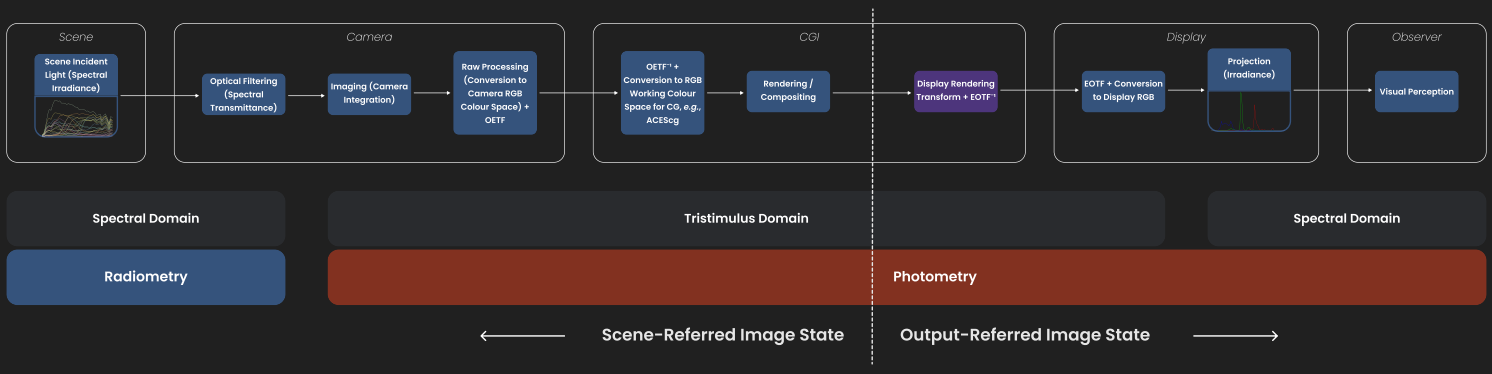
Colour Science Precis

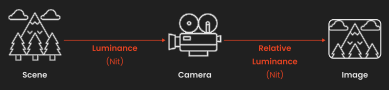
for the CGI Artist

Colour Imaging System - Scene Irradiance to Display Light



Imaging Quantities

ISO 12232-2019 defines the relationship between the luminance of a scene and the digital camera focal plane exposure, *i.e.*, time-integrated illuminance in lux-seconds. The image captured by a digital camera is typically described in terms of relative luminance. When using a RGB renderer, *e.g.*, Arnold or Renderman, the rendered image is also represented using relative luminance.



A digital camera is however not truly colorimetric: It sensitivities are not linear combination of the cone cells sensitivities, mostly for performance reasons, *i.e.*, it does not satisfy the Maxwell-Ives criterion.

Accordingly, it is debatable to discuss about illuminance and luminance, but for simplicity, the precis uses those quantities.

Mapping Between Image States

The two main image states and the mapping between those, are defined by ISO 22028-1 as follows:

Scene-Referred Image State

Image state associated with image data that represents estimates of the colour space coordinates of the elements of a scene.

A scene-referred image does not store the scene radiance, but estimates of its colorimetry for a given observer. It has been converted from the radiometric spectral domain to the photometric tristimulus domain by integration with the camera colour filters or by virtue of being rendered directly into a RGB colour space for CGI.

Additivity and linearity are maintained. A doubling of scene exposure produces a doubling of image relative luminance.

Output-Referred Image State

Image state associated with image data that represents the colour space coordinates of the elements of an image that has undergone colour-rendering appropriate for a specified real or virtual output device and viewing conditions.

This ISO definition specifies the state of an image upon having been processed to be printed or viewed on a display. Due to the non-linear nature of colour-rendering, additivity and linearity are not maintained. A doubling of scene exposure does not produce a doubling of image relative luminance.

Colour Rendering

Mapping of image data representing the colour space coordinates of the elements of a scene to output-referred image data representing the colour space coordinates of the elements of a reproduction.

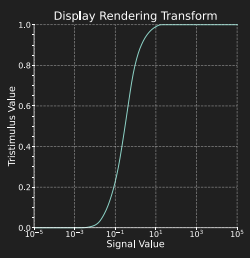
This ISO definition describes the conversion between the two main image states. In CGI, colour rendering is performed by the Display Rendering Transform (DRT).

Display Rendering Transform

The Display Rendering Transform (DRT) converts the image from a scene-referred state to an output-referred state.

Colour rendering is necessary because display devices, often, cannot reproduce the entire scene dynamic range and colorimetry. The viewing conditions are also different between the scene capture and imagery exhibition. The DRT ensures that the displayed image retains the intended artistic look and feel, despite the technical limitations of the display devices and the surround differences.

The DRT involves tone mapping and colour space mapping. Tone mapping transforms the image's relative luminance to fit it within the display's dynamic range, expanding mid-tones, compressing shadows and highlights, and altering contrast to achieve a pleasing result. Colour space mapping ensures that the colours in the image are represented accurately on the target display device, taking into account the device's specific primaries, whitepoint, and EOTF.



The luminance mapping of a DRT has the shape of a sigmoid curve, commonly referred to as a "S-Curve".

The left figure abscissa is using a Log 10 scale.

Numerous DRTs have been engineered, each offering unique aesthetics and look.

Some involve colour rendering in RGB colour space using per-channel processing. Some colour correction operators process images similarly, *e.g.*, Adobe Photoshop Curves, however, this generate undesirable colour clumping at the corners of the RGB colour space.

Perceptual uniform colour spaces (and colour appearance models) have been used in the design of DRT where the achromatic axis, *e.g.*, lightness, is processed separately from the chromatic one.

ARRI's K1S1 and REVEAL, RED's IPP2, ACES 's Output Transforms, Blender's Filmic and AgX, and FilmLight's T-Cam are common DRTs used in the industry.

The maximum pixel value is mapped to the display peak luminance producing a low-contrast, uncolourful and unpleasing image.

Linearly mapping the dynamic range of the scene colour estimates to that of the display produces an image with poor aesthetics. It lacks contrast, colourfulness, and the highlights are clipped.

The colour-rendered image with the DRT applied is appealing, exhibiting more contrast, colourfulness and highlights details.