Flight Of The Pixel

Martin Howe

SEOS Ltd, Edwards Way, Burgess Hill, West Sussex, RH15 9UE, England
martin.howe@seos.com

Abstract. Large spherical and hemispherical screens provide a unique opportunity to display multimedia content of our Universe.

The ability to visualise accurate representations of our cosmos and overlay entertaining multimedia and live data is transforming the industry and opening the science of space to a larger audience on a worldwide basis.

However, as in any new market dependent upon technology, standards and terminology for determining acceptable performance and comparing systems based upon different technology are still evolving.

The challenge to define standards for assessing performance, quality and for determining an interchange format to allow content to be generated independent of the Visualization system is one that needs to be addressed at this early stage of market evolution to ensure that the compelling content being created today will appear in Planetariums around to World to the quality that they were intended.

This challenged is heightened because the issues that affect system performance are diverse and complex covering optics, electronics, physics and human factors relating to vision perception. Each of these issues is an expert subject in their own right, when combined into a Visualization solution these factors interact to add further complication.

This paper seeks to introduce three key performance metrics which define a Hemispheric Visualization system suitable for Planetarium applications; these being spatial resolution, luminance and contrast.

Spatial Resolution

Spatial resolution is the total quantity of pixels displayed at any point of time. Spatial resolution can be described in many ways from the total number of pixels available from the media storage and delivery system, or the total number of pixels available at the projection system, or more importantly the pixel density across the screen surface or the final resolution perceived by the viewer.

Of course, the perception of resolution depends upon three factors; the total number of visible pixels, the total area over which those pixels are displayed and the distance from the viewer to the screen.

In a (true) hemispheric visualization system, the total screen area is defined by the diameter of the Dome screen. By using a common view point, dome centre, the perceived spatial resolution of the Visualisation system can be defined simply by calculating the subtended angle to the eye at dome centre by two adjacent pixels on the screen surface.

This method has the advantage of being able to compare spatial resolution of a Visualization system independent of screen size.

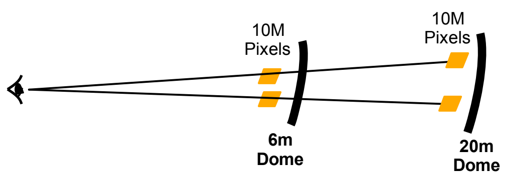

FIGURE 1. Illustration of angular resolution approach

Typically the human eye can perceive a spatial resolution between two adjacent pixels of 3 arc minutes (3 x 1/60th of a degree). Higher resolution is perceivable but typically only if there is a visible reference point available (i.e. comparing 3 arc minutes with 1 arc minute on screen).

To distribute equally spaced pixels across a hemisphere at 3 arc minutes would require a total spatial resolution of around 10 million pixels.

A 6 arc minute resolution would require approximately 6 million pixels distributed equally across the hemisphere.

Importantly, as described earlier, this total pixel count is independent of screen size, thereby providing a meaningful comparison of perceived spatial resolution.

Luminance

Luminance is a measure of the amount of light reflected from a surface over a given area. Expressed either in foot lamberts (ft-L, imperial) or candela per meter square (cd/m^2, metric). The luminance of a visualization system determines the maximum brightness of the white point of an image.

Using luminance as a metric takes into account the combined effect of the total light output of the display device/s, the total area of the screen over which the light will be distributed and the resultant gain of the screen surface.

Importantly again, this measurement is a useful comparison between hemispheric visualization systems using different projection technologies, dome sizes and screen gain and normalises these widely varying factors into a simple metric.

For comparison, typical luminance for a multimedia Dome can range between 0.5 to 1.5 ft-L.

A 20 metre diameter dome may need in excess of 40,000 lumens to produce system luminance of 1 ft-L with sufficient system contrast.

For reference 1 x ft-L = 3.43 cd/m^2.

Contrast

Probably one of the most important measures of a hemispheric multimedia visualization system is contrast, or more importantly, system contrast.

Contrast is simply a measure of the difference in luminance of black and white, expressed as a ratio. However there are so many factors that determine the level of black and there are inherent system wide factors which are specific to spherical screens which affect contrast, that make it critical to express system contrast in a common way.

Firstly it is important to understand contrast and its impact in our daily lives. It is generally accepted that the human eye can perceive an instantaneous contrast ratio of around 100:1 and that it can perceive differences in contrast levels of around 1%.

