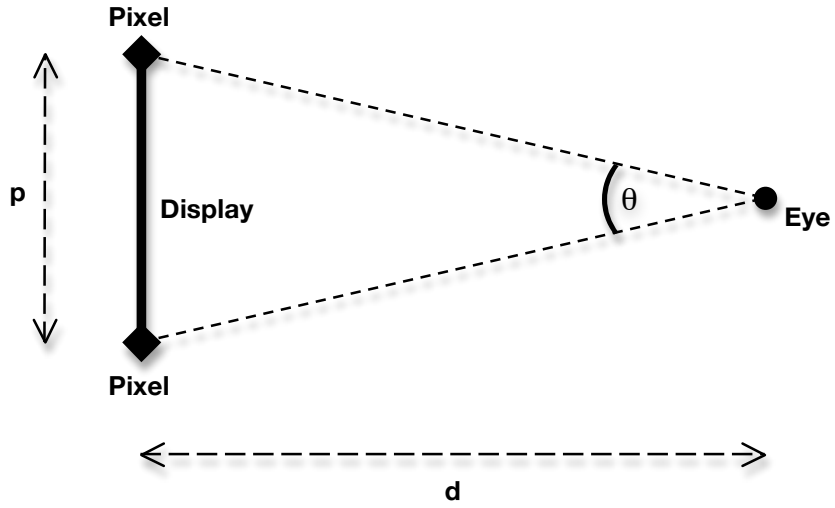
According to many scientific texts, the human eye is said to have a resolution of 1 to 2 arc-minutes. Soneira's value of 50 cycles per degree is consistent with this.

Note: An acuity of 50 cycles per degree can be tested using 50 pairs of black and white lines per degree. In such a test, the subject is distinguishing between lines of the same colour, which are 1/50 of a degree apart. This is why the value for the resolution is 1/50 of a degree and **not** 1/100 of a degree.

In my calculations, I will use Soneira's own figures of 50 cycles per being the limit of the human eye (which translates to a resolution of 1/50 of a degree as stated in the previous paragraph), and 12 inches being the distance away from the eye that the iPhone 4 device is held.

Calculations

The diagram below shows the angle θ subtended by the human eye when viewing two adjacent pixels on a display at a distance of d from the eye.

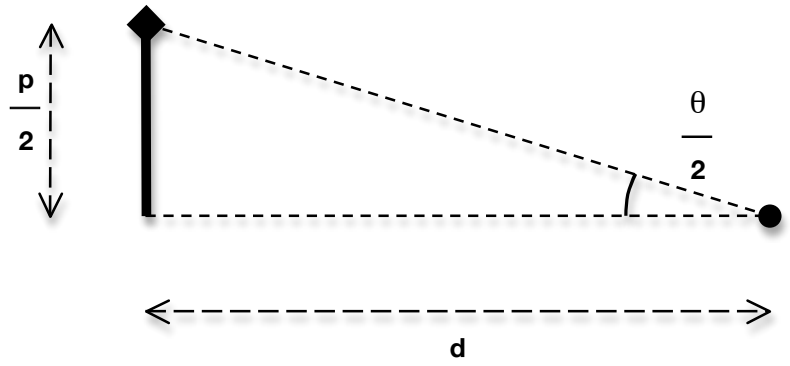


From Soneira's own claim, we know the following:

Angle θ = 0.02°, or **3.491×10^{-4} rad**.

Distance d = **12 in**.

We can use trigonometry to determine the pixel separation, p and from this derive the resolution. In order to do this, we consider one half of the diagram, thus forming a right triangle:



Note: Although it is more accurate to halve the triangle as we have done, the error in not doing so turns out to be negligible because the angle is very small. In other words, if θ is small enough, 2 tan (θ/2) ≈ tan θ. Regardless, we proceed having halved the triangle.

We thus have:

$$\tan(\theta/2) = p / 2d$$

or:

$$p = 2d \tan(\theta/2)$$

Using d = 12 in and $\theta = 3.491 \times 10^{-4}$ rad, we have:

$$p = 4.1892 \times 10^{-3} \text{ in}$$

And so the resolution R of the human eye at a distance of 12 inches, is therefore:

$$R = 1/p = \mathbf{239 \text{ pixels per inch}}.$$

This is **less** than the resolution of the iPhone 4 Retina Display at 326 pixels per inch, supporting Jobs' claims and contradicting Soneira's claims.

