Original Scientific Paper https://doi.org/10.24867/GRID-2026-p26

Influence of Blender Rendering Engines and View Transforms on Colour Reproduction in 3D Visualisation

ABSTRACT

*This study examines the consistency of displayed colour between Blender's EEVEE and Cycles rendering engines under the Standard, Filmic and AgX view transforms. A test matrix comprising 36 rendered samples (six primary and secondary colours across six engine-transform combinations) was shown on a profiled Philips 288E2 monitor and measured with an i1PRO 3 spectrophotometer using an Argyll CMS workflow. The virtual scene used frontal illumination with a simulated 6500 K, 1000 W light source. Corresponding EEVEE and Cycles measurements were compared using the CIE 1976 colour difference ΔE*ab (hereafter ΔE76). All inter-engine differences were below 1.0. AgX produced the lowest mean ΔE76 (M = 0.234, SD = 0.085), followed by Filmic (M = 0.438, SD = 0.187) and Standard (M = 0.440, SD = 0.207). The largest individual difference was measured for red under Standard (ΔE76 = 0.803). The results indicate that inter-engine agreement was greatest under AgX, although the experiment does not establish absolute colour accuracy or perceptual equivalence.*

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KEY WORDS
Colour management, Blender, colour difference, rendering engine, view transform, EEVEE, Cycles, AgX

1. Introduction

Colour management is an important part of 3D design and visualisation because the final appearance of rendered colours is influenced by both the rendering method and the view transform used for display. Blender provides the real-time EEVEE engine and the path-traced Cycles engine. A journal study using both engines reported that Cycles produced more realistic illumination, shadows and material reflections at the cost of longer rendering times, whereas EEVEE reduced computational demand with a possible reduction in realism (Malvido Fresnillo et al., 2024). In a colour managed workflow, this rendering stage must also be distinguished from the subsequent conversion of scene-linear image data for display, as the selected view transform can modify tone scale and chromatic appearance.

The investigated view transforms were Standard, Filmic and AgX. Blender documentation describes Standard as applying no additional transform beyond conversion to the display device, Filmic as a tone-mapping transform for high dynamic range colours, and AgX as its successor with improved handling of saturated and highly exposed colours (Blender Foundation, 2023; Blender Foundation, n.d.). Specifically, AgX applies tone-mapping and desaturates highly exposed colours, whereas Standard does not introduce an additional tone-mapping operation beyond display conversion. These differences make the choice of rendering engine and view transform relevant when colour appearance and consistency are important.

The aim of the study was to compare colour reproduction between EEVEE and Cycles under Standard, Filmic and AgX using controlled colour patches and instrumental measurements. The analysis focused on inter-engine colour differences. Because the primary ΔE76 values compare Cycles directly with

EEVEE, the design evaluates relative agreement between the engines rather than absolute accuracy against an independent reference target.

2. Related work

Research relevant to the present experiment can be organised into two connected strands: the effect of the rendering engine on scene generation and rendering, and the effect of the subsequent display or view transform on reproduced colour. Direct journal comparisons of Blender's real-time and path-traced engines remain limited. In a Blender-based pipeline for generating synthetic cable images, Malvido Fresnillo et al. (2024) allowed either EEVEE or Cycles to be used and reported that Cycles produced more realistic illumination, shadows and material reflections, although with longer rendering times. They also noted that using EEVEE reduced computational demand while slightly compromising image realism. Although their task concerned synthetic data for segmentation rather than colour measurement, the study provides journal-based evidence that engine selection can change visual output before colour management processing is considered.

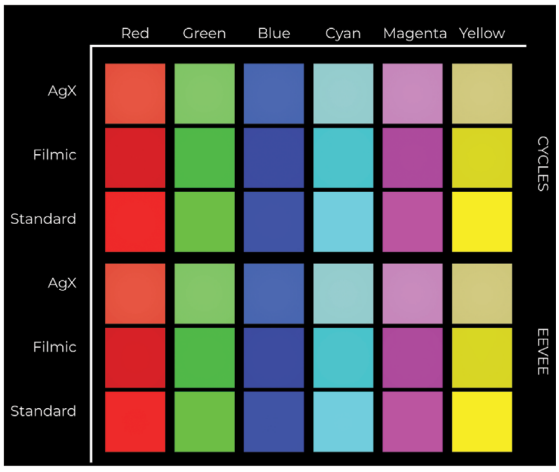
A broader body of work examines the transformation of high dynamic range, or scene referred image data for presentation on displays with a restricted output range. Eilertsen, Mantiuk & Unger (2017) reviewed the reproduction pipeline and categorised a wide range of tone-mapping approaches, emphasising that different operators balance contrast, detail and artefact suppression differently. Their review establishes that a display-ready image is not a neutral representation of the input: the mapping strategy forms a separate processing stage with its own perceptual consequences. This distinction is relevant when Blender outputs are compared across Standard, Filmic and AgX, because a difference in displayed colour may reflect the renderer, the view transform or their interaction. Conventional HDR tone-mapping research therefore provides conceptual context, but it does not directly validate Blender's individual view transforms.

Colour appearance is particularly sensitive at this transformation stage. Mantiuk et al. (2009) demonstrated through subjective appearance-matching experiments that tone-scale manipulation can change perceived colourfulness and that the correction required after contrast compression is nonlinear. Their results show that luminance compression and chromatic appearance cannot be treated as independent variables. More recently, Mehmood et al. (2023) developed a perceptual tone-mapping model based on CIECAM16 correlates of brightness, colourfulness and hue. The model accounts for surround and display conditions and was evaluated using both objective and subjective methods. This work reinforces the importance of evaluating colour management choices in relation to the viewing and display context rather than judging the scene-linear rendering alone.

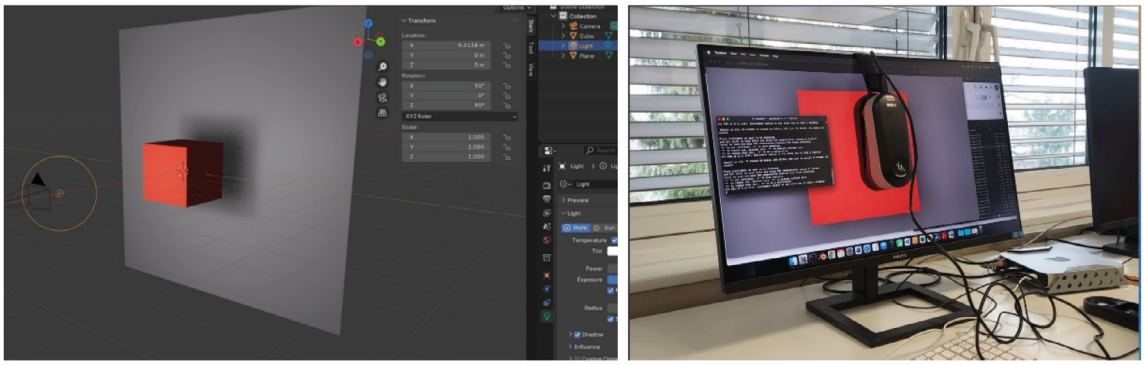
Mehmood, Khan & Luo (2024) extended this line of research with a generic colour correction method for tone-mapping operators. Their approach uses CIECAM16 lightness, chroma and hue, preserves the lightness of the tone-mapped image and the hue of the HDR input, and was validated through objective and subjective assessment. The reported improvement in natural colour reproduction further indicates that transforms designed primarily to compress luminance may also alter chromatic appearance unless colour is explicitly managed. Taken together, the literature supports a methodological separation between rendering and display transformation. However, previous studies have mainly examined rendering realism or tone-mapped natural images; instrumental comparisons of fixed Blender colour patches across both EEVEE and Cycles and multiple view transforms are scarce. The present study addresses this gap by holding the test scene and measurement procedure constant while comparing the two engines under Standard, Filmic and AgX.

3. Methods

The measurement setup comprised an i1PRO 3 spectrophotometer and a Philips 288E2 display. The display was characterised by creating a colour profile, which was then used in the colour measurement workflow. Argyll CMS was used for display characterisation, colour management, measurement acquisition and data processing (Gill, 2026). This distinction is important because display characterisation and profiling describe the behaviour of the physical display, whereas Blender's view transform operates on the rendered scene data before it reaches the display.



» **Figure 1:** *Test colour matrix for Standard, Filmic and AgX in Cycles and EEVEE*



» **Figure 2:** *Blender test scene and physical display measurement setup*

The experiment comprised 36 rendered colour patches: six chromatic colours (red, green, blue, cyan, magenta and yellow), two rendering engines (EEVEE and Cycles) and three view transforms (Standard, Filmic and AgX). The RGB and CMY patches were frontally illuminated by a virtual Blender light source configured to 6500 K, 1000 W. Figure 1 shows the rendered test colour matrix used in the study.

The rendered scene and physical measurement arrangement are shown in Figure 2. Measurements were obtained for corresponding colour samples produced by the two rendering engines. Colour differences between paired Cycles and EEVEE results were expressed as ΔE76 for each tested colour and view transform, following the CIELAB colour difference framework (CIE, 2018). The measured colour coordinates were also plotted on a CIE 1931 x,y chromaticity diagram.