However we are constantly exposed to light levels ranging from a few hundred Lux of illumination in a dark room right up to 100,000 Lux of direct sunlight. Fortunately the eye and the brain adapt to a near infinite contrast ratio by dynamically adapting to the prevailing light level (this is why, when standing outside on a sunny day it is difficult to see through a shop doorway, but once inside the shop the detail is clearly visible).

To understand the contrast of a hemispheric visualization system it would be a mistake to simply look at the performance specification of a single component. For instance projector contrast ratios (CR) are often stated as anything from 500:1 CR up to 1,000:1 CR. This in itself is misleading simply because this is a sequential contrast measurement (a full black image is measured and then a full white one). A more meaningful measurement of projector contrast is the ANSI (American National Standards Institute) checkerboard contrast. This applies equal black and white squares across the image and a measurement is taken from this. A typical ANSI contrast ratio is around 100:1. The reason why the ANSI CR has reduced so much is that now the projector black is being measured at the same time that the projector is outputting full white across 50% of the image area. Through internal scatter at the imaging device and the projector optics the white light contaminates the black areas thereby raising the black level and reducing CR.

This is only part of the story. Stray ambient light within the environment adds light to the black level of the system and further reduces system CR.

Once an image is projected onto the hemispheric screen, cross screen illumination occurs. Diffused light from the screen surface reflects around the hemispheric screen further adding light to the 'black' areas of the screen and further compromising system CR.

With checkerboard content displayed in a hemisphere, expect to measure around 10:1 CR.

For reference, a television will typically have a 40:1 CR in a normally lit room, as will a matt photograph. Newspaper print typically will have a 15:1 CR.

Interestingly, it follows that because cross reflectance affects system CR then so does content. In other words if a few star points are displayed then cross reflectance is low and CR is higher, however if a large planet occupies half the screen area, then system contrast will be reduced.

This system contrast ratio provides the range from black to white within which the content will be displayed.

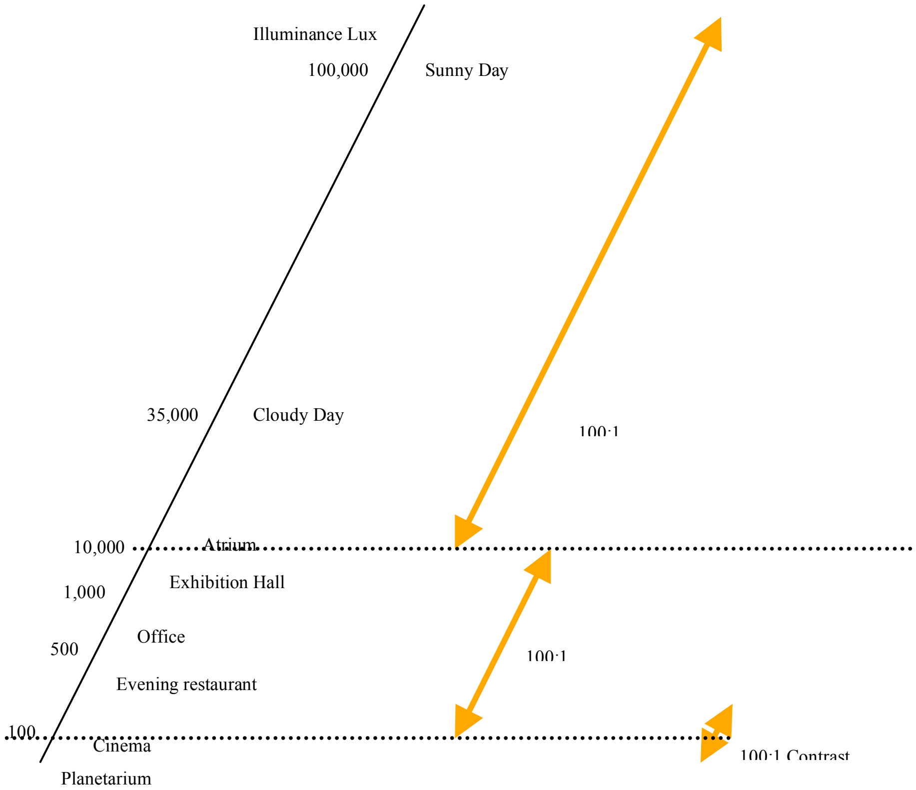

FIGURE 2. Contrast in our every day life

CONCLUSION

Industry standard metrics that relate spatial resolution, luminance and contrast for the complete visualization system which would be independent of dome size or technology employed, would allow sensible performance comparisons to be made between different systems for the purposes of evaluation.

Content could be configured according to these specifications and expectations could be set of how the content quality will be perceived by the audience.