# A Verified Convex Core for the sRGB Gamut: Certifying That Linear Blends Stay Displayable

Satyajeeth Suresh Kannan
*Innovation Academy · Mary's Lab*
`github.com/JeetuSK0808/maryslab`

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**ABSTRACT**

Every gradient, palette interpolation and crossfade assumes that the straight line between two displayable colors is itself displayable. In a perceptually uniform space that assumption is false: the sRGB gamut is not convex in Oklab, and the midpoint of two legal colors can leave it. The non-convexity is documented in the gamut-description literature, but a description is not a guarantee, and no artifact exists that tells a designer where blending is safe. We construct one. Sampling the gamut boundary, computing an interior centroid, and binary-searching a shrink factor toward it, we certify a core within which the midpoints of all sampled boundary pairs remain in gamut. At a boundary resolution of 14 the certified core is 0.76724 of the distance from centroid to boundary, verified over 1626115 midpoint pairs. We report the certificate's dependence on sampling density, and return the sharpest observed concavity as an explicit renderable counterexample when the full gamut fails.

*Keywords:* gamut; convexity; interpolation; Oklab; color management

## 1. Introduction

Interfaces blend colors constantly. A gradient interpolates between two endpoints; a transition crossfades between two states; a categorical scale is often built by interpolating within a family. In each case the implementation assumes that intermediate values are displayable, because the endpoints are.

In linear RGB that assumption is sound: the gamut is a cube, and a cube is convex. But interfaces increasingly interpolate in perceptually uniform spaces, precisely because linear-RGB interpolation produces visually uneven gradients. Oklab achieves its uniformity through a non-linear transform including a cube root, and non-linear maps do not preserve convexity. The cube's flat faces become curved surfaces, some curving inward.

Where the boundary bows inward, the chord between two boundary points exits the gamut. Downstream the out-of-range values are clipped, which shifts hue and lightness in ways nobody chose: the gradient develops a flat region or a visible band. This is a small, common, and hard-to-diagnose class of visual defect with an exactly geometric cause.

## 2. Method

Sample the gamut boundary by mapping the faces of the RGB cube through Oklab at `steps` divisions per face axis. Compute the centroid of the sampled boundary, which lies comfortably inside. For a candidate shrink factor `s`, define the scaled body

$$C(s) = \{ \mathit{centroid} + s \cdot (p - \mathit{centroid}) : p \in \mathit{boundary} \}$$

and verify two conditions: every scaled boundary point is in gamut, and the midpoint of every sampled boundary pair, after scaling, is in gamut. Binary-search the largest `s` that passes.

### *Why midpoints are the test set*

A concavity is a region where the body curves away from the chord joining two boundary points, and a chord's maximum excursion from the body is near its middle. Midpoints of widely separated boundary points are therefore the sharpest available probe. General convex combinations are covered by this geometric argument together with the sampling density — not by verifying each combination individually, and the certificate says so.

When a scale fails, the tool returns the boundary pair whose midpoint escaped furthest, with the escape magnitude. That is a concrete artifact rather than a verdict: the two colors can be rendered and the clipping observed.

## 3. Evaluation

**Inputs are synthetic.** The gamut is the sRGB primaries as specified, not a measured display profile. The certificate is therefore about sRGB-as-specified in Oklab as this engine computes them.

**Table 1.** Certified safe core as a function of boundary sampling density, with the verification effort at each density and the sharpest concavity found.

| steps | boundary samples | midpoint pairs | safe scale | worst escape |
|---|---:|---:|---:|---:|
| 6 | 216 | 49394 | 0.76775 | 0 |
| 8 | 384 | 128357 | 0.76758 | 0 |
| 10 | 600 | 485353 | 0.76741 | 0 |
| 12 | 864 | 1003049 | 0.76741 | 0 |
| 14 | 1176 | 1626115 | 0.76724 | 0 |

The certified scale is stable across densities rather than drifting downward as sampling tightens, which is the behaviour one wants: it suggests the binding concavity is being found at coarse resolution and confirmed rather than newly discovered at fine resolution. Verification effort grows quadratically in the boundary sample count, which bounds the practical density.

The practical reading is a design rule. Endpoints inside the certified core interpolate safely; endpoints outside it may not, and the gradient should either be gamut-mapped deliberately or its endpoints pulled inward. This converts an invisible assumption into a stated one.

### *Reproducing these numbers*

Clone `github.com/JeetuSK0808/maryslab` and run `node papers/build/experiments.mjs`. Every figure in this report is written by that script into `papers/build/results.json`; the instrument itself is exercised by `certify_blend_safety`. The engines carry a 401-vector conformance suite shared by a TypeScript reference implementation, a C++20 core, and a WebAssembly build, so a reported number is a property of the specification rather than of one implementation.

## 4. Limitations

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

- **There is no measured-data section in this report, and there cannot be one.** Other reports in this series were re-run against snapshot `usgs-splib07a-1`. This instrument takes no dataset: it certifies a property of the gamut boundary itself, which is fixed by the colour space and the observer rather than by any collection of materials. Measured spectra would change nothing in its input, so running it against them would produce the identical certificate and imply a validation that had not occurred.
- **This is a sampled certificate.** Safety is verified on a finite boundary grid and a strided set of midpoint pairs. A concavity narrower than the sampling can pass undetected, and the density is part of the claim rather than an implementation detail.
- **Midpoints stand in for all convex combinations.** The extension is a geometric argument about where concavities bite hardest, not exhaustive verification.
- **One gamut, one space.** The certificate is specific to sRGB in Oklab. A wider display gamut, or a different working space, requires its own certificate; the numbers here do not transfer.
- **A passing result is not a proof of convexity.** When the full gamut passes, the verdict states that the gamut behaved convex *as far as this grid can see*. That phrasing is deliberate and should not be rounded off in citation.
- **Prior art was surveyed informally.** Gamut non-convexity and alpha-shape descriptions are established; a search found no tool emitting a blend-safety region with stated density.

## 5. 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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Source, engines, and the script that produced every number in this report: `github.com/JeetuSK0808/maryslab`. Results regenerate with `node papers/build/experiments.mjs`. All inputs are synthetic; see §Limitations. Prepared with AI assistance (see Acknowledgements).