Emulating Emulsion

A Compact Physically-Based Model for Film Colour

SIGGRAPH 2025
Vancouver+ 10-14 August

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Problem

Colour-positive film yield pleasing colours, but many are discontinued. Emulation offers an alternative, typically relying on either:

(1) Look-up tables (LUTs). Created manually or from film-digital pairs, they are prone to interpolation artefacts and lack interpretability.

(2) Neural networks. Require many image pairs for training; this data is costly to obtain on film.

(3) Proprietary methods. Not accessible.

We aim to address all of these limitations.

Proposed Method

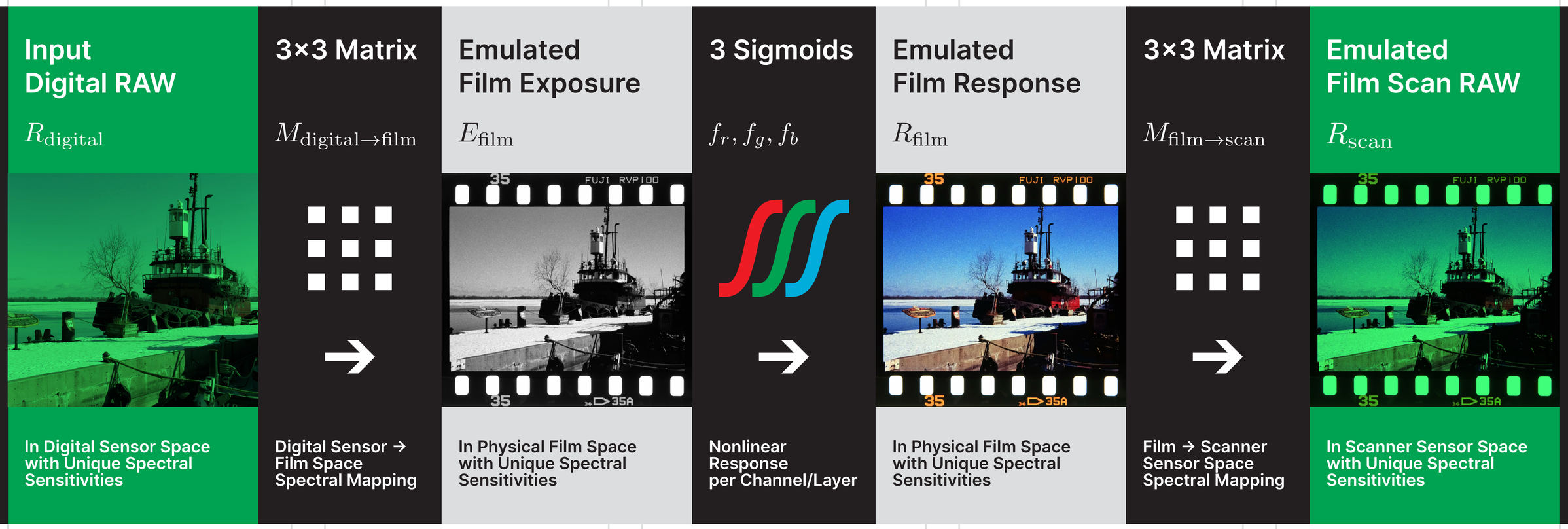
We map a RAW image R_{digital} to an emulated RAW image of scanned film R_{scan}, as a three-stage pipeline mirroring real film processes:

(1) Spectral remapping $M_{\text{digital}\to\text{film}}$. A 3×3 matrix converts R_{digital} into the energy that would have reached the layers of the target film E_{film}.

(2) Three sigmoid response functions f_r, f_g, f_b. Applied channel (layer)-wise to E_{film}, yielding the film's optical density response R_{film}.

(3) Scanner encoding $M_{\text{film}\to\text{scan}}$. A second 3×3 matrix converts R_{film}, illuminated by a (virtual) backlight, into the scanner's RAW space R_{scan}.

This yields 30 parameters, optimised via least-squares using film-digital colour pairs captured from a single roll of film.



Results

Real Film Scan RAW

All RAW images (scan, input, and emulation output) were rendered in sRGB for easy viewing and comparison, using fixed, consistent transformations.

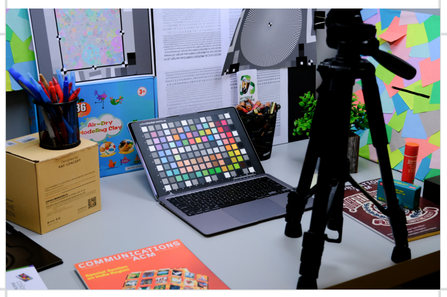
*Rendered with official emulation software by the film manufacturer

Input Digital RAW (of Same Scene)

LUT Baseline
Banding Artefacts

200% Zoom on Smooth Area

Proprietary*
Inaccurate Colour



Our Method
Accurate Emulation

200% Zoom on Smooth Area

Applications

(1) "Film look" in colour grading. Because the emulation is continuous, we can generate LUTs of any resolution, which can be dropped seamlessly into existing production pipelines.

(2) Archival preservation. Artists can digitise the palette of an out-of-production film with a single existing roll, confident that every parameter maps to a verifiable physical quantity.

(3) Creative authoring. Vendors may expose parameters as sliders (e.g. "shadow falloff"), enabling artists to manipulate the emulation in ways that are still physically viable.

Further Work

An in-depth look, other projects, art, and more, via QR: