Metamer Pairs: Spectra That Match Under One Light and Diverge Under Another, With Measured-Colour Anchors

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github.com/JeetuSK0808/maryslab

Datasheet · August 2026 · Mary's Lab dataset DS-02 · CC-BY-4.0

ABSTRACT

A datasheet for the `metamer-pairs` dataset: 1575 pairs of reflectance spectra constructed to be colorimetrically identical under a match illuminant and divergent under a split illuminant, with both separations reported per row. The worst match residual in the corpus is 0 ΔE_{OK} — the pairs are metamers in the operative sense, not merely similar colours. Anchor colours come from two provenances: broad analytic reflectances, and the measured colours of real USGS materials. The two behave differently in a way worth publishing: the generator fails on 36.7% of measured anchors against 15.6% of analytic ones, because real material colours sit nearer the boundary of the object-colour solid, where the metamer set collapses. The intended use is a regression suite: a pipeline that renders both members identically under the split illuminant has collapsed spectra to colour somewhere, and one row proves it.

Keywords: dataset; metamerism; color management; software testing; spectral rendering

1. Motivation

Colour pipelines routinely encode an assumption they never state: that a surface has a colour. The assumption survives testing because test imagery is rendered under one illuminant, where it is indistinguishable from the truth. Metamerism supplies the discriminating input — two surfaces matching under one light and differing under another cannot both be represented by a single colour value — but constructing such pairs by hand is laborious enough that such tests are rare in practice. This dataset makes them a commodity.

2. Composition

1575 rows. Each holds two 38-sample reflectances in [0,1], the match illuminant, the split illuminant, the shared colour, and both separations. Illuminant pairs: D65/A, D50/A, D65/E — tabulated standard illuminants only, since inventing an SPD would put an unverified spectrum in a published dataset.

Table 1. Anchor provenances. Skip rate is the fraction of anchors on which the boundary sampler found no usable metamer pair — higher for measured colours, and diagnostically so.

provenance	anchors attempted	skip rate	pairs	median split ΔE_OK
analytic	180	15.6%	904	0.0166
measured	180	36.7%	671	0.0136

Corpus-wide: worst match residual 0, median split 0.015161, maximum split 0.071541 ΔE_{OK}; 635 pairs clear the 0.02 divergence threshold. Splits are grouped by anchor: train 1293, validation 108, test 174.

3. Collection and labeling

For each anchor colour the generator builds the metamer set — the convex polytope of reflectances producing that colour under the match illuminant — samples its boundary, and keeps the pairs that diverge most under the split illuminant. Labels are computed colorimetry (CIE 1931 observer, Oklab differences), not judgements: what the dataset asserts is a property of the specification, checked by three engine implementations against a shared 401-vector conformance suite.

Measured anchors are the D65/D50 colours of materials from the public-domain USGS library (snapshot `usgs-splib07a-1`); each such row carries its source record id. The pair members are still constructions — what is real is the colour they are constructed at.

4. Uses

The intended use is not machine learning. It is a regression suite: feed both members of a pair through a renderer, colour-management chain, or spectral upsampler, render under the split illuminant, and require distinguishable outputs. Identical outputs mean the pipeline collapsed spectra to colour, and the failure is diagnostic — one row names the condition. Learning tasks are also well-posed (predict split divergence from the two spectra; classify divergence), with grouped splits preventing anchor leakage.

The skip-rate asymmetry is itself usable: it is the phenomenon TR-07 measures as metamer-set envelope width, arriving as a generation failure rate, and any tool that generates metamers for real target colours should expect the same wall.

5. Distribution, license, and maintenance

JSONL splits plus a dataset card. Generated rows and compilation are CC-BY-4.0; measured anchor colours derive from public-domain USGS data (cite Kokaly et al. 2017). Seeded and reproducible from the repository at `datasets/build/`; engine 0.4.1, snapshot usgs-splib07a-1. Corrections arrive as a new version, never a silent overwrite.

6. Limitations

This section states what the result does not establish. It is written to be read before the abstract is quoted.

- **Generated, not manufacturable.** Members are points in a metamer polytope, not pigment formulations. The dataset tests software, not materials.
- **Difficulty is colorimetric, not perceptual.** Separations are ΔE_{OK} under a standard observer; no human study calibrates what a viewer notices under what conditions.
- **Two illuminants per row.** Observer variation and three-illuminant failures are outside this construction.
- **Anchor coverage follows the generator's reach.** The measured-anchor skip rate means saturated real colours are under-represented among the pairs — exactly the colours whose metamer sets are smallest. The card publishes the rate so the bias is visible.

7. Acknowledgements and disclosure

The instruments described here were implemented in Mary's Lab, an open-source computational color science project. Software design, implementation, and the preparation of this report were carried out with substantial assistance from a large language model (Anthropic Claude), under the author's direction and review. All numerical results were produced by executing the released code; none were generated by a language model. The author is responsible for the claims made here.

References

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Generator, statistics, and this datasheet's renderer: `github.com/JeetuSK0808/maryslab` under `datasets/build/`. The build is seeded — the same commit reproduces the same dataset byte for byte — and every number above resolves from the generator's own stats.json. Datasheet structure follows Gebru et al. (2021). Prepared with AI assistance (see Acknowledgements).