Project 1: Colorizing the Prokudin-Gorskii Collection

CS180 • Fall 2025

Overview

I split B/G/R glass plates (top→bottom) into channels, crop borders (10% each side), convert to float, and align G and R to B. Implemented alignment methods: **SSD**, **NCC**, and **Phase Correlation**. For large .tif images, I use a **coarse-to-fine edge-based pyramid** (downscale ×2, 5 levels; central differences / Prewitt edges).

Pipeline

Raw plate
(B/G/R stacked top→bottom)
→
Border crop
(10% each side)
→
Downscale ×2
5 steps, coarsest ~100–120px
→
Edge map
(central differences / Prewitt)

Spotlight: Melons — plain L2 (single-scale)

A deliberately naive single-scale SSD alignment. The strong color fringing shows that plain L2 on raw intensities fails for large displacements and illumination differences, motivating coarse-to-fine and phase-based methods.

← Back to CS 180

Melons — SSD (single-scale): clear misalignment and color fringing

Edge Feature Used for Pyramid Alignment

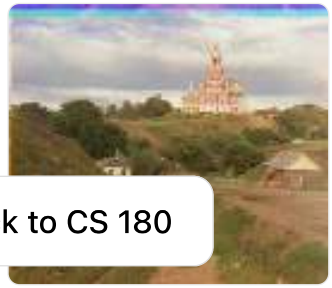
Instead of matching raw brightness, we align on a gradient-magnitude (edge) image. This is more robust to channel brightness differences and produces more precise alignment.

← Back to CS 180

Gradient-magnitude "edge" image used in the pyramid

Small Images (Low Resolution)

Exhaustive **single-scale** alignment (SSD/NCC) and (optionally) phase correlation.

Image	SSD without edge detection	NCC (single)	Phase Corr.
cathedral			

← Back to CS 180

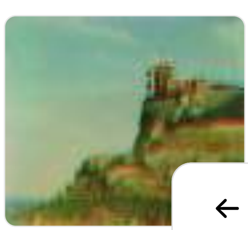
Image	SSD without edge detection	NCC (single)	Phase Corr.
	0.06s G=(2, 5) R=(3, 12)	**0.17s** G=(2, 5) R=(3, 12)	**0.01s** G=(2, 5) R=(3, 12)
monastery	 **0.07s** G=(2, -3) R=(2, 3)	 **0.18s** G=(2, -3) R=(2, 3)	 **0.01s** G=(2, -3) R=(2, 3)
tobolsk	 **0.06s** G=(3, 3) R=(3, 6)	 **0.19s** G=(3, 3) R=(3, 6)	 **0.01s** G=(2, 3) R=(3, 6)

Large Images (High Resolution)

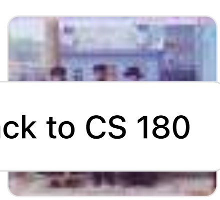
Coarse-to-fine edge pyramid for SSD/NCC; brightness-invariant phase correlation.

Image	SSD without edge detection	Pyramid SSD	Pyramid NCC	Phase Corr.
church	 **10.15s** G=(4, 15) R=(-15, 15)	 **12.15s** G=(4, 25) R=(-4,	 **28.53s** G=(4, 25) R=(-4, 58)	 **2.01s** G=(3, 25) R=(-4, 58)

← Back to CS 180

Image	SSD without edge detection	Pyramid SSD	Pyramid NCC	Phase Corr.
emir	 **9.72s** G=(15, 15) R=(15, 15)	 **15.90s** G=(24, 49) R=(40, 107)	 **28.26s** G=(24, 49) R=(40, 107)	 **2.52s** G=(24, 49) R=(41, 106)
harvesters	 **10.57s** G=(15, 15) R=(-15, 15)	 **16.97s** G=(17, 60) R=(14, 124)	 **28.73s** G=(17, 60) R=(14, 124)	 **2.14s** G=(18, 60) R=(11, 118)
icon	 **10.86s** G=(15, 15) R=(15, 15)	 **17.58s** G=(17, 42) R=(23, 90)	 **35.04s** G=(17, 42) R=(23, 90)	 **1.38s** G=(16, 39) R=(23, 88)
italil	 **10.44s** G=(15, 15) R=(15, 15)	 **16.55s** G=(22, 38) R=(36, 77)	 **32.20s** G=(22, 38) R=(36, 77)	 **2.16s** G=(22, 38) R=(36, 77)
lastochikino	 **9.68s**	 G=(-2, -3) R=(-8,	 **32.46s** G=(-2, -3) R=(-8,	 **2.43s** G=(-2, -3)