Conclusion

Jobs' claims that the resolution of iPhone 4 Retina Display exceeds that of the human eye is **valid** based on a distance of 12 inches and the value of 1/50 of a degree being the resolution of the human eye.

Furthermore, Soneira's calculations (as published in the Wired article) are **inaccurate**, and his criticism of Jobs based upon those calculations is **invalid**. This article has demonstrated that the iPhone 4 Retina Display when held at a distance of 12 inches, does indeed exceed the resolution of the human eye.

Further Analysis

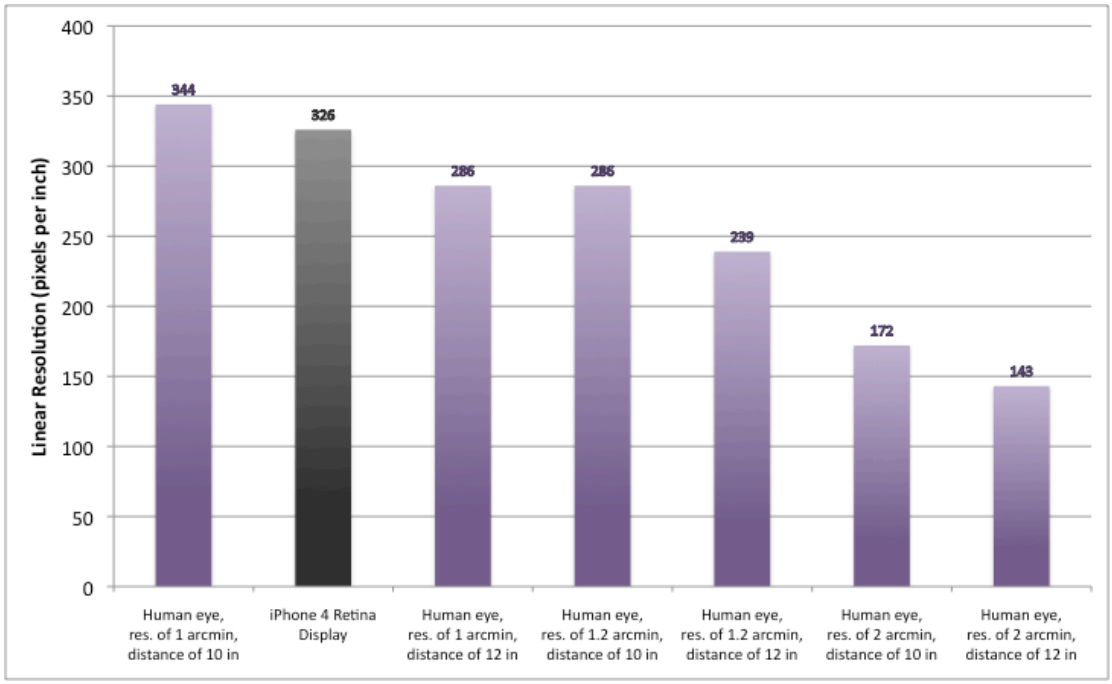
As mentioned earlier, the resolution of the human eye is reported to be between 1 and 2 arc minutes, depending on the text being referenced. We can repeat the calculations using the upper and lower limits of this range. Note: The calculations above used Soneira's own figure of 1/50 of a degree (i.e. 1.2 arc minutes).

Additionally, during his keynote at WWDC 2010, Jobs referred to the distance between the eye and the iPhone 4 device as being between 10 and 12 inches. Again, we can repeat the calculations using the upper and lower limits. Note: The calculations above used Soneira's own figure of 12 inches.

Repeating the calculations with these different values produces the following:

Resolution of the human eye (arc minutes)	Distance between the eye and the iPhone 4 device (inches)	Effective linear resolution of the human eye (pixels per inch)
1 (upper limit)	10 (lower limit)	**344**
	12 (upper limit and Soneira's value)	**286**
1.2 (Soneira's value)	10 (lower limit)	**286**
	12 (upper limit and Soneira's value)	**239**
2 (lower limit)	10 (lower limit)	**172**
	12 (upper limit and Soneira's value)	**143**

These values can be displayed graphically along with the iPhone 4 Retina Display as follows:



This tells us that the only situation where the resolution of the iPhone 4 Retina Display is inferior when compared with the human eye, is when:

- the eye has a resolution at the upper end of the range (i.e. 1 arcmin); AND
- the iPhone 4 device is held at a distance of 10 inches.