4. Results

4.1. ΔE76 differences between Cycles and EEVEE

The ΔE76 values for the six test colours are shown in Table 1. All measured differences between Cycles and EEVEE were below 1.0. The largest individual difference was 0.803 for red under Standard, while the smallest was 0.147 for yellow under AgX. These values indicate relative differences between engines and are not errors measured against an external colour reference. The mean and sample standard deviation were calculated across the six test colours. The standard deviation represents variation between colours, not measurement uncertainty.

Within AgX, ΔE76 ranged from 0.147 to 0.356; within Filmic, from 0.177 to 0.666; and within Standard, from 0.189 to 0.803. Qualitative inspection of the rendered matrix suggests that Standard and Filmic appeared more similar to each other than to AgX; however, this observation was not assessed in a controlled visual experiment.

Figure 3 visualises the same values without assigning a perceptual threshold to the measured differences.

Table 1

ΔE76 differences between Cycles and EEVEE for the tested colours

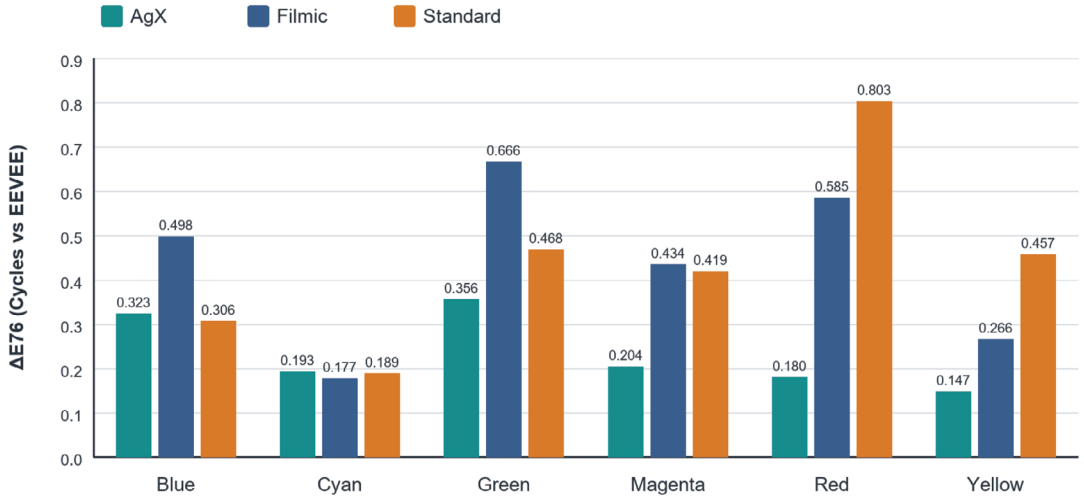
Colour	AgX	Filmic	Standard
Blue	0.323	0.498	0.306
Cyan	0.193	0.177	0.189
Green	0.356	0.666	0.468
Magenta	0.204	0.434	0.419
Red	0.180	0.585	0.803
Yellow	0.147	0.266	0.457
Mean	0.234	0.438	0.440
SD	0.085	0.187	0.207

4.2. Chromaticity distribution

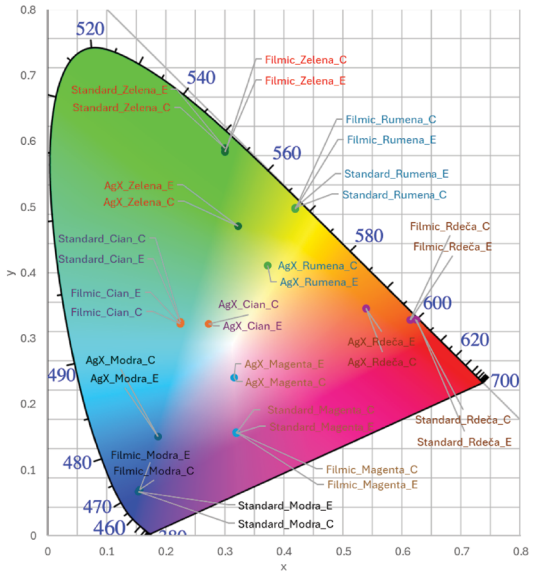
The chromaticity plot for all measurements is shown in Figure 4. The plotted points group the Cycles and EEVEE results for each colour and view transform. Paired points for the two engines remain close within each transform, while AgX points are offset from those associated with Standard and Filmic.