← Back to CS 180

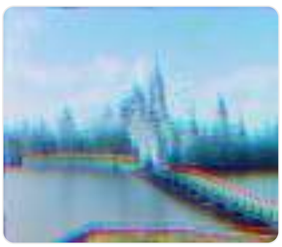
Image	SSD without edge detection	Pyramid SSD	Pyramid NCC	Phase Corr.
	G=(-2, -3) R=(-8, 15)	76)	76)	R=(-9, 76)
lugano	 **10.24s** G=(-15, 15) R=(-15, 15)	 **16.81s** G=(-17, 41) R=(-29, 92)	 **32.18s** G=(-17, 41) R=(-29, 92)	 **0.91s** G=(-17, 41) R=(-29, 92)
melons	 **10.26s** G=(11, 15) R=(15, 15)	 **16.75s** G=(10, 80) R=(13, 177)	 **34.41s** G=(10, 80) R=(13, 177)	 **2.19s** G=(10, 80) R=(14, 176)
self_portrait	 **10.23s** G=(15, 15) R=(15, 15)	 **16.34s** G=(29, 78) R=(37, 175)	 **35.83s** G=(29, 78) R=(37, 175)	 **1.46s** G=(29, 77) R=(37, 175)
siren	 **10.23s** G=(-14, 15) R=(-15, 15)	 **17.27s** G=(-6, 49) R=(-24, 96)	 **32.49s** G=(-6, 49) R=(-24, 96)	 **0.93s** G=(-5, 50) R=(-24, 97)
three_generations				

← Back to CS 180

Image	SSD without edge detection	Pyramid SSD	Pyramid NCC	Phase Corr.
	10.18s G=(13, 15) R=(11, 15)	**15.87s** G=(12, 53) R=(9, 111)	**31.43s** G=(12, 53) R=(9, 111)	**2.51s** G=(12, 55) R=(8, 111)

Large Images (Extra Set)

Same pipeline as above, evaluated on three additional high-resolution plates.

Image	SSD without edge detection	Pyramid SSD	Pyramid NCC	Phase Corr.
castle	 **9.94s** G=(15, 15) R=(15, 15)	 **16.13s** G=(25, 64) R=(37, 141)	 **31.72s** G=(25, 64) R=(37, 141)	 **0.93s** G=(25, 65) R=(37, 140)
dagestan	 **9.68s** G=(4, 8) R=(7, 15)	 **16.31s** G=(4, 8) R=(5, 89)	 **32.28s** G=(4, 8) R=(5, 89)	 **2.61s** G=(3, 8) R=(5, 88)
factory	 **9.99s** G=(11, 15) R=(1, 15)	 **16.39s** G=(9, 61) R=(-5, 136)	 **31.86s** G=(9, 61) R=(-5, 136)	 **3.13s** G=(13, 67) R=(-5, 134)

← Back to CS 180

Discussion

The edge-based pyramid stabilizes SSD/NCC under illumination and texture changes by matching gradients (central differences / Prewitt). Phase correlation is brightness-invariant and provides a good coarse initialization on the smallest level. Parameters: crop=0.10, base_win=20, target_min≈120, levels≤6.

Problems & Takeaways

Why single-scale SSD/NCC failed on large plates. With big displacements and channel brightness differences (e.g., Emir), exhaustive search on raw intensities either misses the true shift or locks onto wrong structures.
Fix: edge-based pyramid. Matching on gradient magnitude (central differences / Prewitt) makes SSD/NCC far more stable across channels and lets a coarse-to-fine search converge reliably.
Why phase correlation helped. (1) *Fast:* FFT-based `O(N log N)`, great on large images. (2) *Brightness-invariant:* uses the cross-power spectrum phase. (3) *Strong initializer:* good coarse shift you can optionally refine at the finest level.
Speed note. On my .tif images, phase correlation was typically the fastest; the edge pyramid was slower but accurate and consistent.
Other issues worth discussing. (1) Border/frame artifacts bias alignment unless cropped. (2) Non-rigid changes (motion/parallax) violate pure translation. (3) Metric robustness—outliers and illumination shifts favor normalized/edge features over raw intensities.

← Back to CS 180