5. Discussion

All 18 paired ΔE76 values between the EEVEE and Cycles measurements were below 1.0. When averaged across the six tested colours, the inter-engine differences were 0.234 for AgX, 0.438 for Filmic, and 0.440 for Standard. AgX had the lowest observed mean inter-engine ΔE76 across the six tested colours, and the lowest ΔE76 value for four of the six colours. The largest individual difference was obtained for red under Standard (ΔE76 = 0.803), whereas the largest differences under Filmic and AgX were obtained for green, at 0.666 and 0.356, respectively. Because ΔE76 is a symmetric distance, these results quantify the dif-



» **Figure 3:** *ΔE76 differences between Cycles and EEVEE by colour and view transform*



» **Figure 4:** *CIE 1931 x,y chromaticity diagram for all measurements*

ference between the two engines but do not indicate which engine was closer to the intended colour target.

The rendered colour matrix also shows that the choice of view transform affects the appearance of the primary and secondary colours. Standard and Filmic appeared more similar to each other, whereas AgX produced a comparatively less saturated and more compressed appearance. This observation is qualitative because no controlled visual assessment was performed. Nevertheless, it is consistent with previous research showing that tone mapping and display transforms can alter saturation, hue, brightness and perceived colourfulness even when applied to the same scene-linear image data (Mantiuk et al., 2009; Eilertsen, Mantiuk & Unger, 2017; Mehmood et al., 2023; Mehmood, Khan & Luo, 2024). It is also consistent with Blender's documented design of AgX, which intentionally desaturates highly exposed colours as part of its tone-mapping behaviour (Blender Foundation, n.d.).

The CIE 1931 x,y chromaticity diagram provides complementary evidence about the relationship between the tested configurations. Corresponding EEVEE and Cycles measurements generally formed closely positioned pairs within each transform, consistent with the relatively small ΔE76 values. The separation between the groups associated with different transforms further indicates that the view transform influenced the resulting chromaticities. However, the diagram represents chromaticity only and does not include luminance information.

The differing computational principles of EEVEE and Cycles offer a plausible explanation for the measured differences between the two engines. Cycles uses a physically based path-tracing approach, whereas EEVEE relies on real-time approximations designed to provide faster rendering. Previous work has similarly shown that rendering pipelines and lighting calculations can influence simulated colour and illumination (Malvido Fresnillo et al., 2024). The present experiment did not isolate individual rendering operations, however, and therefore cannot attribute the observed differences to any particular approximation, sampling procedure or lighting calculation.

Two evaluation criteria must therefore be distinguished. The first is inter-engine consistency: according to the present measurements, agreement between EEVEE and Cycles was greatest with AgX. The second is fidelity to a defined reference colour. Because the reported ΔE76 values compare the engines with each other rather than comparing each configuration with an independently measured target, the experiment does not establish whether AgX, Filmic or Standard provided the most colour-accurate reproduction. Consequently, the lower mean ΔE76 obtained with AgX should be interpreted as greater agreement between the two rendering engines under the tested conditions, not as evidence of greater absolute colour accuracy. Determining absolute colour accuracy would require independently defined or measured reference

CIELAB values and separate target-based colour differences for every engine-transform configuration.

5.1. Limitations

The study was limited to one display, six chromatic colour categories, 36 rendered patches and one measurement workflow. Repeated measurements, uncertainty estimates and observer data were not reported. Because every inter-engine ΔE76 value was below 1.0, instrument and display repeatability should be quantified before the practical significance of the differences is inferred. ΔE76 is useful for a direct metric comparison, but CIELAB is not perfectly perceptually uniform. Consequently, more recent colour difference formulae such as CIEDE2000 can provide a more perceptually refined assessment of small colour differences (Luo, Cui & Rigg, 2001; Sharma, Wu & Dalal, 2005; CIE, 2018). Future work could therefore report repeated measurements with mean values and dispersion, include CIEDE2000 alongside ΔE76, calculate deviations from independently specified reference colours, and evaluate multiple displays.

6. Conclusions

This study identified inter-engine colour differences between corresponding EEVEE and Cycles rendering engines, with all ΔE76 values below 1.0. AgX showed the lowest mean inter-engine ΔE76 across the six tested colours (mean ΔE76 = 0.234), followed by Filmic (0.438) and Standard (0.440). The largest individual difference was measured for red under Standard (ΔE76 = 0.803). These findings demonstrate relative inter-engine consistency but do not establish absolute colour accuracy or perceptual equivalence. Further research should include reference-based comparisons, repeated measurements and controlled observer testing.

7. Acknowledgements

This study is based on seminar work conducted by Neža Mikeln, Špela Polak, Monika Rebec and Laura Rudolf under the mentorship of Professor Raša Urbas and Associate Professor Jože Guna. The authors acknowledge the financial support from the Slovenian Research Agency (research core funding No. P2-0450).

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